Final Report

Determining the causation of low D.O. on the North Branch of the Kawkawlin River

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During the summers of 2013 and 2014, SVSU led a project with Delta College to monitor the Kawkawlin River. The purpose was to determine any unique conditions on the North Branch that could cause the low dissolved oxygen (D.O.) condition noted in the 2007 MDEQ Low D. O. TMDL for the River. Measurements on water quality parameters and *E. coli* were made for 15 weeks from May until August each year. In 2013, 15 sites were sampled which was reduced to 12 sites for 2014. Benthic species were sampled at 14 sites on 6 occasions in 2013. The following are observations on the results which are attached in tables. The tables include results from each site and sampling date as well as season averages for the entire river and each branch.

Dissolved Oxygen

Summer 2013: There were 220 sampling events for D. O. on the Kawkawlin River in 2013, with 78 occurrences where the sites did not meet Michigan's standard of 5 mg/L for a warm water stream. Approximately 44% of North Branch events were below 5 mg/L compared with 44% of South Branch and 17% of Main Branch events. Of all locations, the North Branch sites NB3, NB4, and NB5 exhibited the lowest D.O. levels measured, with a low of 0.4 mg/L at NB4. Site NB4 only met the 5mg/L standard on one occasion. Sites NB2 – NB5 are part of the low D.O. TMDL where 54% of events were below the state standard.

Summer 2014: There were 180 sampling events for D.O. in 2014, with 61 occurrences where the sites did not meet the standard of 5mg/L. Approximately 51% of North Branch, 42% of South Branch, and 9% of Main Branch sampling events were below the standard of 5 mg/L. Site NB3 only had one sampling above the state standard while site NB4 never met the standard during the test period. The low measured value at NB4 was 0.0 mg/L.

Overall: Dissolved oxygen was slightly lower overall on average in 2014 (5.2 mg/L) than in 2013 (5.6 mg/L). Rain events were not significantly different than non-rain events on average. The North Branch of the river was lower than the state standard of 5 mg/L on average, while all other branches were typically above the standard.

Total Phosphorus

In 2013, The North Branch sites generally had the highest levels of total phosphorus, followed by the South Branch, and then the Main Branch. Site NB4 had the highest average total phosphorus for all sites at 0.216 mg/L. Other sites in the Low D.O. TMDL reach were also higher than the rest of the river. The same trend continued in 2014 for each branch, with the North Branch having higher levels than the rest of the river, and site NB4 again giving the highest average total phosphorus of 0.231 mg/L.

When looking at seasonal averages, 2014 levels were lower (at 0.108 mg/L) compared with 2013 (0.157 mg/L). Rain events gave higher total phosphorus than non-rain events on average for all but the North Branch. On average, the North Branch was higher than the South Branch in 2014 but not in 2013.

Soluble Reactive Phosphorus

The trend for soluble reactive phosphorus (only reported in 2014) is similar for total phosphorus with the North Branch and specifically site NB4 giving the highest values with an average of 0.135 mg/L. On average, rain events gave higher SRP levels than non-rain events except on the Main Branch. The Main Branch had the lowest levels of SRP on average.

Nitrate-N and Ammonia-N

Nitrate-N values were significantly lower in 2014 compared to 2013. Ammonia-N values were slightly lower in 2014 compared to 2013. Site NB4 was not unique among sites as noted for phosphorus and D.O. Ammonia-N levels were much lower than nitrate-N levels. Rain events gave higher nitrogen (both nitrate and ammonia) in 2013 but not in 2014. The South Branch was slightly higher than all other areas in both nitrate-N and ammonia-N.

Chemical Oxygen Demand

Chemical oxygen demand measurements showed the highest values on the North Branch, with the highest site average at NB4 of 50.2 mg/L. In comparison, the river average was approximately 38 mg/L. There was no notable difference between rain and non-rain events. Pearson Correlation coefficients between D.O. and COD were calculated for each site and date, and no correlation was noted.

Turbidity

The water clarity was generally very good thereby yielding low turbidity. Rain events were higher than non-rain events, on average. Turbidity in 2013 was higher (at 11.6 NTU avg.) than in 2014 (4.7 NTU avg.). The maximum turbidity was 191 NTU in 2013 and only 23 NTU in 2014. The North Branch was lower than the South Branch on average.

pH

Consistent pH was noted across both years of sampling with an average of approximately 7.8. Of note are the low pH values in the North Branch, particularly at site NB4 where pH fell below 7 during times of low D.O. A lowering of pH typically accompanies the decomposition of organic matter.

River flow

Stream flow velocity measurements were attempted using a Global Water Flow Probe, model FP111, which has a range of 0.1 to 6.1 m/s. The river flow velocity was below the range of this meter at each site during sampling events. Therefore volumetric flow rate could not be calculated, and loading results are not available.

E. coli

***E. coli* exceedances**

The levels of the fecal indicator bacterium were measured with Colilert. Samples were collected over the 2013 and 2014 summers on the dates specified for each of the sites in triplicate. The

exceedances (>300 colony forming units(CFU)/100 mL) are indicated for each site in the results. The total number of samples in 2014 was less than in 2013, so along with the number of exceedances per site and total, the percent exceedances are also reported per site, total and per branch for better comparison between years. Note that the sites that were of particular interest to the MDEQ are denoted in green in the tables.

Overall summary

For each of 2013 and 2014, the total percent of Colilert exceedances (> 300 CFU/100 mL for the geometric mean of three samples at each site) was constant for the 3 branches combined, at 20%. In 2013, the majority of sites were above allowable levels for the first two weeks of sampling; both of these dates were major rain events. When these sampling events are excluded from the analysis, the North Branch clearly had higher levels of bacterial contamination than the other branches for the rest of the season, accounting for 90% of positive results. A similar result, though not as pronounced, was evident for 2014. If the sampling events of 6/24 (a rain event) and 6/30 are eliminated, the North Branch accounted for over half of the exceedances.

Even though the North Branch displayed the most contamination compared to the Main and South Branches, the percent of exceedances decreased from 2013 to 2014. The Main Branch was similar each year. The South Branch exhibited an increase in percent contamination from year one to year two, due to an increase at both SB2 and SB3.

The highest levels of contamination by site were at NB1, NB2, and SB1 in 2013. NB3 and NB4 also had exceedances greater than 25% of the times. In 2014, NB1 and NB4 were the most contaminated in the North Branch, while SB2 and SB3 were contaminated greater than 25% of the sampling dates.

The rain events increased from 4 to 6 sampling days from 2013-2014. These days accounted for 73% of the exceedances in 2013 and 97% of the exceedances in 2014. Of the 12 exceedances that were not following rain events in 2013, 11 of them were in the North Branch.

North Branch *E. coli* levels

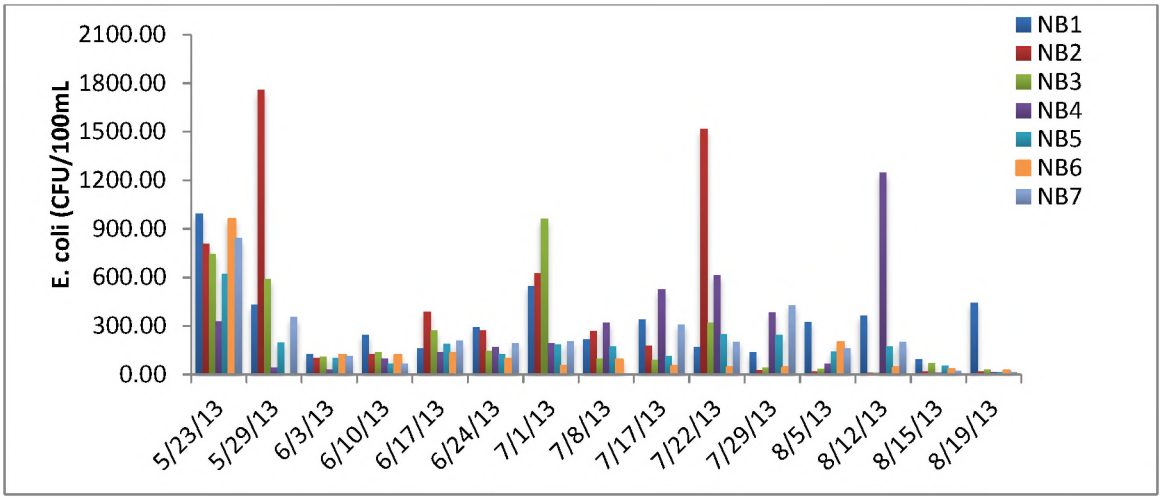

Figure 1. Daily geometric mean *E. coli* levels for the North Branch for all sampling events in 2013.

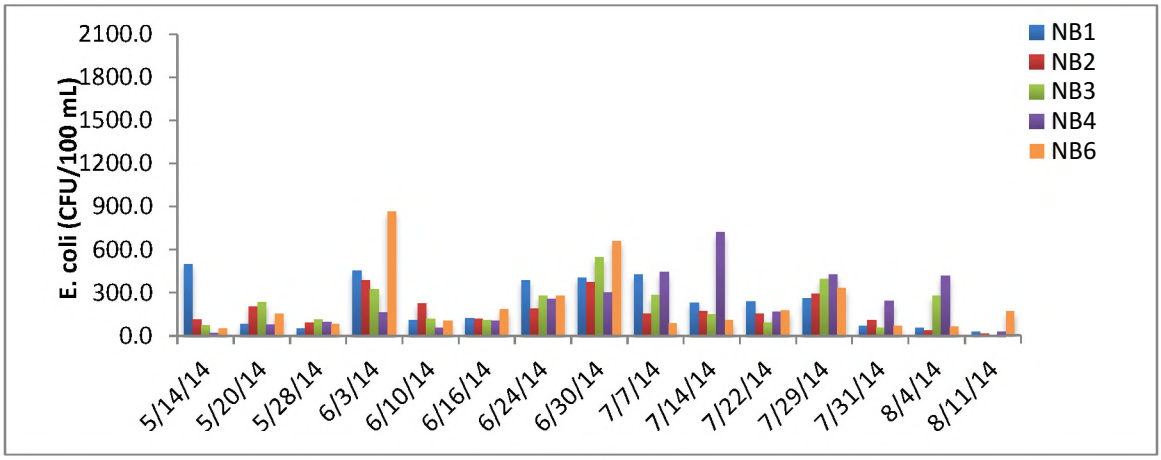

Figure 2. Daily geometric mean *E. coli* levels for the North Branch for all sampling events in 2014.

In 2013, *E. coli* levels ranged from 9-1756 CFU/100 mL for sites in the North Branch (Figure 1), with 24% exceedances. In 2014, the range was 6-867 CFU/100 mL (Figure 2), with 21% exceedances. Not only was the range wider with the top level being higher, it is clear that the sampling events in 2013 resulted in more sites that exceeded the minimum allowed for human contact of 300 CFU/100 mL than occurred in 2014. Further, 2013 had several samplings that were well over the minimum. NB2 had the highest levels for 2013 but rarely was in exceedances in 2014. Conversely, NB6 exhibited the greatest contamination in 2014, but was usually low in 2013.

Main Branch *E. coli* levels

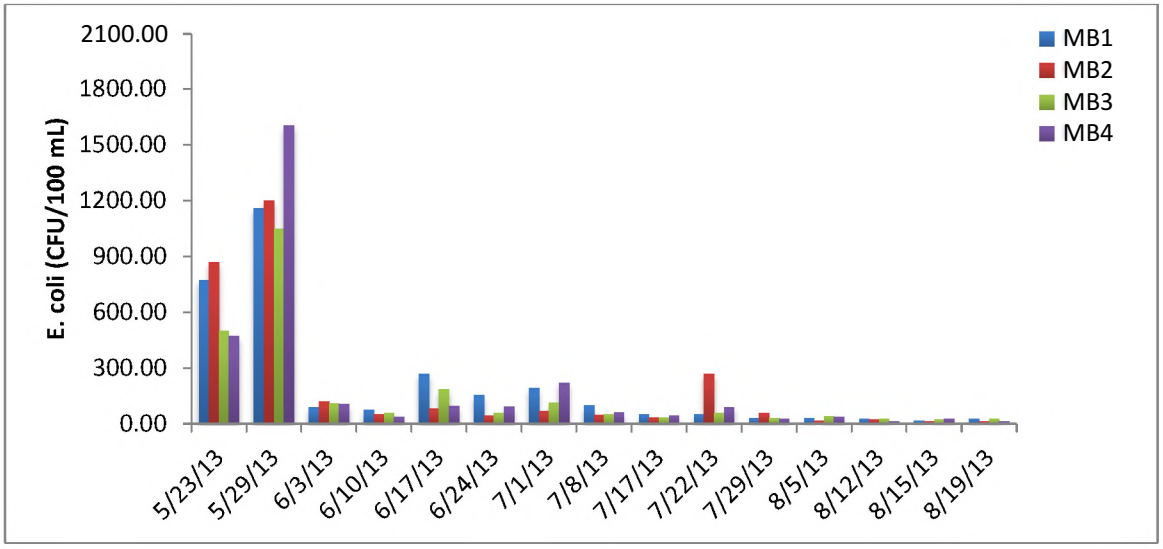

Figure 3. Daily geometric mean *E. coli* levels for the Main Branch for all sampling events in 2013.

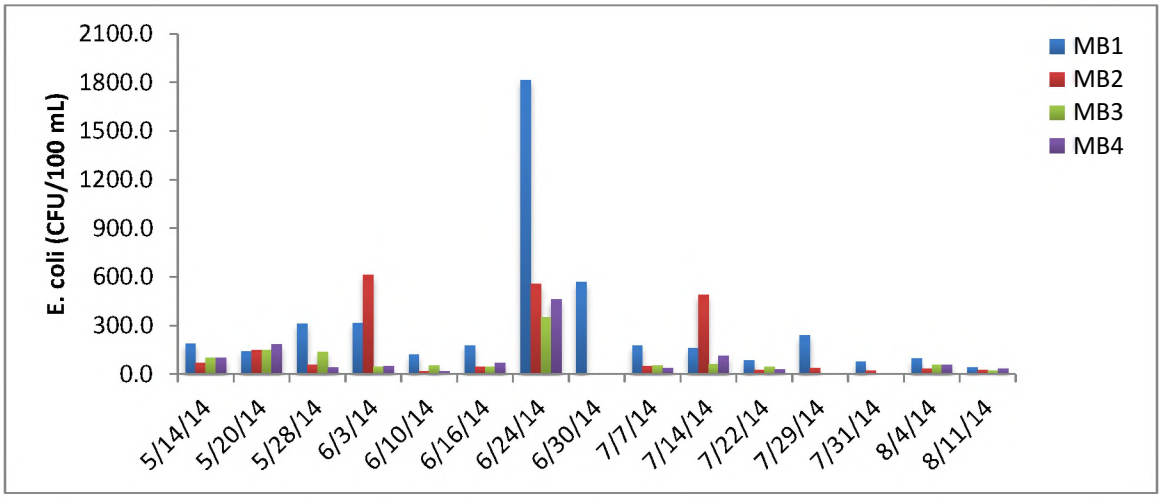

Figure 4. Daily geometric mean *E. coli* levels for the Main Branch for all sampling events in 2014.

In 2013, *E. coli* levels ranged from 6-1606 CFU/100 mL for sites in the Main Branch (Figure 3), with 13% exceedances. In 2014, the range was 16-1814 CFU/100 mL (Figure 4), with 15% exceedances. In both 2013 and 2014, all exceedances followed rain events.

South Branch *E. coli* levels

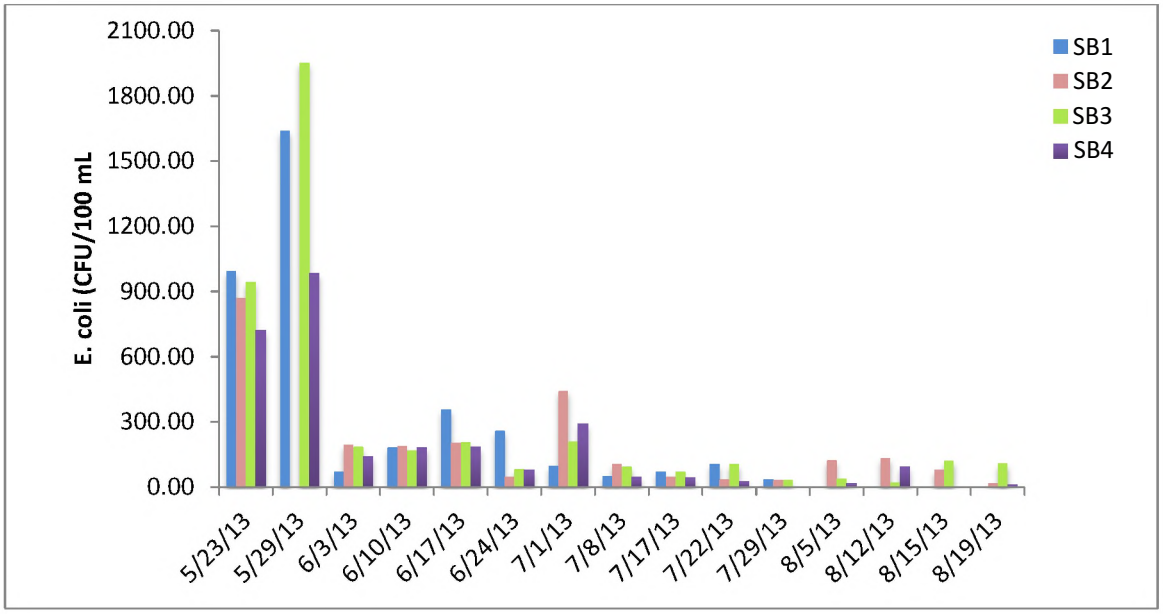

Figure 5. Daily geometric mean *E. coli* levels for the South Branch for all sampling events in 2013.

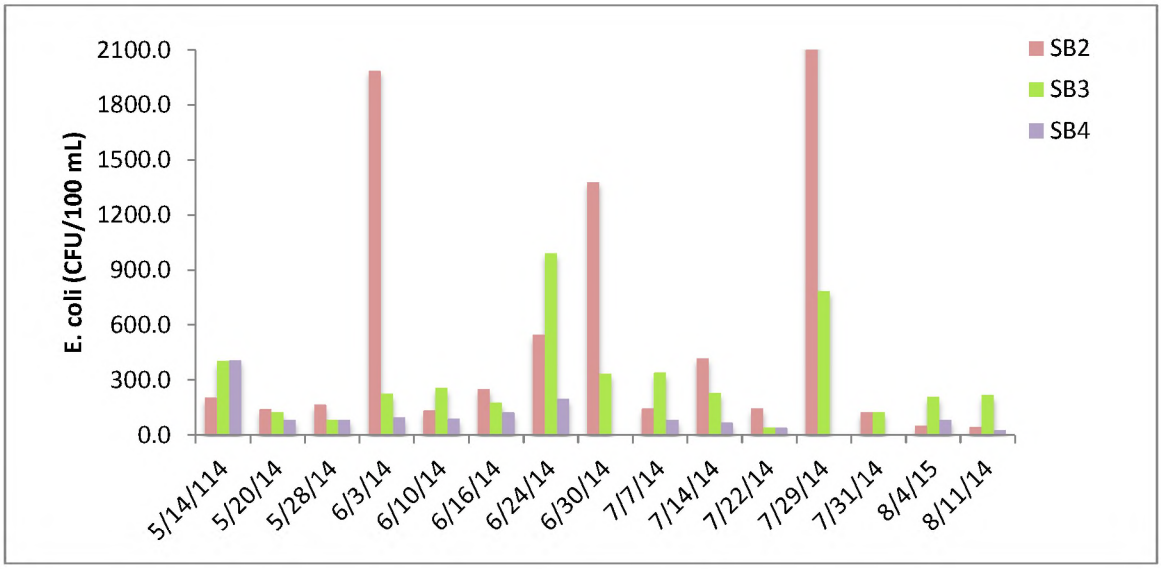

Figure 6. Daily geometric mean *E. coli* levels for the South Branch for all sampling events in 2014.

In 2013, *E. coli* levels ranged from 4-1954 CFU/100 mL for sites in the South Branch (Figure 6), with 16% exceedances. In 2014, the range was 42-2275 CFU/100 mL (Figure 7), with 24% exceedances. The majority of the exceedances followed rain events. Of note is the increase in contamination at SB2 from 2013-2014.

Benthic Macro invertebrates

During the summer (August/September) of 2013, fourteen Kawkawlin River sites were sampled on six separate dates (see tables) utilizing two different commonly used species diversity indices. Accepted stream sampling protocol was implemented (D-net kick method) to collect representative macro invertebrate organisms. Organisms were identified to the lowest possible taxa, (mostly to family) utilizing several keys, including "An introduction to Aquatic Insects of North America (Merritt and Cummins, 3rd edition). Although calculations from both indices are sometimes considered to result in "qualitative/quantitative" data, each gives a relative representation of resident macro invertebrate fauna. Two indices were selected as a method of comparison of relative abundance and pollution tolerance. These two indices were selected for their overall acceptance/utilization and ease of data collection.

The PTI (Pollution Tolerance Index)[2] is a tool based on the concept of "indicator organisms" and their perceived tolerance levels. It was developed by the Izaak Walton League of America as well as the Stream Quality Monitoring program of the Ohio Department of Natural Resources. The PTI value is determined by multiplying the number of types of organisms in each group by its index value; these numbers are then added together to form the PTI. Example: Group I (factor 4 assigned value) includes stone fly, gill snail, mayfly, riffle beetle, dobsonfly water penny and caddis fly. Number of group 1 organism types x 4 would equal first number. There are 4 groups within in the index. These are totaled for an assigned "score". Excellent= 23 or more, Good = 17-22, Fair= 11-16 and poor = 10 or less.

The Biotic index[2] assigns value to each "kind" of organism present in a sample. This biotic index relies on all the different invertebrates found in the sample and is a more sophisticated tool for assessing stream quality. Organisms are placed in three "classes" (Class I, II, III) with the number of each invertebrates (ID to lowest possible taxa, typically family) counted, multiplied times biotic index value assigned (Class I, pollution intolerant - 10; Class II, somewhat tolerant- 8-6; Class III, pollution tolerant - 5-2) with each "score" added for a total biotic index. Where a score of 800-1000 = Excellent; 600-799 = Good; 400-599 = Fair and 0-399 is Poor.

Representative macro invertebrates for both indices included organisms that were mostly "pollution tolerant/somewhat tolerant". Midge larvae (Chironomidae), snails, isopods, dragonfly and damselfly larvae (Odonata), crane fly larvae (Tipulidae) were common in samples at most locations while "pollutant intolerant" organisms were either absent or uncommon. These groups included stonefly (Plecoptera), caddis fly (Trichoptera) and mayfly (Ephemeroptera) larvae. If "somewhat tolerant" organism were found in samples, they would typically be beetle larvae (Coleoptera) and scuds (Amphipoda).

Results presented in the attached tables indicate the following:

1. PTI data from the fourteen sites indicates that the Kawkawlin watershed macro invertebrate population (on average) has a "fair" to "good" pollution tolerance (12 of 14 sample sites in this range) with one site each ranked as "poor" (South Branch at Garfield Road site) or "excellent" (Euclid site). Pollution intolerant organisms were least represented. These results indicate that pollution tolerant organism thrive, which may be indicative of a "stressed" system.
2. Biotic Index results ranked the system as "poor" to "fair" with highest number of sites on average indicating "poor" conditions (8 of the 14 sites), and the remaining 6 sites ranked as "fair". This index looks at overall numbers and diversity of individual organisms identified in the sample, indicating relative abundance. Results from this index also indicate the system is "stressed".
3. Results from these two indices are somewhat correlated in that the Euclid site was scored/ranked by the PTI as "excellent" on average while the Biotic Index showed the highest number of macro invertebrates (551 on average). Also, the South Branch at Garfield site ranked as "poor" in the PTI, with the Biotic Index also indicating "poor" conditions.
4. Considerations: Although a more seasonally inclusive sampling time-frame may have given a broader representation of macro invertebrates, the sampling regime did provide a good representation of water quality conditions (as indicated by biotic factors).
   Reason: Abiotic parameters such as water temperature and other physical/chemical conditions during the sampling period should be taken into consideration as organisms must "tolerate" many of the most "stressful" conditions during this time period (Low D.O., high temperatures, nutrient loading, sedimentation).

<u>Summary</u>

The purpose of the two-year monitoring activities was to determine the cause of the low D.O. condition noted for a specific reach of the North Branch of the Kawkawlin River often referred

to as the "low D.O. TMDL reach" or just "TMDL reach".[3] While the results do not appear to yield a clear reason for hypoxia, there are several notable features in the river water quality. The biotic index results indicated poor conditions within the TMDL reach (Mackinaw Rd, site NB4) thereby indicating prolonged poor conditions. The *E. coli* results indicate that the North Branch of the river had a disproportionately large number of exceedances of the standard of 300 cfu/100 mL compared with other branches; the source of the *E. coli* is unknown as there were no obvious manure operations and septic system conditions are unknown but such sources of *E. coli* would contribute to the oxygen demand of the river. The COD values were somewhat higher for the North Branch, with the highest observed values within the reach (site NB4). However, the values were not exceptionally high compared with the rest of the river. These conditions are not inconsistent with those we observed in a 2011 and 2012 study of the reach.[4] In that study, sediment organic matter was measured and found to be highest at site NB4. Oxygen demand, whether from sediment organic matter or dissolved organic species, could contribute to the hypoxia.

The study period was relatively short from May until August, and our observations of the river suggest that most locations have higher dissolved oxygen outside of this timeframe when water temperatures are cooler. The lowest dissolved oxygen levels were observed in July and August when temperatures were high. Additionally, stream flow is generally very slow, and it becomes nearly stagnant at most locations in July and August. The slow, shallow water coupled with higher temperatures make oxygen recharge very slow. In a separate study at SVSU, the low stream flow in the TMDL reach was attributed primarily to a geological formation just below the TMDL reach that essentially blocks outflow from the reach.[5] Records of this date back to the original surveys in the early to mid-19th century with the implication it is natural.

Recommendations for further work would be to determine the sources of *E. coli* in the North Branch and other areas of the river. In addition to potential health effects to users of the water resource, the sources of *E. coli* may contribute in part to oxygen demand in the river as well as nutrient loading. Nitrogen and phosphorus levels are high in the river when compared, for instance, to target levels suggested for Saginaw Bay (0.015 mg/L). These high levels can contribute to algae growth and subsequently to eutrophication which is accompanied by depressed oxygen levels. Excess algae growth was noted throughout the river in late summer, but chlorophyll-a measurements would be beneficial in understating the response of algae growth to nutrient levels. Additionally, accurate flow measurements at sampling sites will enable calculation of volumetric flow and therefore loading of nutrients. These additional measurements will help in understanding the role of external stresses (potential septic/manure as well as nutrient contamination) and natural features on water quality of the Kawkawlin River.

Citations

1) POLLUTION TOLERANCE INDEX (PTI): Adapted from *Volunteer Stream Monitoring: A Methods Manual*, United States Environmental Protection Agency, Office of Water, Document #EPA 841-B-97-003, November 1997 AND Mitchell and Stapp, *Field Manual for Water Quality Monitoring*, 1996.
2) BIOTIC INDEX: Modified from E. Enger and F. Ross, Delta College and 2006 University of Wisconsin "Water Action Volunteers - Volunteer Stream Monitoring Series"

3) Staron, M., 2007. Total Maximum Daily Load for Dissolved Oxygen for the North Br anch Kawkawlin River, Bay County.
4) Hannah M. Voss, Meaghan E. VanWert, James R. Polega, Jacob W. VanHouten, Arthur L. Martin, and David S. Karpovich. "Implications of hypoxia on the North Branch o f the Kawkawlin River." *Journal of Great Lakes Research* 40 (2014): 28-34. http://0-dx.doi.org.library.svsu.edu/10.1016/j.jglr.2014.01.006
5) Rhett Mohler and Nicholas Ross, "Using aerial photography and satellite imagery to examining potential causes of a low-gradient, anoxic reach of the North Branch Kawkawlin River." Unpublished. Final Report for grant from the Saginaw Bay Environmental Science Institute at SVSU. See attached.

	Average of all sites on the Kawkawlin River - 2013									
	Water Temp	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**	**PTI**	**BI**
	°C	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/100 mL**		
Average Values	17.4	5.6	7.8	11.6	4.47	0.06	0.157	236	17	363
Std Deviation	4.0	2.1	0.3	26.7	2.54	0.10	0.119	347	7	183
Season Max	30.2	9.6	8.9	191.4	14.03	0.77	0.780	1954	34	782
Season Min	7.2	0.4	6.8	0.4	ND	ND	ND	3	2	77

	Average of all sites on the Kawkawlin River - Major Rain Events 2013							
	Water Temp	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**
	°C	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/100 mL**
Average Values	15.3	6.0	7.7	30.3	6.05	0.14	0.192	513
Std Deviation	3.5	1.8	0.3	47.3	3.40	0.16	0.156	493
Season Max	25.0	9.1	8.7	191.4	14.03	0.77	0.780	1954
Season Min	7.2	0.7	6.8	1.6	0.94	ND	ND	3

	Average of all sites on the Kawkawlin River - Non-Rain Events 2013							
	Water Temp	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**
	°C	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/100 mL**
Average Values	18.2	5.4	7.8	5.0	3.94	0.03	0.144	135
Std Deviation	4.0	2.2	0.3	3.7	1.87	0.03	0.101	196
Season Max	30.2	9.6	8.9	28.5	9.19	0.21	0.544	1518
Season Min	10.6	0.4	6.9	0.4	ND	ND	ND	4

PTI = Pollution Tolerance Index Poor = 10 or less Fair = 11-16 Good = 17-22 Excellent = 23 or more
BI = Biotic Index Poor = 0-399 Fair = 400-599 Good = 600-799 Excellent = 800-1000
ND = Data point was below the limit of detection
Major Rain Event Definition = 0.25 inches of rain within a 24 hour period, prior to a 72 hour dry period
Detection Limits: NO_3-N = 0.69 mg/L NH_3-N= 0.01 mg/L Total P = 0.023 mg/L
NO_3-N represents nitrogen from nitrate + nitrite
Non-Detects are represented as half the detection limit in the calculation of the averages

	North Branch Kawkawlin River Averages - 2013									
	Water Temp	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**	**PTI**	**BI**
	ºC	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/100 mL**		
Average Values	15.9	4.9	7.6	8.5	4.16	0.05	0.161	259	18	324
Std Deviation	2.8	2.2	0.2	18.1	2.11	0.06	0.108	322	6	172
Season Max	22.0	9.3	8.0	156.2	11.83	0.37	0.544	1756	31	721
Season Min	9.3	0.4	6.9	0.6	ND	ND	ND	9	6	77

	North Branch Kawkawlin River Averages - Major Rain Events 2013							
	Water Temp	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**
	ºC	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/100 mL**
Average Values	14.1	5.5	7.6	20.2	5.07	0.09	0.157	430
Std Deviation	2.0	2.0	0.2	32.8	2.75	0.10	0.082	400
Season Max	17.3	8.2	7.8	156.2	11.83	0.37	0.458	1756
Season Min	9.3	0.7	7.0	1.6	0.94	ND	0.037	24

	North Branch Kawkawlin River Averages - Non-Rain Events 2013							
	Water Temp	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**
	ºC	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/100 mL**
Average Values	16.5	4.7	7.6	4.3	3.83	0.03	0.163	197
Std Deviation	2.8	2.3	0.3	2.6	1.75	0.03	0.117	266
Season Max	22.1	9.3	8.0	14.6	8.68	0.21	0.544	1518
Season Min	11.5	0.4	6.9	0.6	ND	ND	ND	9

	South Branch Kawkawlin River Averages -2013									
	Water Temp	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**	**PTI**	**BI**
	ºC	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/100 mL**		
Average Values	16.3	5.7	7.9	17.0	5.51	0.09	0.168	247	11	331
Std Deviation	3.6	2.0	0.2	36.9	3.39	0.15	0.147	396	7	168
Season Max	25.7	8.7	8.9	191.4	14.03	0.77	0.780	1954	27	650
Season Min	7.2	2.0	7.5	0.4	1.16	ND	ND	3	2	104

	South Branch Kawkawlin River Averages - Major Rain Events 2013							
	Water Temp	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**
	ºC	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/100 mL**
Average Values	13.9	6.4	7.8	46.1	8.13	0.23	0.240	612
Std Deviation	2.9	1.9	0.3	62.9	4.44	0.24	0.224	614
Season Max	18.2	8.5	8.7	191.4	14.03	0.77	0.780	1954
Season Min	7.2	2.1	7.5	2.2	1.16	ND	ND	3

	South Branch Kawkawlin River Averages - Non-Rain Events 2013							
	Water Temp	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**
	ºC	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/100 mL**
Average Values	17.2	5.4	7.9	6.0	4.53	0.04	0.142	106
Std Deviation	3.4	1.9	0.2	4.1	2.29	0.04	0.096	84
Season Max	25.7	8.7	8.9	19.4	8.85	0.17	0.462	443
Season Min	10.6	2.0	7.6	0.4	1.22	ND	ND	4

	Main Branch Kawkawlin River Averages - 2013									
	Water Temp	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**	**PTI**	**BI**
	^{0}C	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/100 mL**		
Average Values	21.0	6.7	8.0	12.2	4.07	0.05	0.139	187	20	457
Std Deviation	4.1	1.5	0.3	27.5	2.05	0.09	0.109	338	7	186
Season Max	30.2	9.6	8.7	135.7	10.72	0.38	0.514	1606	34	782
Season Min	12.4	2.7	6.8	0.8	0.79	ND	ND	12	8	152

	Main Branch Kawkawlin River Averages - Major Rain Events 2013							
	Water Temp	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**
	^{0}C	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/100 mL**
Average Values	18.3	6.7	7.8	32.6	5.53	0.14	0.209	559
Std Deviation	4.0	1.2	0.4	50.2	2.67	0.14	0.170	517
Season Max	25.0	9.1	8.7	135.7	10.72	0.38	0.514	1606
Season Min	12.4	4.7	6.8	2.0	0.79	ND	0.064	28

	Main Branch Kawkawlin River Averages - Non-Rain Events 2013							
	Water Temp	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**
	^{0}C	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/100 mL**
Average Values	22.0	6.7	8.1	5.4	3.58	0.01	0.115	60
Std Deviation	3.8	1.7	0.3	4.6	1.56	0.01	0.067	47
Season Max	30.2	9.6	8.6	28.5	9.19	0.06	0.364	221
Season Min	15.0	2.7	7.6	0.8	1.30	ND	ND	12

2013 Kawkawlin River results

NB1 Garfield North 43° 43'34.9566'' -84° 5' 14.946								
Date	**Water Temp**	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**
	°C	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/ 100 mL**
5/23/2013†	13.3	6.7	7.5	24.4	7.00	0.23	0.132	994
5/29/2013†	12.3	8.2	7.7	27.0	5.37	0.09	0.127	430
6/3/2013	12.8	7.5	7.9	5.4	ND	0.05	0.086	125
6/10/2013	14.4	7.5	7.9	5.3	4.31	0.02	0.063	244
6/17/2013†	16.7	5.8	7.7	8.8	3.63	0.21	0.037	161
6/24/2013	19.7	6.2	7.7	5.9	4.09	0.04	0.216	292
7/1/2013	15.0	8.5	7.6	7.3	4.44	0.03	0.073	546
7/8/2013	19.3	6.0	7.7	6.9	3.97	0.04	0.308	217
7/17/2013	21.5	4.3	7.6	5.4	5.00	0.05	0.044	339
7/22/2013	18.2	5.9	7.7	7.2	5.23	0.05	0.086	167
7/29/2013†	14.5	6.5	7.6	5.4	1.92	0.05	0.102	137
8/5/2013	15.1	5.2	7.4	3.4	4.25	0.04	0.067	325
8/12/2013	15.9	6.8	7.7	3.0	5.18	0.03	0.064	362 *
8/15/2013	13.6	6.3	7.8	2.9	4.18	0.02	0.063	95
8/19/2013	14.8	7.6	7.9	4.8	4.54	ND	0.072	443
Average	15.8	6.6	7.7	8.2	4.23	0.06	0.103	323

NA = Data point did not meet Quality Assurance Standards ND = Data point was below the limit of detection

Detection Limits: NO_3-N = 0.69 mg/L NH_3-N= 0.01 mg/L Total P = 0.023 mg/L

* = Data point determined as questionable by Quality Assurance Plan

† = Major rain event (0.25 inches of rain within a 24 hour period, prior to a 72 hour dry period)

NO_3-N represents nitrogen from nitrate + nitrite

Non-Detects are represented as half the detection limit in the calculation of the averages

2013 Kawkawlin River results

NB2 8 Mile Rd 43° 42' 15.63" -84° 02' 53.12"								
Date	**Water Temp**	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**
	°C	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/ 100 mL**
5/23/2013†	11.9	7.6	7.6	35.5	8.30	0.09	0.152	808
5/29/2013†	12.6	7.8	7.7	156.2	9.93	0.37	0.458	1756
6/3/2013	12.7	7.4	7.9	7.2	ND	0.05	0.101	103
6/10/2013	14.0	7.7	7.9	4.9	4.42	0.02	0.068	127
6/17/2013†	16.3	5.9	7.8	7.1	5.07	0.07	0.042	388
6/24/2013	19.6	5.5	7.7	7.3	4.22	0.05	0.224	270
7/1/2013	15.1	9.3	7.6	8.5	6.13	0.04	0.083	625
7/8/2013	19.3	4.8	7.7	6.7	3.66	0.04	0.127	268 *
7/17/2013	21.3	4.0	7.5	5.2	5.89	0.04	0.098	178
7/22/2013	17.6	4.3	7.5	7.3	3.49	0.02	0.132	1518
7/29/2013†	14.3	4.3	7.4	3.6	2.90	0.04	0.116	24
8/5/2013	14.8	5.4	7.5	2.6	3.20	0.03	0.078	18
8/12/2013	16.7	8.7	8.0	2.0	3.44	0.01	0.048	9
8/15/2013	14.7	6.5	7.9	2.1	2.89	ND	0.054	17
8/19/2013	15.7	6.7	8.0	2.2	2.77	ND	0.044	17
Average	15.8	6.4	7.7	17.2	4.44	0.06	0.122	418

NA = Data point did not meet Quality Assurance Standards ND = Data point was below the limit of detection

Detection Limits: NO_3-N = 0.69 mg/L NH_3-N= 0.01 mg/L Total P = 0.023 mg/L

* = Data point determined as questionable by Quality Assurance Plan

† = Major rain event (0.25 inches of rain within a 24 hour period, prior to a 72 hour dry period)

NO_3-N represents nitrogen from nitrate + nitrite

Non-Detects are represented as half the detection limit in the calculation of the averages

2013 Kawkawlin River results

NB3 Fraser Rd 43° 42' 1.7316" -84° 0' 29.6886"								
Date	**Water Temp**	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**
	°C	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/ 100 mL**
5/23/2013†	9.3	5.7	7.6	12.1	7.15	0.05	0.128	744
5/29/2013†	12.6	7.6	7.8	19.7	4.06	0.05	0.113	590
6/3/2013	12.8	6.8	7.9	5.8	1.50	0.05	0.104	110
6/10/2013	14.1	6.2	7.8	3.9	5.12	0.03	0.085	137
6/17/2013†	16.6	6.3	7.6	8.1	4.47	ND	0.093	272*
6/24/2013	19.5	3.6	7.5	4.5	4.34	0.06	0.216	143
7/1/2013	15.4	9.1	7.5	6.0	5.45	0.04	0.116	961
7/8/2013	19.4	3.1	7.4	4.1	4.63	0.05	0.134	96
7/17/2013	22.1	3.0	7.3	3.0	4.69	0.06	0.130	88
7/22/2013	19.4	2.3	7.4	2.1	1.30	0.09	0.151	320
7/29/2013†	15.6	3.6	7.4	7.0	2.15	0.03	0.118	40
8/5/2013	15.3	2.6	7.3	9.4	8.03	0.08	0.112	35
8/12/2013	16.0	5.8	7.6	10.0	6.43	0.01	0.110	10
8/15/2013	13.8	4.6	7.6	14.6	7.39	0.01	0.124	70
8/19/2013	14.7	5.0	7.7	6.7	5.56	ND	0.106	31
Average	15.8	5.0	7.6	7.8	4.82	0.04	0.123	241

NA = Data point did not meet Quality Assurance Standards ND = Data point was below the limit of detection

Detection Limits: NO_3-N = 0.69 mg/L NH_3-N= 0.01 mg/L Total P = 0.023 mg/L

* = Data point determined as questionable by Quality Assurance Plan

† = Major rain event (0.25 inches of rain within a 24 hour period, prior to a 72 hour dry period)

NO_3-N represents nitrogen from nitrate + nitrite

Non-Detects are represented as half the detection limit in the calculation of the averages

2013 Kawkawlin River results

NB4 Mackinaw Rd				43° 41' 35.06"	-83° 59' 18.34"			
Date	**Water Temp**	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**
	°C	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/ 100 mL**
5/23/2013†	14.0	2.5	7.3	1.7	4.41	0.20	0.124	328
5/29/2013†	12.7	4.1	7.4	3.1	3.11	0.03	0.071	41
6/3/2013	13.9	2.8	7.6	1.1	8.68	0.01	0.091	29
6/10/2013	14.6	1.3	7.4	0.8	3.92	0.01	0.127	97
6/17/2013†	17.1	1.0	7.5	2.5	4.60	0.03	0.208	138
6/24/2013	19.3	0.5	7.0	6.9	3.38	0.02	0.544	167
7/1/2013	15.9	1.0	7.0	4.2	3.41	0.06	0.309	194 *
7/8/2013	19.2	0.4	6.9	10.4	6.93	0.08	0.532	317 *
7/17/2013	20.7	0.6	6.9	8.3	6.25	0.11	0.352	527
7/22/2013	18.6	0.5	7.1	6.2	2.10	ND	0.210	613
7/29/2013†	14.7	0.7	7.0	3.8	3.25	ND	0.228	382
8/5/2013	15.0	0.9	7.0	2.8	6.07	ND	0.142	66
8/12/2013	16.4	6.0	7.5	1.4	3.58	ND	0.099	1245
8/15/2013	13.9	1.6	7.3	2.6	3.56	ND	0.110	12
8/19/2013	15.3	2.8	7.4	0.7	3.68	ND	0.099	15
Average	16.1	1.8	7.2	3.8	4.46	0.04	0.216	281

NA = Data point did not meet Quality Assurance Standards ND = Data point was below the limit of detection

Detection Limits: NO_3-N = 0.69 mg/L NH_3-N= 0.01 mg/L Total P = 0.023 mg/L

* = Data point determined as questionable by Quality Assurance Plan

† = Major rain event (0.25 inches of rain within a 24 hour period, prior to a 72 hour dry period)

NO_3-N represents nitrogen from nitrate + nitrite

Non-Detects are represented as half the detection limit in the calculation of the averages

2013 Kawkawlin River results

NB5 Beaver				43°40'2.50"N	83°58'12.84"W			
Date	**Water Temp**	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**
	^{0}C	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/ 100 mL**
5/23/2013†	11.6	6.5	7.6	84.3	11.83	0.21	0.202	961
5/29/2013†	Flooding made it impossible to distinguish channel							
6/3/2013	14.8	4.8	7.6	0.6	ND	0.02	0.099	121
6/10/2013	15.2	3.5	7.5	1.2	1.52	0.03	0.161	122
6/17/2013†	16.8	5.2	7.7	1.6	4.62	0.06	0.194	131
6/24/2013	20.3	2.8	7.4	2.0	3.81	ND	0.345	98
7/1/2013	16.1	4.4	7.4	3.1	2.73	0.05	0.263	54
7/8/2013	19.2	1.7	7.3	2.2	2.66	0.02	0.307	94
7/17/2013	21.6	2.2	7.4	2.4	3.04	0.14	0.237	52
7/22/2013	17.9	2.0	7.7	2.8	3.06	0.21	0.246	44
7/29/2013†	14.2	2.8	7.3	2.3	1.06	ND	0.208	44
8/5/2013	14.1	2.9	7.4	2.3	4.58	0.05	0.167	199
8/12/2013	15.6	2.2	7.5	3.2	2.01	0.02	0.181	44
8/15/2013	11.5	2.8	7.6	2.7	4.47	0.03	ND	33
8/19/2013	12.9	1.7	7.7	5.1	4.25	0.06	0.210	24
Average	15.8	3.3	7.5	8.3	3.57	0.07	0.202	144

NA = Data point did not meet Quality Assurance Standards ND = Data point was below the limit of detection
Detection Limits: NO_3-N = 0.69 mg/L NH_3-N= 0.01 mg/L Total P = 0.023 mg/L
* = Data point determined as questionable by Quality Assurance Plan
† = Major rain event (0.25 inches of rain within a 24 hour period, prior to a 72 hour dry period)
NO_3-N represents nitrogen from nitrate + nitrite
Non-Detects are represented as half the detection limit in the calculation of the averages

2013 Kawkawlin River results

NB6 Old Beaver North 43° 39' 20.76" -83° 57' 41.98"								
Date	**Water Temp**	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**
	°C	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/ 100 mL**
5/23/2013†	13.4	5.6	7.7	10.1	7.18	0.22	0.185	621
5/29/2013†	13.1	5.2	7.5	38.7	4.78	0.11	0.184	197
6/3/2013	14.8	3.9	7.7	1.3	7.49	0.02	0.099	102
6/10/2013	15.3	4.5	7.5	1.4	3.96	0.01	0.147	67
6/17/2013†	17.3	5.4	7.8	1.9	3.38	ND	0.184	189
6/24/2013	20.6	4.6	7.5	2.7	2.93	ND	0.335	123
7/1/2013	16.2	7.5	7.6	4.1	1.96	ND	0.500	184
7/8/2013	19.4	5.3	7.4	2.6	2.92	ND	0.487	172
7/17/2013	21.9	4.1	7.5	2.6	5.21	0.07	0.238	113
7/22/2013	18.3	4.6	7.6	3.6	2.12	0.04	NA	247 *
7/29/2013†	14.3	5.7	7.6	4.2	3.28	ND	0.171	243
8/5/2013	14.0	4.7	7.5	3.5	3.46	ND	0.128	141
8/12/2013	16.0	3.8	7.7	4.4	3.43	ND	0.106	172
8/15/2013	12.7	5.5	7.9	4.6	4.51	ND	0.098	53
8/19/2013	14.7	5.0	8.0	4.3	4.75	ND	0.121	14
Average	16.1	5.0	7.6	6.0	4.09	0.04	0.213	171

NA = Data point did not meet Quality Assurance Standards ND = Data point was below the limit of detection

Detection Limits: NO_3-N = 0.69 mg/L NH_3-N= 0.01 mg/L Total P = 0.023 mg/L

* = Data point determined as questionable by Quality Assurance Plan

† = Major rain event (0.25 inches of rain within a 24 hour period, prior to a 72 hour dry period)

NO_3-N represents nitrogen from nitrate + nitrite

Non-Detects are represented as half the detection limit in the calculation of the averages

2013 Kawkawlin River results

NB7 Chip 43° 38' 56.56" -83° 57' 29.30"								
Date	**Water Temp**	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**
	°C	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/ 100 mL**
5/23/2013†	12.0	7.4	7.8	28.6	10.38	0.20	0.196	844
5/29/2013†	13.2	5.5	7.5	40.7	6.00	0.05	0.251	353
6/3/2013	14.4	6.1	7.7	1.5	ND	ND	0.096	111
6/10/2013	15.4	5.3	7.6	1.5	1.21	ND	0.141	67
6/17/2013†	17.3	5.9	7.8	5.0	6.17	ND	0.068	210
6/24/2013	20.6	5.8	7.6	3.1	3.79	0.02	0.321	192
7/1/2013	15.9	7.2	7.6	4.0	2.69	0.01	0.244	204
7/8/2013	19.3	6.1	no sample - water level too low					
7/17/2013	21.8	4.6	7.6	2.7	2.17	0.03	0.184	309
7/22/2013	18.3	5.3	7.7	3.9	2.19	ND	0.180	202
7/29/2013†	14.2	7.4	7.8	2.8	0.94	ND	0.145	427
8/5/2013	14.3	7.9	8.0	4.2	3.05	ND	0.106	162
8/12/2013	16.2	8.5	8.0	6.2	2.55	ND	0.124	202
8/15/2013	11.7	7.9	8.0	4.3	3.44	ND	ND	23
8/19/2013	14.1	3.7	7.9	5.0	2.73	0.01	0.109	13
Average	15.9	6.3	7.8	8.1	3.41	0.03	0.155	237

NA = Data point did not meet Quality Assurance Standards ND = Data point was below the limit of detection
Detection Limits: NO_3-N = 0.69 mg/L NH_3-N= 0.01 mg/L Total P = 0.023 mg/L
* = Data point determined as questionable by Quality Assurance Plan
† = Major rain event (0.25 inches of rain within a 24 hour period, prior to a 72 hour dry period)
NO_3-N represents nitrogen from nitrate + nitrite
Non-Detects are represented as half the detection limit in the calculation of the averages

2013 Kawkawlin River results

MB1 Old Beaver				43° 39' 2.1924"	-83° 56' 54.9492"			
Date	**Water Temp**	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**
	°C	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/ 100 mL**
5/23/2013†	12.4	6.5	7.8	26.8	9.51	0.27	0.175	772
5/29/2013†	13.3	6.0	7.7	127.0	10.72	0.34	0.446	1158
6/3/2013	15.0	4.1	7.8	7.9	2.79	0.03	0.106	88
6/10/2013	15.8	7.1	7.7	2.7	3.39	ND	0.096	77
6/17/2013†	18.4	7.7	8.0	4.9	6.13	0.01	0.135	268
6/24/2013	21.5	6.4	7.8	4.8	3.54	0.01	0.273	155
7/1/2013	16.9	6.7	7.7	6.9	4.25	0.02	0.147	193
7/8/2013	20.2	5.3	7.6	3.6	2.95	0.01	0.364	100
7/17/2013	24.1	3.6	7.6	2.2	1.77	0.02	0.170	52
7/22/2013	19.7	3.6	7.6	2.6	2.30	0.01	0.193	53
7/29/2013†	16.1	5.9	7.9	2.0	0.79	ND	0.133	31
8/5/2013	16.9	5.5	7.7	2.1	2.53	ND	0.099	29
8/12/2013	19.0	8.5	8.2	1.4	1.30	0.01	0.065	28
8/15/2013	15.9	8.1	8.1	1.2	1.42	ND	ND	18
8/19/2013	18.2	9.6	8.5	0.8	2.01	ND	0.068	28
Average	17.6	6.3	7.8	13.1	3.69	0.05	0.166	203

NA = Data point did not meet Quality Assurance Standards ND = Data point was below the limit of detection
Detection Limits: NO_3-N = 0.69 mg/L NH_3-N= 0.01 mg/L Total P = 0.023 mg/L
* = Data point determined as questionable by Quality Assurance Plan
† = Major rain event (0.25 inches of rain within a 24 hour period, prior to a 72 hour dry period)
NO_3-N represents nitrogen from nitrate + nitrite
Non-Detects are represented as half the detection limit in the calculation of the averages

2013 Kawkawlin River results

MB2 Euclid				43° 38' 36.7578''	-83° 54' 48.1068''			
Date	**Water Temp**	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**
	°C	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/ 100 mL**
5/23/2013†	14.6	6.1	7.7	11.3	7.42	0.03	0.137	501
5/29/2013†	17.5	6.7	7.5	135.7	5.65	0.38	0.470	1050
6/3/2013	17.7	4.6	7.8	11.2	4.11	0.06	0.117	111
6/10/2013	18.7	7.1	7.9	2.5	5.55	ND	0.092	58
6/17/2013†	24.5	8.0	8.3	5.3	3.07	0.05	0.087	186
6/24/2013	26.1	8.9	8.4	3.4	3.51	ND	0.207	57
7/1/2013	22.1	7.4	8.1	5.4	1.95	0.01	0.087	112
7/8/2013	24.8	4.9	7.7	3.0	4.00	0.02	0.103	53
7/17/2013	29.0	6.8	8.1	2.7	2.86	ND	0.108	36
7/22/2013	26.4	6.7	8.3	4.6	1.81	ND	0.048	58
7/29/2013†	21.2	6.3	8.0	4.3	3.46	ND	0.125	30
8/5/2013	22.0	5.3	7.8	2.4	4.48	ND	0.147	42
8/12/2013	23.6	5.4	7.8	4.0	3.10	ND	0.151	28
8/15/2013	20.4	6.7	8.0	4.1	3.58	ND	0.057	23
8/19/2013	23.2	6.9	8.1	4.0	4.36	ND	0.123	28
Average	22.1	6.5	8.0	13.6	3.93	0.04	0.137	158

NA = Data point did not meet Quality Assurance Standards ND = Data point was below the limit of detection
Detection Limits: NO_3-N = 0.69 mg/L NH_3-N= 0.01 mg/L Total P = 0.023 mg/L
* = Data point determined as questionable by Quality Assurance Plan
† = Major rain event (0.25 inches of rain within a 24 hour period, prior to a 72 hour dry period)
NO_3-N represents nitrogen from nitrate + nitrite
Non-Detects are represented as half the detection limit in the calculation of the averages

2013 Kawkawlin River results

MB3 Castaways 43° 39' 7.39" -83° 53' 51.01"								
Date	**Water Temp**	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**
	°C	**mg./L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/ 100 mL**
5/23/2013†	15.4	5.9	7.7	8.8	5.99	0.28	0.116	871
5/29/2013†	17.4	5.7	7.5	14.2	7.31	0.08	0.514	1201
6/3/2013	17.9	4.2	7.8	9.7	4.87	0.05	0.120	119
6/10/2013	18.9	7.4	8.0	2.2	5.67	0.01	0.098	50
6/17/2013†	25.0	7.4	8.3	3.8	4.87	0.02	0.085	82
6/24/2013	26.1	8.3	8.3	4.5	4.62	0.02	0.214	43
7/1/2013	22.7	7.4	8.1	3.7	2.55	0.02	0.159	68
7/8/2013	25.3	7.3	8.0	2.9	2.94	0.02	0.090	47
7/17/2013	30.2	7.3	8.2	4.0	4.16	ND	0.107	33
7/22/2013	26.6	2.7	7.8	3.1	1.31	ND	0.143	268 *
7/29/2013†	21.1	5.8	7.9	5.3	3.00	ND	0.111	57
8/5/2013	22.0	6.9	8.0	4.5	4.69	ND	0.108	17
8/12/2013	23.6	4.8	7.9	4.6	4.02	ND	0.123	24
8/15/2013	21.0	5.8	8.0	6.3	4.90	ND	ND	13
8/19/2013	22.9	7.3	8.2	5.3	3.63	ND	0.082	12
Average	22.4	6.3	8.0	5.5	4.30	0.04	0.139	188

NA = Data point did not meet Quality Assurance Standards ND = Data point was below the limit of detection
Detection Limits: NO_3-N = 0.69 mg/L NH_3-N= 0.01 mg/L Total P = 0.023 mg/L
* = Data point determined as questionable by Quality Assurance Plan
† = Major rain event (0.25 inches of rain within a 24 hour period, prior to a 72 hour dry period)
NO_3-N represents nitrogen from nitrate + nitrite
Non-Detects are represented as half the detection limit in the calculation of the averages

2013 Kawkawlin River results

MB4 Mouth 43° 39' 32.3748" -83° 52' 58.4142"								
Date	**Water Temp**	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**
	°C	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/ 100 mL**
5/23/2013†	15.9	6.3	7.6	6.1	6.60	0.19	0.108	471
5/29/2013†	18.0	4.7	6.8	124.0	4.93	0.34	0.479	1606
6/3/2013	18.3	4.3	7.8	7.7	1.89	0.04	0.108	106
6/10/2013	19.0	7.8	8.0	2.1	9.19	0.02	0.092	37
6/17/2013†	24.5	8.3	8.3	3.4	5.05	0.01	0.072	97
6/24/2013	25.8	8.5	8.2	4.0	4.39	0.02	0.206	92
7/1/2013	19.9	8.7	8.5	28.5	5.00	0.03	0.098	221
7/8/2013	25.4	7.3	8.0	3.9	1.75	0.05	0.083	63
7/17/2013	30.2	6.7	8.4	5.6	3.68	ND	0.067	44
7/22/2013	25.9	7.9	8.5	10.0	3.02	ND	0.067	89
7/29/2013†	20.0	9.1	8.7	11.2	1.98	0.12	0.064	28
8/5/2013	21.4	7.6	8.4	10.6	6.44	ND	0.053	39
8/12/2013	22.9	8.6	8.6	9.6	1.79	ND	0.052	12
8/15/2013	19.9	8.8	8.5	12.8	4.88	ND	ND	28
8/19/2013	23.2	8.4	8.6	8.8	4.49	ND	0.138	14
Average	22.4	7.5	8.2	16.6	4.34	0.06	0.113	196

NA = Data point did not meet Quality Assurance Standards ND = Data point was below the limit of detection
Detection Limits: NO_3-N = 0.69 mg/L NH_3-N= 0.01 mg/L Total P = 0.023 mg/L
* = Data point determined as questionable by Quality Assurance Plan
† = Major rain event (0.25 inches of rain within a 24 hour period, prior to a 72 hour dry period)
NO_3-N represents nitrogen from nitrate + nitrite
Non-Detects are represented as half the detection limit in the calculation of the averages

2013 Kawkawlin River results

SB1 South Branch Garfield 43° 40'57.43" -84° 05' 16.24"								
Date	**Water Temp**	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**
	ºC	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/ 100 mL**
5/23/2013†	7.2	7.2	7.6	26.1	11.29	0.18	0.128	994
5/29/2013†	12.6	6.9	7.6	109.9	10.67	0.23	0.375	1641
6/3/2013	10.6	8.6	8.0	3.1	3.23	0.02	0.028	72
6/10/2013	14.3	6.7	8.0	1.7	6.00	ND	ND	183
6/17/2013†	16.2	6.6	8.0	3.0	6.39	ND	ND	358
6/24/2013	19.0	4.0	7.7	1.2	5.22	ND	ND	260
7/1/2013	14.5	6.7	7.8	1.6	7.78	ND	ND	98
7/8/2013	18.7	3.7	7.7	0.4	1.22	0.02	0.242	53
7/17/2013	20.2	2.0	7.7	2.1	5.49	0.06	0.115	73
7/22/2013	16.4	3.0	7.8	3.6	2.56	0.17	0.238	108
7/29/2013†	12.8	3.8	7.7	2.2	5.02	0.77	0.417	38
8/5/2013	No Sample - Water Level too low							
8/12/2013								
8/15/2013								
8/19/2013								
Average	14.8	5.4	7.8	14.1	5.90	0.13	0.144	352.6

NA = Data point did not meet Quality Assurance Standards ND = Data point was below the limit of detection

Detection Limits: NO_3-N = 0.69 mg/L NH_3-N= 0.01 mg/L Total P = 0.023 mg/L

* = Data point determined as questionable by Quality Assurance Plan

† = Major rain event (0.25 inches of rain within a 24 hour period, prior to a 72 hour dry period)

NO_3-N represents nitrogen from nitrate + nitrite

Non-Detects are represented as half the detection limit in the calculation of the averages

2013 Kawkawlin River results

SB2 8 Mile Rd South 43° 37' 54.7746'' -84° 2' 56.6232''								
Date	**Water Temp**	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**
	ºC	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/ 100 mL**
5/23/2013†	11.2	8.5	7.7	59.8	14.03	0.26	0.164	872
5/29/2013†	Flooding made it impossible to distinguish channel							
6/3/2013	12.3	8.2	8.0	8.3	5.48	0.03	0.070	197
6/10/2013	14.8	7.5	7.9	6.3	8.58	0.02	0.142	191
6/17/2013†	16.6	7.1	8.0	20.0	6.66	ND	0.044	206
6/24/2013	21.1	3.6	7.7	10.3	6.77	0.14	0.234	49
7/1/2013	15.4	6.5	7.8	12.9	8.85	0.04	0.071	443
7/8/2013	20.1	3.5	7.8	7.2	5.99	0.11	0.273	108
7/17/2013	22.9	6.7	7.9	6.7	2.75	0.02	0.171	49
7/22/2013	20.3	3.2	7.8	6.9	2.26	0.13	0.236	36
7/29/2013†	15.9	2.1	7.6	4.9	1.16	0.05	0.246	34
8/5/2013	15.9	3.8	7.7	9.6	6.26	0.01	0.125	124
8/12/2013	16.9	3.8	7.6	8.7	2.36	0.03	0.117	135
8/15/2013	14.6	4.5	7.7	7.6	3.97	0.04	0.107	81
8/19/2013	15.7	4.6	7.8	5.5	1.76	0.03	0.121	20
Average	16.7	5.3	7.8	12.5	5.49	0.07	0.152	182

NA = Data point did not meet Quality Assurance Standards ND = Data point was below the limit of detection
Detection Limits: NO_3-N = 0.69 mg/L NH_3-N= 0.01 mg/L Total P = 0.023 mg/L
* = Data point determined as questionable by Quality Assurance Plan
† = Major rain event (0.25 inches of rain within a 24 hour period, prior to a 72 hour dry period)
NO_3-N represents nitrogen from nitrate + nitrite
Non-Detects are represented as half the detection limit in the calculation of the averages

2013 Kawkawlin River results

SB3 Fraser Rd South 43° 37' 6.3516'' -84° 0' 41.6046''								
Date	**Water Temp**	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**
	°C	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/ 100 mL**
5/23/2013†	11.5	8.4	7.9	12.1	13.79	0.29	0.166	946
5/29/2013†	13.0	7.7	7.7	191.4	10.45	0.54	0.780	1954
6/3/2013	12.4	7.8	8.0	11.3	7.62	0.04	0.100	187
6/10/2013	15.0	8.0	8.0	4.4	6.38	0.02	0.033	169
6/17/2013†	17.6	7.0	7.9	14.9	7.89	ND	0.102	209
6/24/2013	21.0	3.8	7.8	5.8	6.49	0.03	0.268	83
7/1/2013	15.6	6.3	7.7	10.9	8.78	0.04	0.128	210
7/8/2013	20.1	3.3	7.8	4.8	5.96	0.05	0.307	96
7/17/2013	22.2	2.9	7.7	2.7	1.63	0.12	0.235	71
7/22/2013	19.5	3.3	7.9	8.3	2.53	ND	0.462	107
7/29/2013†	15.0	3.0	7.7	10.9	1.59	0.11	0.219	33
8/5/2013	15.1	3.5	7.8	12.3	5.38	0.04	0.170	40
8/12/2013	16.1	4.2	7.7	5.5	2.16	0.03	0.162	23
8/15/2013	13.0	4.8	7.8	11.7	3.80	0.05	0.164	123
8/19/2013	15.0	4.7	7.8	7.0	3.21	0.02	0.145	110
Average	16.1	5.2	7.8	20.9	5.84	0.09	0.229	291

NA = Data point did not meet Quality Assurance Standards ND = Data point was below the limit of detection
Detection Limits: NO_3-N = 0.69 mg/L NH_3-N= 0.01 mg/L Total P = 0.023 mg/L
* = Data point determined as questionable by Quality Assurance Plan
† = Major rain event (0.25 inches of rain within a 24 hour period, prior to a 72 hour dry period)
NO_3-N represents nitrogen from nitrate + nitrite
Non-Detects are represented as half the detection limit in the calculation of the averages

2013 Kawkawlin River results

SB4 Wheeler Rd				43° 38' 19.4388'' -83° 58' 34.0176''				
Date	**Water Temp**	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**
	°C	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/ 100 mL**
5/23/2013†	11.8	8.1	8.0	40.4	12.18	0.31	0.168	722
5/29/2013†	13.3	5.5	7.5	177.3	12.23	0.60	0.639	986
6/3/2013	13.9	6.7	7.9	19.4	7.14	0.08	0.144	140
6/10/2013	15.3	8.7	8.0	5.0	2.74	0.01	0.023	183
6/17/2013†	18.2	7.0	8.0	14.9	7.41	0.02	0.039	185
6/24/2013	22.1	7.0	8.1	3.7	5.67	ND	0.197	80
7/1/2013	16.0	6.7	7.8	8.0	6.56	0.01	0.119	293*
7/8/2013	21.2	4.2	7.8	2.0	4.33	0.02	0.043	47
7/17/2013	25.7	6.3	7.9	2.5	1.82	0.01	0.167	44
7/22/2013	20.7	7.3	8.4	3.1	1.28	ND	0.199	28
7/29/2013†	15.8	6.4	8.7	3.5	1.28	0.03	0.100	3
8/5/2013	16.4	7.0	8.9	2.8	4.26	ND	0.083	16
8/12/2013	18.0	3.5	7.8	2.1	1.72	ND	0.101	96
8/15/2013	15.2	7.3	8.1	2.1	2.98	ND	0.059	4
8/19/2013	16.7	8.0	8.4	2.0	2.29	ND	0.035	12
Average	17.4	6.6	8.1	19.3	4.93	0.07	0.141	182

NA = Data point did not meet Quality Assurance Standards ND = Data point was below the limit of detection

Detection Limits: NO_3-N = 0.69 mg/L NH_3-N= 0.01 mg/L Total P = 0.023 mg/L

* = Data point determined as questionable by Quality Assurance Plan

† = Major rain event (0.25 inches of rain within a 24 hour period, prior to a 72 hour dry period)

NO_3-N represents nitrogen from nitrate + nitrite

Non-Detects are represented as half the detection limit in the calculation of the averages

Pollution Tolerance Index

Site	8/5/2013	8/13/2013	8/19/2013	8/27/2013	9/3/2013	9/9/2013	Average
South Branch Garfield	16	12	6	2	2	2	7
Garfield North	6	29	21	30	18	22	21
8 Mile Rd	8	23	20	23	18	16	18
Fraser Rd	18	25	25	23	22	18	22
Mackinaw Rd	8	15	14	14	11	13	13
Old Beaver North	18	19	29	24	20	21	22
Euclid	26	34	27	21	26	24	26
Castaways	26	15	15	26	23	12	20
Mouth	10	8	25	11	10	25	15
Beaver Rd	14	31	19	7	7	18	16
Old Beaver	21	26	26	17	14	22	21
Chip Rd	12	14	14	13	13	18	14
8 Mile Rd South	12	10	11	27	27	16	17
Fraser Rd South	8	14	9	13	9	10	11

Poor= 10 or less Fair= 11-16 Good= 17-22 Excellent= 23 or more

Biotic Index

Site	8/5/2013	8/13/2013	8/19/2013	8/27/2013	9/3/2013	9/9/2013	Average
South Branch Garfield	351	566	126	140	532	650	394
Garfield North	77	523	532	611	295	427	411
8 Mile Rd	90	504	110	469	273	231	280
Fraser Rd	193	714	349	543	459	358	436
Mackinaw Rd	106	138	220	182	223	151	170
Old Beaver North	302	440	721	682	316	224	448
Euclid	382	782	656	578	336	574	551
Castaways	550	225	298	445	455	232	368
Mouth	152	484	774	193	329	603	423
Beaver	168	404	182	334	250	270	268
Old Beaver	236	486	404	763	576	448	486
Chip Rd	274	358	240	158	217	289	256
8 Mile Rd	391	585	172	316	379	202	341
Fraser Rd South	104	193	228	345	401	271	257

Poor= 0-399 Fair= 400-599 Good= 600-799 Excellent= 800-1000

2013 Kawkawlin River Results

	E. coli exceedances														
	NB1	**NB2**	**NB3**	**NB4**	**NB5**	**NB6**	**NB7**	**MB1**	**MB2**	**MB3**	**MB4**	**SB1**	**SB2**	**SB3**	**SB4**
5/23/2013†	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
5/29/2013†	X	X	X		NS		NS	X	X	X	X	X	X	X	X
6/3/2013															
6/10/2013															
6/17/2013†		X										X			
6/24/2013															
7/1/2013	X	X	X										X		
7/8/2013							NS								
7/17/2013	X			X			X								
7/22/2013		X	X	X											
7/29/2013†				X			X								
8/5/2013												NS			
8/12/2013				X								NS			
8/15/2013												NS			
8/19/2013	X											NS			
Exceedances per site	7	5	4	5	1	1	4	2	2	2	2	3	2	2	2
% Exceedances	47	33	27	33	7	29	13	13	13	13	13	27	14	13	13

X=*E.coli* exceedances (geometric mean> 300 CFU/100 mL) Total Exceedances: 44 NB % Exceedances: 26

NS: not sampled Total % Exceedances: 20 MB % Exceedances: 13

Sites in green are MDEQ sites SB % Exceedances: 16

† = Major rain event (0.25 inches of rain within a 24 hour period, prior to a 72 hour dry period)

	Average of all sites on the Kawkawlin River - 2014									
	Water Temp	**DO**	**pH**	**Turbidity**	**NO3-N**	**NH3-N**	**Total P**	**SRP**	**COD**	**E. coli**
	⁰C	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**ppm**	**cfu/100 mL**
Average Values	20.8	5.2	7.8	4.7	0.6	0.04	0.108	0.063	39	230
Std Deviation	2.9	2.1	0.5	3.6	0.5	0.03	0.066	0.048	13	313
Season Max	26.7	9.9	9.1	23.3	2.2	0.21	0.481	0.324	133	2275
Season Min	14.0	0.0	6.6	0.1	0.1	0.01	0.022	0.005	12	6

	Average of all sites on the Kawkawlin River - Major Rain Events 2014									
	Water Temp	**DO**	**pH**	**Turbidity**	**NO3-N**	**NH3-N**	**Total P**	**SRP**	**COD**	**E. coli**
	⁰C	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**ppm**	**cfu/100 mL**
Average Values	20.7	4.8	7.7	5.1	0.4	0.04	0.115	0.071	37	353
Std Deviation	2.4	1.8	0.5	4.5	0.383631	0.03	0.068	0.054	11	416
Season Max	25.2	8.0	8.6	23.3	1.3	0.21	0.428	0.306	61	2275
Season Min	16.0	0.0	6.7	0.1	0.1	0.01	0.029	0.005	12	19

	Average of all sites on the Kawkawlin River - Non-Rain Events 2014									
	Water Temp	**DO**	**pH**	**Turbidity**	**NO3-N**	**NH3-N**	**Total P**	**SRP**	**COD**	**E. coli**
	⁰C	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**ppm**	**cfu/100 mL**
Average Values	20.9	5.4	7.8	4.4	0.7	0.04	0.104	0.057	40	146
Std Deviation	3.1	2.2	0.5	2.8	0.6	0.03	0.064	0.043	14	172
Season Max	26.7	9.9	9.1	14.3	2.2	0.18	0.481	0.324	133	1379
Season Min	14.0	0.0	6.6	0.3	0.1	0.01	0.022	0.005	16	6

NA = Data point did not meet Quality Assurance Standards or sample was not taken.
ND = Data point was below the limit of detection
Detection Limits: NO_3-N = 0.1 mg/L NH_3-N= 0.01 mg/L SRP and Total-P = 0.005 mg/L
Major rain event (0.25 inches of rain within a 24 hour period, prior to a 72 hour dry period)
NO_3-N represents nitrogen from nitrate + nitrite
Non-Detects are represented as half the detection limit in the calculation of the averages

	North Branch Kawkawlin River Averages - 2014									
	Water Temp	**DO**	**pH**	**Turbidity**	**NO3-N**	**NH3-N**	**Total P**	**SRP**	**COD**	**E. coli**
	ºC	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**ppm**	**cfu/100 mL**
Average Values	19.8	4.2	7.6	3.6	0.3	0.04	0.124	0.071	46	214
Std Deviation	2.2	2.2	0.5	2.1	0.3	0.02	0.081	0.058	7	173
Season Max	23.0	7.6	8.7	8.3	1.5	0.09	0.481	0.324	61	866
Season Min	14.2	0.0	6.6	0.3	0.1	0.01	0.042	0.013	28	6

	North Branch Kawkawlin River Averages - Major Rain Events 2014									
	Water Temp	**DO**	**pH**	**Turbidity**	**NO3-N**	**NH3-N**	**Total P**	**SRP**	**COD**	**E. coli**
	ºC	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**ppm**	**cfu/100 mL**
Average Values	19.8	4.0	7.6	3.6	0.2	0.04	0.129	0.080	45	295
Std Deviation	2.0	2.1	0.5	2.3	0.2	0.02	0.081	0.064	8	190
Season Max	21.8	6.3	8.4	8.3	0.6	0.08	0.428	0.306	61	866
Season Min	16.4	0.0	6.7	0.6	0.1	0.01	0.054	0.013	28	19

	North Branch Kawkawlin River Averages - Non-Rain Events 2014									
	Water Temp	**DO**	**pH**	**Turbidity**	**NO3-N**	**NH3-N**	**Total P**	**SRP**	**COD**	**E. coli**
	ºC	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**ppm**	**cfu/100 mL**
Average Values	19.7	4.3	7.6	3.5	0.4	0.04	0.121	0.065	48	160
Std Deviation	2.3	2.2	0.5	2.0	0.4	0.02	0.081	0.053	6	139
Season Max	23.0	7.6	8.7	8.2	1.5	0.09	0.481	0.324	60	661
Season Min	14.2	0.0	6.6	0.3	0.1	0.01	0.042	0.016	36	6

	South Branch Kawkawlin River Averages - 2014									
	Water Temp	**DO**	**pH**	**Turbidity**	**NO3-N**	**NH3-N**	**Total P**	**SRP**	**COD**	**E. coli**
	ºC	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**ppm**	**cfu/100 mL**
Average Values	20.6	5.2	7.9	7.7	1.0	0.06	0.108	0.074	26	333
Std Deviation	2.9	1.7	0.5	5.1	0.6	0.05	0.064	0.048	5	486
Season Max	26.2	9.9	8.9	23.3	2.2	0.21	0.244	0.181	39	2275
Season Min	14.0	2.6	7.1	1.7	0.1	0.01	0.022	0.005	12	27

	South Branch Kawkawlin River Averages - Major Rain Events 2014									
	Water Temp	**DO**	**pH**	**Turbidity**	**NO3-N**	**NH3-N**	**Total P**	**SRP**	**COD**	**E. coli**
	ºC	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**ppm**	**cfu/100 mL**
Average Values	20.6	4.7	7.9	9.0	0.8	0.06	0.122	0.091	26	554
Std Deviation	2.7	1.3	0.4	6.6	0.4	0.05	0.071	0.055	7	645
Season Max	24.1	6.8	8.6	23.3	1.3	0.21	0.243	0.181	39	2275
Season Min	16.0	3.0	7.3	1.9	0.2	0.01	0.029	0.005	12	68

	South Branch Kawkawlin River Averages - Non-Rain Events 2014									
	Water Temp	**DO**	**pH**	**Turbidity**	**NO3-N**	**NH3-N**	**Total P**	**SRP**	**COD**	**E. coli**
	ºC	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**ppm**	**cfu/100 mL**
Average Values	20.6	5.5	8.1	6.7	1.0	0.06	0.099	0.064	26	182
Std Deviation	3.1	1.8	0.5	3.6	0.7	0.04	0.059	0.042	4	261
Season Max	26.2	9.9	8.9	14.3	2.2	0.18	0.244	0.173	35	1379
Season Min	14.0	2.6	7.3	1.7	0.1	0.01	0.022	0.008	19	27

	Main Branch Kawkawlin River Averages - Whole Season 2014									
	Water Temp	**DO**	**pH**	**Turbidity**	**NO3-N**	**NH3-N**	**Total P**	**SRP**	**COD**	**E. coli**
	ºC	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**ppm**	**cfu/100 mL**
Average Values	22.3	6.4	7.9	4.0	0.5	0.03	0.087	0.045	39	170
Std Deviation	3.1	1.6	0.5	2.6	0.4	0.01	0.030	0.025	16	276
Season Max	26.7	9.5	9.1	12.2	1.3	0.05	0.175	0.097	133	1814
Season Min	14.5	0.0	7.2	0.1	0.1	0.01	0.036	0.005	16	16

	Main Branch Kawkawlin River Averages - Major Rain Events 2014									
	Water Temp	**DO**	**pH**	**Turbidity**	**NO3-N**	**NH3-N**	**Total P**	**SRP**	**COD**	**E. coli**
	ºC	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**ppm**	**cfu/100 mL**
Average Values	21.9	6.0	7.9	4.0	0.4	0.03	0.091	0.048	34	276
Std Deviation	2.4	1.1	0.4	3.1	0.4	0.01	0.031	0.028	9	389
Season Max	25.2	8.0	8.6	12.2	1.0	0.05	0.147	0.097	55	1814
Season Min	16.8	3.9	7.4	0.1	0.1	0.01	0.041	0.007	17	36

	Main Branch Kawkawlin River Averages - Non-Rain Events 2014									
	Water Temp	**DO**	**pH**	**Turbidity**	**NO3-N**	**NH3-N**	**Total P**	**SRP**	**COD**	**E. coli**
	ºC	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**ppm**	**cfu/100 mL**
Average Values	22.6	6.9	7.9	4.7	0.6	0.03	0.085	0.043	42	94
Std Deviation	3.4	1.3	0.5	4.4	0.5	0.01	0.030	0.023	18	110
Season Max	26.7	9.5	9.1	23.3	1.3	0.05	0.175	0.084	133	568
Season Min	14.5	4.4	7.2	1.3	0.1	0.01	0.036	0.005	16	16

2014 Kawkawlin River results

NB1 Garfield North 43° 43'34.9566" -84° 5' 14.946										
Date	**Water Temp**	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**	**COD**	**SRP**
	°C	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/100 mL**	**ppm**	**mg/L**
5/14/2014†	16.4	5.58	8.01	8.29	0.1	0.03	0.067	499.7	51.23	ND
5/20/2014	14.7	7.32	7.36	5.46	0.2	0.04	0.050	84.5	54.47	0.026
5/28/2014	19.2	5.71	7.37	6.79	0.3	0.07	0.078	50.4	56.80	0.051
6/3/2014†	20.9	4.45	7.36	7.33	0.2	0.07	0.099	452.2	50.24	0.049
6/10/2014	19.0	6.43	7.19	6.00	0.2	0.02	0.080	107.6	50.70	0.036
6/16/2014	19.5	6.17	7.91	6.46	0.1	0.02	0.069	122.3	43.53	0.038
6/24/2014†	20.8	5.53	7.08	5.45	0.1	0.04	0.084	387.8	41.01	0.042
6/30/2014	22.8	5.04	7.11	5.65	0.9	0.06	0.068	402.7	39.09	0.032
7/7/2014†	20.9	6.01	7.54	0.60	0.4	0.02	0.069	426.0	35.66	0.035
7/14/2014†	21.3	5.70	7.83	3.30	0.2	0.04	0.080	231.3	43.30	0.037
7/22/2014	22.0	5.69	8.17	2.40	ND	0.04	0.073	241.2	45.87	0.035
7/29/2014†	17.5	5.41	8.37	2.77	0.1	0.03	0.085	259.6	47.20	0.044
7/31/2014	18.1	5.98	8.64	1.57	0.2	0.04	0.075	70.0	41.93	0.035
8/4/2015	20.5	6.06	8.29	3.17	ND	0.03	0.081	55.9	40.60	0.018
8/11/2014	20.6	6.97	7.18	1.30	ND	ND	0.058	27.5	42.50	0.029
Average	19.6	5.87	7.69	4.44	0.2	0.04	0.074	227.9	45.61	0.034

NA = Data point did not meet Quality Assurance Standards or sample was not taken. ND = Data point was below the limit of detection
Detection Limits: NO_3-N = 0.1 mg/L NH_3-N= 0.01 mg/L SRP and Total-P = 0.005 mg/L
* = Data point determined as questionable by Quality Assurance Plan
† = Major rain event (0.25 inches of rain within a 24 hour period, prior to a 72 hour dry period)
NO_3-N represents nitrogen from nitrate + nitrite
Non-Detects are represented as half the detection limit in the calculation of the averages

2014 Kawkawlin River results

NB2 8 Mile Rd 43° 42' 15.63" -84° 02' 53.12"										
Date	**Water Temp**	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**	**COD**	**SRP**
	°C	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/100 mL**	**ppm**	**mg/L**
5/14/2014†	16.5	6.10	8.27	6.22	0.3	0.04	0.141	115.6	48.1	ND
5/20/2014	14.3	7.61	7.45	7.77	0.4	0.04	0.049	204.8	54.3	0.023
5/28/2014	19.0	5.64	7.51	5.71	0.4	0.06	0.084	90.5	57.6	0.052
6/3/2014†	20.8	4.48	7.37	6.10	0.3	0.04	0.097	387.9	54.9	0.048
6/10/2014	18.8	6.43	7.30	5.33	0.2	0.02	0.084	225.8	35.9	0.038
6/16/2014	19.5	6.36	7.83	4.93	0.1	0.01	0.067	119.6	45.0	0.041
6/24/2014†	20.5	5.36	6.94	7.23	0.3	0.04	0.100	188.4	42.0	0.050
6/30/2014	22.9	4.96	7.18	6.21	1.5	0.07	0.074	373.0	38.9	0.042
7/7/2014†	20.8	6.29	7.62	2.00	0.5	0.02	0.074	153.7	37.5	0.047
7/14/2014†	21.4	5.43	7.89	4.90	0.1	0.05	0.083	170.3	40.7	0.048
7/22/2014	21.4	5.42	8.20	2.67	ND	0.04	0.084	154.1	47.1	0.050
7/29/2014†	17.2	6.02	8.15	6.47	ND	0.04	0.103	294.9	44.7	0.057
7/31/2014	17.8	4.68	8.58	3.00	0.1	0.05	0.104	111.6	40.3	0.054
8/4/2015	20.3	3.74	8.13	2.40	ND	0.04	0.103	39.8	43.3	0.039
8/11/2014	20.3	4.72	7.35	3.23	ND	ND	0.100	16.5	42.1	0.045
Average	19.4	5.55	7.72	4.94	0.3	0.04	0.090	176.4	44.8	0.042

NA = Data point did not meet Quality Assurance Standards or sample was not taken. ND = Data point was below the limit of detection
Detection Limits: NO_3-N = 0.1 mg/L NH_3-N= 0.01 mg/L SRP and Total-P = 0.005 mg/L
* = Data point determined as questionable by Quality Assurance Plan
† = Major rain event (0.25 inches of rain within a 24 hour period, prior to a 72 hour dry period)
NO_3-N represents nitrogen from nitrate + nitrite
Non-Detects are represented as half the detection limit in the calculation of the averages

2014 Kawkawlin River results

NB3 Fraser Rd 43° 42' 1.7316'' -84° 0' 29.6886''										
Date	**Water Temp**	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**	**COD**	**SRP**
	°C	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/100 mL**	**ppm**	**mg/L**
5/14/2014†	16.5	4.96	8.18	4.90	0.3	0.07	0.066	74.2	45.7	0.013
5/20/2014	14.2	7.06	7.50	6.53	0.4	0.05	0.055	235.7	52.9	0.023
5/28/2014	19.2	4.00	7.35	4.34	0.3	0.07	0.112	111.8	60.0	0.068
6/3/2014†	21.0	2.56	7.15	3.65	ND	0.03	0.130	325.9	59.4	0.056
6/10/2014	19.0	4.54	7.20	3.85	0.4	0.03	0.106	116.8	39.9	0.036
6/16/2014	19.3	4.88	7.82	3.93	0.1	0.03	0.098	110.6	43.7	0.055
6/24/2014†	20.5	3.59	6.90	3.77	0.3	0.08	0.123	280.3	42.3	0.074
6/30/2014	22.8	3.01	7.02	3.58	1.4	0.09	0.095	547.5	40.3	0.061
7/7/2014†	21.0	4.57	7.37	1.60	0.6	0.05	0.070	281.7	32.4	0.054
7/14/2014†	21.8	3.38	7.59	2.30	ND	0.06	0.109	151.2	40.8	0.061
7/22/2014	21.8	3.60	7.97	1.63	ND	0.04	0.105	93.0	46.2	0.062
7/29/2014†	18.6	2.49	7.98	1.83	ND	0.04	0.106	397.7	46.8	0.067
7/31/2014	18.8	3.02	8.35	0.60	0.1	0.06	0.094	55.1	39.3	0.064
8/4/2015	20.8	1.55	7.87	2.70	ND	0.02	0.131	280.7	42.3	0.032
8/11/2014	21.1	1.79	7.13	2.67	ND	ND	0.109	6.0	43.4	0.081
Average	19.8	3.67	7.56	3.19	0.3	0.05	0.101	204.5	45.0	0.054

NA = Data point did not meet Quality Assurance Standards or sample was not taken. ND = Data point was below the limit of detection

Detection Limits: NO_3-N = 0.1 mg/L NH_3-N= 0.01 mg/L SRP and Total-P = 0.005 mg/L

* = Data point determined as questionable by Quality Assurance Plan

† = Major rain event (0.25 inches of rain within a 24 hour period, prior to a 72 hour dry period)

NO_3-N represents nitrogen from nitrate + nitrite

Non-Detects are represented as half the detection limit in the calculation of the averages

2014 Kawkawlin River results

NB4 Mackinaw Rd 4 43° 41' 35.06" -83° 59' 18.34"										
Date	**Water Temp**	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**	**COD**	**SRP**
	°C	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/100 mL**	**ppm**	**mg/L**
5/14/2014†	16.9	1.78	7.91	1.12	ND	0.03	0.054	19.0	41.35	0.016
5/20/2014	14.2	2.98	7.31	2.14	0.3	0.04	0.042	78.8	45.91	0.016
5/28/2014	19.5	1.20	7.11	0.85	ND	0.02	0.101	96.2	58.74	0.048
6/3/2014†	21.5	0.23	6.91	4.43	ND	0.03	0.304	161.6	61.11	0.206
6/10/2014	20.4	0.58	6.94	1.76	0.1	0.01	0.164	55.2	51.70	0.100
6/16/2014	20.6	0.40	7.58	3.28	ND	0.01	0.266	106.0	54.63	0.191
6/24/2014†	21.2	0.29	6.73	7.07	0.1	0.06	0.428	254.9	53.26	0.306
6/30/2014	23.0	0.23	6.61	8.23	ND	0.04	0.481	299.8	58.79	0.324
7/7/2014†	21.1	0.00	6.87	1.28	ND	0.03	0.226	443.2	27.54	0.172
7/14/2014†	21.8	0.00	7.28	2.00	ND	0.01	0.259	720.6	44.50	0.165
7/22/2014	21.6	0.31	7.64	0.33	ND	0.03	0.252	165.9	51.40	0.073
7/29/2014†	18.5	0.20	7.75	1.33	ND	ND	0.194	427.4	53.40	0.118
7/31/2014	18.6	0.17	8.10	1.80	ND	0.02	0.245	242.4	50.97	0.092
8/4/2015	20.7	0.00	7.65	3.77	ND	0.06	0.269	420.0	48.53	0.092
8/11/2014	22.1	1.52	6.96	1.07	ND	ND	0.174	28.6	50.83	0.101
Average	20.1	0.66	7.29	2.70	ND	0.03	0.231	234.6	50.18	0.135

NA = Data point did not meet Quality Assurance Standards or sample was not taken. ND = Data point was below the limit of detection

Detection Limits: NO_3-N = 0.1 mg/L NH_3-N= 0.01 mg/L SRP and Total-P = 0.005 mg/L

* = Data point determined as questionable by Quality Assurance Plan

† = Major rain event (0.25 inches of rain within a 24 hour period, prior to a 72 hour dry period)

NO_3-N represents nitrogen from nitrate + nitrite

Non-Detects are represented as half the detection limit in the calculation of the averages

2014 Kawkawlin River results

NB6 Old Beaver North 43° 39' 20.76" -83° 57' 41.98"										
Date	**Water Temp**	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**	**COD**	**SRP**
	°C	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/100 mL**	**ppm**	**mg/L**
5/14/2014†	17.0	3.76	8.10	1.81	0.2	0.02	0.070	52.4	37.44	0.034
5/20/2014	14.9	5.86	7.40	3.90	0.5	0.03	0.047	156.3	49.35	0.021
5/28/2014	19.8	3.55	7.26	2.23	0.1	0.02	0.114	83.5	57.41	0.082
6/3/2014†	21.7	4.77	7.19	2.38	ND	0.03	0.150	866.5	55.91	0.108
6/10/2014	19.3	5.83	7.42	2.32	ND	ND	0.133	106.2	54.10	0.096
6/16/2014	20.2	5.93	8.02	3.70	ND	ND	0.113	185.6	44.93	0.068
6/24/2014†	20.8	4.60	7.19	2.83	ND	0.02	0.129	280.8	41.87	0.078
6/30/2014	22.7	3.69	7.14	5.18	1.2	0.08	0.232	661.2	48.49	0.170
7/7/2014†	20.9	5.39	7.38	1.50	ND	0.01	0.138	88.4	42.12	0.098
7/14/2014†	21.8	5.72	7.79	0.67	ND	0.02	0.124	111.4	41.57	0.075
7/22/2014	22.5	6.67	8.33	0.80	ND	0.01	0.096	177.8	48.40	0.057
7/29/2014†	16.9	5.51	8.26	2.70	0.1	ND	0.113	335.9	37.10	0.078
7/31/2014	18.5	6.01	8.69	1.53	ND	0.02	0.093	71.3	44.43	0.058
8/4/2015	20.8	5.26	8.23	2.60	ND	0.02	0.134	65.7	43.97	0.062
8/11/2014	21.3	4.68	7.40	3.90	ND	ND	0.198	167.4	48.03	0.103
Average	19.9	5.15	7.72	2.54	0.2	0.02	0.125	227.4	46.34	0.079

NA = Data point did not meet Quality Assurance Standards or sample was not taken. ND = Data point was below the limit of detection

Detection Limits: NO_3-N = 0.1 mg/L NH_3-N= 0.01 mg/L SRP and Total-P = 0.005 mg/L

* = Data point determined as questionable by Quality Assurance Plan

† = Major rain event (0.25 inches of rain within a 24 hour period, prior to a 72 hour dry period)

NO_3-N represents nitrogen from nitrate + nitrite

Non-Detects are represented as half the detection limit in the calculation of the averages

2014 Kawkawlin River results

SB2 8 Mile Rd South 43° 37' 54.7746" -84° 2' 56.6232"										
Date	**Water Temp**	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**	**COD**	**SRP**
	°C	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/100 mL**	**ppm**	**mg/L**
5/14/2014†	16.1	6.80	8.30	14.84	0.9	0.03	0.034	204.5	34.35	ND
5/20/2014	14.1	7.87	7.71	8.75	1.9	0.02	0.026	141.0	21.60	0.008
5/28/2014	19.0	5.48	7.67	9.21	2.0	0.07	0.047	165.6	28.38	0.024
6/3/2014†	21.3	3.15	7.51	12.70	1.1	0.02	0.073	1986.3	39.11	0.010
6/10/2014	19.8	4.40	7.58	9.97	1.0	0.18	0.068	133.4	21.70	0.051
6/16/2014	19.5	4.75	8.44	14.27	0.5	0.10	0.079	251.9	27.73	0.048
6/24/2014†	22.1	3.43	7.39	5.20	0.7	0.10	0.243	547.4	21.91	0.181
6/30/2014	23.2	2.56	7.43	13.96	0.8	0.13	0.146	1379.2	27.06	0.095
7/7/2014†	21.6	5.62	7.79	16.39	ND	0.07	0.106	145.5	23.22	0.069
7/14/2014†	22.8	3.55	7.95	7.90	ND	0.05	0.132	420.1	24.13	0.091
7/22/2014	23.5	6.04	8.60	4.27	0.1	0.01	0.120	144.2	31.27	0.061
7/29/2014†	17.7	4.23	8.40	7.65	1.2	0.07	0.146	2275.2	31.30	0.082
7/31/2014	19.2	4.32	8.73	4.47	1.2	0.05	0.101	125.2	25.23	0.043
8/4/2015	21.8	5.10	8.42	5.87	ND	0.09	0.095	52.4	22.07	0.042
8/11/2014	21.4	4.67	7.64	7.97	ND	ND	0.110	45.6	26.60	0.069
Average	20.2	4.80	7.97	9.56	0.8	0.07	0.102	534.5	27.04	0.058

NA = Data point did not meet Quality Assurance Standards or sample was not taken. ND = Data point was below the limit of detection

Detection Limits: NO_3-N = 0.1 mg/L NH_3-N= 0.01 mg/L SRP and Total-P = 0.005 mg/L

* = Data point determined as questionable by Quality Assurance Plan

† = Major rain event (0.25 inches of rain within a 24 hour period, prior to a 72 hour dry period)

NO_3-N represents nitrogen from nitrate + nitrite

Non-Detects are represented as half the detection limit in the calculation of the averages

2014 Kawkawlin River results

SB3 Fraser Rd South 43° 37' 6.3516" -84° 0' 41.6046"										
Date	**Water Temp**	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**	**COD**	**SRP**
	°C	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/100 mL**	**ppm**	**mg/L**
5/14/2014†	16.0	6.41	8.40	14.42	0.9	0.02	0.029	403.0	22.88	ND
5/20/2014	14.0	7.47	7.85	6.57	1.9	0.02	0.026	125.6	20.48	0.013
5/28/2014	19.1	5.70	7.68	8.38	1.9	0.07	0.057	82.9	28.42	0.029
6/3/2014†	21.5	4.97	7.63	5.44	1.0	0.15	0.071	224.8	28.64	0.033
6/10/2014	19.6	5.51	7.66	6.32	0.7	0.05	0.070	257.7	30.20	0.043
6/16/2014	20.6	5.49	8.53	4.05	0.4	0.04	0.078	179.4	25.40	0.046
6/24/2014†	21.8	3.63	7.30	17.42	0.2	0.21	0.229	991.8	24.76	0.153
6/30/2014	23.7	3.28	7.55	2.41	1.2	0.14	0.177	337.5	20.85	0.135
7/7/2014†	21.9	4.96	7.74	3.60	ND	0.05	0.147	340.4	19.11	0.108
7/14/2014†	22.3	3.51	7.97	3.10	0.3	0.07	0.196	232.6	22.70	0.155
7/22/2014	23.0	5.80	8.59	5.00	ND	0.04	0.244	42.2	27.17	0.173
7/29/2014†	18.0	5.70	8.62	4.07	ND	0.02	0.228	787.8	28.73	0.151
7/31/2014	18.9	4.98	8.81	3.63	0.9	0.05	0.098	127.2	26.57	0.069
8/4/2015	21.4	5.10	8.49	4.87	ND	0.06	0.196	208.7	28.27	0.076
8/11/2014	21.0	5.39	7.69	3.33	ND	ND	0.154	220.1	25.13	0.086
Average	20.2	5.19	8.03	6.17	0.6	0.07	0.133	304.1	25.29	0.085

NA = Data point did not meet Quality Assurance Standards or sample was not taken. ND = Data point was below the limit of detection
Detection Limits: NO_3-N = 0.1 mg/L NH_3-N= 0.01 mg/L SRP and Total-P = 0.005 mg/L
* = Data point determined as questionable by Quality Assurance Plan
† = Major rain event (0.25 inches of rain within a 24 hour period, prior to a 72 hour dry period)
NO_3-N represents nitrogen from nitrate + nitrite
Non-Detects are represented as half the detection limit in the calculation of the averages

2014 Kawkawlin River results

SB4 Wheeler Rd 43° 38' 19.4388'' -83° 58' 34.0176''										
Date	**Water Temp**	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**	**COD**	**SRP**
	°C	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/100 mL**	**ppm**	**mg/L**
5/14/2014†	16.5	6.29	8.41	23.29	1.3	0.05	0.048	409.5	26.40	ND
5/20/2014	14.3	5.84	7.63	11.58	2.2	0.04	0.038	85.1	23.42	0.025
5/28/2014	19.0	5.05	7.62	8.91	1.7	0.07	0.053	85.4	29.35	0.025
6/3/2014†	21.8	5.66	7.75	2.05	0.9	0.06	0.046	97.9	31.39	0.005
6/10/2014	21.3	8.63	7.68	2.55	ND	0.02	0.024	89.1	19.20	ND
6/16/2014	22.4	9.88	8.93	1.74	0.1	0.01	0.022	123.7	28.67	ND
6/24/2014†	21.9	2.97	7.26	4.13	0.3	0.02	0.085	198.8	20.48	0.066
6/30/2014	26.2	8.89	N/A	N/A	1.3	0.03	0.088	N/A	31.60	0.045
7/7/2014†	23.5	5.71	7.72	1.90	ND	0.01	0.107	85.2	12.06	0.063
7/14/2014†	24.1	2.96	7.58	N/A	ND	0.04	0.158	68.3	34.80	0.110
7/22/2014	23.8	3.09	N/A	N/A	0.1	0.02	0.129	39.0	34.73	0.097
7/29/2014†	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/31/2014	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/4/2015	23.5	3.72	7.14	N/A	ND	0.04	0.158	82.7	24.87	0.131
8/11/2014	23.0	3.84	7.27	N/A	ND	ND	0.159	26.7	30.73	0.105
Average	21.6	5.58	7.73	7.02	0.6	0.03	0.086	115.9	26.75	0.052

NA = Data point did not meet Quality Assurance Standards or sample was not taken. ND = Data point was below the limit of detection
Detection Limits: NO_3-N = 0.1 mg/L NH_3-N= 0.01 mg/L SRP and Total-P = 0.005 mg/L
* = Data point determined as questionable by Quality Assurance Plan
† = Major rain event (0.25 inches of rain within a 24 hour period, prior to a 72 hour dry period)
NO_3-N represents nitrogen from nitrate + nitrite
Non-Detects are represented as half the detection limit in the calculation of the averages

2014 Kawkawlin River results

MB1 Old Beaver 43° 39' 2.1924" -83° 56' 54.9492"										
Date	**Water Temp**	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**	**COD**	**SRP**
	°C	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/100 mL**	**ppm**	**mg/L**
5/14/2014†	16.8	5.07	8.27	12.18	1.0	0.03	0.041	188.9	33.74	0.020
5/20/2014	14.5	6.68	7.50	7.16	1.3	0.04	0.045	142.7	37.86	0.024
5/28/2014	26.7	4.6	7.25	3.72	0.2	0.05	0.107	309.8	46.44	0.069
6/3/2014†	22.6	5.41	7.51	3.21	0.1	0.05	0.110	315.0	47.41	0.064
6/10/2014	20.3	6.7	7.52	2.82	ND	0.01	0.104	121.9	50.60	0.060
6/16/2014	21.2	8.45	8.49	3.53	ND	0.02	0.075	175.4	45.83	0.042
6/24/2014†	21.7	3.93	7.35	10.78	0.4	0.03	0.100	1813.6	29.41	0.054
6/30/2014	24.0	4.37	7.22	4.72	0.4	0.04	0.135	568.5	43.05	0.078
7/7/2014†	22.2	5.55	7.56	1.60	ND	ND	0.109	176.2	29.11	0.073
7/14/2014†	23.7	4.58	7.86	2.33	ND	0.03	0.122	160.8	37.70	0.090
7/22/2014	23.8	5.44	8.34	1.33	ND	0.01	0.124	86.1	43.07	0.080
7/29/2014†	19.2	3.97	8.26	0.10	ND	0.01	0.147	237.9	44.50	0.097
7/31/2014	20.4	5.98	8.65	1.80	0.2	0.02	0.120	76.9	39.90	0.084
8/4/2015	23.3	6.10	8.38	1.83	ND	0.03	0.101	97.3	35.40	0.066
8/11/2014	23.4	4.83	7.49	1.93	ND	ND	0.111	42.2	40.77	0.073
Average	21.6	5.4	7.8	3.9	0.3	0.0	0.1	300.9	40.3	0.065

NA = Data point did not meet Quality Assurance Standards or sample was not taken. ND = Data point was below the limit of detection

Detection Limits: NO_3-N = 0.1 mg/L NH_3-N= 0.01 mg/L SRP and Total-P = 0.005 mg/L

* = Data point determined as questionable by Quality Assurance Plan

† = Major rain event (0.25 inches of rain within a 24 hour period, prior to a 72 hour dry period)

NO_3-N represents nitrogen from nitrate + nitrite

Non-Detects are represented as half the detection limit in the calculation of the averages

2014 Kawkawlin River results

MB2 Euclid				43° 38' 36.7578''		-83° 54' 48.1068''				
Date	**Water Temp**	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**	**COD**	**SRP**
	ºC	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/100 mL**	**ppm**	**mg/L**
5/14/2014†	17.5	6.03	8.31	5.69	1.0	0.03	0.046	102.4	31.95	0.010
5/20/2014	14.9	6.33	7.52	6.24	1.2	0.03	0.042	149.3	35.76	0.016
5/28/2014	21.3	5.84	7.47	2.48	0.6	0.04	0.077	135.4	43.80	0.051
6/3/2014†	22.9	6.35	7.37	2.26	0.1	0.04	0.094	44.1	49.42	0.051
6/10/2014	21.7	6.75	7.56	9.91	ND	0.02	0.175	55.1	62.90	0.054
6/16/2014	21.8	9.27	8.72	2.69	ND	0.01	0.080	45.3	44.60	0.041
6/24/2014†	22.2	6.25	7.43	3.27	0.1	0.02	0.087	349.7	31.98	0.047
6/30/2014	26.6	9.52	N/A	N/A	ND	0.02	0.061	N/A	30.69	0.015
7/7/2014†	23.1	7.00	7.94	1.20	ND	0.02	0.107	52.5	29.36	0.062
7/14/2014†	24.6	7.00	7.92	N/A	ND	0.02	0.112	62.6	34.57	0.067
7/22/2014	25.4	8.15	N/A	N/A	ND	0.01	0.100	44.4	44.97	0.069
7/29/2014†	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/31/2014	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/4/2015	25.8	6.68	7.58	N/A	ND	0.02	0.108	55.8	40.17	0.066
8/11/2014	25.4	7.53	8.05	N/A	ND	ND	0.103	22.6	35.07	0.059
Average	22.6	7.13	7.81	4.22	0.3	0.02	0.092	93.3	39.63	0.047

NA = Data point did not meet Quality Assurance Standards or sample was not taken. ND = Data point was below the limit of detection
Detection Limits: NO_3-N = 0.1 mg/L NH_3-N= 0.01 mg/L SRP and Total-P = 0.005 mg/L
* = Data point determined as questionable by Quality Assurance Plan
† = Major rain event (0.25 inches of rain within a 24 hour period, prior to a 72 hour dry period)
NO_3-N represents nitrogen from nitrate + nitrite
Non-Detects are represented as half the detection limit in the calculation of the averages

2014 Kawkawlin River results

MB3 Castaways 43° 39' 7.39" -83° 53' 51.01"										
Date	**Water Temp**	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**	**COD**	**SRP**
	°C	**mg./L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/100 mL**	**ppm**	**mg/L**
5/14/2014†	18.1	7.03	8.38	6.50	1.0	0.03	0.043	69.0	31.23	0.007
5/20/2014	15.0	7.00	7.60	6.53	1.1	0.03	0.044	149.5	34.96	0.014
5/28/2014	21.4	5.83	7.48	2.99	0.7	0.04	0.067	57.5	41.40	0.038
6/3/2014†	22.8	6.60	7.39	3.16	0.1	0.02	0.082	613.1	55.03	0.025
6/10/2014	22.3	8.89	8.03	6.50	ND	0.02	0.079	16.9	43.20	0.024
6/16/2014	22.7	7.39	8.64	2.16	ND	0.05	0.086	43.8	47.53	0.057
6/24/2014†	22.6	5.60	7.40	3.45	0.1	0.02	0.117	557.8	33.24	0.071
6/30/2014	25.8	8.68	N/A	N/A	ND	0.02	0.076	N/A	17.82	0.032
7/7/2014†	23.6	6.12	7.71	1.33	0.1	0.01	0.143	50.3	32.82	0.086
7/14/2014†	24.9	5.20	7.93	N/A	ND	0.01	0.101	490.0	26.07	0.055
7/22/2014	25.3	5.83	N/A	N/A	ND	0.01	0.098	23.8	39.23	0.053
7/29/2014†	21.7	5.42	8.61	2.30	ND	ND	0.095	36.1	35.70	0.054
7/31/2014	22.2	6.30	9.06	2.00	0.2	0.02	0.102	21.3	133.23	0.049
8/4/2015	25.6	6.05	7.54	N/A	ND	0.03	0.085	32.4	35.33	0.037
8/11/2014	25.1	6.02	7.84	2.00	ND	ND	0.088	25.2	31.13	0.046
Average	22.6	6.53	7.97	3.54	0.2	0.02	0.087	156.2	42.53	0.043

NA = Data point did not meet Quality Assurance Standards or sample was not taken. ND = Data point was below the limit of detection
Detection Limits: NO_3-N = 0.1 mg/L NH_3-N= 0.01 mg/L SRP and Total-P = 0.005 mg/L
* = Data point determined as questionable by Quality Assurance Plan
† = Major rain event (0.25 inches of rain within a 24 hour period, prior to a 72 hour dry period)
NO_3-N represents nitrogen from nitrate + nitrite
Non-Detects are represented as half the detection limit in the calculation of the averages

2014 Kawkawlin River results

MB4 Mouth 43° 39' 32.3748" -83° 52' 58.4142"										
Date	**Water Temp**	**DO**	**pH**	**Turbidity**	**NO_3-N**	**NH_3-N**	**Total P**	**E. coli**	**COD**	**SRP**
	°C	**mg/L**		**NTU**	**mg/L**	**mg/L**	**mg/L**	**cfu/100 mL**	**ppm**	**mg/L**
5/14/2014†	17.9	6.67	8.33	6.58	0.8	0.04	0.043	102.0	28.35	0.009
5/20/2014	15.2	7.39	7.58	6.43	1.3	0.04	0.036	183.7	29.42	0.019
5/28/2014	21.3	7.24	7.58	4.41	0.6	0.05	0.063	43.4	34.03	0.038
6/3/2014†	22.9	7.17	7.59	3.93	ND	0.04	0.078	48.1	46.08	0.034
6/10/2014	22.1	8.14	7.74	6.34	ND	0.01	0.075	16.4	45.60	0.012
6/16/2014	22.5	6.63	8.59	3.87	0.1	0.04	0.076	70.2	47.10	0.035
6/24/2014†	22.8	5.16	7.41	3.52	ND	0.04	0.086	459.9	31.49	0.036
6/30/2014	26.0	8.00	N/A	N/A	0.1	0.03	0.056	N/A	16.15	0.015
7/7/2014†	23.3	7.01	8.08	3.16	0.1	0.04	0.074	38.0	17.32	0.018
7/14/2014†	25.2	8.01	8.39	N/A	ND	0.02	0.063	111.9	20.53	0.015
7/22/2014	24.9	8.45	N/A	N/A	ND	0.01	0.070	28.9	34.97	0.014
7/29/2014†	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/31/2014	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/4/2015	25.7	6.68	7.69	N/A	ND	0.04	0.057	56.4	30.80	0.005
8/11/2014	24.6	7.53	8.20	3.47	ND	ND	0.056	31.9	28.33	0.015
Average	22.6	7.2	7.9	4.6	0.2	0.0	0.1	99.2	31.6	0.020

NA = Data point did not meet Quality Assurance Standards or sample was not taken. ND = Data point was below the limit of detection
Detection Limits: NO_3-N = 0.1 mg/L NH_3-N= 0.01 mg/L SRP and Total-P = 0.005 mg/L
* = Data point determined as questionable by Quality Assurance Plan
† = Major rain event (0.25 inches of rain within a 24 hour period, prior to a 72 hour dry period)
NO_3-N represents nitrogen from nitrate + nitrite
Non-Detects are represented as half the detection limit in the calculation of the averages

2014 Kawkawlin River results

	E. coli exceedances											
	NB1	**NB2**	**NB3**	**NB4**	**NB6**	**MB1**	**MB2**	**MB3**	**MB4**	**SB32**	**SB3**	**SB4**
5/14/2014†	X											
5/20/2014												
5/28/2014												
6/3/2014†		X	X		X	X	X			X		
6/10/2014												
6/16/2014												
6/24/2014†	X					X	X	X	X	X	X	
6/30/2014	X	X	X		X	X	NS	NS	NS	X	X	NS
7/7/2014†	X			X							X	
7/14/2014†				X			X			X		
7/22/2014												
7/29/2014†			X	X	X			NS	NS	X		NS
7/31/2014								NS	NS			NS
8/4/2014				X								
8/11/2014												
Exceedances per site	4	2	3	4	3	3	3	1	1	5	4	1
% Exceedances	27	13	29	27	20	20	21	8	8	33	27	8

X=*E.coli* exceedances (geometric mean> 300 CFU/100 mL)
NS: not sampled
Sites in green are MDEQ sites
† = Major rain event (0.25 inches of rain within a 24 hour period, prior to a 72 hour dry period)

Total Exceedances: 34
Total % Exceedances: 20

NB % Exceedances: 21
MB % Exceedances: 15
SB % Exceedances: 24

Final report on the project entitled *Using aerial photography and satellite imagery to examining potential causes of a low-gradient, anoxic reach of the North Branch Kawkawlin River.* This project was funded by the Saginaw Bay Environmental Science Institute (SBESI).

Rhett Mohler (PI), Department of Geography, Saginaw Valley State University
Nicholas Ross (Student Employee), Saginaw Valley State University

Recently, a study by Voss *et al*. (2014) further confirmed what sampling by the Michigan Department of Environmental Quality (DEQ) documented in 2007: that dissolved oxygen (DO) levels on a section of the North Branch of the Kawkawlin River consistently fall below the minimum standards set by the state of Michigan. Although the entire lower half of the North Branch failed to meet the state standard, one site showed particularly low DO levels. This was located in a very low-flow, low gradient, marshy section of the river with a poorly defined channel (Figure 1). While it is clear that this section experiences chronic low DO levels, the actual cause for the swampy nature of this reach is currently unknown, including when the reach first came to be this way and if the cause is human or natural.

Figure 1: Impaired section of the North Branch of the Kawkawlin River. Notice the swampy reach that begins approximately 3/4 of a mile north of East Beaver Road.

The two main goals of this project, therefore, were 1) to identify when these conditions first developed in this reach of the river, and 2) to identify what caused this low-gradient, swampy reach of river and if that cause is human or natural.

Often, impairment of waterways can be traced back to land use/land cover changes within the watershed. In this study area, the

size of agricultural fields has increased considerably over the last century. This raised the possibility that the impaired reach could be a result of extra sediment associated with changes in the scale of local agriculture. This seemed plausible, given that the North Branch had purportedly not always experienced chronic hypoxia. Consequently, this study first sought to quantify land cover change within the basin of the North Branch of the Kawkawlin River between 1938 (when the first aerial photographs of the area were taken) and 2012 (the date of the most recent aerial photographs).

Upon acquiring the 1938 aerial photographs of the river section in question, it became immediately clear that changes in agricultural practices (at least those since the 1930s) were not responsible for the development of the swampy reach. Although field size has clearly increased in the watershed since 1938, the swampy reach already existed in roughly its current state prior to these changes (Figure 2). This is an important finding because it suggests that, if the swampy reach is caused by agricultural land use change, it would have to have been caused by the initial conversion of the area to farmland, rather than by the switch to modern, larger-scale agriculture.

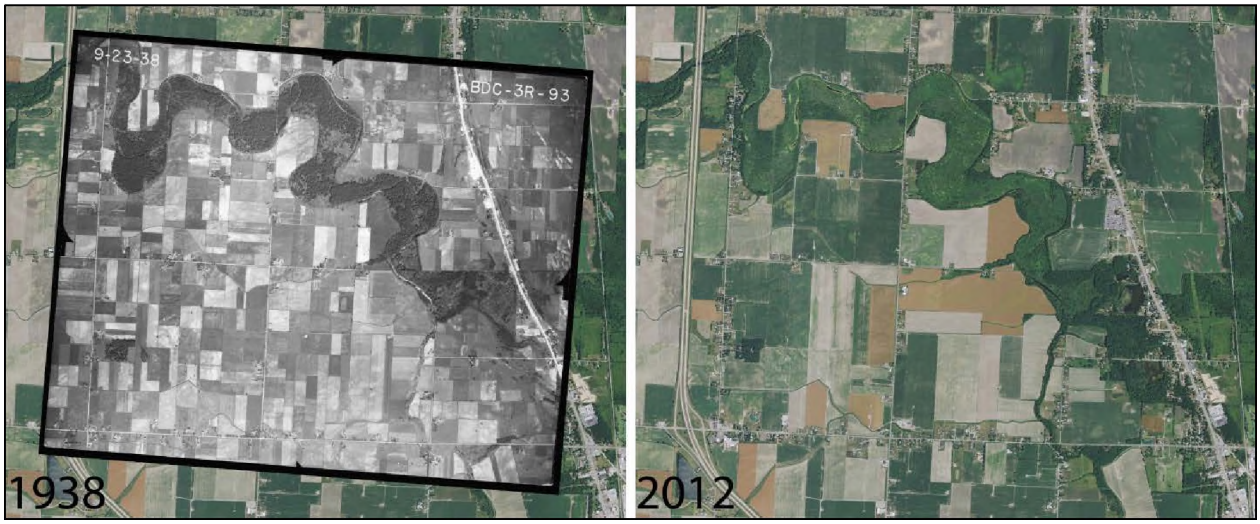

Figure 2: Comparison of the swampy reach between 1938 and 2012. Notice how the extent of the reach has remained the same over this time period, even though field size has increased greatly.

Because the cause of the swampy reach of the North Branch of the Kawkawlin River must have predated 1938, it could not be studied in terms of land cover change as derived from remote sensing data, which was the original intent of this grant. However, the earliest surveys in the area were performed in 1843, and would contain information about the nature of the North

Branch of the Kawkawlin River during this time. In fact, the survey notes and plat maps from 1843 give several indications that the swampy reach of the North Branch of the Kawkawlin River existed even then. For example, in the plat map a swampy area is indicated where sections 15, 16, 21, and 22 meet (the location of the red pushpin in Figure 3), and the swampy area extends southeast along the course of the river just as it currently does. Upon reaching this location during the survey, they surveyors noted that the "land is mostly swamp." In addition to this comment, the general survey notes on this township note that "the North Branch of the Kawkawling [*sic*] River passes through this township is a very sluggish stream and but little water running in it at present."

Figure 3: Comparison of 2012 aerial photograph with the 1843 plat map. The red pushpin indicates the point described by the surveyors as swampy and marked as such on the 1843 map.

While the 1938 aerial photographs confirm that this reach of the North Branch of the Kawkawlin River has been in its current, swampy state for over 70 years, the survey notes and maps suggest that at least part of this reach has been this way for over 170 years. This is important for two main reasons. First, the survey notes suggest that the swampy reach predates both lumbering and agricultural activities – at least those on a scale significant enough to alter the river bed. Second, because the surveys predate significant human activity in the area, it is reasonable to assume that the cause of the swampy reach is natural, rather than human-caused.

With the discovery that the swampy reach of the river was likely natural and likely pre-dated significant land cover change in the area, the goal of the study turned toward identifying the cause. With human-related causes ruled out, it made logical sense to assume that some

natural aspect of the streambed was responsible, and confirming this required a visit to the area which was made on October 17, 2013. During this time, stream flow on the North Branch of the Kawkawlin River was zero. Consequently, simply walking along the channel allowed for an inspection of the streambed. Interestingly, the streambed from the blue pushpin in Figure 3 south to at least East Beaver Road (Figure 1) was very rocky in nature. This rocky stretch has a high gradient and rapid flow conditions when there is water in the river channel. Upstream of the blue pushpin, however, the stream becomes a stagnant pool where standing water was present during the October visit (Figure 4), and the rocky bottom becomes muddy. This reach with standing water corresponds to the sample location with chronically low DO. A 1 m core down through the mud layer revealed that the rocky bottom is not within one meter of the surface of the river bed, if it exists below the mud layer at all.

Figure 4: The left photo shows the northern end of the rocky channel section indicated by the blue pushpin in Figure 3. From here the swampy, low-flow portion of the river extends to the north and west as shown in Figures 1 and 2. The photo on the right shows a core sample taken upstream from the rocky area in standing water. The core went down approximately 1 m and did not hit rocks.

The field investigation of the study area shows that the rocky stream bed at the blue pushpin (shown in Figure 4) is actually higher in elevation than the muddy stream bottom upstream, and that this is creating stagnant pools of water and marshy conditions in the river valley upstream of this area. In effect, the deposit of rocks in the streambed is creating a dam. Because this reach of river was already swampy in 1843, it is likely that the rocky stream bottom was present in 1843, and that the rocky deposit is therefore natural. In this region, this most likely means that the deposit of rocks is glacial in origin. The next step in this research is to determine the origin of the rocky channel, and to confirm that this is in fact a natural feature.

So far, Nicholas Ross has presented this research at the Michigan Academy of Science, Arts, and Letters Conference at Oakland University and at the Association of American Geographers Annual Meeting in Tampa, Florida. This research will also be presented at 37th Annual Applied Geography Conference in Atlanta, Georgia, in October of 2014. As part of this presentation, a paper similar to this one will be published in *Papers in Applied Geography*, which is the peer-reviewed proceedings volume from this conference.

Reference

Voss, H. M., M. E. VanWert, J. R. Polega, J. W. VanHouten, A. L. Martin, and D. S. Karpovich. 2014. Implications of hypoxia on the North Branch of the Kawkawlin River. *Journal of Great Lakes Research* 40:28-34.