BROWN'S CREEK WATERSHED DISTRICT
2010 WATER MONITORING REPORT

Prepared for:

BROWN'S CREEK
WATERSHED DISTRICT

Prepared By:

WASHINGTON CONSERVATION DISTRICT

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Many agencies and individuals were directly involved in many aspects of this project, such as: data collection, data analysis, as well as technical and administrative assistance.

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ABBREVIATIONS, ACRONYMS, AND SYMBOLS

CAMP	Citizen-Assisted Lake Monitoring Program
cfs	cubic feet per second
Chl-*a*	Chlorophyll-*a*
BCWD	Brown's Creek Watershed District
COD	Total Chemical Oxygen Demand
DO	Dissolved Oxygen
E. Coli	*Escherichia coli*
mg/L	milligram per liter
MN DNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
MPN	most probable number
NTU	nephelometric turbidity units
OHW	Ordinary High Water level
Ortho-P	Ortho-phosphate
TBOD	Total Biochemical Oxygen Demand
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TOC	Total Organic Carbon
TP	Total Phosphorus
TSI	Trophic State Index
TSMP	Trout Stream Mitigation Project
TSS	Total Suspended Solids
µg/L	microgram per liter
µmhos/cm	micromhos per centimeter
VSS	Volatile Suspended Solids
WCD	Washington Conservation District

2010 BCWD Baseline Water Quality Monitoring
EXECUTIVE SUMMARY

This report focuses on the summary and comparison of the lake and stream water quality data collected by the Washington Conservation District (WCD) from 2003-2010 and previous monitoring seasons. In 2010, Brown's Creek was monitored at Highway 15, McKusick Road, Stonebridge and the Creek Outlet; Long Lake drainage sites were monitored at 62nd St., the Herberger's Pond Outlet and the Marketplace Pond; the tributary to McKusick Lake was monitored at the Brown's Creek Diversion Structure; and the Diversion drainage was monitored at Long Lake outlet, Jackson WMA outlet, West Branch 1, West Branch 2, South Branch, North Branch and Boutwell Rd. crossing. Four additional branches of the Diversion drainage were also monitored by Emmons and Olivier Resources beginning in 2010 (Figure 1).

In addition to these stream sites, BCWD continued to monitor Masterman Lake, Bass Lake East (82-0124), Bass Lake West (82-0123), Lynch Lake, July Avenue Wetland, Wood Pile Lake, Pat Lake, Goggin's Lake, Kismet Basin, Long Lake, South School Section Lake, Benz Lake, and Plaisted Lake. July Avenue Wetland, while scheduled to be monitored, never reached a water elevation high enough to monitor. A new lake, Jackson WMA Pond, was added to the list of Brown's Creek Lake Monitoring Sites. In addition, Lynch Lake was monitored in 2010 as two separate basins: Lynch Lake North and Lynch Lake South. Lynch Lake North was the original site for Lynch Lake monitoring in 2009. A deeper location in Pat Lake was discovered, and the monitoring location for this lake changed due to this new information.

In 2010, the fourteen lakes monitored had good to very poor water quality ratings and were classified as: mesotrophic (Bass Lake East), eutrophic (Bass Lake West, Jackson WMA Pond, Kismet Basin, Long Lake, Masterman Lake, Pat Lake, and Wood Pile Lake) and hypereutrophic (Benz Lake, Goggin's Lake, Plaisted Lake, Lynch Lake-North and South Basin and South School Section Lake). The overall 2010 lake grades for BCWD lakes were: Bass Lake East – B, Long Lake – B-, Bass Lake West – C+, Kismet Basin – C, Masterman Lake – C , Pat Lake – C , Wood Pile Lake – C, Plaisted Lake –C-, South School Section Lake – C-, Benz Lake – D, Goggin's Lake – D-, Lynch Lake North – F, and Lynch Lake South – F. Of the lakes that were monitored in 2009, there was a range of increasing/decreasing water quality measured by overall lake grade during 2010. Five lakes showed a slight deterioration in water quality for the 2010 season (Goggin's Lake, Masterman Lake, Pat Lake, South School Section Lake, and Woodpile Lake), three lakes maintained their water quality (Bass Lake West, Kismet Lake, and Lynch Lake North, and four lakes improved in water quality (Bass Lake East, Benz Lake, Long Lake and Plaisted Lake). Jackson WMA Pond and Lynch Lake South did not have any water quality data from 2009 for comparison. Benz Lake, Goggin's Lake, and Lynch Lake North and South were considered worse than the ecoregion range for all parameters measured (total phosphorus, total Kjeldahl nitrogen, chlorophyll-*a,* and Secchi disk transparency). There were no lakes that were within the ecoregion range for all parameters (total phosphorus, total Kjeldahl nitrogen, chlorophyll-*a*, and Secchi disk

transparency). In 2010, the Washington Conservation District conducted Kendall Tau statistical analysis of all lakes monitored by the WCD to determine any long-term water quality trends. For Brown's Creek Watershed District lakes, only three lakes had a significant trend. Benz Lake had a statistically significant improving trend for total phosphorus, Goggin's Lake had a statistically significant declining Secchi transparency trend, and Long Lake had significantly improving Secchi disk transparency and total phosphorus trends.

In 2010, BCWD continued monitoring stream/stormwater sites at: Brown's Creek Outlet, Brown's Creek at Stonebridge, Brown's Creek at McKusick Road, Brown's Creek at Hwy 15, the Brown's Creek Diversion Structure, Long Lake Inlet at 62nd St., Tributary to Long Lake at the Herberger's Pond Outlet and Tributary to Long Lake at Marketplace Pond (Figure 1).

Of the sites monitored on Brown's Creek, all but Brown's Creek at Hwy 15 showed decreased or nearly the same total discharges in 2010 compared to 2009 (Figure 10, Figure 11, Figure 12 and Figure 13). The cause of this reduction in flow at the downstream sites is unknown, but one possibility is a pooling effect resulting from a series of beaver dams that were constructed upstream of the McKusick Road site. These same sites showed reduced TP loads in 2010 compared to 2009 (Figure 10 and Figure 12). Brown's Creek at Highway 15 was also the only site on the creek to have an increased TSS load in 2010 (Figure 11 and Figure 13). The Brown's Creek Diversion Structure, Tributary to Long Lake at 62nd Street, Tributary to Long Lake at Herberger's Pond Outlet and Tributary to Long Lake at Marketplace Pond showed increases in discharge and in total loads of TP/TSS during the 2010 season compared to 2009 (Table 19 and Table 25). The total phosphorus load from Brown's Creek to the St. Croix River in 2010 was **1,126 lbs (0.12 lbs per acre of watershed land)**, determined by the Brown's Creek Outlet station results.

Temperatures in Brown's Creek for 2010 displayed some interesting results when examining thermal impacts. The Highway 15, McKusick Road and Stonebridge sites recorded daily average temperatures near 18.3°C during the warmest portions of the year (Figure 21 through Figure 23). The daily average temperature at the Brown's Creek Outlet only exceeded 18.3°C for a brief period in August (Figure 24). 18.3°C is the temperature threshold where low impacts to trout survival are observed, as identified by the Brown's Creek Biota TMDL. One important and equally interesting note is that the temperature difference between the McKusick Road and Stonebridge sites did not vary as significantly as they did in 2008, and was similar to 2009 (Figure 18). This is difficult to explain, but may be due to the lack of precipitation in the summers of 2008 and 2009. This lack of rainfall may have prevented the stormwater pond that enters the creek downstream of the McKusick Road site from reaching capacity. This would have an effect on stream temperature because it would have prevented warm, stagnant water from discharging from the pond into the creek.

The MPCA and the MN DNR, as part of the Brown's Creek TMDL, conducted fisheries surveys in 2010 as well as historically as part of their biological monitoring programs.

No DNR survey was conducted in 2009. The MPCA conducted biological surveys in 2009. Data pertaining to historical fisheries surveys can be found by contacting the MPCA Biological Monitoring Section (http://www.pca.state.mn.us/water/biomonitoring/bio-staffdirectory.html) or MN DNR Division of Fish and Wildlife area fisheries office (http://www.dnr.state.mn.us/areas/fisheries/eastmetro/index.html). Due to differences in sampling procedures between agencies, variation in results, the complexity of reporting these results and not being the organization that collected the data, those data are not shown in this report. Annual fish stocking occurred as it usually does on a yearly basis. In 2010, 500 brown trout were stocked in Brown's Creek. This stocking follows the MN DNR long-term management plan for trout stocking efforts in Brown's Creek.

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I. INTRODUCTION

This report focuses on the summary and comparison of lake and stream water quality data collected by the Washington Conservation District (WCD) from 2000-2010 and previous monitoring seasons. In 2010, Brown's Creek Watershed District (BCWD) monitored fourteen lakes: Bass Lake (East), Bass Lake (West), Benz Lake, Goggin's Lake, Jackson WMA Pond, , Kismet Basin, Long Lake, Lynch Lake North, Lynch Lake South, Masterman Lake, Pat Lake, Plaisted Lake, South School Section Lake, and Wood Pile Lake. July Avenue Wetland was scheduled to be monitored in 2010 but low water levels for the duration of the monitoring season prevented this. Eight stream/stormwater sites were monitored and located at: Brown's Creek at Highway 15, McKusick Road, Stonebridge, Brown's Creek Outlet, Brown's Creek Diversion Structure, Tributary to Long Lake at 62nd St., Tributary to Long Lake at Herberger's Pond and Tributary to Long Lake at Marketplace Pond (Figure 1). Field flow measurements and water quality grab samples were collected along the diversion drainage to McKusick Lake at Long Lake Outlet, Jackson WMA Pond Outlet, North Branch, South Branch, West Branch 1, West Branch 2 and the drainage crossing at Boutwell Rd. Four additional sites, named Creekside, North Settlers, East Settlers and South Settlers were added along this drainage in 2010 (Figure 2). Emmons and Olivier Resources (EOR) sampled these sites. Multiple water quality parameters were monitored at each lake and stream/stormwater site. Also included in this report are summarized daily minimum, maximum and average temperatures for all sites on Brown's Creek. Fifteen minute continuous temperature data for these sites is available from the WCD by request. The purpose of this monitoring was to assess and document the current water quality conditions of the lakes and streams, identify problem resources or areas, and to continue a long-term monitoring program which will enable the BCWD to identify trends associated with land use changes in their watershed.

The work plan for 2010 included the following activities: bi-weekly sampling (14 sampling sessions) of all fourteen lakes from April through October, and water elevation readings on twenty water bodies. Additional sampling of the middle and south basin of Long Lake was conducted monthly from June through September (4 sampling sessions). Four continuous monitoring stations were installed on Brown's Creek at Highway 15, McKusick Road, Stonebridge, and at the Brown's Creek Outlet, three continuous monitoring stations were installed on tributaries to Long Lake at 62nd St., Herberger's Pond and Marketplace Pond, and one continuous monitoring station was installed at the Brown's Creek Diversion Structure. Table 1 summarizes monitoring site locations and parameters monitored in 2010. The WCD and EOR performed the water quality sampling for the BCWD. Metropolitan Council Environmental Services Lab performed the analytical lab analyses on lake samples and samples from continuous monitoring stations. Minnesota Valley Testing Laboratories performed the analytical analyses on samples collected along the diversion drainage to McKusick Lake.

In 2007, BCWD in partnership with the WCD and MPCA began a Total Maximum Daily Load study on Brown's Creek. The purpose of a TMDL is to specifically identify and address the stressor(s) of impaired water(s). Brown's Creek was listed as impaired due to its poor macroinvertebrate IBI (index of biotic integrity) and lack of coldwater assemblage for trout and other coldwater fish species. During the early phase of this study, different agencies collected data that were needed to identify the stressor(s) that could be affecting macroinvertebrates and the coldwater assemblage. Agencies or individuals collecting or working with the data for this study included the WCD, BCWD, Emmons and Olivier Resources, Inc, MPCA, MN DNR, and Len Ferrington of the University of Minnesota. Data collected in 2008 was used as additional or supportive data for the TMDL. For further information about this TMDL please visit www.pca.state.mn.us/water/tmdl/index.html, or contact the MPCA or BCWD.

Table 1. Monitoring Site Location, Description, and Parameter(s) Monitored

Site Description	Map Site ID#	Site Name	General Site Location	Monitored Parameters*
Stream Monitoring	**1**	Brown's Creek Outlet	Hwy 95 & 96	Discharge and Water Quality Composite Samples
Stream Monitoring	**2**	Brown's Creek at McKusick Road	McKusick Road	Discharge and Water Quality Composite Samples
Stream Monitoring	**3**	Browns' Creek at Hwy 15	Hwy 15	Discharge and Water Quality Composite Samples
Stream Monitoring	**4**	Tributary to Long Lake at 62nd St.	62nd St.	Discharge and Water Quality Composite Samples
Stream Monitoring	**5**	Tributary to Long Lake at Marketplace Pond	Market Dr.	Discharge and Water Quality Composite Samples
Stream Monitoring	**6**	Tributary to McKusick Lake at Brown's Creek Diversion	Neal Ave.	Discharge and Water Quality Composite Samples
Stream Monitoring	**7**	Brown's Creek at Stonebridge Trail	Stonebridge Trail	Discharge and Water Quality Composite Samples
Stream Monitoring	**8**	Herberger's Pond Outlet	Frontage Rd., Hwy. 36	Discharge and Water Quality Composite Samples
Stream Monitoring	**9**	Long Lake Outlet	Long Lake Dr.	Field Discharge Measurements and Grab Samples
Stream Monitoring	**10**	Jackson WMA Outlet	Hwy 12	Field Discharge Measurements and Grab Samples
Stream Monitoring	**11**	Boutwell Road	Boutwell Road	Field Discharge Measurements and Grab Samples
Stream Monitoring	**12**	Brown's Creek Diversion at North Branch	Morgan Ave. N	Field Discharge Measurements and Grab Samples
Stream Monitoring	**13**	Brown's Creek Diversion at South Branch	Morgan Ave. N	Field Discharge Measurements and Grab Samples
Stream Monitoring	**14**	Brown's Creek Diversion at West Branch 1	Morgan Ave. N	Field Discharge Measurements and Grab Samples
Stream Monitoring	**15**	Brown's Creek Diversion at West Branch 2	Boutwell Road	Field Discharge Measurements and Grab Samples
Stream Monitoring	**16**	Brown's Creek Diversion at North Settlers	Morgan Ave. N	Field Discharge Measurements and Grab Samples
Stream Monitoring	**17**	Brown's Creek Diversion at East Settlers	Morgan Ave. N	Field Discharge Measurements and Grab Samples
Stream Monitoring	**18**	Brown's Creek Diversion at Morgan	Morgan Ave. N	Field Discharge Measurements and Grab Samples
Stream Monitoring	**19**	Brown's Creek Diversion at South Settlers	Boutwell Road	Field Discharge Measurements and Grab Samples
Stream Monitoring	**20**	Brown's Creek Diversion at Creekside	Morgan Ave. N	Field Discharge Measurements and Grab Samples
Stream Monitoring	**21**	Brown's Creek Diversion at Minar	Minar Ave. N	Field Discharge Measurements and Grab Samples
Lake Monitoring	**22**	Kismet Basin	--	Surface Water Quality Samples, Elevation
Lake Monitoring	**23**	Long Lake	--	Surface Water Quality Samples (3 Locations), Elevation
Lake Monitoring	**24**	Goggin's Lake	--	Surface Water Quality Samples, Elevation
Lake Monitoring	**25**	South School Section Lake	--	Surface Water Quality Samples, Elevation
Lake Monitoring	**26**	Benz Lake	--	Surface Water Quality Samples, Elevation
Lake Monitoring	**27**	Masterman Lake	--	Surface Water Quality Samples, Elevation
Lake Monitoring	**28**	Wood Pile Lake	--	Surface Water Quality Samples, Elevation
Lake Monitoring	**29**	Lynch Lake (North Basin)	--	Surface Water Quality Samples, Elevation
Lake Monitoring	**30**	Lynch Lake (South Basin)	--	Surface Water Quality Samples, Elevation
Lake Monitoring	**31**	Bass Lake (West)	--	Surface Water Quality Samples, Elevation, Zooplankton/phytoplankton Tow
Lake Monitoring	**32**	Bass Lake (East)	--	Surface Water Quality Samples, Elevation
Lake Monitoring	**33**	July Avenue Pond	--	Surface Water Quality Samples, Elevation
Lake Monitoring	**34**	Pat Lake	--	Surface Water Quality Samples, Elevation
Lake Monitoring	**35**	Plaisted Lake	--	Surface Water Quality Samples, Elevation
Lake Monitoring	**36**	Jackson Wildlife Management Area Pond	--	Surface Water Quality Samples, Elevation
Lake Monitoring	**37**	Hwy 12 & Kimbro Pond	--	Elevation
Lake Monitoring	**38**	Brown's Creek at Gateway Trail	--	Elevation
Lake Monitoring	**39**	55th St. Pond	--	Elevation

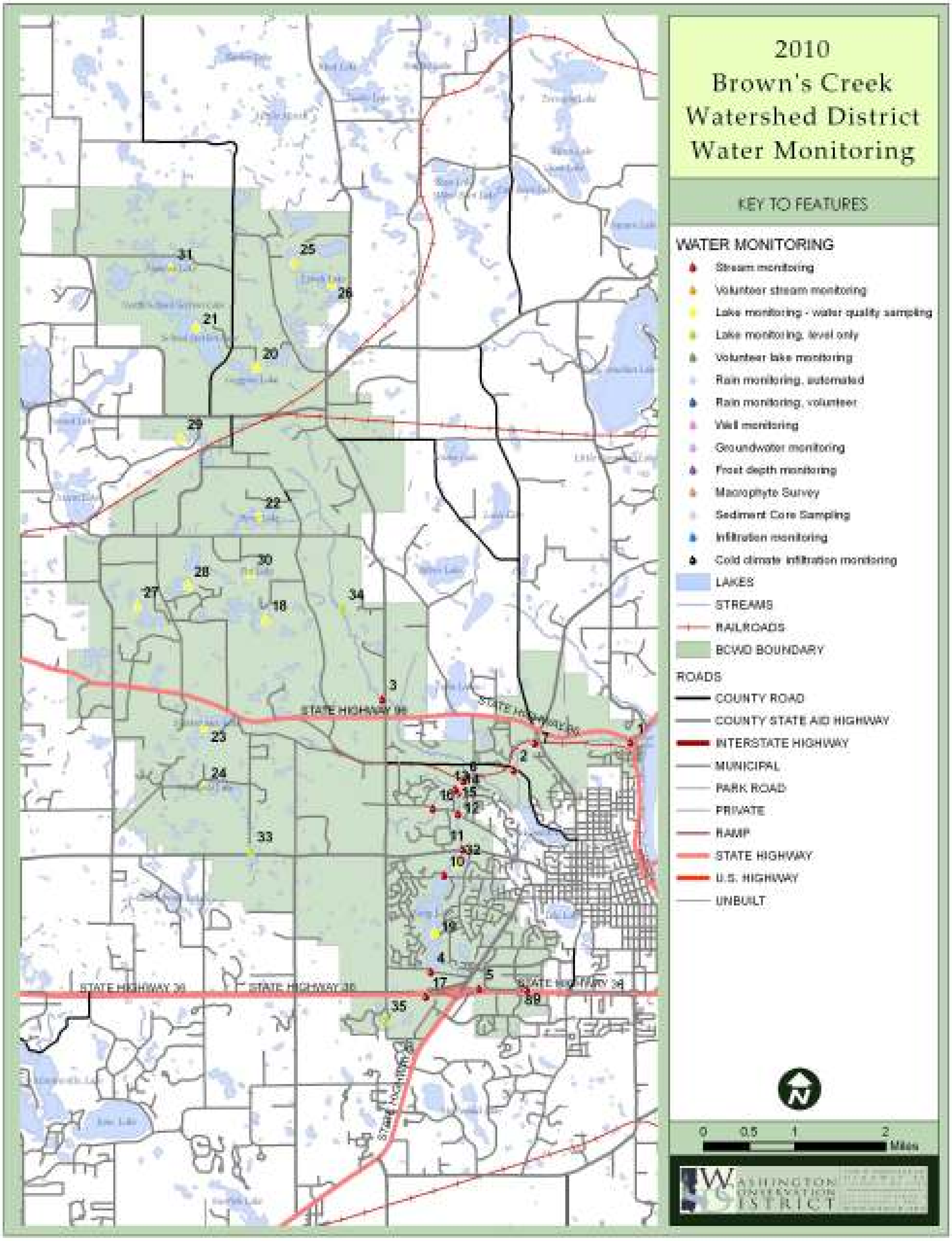


Figure 1: Sampling Location Map

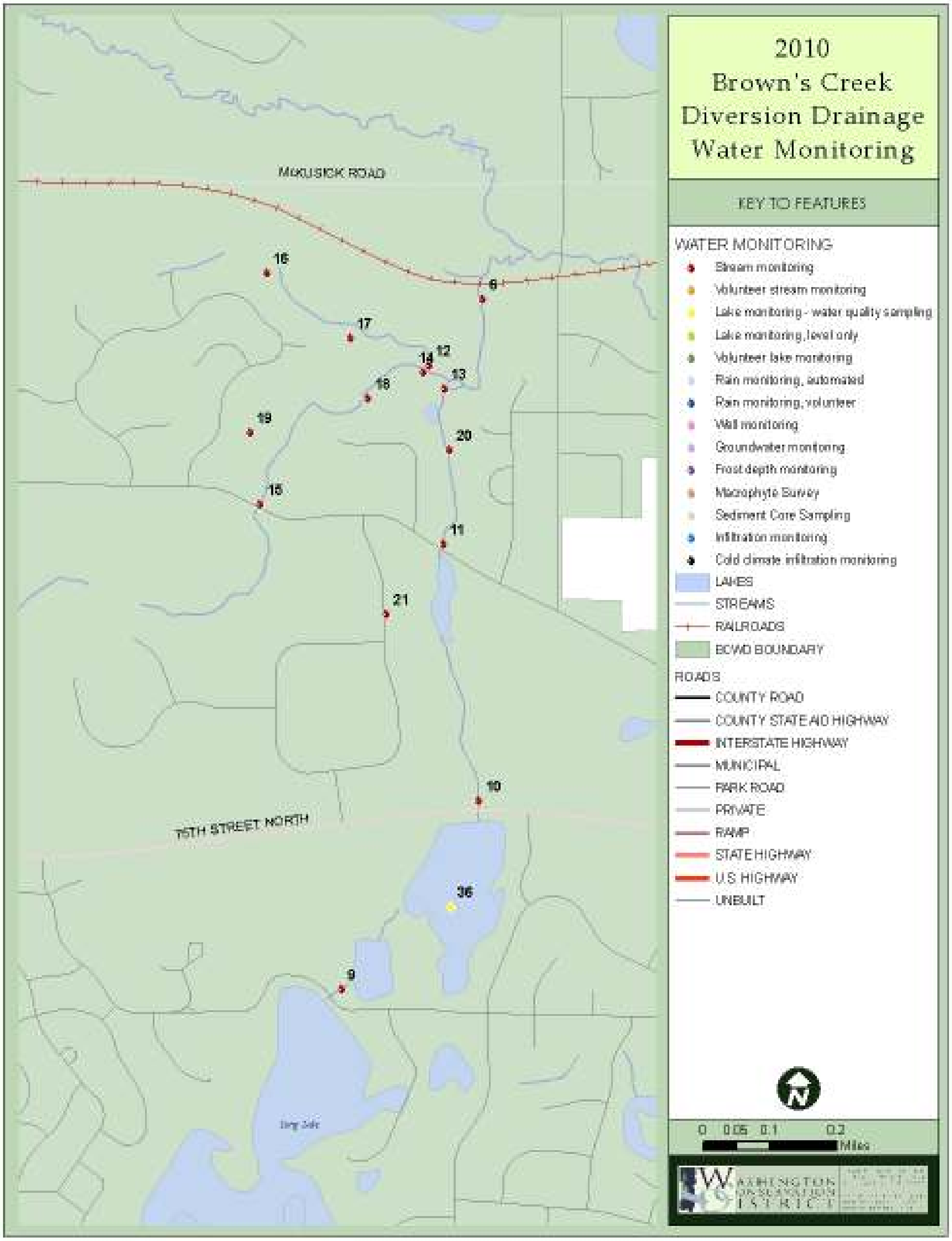


Figure 2. Long Lake to Diversion Structure Sampling Locations

II. LAKES

A. METHODS, RESULTS AND DISCUSSION

In 2010, water quality data was collected biweekly over seven consecutive months (April–October) by the WCD on Bass Lake East, Bass Lake West, Benz Lake, Goggin's Lake, Jackson WMA Pond, Kismet Basin, Long Lake, Lynch Lake North, Lynch Lake South, Masterman Lake, Pat Lake, Plaisted Lake, South School Section Lake, and Wood Pile Lake. Additional water quality data was collected monthly on the middle and south basins of Long Lake from June to September. July Avenue Wetland was scheduled to be sampled biweekly, but extremely low water levels prevented sampling from occurring. Two-meter (6.56 feet) integrated surface water samples were collected with a column sampler. Metropolitan Council Environmental Services Lab analyzed these samples for total phosphorus, chlorophyll-*a*, and total Kjeldahl nitrogen. A complete listing of the laboratory data is contained in Appendix A. Field measurements of Secchi disk transparency, dissolved oxygen and temperature profiles, and lake level were also recorded, as well as a user perception ranking (physical and recreational suitability). This data is available via request or on the Metropolitan Council's EIMS (Environmental Information Management System) Water Quality Database website (http://es.metc.state.mn.us/eims). Measurements obtained over the sampling season are averaged for a comparison of individual lake dynamics from year to year, for differences between lakes within the watershed, and for comparison with the average North Central Hardwood Forest Ecoregion values. Average values for all parameters, as well as the typical ranges for lakes in this ecoregion, are presented in Table 2 and Appendix A. Table 5 shows the lake grade and trophic state of the lakes sampled. Figure 3 through Figure 6 show the historic summer averages for each parameter.

Table 2: Ecoregion Values and Average 2010 Parameters

2010 Brown's Creek Watershed Lakes' Summer Averages (June-September)

Lake/Units	Total Phosphorus (mg/L)	Chlorophyll-a (ug/L)	Secchi (feet)	Kjeldahl Nitrogen (mg/L)
Eco-Region Value	*0.023-0.050*	*5.00-22.00*	*4.9-10.5*	*0.60-1.20*
Goggins	0.146	78.00	2.3	3.63
Kismet	0.047	22.00	4.6	0.95
South School Section	0.063	49.90	4.9	1.48
Long	0.051	14.00	7.8	1.14
Benz	0.110	58.00	2.4	2.17
Bass East	0.051	8.00	8.0	1.19
Bass West	0.055	18.90	6.2	1.38
July Ave	NA	NA	NA	NA
Lynch North	1.398	653.00	0.3	18.10
Lynch South	0.088	111.00	2.2	2.60
Masterman	0.052	22.00	5.9	1.21
Pat	0.061	20.00	7.1	1.34
Wood Pile	0.063	30.00	5.4	1.55
Plaisted	0.088	42.00	4.2	1.90
Jackson WMA	0.050	14.00	6.7	1.27

1. TRANSPARENCY (SECCHI DISK)

The measurement of depth of light penetration using a Secchi disk gives a simple measure of water transparency, or clarity. It is also a possible indication of turbidity in the water, as well as an indication of the trophic state of the lake. A reduction in water transparency is usually the result of turbidity composed of suspended sediments, organic matter and/or phytoplankton (algae). The summer average (June-September) water transparency in BCWD lakes, as measured by Secchi disk during the 2010 study can be seen in Figure 3 and Table 2. Typical ranges for this ecoregion are 4.9 - 10.5 feet. Goggin's Lake, Kismet Basin, Plaisted Lake, Benz Lake, Lynch Lake North and Lynch Lake South had Secchi disk readings less (worse) than the ecoregion range, while, Bass Lake East, Bass Lake West, Long Lake, Masterman Lake, South School Section Lake, Jackson WMA Pond, Pat Lake and Wood Pile Lake were within the ecoregion range. No lakes were better than the ecoregion range for Secchi transparency.

2. CHLOROPHYLL-*a*

Chlorophyll-*a* is a photosynthetic component found in algae and aquatic plants. It is also an indication of algal productivity. The 2010 summer average chlorophyll-*a* concentrations of BCWD lakes can be seen in Figure 4 and Table 2. The ecoregion value range for chlorophyll-*a* is 5-22 µg/L. Goggin's Lake, Benz Lake, South School Section Lake, Plaisted Lake, Woodpile Lake, Lynch Lake North and Lynch Lake South exceeded (were poorer than) the ecoregion range for chlorophyll-*a*. Bass Lake West, Bass Lake East, Jackson WMA Pond, Masterman Lake, Pat Lake, Kismet Basin and Long Lake were within the ecoregion range. No lake was better than the ecoregion range for chlorophyll-*a*.

3. PHOSPHORUS

Phosphorus is a major nutrient involved in eutrophication and is generally associated with the growth of aquatic plants and algal blooms. Common sources of phosphorus include runoff from agricultural fields, livestock areas, urban areas, lakeshore lawns, and improperly operating septic systems. In most lakes in this region, phosphorus is the least available nutrient; therefore, its abundance or scarcity controls the extent of algal growth. Algal growth in turn affects the clarity of the water and light penetration. Total phosphorus (TP) summer average concentrations in BCWD lakes for 2010 can be found in Figure 5 and Table 2. The typical range of the ecoregion values for total phosphorus is 0.023 – 0.050 mg/L. All lakes except Kismet Basin and Jackson WMA Pond exceeded (were poorer than) the ecoregion range for total phosphorus in 2010.

4. NITROGEN

Several forms of nitrogen are responsible for health problems and increase the rate of lake eutrophication. Total Kjeldahl nitrogen (TKN) concentrations in BCWD lakes for 2010 can be found in Figure 6 and Table 2. The ecoregion range for total Kjeldahl nitrogen is 0.60-1.20 mg/L. Bass Lake East, Kismet Basin and Long Lake were within the ecoregion value range, but the remaining lakes exceeded (were poorer than) the ecoregion range for total Kjeldahl nitrogen.

5. TEMPERATURE AND DISSOLVED OXYGEN

In addition to surface water measurements, temperature and dissolved oxygen data were taken at each lake during each sampling event. Temperature and dissolved oxygen were recorded at one-meter increments from the surface down to the lake bottom. The data collected from these profiles are contained in a database at the WCD office and are available upon request or can be obtained using the Metropolitan Council's EIMS (Environmental Information Management System) Water Quality Database website (http://es.metc.state.mn.us/eims). These data show the extent of summer stratification and are useful in identifying the thermocline (the layer of water in which the temperature rapidly declines), if one exists. As a lake stratifies, the water column becomes more stable and mixing is less likely to occur. If mixing occurs during the growing season, bottom nutrients become available and can result in increased algal production. Long Lake, Bass Lake East, Pat Lake, Lynch Lake South and Wood Pile Lake exhibited thermal stratification during the summer months. These lakes are less likely to completely mix during the summer months, whereas Bass Lake West, Goggin's Lake, July Avenue Wetland, Lynch Lake North, Plaisted Lake, South School Section Lake, Kismet Basin, Jackson WMA Pond, Masterman Lake and Benz Lake did not stratify and were able to mix throughout the summer allowing for more internal loading from available nutrients.

6. TROPHIC STATE AND LAKE GRADES

Many water quality scientists classify lakes according to their trophic state. Average summer values of total phosphorus, chlorophyll-*a*, and transparency (measured with the Secchi disk) are most often used to determine a lake's trophic state. The Carlson Trophic State Index is used to quantify the relationship between trophic status and water quality data. Lakes with low biological productivity or oligotrophic lakes, such as lakes common in the northeast part of Minnesota, have low phosphorus concentrations, low chlorophyll-*a* concentrations, and high Secchi disk transparencies. A good local example of an oligotrophic lake is Little Carnelian Lake, located in Section 3 of Stillwater Township. Mesotrophic lakes have slightly more biological production, and are characteristic of lakes found in the north central forest regions of Minnesota. On the other end of the spectrum, lakes with high biological productivity, characterized by high phosphorus concentrations, high chlorophyll-*a* concentrations, and low Secchi disk transparencies, are eutrophic or even hypereutrophic.

Based upon the 2010 data and utilizing the Carlson's Trophic State Index (Table 3), Goggin's Lake, South School Section Lake, Benz Lake, Plaisted Lake, Lynch Lake North and Lynch Lake South are classified as hypereutrophic; Bass Lake West, Kismet Basin, Masterman Lake, Pat Lake, Long Lake, Jackson WMA Pond and Wood Pile Lake are classified as eutrophic; and Bass Lake East is classified as mesotrophic (Table 5). Lakes within the hypereutrophic range typically receive excess nutrient loading from sources within their watersheds. However, some percentage of these nutrients can also be attributed to internal loading within the lake, which is typical of shallow, sediment-rich lakes.

Table 3: Trophic State Index and Ranges

	Trophic State Index	TP (ug/L)	CLA (ug/L)	Secchi (m)
Oligotrophic	<40	<10	<4	>4.8
Mesotrophic	40-50	10-30	4-10	4.8-1.8
Eutrophic	50-70	30-60	10-30	1.8-0.8
Hypereutrophic	>70	>60	>30	<0.8

To allow for a better understanding of lake water quality data and to aid in the comparison of lakes, a Lake Grading System is also used in this report (Table 4). The lake water quality grading system was developed following the 1989 sampling season by Dick Osgood, formerly of the Metropolitan Council. The concept of the lake grading system is a ranking of water quality characteristics by comparing measured values to those of other metro area lakes. The grading curve represents percentile ranges for three water quality indicators; the May through September average values for total phosphorous, chlorophyll-*a* and Secchi disk. These percentiles use ranked data from 119 lakes sampled from 1980-1988 and are shown in Table 4.

Table 4: Lake Grade Ranges

Grade	Percentile	TP (ug/l)	CLA (ug/l)	SD (m)
A	<10	<23	<10	>3.00
B	10-29	23-31	10-19	2.20-3.00
C	30-69	32-67	20-47	1.20-2.19
D	70-90	68-152	48-77	0.70-1.19
F	>90	>152	>77	<0.70

The variables used in the grading system strongly relate to open-water nuisance aspects of a lake (i.e. algal blooms), which can indicate accelerated aging (cultural eutrophication). The Lake Grading System was used for lakes sampled in 2010 with the grades presented in Table 5. Comparing the Lake Trophic Status and the Lake Grading System shows a fair to good correlation between the two systems.

Table 5: 2010 Lake Grades, Trophic State Index, and Trophic Status

Lake	Summer TP Grade & TSI	Summer CLA Grade & TSI	Summer Secchi Grade & TSI	Summer Average Grade & TSI	Trophic Status
Goggins	D	D	F	**D-**	Hypereutrophic
	76	73	65	**71**	
Kismet	C	C	C	**C**	Eutrophic
	60	61	55	**59**	
Long	C	B	B	**B-**	Eutrophic
	61	56	48	**55**	
S School Sec	C	D	C	**C-**	Hypereutrophic
	64	69	54	**62**	
Benz	D	D	D	**D**	Hypereutrophic
	70	72	65	**69**	
Bass East	C	A	B	**B**	Mesotrophic
	61	51	47	**53**	
Bass West	C	B	C	**C+**	Eutrophic
	62	59	51	**57**	
July Ave	NA	NA	NA	**NA**	NA
	NA	NA	NA	**NA**	
Lynch North	F	F	F	**F**	Hypereutrophic
	109	94	95	**99**	
Lynch South	D	F	F	**F**	Hypereutrophic
	69	77	66	**71**	
Masterman	C	C	C	**C**	Eutrophic
	61	61	51	**58**	
Pat	C	B	C	**C+**	Eutrophic
	63	60	49	**57**	
Wood Pile	C	C	C	**C**	Eutrophic
	64	64	53	**60**	
Plaisted	D	C	C	**C-**	Hypereutrophic
	69	67	56	**64**	
Jackson WMA	C	B	C	**C+**	Eutrophic
	61	56	50	**56**	

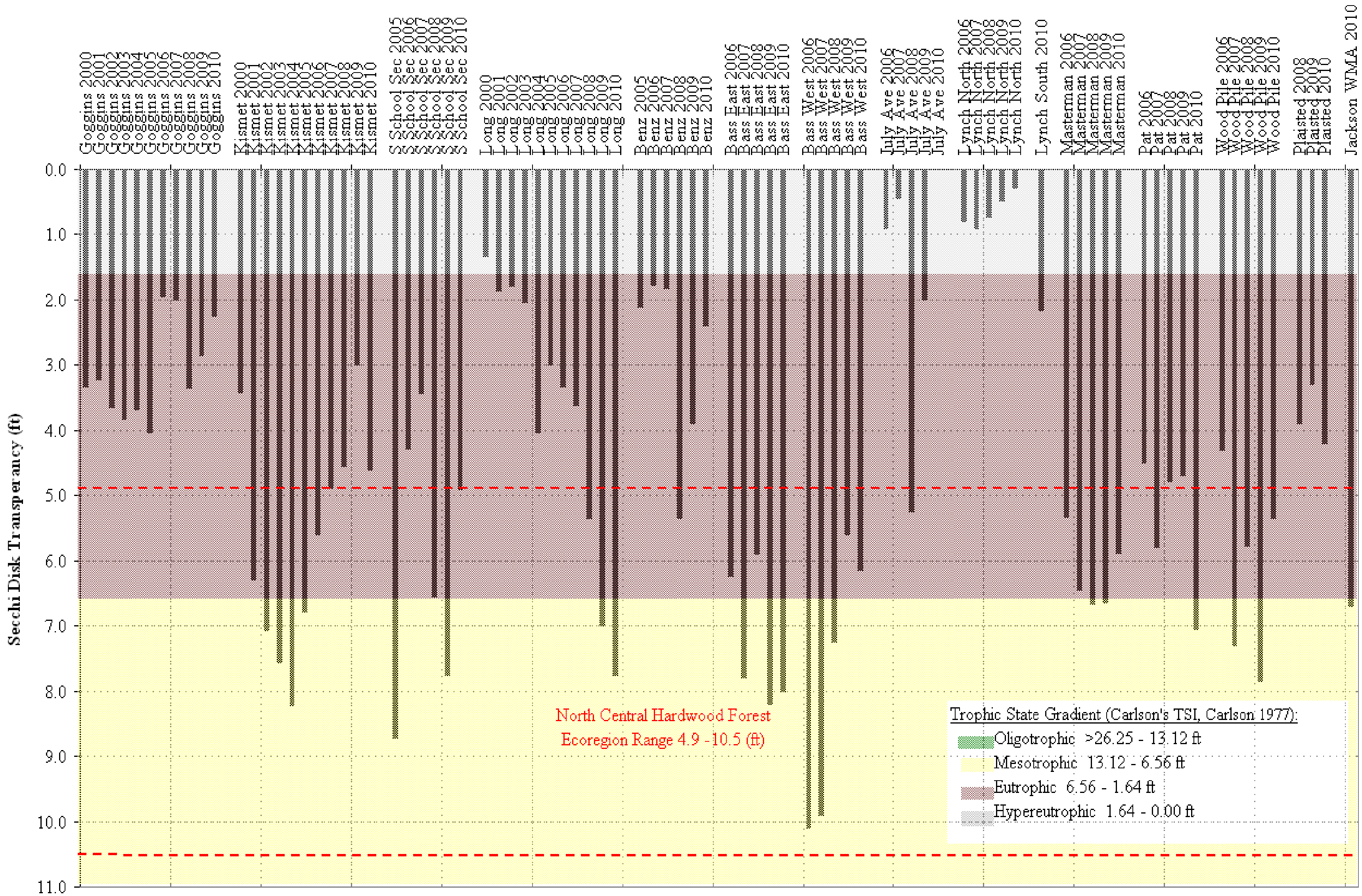


Figure 3: 2010 and Historic Secchi Data

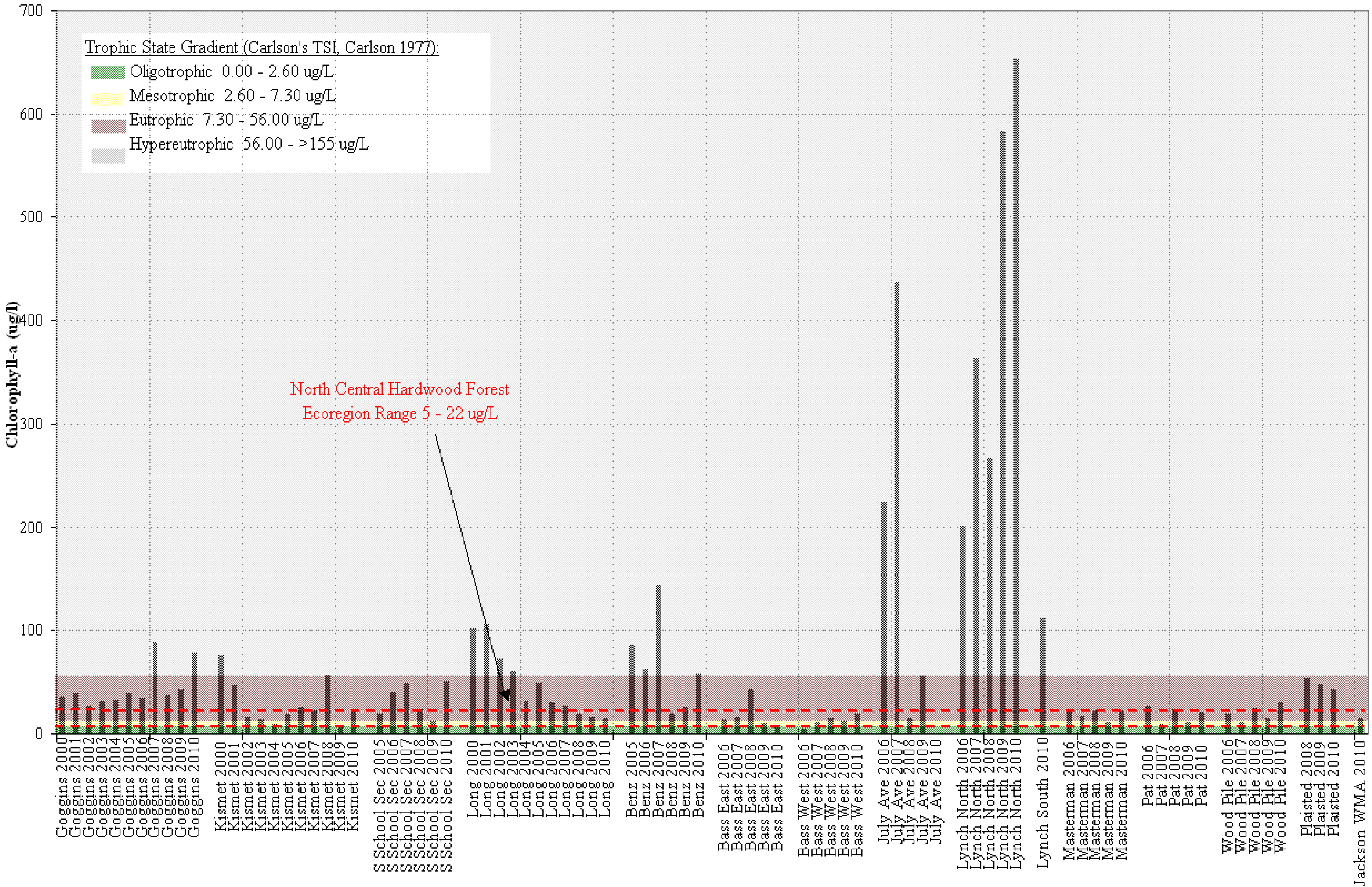
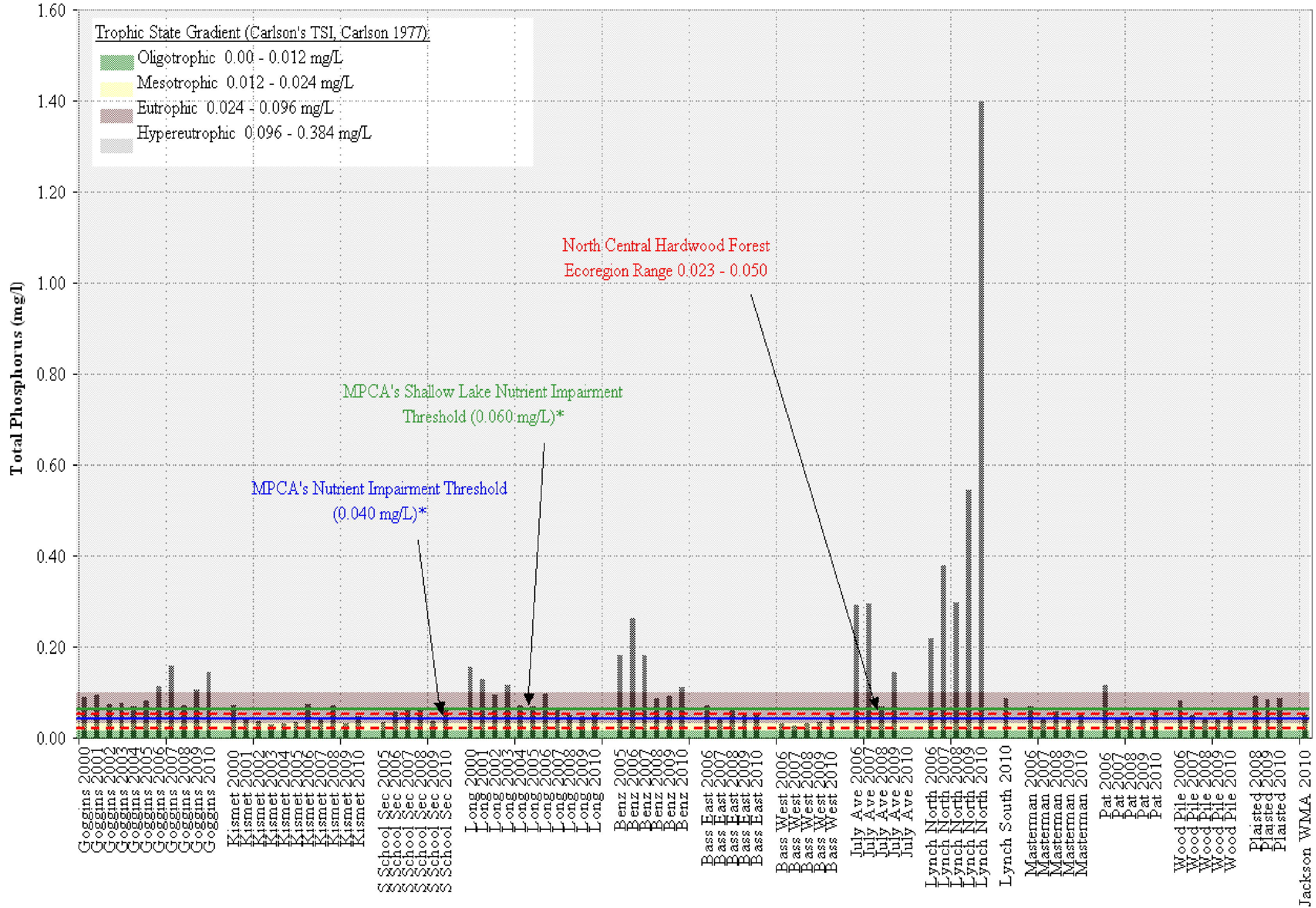


Figure 4: 2010 and Historic Chlorophyll-*a* Data



*Total Phosphorus impairment level, with minimum of 4 samples during the summer months (MPCA)

Figure 5: 2010 and Historic Total Phosphorus Data

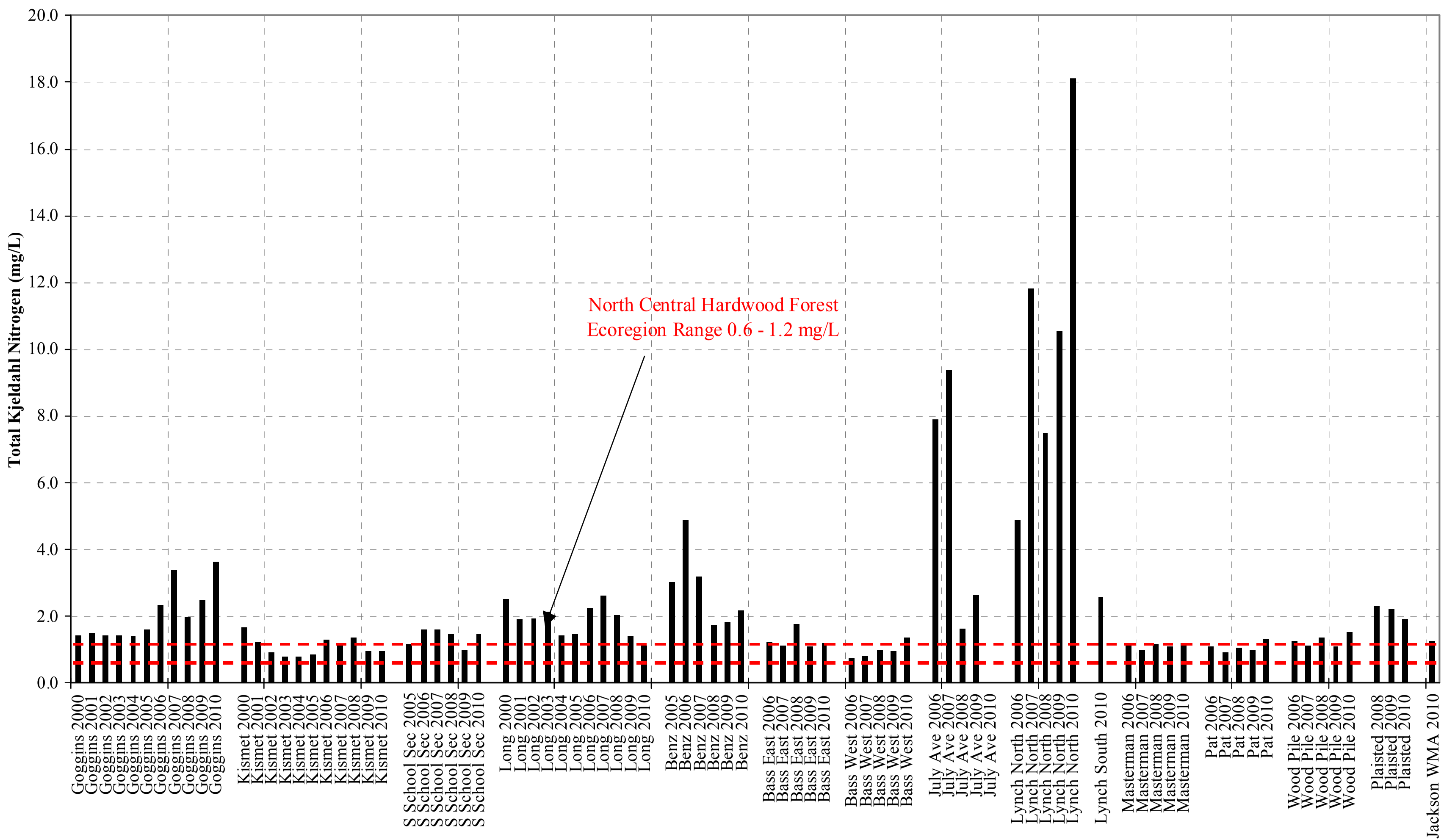


Figure 6: 2010 and Historic Total Kjeldahl Nitrogen Data

7. LAKE ELEVATIONS

Lake elevation gages are located on twenty lakes and/or wetlands throughout BCWD and are monitored by both WCD staff and volunteers. Complete lake/wetland elevation data for 2010 can be found in Figure 8.

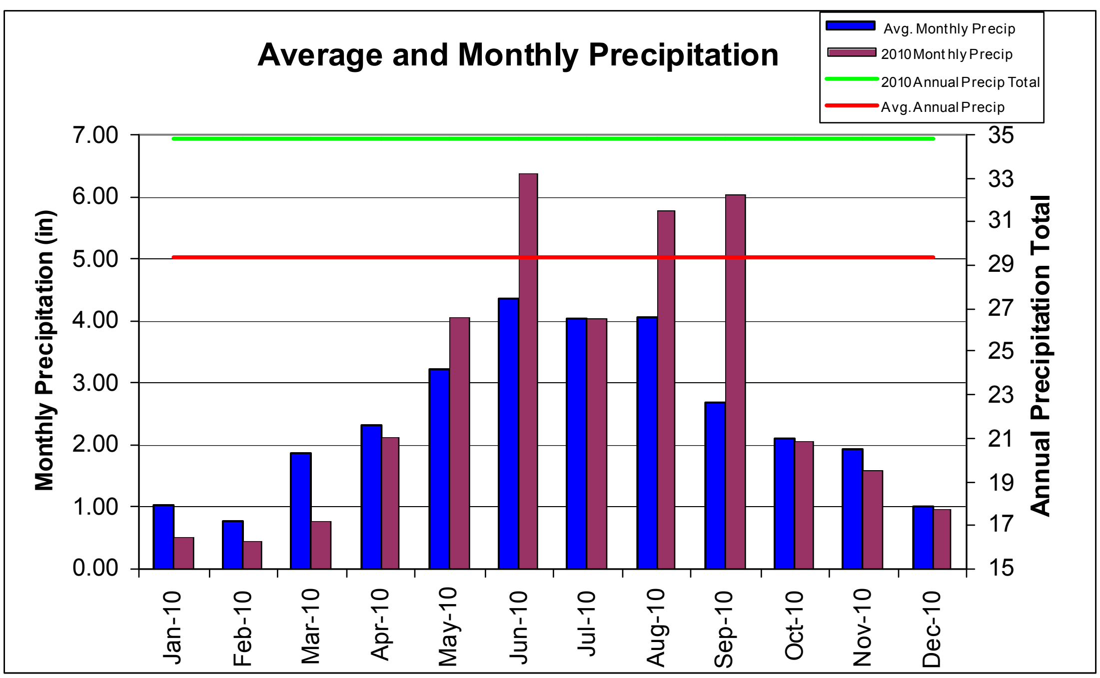
Brown's Creek Watershed District Hydrologic/Hydraulic Study November 1998 (H&H) developed an issues matrix to quantify and summarize flooding impacts. Impacts due to water elevations were determined relative to land that is normally not inundated such as septic systems, wells, residential structures, outbuildings, roads, and driveways. Low impact levels would be water levels above the MN DNR's Ordinary High Water Level that are sustained for long periods of time. Moderate impact levels affect septic systems, drinking water wells, uninhabited structures, or the lowest floor of inhabited structures. In high impact water elevations, water levels are at the lowest opening of inhabited structure or the lowest floor for sustained periods of time. The BCWD updated the H&H Study in 2003, but the issues matrix to quantify and summarize flooding impacts remained unchanged.

Due to the dry summers of 2003-2010, the elevations of the lakes in Brown's Creek Watershed District were never within these developed flooding impact ranges in 2010 (Table 6). Plaisted Lake, South School Section Lake and Wood Pile Lake were within the low impact range for portions of 2008, and Kismet Basin was within the moderate impact range in portions of 2008. This is the last time any basins in BCWD were within any of these developed impact ranges.

Table 6: 2010 Water Elevation Flooding Impacts

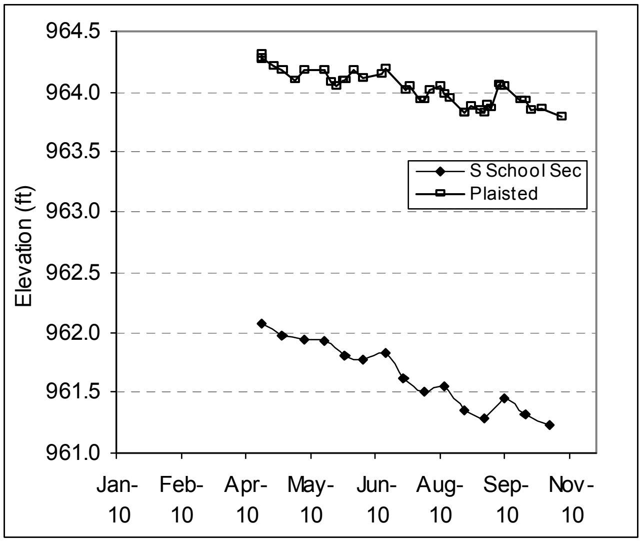
LAKE/WATERBODY	Average Elevation for 2010	Highest Elevation for 2010	Low Impact*	Moderate Impact*	High Impact*
Plaisted	964.03	964.32	*966.0-970.5*	*970.5-971.7*	*>971.7*
School Section	961.64	962.08	*965.3-971.0*	*971-977.2*	*>977.2*
Lynch North	1002.23	1002.54	NA	NA	NA
Lynch South	1001.00	1001.43	NA	NA	NA
Goggins	960.71	961.13	*966.5-968.2*	----	*>968.2*
July Avenue	970.40	970.73	NA	NA	NA
Benz	952.23	952.47	NA	NA	NA
Bass (West)	946.55	947.04	NA	NA	NA
Unnamed (Bass {East})	953.10	953.42	NA	NA	NA
Pat	937.61	937.90	NA	NA	NA
Kismet	938.26	938.95	*<940.6*	*940.6-946.6*	*>946.6*
BC at Gateway Trail	908.35	908.90	NA	NA	NA
Unnamed 82-0128	976.90	977.08	NA	NA	NA
Masterman	951.48	951.78	NA	NA	NA
Wood Pile	961.97	962.22	*<968.5*	NA	NA
Kimbro and Hwy 12	923.61	923.92	NA	NA	NA
Jackson WMA	889.38	890.14	NA	NA	>893.4
Long	889.75	890.17	NA	NA	*>893.4*
Unnamed (316w)	925.44	925.67	NA	NA	NA
Unnamed (Palmquist)	925.73	926.78	NA	NA	NA

** Brown's Creek Watershed District Hydrologic/Hydraulic Study, February 2004, Section VI Table 21*

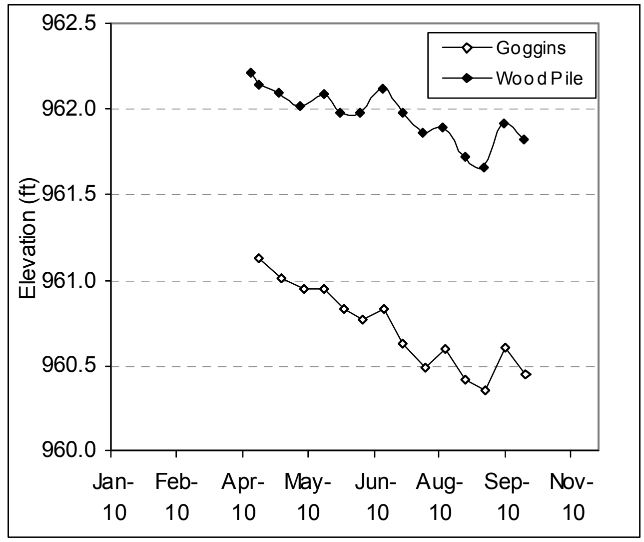


Data from WCD Precipitation Gage T 30N R 20W Sec 32

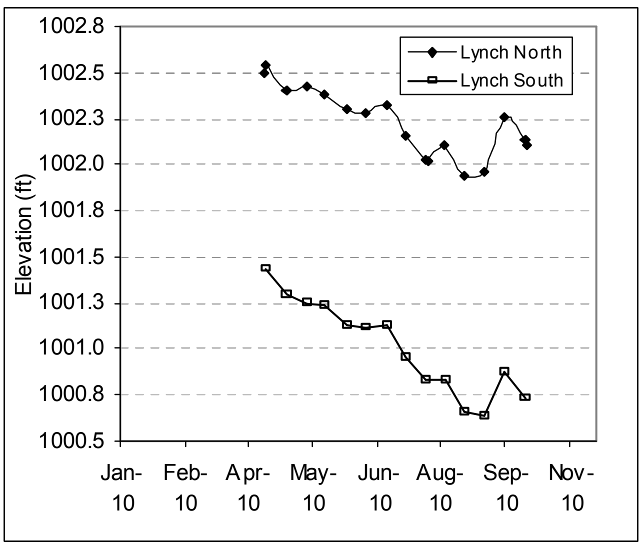
Figure 7: Annual and Monthly Precipitation



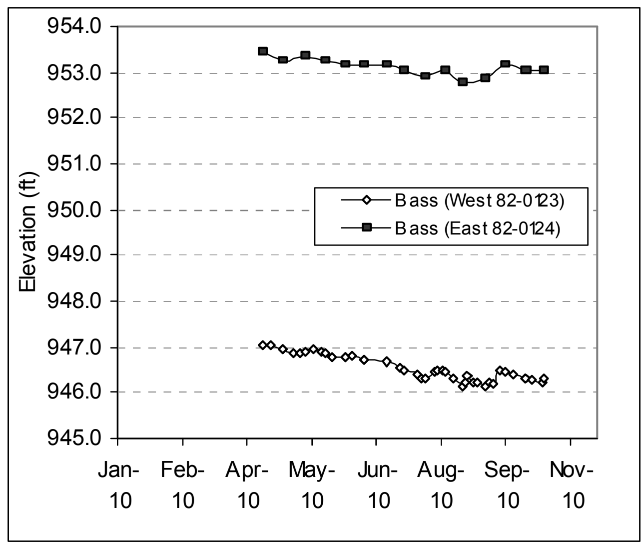
964.5
964.0
963.5
963.0
962.5
962.0
961.5
961.0
Elevation (ft)
S School Sec
Plaisted
Jan-10
Feb-10
Apr-10
May-10
Jun-10
Aug-10
Sep-10
Nov-10



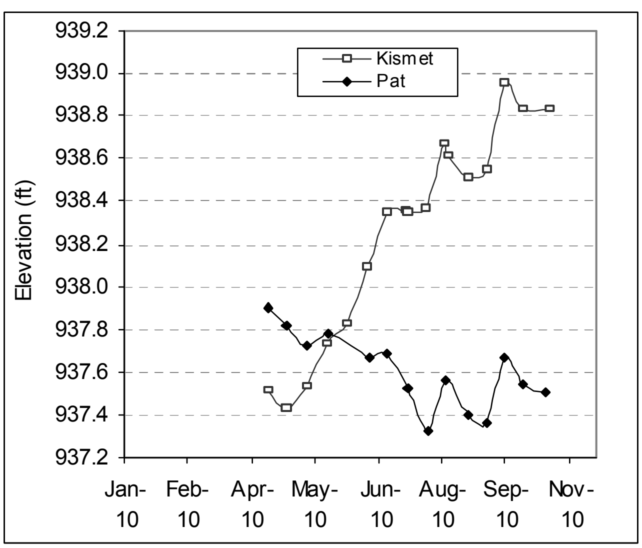
962.5
962.0
961.5
961.0
960.5
960.0
Elevation (ft)
Goggins
Wood Pile
Jan-10
Feb-10
Apr-10
May-10
Jun-10
Aug-10
Sep-10
Nov-10



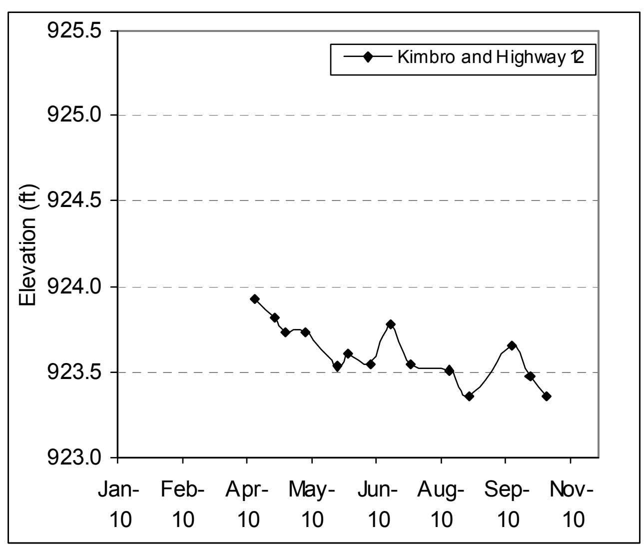
1002.8
1002.5
1002.3
1002.0
1001.8
1001.5
1001.3
1001.0
1000.8
1000.5
Elevation (ft)
Lynch North
Lynch South
Jan-10
Feb-10
Apr-10
May-10
Jun-10
Aug-10
Sep-10
Nov-10



954.0
953.0
952.0
951.0
950.0
949.0
948.0
947.0
946.0
945.0
Elevation (ft)
Bass (West 82-0123)
Bass (East 82-0124)
Jan-10
Feb-10
Apr-10
May-10
Jun-10
Aug-10
Sep-10
Nov-10



939.2
939.0
938.8
938.6
938.4
938.2
938.0
937.8
937.6
937.4
937.2
Elevation (ft)
Kismet
Pat
Jan-10
Feb-10
Apr-10
May-10
Jun-10
Aug-10
Sep-10
Nov-10



925.5
925.0
924.5
924.0
923.5
923.0
Elevation (ft)
Kimbro and Highway 12
Jan-10
Feb-10
Apr-10
May-10
Jun-10
Aug-10
Sep-10
Nov-10

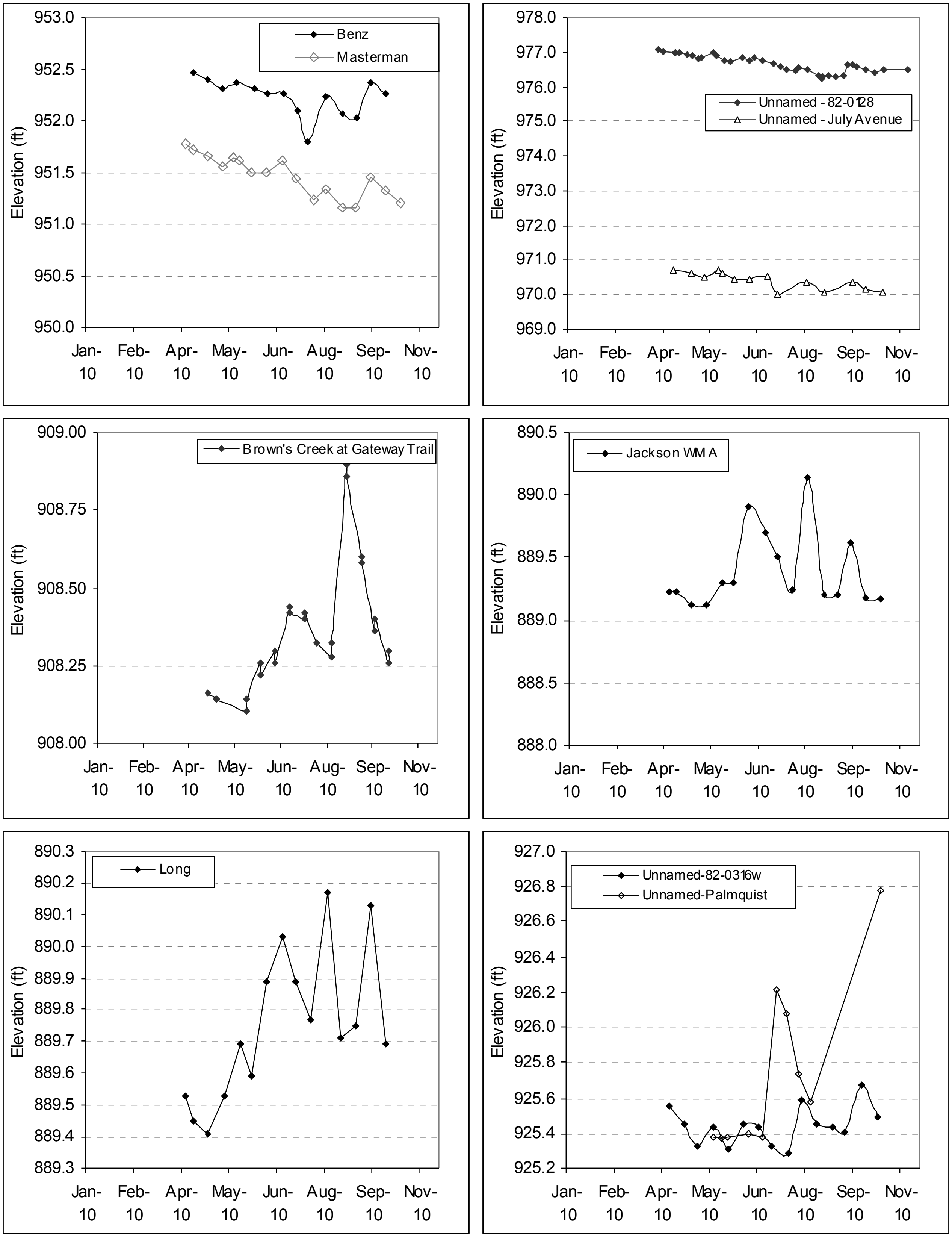


Figure 8: 2010 Lake Levels

LAKE WATER QUALITY CONCLUSIONS AND RECOMMENDATIONS

Lake monitoring in Brown's Creek Watershed District continues to provide valuable baseline water quality information. To determine the health of the lakes in BCWD, physical and chemical parameters are compared on a year-to-year basis.

In 2010, the fourteen lakes monitored had good to very poor water quality ratings and were classified as, mesotrophic (Bass Lake East), eutrophic (Bass Lake West, Kismet Basin, Long Lake, Masterman Lake, Pat Lake, Jackson WMA Pond and Wood Pile Lake) and hypereutrophic (Goggin's Lake, Plaisted Lake, South School Section Lake, Benz Lake, Lynch Lake North and Lynch Lake South). The overall 2010 lake grades for BCWD lakes were: Bass Lake East – B, Long Lake – B-, Pat Lake – C+, Bass Lake West – C+, Jackson WMA Pond – C+, Masterman Lake – C, Woodpile Lake – C, Kismet Basin – C, South School Section Lake – C-, Plaisted Lake – C-, Benz Lake – D, Goggin's Lake – D-, Lynch Lake North – F, Lynch Lake South – F. Of the lakes that have water quality data for 2009, five lakes showed a slight deterioration in water quality for the 2010 season (Masterman Lake, Woodpile Lake, Benz Lake, South School Section Lake and Goggin's Lake), four lakes maintained their water quality (Bass Lake West, Pat Lake, Kismet Basin and Lynch Lake North), and three lakes improved in water quality (Bass Lake East, Long Lake and Plaisted Lake). Goggin's Lake, Plaisted Lake, Benz Lake, Lynch Lake North and Lynch Lake South were considered worse than the ecoregion range for total phosphorus, total Kjeldahl nitrogen, chlorophyll-*a,* and Secchi disk transparency. Bass Lake East and Long Lake were worse than the ecoregion range for total phosphorus and within the ecoregion range for total Kjeldahl nitrogen, chlorophyll-*a*, and Secchi disk transparency. Woodpile Lake and South School Section Lake were worse than the ecoregion range for chlorophyll-*a*, total phosphorus and total Kjeldahl nitrogen, but within the ecoregion range for Secchi disk transparency. Pat Lake, Bass Lake West and Masterman Lake were worse than the ecoregion range for total phosphorus and total Kjeldahl nitrogen, and within ecoregion range for chlorophyll-*a* and Secchi disk transparency. Jackson WMA Pond was worse than the ecoregion range for total Kjeldahl nitrogen, and within ecoregion range for total phosphorus, chlorophyll-*a,* and Secchi disk transparency. Kismet Basin was worse than ecoregion values for Secchi disk transparency, and within the ranges for total phosphorus, chlorophyll-*a* and total Kjeldahl nitrogen.

The Washington Conservation District conducted Kendal Tau statistical analysis of all lakes monitored by the WCD to determine any long-term water quality trends. For Brown's Creek Watershed District lakes, only three lakes had a significant trend. Goggin's Lake had a statistically significant decreasing Secchi transparency trend ($p<0.10$), Benz Lake had an improving total phosphorus trend and Long Lake had significantly increasing Secchi disk transparency and improving total phosphorus trends.

Water quality in a lake depends on a number of different variables such as: size of the contributing watershed, depth of the lake, current amount of nutrients available, and amount of nutrients periodically released from the lake bottom and from external sources. Low water quality ratings of BCWD lakes are most likely due to the shallowness of the lakes. Shallow lakes typically will exist in a low algal production, clear-water state or a high-algal production, turbid water state, but not in between the two states. Shallow lakes do not completely stratify in the summer; therefore they are capable of continually mixing. Mixing causes phosphorus to be distributed throughout the water column, causing more frequent heavy algal blooms. This is unlike deeper, stratified lakes where the phosphorus below the thermocline is not available for primary production. In 2010, both deep and shallow lakes throughout the county showed water quality degradation. One explanation for this reduction in water quality is the period of warm, dry summers that occurred in the past six years. Although 2010 returned to average precipitation amounts, lake elevations continued to be lower than normal and may have contributed to higher water temperatures, more algae production, less dissolved oxygen, and in the breaking of chemical and sediment bonds, resulting in the release of more nutrients into the water. The possibility exists in some lakes with invasive/exotic macrophytes present, for these macrophytes to dieback early in the season releasing more nutrients. The continued low water levels present in all of the monitored lakes certainly allowed the mixing of shallow lakes to release more phosphorus. Warmer water has less capacity to hold dissolved oxygen and when lakes or wetlands become anoxic (lacking in oxygen), the possibility of phosphorus release becomes greater. Another factor that may be contributing to the degradation in many of the shallow lakes is that many of our runoff events were intense and short in duration. More pollutants can be introduced in short, heavy storm events than in slow, less intense storm events. Controls on land use practices in the watershed may halt the decline in water quality although it may not be enough to provide short-term noticeable improvements in water quality trends. It is recommended that the BCWD continue lake water quality monitoring to track trends and identify any potential water quality impairments.

The twenty basins monitored for water elevation showed peaks from late April to early May in 2010. Levels steadily declined from May until November. Exceptions to this are BC Bike Trail, Long Lake and Jackson WMA, which had their highest levels occur in August, and overall experienced seasonal fluctuation. Kismet Basin was the only monitored basin that experienced an overall gain in elevation as the season progressed. The cause of the decrease in elevation throughout the summer and fall is not entirely apparent, but likely due in large part to the lack of precipitation during the previous years. All average water elevations of lakes were below flooding impact ranges, as compared to the Brown's Creek Watershed District's 2003 Hydrologic/Hydraulic Study. It is recommended that water level monitoring continue in the BCWD lakes and wetlands.

The Trophic State Index (TSI), which was developed by Carlson in 1977, is similar to the Metropolitan Council lake grading system in that it is a method to classify and rank lakes based on water quality. A lower TSI value corresponds to lower concentrations of total phosphorus and chlorophyll-*a* and greater Secchi transparencies. The TSI also provides a method of analysis to determine how a lake is functioning. The TSI values for Secchi depth, chlorophyll-*a*, and total phosphorus are calculated such that equal values for each should occur if a lake is functioning "normally". Deviations from equality in TSI values may give more detailed information about the water quality of a lake (Table 9 and Figure 9). The following tables from Carlson and Simpson (1986) describe how TSI is calculated and what information the TSI values will provide.

Table 7: Trophic State Index Equations

$$TSI(SD) = 60 - 14.41 \ln(SD)$$

$$TSI(CHL) = 9.81 \ln(CHL) + 30.6$$

$$TSI(TP) = 14.42 \ln(TP) + 4.15$$

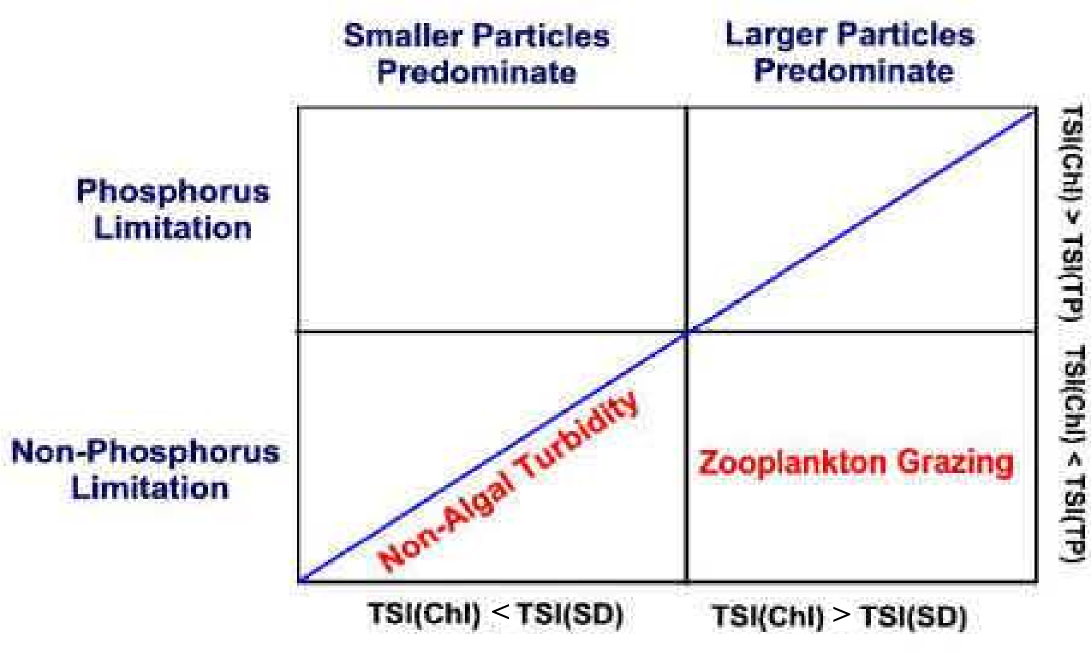
Table 8: Trophic State Gradient

A list of possible changes that might be expected in a north temperate lake as the amount of algae changes along the trophic state gradient.

TSI	CLA (µg/L)	SD (m)	TP (µg/L)	Attributes	Water Supply	Fisheries & Recreation
<30	<0.95	>8	<6	**Oligotrophy:** Clear water, oxygen throughout the year in the hypolimnion	Water may be suitable for an unfiltered water supply.	Salmonid fisheries dominate
30-40	0.95-2.6	8-4	6-12	Hypolimnia of shallower lakes may become anoxic		Salmonid fisheries in deep lakes only
40-50	2.6-7.3	4-2	12-24	**Mesotrophy:** Water moderately clear; increasing probability of hypolimnetic anoxia during summer	Iron, manganese, taste, and odor problems worsen. Raw water turbidity requires filtration.	Hypolimnetic anoxia results in loss of salmonids. Walleye may predominate
50-60	7.3-20	2-1	24-48	**Eutrophy:** Anoxic hypolimnia, macrophyte problems possible		Warm-water fisheries only. Bass may dominate.
60-70	20-56	0.5-1	48-96	Blue-green algae dominate, algal scums and macrophyte problems	Episodes of severe taste and odor possible.	Nuisance macrophytes, algal scums, and low transparency may discourage swimming and boating.
70-80	56-155	0.25-0.5	96-192	**Hypereutrophy:** (light limited productivity). Dense algae and macrophytes		
>80	>155	<0.25	192-384	Algal scums, few macrophytes		Rough fish dominate; summer fish kills possible

Table 9: Relationship between TSI Variables

Relationship Between TSI Variables	Conditions
TSI(CLA) = TSI(TP) = TSI(SD)	Algae dominate light attenuation; TN/TP ~ 33:1
TSI(CLA) > TSI(SD)	Large particulates, such as *Aphanizomenon* flakes, dominate
TSI(TP) = TSI(SD) > TSI(CHL)	Non-algal particulates or color dominate light attenuation
TSI(SD) = TSI(CHL) > TSI(TP)	Phosphorus limits algal biomass (TN/TP >33:1)
TSI(TP) >TSI(CHL) = TSI(SD)	Algae dominate light attenuation but some factor such as nitrogen limitation, zooplankton grazing or toxics limit algal biomass.



A representation of possible explanations of deviations of the Trophic State Index equations.

Figure 9: Deviations of the Trophic State Index Values for Different Parameters

III. BROWN'S CREEK

A. METHODS, RESULTS, AND DISCUSSION

Brown's Creek is a spring fed tributary of the St. Croix River. It is 9.7 miles long, flowing from its source through a variety of glacial drift landscapes. The middle reach of the stream flows through various wetlands and marshes with substrates of mucky peat, changing to course sand-gravel in areas with higher gradients. The lower reaches of the stream cut deeply into steeply sloping hills of sandstone and dolomite adjacent to the St. Croix River. Groundwater springs provide a major hydrologic input of this portion of the stream, and is the only portion that supports trout. The DNR Fisheries have stocked the lower reach annually with as many as 1,000 yearling trout. In 2010, 500 larger adult trout were stocked. Brown trout do reproduce naturally in the stream.

About 2,200 feet of Brown's Creek underwent realignment in the fall of 1999. Before the realignment the stream ran through a ditched channel in a wetland adjacent to McKusick Lake. The new channel no longer runs through the wetland and was constructed to mimic a natural gravel streambed with a series of pools and riffles. This restored channel is significantly shorter than the old channel; therefore peak flows are expected to increase downstream. The time of travel through this section of stream will decrease significantly, so water temperature should decrease as well. The macroinvertebrate and fish population may also change along with changes in hydrology, substrate, dissolved oxygen and temperature in this portion of the stream.

The City of Stillwater completed the Trout Stream Mitigation Project (TSMP) in June 2003 and has been functioning to divert stormwater from the 1800-acre Annexation Area away from Brown's Creek, through McKusick Lake to the St. Croix River. This diversion structure will keep the warmer urban stormwater from the southern tributary out of the temperature and nutrient sensitive Brown's Creek Ravine.

In 2008, the subwatershed acreages for each monitoring site were updated in accordance with the 2003 H&H study. Previous drainage areas had been based on the 1998 study. Landlocked basins, areas that do not produce runoff in a 100-year or 24 hour storm event, were not included in the new drainage acreages. Note that these changes will make current and future loading amounts per acre appear to be higher than past values. This is because the number of acres for each subwatershed decreased, thereby increasing the concentration load. Also note that the TSMP/Diversion Structure is designed to divert flows from the Long Lake drainage away from Brown's Creek up to the 1.5-year storm event under fully developed conditions. Since the diversion structure was completed in June 2003, all flows from the Long Lake drainage have been diverted away from Brown's Creek toward McKusick Lake and on to the St. Croix River. Therefore, the drainage areas for the monitoring sites downstream of the diversion structure (McKusick, Stonebridge, and the Outlet) do not include the diversion drainage areas. It may be necessary in the future to add the diversion drainage areas for these sites if monitoring data shows that the flows are not being diverted in their entirety.

1. FLOW AND WATER QUALITY

In 2010, the WCD took grab samples and/or flow-weighted samples during both base flow and storm event conditions at fifteen locations within the watershed. Seven automated samplers continuously monitored stream flow and collected storm and base flow composite samples from March through November and one continuously monitored stream flow all year (Brown's Creek Outlet). Brown's Creek was monitored at Highway 15, (approximately 4.5 miles from the mouth), McKusick Road, (approximately 1.7 miles from the mouth), Stonebridge, (approximately 1.2 miles from the mouth), and at the Creek Outlet (Figure 1). Tributaries to Long Lake were monitored at 62nd Street (south drainage to Long Lake), the Herberger's Pond (~0.95 miles southeast of Long Lake) and the Marketplace pond (~0.5 miles southeast of Long Lake). The drainage from Long Lake to McKusick Lake (at the Brown's Creek Diversion Structure) was also monitored to determine quantity and quality of water diverted to McKusick Lake. Field flow measurements and water quality grab samples were collected at Long Lake Outlet, Jackson WMA Pond Outlet, West Branch 1,West Branch 2, North Branch, South Branch and the drainage crossing at Boutwell Rd. In 2010 Emmons and Olivier Resources collected field flow measurements and water quality grab samples at four additional sites along the annexation area drainage (Creekside, North Settlers, South Settlers and East Settlers). Results from all of the samples collected, as well as estimates of daily flow and load for each site in the diversion drainage area are summarized in Table 28. Data collected by the WCD and EOR included the total discharge, temperature, precipitation, conductivity, dissolved oxygen, pH, and analytical analysis (performed by MVTL lab) can be seen in Table 1. A list of WCD standard operating procedures can be found at http://www.mnwcd.org/water_monitoring_standards.php. All stream flow and chemistry data from 2010 can be found on pages 25-46. Historical ranges for water quality samples collected on Brown's Creek can be seen starting with Figure 10. Using a combination of composite and grab samples, total phosphorus and total suspended solid loads were calculated at all sites. From 2003 to 2010, the total phosphorus and total suspended solids loading estimates generally decreased (Figure 10, Figure 11, Figure 12 and Figure 13). The lack in overall runoff during the 2003 to 2010 seasons is the major contributor to the decline in total loads that were seen. The minimal snowfall in the winters of 2002-03, 2003-04, 2004-05, 2005-06, 2006-07 and 2007-08 and the dry summers of 2003-09 primarily caused the runoff reduction experienced in 2003-09. Although 2010 returned to normal levels of precipitation, sites downstream of Highway 15 experienced a decrease in discharge and nutrient loading. The exact cause of this is unknown, but a potential explanation is that a series of beaver dams were constructed upstream of the McKusick road site during the monitoring season. Also note that values before 2003 are omitted from the report, due to the monitoring data showing that the diversion drainage has not directly impacted the creek since the completion of the diversion structure, as well as updates made by the 2003 H&H study.

The total phosphorus load from Brown's Creek to the St. Croix River in 2010 was **1,126 lbs (0.12 lbs per acre of watershed land)**, determined by the Brown's Creek Outlet station results.

Brown's Creek Total Phosphorus Load

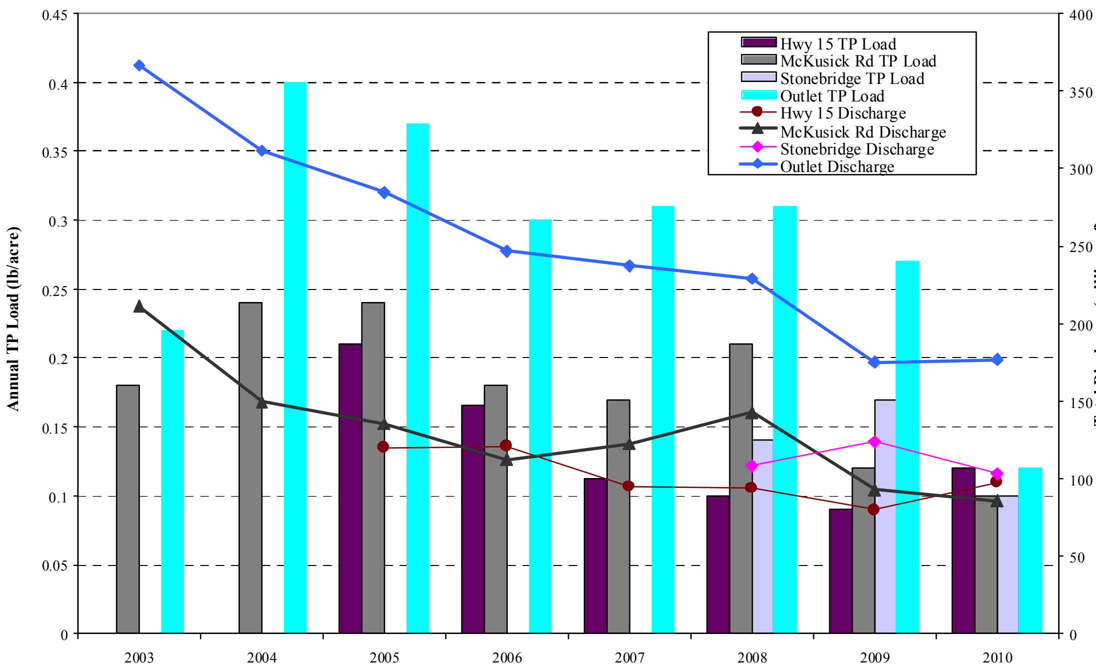


Figure 10: Brown's Creek Annual Total Phosphorus Load per Acre

Brown's Creek Total Suspended Solid Load

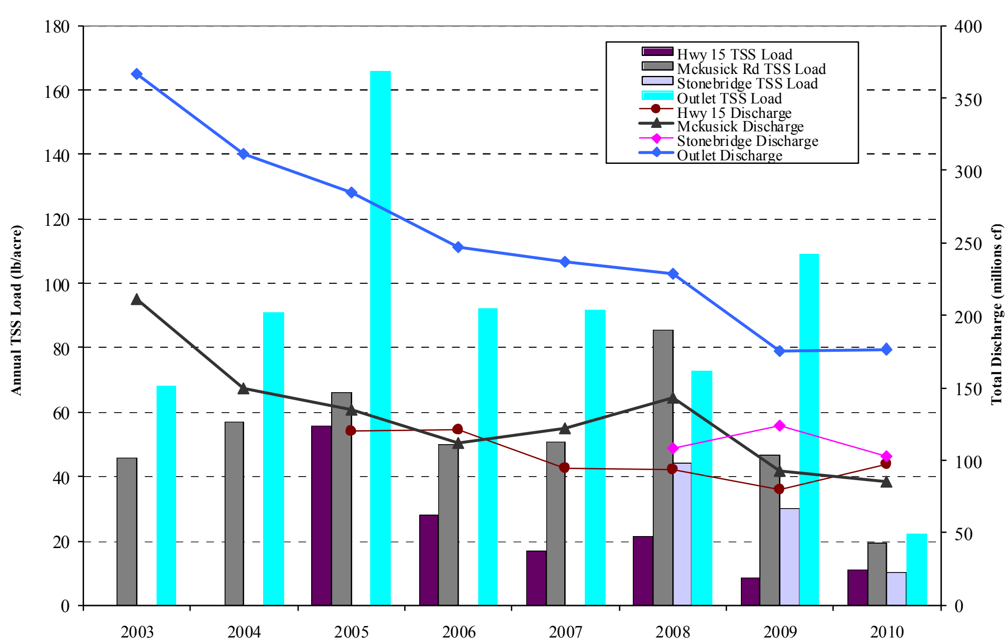


Figure 11: Brown's Creek Annual Total Suspended Solids Load per Acre

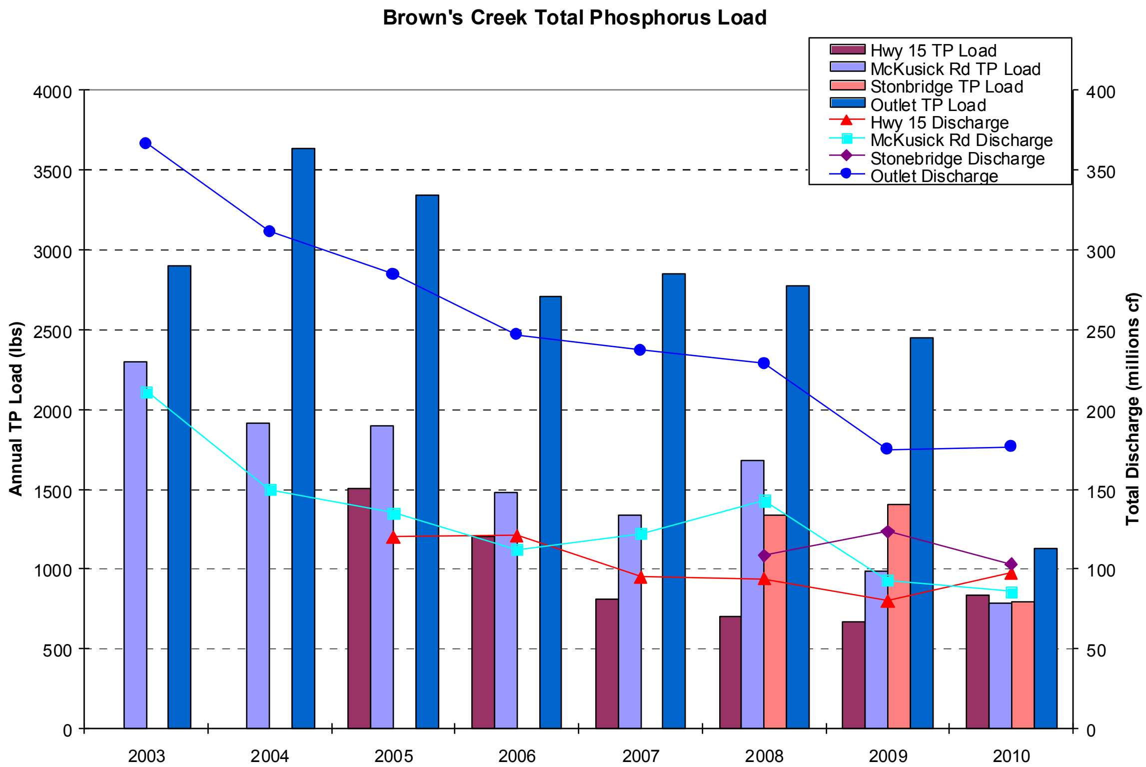


Figure 12: Brown's Creek Annual Total Phosphorous Loads

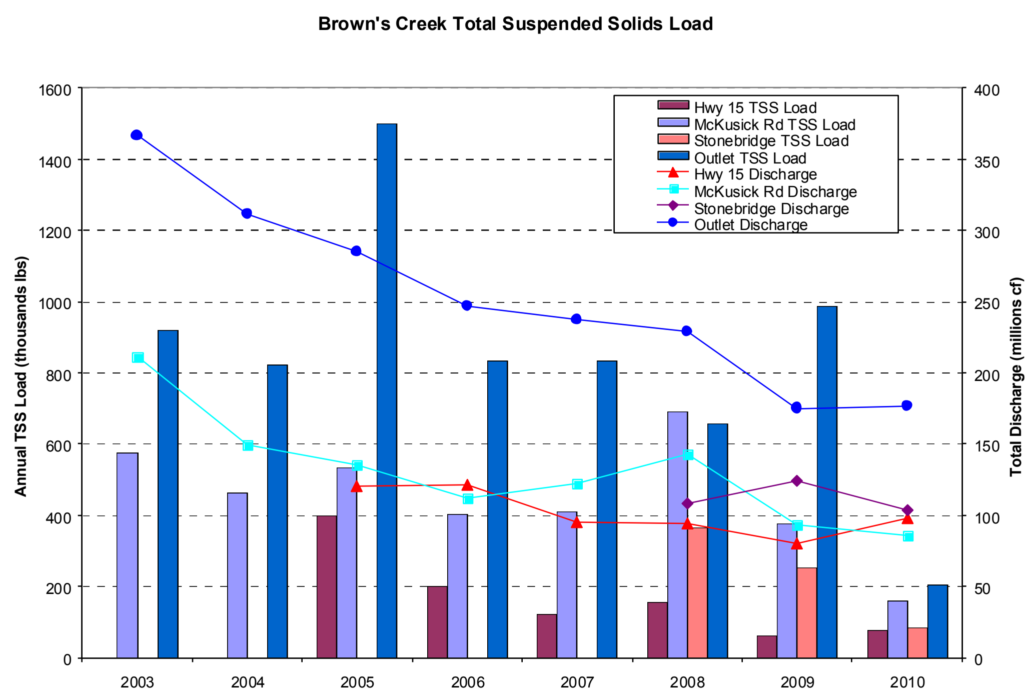


Figure 13: Brown's Creek Annual Total Suspended Solids Loads

Table 10. Brown's Creek Annual Flow and Loading Amounts

	2003	2004	2005	2006	2007	2008	2009	2010
Brown's Creek at Highway 15								
Discharge (cf)			120,053,422	120,925,470	94,837,449	93,807,247	79,814,166	97,611,702
Total pounds of Phosphorus exported			1,507	1,206	812	705	672	833
TP (lb/ac/yr)			0.210	0.166	0.113	0.100	0.090	0.120
Total pounds of TSS exported			398,661	201,190	121,471	153,834	62,160	78,762
TSS (lb/ac/yr)			55.87	28.20	17.02	21.56	8.71	11.04
Brown's Creek at McKusick Road								
Discharge (cf)	211,048,686	149,679,336	135,350,245	112,178,365	122,217,561	142,818,797	92,884,028	85,721,155
Total pounds of Phosphorus exported	2,297	1,916	1,901	1,478	1,337	1,678	985	787
TP (lb/ac/yr)	0.180	0.240	0.240	0.180	0.170	0.210	0.120	0.100
Total ponds of TSS exported	575,181	461,349	534,090	404,195	409,774	690,483	375,461	157,616
TSS (lb/ac/yr)	46.01	57.21	66.23	50.12	50.82	85.63	46.56	19.55
Brown's Creek at Stonebridge								
Discharge (cf)						108,322,492	123,669,192	103,170,269
Total pounds of Phosphorus exported						1,338	1,405	796
TP (lb/ac/yr)						0.140	0.170	0.100
Total pounds of TSS exported						366,299	251,770	83,856
TSS (lb/ac/yr)						44.08	30.30	10.09
Brown's Creek Outlet								
Discharge (cf)	366,454,418	311,486,775	284,689,396	246,911,275	237,176,413	228,887,041	175,097,177	176,755,632
Total pounds of Phosphorus exported	2,902	3,633	3,338	2,706	2,850	2,775	2,448	1,126
TP (lb/ac/yr)	0.220	0.400	0.370	0.300	0.310	0.310	0.270	0.120
Total pounds of TSS exported	919,534	821,769	1,499,031	834,863	831,819	657,250	988,987	202,744
TSS (lb/ac/yr)	68.16	90.79	165.62	92.24	91.90	72.62	109.27	22.40

Table 11: Brown's Creek at Highway 15 2010 Primary Chemistry Results

Sample Type	Start	End	TSS (mg/L)	VSS (mg/L)	TKN (mg/L)	TP (mg/L)	Dissolved P (mg/L)	E Coli (mpn/100 mL)	COD (mg/L)	TBOD 5-Day (mg/L)	CBOD 5-Day (mg/L)	Turbidity (NTRU)
Snowmelt Grab	3/11/2010 8:14	3/11/2010 8:14	32	20	0.99	0.166	0.092		52	4.9	3.5	12
Base Grab	1/25/2010 9:09	1/25/2010 9:09	4	3	0.58	0.077	~0.021		16	1.1		3
Base Grab	4/29/2010 11:12	4/29/2010 11:12	8	4	0.41	0.067	~0.036		18	<1.0	<1.0	4
Base Grab	5/24/2010 11:13	5/24/2010 11:13	7	5	0.69	0.143	0.09		28	1.3	<1.0	6
Base Grab	7/21/2010 8:35	7/21/2010 8:35	3	~2	0.5	0.111	~0.049		20	<1.0	<1.0	3
Base Grab	8/23/2010 8:57	8/23/2010 8:57	~5	~3	0.63	0.15	0.059		32	1.7	1.1	6
Base Grab	9/20/2010 10:21	9/20/2010 10:21	~2	~1	0.50	0.085	~0.034		21	<1.0	<1.0	4
Base Grab	9/28/10 8:27	9/28/10 8:27	4	4								3
Base Grab	10/6/10 9:03	10/6/10 9:03	3	~2	0.45	0.076	~0.034		20	<1.0	<1.0	4
Base Grab	10/12/10 8:10	10/12/10 8:10	4	~2								5
Storm Composite	4/15/2010 4:36	4/15/2010 14:03	21	13	0.6	0.08	~0.030		37			
Storm Composite	5/11/2010 4:27	5/13/2010 7:59	30	20	1.5	0.129	~0.029		41			
Storm Composite	6/8/2010 16:52	6/9/2010 15:38	33	18	1.2	0.206	0.06		53			
Storm Composite	6/25/2010 19:29	6/27/2010 4:44	49	26	1.9	0.271	0.096		72			
Storm Composite	8/8/2010 7:23	8/9/2010 15:14	43	~24	1.5	0.297	0.07		62			
Storm Composite	8/10/2010 23:06	8/11/2010 21:20	54	~12	1.8	0.423	0.077		78			
Storm Composite	9/2/2010 5:33	9/3/2010 13:38	36	18	1.3	0.275	0.101		58			
Storm Composite	9/15/2010 22:45	9/16/2010 8:05	51	27	1.4	0.291	0.074		58			
Storm Composite	9/23/10 1:35	9/24/10 5:32	101	59	2.50	0.351	0.083		104			
Storm Grab	10/26/10 10:29	10/26/10 10:29	13	9								7
E. Coli Grab	5/25/2010 7:56	5/25/2010 7:56						326				
E. Coli Grab	6/24/2010 9:40	6/24/2010 9:40						144				
E. Coli Grab	7/28/2010 11:58	7/28/2010 11:58						818				
E. Coli Grab	8/26/2010 9:04	8/26/2010 9:04						225				
E. Coli Grab	9/30/10 7:54	9/30/10 7:54						101				

Exceeds Water Quality Standard

Exceeds Water Quality Standard for Turbidity(TSS Value used to calculate)

Table 12: Brown's Creek at Highway 15 2010 Secondary Chemistry Results including Exceeded MPCA 7050 Water Quality Standards

Sample Type	Start Date	Start Time	Copper (mg/L)	Nickel (mg/L)	Lead (mg/L)	Zinc (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Chloride (mg/L)	Nitrite N (mg/L)	Nitrate N (mg/L)	Ammonia Nitrogen (mg/L)	Hardness (mg/L)
Snowmelt Grab	3/11/2010 8:14	3/11/2010 8:14	0.0011	0.0014	<0.0005	0.0054	<0.0005	<0.005	11	<0.03	0.59	0.17	120
Base Grab	1/25/2010 9:09	1/25/2010 9:09	0.0006	0.0021	0.0001	<0.005	<0.0005	<0.005	12	<0.03	0.94	0.13	200
Base Grab	4/29/2010 11:12	4/29/2010 11:12	<0.0005	0.0025	<0.0001	<0.005	<0.0005	<0.005	14	<0.03	0.25	~0.03	196
Base Grab	5/24/2010 11:13	5/24/2010 11:13	<0.0005	0.0016	0.0002	<0.005	<0.0005	<0.005	12	<0.03	0.2	0.07	196
Base Grab	7/21/2010 8:35	7/21/2010 8:35	<0.0005	0.002	<0.0001	<0.005	<0.0005	<0.005	12	<0.03	0.16	~0.05	236
Base Grab	8/23/2010 8:57	8/23/2010 8:57	<0.0005	0.0021	<0.0001	<0.005	<0.0005	<0.005	11	<0.03	0.06	~0.05	214
Base Grab	9/20/2010 10:21	9/20/2010 10:21	<0.0005	0.00190	<0.0005	0.0106	<0.0005	<0.005	11	<0.03	0.18	~0.04	194
Base Grab	9/28/10 8:27	9/28/10 8:27											
Base Grab	10/6/10 9:03	10/6/10 9:03	<0.010	<0.020	<0.003	<0.020	<0.001	<0.010	12	<0.03	0.34	0.08	190
Base Grab	10/12/10 8:10	10/12/10 8:10											
Storm Composite	6/8/2010 16:52	6/9/2010 15:38	0.0008	0.002	0.0004	0.0103	<0.0005	<0.005	9	0.35	0.25	~0.04	112
Storm Composite	4/15/2010 4:36	4/15/2010 14:03	0.0012	0.0022	0.0005	<0.005	<0.0005	<0.005	16	<0.03	0.18	~0.02	164
Storm Composite	5/11/2010 4:27	5/13/2010 7:59	0.0013	0.0019	0.0005	<0.005	<0.0005	<0.005	14	<0.03	0.06	~0.02	140
Storm Composite	6/25/2010 19:29	6/27/2010 4:44	0.0013	0.0017	0.0006	<0.005	<0.0005	<0.005	6	<0.03	0.08	~0.05	142
Storm Composite	8/8/2010 7:23	8/9/2010 15:14	0.001	0.0022	0.0006	<0.005	<0.0005	<0.005	8	<0.03	0.09	<0.02	164
Storm Composite	8/10/2010 23:06	8/11/2010 21:20	0.001	0.0019	0.0005	<0.005	<0.0005	<0.005	7	<0.03	0.1	0.06	128
Storm Composite	9/2/2010 5:33	9/3/2010 13:38	0.0007	0.0019	0.0006	<0.005	<0.0005	<0.005	10	<0.03	0.07	~0.03	158
Storm Composite	9/15/2010 22:45	9/16/2010 8:05	0.0009	0.0021	0.0009	0.0135	<0.0005	<0.005	12	<0.03	0.15	~0.03	160
Storm Composite	9/23/10 1:35	9/24/10 5:32	<0.010	<0.020	<0.003	<0.020	<0.001	<0.010	8	<0.03	0.07	<0.02	32
Storm Grab	10/26/10 10:29	10/26/10 10:29											
E. Coli Grab	5/25/2010 7:56	5/25/2010 7:56											
E. Coli Grab	6/24/2010 9:40	6/24/2010 9:40											
E. Coli Grab	7/28/2010 11:58	7/28/2010 11:58											
E. Coli Grab	8/26/2010 9:04	8/26/2010 9:04											
E. Coli Grab	9/30/10 7:54	9/30/10 7:54											

No Exceedance Determinable
Exceeds Chronic Standard
Exceeds Max Standard
Exceeds Final Acute Standard

Table 13: Brown's Creek at McKusick Road 2010 Primary Chemistry Results

Sample Type	Start	End	TSS (mg/L)	VSS (mg/L)	TKN (mg/L)	TP (mg/L)	Dissolved P (mg/L)	E Coli (mpn/100 mL)	COD (mg/L)	TBOD 5-Day (mg/L)	CBOD 5-Day (mg/L)	Turbidity (NTRU)
Snowmelt Grab	3/11/2010 8:43	3/11/2010 8:43	50	19	1.3	0.207	0.08		50	4	2.5	20
Base Grab	4/29/2010 11:41	4/29/2010 11:41	10	5	0.55	0.072	~0.039		21	<1.0	<1.0	5
Base Grab	5/24/2010 11:35	5/24/2010 11:35	15	9	0.69	0.137	0.055		38	1.5	<1.0	9
Base Grab	7/21/2010 8:23	7/21/2010 8:23	9	4	0.62	0.136	0.066		19	<1.0	<1.0	7
Base Grab	8/9/2010 14:49	8/9/2010 14:49	16	~6	1.3	0.173	0.096		44	1.6	<1.0	9
Base Grab	8/11/2010 15:20	8/11/2010 15:20	21	10	1.3	0.201	0.088		64	1.7	<1.0	9
Base Grab	8/23/2010 9:18	8/23/2010 9:18	7	~4	0.64	0.164	0.102		24	1.2	<1.0	6
Base Grab	9/20/2010 10:38	9/20/2010 10:38	5	~2	0.43	0.098	~0.042		20	<1.0	<1.0	8
Base Grab	9/28/2010 8:42	9/28/2010 8:42	5	3								4
Base Grab	10/6/2010 9:33	10/6/2010 9:33	4	~2	0.51	0.080	~0.042		26	<1.0	<1.0	5
Base Grab	10/12/2010 8:23	10/12/2010 8:23	5	~2								7
Base Grab	10/26/2010 9:59	10/26/2010 9:59	9	3								7
Storm Grab	5/13/2010 9:32	5/13/2010 9:32	38	17	1.1	0.129	~0.034		43	1.3	<1.0	
Storm Composite	6/8/2010 11:42	6/9/2010 15:15	61	19	1.3	0.231	0.071		51			
Storm Composite	6/11/2010 7:52	6/12/2010 10:19	324	96	2.3	0.442	0.101		83			
Storm Composite	6/25/2010 18:43	6/27/2010 8:27	184	55	3	0.479	0.109		114			
Storm Composite	6/25/2010 18:43	6/27/2010 8:27	209	57	2.9	0.492	0.095		118			
Storm Composite	9/2/2010 4:07	9/3/2010 14:19	46	13	0.99	0.282	0.1		54			
Storm Composite	9/15/2010 20:12	9/16/2010 10:06	38	11	0.88	0.203	0.064		42			
Storm Grab	9/24/2010 14:53	9/24/10 14:53	112	44	1.30	0.180	0.080		74	<3.0	3.0	14
Storm Composite	10/26/2010 0:50	10/26/2010 2:21	59	13								
E. Coli Grab	5/25/2010 8:11	5/25/2010 8:11						179				
E. Coli Grab	6/24/2010 9:15	6/24/2010 9:15						921				
E. Coli Grab	7/28/2010 11:51	7/28/2010 11:51						1046				
E. Coli Grab	8/26/2010 9:29	8/26/2010 9:29						210				
E. Coli Grab	9/30/2010 8:17	9/30/2010 8:17						517				

Exceeds Water Quality Standard (green)

Exceeds Water Quality Standard for Turbidity(TSS Value used to calculate) (pink)

Table 14: Brown's Creek at McKusick Road 2010 Secondary Chemistry Results including Exceeded MPCA 7050 Water Quality Standards

Sample Type	Start	End	Copper (mg/L)	Nickel (mg/L)	Lead (mg/L)	Zinc (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Chloride (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	Ammonia Nitrogen (mg/L)	Hardness (mg/L _CaCO3)
Snowmelt Grab	3/11/2010 8:43	3/11/2010 8:43	0.0015	0.0019	0.0007	0.0144	<0.0005	<0.005	17	<0.03	0.65	0.2	100
Base Grab	4/29/2010 11:41	4/29/2010 11:41	0.0005	0.0028	0.0001	0.0116	<0.0005	<0.005	30	<0.03	0.33	<0.02	216
Base Grab	5/24/2010 11:35	5/24/2010 11:35	0.0006	0.0019	0.0003	<0.005	<0.0005	<0.005	17	<0.03	0.32	~0.04	208
Base Grab	7/21/2010 8:23	7/21/2010 8:23	0.0006	0.0023	0.0002	<0.005	<0.0005	<0.005	19	<0.03	0.27	~0.03	240
Base Grab	8/9/2010 14:49	8/9/2010 14:49	0.0007	0.0021	0.0002	<0.005	<0.0005	<0.005	13	<0.03	0.08	<0.02	170
Base Grab	8/11/2010 15:20	8/11/2010 15:20	0.001	0.0021	0.0004	<0.005	<0.0005	<0.005	10	<0.03	0.07	<0.02	134
Base Grab	8/23/2010 9:18	8/23/2010 9:18	0.0006	0.0024	0.0001	<0.005	<0.0005	<0.005	17	<0.03	0.21	~0.03	222
Base Grab	9/20/2010 10:38	9/20/2010 10:38	0.0007	0.0021	0.0002	<0.01	<0.0005	<0.005	18	<0.03	0.25	~0.02	196
Base Grab	9/28/2010 8:42	9/28/2010 8:42											
Base Grab	10/6/2010 9:33	10/6/2010 9:33	<0.010	<0.020	<0.003	<0.020	<0.001	<0.010	21	<0.03	0.32	~0.05	182
Base Grab	10/12/2010 8:23	10/12/2010 8:23											
Base Grab	10/26/2010 9:59	10/26/2010 9:59											
Storm Grab	5/13/2010 9:32	5/13/2010 9:32	0.0012	0.0024	0.0006	0.016	<0.0005	<0.005	16	<0.03	0.14	~0.02	152
Storm Composite	6/8/2010 11:42	6/9/2010 15:15	0.0028	0.0027	0.0008	0.0087	<0.0005	<0.005	15	<0.03	0.15	<0.02	512
Storm Composite	6/11/2010 7:52	6/12/2010 10:19	0.005	0.0036	0.0028	0.015	0.0006	<0.005	13	<0.03	0.18	0.45	168
Storm Composite	6/25/2010 18:43	6/27/2010 8:27	0.0055	0.0041	0.003	0.0155	<0.0005	0.0053	9	<0.03	0.18	~0.06	124
Storm Composite	6/25/2010 18:43	6/27/2010 8:27	0.0056	0.0041	0.003	0.0122	<0.0005	0.0054	9	<0.03	0.18	0.08	124
Storm Composite	9/2/2010 4:07	9/3/2010 14:19	0.0019	0.0023	0.0009	0.0062	<0.0005	<0.005	14	<0.03	0.32	0.06	164
Storm Composite	9/15/2010 20:12	9/16/2010 10:06	0.0019	0.0022	0.0006	<0.01	<0.0005	<0.005	16	<0.03	0.3	~0.03	186
Storm Grab	9/24/2010 14:53	9/24/10 14:53	<0.010	<0.020	<0.003	<0.020	<0.001	<0.010	8	<0.03	<0.05	~0.03	32
Storm Composite	10/26/2010 0:50	10/26/2010 2:21	<0.010	<0.020	<0.003	<0.020	<0.001	<0.010		<0.03	0.52	0.17	160
E. Coli Grab	5/25/2010 8:11	5/25/2010 8:11											
E. Coli Grab	6/24/2010 9:15	6/24/2010 9:15											
E. Coli Grab	7/28/2010 11:51	7/28/2010 11:51											
E. Coli Grab	8/26/2010 9:29	8/26/2010 9:29											
E. Coli Grab	9/30/2010 8:17	9/30/2010 8:17											

No Exceedance Determinable
Exceeds Chronic Standard
Exceeds Max Standard
Exceeds Final Acute Standard

Table 15: Brown's Creek at Stonebridge 2010 Primary Chemistry Results

Sample Type	Start	End	TSS (mg/L)	VSS (mg/L)	TKN (mg/L)	TP (mg/L)	Dissolved P (mg/L)	E Coli (mpn/100 mL)	COD (mg/L)	TBOD 5 Day (mg/L)	CBOD 5-Day (mg/L)	Turbidity (NTRU)
Snowmelt Grab	3/11/2010 8:59	3/11/2010 8:59	44	20	1.5	0.226	0.134		56	4.3	3	21
Base Grab	4/29/2010 11:57	4/29/2010 11:57	11	4	0.55	0.073	~0.038		22	1.2	<1.0	6
Base Grab	5/24/2010 11:47	5/24/2010 11:47	12	7	0.69	0.129	0.053		35	1.5	<1.0	
Base Grab	7/21/2010 8:50	7/21/2010 8:50	5	3	0.47	0.123	0.095		22	<1.0	<1.0	5
Base Grab	8/23/2010 9:38	8/23/2010 9:38	5	~2	0.59	0.145	0.085		26	1.1	<1.0	6
Base Grab	8/23/2010 9:38	8/23/2010 9:38	5	3	0.48	0.14	0.085		28	1.3	<1.0	6
Base Grab	9/20/2010 11:01	9/20/2010 11:01	~2	~1	0.45	0.092	~0.039		19	<1.0	<1.0	5
Base Grab	9/28/2010 8:58	9/28/2010 8:58	5	3								4
Base Grab	10/6/2010 8:57	10/6/2010 8:57	5	3	0.52	0.08	~0.042		25	<1.0	<1.0	6
Base Grab	10/12/2010 8:45	10/12/2010 8:45	5	~2								5
Base Grab	10/26/2010 9:40	10/26/2010 9:40	14	6								10
Storm Composite	5/11/2010 2:27	5/13/2010 9:25	71	34	1.7	0.241	~0.033		64			
Storm Composite	5/26/2010 2:02	5/26/2010 19:26	45	19	1.1	0.213	~0.048		48			
Storm Composite	6/8/2010 12:15	6/9/2010 0:08	67	25	1.3	0.233	0.069		63			
Storm Composite	6/11/2010 8:22	6/12/2010 15:17	59	21	1.2	0.228	0.066		56			
Storm Composite	8/8/2010 20:28	8/8/2010 23:53	115	40	2.2	0.377	0.072		82			
Storm Composite	9/2/2010 4:31	9/3/2010 4:44	34	12	1.1	0.254	0.091		47			
Storm Composite	9/15/2010 20:19	9/15/2010 23:54	89	32	1.8	0.399	~0.036		68			
Storm Composite	9/23/2010 0:13	9/23/2010 10:50	37	17	1.3	0.247	0.067		52			
Storm Composite	9/23/2010 11:16	9/24/2010 4:38	120	53	2.2	0.415	0.083		84			
E. Coli Grab	5/25/2010 8:20	5/25/2010 8:20						248				
E. Coli Grab	6/24/2010 9:55	6/24/2010 9:55						816				
E. Coli Grab	7/28/2010 11:30	7/28/2010 11:30						687				
E. Coli Grab	8/26/2010 7:52	8/26/2010 7:52						206				
E. Coli Grab	9/30/2010 8:29	9/30/2010 8:29						291				

Exceeds Water Quality Standard (green)

Exceeds Water Quality Standard for Turbidity(TSS Value used to calculate) (pink)

Table 16: Brown's Creek at Stonebridge 2010 Secondary Chemistry Results including Exceeded MPCA 7050 Water Quality Standards

Sample Type	Start	End	Copper (mg/L)	Nickel (mg/L)	Lead (mg/L)	Zinc (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Chloride (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	Ammonia Nitrogen (mg/L)	Hardness (mg/L CaCO3)
Snowmelt Grab	3/11/2010 8:59	3/11/2010 8:59	0.002	0.002	0.0009	0.0055	<0.0005	<0.005	17	<0.03	0.60	0.18	128
Base Grab	4/29/2010 11:57	4/29/2010 11:57	0.0007	0.0028	0.0002	0.015	<0.0005	<0.005	21	<0.03	0.37	<0.02	264
Base Grab	5/24/2010 11:47	5/24/2010 11:47	0.0006	0.0018	0.0003	<0.005	<0.0005	<0.005	16	<0.03	0.35	~0.04	204
Base Grab	7/21/2010 8:50	7/21/2010 8:50	0.0006	0.0025	0.0001	<0.005	<0.0005	<0.005	20	<0.03	0.26	~0.03	232
Base Grab	8/23/2010 9:38	8/23/2010 9:38	0.0005	0.0022	0.0001	<0.005	<0.0005	<0.005	17	<0.03	0.23	~0.02	214
Base Grab	8/23/2010 9:38	8/23/2010 9:38	0.0005	0.0023	0.0001	<0.005	<0.0005	<0.005	17	<0.03	0.24	~0.02	216
Base Grab	9/20/2010 11:01	9/20/2010 11:01	0.0005	0.002	0.0001	<0.01	<0.0005	<0.005	18	<0.03	0.24	<0.02	202
Base Grab	9/28/2010 8:58	9/28/2010 8:58											
Base Grab	10/6/2010 8:57	10/6/2010 8:57	<0.010	<0.020	<0.003	<0.020	<0.001	<0.010	19	<0.03	0.30	~0.05	186
Base Grab	10/12/2010 8:45	10/12/2010 8:45											
Base Grab	10/26/2010 9:40	10/26/2010 9:40											
Storm Composite	5/11/2010 2:27	5/13/2010 9:25	0.0027	0.0027	0.0011	0.0057	<0.0005	<0.005	18	<0.03	0.22	~0.04	158
Storm Composite	5/26/2010 2:02	5/26/2010 19:26	0.0017	0.0023	0.0009	0.0357	<0.0005	<0.005	17	<0.03	0.17	<0.02	196
Storm Composite	6/8/2010 12:15	6/9/2010 0:08	0.0054	0.0029	0.0012	0.0398	<0.0005	<0.005	18	<0.03	0.17	<0.02	352
Storm Composite	6/11/2010 8:22	6/12/2010 15:17	0.0019	0.0023	0.001	0.006	<0.0005	<0.005	14	<0.03	0.12	~0.03	150
Storm Composite	8/8/2010 20:28	8/8/2010 23:53	0.0039	0.0035	0.0023	0.0099	<0.0005	<0.005	11	<0.03	0.29	<0.02	117
Storm Composite	9/2/2010 4:31	9/3/2010 4:44	0.0017	0.0021	0.0006	0.007	<0.0005	<0.005	13	<0.03	0.15	<0.02	136
Storm Composite	9/15/2010 20:19	9/15/2010 23:54	0.0033	0.0029	0.0016	0.0114	<0.0005	<0.005	13	<0.03	0.16	<0.02	150
Storm Composite	9/23/2010 0:13	9/23/2010 10:50	<0.010	<0.020	<0.003	<0.020	<0.001	<0.010	14	<0.03	0.14	<0.02	96
Storm Composite	9/23/2010 11:16	9/24/2010 4:38	<0.010	<0.020	<0.003	<0.020	<0.001	<0.010	10	<0.03	0.19	<0.02	108
E. Coli Grab	5/25/2010 8:20	5/25/2010 8:20											
E. Coli Grab	6/24/2010 9:55	6/24/2010 9:55											
E. Coli Grab	7/28/2010 11:30	7/28/2010 11:30											
E. Coli Grab	8/26/2010 7:52	8/26/2010 7:52											
E. Coli Grab	9/30/2010 8:29	9/30/2010 8:29											

No Exceedance Determinable
Exceeds Chronic Standard
Exceeds Max Standard
Exceeds Final Acute Standard

Table 17: Brown's Creek Outlet 2010 Primary Water Quality Results

Sample Type	Start	End	TSS (mg/L)	VSS (mg/L)	TKN (mg/L)	TP (mg/L)	Dissolved P (mg/L)	E Coli (mpn/100 mL)	COD (mg/L)	TOC (mg/L)	TBOD 5-Day (mg/L)	Sulfate (mg/L)	Ortho P (mg/L as P)	Alkalinity (mg/L_CaCO3)
Snowmelt Grab	3/11/2010 9:17	3/11/2010 9:17	39	15	1.20	0.172	0.085		39	8.9	3.7	6.14	0.059	102
Base Grab	1/19/2010 8:35	1/19/2010 8:35	8	3	0.17	~0.048	~0.014		~10	2	1	11.8	0.023	206
Base Grab	2/23/2010 8:08	2/23/2010 8:08	11	4	0.21	0.061	~0.014		17	2.9	<1	8.86	0.024	199
Base Grab	4/29/2010 12:20	4/29/2010 12:20	8	4	0.39	0.068	~0.027		~13	4.4	<1	6.97	0.028	178
Base Grab	5/24/2010 12:28	5/24/2010 12:28	13	6	0.53	0.109	~0.042		25	8.6	1.1	6.82	0.049	176
Base Grab	7/21/2010 9:17	7/21/2010 9:17	3	~2	0.34	0.076	0.08		~12	4.2	<1	7.65	0.044	200
Base Grab	8/23/2010 10:19	8/23/2010 10:19	3	~1	0.36	0.088	~0.049		16	4.9	<1	5.72	0.051	188
Base Grab	9/20/2010 11:26	9/20/2010 11:26	~2	~1	0.27	0.067	~0.041		~14	4.8	<1	6.76	0.042	191
Base Grab	9/28/2010 9:14	9/28/2010 9:14	5	3										
Base Grab	10/6/2010 9:33	10/6/2010 9:33	4	~2	0.32	0.069	0.052		18	5	<1	6.75	0.042	182
Base Grab	10/12/2010 8:56	10/12/2010 8:56	3	~2										
Base Grab	10/26/2010 9:07	10/26/2010 9:07	6	3										
Base Grab	11/29/2010 9:44	11/29/2010 9:44	4	~2					~11		1.1	8.03	0.023	169
Storm Composite	6/25/2010 19:20	6/28/2010 3:01	227	54	2.60	0.443	0.093		104	13		3.17		116
Storm Composite	8/8/2010 20:59	8/8/2010 23:15	320	~116	4.10	0.945	0.102		158	8.2				102
Storm Composite	8/10/2010 23:22	8/12/2010 8:22	198	57	2.40	0.457	0.1		100	16.1		3.33		102
Storm Composite	9/2/2010 4:13	9/3/2010 5:52	111	36	1.60	0.417	0.081							
Storm Composite	9/15/2010 20:50	9/16/2010 2:30	82	30	1.50	0.365	0.053		62	6		5.3		151
Storm Composite	9/23/2010 0:40	9/24/2010 11:35	72	28	1.10	0.257	0.056		52	9.6		4.31		126
E. Coli Grab	5/25/2010 8:30	5/25/2010 8:30						162						
E. Coli Grab	6/24/2010 9:00	6/24/2010 9:00						548						
E. Coli Grab	7/28/2010 11:18	7/28/2010 11:18						435						
E. Coli Grab	8/26/2010 10:19	8/26/2010 10:19						124						
E. Coli Grab	9/30/2010 9:10	9/30/2010 9:10						125						

(green) Exceeds Water Quality Standard

Table 18: Brown's Creek Outlet 2010 Secondary Water Quality Results including Exceeded MPCA 7050 Water Quality Standards

Sample Type	Start	End	Copper (mg/L)	Nickel (mg/L)	Lead (mg/L)	Zinc (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Chloride (mg/L)	Nitrite N (mg/L)	Nitrate N (mg/L)	Ammonia Nitrogen (mg/L)	Hardness (mg/L_CaCO3)
Snowmelt Grab	3/11/2010 9:17	3/11/2010 9:17	0.0017	0.002	0.0007	0.006	<0.0005	<0.005	20	<0.03	0.68	0.15	148
Base Grab	1/19/2010 8:35	1/19/2010 8:35	0.0006	0.0023	0.0002	<0.005	<0.0005	<0.005	23	<0.03	0.95	~0.04	232
Base Grab	2/23/2010 8:08	2/23/2010 8:08	0.0006	0.002	0.0002	<0.005	<0.0005	<0.005	23	<0.03	1.09	~0.06	244
Base Grab	4/29/2010 12:20	4/29/2010 12:20	0.0007	0.0032	0.0001	<0.005	<0.0005	<0.005	24	<0.03	0.58	<0.02	244
Base Grab	5/24/2010 12:28	5/24/2010 12:28	0.0007	0.0018	0.0002	<0.005	<0.0005	<0.005	21	<0.03	0.64	~0.04	216
Base Grab	7/21/2010 9:17	7/21/2010 9:17	<0.0005	0.0023	<0.0001	<0.005	<0.0005	<0.005	23	<0.03	0.75	<0.02	244
Base Grab	8/23/2010 10:19	8/23/2010 10:19	0.0006	0.0023	<0.0001	<0.005	<0.0005	<0.005	22	<0.03	0.63	<0.02	252
Base Grab	9/20/2010 11:26	9/20/2010 11:26	<0.0005	0.0021	<0.0001	<0.01	<0.0005	<0.005	22	<0.03	0.61	<0.02	228
Base Grab	9/28/2010 9:14	9/28/2010 9:14											
Base Grab	10/6/2010 9:33	10/6/2010 9:33							24	<0.03	0.62	~0.02	232
Base Grab	10/12/2010 8:56	10/12/2010 8:56											
Base Grab	10/26/2010 9:07	10/26/2010 9:07											
Base Grab	11/29/2010 9:44	11/29/2010 9:44										~0.05	240
Storm Composite	6/25/2010 19:20	6/28/2010 3:01	0.0076	0.0048	0.0036	0.017	<0.0005	0.0067	11	<0.03	0.22	~0.04	124
Storm Composite	8/8/2010 20:59	8/8/2010 23:15	0.0105	0.008	0.0075	0.026	<0.0005	0.0138	12	<0.03	0.44	<0.02	128
Storm Composite	8/10/2010 23:22	8/12/2010 8:22	0.005	0.0041	0.0029	0.01	<0.0005	0.0059	11	<0.03	0.26	~0.03	132
Storm Composite	9/2/2010 4:13	9/3/2010 5:52	0.0038	0.0035	0.0022	0.0140	<0.0005	<0.005				<0.02	
Storm Composite	9/15/2010 20:50	9/16/2010 2:30	0.0032	0.0031	0.0019	<0.01	<0.0005	<0.005	15	<0.03	0.39	<0.02	164
Storm Composite	9/23/2010 0:40	9/24/2010 11:35							17	<0.03	0.33	<0.02	180
E. Coli Grab	5/25/2010 8:30	5/25/2010 8:30											
E. Coli Grab	6/24/2010 9:00	6/24/2010 9:00											
E. Coli Grab	7/28/2010 11:18	7/28/2010 11:18											
E. Coli Grab	8/26/2010 10:19	8/26/2010 10:19											
E. Coli Grab	9/30/2010 9:10	9/30/2010 9:10											

(grey)	No Exceedance Determinable
(yellow)	Exceeds Chronic Standard
(cyan)	Exceeds Max Standard
(dark red)	Exceeds Final Acute Standard

Figure 14. Brown's Creek Annual Copper Exceedences

Table 19. Tributary to Long Lake Sites Annual Flow and Loading Amounts

	2006	2007	2008	2009	2010
Tributary to Long Lake at Herberger's Pond					
Discharge (cf)				4,981,420	5,292,359
Total pounds of Phosphorus exported				29	32
TP (lb/ac/yr)				0.260	0.287
Total pounds of TSS exported				5,653	3,163
TSS (lb/ac/yr)				50.92	28.49
Tributary to Long Lake at Marketplace Pond					
Discharge (cf)	8,233,697	17,990,506	19,648,471	25,597,268	29,863,356
Total pounds of Phosphorus exported	94	153	152	165	172
TP (lb/ac/yr)	0.210	0.342	0.339	0.369	0.384
Total pounds of TSS exported	40,309	29,827	27,293	18,315	9,514
TSS (lb/ac/yr)	89.98	66.58	60.92	40.88	21.24
Tributary to Long Lake at 62nd Street					
Discharge (cf)	1,783,031	1,963,546	1,993,669	1,526,291	2,215,192
Total pounds of Phosphorus exported	30	45	55	42	61
TP (lb/ac/yr)	0.054	0.080	0.099	0.074	0.109
Total pounds of TSS exported	2,481	3,890	11,051	5,898	11,131
TSS (lb/ac/yr)	4.42	6.93	19.70	10.51	19.84

Table 20. Tributary to Long Lake at Herberger's Pond 2010 Primary Chemistry Results

Sample Type	Start	End	TSS (mg/L)	VSS (mg/L)	TKN (mg/L)	TP (mg/L)	Dissolved P (mg/L)
Storm Composite	4/15/10 4:47	4/15/10 8:28	21	10	1.7	0.073	<0.010
Storm Composite	5/11/10 2:22	5/11/10 15:30	9	5	1.1	~0.048	<0.010
Storm Composite	5/25/10 21:41	5/26/10 3:30	22	~8	1.0	0.106	~0.026
Storm Composite	6/8/10 7:29	6/8/10 21:05	11	5	0.7	0.214	~0.030
Storm Composite	6/8/10 7:29	6/8/10 21:05	12	5	0.7	0.075	~0.042
Storm Composite	6/11/10 7:11	6/11/10 13:23	23	5	0.6	0.062	~0.035
Storm Composite	6/25/10 19:01	6/25/10 21:39	32	7	0.8	0.086	~0.025
Storm Composite	6/26/10 23:07	6/27/10 2:53	25	5	0.5	0.085	~0.025
Storm Composite	7/5/10 16:38	7/6/10 2:23	8	4	0.4	0.058	<0.010
Storm Composite	7/17/10 21:16	7/18/10 1:12	12	~4	0.8	0.088	0.051
Storm Composite	8/8/10 2:25	8/8/10 4:47	9	~5	0.9	0.133	~0.041
Storm Composite	8/8/10 19:08	8/8/10 23:49	16	~5	0.6	~0.046	0.051
Storm Composite	8/10/10 22:41	8/11/10 6:10	9	~3	0.5	0.078	~0.024
Storm Composite	8/13/2010 15:55	8/13/2010 23:06	9	~3	0.5	0.068	~0.042
Storm Composite	9/2/10 3:39	9/2/10 11:26	8	~3	0.6	0.132	0.058
Storm Composite	9/15/10 21:00	9/16/10 1:03	50	~27	0.7	0.079	0.050
Base Grab	5/24/10 10:16	5/24/10 10:16	19	7	1.2	0.117	0.054
Base Grab	7/21/10 7:51	7/21/10 7:51	~2	~2	0.4	0.072	0.068
Base Grab	8/23/10 15:03	8/23/10 15:03	6	~4	0.8	0.138	0.062

Exceeds Water Quality Standard

Table 21: Tributary to Long Lake at Marketplace Pond 2010 Primary Water Quality Results

Sample Type	Start	End	TSS (mg/L)	VSS (mg/L)	TKN (mg/L)	TP (mg/L)	Dissolved TP (mg/L)
Snowmelt Grab	3/8/2010 12:49	3/8/2010 12:49	5	~2	2	0.091	~0.044
Storm Composite	4/15/2010 3:24	4/15/2010 14:48	20	9	1.3	0.054	<0.01
Storm Composite	5/11/2010 1:12	5/11/2010 21:40	10	6	1.2	0.068	~0.01
Storm Composite	5/13/2010 3:52	5/14/2010 2:19	14	5	1.2	0.05	<0.01
Storm Composite	5/25/2010 21:54	5/26/2010 20:45	12	~4	1.2	0.065	~0.016
Storm Composite	6/4/2010 3:50	6/4/2010 15:15	24	8	0.97	0.078	<0.01
Storm Composite	6/8/2010 7:25	6/8/2010 23:50	12	5	0.92	~0.036	~0.01
Storm Composite	6/11/2010 6:59	6/11/2010 18:11	13	4	0.97	~0.044	~0.024
Storm Composite	7/17/2010 21:00	7/18/2010 1:20	19	7	0.88	0.149	~0.034
Storm Composite	8/8/2010 2:13	8/8/2010 7:49	12	~5	0.84	0.083	~0.036
Storm Composite	8/8/2010 19:05	8/9/2010 10:07	15	7	1.1	0.109	<0.01
Storm Composite	8/10/2010 22:40	8/11/2010 17:05	8	~4	0.65	0.062	~0.021
Storm Composite	8/13/2010 4:57	8/14/2010 10:22	10	~5	0.62	0.079	~0.023
Storm Grab	9/23/2010 14:47	9/23/2010 14:47	8	~2	0.18	~0.021	~0.013
Base Grab	4/29/2010 11:31	4/29/2010 11:31			0.94	0.064	~0.021
Base Grab	8/24/2010 11:11	8/24/2010 11:11	~2	~2	0.74	0.144	0.086

(green)	Exceeds Water Quality Standard
(pink)	Exceeds Water Quality Standard for Turbidity(TSS Value used to calculate)

Table 22: Tributary to Long Lake at Marketplace Pond 2010 Secondary Water Quality Results

Sample Type	Start	End	Copper (mg/L)	Nickel (mg/L)	Lead (mg/L)	Zinc (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Chloride (mg/L)	Nitrite N (mg/L)	Nitrate N (mg/L)	Ammonia Nitrogen (mg/L)	Hardness (mg/L)
Snowmelt Grab	3/8/2010 12:49	3/8/2010 12:49	0.0086	0.0023	0.0005	0.0276	<0.0005	<0.005	231	0.03	0.27	0.54	76
Storm Composite	4/15/2010 3:24	4/15/2010 14:48	0.0089	0.0019	0.0008	0.017	<0.0005	<0.005	271	<0.03	0.26	0.24	64
Storm Composite	5/11/2010 1:12	5/11/2010 21:40	0.0067	0.0016	0.0011	0.0193	<0.0005	<0.005	179	<0.03	0.2	0.14	52
Storm Composite	5/13/2010 3:52	5/14/2010 2:19	0.0066	0.0015	0.001	0.0151	<0.0005	<0.005	122	<0.03	0.18	0.28	48
Storm Composite	5/25/2010 21:54	5/26/2010 20:45	0.0055	0.0013	<0.0005	0.0093	<0.0005	<0.005	102	0.12	0.17	0.3	44
Storm Composite	6/4/2010 3:50	6/4/2010 15:15	0.0065	0.0023	0.0006	0.0254	<0.0005	<0.005		0.17	0.11	0.11	44
Storm Composite	6/8/2010 7:25	6/8/2010 23:50	0.0051	0.0014	<0.0005	0.0122	<0.0005	<0.005	83	0.05	0.15	0.12	40
Storm Composite	6/11/2010 6:59	6/11/2010 18:11	0.0039	0.0011	0.0005	0.0104	<0.0005	<0.005	67	0.04	0.13	0.1	44
Storm Composite	7/17/2010 21:00	7/18/2010 1:20	0.0046	0.0015	0.0008	0.0153	<0.0005	<0.005	40	<0.03	0.16	~0.05	30
Storm Composite	8/8/2010 2:13	8/8/2010 7:49	0.0035	0.0012	0.0005	0.0083	<0.0005	<0.005	23	<0.03	0.12	0.1	28
Storm Composite	8/8/2010 19:05	8/9/2010 10:07	0.0041	0.0017	0.0063	0.0152	<0.0005	<0.005	28	<0.03	0.11	0.08	36
Storm Composite	8/10/2010 22:40	8/11/2010 17:05	0.0035	0.001	0.0002	0.0059	<0.0005	<0.005	17	<0.03	0.08	~0.05	28
Storm Composite	8/13/2010 4:57	8/14/2010 10:22	0.0037	0.001	0.0004	0.0076	<0.0005	<0.005	12	<0.03	0.16	0.09	36
Storm Grab	9/23/2010 14:47	9/23/2010 14:47	0.0012	<0.0005	<0.0005	0.0107	<0.0005	<0.005	<2	<0.03	0.1	~0.04	32
Base Grab	4/29/2010 11:31	4/29/2010 11:31	0.0075	0.0026	0.0003	0.018	<0.0005	<0.005		<0.03	0.17	~0.06	100
Base Grab	8/24/2010 11:11	8/24/2010 11:11	0.0025	0.0013	0.0003	0.0062	<0.0005	<0.005	20	<0.03	0.24	0.09	68

Grey	No Exceedance Determinable
Yellow	Exceeds Chronic Standard
Cyan	Exceeds Max Standard
Dark red	Exceeds Final Acute Standard

Table 23. Tributary to Long Lake at 62nd St. 2010 Primary Water Quality Results

Sample Type	Start	End	TSS (mg/L)	VSS (mg/L)	TKN (mg/L)	TP (mg/L)	Dissolved P (mg/L)	E Coli (mpn/100 mL)
Snowmelt Grab	3/10/2010 16:40	3/10/2010 16:40	7	3	1.2	0.269	0.198	
Base Grab	4/29/2010 11:17	4/29/2010 11:17	33	10	1.2	0.239	~0.013	
Storm Composite	6/11/2010 15:48	6/11/2010 15:48			1.3	0.834	0.127	
Storm Composite	7/6/2010 8:36	7/6/2010 8:36	229	77	2.7	0.86	0.205	
Storm Composite	8/8/2010 23:16	8/8/2010 23:16			2.7	0.49	0.189	
Storm Composite	8/10/2010 23:30	8/11/2010 6:42	77	46	2.0	0.543	0.221	
Storm Composite	8/13/2010 21:26	8/13/2010 21:26			2.4	0.413	0.15	
Storm Composite	9/2/2010 5:47	9/2/2010 7:06			1.3	0.423		
Storm Composite	9/23/2010 2:16	9/24/2010 13:48	109	62	2.6	0.53	0.253	
E. Coli Grab	9/30/2010 9:33	9/30/2010 9:33						206

(green)	Exceeds Water Quality Standard
(pink)	Exceeds Water Quality Standard for Turbidity(TSS Value used to calculate)

Table 24. Tributary to Long Lake at 62nd St. 2010 Secondary Water Quality Results

Sample Type	Start	End	Copper (mg/L)	Nickel (mg/L)	Lead (mg/L)	Zinc (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Chloride (mg/L)	Nitrite mg/L)	Nitrate mg/L)	Ammonia Nitrogen (mg/L)	Hardness (mg/L)
Snowmelt Grab	3/10/2010 16:40	3/10/2010 16:40	0.0072	0.0026	0.0012	0.0274	<0.0005	<0.005	100	<0.03	0.31	0.18	60
Base Grab	4/29/2010 11:17	4/29/2010 11:17	0.002	0.0055	0.0004	0.0378	<0.0005	<0.005	25	<0.03	<0.05	<0.02	284
Storm Composite	6/11/2010 15:48	6/11/2010 15:48							33	0.03	0.12	~0.03	
Storm Composite	7/6/2010 8:36	7/6/2010 8:36											
Storm Composite	8/8/2010 23:16	8/8/2010 23:16							18	<0.03	<0.05	~0.02	
Storm Composite	8/10/2010 23:30	8/11/2010 6:42	0.0116	0.0064	0.0166	0.0373	<0.0005	0.0066	15	<0.03	0.15	0.07	42
Storm Composite	8/13/2010 21:26	8/13/2010 21:26							29	<0.03	<0.05	<0.02	
Storm Composite	9/2/2010 5:47	9/2/2010 7:06	0.0083	0.0034	0.0062	0.0225	<0.0005	<0.005	16	0.03	0.18	<0.02	
Storm Composite	9/23/2010 2:16	9/24/2010 13:48	0.013	<0.020	0.024	0.05	<0.001	<0.010	24	0.04	0.14	~0.06	204
E. Coli Grab	9/30/2010 9:33	9/30/2010 9:33											

No Exceedance Determinable
Exceeds Chronic Standard
Exceeds Max Standard
Exceeds Final Acute Standard

Table 25. Brown's Creek Diversion Structure Drainage Annual Flow and Loading Amounts

	2006	2007	2008	2009	2010
Brown's Creek Diversion Structure Drainage					
Discharge (cf)	33,916,362	49,768,967	29,397,219	31,166,264	38,197,468
Total pounds of Phosphorus exported	676	653	206	544	608
TP (lb/ac/yr)	0.176	0.170	0.050	0.140	0.160
Total pounds of TSS exported	455,793	232,190	59,313	227,372	353,007
TSS (lb/ac/yr)	118.79	60.51	15.46	59.26	92.00

Table 26: Brown's Creek Diversion Structure Drainage 2010 Primary Water Quality Results

Sample Type	Start	End	TSS (mg/L)	VSS (mg/L)	TKN (mg/L)	TP (mg/L)	Dissolved P (mg/L)	E Coli (mpn/100mL)
Snowmelt Grab	3/11/2010 8:29	3/11/2010 8:29	29	10	0.92	0.219	0.116	
Snowmelt Grab	3/12/2010 11:40	3/12/2010 11:40	58			0.387		
Base Grab	4/29/2010 11:27	4/29/2010 11:27	3	~1	0.32	0.05	~0.033	
Base Grab	5/24/2010 11:24	5/24/2010 11:24	14	7	0.84	0.109	0.053	
Base Grab	7/21/2010 8:08	7/21/2010 8:08	4	~2	0.54	0.08	~0.048	
Base Grab	8/23/2010 14:20	8/23/2010 14:20	6	3	0.68	0.063	0.051	
Base Grab	9/16/2010 8:42	9/16/2010 8:42	11			0.083		
Base Grab	10/6/2010 9:13	10/6/2010 9:13	~2	~1	0.51	~0.045	~0.029	
Storm Composite	5/11/2010 1:55	5/13/2010 7:42	39	17	1	0.152	~0.037	
Storm Grab	5/26/2010 7:48	5/26/2010 7:48	40			0.178		
Storm Composite	6/8/2010 13:05	6/9/2010 1:54	660	340	4.3	0.554	~0.033	
Storm Grab	6/11/2010 11:09	6/11/2010 11:09	126			0.404		
Storm Composite	6/11/2010 8:35	6/11/2010 22:39	1800	840	9.4	0.86	0.061	
Storm Composite	6/22/2010 14:25	6/22/2010 21:33	7660	3190	45	4.280	~0.049	
Storm Composite	6/24/2010 17:11	6/25/2010 7:15	2100	960	18	1.86	0.06	
Storm Composite	6/25/2010 19:35	6/26/2010 9:19	2600	680	17	4.02	0.106	
Storm Grab	8/2/2010 8:40	8/2/2010 8:40	24			0.149		
Storm Grab	8/2/2010 8:40	8/2/2010 8:40	29	~14	0.95	0.139	~0.039	
Storm Composite	8/8/2010 20:15	8/8/2010 20:50			9	1.280	0.057	
Storm Composite	8/10/2010 23:20	8/11/2010 12:36	768	228	6.7	1.3	0.109	
Storm Composite	9/2/2010 4:03	9/3/2010 7:11	218	71	7.60	1.330	0.058	
Storm Grab	9/2/2010 9:10	9/2/2010 9:10	84			~0.341		
Storm Composite	9/23/2010 0:24	9/23/2010 9:33	365	137	3.5	0.592	0.064	
Storm Composite	9/23/2010 10:52	9/24/2010 11:18	714	206	0.94	1.09	0.091	
E. Coli Grab	5/25/2010 8:05	5/25/2010 8:05						214
E. Coli Grab	6/24/2010 9:25	6/24/2010 9:25						248
E. Coli Grab	7/28/2010 11:55	7/28/2010 11:55						166
E. Coli Grab	8/26/2010 9:17	8/26/2010 9:17						308
E. Coli Grab	9/30/2010 8:07	9/30/2010 8:07						54

(green) Exceeds Water Quality Standard

(pink) Exceeds Water Quality Standard for Turbidity(TSS Value used to calculate)

Table 27: Brown's Creek Diversion Structure Drainage 2010 Secondary Water Quality Results

Sample Type	Start Date	End Time	Copper (mg/L)	Nickel (mg/L)	Lead (mg/L)	Zinc (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Chloride (mg/L)	Nitrite (mg/L)	Nitrate mg/L)	Ammonia Nitrogen (mg/L)	Hardness (mg/L _CaCO3)
Snowmelt Grab	3/11/2010 8:29	3/11/2010 8:29	0.0022	0.0025	0.0007	0.006	<0.0005	<0.005	42	<0.03	0.94	0.07	128
Snowmelt Grab	3/12/2010 11:40	3/12/2010 11:40											
Base Grab	4/29/2010 11:27	4/29/2010 11:27	0.0006	0.0032	<0.0001	0.0062	<0.0005	<0.005	41	<0.03	0.81	<0.02	232
Base Grab	5/24/2010 11:24	5/24/2010 11:24	0.0012	0.0016	0.0003	<0.005	<0.0005	<0.005	61	<0.03	0.41	0.06	116
Base Grab	7/21/2010 8:08	7/21/2010 8:08	0.0008	0.0016	0.0001	<0.005	<0.0005	<0.005	67	<0.03	0.49	~0.04	140
Base Grab	8/23/2010 14:20	8/23/2010 14:20	0.0012	0.0011	0.0002	<0.005	<0.0005	<0.005	83	<0.03	0.11	~0.02	56
Base Grab	9/16/2010 8:42	9/16/2010 8:42											
Base Grab	10/6/2010 9:13	10/6/2010 9:13	<0.010	<0.020	<0.003	<0.020	<0.001	<0.010	63	<0.03	0.25	~0.04	92
Storm Composite	5/11/2010 1:55	5/13/2010 7:42	0.0021	0.0032	0.0007	0.0202	<0.0005	<0.005	38	<0.03	0.35	<0.02	170
Storm Grab	5/26/2010 7:48	5/26/2010 7:48											
Storm Composite	6/8/2010 13:05	6/9/2010 1:54	0.0081	0.0092	0.0047	0.0309	<0.0005	0.0052	47	<0.03	0.19	~0.02	132
Storm Grab	6/11/2010 11:09	6/11/2010 11:09											
Storm Composite	6/11/2010 8:35	6/11/2010 22:39	0.0113	0.0156	0.0092	0.0563	<0.0005	0.0079	31	<0.03	0.16	~0.02	130
Storm Composite	6/22/2010 14:25	6/22/2010 21:33	0.0627	0.0903	0.0428	0.303	0.0014	0.0539	70	<0.03	0.08	<0.02	92
Storm Composite	6/24/2010 17:11	6/25/2010 7:15	0.018	0.0216	0.0145	0.0826	<0.0005	0.0163	66	<0.03	0.11	0.07	88
Storm Composite	6/25/2010 19:35	6/26/2010 9:19	0.0244	0.0264	0.032	0.102	<0.0005	0.0293	26	<0.03	0.16	0.13	82
Storm Grab	8/2/2010 8:40	8/2/2010 8:40											
Storm Grab	8/2/2010 8:40	8/2/2010 8:40	0.0014	0.0018	0.0005	<0.005	<0.0005	<0.005	64	<0.03	0.13	~0.04	20
Storm Composite	8/8/2010 20:15	8/8/2010 20:50							34	<0.03	0.56	<0.02	92
Storm Composite	8/10/2010 23:20	8/11/2010 12:36	0.0124	0.0135	0.0136	0.0549	<0.0005	0.0144	24	<0.03	0.41	~0.06	63
Storm Composite	9/2/2010 4:03	9/3/2010 7:11	0.0144	0.0166	0.01310	0.0583	<0.0005	0.0137	46	<0.03	0.22	<0.02	92
Storm Grab	9/2/2010 9:10	9/2/2010 9:10											
Storm Composite	9/23/2010 0:24	9/23/2010 9:33	<0.010	<0.020	0.004	0.022	<0.001	<0.010	47	<0.03	0.33	<0.02	130
Storm Composite	9/23/2010 10:52	9/24/2010 11:18	<0.010	<0.020	0.008	0.033	<0.001	<0.010	35	<0.03	0.4	<0.02	208
E. Coli Grab	5/25/2010 8:05	5/25/2010 8:05											
E. Coli Grab	6/24/2010 9:25	6/24/2010 9:25											
E. Coli Grab	7/28/2010 11:55	7/28/2010 11:55											
E. Coli Grab	8/26/2010 9:17	8/26/2010 9:17											
E. Coli Grab	9/30/2010 8:07	9/30/2010 8:07											

No Exceedance Determinable
Exceeds Chronic Standard
Exceeds Max Standard
Exceeds Final Acute Standard

Table 28: Long Lake-Brown's Creek Diversion Drainage 2010 Water Quality Results

Site	Sample Type	Date	TSS (mg/L)	TP (mg/L)	Flow (cfs)	TP lb/day*	TSS lb/day*
Long Lake Outlet	Snowmelt Grab	3/12/2010	No Sample	No Sample	No Measurement	N/A	N/A
Long Lake Outlet	Base Grab	4/28/10 13:48	<2	0.056	0.07	0.02	0.40
Long Lake Outlet	Storm Grab	5/26/10 9:20	3	0.036	0.82	0.16	13.33
Long Lake Outlet	Storm Grab	6/11/10 11:54	3	0.032	1.71	0.29	27.60
Long Lake Outlet	Storm Grab	8/2/10 10:23	4	0.033	2.45	0.44	52.86
Long Lake Outlet	Storm Grab	9/2/10 10:50	<2	0.04	2.32	0.50	25.03
Long Lake Outlet	Storm Grab	9/16/10 10:10	3	0.045	1.70	0.41	27.51
Jackson WMA	Snowmelt Grab	3/12/2010	No Sample	No Sample	No Measurement	N/A	N/A
Jackson WMA	Base Grab	4/28/10 14:07	3	0.062	0.0025	0.00	0.04
Jackson WMA	Storm Grab	5/26/10 9:00	2	0.04	0.2979	0.06	3.21
Jackson WMA	Storm Grab	6/11/10 11:38	2	0.029	0.2964	0.05	3.20
Jackson WMA	Storm Grab	8/2/10 10:07	4	0.035	1.07	0.20	23.18
Jackson WMA	Storm Grab	9/2/10 10:26	18	0.056	1.45	0.43	140.79
Jackson WMA	Storm Grab	9/16/10 10:00	5	0.049	1.70	0.45	45.85
Boutwell Rd.	Snowmelt Grab	3/12/10 11:30	3	~0.225	0.12	0.15	1.97
Boutwell Rd.	Base Grab	4/28/2010	No Sample	No Sample	No Measurement	N/A	N/A
Boutwell Rd.	Storm Grab	5/26/10 8:50	<2	0.116	0.2703	0.17	1.46
Boutwell Rd.	Storm Grab	6/11/10 10:54	2	0.07	0.3446	0.13	3.72
Boutwell Rd.	Storm Grab	8/2/10 9:53	7	0.079	1.43	0.61	54.03
Boutwell Rd.	Storm Grab	9/2/10 10:20	9	0.11	2.33	1.38	113.12
Boutwell Rd.	Storm Grab	9/16/10 9:40	<2	0.054	1.18	0.34	12.73
South Branch	Snowmelt Grab	3/12/10 10:20	38	~0.263	0.96	1.36	196.58
South Branch	Base Grab	4/28/10 14:59	2	0.071	0.02	0.01	0.26
South Branch	Storm Grab	5/26/10 8:05	35	0.153	0.48	0.40	91.16
South Branch	Storm Grab	6/11/10 10:20	55	0.169	0.85	0.78	252.82
South Branch	Storm Grab	8/2/10 9:00	39	0.123	1.52	1.01	319.83
South Branch	Storm Grab	9/2/10 9:30	13	0.126	1.74	1.18	122.02
South Branch	Storm Grab	9/16/10 9:00	11	0.064	1.22	0.42	72.39
West Branch 2	Snowmelt Grab	3/12/10 11:15	6	~0.294	7.63	12.10	246.95
West Branch 2	Base Grab	4/28/10 14:35	<2	0.058	0.13	0.04	0.72
West Branch 2	Storm Grab	5/26/10 8:40	11	0.164	0.29	0.26	17.45
West Branch 2	Storm Grab	6/11/10 10:02	41	0.349	1.01	1.91	224.39
West Branch 2	Storm Grab	8/2/10 9:36	28	0.253	0.11	0.15	16.69
West Branch 2	Storm Grab	9/2/10 10:10	16	~0.274	1.56	2.31	134.64
West Branch 2	Storm Grab	9/16/10 9:30	10	0.148	0.14	0.11	7.55
West Branch 1	Snowmelt Grab	3/12/10 10:35	23	~0.2	0.52	0.56	64.58
West Branch 1	Base Grab	4/28/10 15:24	3	0.064	0.08	0.03	1.33
West Branch 1	Storm Grab	5/26/10 8:25	27	0.17	0.26	0.23	37.14
West Branch 1	Storm Grab	6/11/10 10:39	135	0.458	1.76	4.36	1284.93
West Branch 1	Storm Grab	8/2/10 9:18	36	0.251	0.22	0.30	42.82
West Branch 1	Storm Grab	9/2/10 10:00	65	~0.297	2.34	3.75	820.48
West Branch 1	Storm Grab	9/16/10 9:17	20	0.156	0.54	0.45	57.83
North Branch	Snowmelt Grab	3/12/10 10:50	44	0.432	0.107	0.25	25.40
North Branch	Base Grab	4/28/10 15:15	44	0.143	0.05	0.03	10.68
North Branch	Storm Grab	5/26/10 8:17	92	0.265	0.03	0.05	16.75
North Branch	Storm Grab	6/11/10 10:32	201	0.503	0.11	0.29	115.74
North Branch	Storm Grab	8/2/10 9:12	125	0.38	0.03	0.06	20.73
North Branch	Storm Grab	9/2/10 9:50	47	~0.347	0.554	1.037	140.46
North Branch	Storm Grab	9/16/10 9:10	26	0.151	0.03	0.03	4.49
Browns Creek Diversion	Snowmelt Grab	3/12/10 11:40	58	0.387	7.90	16.49	2471.68
Browns Creek Diversion	Base Grab	4/28/2010	No Sample	No Sample	No Measurement	N/A	N/A
Browns Creek Diversion	Storm Grab	5/26/10 7:50	40	0.178	0.82	0.79	177.72
Browns Creek Diversion	Storm Grab	6/11/10 11:09	126	0.404	3.53	7.70	2401.60
Browns Creek Diversion	Storm Grab	8/2/10 8:40	24	0.149	1.90	1.53	245.98
Browns Creek Diversion	Storm Grab	9/2/10 9:10	84	~0.341	5.55	10.21	2514.83
Browns Creek Diversion	Storm Grab	9/16/10 8:42	11	0.083	1.95	0.87	115.71
Creekside	Storm Grab	6/11/10 11:16	22	0.211	0.07	0.08	8.31
Creekside	Storm Grab	8/2/10 12:48	3	0.074	0.04	0.02	0.65
Creekside	Storm Grab	9/2/10 11:37	2	0.075	0.21	0.08	2.27
Creekside	Storm Grab	9/16/10 8:50	<2	0.036	0.04	0.01	0.43
S. Settlers	Storm Grab	6/11/2010 11:40	6	0.08	0.17	0.07	5.50
S. Settlers	Storm Grab	8/2/2010 0:00	No Sample	No Sample	No Measurement	N/A	N/A
S. Settlers	Storm Grab	9/2/2010 12:03	9	0.133	0.25	0.18	12.14
N. Settlers	Storm Grab	6/11/10 12:07	3	0.062	0.40	0.13	6.47
N. Settlers	Storm Grab	8/2/10 11:52	3	0.04	0.29	0.06	4.69
N. Settlers	Storm Grab	9/2/10 12:36	8	0.172	1.06	0.98	45.74
N. Settlers	Storm Grab	9/16/10 9:46	<2	0.045	0.01	0.00	0.13
E. Settlers	Storm Grab	9/2/10 12:25	8	0.172	0.36	0.33	15.54

* Loadings are based on instantaneous flow and values should be used with caution

2. TEMPERATURE DATA

Temperature in Brown's Creek has been monitored by several organizations since 1998 and a portion of this data is summarized in a report by the Minnesota Department of Natural Resources as well as in this report. Temperatures are recorded in Brown's Creek to monitor existing conditions and to identify areas where warming or cooling may occur. Water temperatures less than 18°C are considered preferred, between 18 and 20°C are low impact, 20 to 25°C have a moderate impact, and greater than 25°C is considered high impact to trout. The Brown's Creek Biota TMDL has further refined these standards. The TMDL standards indicate a threat level temperature of 18.3°C and a critical temperature of 23.9°C. The threat level impact is defined as physiological stress, reduced growth and egg mortality. The critical level impact is defined as where direct mortality can be expected. For the purposes of this report, daily average temperatures are used to determine if impact levels have been reached. Temperature relations in trout streams are complex and depend on exposure time, conditions leading up to the exposure, the availability of refugia (small pockets of colder water), and other factors that are not easily identified. The same impact levels are used in the BCWD H&H study. Temperature data prior to 2001 comes from a Report on Water Temperatures for 1998 and 1999 in Brown's Creek, Washington County, Minnesota, by Jason Moeckel, MN DNR.

Sustained periods of increased water temperatures can be stressful and even lethal to trout, particularly smaller fish. Warm temperatures affect small fish more easily than larger ones. Water temperatures in a stream go up and down throughout the day. They are usually coolest in the early morning hours (about sunrise) and warmest in the late afternoon (about 5pm). Even during the warmest days, the cooler water during the night can serve as somewhat of a refuge for trout. At one time in its history, Brown's Creek was diverted into McKusick Lake, which supplied water to Stillwater residents. By 1955 fisheries managers recognized that warm lake water was putting a strain on the trout population in Brown's Creek. In an effort to reduce water temperatures for the benefit of trout, a dike was constructed to separate the stream from the lake and return the flow back to Brown's Creek. The dike still exists today.

Efforts to improve habitat and water quality in Brown's Creek continue. With the goal of further reducing water temperatures and improving trout habitat, the city of Stillwater and the Minnesota DNR collaborated to construct a new stream channel along the Minnesota Zephyr rail line and the Oak Glen Golf Course in 1999. This project created a new section of stream, 2,000 feet long, which replaces a 5,130-foot long section that flowed through the wetland just north of McKusick Lake and across the golf course. Water now moves through the new channel in about 30 minutes, compared with the 10 hours it took to flow through the wetland. This translates to cooler water, since it doesn't sit in the hot sun and warm up as it flows downstream. In addition, fish and insect habitat in the new channel is much better than in the old channel. The habitat is so much better that brown trout have been found farther upstream than ever before. Limiting high temperature inputs to Brown's Creek made additional improvements.

During 2003, a project to divert suburban stormwater from Brown's Creek was completed. An approximately 2,000 acre area of Stillwater now is diverted into McKusick Lake and eventually to the St. Croix. This appears to have enhanced the thermal regime of the creek even more.

Warming is still likely to occur in the area downstream of the realigned channel due to lack of shade and runoff from the golf course, but work is being done to address this issue. In previous years, the DNR and Trout Unlimited have worked with the golf course to improve trout habitat in what has been some of the poorest quality habitat for a number of years. Brown's Creek is probably at its thermal maximum for a cold-water stream, but continued efforts to improve shade through the middle and upper reaches will likely improve temperature conditions.

Trout in Brown's Creek were exposed to much warmer water in 2001 and 2002 when compared to 2003 through 2010, even during the night and early morning hours when water temperatures are usually coolest. This decrease is likely due to a number of factors, including the relatively dry periods during the mid-late summers and falls as well as an effect from the Brown's Creek diversion structure diverting warm water away from the stream towards McKusick Lake. Due to the change in flow conditions resulting from the completion of the diversion structure, further discussion of historic values will be limited to 2003 through the present. Pre-2003 data will still be available upon request.

In 2010 the Highway 15, McKusick and Stonebridge sites had the highest number of days on record with an average temperature over the threat level threshold of 18.3 degrees. The Outlet site recorded the third highest number days over the threat level since 2003.The Outlet site had the lowest number of days over the threat level threshold in 2010, followed by McKusick, Stonebridge then Highway 15. No site has had a daily average that exceeded the critical level threshold since 2003. These results can be found in Figure 15.

Water temperatures in a stream are influenced by a number of factors, but two of the most prominent are air temperature and the amount of solar radiation or direct sunlight that reaches the water. In general, days in which air temperatures meet or exceed 90º F are typically the days when water temperatures are highest. The more days with air temperature at 90º F or above, the more stressful the conditions in the stream for trout. Based on the past 30 years of records, the average number of days at or above 90ºF in Twin Cities is about 17.6 days a year. Figure 15-Figure 16 show the correlation between the number of warm days and warm stream temperatures at the four sites where trout are known to exist or could possibly exist under the right conditions. 2010 seems to be an exception to this trend, as relatively few days exceeded 90ºF but many more days averaging over the threat level occurred when compared to 2009. 2003 had a significant amount of above average number of these "hot days", while 2004 had significantly less "hot days", 2005 and 2006 were close to average, 2007 was also below average, 2008, 2009 and 2010 had the lowest number recorded in the last 10 years (Figure 16).

In the past, daily maximum, mean, and minimum water temperatures had been thought to generally decrease in the downstream direction of Brown's Creek in the summer months due to increased groundwater inputs in the downstream reaches. Recent data from the Brown's Creek TMDL monitoring, as well as from the BCWD baseline-monitoring program that have implemented monitoring at upper watershed locations, have proven to show otherwise. Figure 17-Figure 24 show the temperature differences between each of the sites on Brown's Creek as well as daily maximum, average, and minimum temperatures at each site.

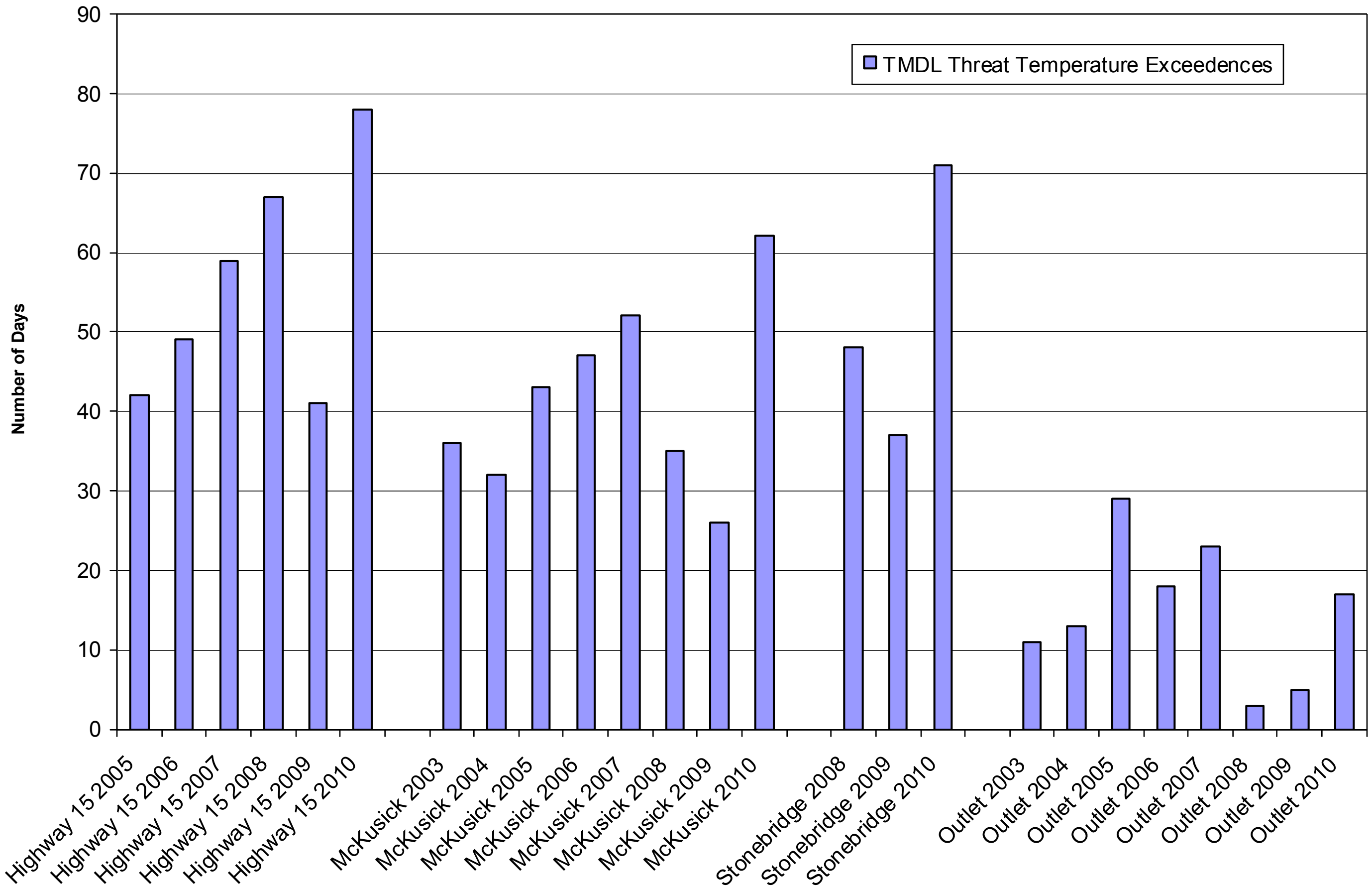
With respect to trout survival, the comparisons made by the following discussion will focus mainly on the summer months of data collection (June, July, August, September) since these months have the most potential to affect trout survival because of warmer air and subsequently warmer water temperatures.

The Highway 15 site shows maximum, minimum and average daily temperatures that were slightly warmer than the McKusick Road site. Daily average temperatures generally were above the threat level threshold of 18.3ºC during the warmest portions of the summer, but the daily minimum temperatures rarely exceeded 18.3ºC. Highway 15 was the only site the consistently had a daily maximum over the critical level threshold of 23.9ºC. The fact that the daily maximum temperatures were warmer and the daily minimum temperatures were approximately the same at Hwy 15 compared to McKusick Road may indicate that the more channelized stream and increased riparian shade as well as some possible groundwater contribution is affecting the diurnal temperature variation between these two sites. Dissolved oxygen concentrations at the Highway 15 site were generally well below the 7 mg/L threshold considered suitable for trout during the warmest portions of the summer (Appendix B). When compared to 2009, the temperature is generally 1-2° warmer, and dissolved oxygen was much lower. One possible cause of this is the increased precipitation that occurred in 2010. This may have allowed the wetlands upstream to contribute more water to the overall flow. The water present in a wetland is generally warm and low in dissolved oxygen, due to the biological demand and anoxic conditions that are usually present. The morphology of this site is fairly suitable for trout, but the temperatures and changes in dissolved oxygen may prevent trout from inhabiting this reach. With further BMP efforts specifically designed to improve trout habitat, this reach may be able to obtain future trout conditions, but based on data shown here, locations upstream of this site would still inhibit trout survival.

The McKusick Road site shows maximum, minimum and average daily temperatures about 1º-2º C cooler than the Stonebridge site during the warmest portions of the summer. This seems counterintuitive because of the increased riparian shade and more naturalized channel present at the Stonebridge site. However, downstream of the site at McKusick Road, much of the channel runs through the open golf course. This lack of shading allows direct sunlight to increase the water temperature. Additionally, a wetland connected to a nearby neighborhood has its storm runoff empty into this reach of the creek. As in 2009, in 2010 the average difference in temperature between the McKusick and Stonebridge sites was much smaller when compared to 2008 (Figure 18). It is not known what caused this, however one possibility is that below average rainfall amounts from previous years prevented the wetland downstream of the site from discharging into the creek. Even with precipitation numbers returning to average in 2010, many basins across the county continued to stay below normal levels. Daily maximum temperatures were near, but rarely exceeded, 23.9º C during the warmest parts of the summer and not suitable for trout, but daily average and daily minimum temperatures were near or below 18.3ºC and considered more suitable. A beaver dam was found in the channel by the DNR during their fall fish survey. Efforts will be made in 2011 to remove both the dam and beaver. It is interesting to note that the average temperatures at this site were slightly warmer in 2010 compared to 2009. This is likely due to the series of dams being built and allowing water to sit in the sun just upstream of the datalogger and warm up. There is an additional slight pooling, due to the large amount of sediment that accumulated in that area of stream from a dam that was removed in 2009, just ahead of the datalogger that may be contributing to increased water temperatures as well. Dissolved oxygen at this location was near the 7 mg/L threshold for much of the year, but rarely dropped below (Appendix B). Although a riparian restoration project was implemented near this location in the past, additional plantings that would shade the stream in this reach (possibly trees that would hover over the stream) would help in reducing temperatures even more and would potentially increase dissolved oxygen concentrations.

The Stonebridge site shows average daily temperatures that were typically around 20°C, and minimum temperatures near the 18.3°C threshold during the warmest parts of the summer. However, daily maximum temperatures rarely exceeded 23.9° C during the warmest periods of the summer. Average daily and minimum temperatures are on average roughly a degree warmer than those recorded in 2009. This is likely due to the increased precipitation that occurred in 2010 when compared to 2009. In 2010, temperatures were about 2-4° C warmer than those recorded at the Outlet site during the warmest parts of the summer. This is consistent with what was observed in 2009 and 2008 (
Figure 17). Dissolved oxygen was near or above 7 mg/L during the summer months, rarely dipping below this threshold (Appendix B). These temperature and dissolved oxygen results indicate suitable trout habitat. Likewise, the morphology of the site lends itself well for trout suitability.

The Brown's Creek Outlet site continues to show that groundwater contribution, increased riparian shade, and shade from the ravine, is maintaining much cooler maximum, average, and daily temperatures than any upstream monitoring location. Daily average, and minimum temperatures were near or below 18.3ºC during the warmest portions of the summer. Daily maximum temperatures were just above this threshold during the warmest periods of the summer. Based on 15-minute data from the site, temperatures never exceeded the critical threshold of 23.9º C the entire year. Dissolved oxygen readings only went below the 7 mg/L threshold for an approximately 4 hour period in late May (Appendix B).



No recorded daily averages have exceeded the TMDL Critical Temperature of 23.9 degrees Celsius

Figure 15. Annual Occurrences of Brown's Creek Daily Average Temperature Greater than 18.3° Celsius

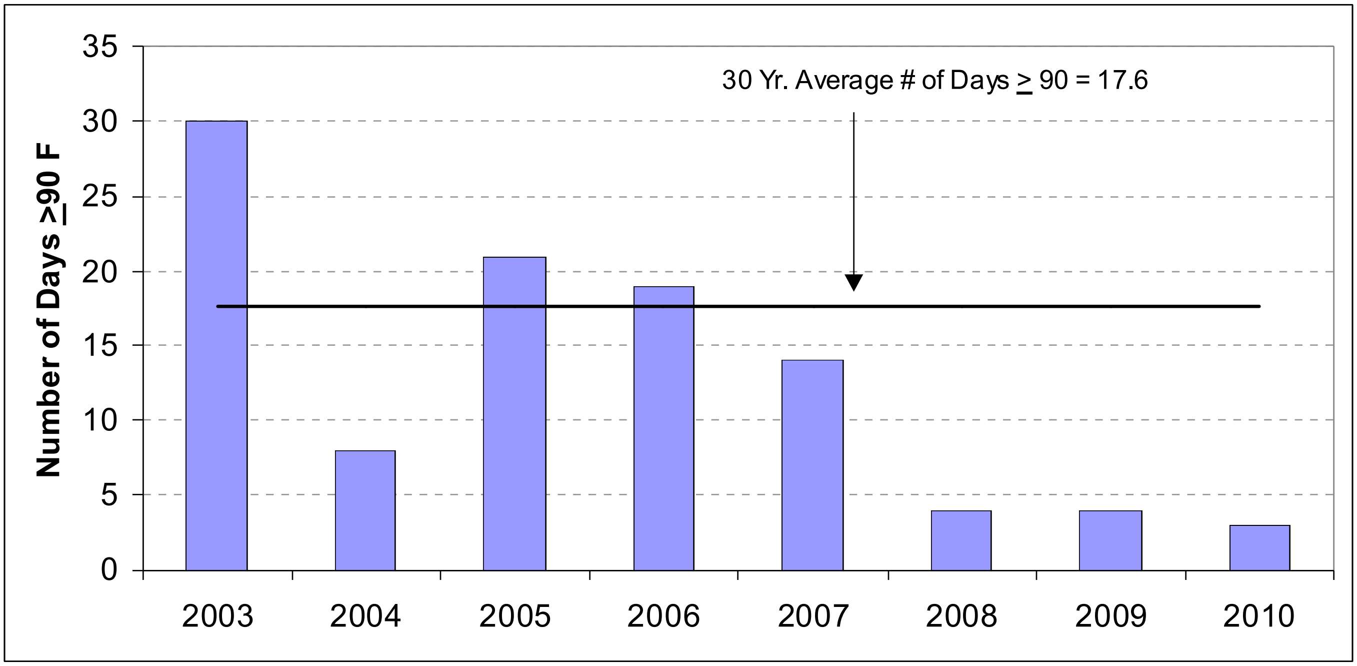


Figure 16. Days With Air Temperatures Over 90 Degrees Fahrenheit, Stillwater, MN (Source: National Weather Service {Stillwater 30N, 20W, S34})

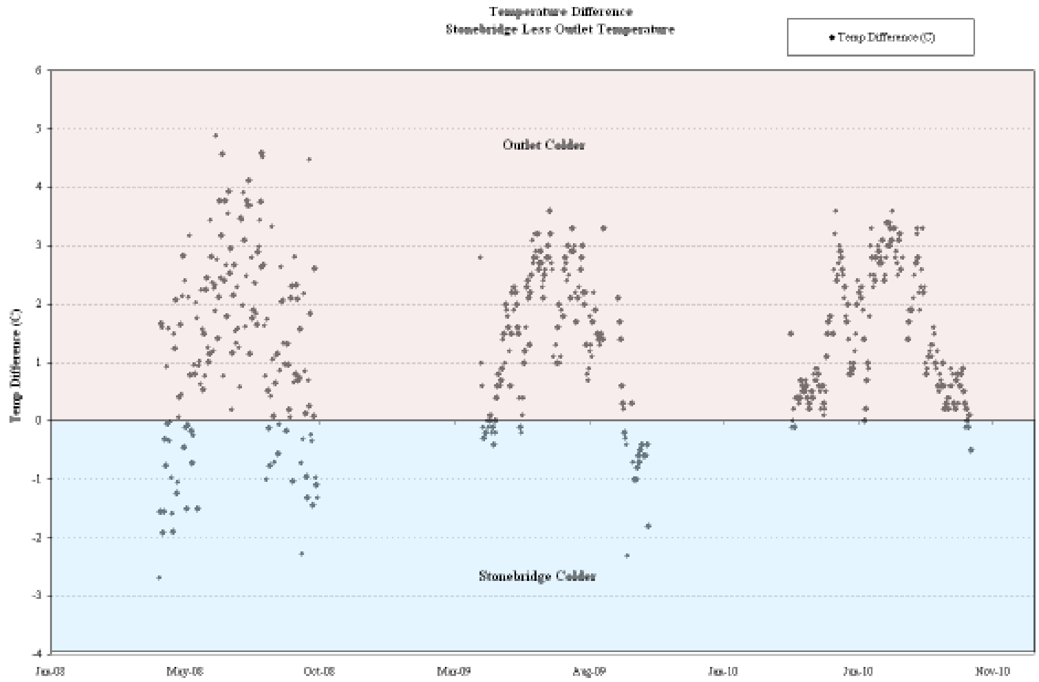


Figure 17: Daily Average Temperature Differences Between Stonebridge & Outlet Sites

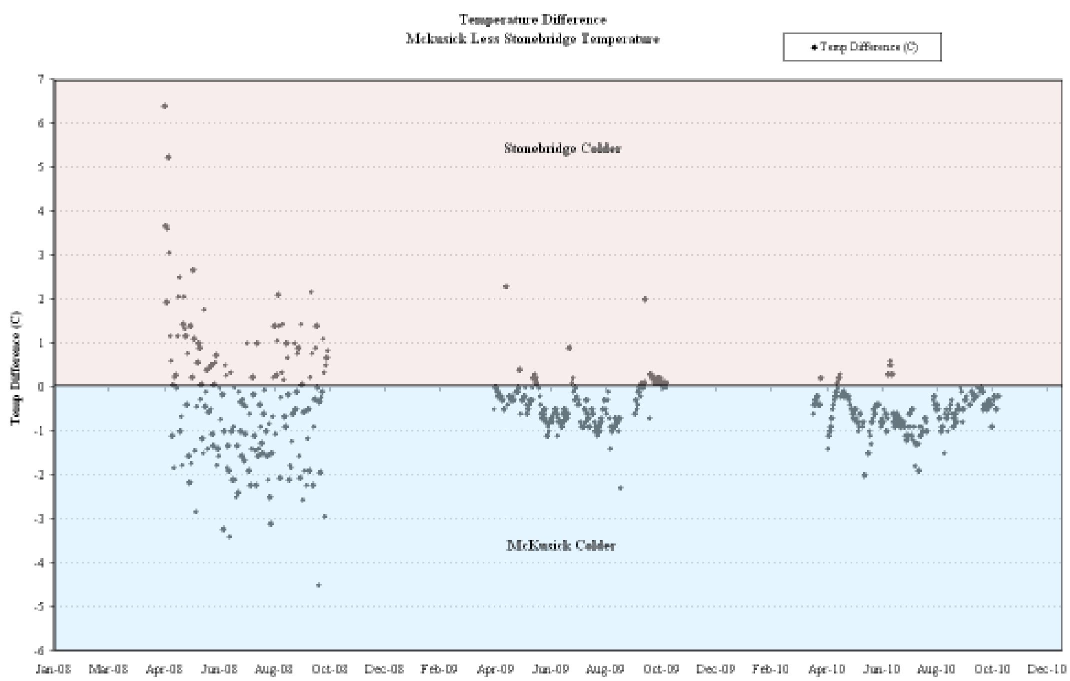


Figure 18: Daily Average Temperature Differences Between Stonebridge & McKusick Sites

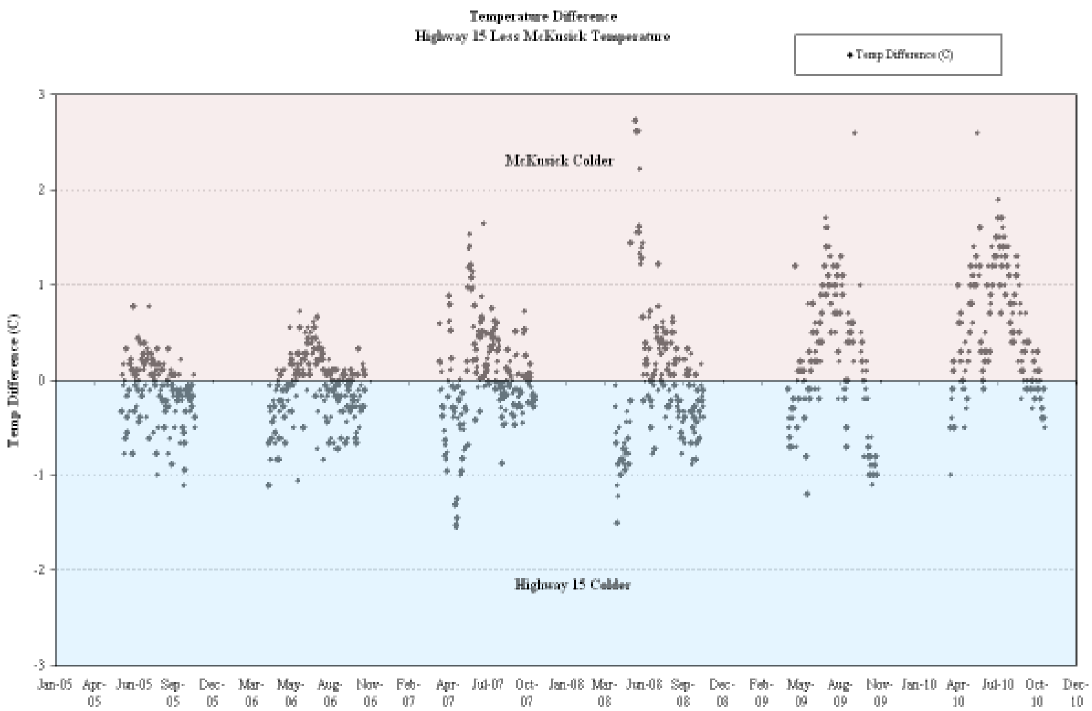


Figure 19: Daily Average Temperature Differences Between McKusick & Highway 15 Sites

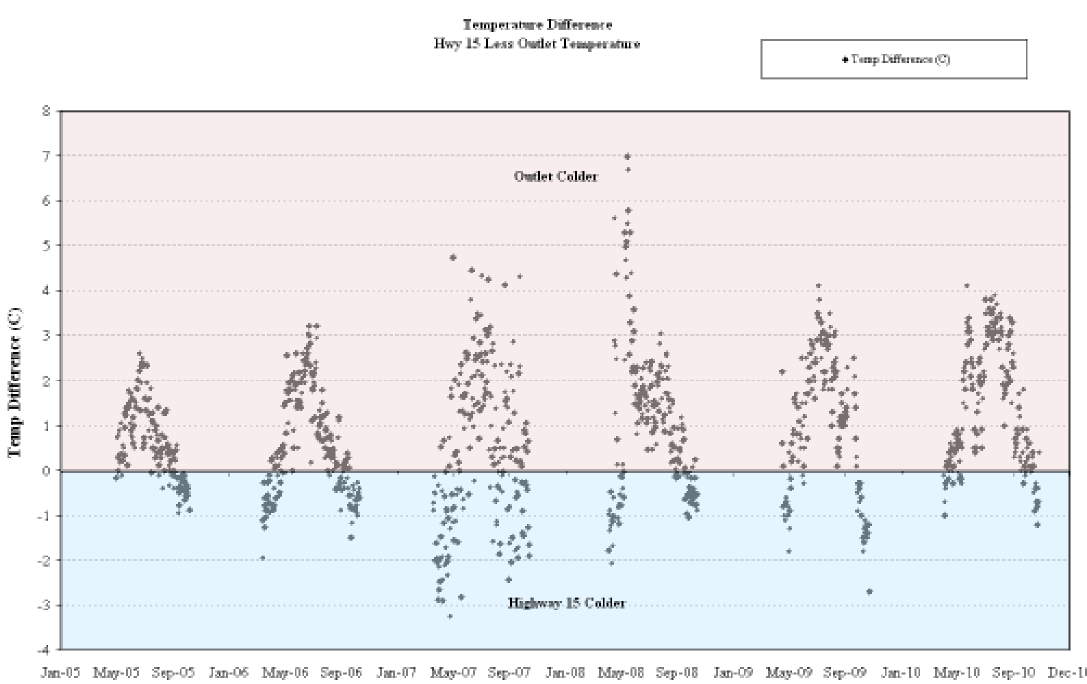


Figure 20: Daily Average Temperature Differences Between Highway 15 & Outlet Sites

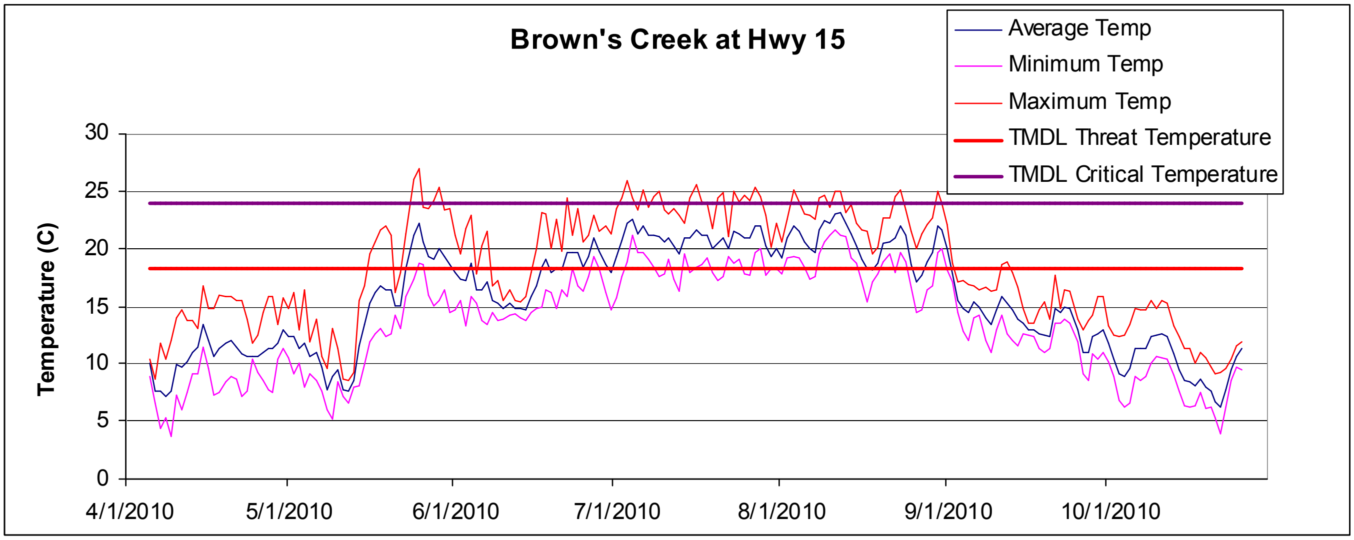


Figure 21: 2010 Brown's Creek at Highway 15 Daily Average, Minimum, and Maximum Temperatures

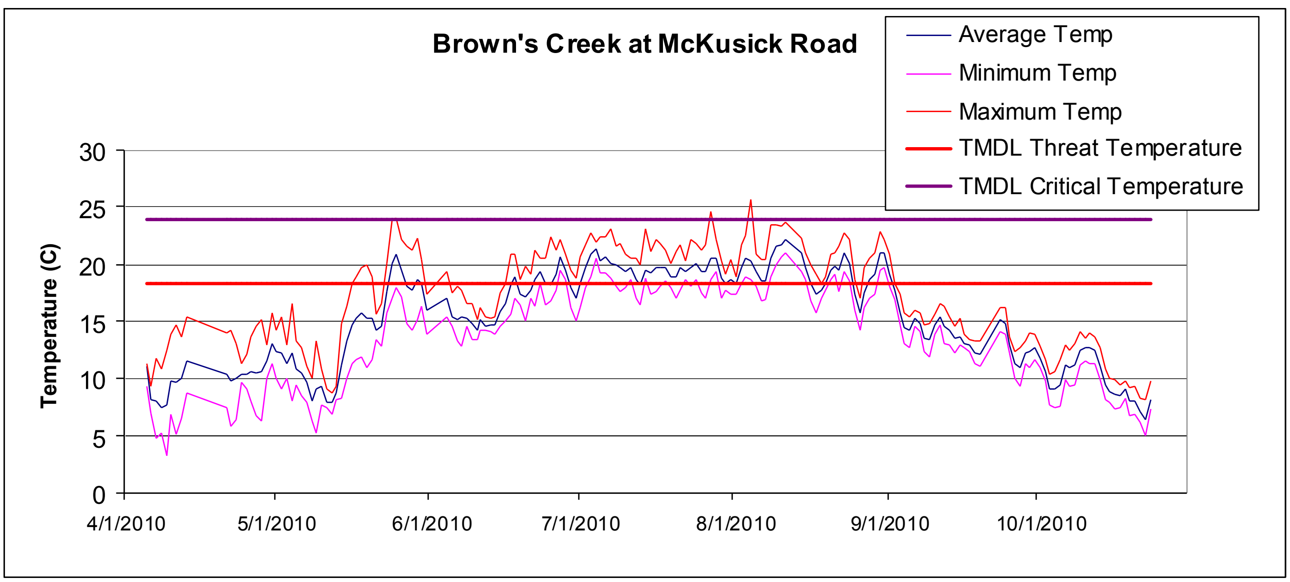


Figure 22: 2010 Brown's Creek at McKusick Road Daily Average, Minimum, and Maximum Temperatures

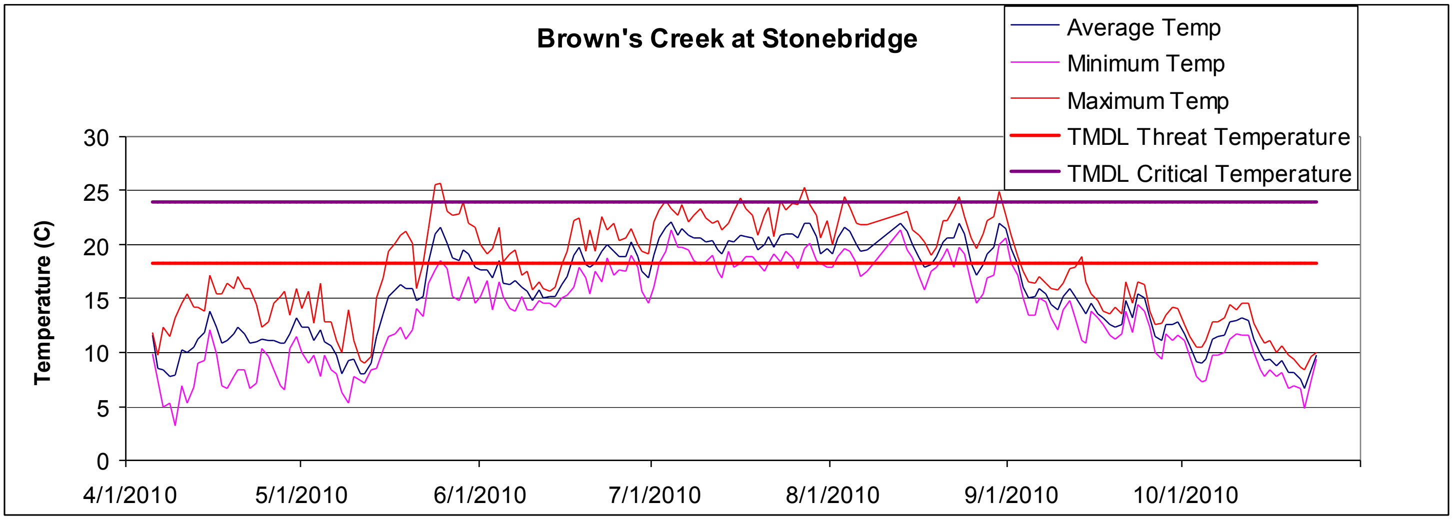


Figure 23. 2010 Brown's Creek at Stonebridge Daily Average, Minimum, and Maximum Temperatures

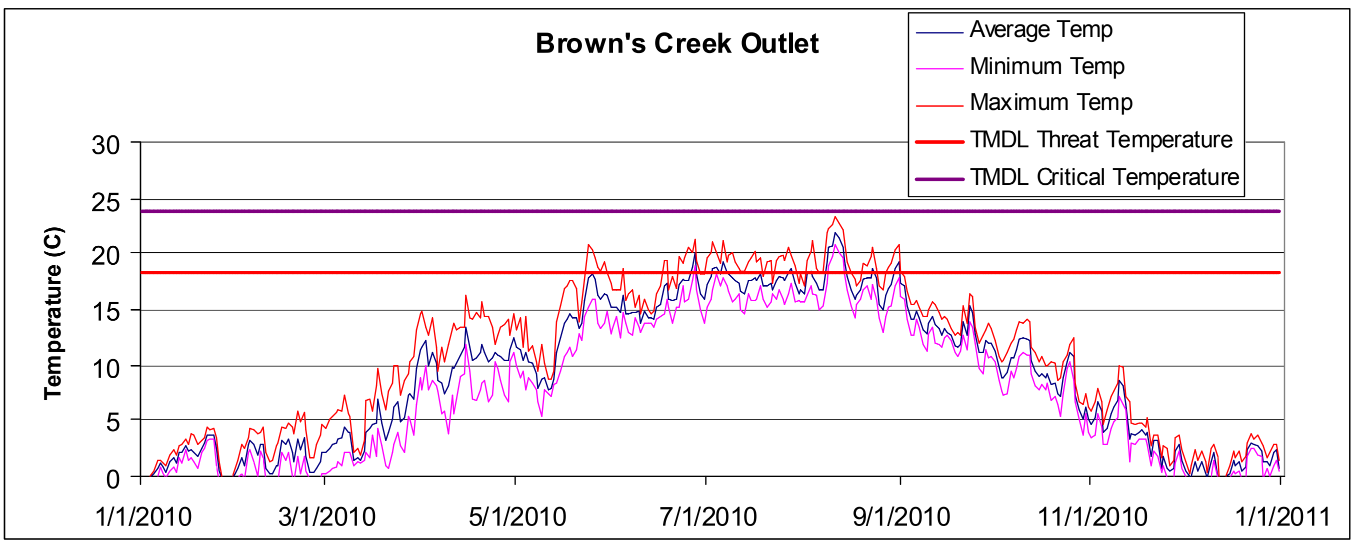


Figure 24. 2010 Brown's Creek Outlet Daily Average, Minimum, and Maximum Temperatures

B. CONCLUSIONS

The stream monitoring sites on Brown's Creek are producing valuable baseline water quality information that will be a helpful tool in determining a healthy balance of resources as the watershed continues to experience growth and changes in land use. To determine the health of the stream, discharge (base and storm), chemical, physical and biological parameters are compared on a year-to-year basis and with other streams in the region.

Base flow at the outlet of the stream consistently averages around 7 cubic feet per second (cfs). The 2002 monitoring season had the highest base flow of 10 cfs within the past seven years. For 2010, stream flow averaged 5.2 cfs. This is the lowest average annual flow during recorded data, 0.4 cfs below the 2009 low of 5.6 cfs. While the base flow may fluctuate with climatic cycles, it provides a good point of reference for overall groundwater recharge to the stream. A drop in base flow during periods of normal or high precipitation may suggest a loss of groundwater recharge in the watershed. This may have been seen slightly in 2004 when compared to 2003 and in 2006 when compared to 2005. As in the previous two monitoring seasons, Brown's Creek was at base flow levels for the majority of the year.

While phosphorous has not been identified as a problem nutrient at the mouth or within other reaches of the stream, it is a common nutrient associated with lake eutrophication and is therefore routinely monitored in streams throughout the state. Total loading and loading per unit area are additional tools to help assess the health of the stream. During 2010, Brown's Creek Outlet had an annual loading rate per unit area (Kg/ha) of 0.14, for a total of 1,126 lbs. The average total phosphorus concentration in the stream at the Outlet was 0.24 mg/L in 2010. This is consistent with the moderate impact range according to the H&H study (Table 29). The Stonebridge site had a loading rate per unit area (Kg/ha) of 0.11, for a total of 796 lbs. The McKusick Road sites exhibited an annual loading rate per unit area (Kg/ha) of 0.11, for a total load of 787 lbs. The Highway 15 site had a loading rate per unit area (Kg/ha) of 0.13, for a total load of 833 lbs. These three sites recorded nearly the same annual discharge as in 2009, and roughly half of the total phosphorus load was estimated. This seems counterintuitive because of the return to average precipitation amounts, which caused the Highway 15 site to experience a roughly 25% increase in load and discharge. The cause of this reduction is not known, but one possible explanation is that a series of beaver dams were constructed between the Highway 15 and McKusick Road sites. The pooling caused by these could have reduced the numbers observed at the sites downstream of them. The Brown's Creek Diversion Structure site, although not completely connected with Brown's Creek as it was historically, exhibited a loading rate per unit area of 0.18 Kg/ha, for a total of 608 lbs. The total phosphorus load from Brown's Creek to the St. Croix River in 2010 was **1,126 lbs (0.12 lbs per acre of watershed land)**, determined by the Outlet station results.

The inlet to Long Lake at 62nd St. exhibited loading per unit area of 0.109, for a total of 61 lbs. The inlet at Marketplace Pond exhibited loading per unit area of 0.384, for a total of 172 lbs. The inlet to Long Lake at the Herberger's Pond Outlet exhibited loading per unit area of 0.287, for a total of 32 lbs. From these loadings it is quite obvious that the

Marketplace Pond subwatershed is draining either much more impervious areas without adequate treatment prior to this site or is draining a subwatershed that has a lot of erosion and sediment control problems. Although there is some construction activity in that subwatershed, the untreated drainage from impervious surfaces seems to be the more likely explanation. One factor that needs to be considered is that a series of settling ponds exists between Marketplace Pond and Long Lake to provide further treatment, whereas the 62nd St. site has no further treatment prior to discharging to Long Lake.

Total suspended solids (TSS) concentration is a good measure of the particulate matter in the stream and can be correlated to disturbances within the watershed. The average TSS in 2010 at the Brown's Creek Outlet was 59 mg/L. This is within the moderate impact modeled condition for the Outlet site from the H&H Study. All sites on Brown's Creek had average TSS concentrations less than the average concentration found at the Outlet. The Brown's Creek Diversion Structure site had an average concentration of 498 mg/L. One storm composite sample TSS result at the Diversion site was omitted from the average. This was left out of average calculations due to the extremely high value recorded, and based on our professional judgment. At the Diversion site, base flow concentrations are relatively low, but storm concentrations are much higher and may indicate that impervious surfaces, stormwater runoff from development, or remaining agricultural lands in this subwatershed may be contributing to these higher concentrations.

The Long Lake drainage sites at 62nd St. and Marketplace Pond had average TSS concentrations of 91 mg/L and 12 mg/L, respectively. The drainage site at Herberger's Pond Outlet had an average TSS concentration of 16 mg/L. The value for 62nd St. was higher in 2010 compared to 2009, likely due in part to more overall precipitation and storm events. The values from the Herberger's and Marketplace Ponds are consistent with the previous year. It is recommended that monitoring continue at these sites in order to generate conclusions and long-term trends.

Turbidity or suspended solids should continue to be monitored in Brown's Creek. The average TSS value for the Brown's Creek Diversion Structure drainage (498 mg/L) was in the high water quality impact range of modeled conditions. Stonebridge (39 mg/L), McKusick Road (42 mg/L) and the Outlet sites (59 mg/L) were in the moderate impact range. The TSS average value at Highway 15 (25 mg/L) was within the low impact range (Table 29). The TSS value for the 62nd St. site (91 mg/L) was within the high impact range, and the Marketplace and Herberger's Pond Outlet drainages (12 mg/L and 16 mg\L) were within the low impact range. Based on the Brown's Creek Impaired Biota TMDL, the average TSS load at the Outlet was 36 mg\L above the targeted goal of 23 mg\L (Table 30). This translates to 973 pounds of daily discharge over the low flow condition threshold allowed within the TMDL framework.

Sampling was conducted at eleven sites along the diversion drainage from March through October. Groundwater inflow is most likely present between Boutwell Rd. and the S. Branch, upstream from the N. Branch, upstream from the W. Branch 1 and the W. Branch 2, and potentially between the Diversion Structure and the confluence of the N., S., and W. Branches. The North, South and East Settlers sites, as well as the Creekside site, are storm water pond outlets and only flow when the ponds are at capacity. Looking at the results, there appears to be some additional contribution of TSS and TP between W. Branch 2 and W. Branch 1, and between Boutwell Road and S. Branch. The pond outlet sites do not seem to be contributing to these increases. When comparing TSS at S. Branch and W. Branch 1, all sample results were similar. The groundwater present at S. Branch, W. Branch 2, W. Branch 1, N. Branch, and the Diversion Structure has some affect on the water quality and flows as well. The higher results from the 6/11/10 and 8/2/10 samples at N. Branch may have been due to bottom sediment contaminating the sample. This channel is very shallow, narrow, incised, and covered with vegetation making it very difficult to collect a representative sample. Additional monitoring in 2011 should make more precise identification of what is occurring in this drainage possible. Again, further BMP's may need to be investigated for the Diversion Structure drainage.

Table 29: Issues Matrix: Water Quality

	Total Phosphorus (mg/L)	Total Suspended Solids (mg/L)
Low Impact	0-0.15	0-30
Moderate Impact	0.15-0.25	30-100
High Impact	>0.250	>100

Brown's Creek Watershed District Hydrologic/Hydraulic Study, November 1999

Table 30. TSS Loading Capacity

Flow Range	Flow Range Midpoint (cfs)	TSS TMDL (lbs/day) @ 23 mg/L
High	25.0	3,105
Moist	11.7	1,456
Mid	8.5	1,049
Dry	6.8	839
Low	5.5	684

Brown's Creek Impaired Biota TMDL, November 2009

Temperatures in Brown's Creek are at the thermal maximum for a cold-water stream. Maximum temperatures for young of the year Brown trout were regularly exceeded during the 2000-2002 seasons at both the Outlet and at McKusick Road. However, since the completion of the Diversion Structure in 2003, no daily average exceedences of the critical temperature threshold have been recorded at any site on Brown's Creek. Since 2003, 2010 had the highest number of days with the average temperature exceeding the threat level temperature at the Highway 15, McKusick Road and Stonebridge sites. The Outlet site experienced the third highest number of days with the average temperature exceeding the threat level threshold. This is a stark contrast to 2009, which had the lowest, or in the case of the Outlet site the second lowest, number of days that exceeded the threat level threshold. One possible cause of the increase observed in 2010 was the return to average amounts of precipitation. Many of the previous years had well below average amounts of rainfall, which in turn contributes less warm water runoff to the stream. As in 2008 and 2009, in 2010 all monitored sites had daily minimum temperatures near or below the 18.3°C threshold. Continued efforts to improve shade throughout critical areas as well as in areas upstream of where trout are known to live will likely improve temperature conditions for trout throughout the stream. In 2001 and 2002 stream temperatures reached levels above ideal conditions for trout habitat but showed no direct negative correlation to natural reproduction rates.

C. RECOMMENDATIONS

- Continue collecting water quality and continuous discharge data at existing monitoring stations to determine long term trends.
- Continue to assess the performance of the EcoStorm Plus system at the Herberger's Pond outlet.
- Continue collecting total dissolved phosphorus data at several locations in the Brown's Creek diversion structure drainage to better assess effectiveness of future iron-enhanced sand filtration BMPs.
- Begin implementation of TMDLs on waters currently listed on the 303d impaired water's list (Goggin's Lake, Long Lake, Lynch Lake, and South School Section Lake) as well as staging implementation on waters that will be listed based on water quality data with a small period of record.
- Continue monitoring the second (deeper) basin of Lynch Lake to confirm impairment status and compare the two basins.
- Expand monitoring on Benz Lake according to the Benz Lake Management Plan.
- Continue implementation of activities to de-list Brown's Creek from the MPCA's impaired waters list.
- Continue to gather baseline water quality data at all sites on Brown's Creek as BCWD continues to become more developed.
- Support continued biological monitoring of Brown's Creek through the volunteer efforts of Stillwater Area High School.
- Begin to track BMP effectiveness according to the Monitoring Plan in the Brown's Creek Biotia TMDL.
- Perform macrophyte surveys on lakes that are lacking data.