Final Report to the Bad River Watershed Association on Monitoring of Total Phosphorus and Associated Parameters, 2014.

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Introduction

Phosphorus is a common element in some types of rock and is fairly abundant in soil. Along with nitrogen, phosphorus is the most influential nutrient in terms of regulating phytoplankton and aquatic macrophyte growth. Excessive inputs of nutrients can lead to abundant algal growth and eutrophication and are an important threat to Upper Midwest river systems.

Nutrients are carried into rivers and streams primarily through surface runoff and percolation through the surrounding rocks and soils. Phosphorus in dry fallout and wet precipitation may come from dust, fine soil particles, and fertilizer from agricultural fields. Concentrations of total phosphorus (TP) in natural water are normally no more than a few tenths of a milligram per liter (mg/L). Sources of high concentrations of phosphorus include domestic and industrial sewage effluent and soil erosion may add considerable amounts of TP to streams via suspended sediments. Dust from rock crushing operations may also be a source of airborne phosphorus.

Specific conductance (SC, or conductivity) is a measure of the capacity of water to conduct an electrical current. The level of SC is controlled largely by the underlying geology of the watershed. Specific conductance readings elevated over background levels may indicate sources of pollution, such as from sewage treatment plants or individual home septic systems, runoff from roads or agriculture, and deposition from airborne sources. Conductivity can be used as an important indicator of polluted runoff that may contain pollutants such as excess nutrients, organic matter, pathogenic microbes, heavy metals, and organic contaminants.

The purpose of this project was to sample select stream waters for total phosphorus, specific conductance, water temperature, and other parameters as possible to begin to understand baseline conditions and identify areas of high phosphorus concentrations in select areas of the Bad River Watershed.

Methods

Site Selection

BRWA selected 20 sites in the eastern portion of the watershed in the Tyler Forks, Upper Bad River, and Potato River sub-watersheds (Table 1). Four sites were downstream of potential phosphorus inputs: Barr Creek (downstream of a large dairy cow operation), Potato River at Perry's (downstream of the Barr Creek input), Bad River in Mellen (downstream of the Mellen sewage treatment ponds), and Vaughn Creek on Lower Road (downstream of the Saxon sewage treatment pond). The remaining 16 sites were located in the vicinity of a potential large open pit taconite mine and processing operation – some sites were directly downstream of the potential operation and others were within the airshed but not directly downstream.

Parameters

Water samples were collected for total phosphorus analysis at every site approximately monthly from early June through October. At the time of sampling, water temperature, air temperature, and specific conductance were measured at every site; pH was measured at 12 sites; and continuous temperature data were collected at 8 sites (Table 1).

Two contractors conducted all field work following a Standard Operating Procedure (attached). Specific conductance, pH, and temperature were measured with a hand-held multiprobe (Hannah model 98129). Total phosphorus samples were sent to Northern Lake Service, Inc. Analytical Laboratory and Environmental Services; samples were handled according to the lab's specifications (preserved with sulfuric acid and kept on ice). The lab used Standard Method 4500P-E (APHA 1998) to analyze for total phosphorus.

Table 1. Bad River Watershed Association (BRWA) sampling sites, 2014. All sites were sampled for total phosphorus, specific conductance, and water and air temperature. * indicates sites where pH was also measured. ^ indicates where continuous temperature was measured.

Basin	Stream	BRWA Site #	latitude	Longitude
Potato	Apple^	2021	46.34777	-90.40246
Potato	Potato	463	46.46219	-90.50814
Potato	Potato at Perry's		46.45677	-90.52010
Potato	Barr		46.45576	-90.51486
Potato	Vaughn at Lower Rd	1029	46.49136	-90.46649
Potato	Vaughn at Hwy 169^	469	46.48723	-90.50939
Tyler Forks	Erickson*	17	46.37250	-90.46510
Tyler Forks	Rouse*^	2014	46.36083	-90.46577
Tyler Forks	Gehrman	885	46.37811	-90.60586
Tyler Forks	Javorsky*	23	46.34484	-90.51842
Tyler Forks	Unnamed Tyler Forks Trib*^	2019	46.29086	-90.50150
Tyler Forks	Bull Gus*	32	46.30306	-90.50600
Upper Bad	Bad at Caroline*	2017	46.26786	-90.56161
Upper Bad	Bad at Olson Rd		46.32699	-90.65277
Upper Bad	Bad in Mellen		46.32766	-90.65585
Upper Bad	Bad at Gilman Park*^	785	46.32292	-90.66322
Upper Bad	Montreal*^	809	46.35599	-90.54869
Upper Bad	Opergard*	2013	46.34160	-90.58571
Upper Bad	Ballou*^	869	46.30590	-90.57594
Upper Bad	City Creek*	829	46.30878	-90.64485
Upper Bad	Devils*^	2010	46.32129	-90.65186

Quality Assurance/Quality Control (QA/QC)

The quality of data was assured and controlled throughout the project via personnel training, calibration of multiprobes, measurement of precision and bias, blank and duplicate sampling, and proper cleaning

of equipment. The analytical laboratory (Northern Lake Service, Inc.) used for total phosphorus analysis is a commercial lab certified by the State of Wisconsin (WDATCP certification No. 105-330 and WDNR No. 721026460) and by the EPA (No. W100034). The lab method used for analysis of TP yielded a limit of detection and limit of quantitation appropriate for the range of field conditions. Data were entered into MS Excel workbooks and checked. Details of QA/QC procedures follow.

Personnel were proficient in the use of the hand-held multiprobes and the proper water sample collecting and handling techniques. Previous BRWA staff trained the contractors in the specific use of the Hannah hand-held multiprobes.

Hannah hand-held multiprobes were calibrated daily, prior to each day's use. Conductivity was calibrated with a 1413µS/cm standard and checked with a 74µS/cm standard. pH was calibrated (on one multiprobe; the other multiprobe did not measure pH) using 7.0 and 4.0 standards. At the end of each sampling day, the multiprobes were checked again against a conductivity standard (either 1413 or 74 µS/cm). At the beginning of the season, one multiprobe was checked against a NIST certified thermometer; at the end of the season, both multiprobes were checked against a NIST certified thermometer. A calibration log was kept for the season and will remain on file in the BRWA office.

Duplicate water samples for total phosphorus were collected at the rate of approximately 10%. Each contractor collected a duplicate each sampling round. Duplicate sites were selected haphazardly. The duplicates were split samples taken from the same field collection bottle. Precision was measured by calculating Relative Percent Difference (RPD) between duplicate sample results. The duplicates were labelled as such on the sample label and the datasheets.

Additional duplicate field samples were collected for comparison of analytical labs in the same manner as described above (i.e., split samples from the same field collection bottle). These additional samples were analyzed by Northland College. Sites were selected after the first two rounds of sampling to span the gradient of TP levels.

One blank sample was sent with stream samples each round of sampling. The blank sample consisted of distilled or deionized water poured into the field collection bottle and then into the lab sample bottle. The purpose of the blank was to field test the adequacy of rinsing the field collection bottles.

Field collection bottles were acid washed (20% HCl, vol:vol) and rinsed five times with deionized water between sampling rounds by BRWA.

Results

Six rounds of sampling were completed between June 3 and October 22, 2014 (Table 2). Each round of sampling was completed in a single day. Rain events occurred at all sites on one sampling date and a portion of sites on two additional dates. We considered a rain event to be when run-off was observed from the land into the stream at the time of sampling.

During the first round of sampling, Bad River at Olson Road was sampled in error. Thereafter, sampling occurred at the correct site (Bad River in Mellen). Results from the Bad River at Olson Road are included in this report.

All results are included in Appendices A – E. Summaries of results are presented below.

Table 2. Bad River Watershed Association sampling dates, rain events, and numbers of sampling sites, 2014.

Sampling Date	Rain Event (Y/N)	# Sites Sampled	# Rain Event Sites
6/3/2014	Y	20	20
7/1/2014	Y&N	20	7
7/23/2014	N	20	0
8/19/2014	Y&N	20	12
9/20/2014	N	20	0
10/22/2014	N	20	0

Completeness

All total phosphorus samples (including duplicates and blanks) were collected and analyzed as planned, which is 100% complete. Specific conductance and pH were not measured during the first sampling round as supplies were not yet procured. Additionally, only one of the hand-held Hannah instruments was capable of measuring pH accurately, so pH was measured at only 12 sites. SC measurements were 83% complete; pH measurements were 50% complete.

Dissolved oxygen and chloride were measured sporadically at one site (Vaughn Creek, downstream of the Saxon waste water treatment pond). These measurements were conducted in addition to the planned measurements detailed above.

Total Phosphorus

Average total phosphorus levels ranged from 0.013mg/L at Gehrman Creek to 0.126mg/L at Vaughn Creek at Lower Road (Table 3). The Vaughn Creek site at Lower Road (BRWA site # 1029) consistently had higher total phosphorus levels than other sites with the exception of a single rain event at the unnamed tributary to Tyler Forks (BRWA site # 2019, Appendix A).

Specific Conductance

Average conductivity measurements were generally typical of surface waters and ranged from a low of 44µS/cm in the Bad River at the Caroline Lake outflow to a high of 229µS/cm in the Vaughn Creek at Lower Road (Table 3). Throughout the season the Vaughn Creek site had the highest conductivity measurements with the exception of Barr Creek that had the same measurement on one sampling date (Appendix B).

pH

As mentioned above, pH was measured at only 12 sites (Appendix C). All of these sites had average pH levels within state of Wisconsin water quality criteria range of 6.0 – 9.0 (Table 3).

Water Temperature

Results of continuous temperature monitoring will be reported elsewhere and submitted to the Wisconsin Department of Natural Resources Surface Water Integrated Management System (project name "BRWA_Penokee"). The results of instantaneous temperature measured at the time of sampling suggest that many of the sites may be located in cold water streams (Appendix D).

Table 3. Bad River Watershed Association (BRWA) 2014 average (ave) results and standard deviation (stdev) for total phosphorus (TP), specific conductance (SC), and pH. NA = data not available.

			TP (mg/L)		SC µS/cm)		pH	
Basin	**Stream**	**BRWA Site #**	**ave**	**stdev**	**ave**	**stdev**	**ave**	**stdev**
Potato	Apple	2021	0.026	0.009	66	22.4	NA	NA
Potato	Potato	463	0.021	0.009	105	26.2	NA	NA
Potato	Potato at Perry's		0.022	0.009	107	27.3	NA	NA
Potato	Barr		0.035	0.013	210	35.5	NA	NA
Potato	Vaughn	1029	0.126	0.057	229	47.5	NA	NA
Potato	Vaughn	469	0.034	0.013	146	10.0	NA	NA
Tyler Forks	Erickson	17	0.029	0.012	133	18.4	7.28	0.21
Tyler Forks	Rouse	2014	0.035	0.010	128	29.4	6.96	0.17
Tyler Forks	Gehrman	885	0.013	0.008	145	17.4		
Tyler Forks	Javorsky	23	0.036	0.019	101	22.1	7.02	0.24
Tyler Forks	Unnamed Tyler Forks Trib	2019	0.065	0.081	76	39.5	6.93	0.37
Tyler Forks	Bull Gus	32	0.043	0.023	77	21.8	6.81	0.09
Upper Bad	Bad at Caroline	2017	0.030	0.004	44	4.8	6.46	0.16
Upper Bad	Olson Rd*		0.031	NA	NA	NA	NA	NA
Upper Bad	Bad in Mellen		0.041	0.017	77	25.8	NA	NA
Upper Bad	Bad at Gilman Park	785	0.031	0.008	75	23.6	7.29	0.28
Upper Bad	Montreal	809	0.041	0.019	79	17.6	6.58	0.17
Upper Bad	Opergard	2013	0.029	0.009	71	13.3	7.25	0.19
Upper Bad	Ballou	869	0.033	0.012	64	11.1	7.03	0.20
Upper Bad	City Creek	829	0.033	0.034	99	16.1	7.48	0.17
Upper Bad	Devils	2010	0.024	0.006	105	12.2	7.41	0.13

* single value only

Quality Control and Quality Assurance

Instrument Calibration - both Hannah hand-held multiprobes calibrated correctly for specific conductance each round of sampling and passed post-sampling criteria (±10%) at the end of each sampling day. The multiprobe with a functional pH probe also calibrated correctly for each round; checks at the end of the sampling day were not conducted.

Both multiprobes compared well to a NIST certified thermometer at warmer temperatures (approximately 10 – 20°C), but at colder temperature (approaching 0°C) the multiprobes did not compare as well (Appendix E). Apparently the temperatures measured in the field can be trusted, as they never approached 0°C. Additionally, the poor comparisons with the NIST-certified thermometer at low temperatures may be due to melting ice in the test bath, which could have resulted in unstable temperatures and a poorly mixed bath.

Duplicate Samples (contract analytical laboratory, NLS) - relative percent differences (RPD) between duplicate samples were generally less than 30% (Table 4), our target measurement quality objective. Because all of the duplicate samples had low levels of phosphorus, high relative percent differences are less ecologically meaningful and the data are usable. For example, a sample result of 0.01mg/L and a duplicate result of 0.007mg/L would result in an RPD of over 35%, yet both samples are at extremely low levels (the analytical laboratory cannot accurately measure levels less than 0.007mg/L).

Table 4. Results of duplicate sampling for total phosphorus (TP) by Northern Lake Service, Bad River Watershed Association (BRWA), 2014. RPD = relative percent difference.

			TP Results (mg/L)		
Date	**Location**	**BRWA Site #**	**sample**	**duplicate**	**RPD**
6/3/2014	Erickson	17	0.028	0.030	6.90
6/3/2014	Barr		0.049	0.048	2.06
7/1/2014	Montreal	809	0.057	0.050	13.08
7/1/2014	Gehrman	885	0.022	0.012	58.82
7/23/2014	Apple	2021	0.034	0.036	5.71
7/23/2014	Javorsky	23	0.041	0.048	15.73
8/19/2014	Potato	463	0.014	0.012	15.38
8/19/2014	City Creek	829	0.019	0.016	17.14
9/20/2014	Potato		0.013	0.018	32.26
9/20/2014	Opergard	2013	0.027	0.023	16.00
10/22/2014	Apple	2021	0.014	0.014	0.00
10/22/2014	Montreal	809	0.015	0.018	18.18

Duplicate Samples (Northland College analytical laboratory) – duplicate samples sent to the two labs (Northland College and NLS) compared well, with RPDs generally less than 30% (Table 5). The instances of RPDs exceeding 30% occurred at low levels of total phosphorus. Note that Northland College lab also

conducted a comparison of preservation methods – field preserved vs. lab preserved. These results are not included.

Blanks – all results of blank samples were reported as either zero (0) or non-detect, indicating that our field rinsing of sampling containers was adequate to avoid contamination.

Table 5. Results of duplicate sampling for total phosphorus by Northern Lake Service (*) and Northland College (^) laboratories, Bad River Watershed Association, 2014. Results are in mg/L; RPD = relative percent difference.

Stream	BRWA Site #	8/19/2014	9/20/2014	10/22/2014
Barr*		0.023	0.025	0.022
Barr^		0.024	0.027	0.019
RPD		4.26	7.69	14.63
Gehrman*	885	0.014	ND	0.008
Gehrman^	885	0.012	0.005	0.005
RPD		15.38	NA	46.15
Javorsky*	23	0.051	0.027	0.012
Javorsky^	23	0.049	0.018	0.011
RPD		4.00	40.00	8.70
Bull Gus*	32	0.056	0.027	0.016
Bull Gus^	32	0.054	0.027	0.018
RPD		3.64	0.00	11.76
Vaughn*	1029	0.18	0.093	0.044
Vaughn^	1029	0.176	0.099	0.047
RPD		2.25	6.25	6.59

Discussion and Recommendations

Two sites were selected because they are located downstream of potential sources of pollution: Vaughn Creek at Lower Road (BRWA site # 1029) is downstream from the Town of Saxon's sewage treatment pond and Barr Creek is downstream of a large dairy farm. Both sites had substantially higher specific conductance (SC) measurements than other sites and the Vaughn Creek site had the highest total phosphorus (TP) levels of all sites. While severe pollution is not indicated, these sites should continue to be monitored in the future.

Average TP and SC levels at the Vaughn Creek site at Highway 169 (BRWA site #469), which is approximately 3.4 stream miles downstream of site #1029, were considerably lower than at site #1029 indicating dilution effects from tributaries and groundwater inputs. Elevated levels of TP and SC levels at BRWA site #1029 suggest pollution from the sewage treatment ponds. Lower water temperatures at the downstream site also indicate groundwater inputs along the 3.4 miles of stream between sites.

The Barr Creek site may not have been the ideal location for capturing downstream inputs from the large dairy operation. While the effects of the dairy on water quality warrant future monitoring vigilance, additional reconnaissance work should be done to determine the best location.

Several sites, but not all, demonstrated higher TP and SC levels during rain events, indicating effects of runoff from the land. Future monitoring efforts should include descriptions of the surrounding uplands and watershed, especially ground flora cover and slope. Such additional information may help explain elevated TP and SC levels.

In 2014, sampling did not begin until early June. In future years, sampling should begin earlier with an attempt to measure the effects of the spring snowmelt.

In future years, BRWA should purchase an additional handheld multiprobe that will measure conductivity, pH, and temperature. The quality control for pH measurements should be increased to the same level as that for conductivity. Specifically, QC for pH should include end-of-day calibration checks.

BRWA should use the preliminary temperature data to help prioritize sites for future continuous temperature monitoring.

Literature Cited

APHA (1998). *Standard Methods for the Examination of Water and Wastewater*, 20th edition. American Public Health Association, Washington, D.C.

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Appendix A. Total Phosphorus Results (mg/L).

Bold indicates rain event; ND = non-detect

Basin	Stream	BRWA Site #	6/3/2014	7/1/2014	7/23/2014	8/19/2014	9/20/2014	10/22/2014
		rain event?	Y	Y&N	N	Y&N	N	N
Potato	Apple	2021	**0.028**	0.035	0.034	0.026	0.018	0.014
Potato	Potato	463	**0.035**	0.03	0.021	0.014	0.013	0.016
Potato	Potato at Perry's		**0.034**	0.032	0.022	0.013	0.013	0.014
Potato	Barr		**0.049**	0.048	0.043	0.023	0.025	0.022
Potato	Vaughn	1029	**0.096**	0.15	0.19	0.18	0.093	0.044
Potato	Vaughn	469	**0.056**	0.034	0.042	0.028	0.027	0.019
Tyler Forks	Erickson	17	**0.028**	0.043	0.032	**0.039**	0.014	0.015
Tyler Forks	Rouse	2014	**0.045**	0.048	0.034	**0.032**	0.021	0.027
Tyler Forks	Gehrman	885	**0.019**	0.022	0.02	0.014	ND	0.008
Tyler Forks	Javorsky	23	**0.022**	0.06	0.041	**0.051**	0.027	0.012
Tyler Forks	Unnamed Tyler Forks Trib	2019	**0.035**	**0.23**	0.037	**0.037**	0.029	0.023
Tyler Forks	Bull Gus	32	**0.026**	**0.063**	0.07	**0.056**	0.027	0.016
Upper Bad	Bad at Caroline	2017	**0.025**	**0.034**	0.031	**0.035**	0.026	0.026
Upper Bad	Olson Rd		**0.031**					
Upper Bad	Bad in Mellen			0.048	0.046	0.064	0.027	0.022

Appendix A (continued). Total Phosphorus Results (mg/L).

Basin	Stream	BRWA Site #	6/3/2014	7/1/2014	7/23/2014	8/19/2014	9/20/2014	10/22/2014
Upper Bad	Bad at Gilman Park	785	**0.036**	**0.04**	0.037	**0.025**	0.024	0.022
Upper Bad	Montreal	809	**0.036**	0.057	0.065	**0.054**	0.022	0.015
Upper Bad	Opergard	2013	**0.033**	0.031	0.028	**0.041**	0.027	0.015
Upper Bad	Ballou	869	**0.032**	**0.046**	0.043	**0.036**	0.023	0.016
Upper Bad	City Creek	829	**0.023**	**0.1**	0.029	**0.019**	0.012	0.014
Upper Bad	Devils	2010	**0.026**	**0.034**	0.022	**0.027**	0.019	0.018
	Blank		ND	0	0	0	ND	0
	Duplicate		**0.03**	0.05	0.036	0.012	0.018	0.014
	Duplicate Location		Erickson	Montreal (809)	Apple	Potato - 463 Dup	Potato - Perry's	Apple
	Duplicate		**0.048**	0.012	0.048	**0.016**	0.023	0.018
	Duplicate Location		Barr	Gehrman	Javorsky	City Crk	Opergard	Montreal

Appendix B. Specific Conductance Results (µS/cm).

Bold indicates rain event

Basin	Stream	BRWA Site #	7/1/2014	7/23/2014	8/19/2014	9/20/2014	10/22/2014
		rain event?	Y&N	N	Y&N	N	N
Potato	Apple	2021	54	72	102	59	44
Potato	Potato	463	92	113	147	94	80
Potato	Potato at Perry's		91	115	151	95	83
Potato	Barr		191	216	270	187	187
Potato	Vaughn	1029	230	257	292	179	187
Potato	Vaughn	469	151	155	152	130	144
Tyler Forks	Erickson	17	136	152	**149**	119	110
Tyler Forks	Rouse	2014	118	143	**169**	119	91
Tyler Forks	Gehrman	885	127	146	170	153	131
Tyler Forks	Javorsky	23	127	122	**95**	86	77
Tyler Forks	Unnamed Tyler Forks Trib	2019	**34**	98	**132**	68	48
Tyler Forks	Bull Gus	32	**78**	108	**86**	60	53
Upper Bad	Bad at Caroline	2017	**38**	42	**51**	43	45
Upper Bad	Olson Rd						
Upper Bad	Bad in Mellen		48	93	113	67	64
Upper Bad	Bad at Gilman Park	785	**54**	87	**111**	62	62
Upper Bad	Montreal	809	86	98	**89**	62	58
Upper Bad	Opergard	2013	73	87	**80**	57	58
Upper Bad	Ballou	869	**57**	78	**74**	59	53
Upper Bad	City Creek	829	**80**	108	**122**	96	91
Upper Bad	Devils	2010	**94**	120	**116**	102	94

Appendix C. pH Results (standard units).

Bold indicates rain event

Basin	Stream	BRWA site #	7/1/2014	7/23/2014	8/19/2014	9/20/2014	10/22/2014
		rain event?	Y&N	N	Y&N	N	N
Tyler Forks	Erickson	17	7.39	7.40	**7.46**	7.23	6.94
Tyler Forks	Rouse	2014	6.76	7.08	**7.18**	6.87	6.93
Tyler Forks	Javorsky	23	7.21	7.34	**6.83**	6.82	6.92
Tyler Forks	Unnamed Tyler Forks Trib	2019	**6.61**	7.36	**7.25**	6.89	6.54
Tyler Forks	Bull Gus	32	**6.82**	6.95	**6.69**	6.83	6.77
Upper Bad	Bad at Caroline	2017	**6.51**	6.63	**6.47**	6.19	6.52
Upper Bad	Bad at Gilman Park	785	**7.27**	7.64	**7.50**	7.01	7.03
Upper Bad	Montreal	809	6.57	6.61	**6.71**	6.30	6.70
Upper Bad	Opergard	2013	7.36	7.42	**7.36**	7.02	7.07
Upper Bad	Ballou	869	**7.07**	7.28	**7.12**	6.76	6.90
Upper Bad	City Creek	829	**7.57**	7.62	**7.63**	7.33	7.27
Upper Bad	Devils	2010	**7.42**	7.57	**7.50**	7.33	7.24

Appendix D. Water Temperature Results (°C).

Bold indicates rain event

Basin	Stream	BRWA Site #	6/3/2014	7/1/2014	7/23/2014	8/19/2014	9/20/2014	10/22/2014
		rain event?	Y	Y&N	N	Y&N	N	N
Potato	Apple	2021	**16.5**	18.9	18.3	17.2	13.6	4.7
Potato	Potato	463	**19.0**	21.5	20.3	17.9	14.4	6.4
Potato	Potato at Perry's		**18.0**	21.1	21.9	18.1	14.1	6
Potato	Barr		**16.5**	17.4	17.5	14.7	13.5	6.1
Potato	Vaughn at Lower Rd	1029	**19.0**	23.1	21.0	17.4	13.9	7.7
Potato	Vaughn at Hwy 169	469	**16.0**	18.6	16.5	15.1	13.1	5.9
Tyler Forks	Erickson	17	**16.5**	17.5	16.5	**17.2**	13.3	5.1
Tyler Forks	Rouse	2014	**17.0**	18.4	17.6	**16.4**	13.5	6.2
Tyler Forks	Gehrman	885	**16.0**	16.6	16.0	15.1	13.5	5.6
Tyler Forks	Javorsky	23	**16.0**	18.1	16.8	**15.7**	13.2	5.2
Tyler Forks	Unnamed Tyler Forks Trib	2019	**17.0**	**17.2**	15.2	**12.7**	13.5	8.4
Tyler Forks	Bull Gus	32	**18.0**	**18.4**	18.9	**15.7**	14.1	5.7
Upper Bad	Bad at Caroline	2017	**21.5**	**21.3**	26.1	**20.8**	17.0	8.4
Upper Bad	Olson Rd		**17.0**					
Upper Bad	Bad in Mellen			20.5	19.5	17	13.5	5.8
Upper Bad	Bad at Gilman Park	785	**19.5**	**20.4**	21.9	**18.3**	14.6	7.1
Upper Bad	Montreal	809	**17.0**	19.6	18.9	**16.9**	13.7	5.4
Upper Bad	Opergard	2013	**17.5**	18.3	16.6	**16.4**	14.2	6.2
Upper Bad	Ballou	869	**17.0**	**19.1**	17.7	**15.9**	15.1	5.5
Upper Bad	City Creek	829	**15.5**	**15.8**	17.0	**14.8**	13.5	7.4
Upper Bad	Devils	2010	**16.0**	**16.8**	17.3	**15.4**	13.2	7.2

Appendix E. Quality Assurance for Temperature Probes.

NIST model 4244, S/N 130514523
Hannah model 98129 #1 (old probe) #2 (new probe)
RPD = Relative Percent Difference

Early Season 7/18/2014

Room Temperature			
	Hannah #2	NIST	RPD 2
measurement 1	19	18.99	0.053
measurement 2	19.1	19.07	0.157
measurement 3	19.1	19.11	-0.052
Ice Bath			
measurement 1	0.5	0.26	63.158
measurement 2	0.6	0.4	40.000
measurement 3	0.5	0.33	40.964

Post Season 10/26/2014

Room Temperature					
	Hannah #1	Hannah #2	NIST	RPD 1	RPD 2
measurement 1	9.7	9.6	9.63	0.724	-0.312
measurement 2	9.7	9.7	9.66	0.413	0.413
measurement 3	9.7	9.7	9.68	0.206	0.206
measurement 4	9.7	9.7	9.70	0.000	0.000
measurement 5	9.7	9.7	9.71	-0.103	-0.103
measurement 6	9.8	9.7	9.75	0.512	-0.514
measurement 7	9.8	9.7	9.75	0.512	-0.514
Ice Bath					
	Hannah #1	Hannah #2	NIST	RPD 1	RPD 2
measurement 1	1.2	1.7	0.82	37.624	69.841
measurement 2	0.9	1.1	0.81	10.526	30.366
measurement 3	0.9	1	0.82	9.302	19.780
measurement 4	0.9	1	0.87	3.390	13.904
measurement 5	0.9	1	0.91	-1.105	9.424
measurement 6	0.9	1	0.82	9.302	19.780
measurement 7	0.9	0.9	0.82	9.302	9.302