BUCK CREEK MONITORING PROJECT

CMI #2015-0524

PREPARED BY:

SCHREMS WEST MICHIGAN TROUT UNLIMITED

streamside ecological services

Timmermans Environmental Services, Inc.

October 23, 2017

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STATE OF MICHIGAN
DEQ
DEPARTMENT OF ENVIRONMENTAL QUALITY

Table of Contents

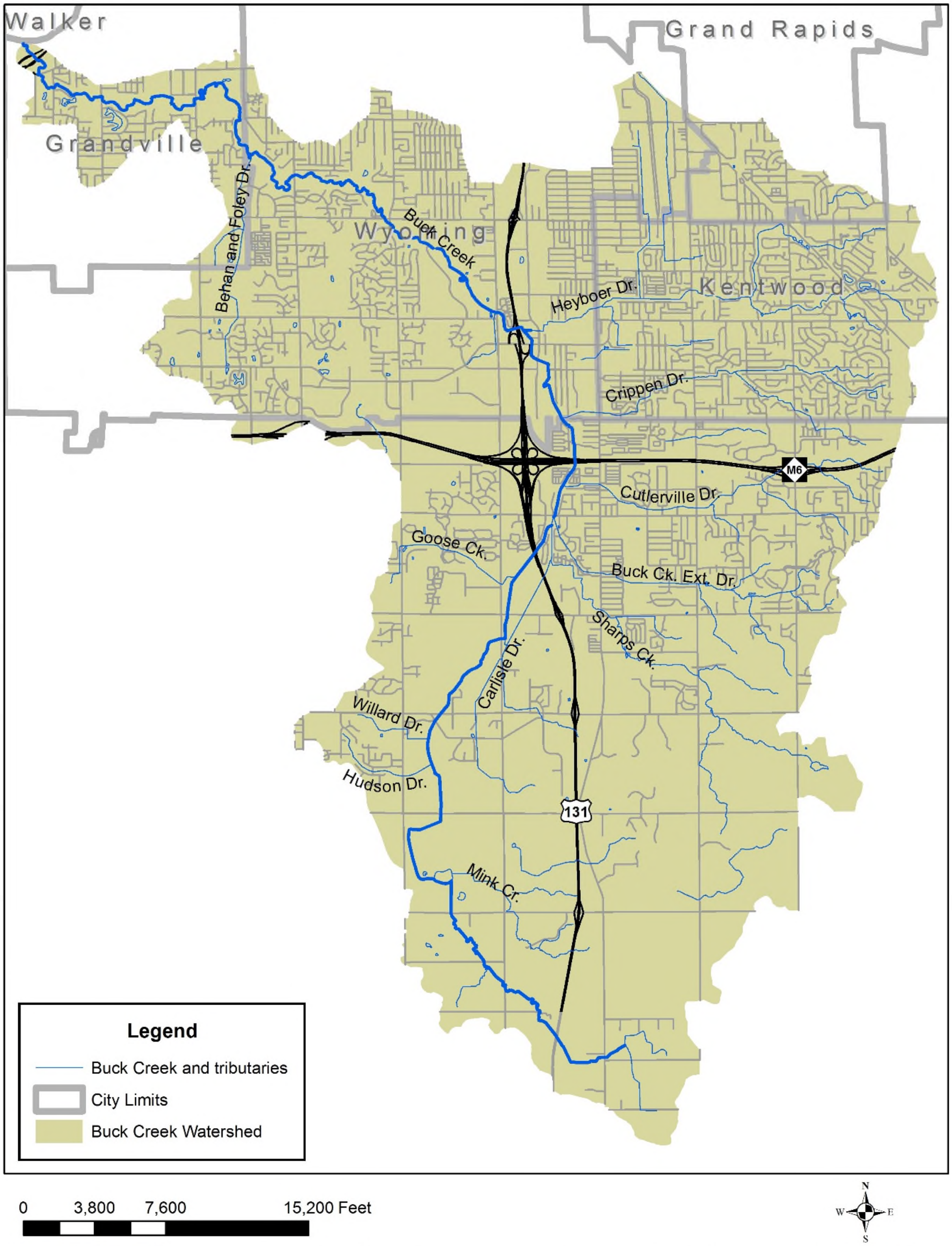
Introduction

Buck Creek, a tributary to the Grand River, drains about 51 square miles of land in portions of the Cities of Kentwood, Wyoming and Grandville, as well as the more rural areas of Byron and Gaines Township (Figure 1). The creek and its tributaries are currently listed as designated trout streams and have been stocked with brown trout for several years by the Michigan Department of Natural Resources (MDNR). Trout stocking was cancelled in 2012 due to ongoing degradation of the stream, until feedback from disgruntled anglers reversed this decision (Personal Communication, Scott Hanshue, MDNR Fisheries Biologist (2013)).

According to the Draft Grand River Assessment (Hanshue and Harrington 2011), “Buck Creek begins as a cold-transitional stream and changes to a warm-transitional stream in the lower half of the watershed. The stream flows through an urban environment and is the receiving water for relatively large amounts of stormwater runoff. Water temperature data for this stream is limited, but indicates that mean temperatures are at the upper thermal limits for supporting trout populations.” “It is possible the stream quality has declined and can no longer sustain a brown trout fishery; further evaluation of this management strategy should be conducted.” (Hanshue and Harrington 2011)

The latest fish survey of Buck Creek was conducted by MDNR in 2002 (Hanshue and Harrington). The results included 28 brown trout and one rainbow trout. An angler survey conducted during the 2002 trout season found an estimated 46 angler trips on Buck Creek, and reported no trout in the catch; however, reliable evidence suggests that a population of brown trout exists in the stream and provides for a fishery that includes several age classes (Personal Communication, Jim Bedford, Avid Buck Creek Angler (2014)).

Significant development of the watershed has led to a variety of impacts typically found in urban watersheds, including extreme hydrologic fluctuation, sedimentation and thermal pollution. The Lower Grand River Watershed Management Plan (LGROW 2011) lists Buck Creek as a critical area for restoration due to pollution by pathogens and bacteria, sediment and nutrients. This plan lists the coldwater fishery as being threatened by sediment and nutrients and as being impaired north of 84th Street to the limits of the City of Grandville, and severely impaired in Lemery Park and near Burlingame Avenue. The Draft Grand River Assessment recommended to “Survey water temperatures and trout survival in managed waters (e.g., Buck Creek, etc.) to determine if trout stocking is prudent...”. The Coldwater Fisheries Inventory for Kent County, MI report (Inventory), completed by Schrems West Michigan Trout Unlimited (Schrems) in 2012 (Schrems 2012), recommends working with MDNR and interested anglers to determine if Buck Creek should continue to be stocked with trout, completing a detailed assessment of water temperature, completing a thermal classification of Buck Creek and its tributaries, and conducting population estimates of trout. The 2014 Michigan Department of Environmental Quality (MDEQ) 303d list indicates that Buck Creek is not meeting its designated uses of partial and total body contact recreation due to Escherichia coli (*E. coli*) contamination (AUID 040500060508-01); a 2006 Total Maximum Daily Load (TMDL) details these *E. coli* issues.



SCHREMS WEST MICHIGAN TROUT UNLIMITED PO Box 230094 Grand Rapids, MI 49523	BUCK CREEK AND TRIBUTARIES	SES-15-27	FIGURE NO.
	Schrems TU - BUCK CREEK CMI	07/25/17	1

Successful implementation projects start with a sound, scientific approach to gathering as much background data and information as possible, and having a clear vision of goals and objectives. This strategy also provides the information necessary to establish 'baseline' conditions and is indispensable in determining overall benefits of improvement projects. This data is useful to project partners, MDNR, and MDEQ for setting management objectives and making decisions related to development and implementation of appropriate TMDLs. With these ideas in mind, the following goals and objectives were developed (and are described in greater detail in the paragraphs below) for the project:

Goal No. 1*: Compile a dataset to be used as a benchmark for past and future conditions, to document changes in Buck Creek, and to develop recommendations for long-term protection and enhancement.*

Goal No. 2: *Collect water chemistry parameters at 12 sites (previously determined within the 2011 Watershed Management Plan) based upon the strategy being established by the Lower Grand River Organization of Watersheds (LGROW) Data, Information and Procedures (DIP) Committee.*

> ***Objective No. 1:*** Collect water chemistry data, including, but not limited to, Dissolved Oxygen (DO), *E. coli*, fecal coliform, pH, bacterial oxygen demand (BOD), total phosphate, Nitrates (as N), Total Suspended Solids (TSS) and chlorides
>
> ***Objective No. 2:*** Install gage plates and measure discharge during four distinct runoff events. Develop a model for stream elevation versus discharge to estimate total pollutant loading

Goal No. 3: *Collect water chemistry parameters at one site using a continuously recording Hydrolab Data Sonde*

> ***Objective No. 1:*** Install Hydrolab Data Sonde at one location for the duration of the project

Goal No. 4: *Determine if Buck Creek is meeting its designated use as a coldwater fishery*

> ***Objective No. 1****:* Conduct water temperature monitoring at 20 locations (including 12 sites from Goal No. 2) to thermally classify the watershed
>
> ***Objective No. 2:*** Complete fish surveys at two locations, including population estimates for trout

Goal No. 5*: Establish a monitoring committee to review project progress and results, and to serve as the foundation of an organized leadership group committed to the long-term management of Buck Creek*

Methods

A project committee was formed at the onset of the project to periodically review work progress, results and planning. This committee consisted of: Pete Miller and Steve Frendt, Schrems; Aaron Vis, City of Wyoming; Jim Beke, City of Kentwood; Martha Vermuelen, Friends of Buck Creek; Dana Strouse, MDEQ; Aaron Snell, Streamside Ecological Services, Inc.; Gary Mast, Timmermans Environmental Services and; Brad Boomstra, Kent County Drain Commissioner's Office. The project committee met three times over the duration of the project, though not all members were able to attend each meeting. All methods used for this project were approved by the project committee and are included in a Quality Assurance Project Plan that was approved on September 23, 2015.

Water Temperature

Scientific literature supports the idea that water temperature is the most critical factor affecting trout distribution in a stream. Water temperature was monitored June through October, using Onset HOBO® Water Temp Pro V2 data loggers. Loggers were programmed to record water temperature every hour for the duration of their deployment. Data were downloaded using HOBOware Pro (v.3.2.0) and analyzed in an Excel spreadsheet developed by Mr. Dave Smith, Michigan Trout Unlimited. The scoring parameters for the MITU spreadsheet are based on the following criteria (Hamilton and Seelbach 2011):

- **Cold** = July mean water temperature ≤63.5° F (17.5°C)
- **Cold-transitional** = July mean water temperature >63.5° F (17.5°C) and ≤67° F (19.5°C)
- **Cool (or warm transitional)** = July mean water temperature >67° F (19.5°C) and ≤70° F (21°C)
- **Warm** = July mean water temperature >70° F (21°C)

The MITU Summer Score is based upon the minimum, mean and maximum water temperatures, and duration of those temperatures, during the months of June, July and August. The higher the score, the more likely it is that trout will survive in the stream. Generally, a minimum score of 6 is necessary for long-term success of trout populations.

Part 4 of the WQC, R 323.1075, Rule 75 states that "(1) Rivers, streams, and impoundments naturally capable of supporting coldwater fish shall not receive a heat load which would do either of the following: (a) Increase the temperature of the receiving waters at the edge of the mixing zone more than 2 degrees Fahrenheit above the existing natural water temperature. (b) Increase the temperature of the receiving waters at the edge of the mixing zone to temperatures greater than the following monthly maximum temperatures". The July maximum temperature is 68°F.

Water Chemistry

Dissolved Oxygen (DO), *E. coli*, fecal coliform, pH, BOD, total phosphate, Nitrates (as N), Total Suspended Solids (TSS) and chlorides were monitored quarterly for one year at 12 sites. These parameters were identified by the Lower Grand River Organization of Watersheds' (LGROW) DIP Committee as important for developing a watershed quality indicator (based on National Sanitation Foundation's (NSF) recommended indicators), determining the effect of Best Management Practices at both public and private sites, and determining compliance with TMDLs. All samples were collected and analyzed by the City of Wyoming Clean Water Plant and Drinking Water Plant laboratory. *E. coli* samples were collected and analyzed using a multiple tube fermentation method reported in MPN (Most Probable Number). This method is different than the traditional membrane filtration or Colony Forming Unit (CFU) method, in that it is an index of the number of coliform bacteria most likely to give the results produced during testing, whereas the membrane filter procedure enables the analyst to actually count coliform colonies. The precision of this method can be rather low unless many sample portions are examined (APHA 2012). The City of Wyoming was approved by the EPA in December 2013 to use the IDEXX QUANTI-TRAY 2000 system for their analysis. This system is capable of detecting down to one organism per 100ml and has a 95% confidence limit better than a 5 or 10 tube MPN. It also has a 95% confidence limit better or comparable to membrane filtration (https://www.idexx.com/water/products/quanti-tray.html 2017). While not an exact count of the colonies as is done in the plated method, the QUANTI-TRAY method removes or significantly lowers a large portion of the human error component that leads to such as pipette error, contamination, counting errors and false positives. While the EPA does not officially recognize the direct 1:1 correlation of a MPN result to a CFU result, City of Wyoming lab staff have conducted testing that concludes that a direct correlation exists. For discussion purposes, the MPN numbers contained within this report can be compared to a CFU value.

Stream Discharge and Pollutant Loading

Stream discharge was measured at water quality monitoring site 2WCT during five distinct flow events, using a Marsh-McBirney flow meter. The stream discharge was measured at the remaining water quality monitoring sites during four distinct flow events. Discharge measurements were compared to stream elevation read from a staff gage installed at each site. Discharge measurements were used to determine annual pollutant loading, and to evaluate whether streamflow is diluting sources of pollution between sampling stations, etc.

Hydrolab Data Sonde

A Hydrolab Data Sonde 4A was installed at one secure location. This unit was programmed to monitor water temperature, pH, dissolved oxygen (mg/L and % saturation), specific conductivity and total dissolved solids at 15 minute intervals. This unit was deployed for approximately two weeks from October 26, 2015 to November 10, 2015; and approximately 19 weeks from April 15, 2016 to August 26, 2016.

Biology

Fish surveys were conducted at two sites with barge electrofishing equipment, following standard mark-recapture (Lockwood and Schneider 2000) protocols, as recommended by MDNR-Fisheries. All trout captured were counted and measured; trout captured during the first run were marked with a tail clip. The second run was conducted the following day to compare numbers of marked vs. unmarked individuals. All other species collected over the first 500 feet on the first day were identified and counted. If new species were encountered in the remaining 500 feet of sample length, the species was noted. Physical habitat was also rated at each site, in accordance with the Great Lakes Environmental Assessment Section (GLEAS) Procedure No. 51 (MDEQ 1990).

Results

Water Temperature

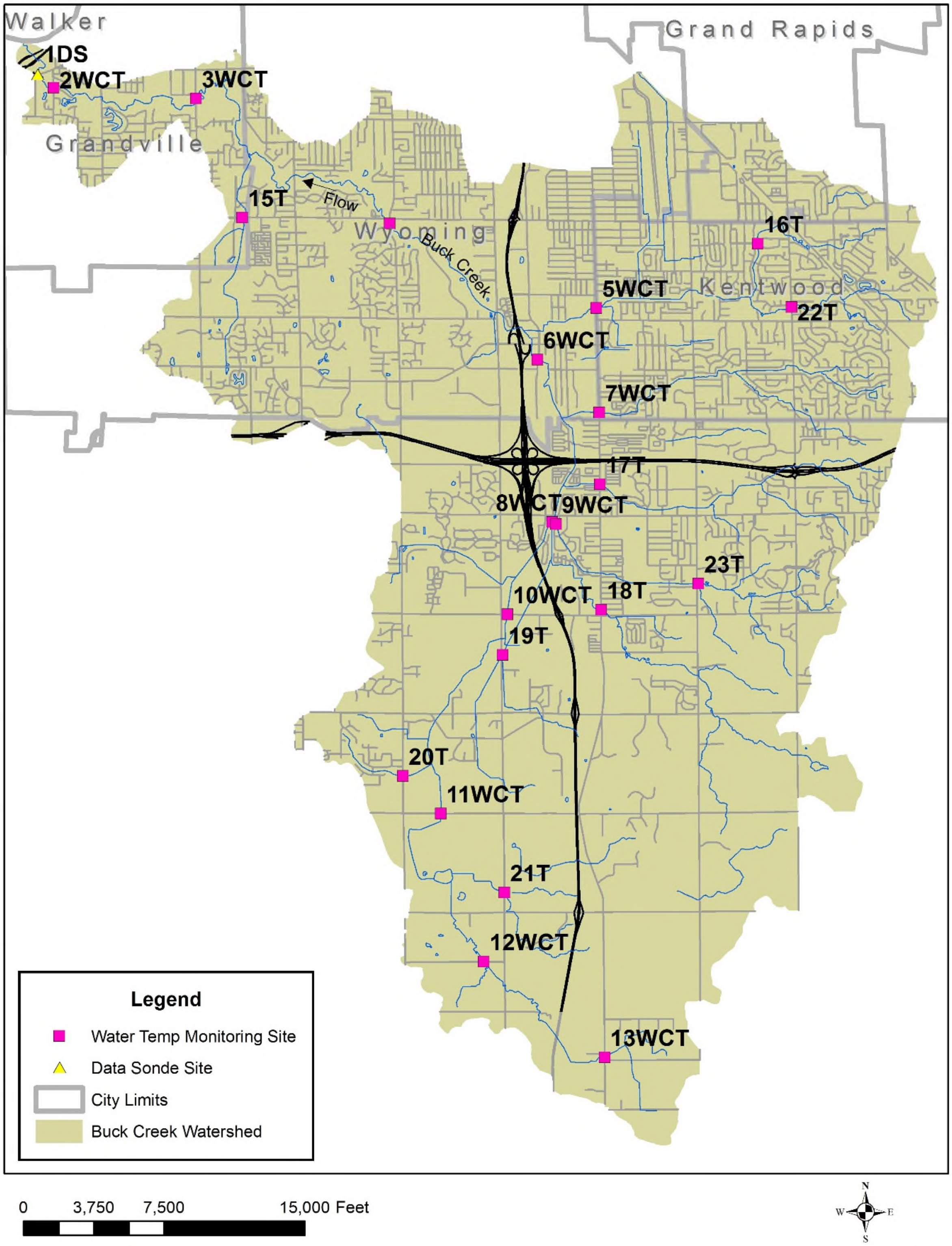
Water temperature data was collected at a total of 22 sites during 2015 and 2016 (Figure 2). Loggers were initially placed at 15 locations in the beginning of June and removed in late October 2015; though one logger was temporarily lost under sediment and remained in the stream for over one year. Another seven loggers were deployed from the beginning of June to the end of October, 2016, to fill data gaps and answer additional questions that arose from the 2015 sampling; one of these loggers (14T) was permanently lost. Monthly data summaries for all sites are included in Appendix A.

Table 1 shows mean and maximum July water temperatures, as well as the MITU Summer Score for each site. Mean July water temperature is also depicted in Figure 3, along with the upper mean thermal limit (67°F) for trout.

The upper reaches of Buck Creek appear to be managed strictly as an agricultural drain, with little regard for ecological communities or processes. The water temperatures associated with this upper section are very high, but cool rapidly as the stream receives cooler water from Mink Creek and the Hudson Drain in the vicinity of 100th Street.

From approximately 84th Street downstream to Ivanrest, on the mainstem of Buck Creek, water temperatures cool to the extent that they are conducive to the long-term survival of trout and other coldwater species. Sharps Creek (18T) received the highest summer score due to coldest mean and maximum temperatures. Buck Creek (2WCT) and Cutlerville Drain (17T) nearly meet the requirements of cold-transitional streams. Conversely, Buck Creek at Ivanrest (3WCT) and Carlisle Drain (19T) are pushing the upper limit for trout and slight warming could make these stream reaches too warm. Based upon the data collected, Figure 4 illustrates the thermal classification of most major stream reaches in the watershed.

Weather and air temperature have impacts on water temperature. Mean July air temperature was relatively cool (72.7°F) during stream temperature monitoring in July 2016. During a warmer summer, it is possible that temperature classifications will shift into a warmer category for some of the sites that were near the maximum of their current classification.



SCHREMS WEST MICHIGAN Environmentally Involved Since 1962 TROUT UNLIMITED	PO Box 230094 Grand Rapids, MI 49523	MONITORING SITES - WATER TEMPERATURE		FIGURE NO.
		Schrems TU - BUCK CREEK CMI	SES-15-27 07/25/17	2

Table 1. Average and Maximum July Water Temperatures in the Buck Creek and its Tributaries, 2015 and 2016.

				July Water Temp (F)		
Site ID	Stream	Road	Classification	Mean	Maximum	Meeting Coldwater Designation (<67.1 F mean)
1DS	Buck Creek	Chicago Drive	Cool	69.6	76.3	No
2WCT	Buck Creek	Canal	Cool	67.5	74.5	No
3WCT	Buck Creek	Ivanrest	Cold-Transitional	66.8	72.1	Yes
4WCT	Buck Creek	Burlingame	Cold-Transitional	65.7	71.6	Yes
5WCT	Heyboer Drain	Division	Cool	67.9	79.1	No
6WCT	Buck Creek	Clay	Cold-Transitional	65.0	73.0	Yes
7WCT	Crippen Drain	Division	Warm	70.8	84.1	No
8WCT	Buck Creek	68th	Cold-Transitional	65.3	71.5	Yes
9WCT	Buck Creek Ext. Drain	68th	Cold-Transitional	64.3	74.5	Yes
10WCT	Buck Creek	76th	Cold-Transitional	65.9	73.9	Yes
11WCT	Buck Creek	92nd	Warm	71.9	81.0	No
12WCT	Buck Creek	104th	Warm	71.9	81.0	No
13WCT	Buck Creek	Division	Warm	71.6	83.1	No
15T	Behan and Foley Drain	44th	Cool	69.8	80.5	No
16T	Heyboer Drain	Curwood	Cool	69.6	77.6	No
17T	Cutlerville Drain	Division	Cool	67.6	75.0	No
18T	Sharps Creek	Division	Cold-Transitional	64.2	68.4	Yes
19T	Carlisle Drain	Clyde Park	Cold-Transitional	65.6	77.1	Yes
20T	Hudson Drain	Burlingame	Cool	68.0	76.9	No
21T	Mink Creek	Clyde Park	Cool	69.6	79.7	No
22T	Heyboer Drain	Kalamazoo	Cool	69.6	80.4	No
23T	Buck Creek Ext. Drain	Eastern	Cool	67.4	78.2	No

***Shaded cells are sites located on designated county drains.**

Cold = July mean water temperature ≤63.5° F (17.5°C)

Cold-transitional = July mean water temperature >63.5° F (17.5°C) and ≤67° F (19.5°C)

Cool (or warm transitional) = July mean water temperature >67° F (19.5°C) and ≤70° F (21°C)

Warm = July mean water temperature >70° F (21°C)

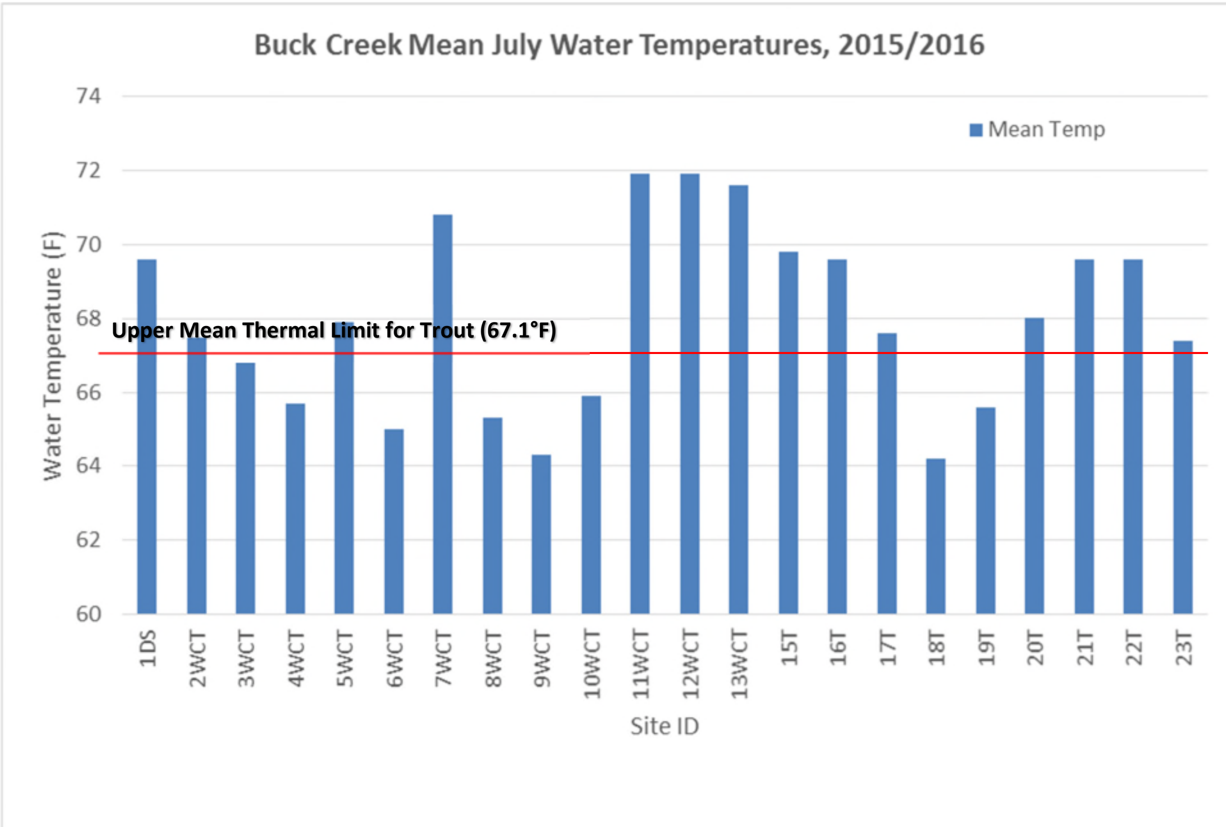
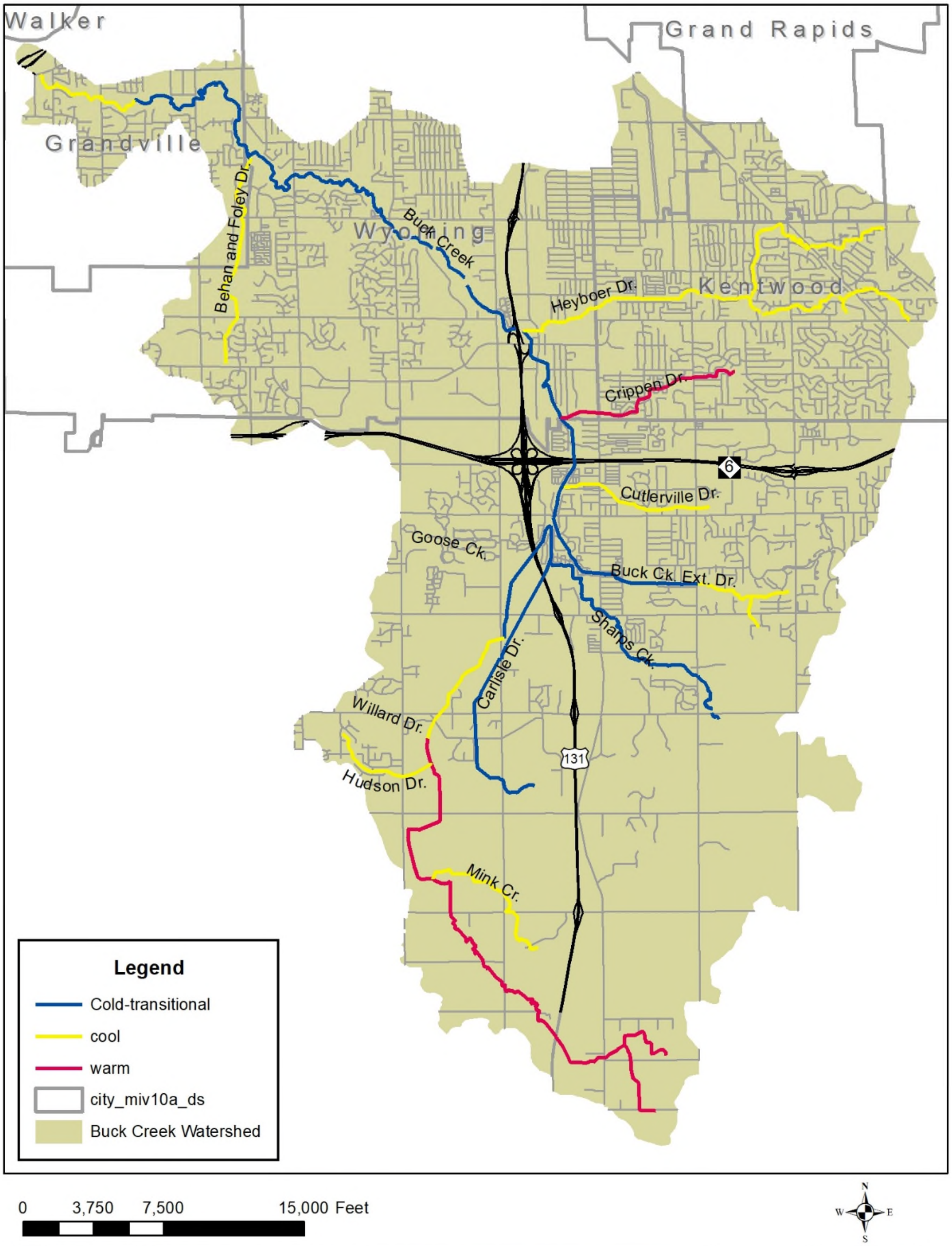


Figure 3. Buck Creek Mean July Water Temperatures, 2015/2016.



SCHREMS WEST MICHIGAN TROUT UNLIMITED PO Box 230094 Grand Rapids, MI 49523	THERMAL CLASSIFICATION	SES-15-27	FIGURE NO. 4
	Schrems TU - BUCK CREEK CMI	08/30/17	

Water Chemistry

When available, Michigan Part 4 Water Quality Criteria (WQC) Rules were used to understand where nutrient concentrations were excessive throughout the Buck Creek Watershed. If a Water Quality Criteria (WQC) does not exist, sampling results were compared to those collected across US EPA Ecoregion VII (Southern Michigan/Northern Indiana Drift Plains Ecoregion (SMNIDP) sites) or WQC developed by other states. Table 2 summarizes the target values used to assess pollutants of concern within the watershed.

Table 2. Water Quality Criteria and Comparable Standards for Buck Creek Water Chemistry Sampling.

Parameter	Target Value	Units	WQC or Comparable	Type	Source
E. coli	130	cfu/100 mL	WQC	Total Body Contact Recreation in all waters of the state. Calculated as a 30-day geometric mean from 5 or more sampling events.	Michigan Department of Environmental Quality Water Bureau Water Resources Protection. (2006, January 13). Part 4 Water Quality Standards
E. coli	300	cfu/100 mL	WQC	Total Body Contact in all waters of the state	Michigan Department of Environmental Quality Water Bureau Water Resources Protection. (2006, January 13). Part 4 Water Quality Standards
E. coli	1,000	cfu/100 mL	WQC	Partial Body Contact in all waters of the state	Michigan Department of Environmental Quality Water Bureau Water Resources Protection. (2006, January 13). Part 4 Water Quality Standards
Water Temperature	67.1	Deg F July mean	WQC	Coldwater Fishery	Michigan Department of Natural Resources Water Withdrawal Assessment Tool.
Dissolved Oxygen	7	mg/L	WQC	Waters connected to Great Lakes	Michigan Department of Environmental Quality Water Bureau Water Resources Protection. (2006, January 13). Part 4 Water Quality Standards.
Dissolved Oxygen	5	mg/L	WQC	All other waters	Michigan Department of Environmental Quality Water Bureau Water Resources Protection. (2006, January 13). Part 4 Water Quality Standards.
pH	6.0 – 9.0	SU	WQC	All surface waters of the state	Michigan Department of Environmental Quality Water Bureau Water Resources Protection. (2006, January 13). Part 4 Water Quality Standards.
Chloride	230	mg/L	WQC	Chronic, four-day average	Vermont Department of Environmental Conservation. 2014.
Chloride	860	mg/L	WQC	Acute, one-hour average	Vermont Department of Environmental Conservation. 2014.
Ammonia (NH3-N)	0.042	mg/L	C	Mean concentration calculated from SMNIDP ecoregion sites	Lundgren, R. 1994. Reference Site Monitoring Report 1992-1993. Michigan Department of Natural Resources, Surface Water Quality Division, Lansing, Michigan. Report No. MI/DNR/SWQ-94-048.
Total Phosphorus	0.0313	mg/L	C	Ambient WQ criteria recommendations; 25th percentile of ecoregion stream population	Ambient Water Quality Criteria Recommendations: Information Supporting the Development of State and Tribal Nutrient Criteria: Rivers and Streams in

					Nutrient Ecoregion VII. US EPA 822-B-00-018). Washington D.C.
Total Suspended Solids	80	mg/L	C	Informal target	
Total Kjeldahl Nitrogen	0.24	mg/L	C	Ambient WQ criteria recommendations; 25th percentile of region stream population	United State Environmental Protection Agency Office of Water Office of Science and Technology Health and Ecological Criteria Division. (2000, December). Ambient Water Quality Criteria Recommendations: Information Supporting the Development of State and Tribal Nutrient Criteria: Rivers and Streams in Nutrient Ecoregion VII. US EPA 822-B-00-018). Washington D.C.
Nitrite and Nitrate- as Nitrogen (measured only NO3-N)	0.41	mg/L	C	Ambient WQ criteria recommendations; 25th percentile of ecoregion stream population	Ambient Water Quality Criteria Recommendations: Information Supporting the Development of State and Tribal Nutrient Criteria: Rivers and Streams in Nutrient Ecoregion VII. US EPA 822-B-00-018). Washington D.C.

Five data collection events occurred at twelve sites throughout the Buck Creek watershed (Table 3; Figure 5). The majority of the sites were located on Buck Creek itself (2WCT, 3WCT, 4WCT, 6WCT, 8WCT, 10WCT, 11WCT, 12WCT, and 13WCT), while other locations were sampled prior to their confluence with Buck Creek (5WCT, 7WCT, and 9 WCT). The sampling events occurred on a quarterly basis, from the third quarter of 2015 to the fourth quarter of 2016.

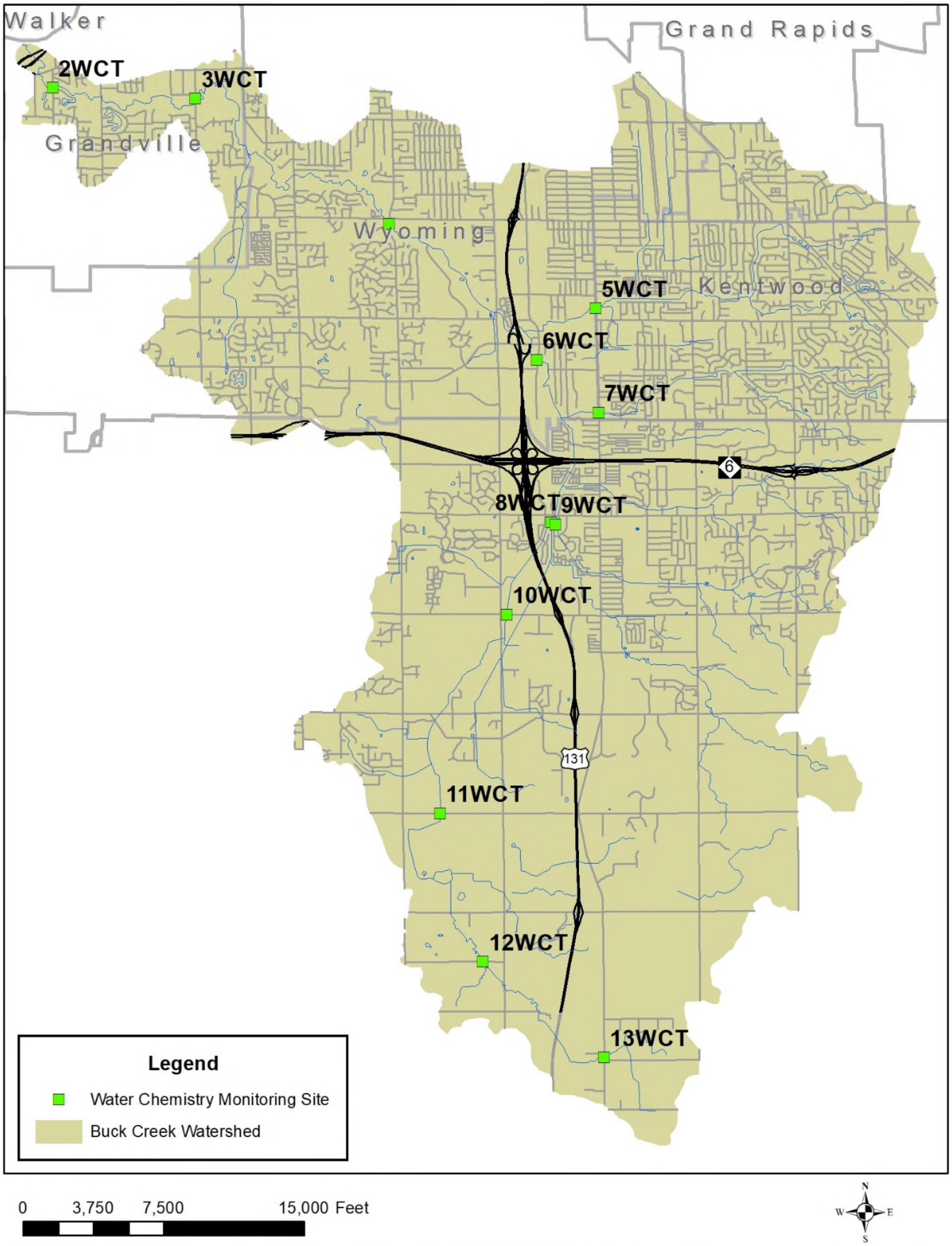
Table 3. Water Chemistry Monitoring Sites in the Buck Creek Watershed.

Site ID	Stream	Road
2WCT	Buck Creek	Canal
3WCT	Buck Creek	Ivanrest
4WCT	Buck Creek	Burlingame
5WCT	Heyboer Drain	Division
6WCT	Buck Creek	Clay
7WCT	Crippen Drain	Division
8WCT	Buck Creek	68th
9WCT	Buck Creek Ext. Drain	68th
10WCT	Buck Creek	76th
11WCT	Buck Creek	92nd
12WCT	Buck Creek	104th
13WCT	Buck Creek	Division

The water chemistry data is included in Table 4, and is presented on a site-specific basis. The average, maximum and minimum values are presented. Graphs presenting the mean average water chemistry data for each monitoring station are provided in Appendix B. Following are summaries of the results on a parameter basis:

1. **Ammonia** results were fairly consistent throughout all sampling sites. Average ammonia results ranged from 0.02 to 0.09 mg/L, with lower values generally observed near the outlet of Buck Creek. At some point during sampling, ammonia levels at all sites exceeded the regional comparison values. While not indicated on the tables, the highest level at each site occurred in the June and August 2016 sampling events while the lowest occurred in November 2015 and March 2016. This indicates that it is likely that fertilizer or other runoff, both in the urban and rural areas, contributed to the increased ammonia values.
2. **Biochemical oxygen demand (BOD)** is a measurement that is used primarily in wastewater treatment in order to determine the amount of oxygen needed to break down organic material in a solution. The higher the BOD number, the larger amount of organic material is present. BOD results were fairly consistent through the more urban areas of the watershed at about 0.5 mg/L. However, the upstream and more rural areas (11WCT, 12WCT, and 13WCT) of the watershed exhibited BOD values ranging from 1.0 to 3.74 mg/L. When compared to traditional wastewater BOD levels, the results from the sampling events are relatively low.
3. Average **chloride** results ranged from 51.1 to 167.2 mg/L throughout the watershed. Chlorides are a result of the breakdown of both road salt and synthetic fertilizer. The chloride concentrations generally increase heading downstream. The highest chloride concentrations occurred in the urban areas (2WCT, 3WCT, 4WCT, 6WCT) and in the spring (March 2016) and summer (August) sampling events. The March result indicates that the source of the chloride could be road salt, while the August results indicate that sources may be fertilizer. Concentrations in the urban areas were generally two to three times higher than rural areas. The highest value detected was 251.7 mg/L (5WCT), less than the EPA acute standard of 860 mg/L.
4. Average ***E. coli*** values across the watershed ranged from 255 to 1,970 MPN. Lower values were noted at the headwaters and near the outlet of Buck Creek. The highest values were observed at the 5WCT, 6WCT, 7WCT, 8WCT and 9WCT locations, which are located in the most urban portions of the watershed. *E. coli* is a measurement of a bacterium that lives in the gut of humans, livestock and wildlife. All of these areas where increased elevated values were observed are serviced by a sanitary sewer system. Thus, it is unlikely that the increased values are caused by humans; rather, it is likely that the source is animal in nature, likely pet or waterfowl. All sites, at some point, had *E. coli* levels that exceeded the Michigan full body contact water quality standard. Also, the *E. coli* levels periodically exceeded the Michigan partial body contact water quality standard at 5WCT, 6WCT, 7WCT, 8WCT and 9WCT.
5. Indicative of fertilizers, **nitrate and nitrite** values were higher at each site during the June and August 2016 sampling events. Fluctuations at each site were minimal. Variations between most sites were not significant. The exceptions were tributary location 7WCT and headwater location 13WCT, which had notably higher nitrate and nitrite concentrations. All of the sites had average values that exceeded the EPA Region VII Ambient Water Quality Criteria Recommendations.

6. **pH** values remained relatively consistent throughout all sampling sites with the exception of site 2WCT, located nearest Buck Creeks confluence with the Grand River. The average pH of site 2WCT was 6.48, with one event recorded at 5.7 which is below the Michigan pH water quality standard range of 6.0 to 9.0 SU. The average values of the remaining sites ranged from 7.4 to 8.
7. **Phosphorus and soluble reactive phosphorus** are also indicative of fertilizer use. Geographically, the rural areas upstream and south of Byron Center (sites 10WCT, 11WCT, 12WCT and 13WCT) had phosphorus values over six times higher than the urban sites, with the most downstream site (13WCT) having an average value about 13 times higher than those in the urban area. Interestingly, seasonality does not seem to play a part in the phosphorus concentrations, as almost no fluctuation was seen within each site. The previously mentioned rural sites had average phosphorous results that exceed the EPA Region VII Ambient Water Quality Criteria Recommendations.
8. **Total Kjeldahl Nitrogen (TKN)** refers to the total concentration of nitrogen in ammonia combined with organic nitrogen, and is another measurement of fertilizer. TKN values were consistent throughout the sampling sites with the exception of headwater location 13WCT, which was about two times higher than the remaining sites. While some seasonal fluctuation occurs at each site, it is minimal and does not seem to be correlated to season change. As with the nitrate/nitrite results, all average values exceeded the EPA Region VII Ambient Water Quality Criteria Recommendations.
9. **Total Suspended Solids (TSS)** is a measurement of mostly inorganic materials (sediment, sand, silt) but also organics such as algae or decomposing material. This parameter is indicative of soil loss or erosion. Values in the urbanized area of the watershed had an average value under 8 mg/L. The upstream and rural portions of the watershed (sampling sites 10WCT, 11WCT, 12WCT and 13WCT) had average values ranging from 8.2 to 37 mg/L.



SCHREMS WEST MICHIGAN TROUT UNLIMITED PO Box 230094 Grand Rapids, MI 49523	MONITORING SITES - WATER CHEMISTRY	SES-15-27	FIGURE NO. 5
	Schrems TU - BUCK CREEK CMI	8/30/17	

Table 4. Buck Creek Concentration Sampling (3rd Qtr 2015 - 4th Qtr 2016)

PARAMETER	2WCT			3WCT			4WCT		
	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
Ammonia (mg/L)	0.02	0	0.06	0.036	0	0.07	0.06	0.04	0.09
BOD (mg/L)	0.5	0	2	0.54	0	2	0.54	0	2
Chloride (mg/L)	121.74	19.5	164	121.26	18.1	165	123.14	18	164
E. coli (MPN/100mL)	368.79	30.3	633.3	361.46	56.05	609.8	438.83	79.65	781.8
Nitrate (mg/L)	1.18	0.976	1.4	1.21	1	1.39	1.14	0.937	1.41
Nitrite (mg/L)	0.0078	0	0.09	0.008	0	0.03	0.0084	0	0.03
pH (SU)	6.48	5.7	7.8	7.98	7.4	8.5	7.98	7.7	8.1
Phosphorus (mg/L)	0.012	0	0.06	0.012	0	0.06	0.012	0	0.06
Soluble Reactive Phosphorus (mg/L)	0.012	0	0.06	0.012	0	0.06	0.012	0	0.06
TKN (mg/L)	0.48	0.348	0.612	0.37	0.24	0.474	0.35	0.21	0.508
TSS (mg/L)	7.40	2	13	5.40	2	12	4.80	2	8

PARAMETER	5WCT			6WCT			7WCT		
	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
Ammonia (mg/L)	0.09	0.05	0.16	0.07	0.05	0.09	0.05	0	0.11
BOD (mg/L)	0.54	0	2	0.58	0	2	0.58	0	2
Chloride (mg/L)	167.24	17.5	251.7	102.30	17.3	139	91.28	21	119.4
E. coli (MPN/100mL)	899.73	157.9	1578.9	613.04	97	1259.7	1970.38	248.15	2381.5
Nitrate (mg/L)	1.34	1.06	1.78	0.95	0.72	1.3	1.91	1.61	2.17
Nitrite (mg/L)	0.0142	0	0.04	0.0086	0	0.03	0.0824	0	0.4
pH (SU)	7.60	6.8	8.1	7.70	7.5	8	8.02	7.4	8.4
Phosphorus (mg/L)	0.012	0	0.06	0.012	0	0.06	0.012	0	0.06
Soluble Reactive Phosphorus (mg/L)	0.012	0	0.06	0.012	0	0.06	0.012	0	0.06
TKN (mg/L)	0.46	0.15	0.66	0.37	0.26	0.428	0.35	0.198	0.515
TSS (mg/L)	3.60	2	6	8.00	6	11	4.80	2	12

PARAMETER	8WCT			9WCT			10WCT		
	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
Ammonia (mg/L)	0.07	0.05	0.1	0.07	0.05	0.1	0.07	0.05	0.1
BOD (mg/L)	0.56	0	2	0.52	0	2	0.62	0	2
Chloride (mg/L)	91.14	19.4	128	51.06	21.1	75.2	75.04	18.1	100
E. coli (MPN/100mL)	596.20	58.5	1605.1	733.48	55.5	1775.4	261.69	55.95	444.6
Nitrate (mg/L)	0.88	0.673	1.26	0.73	0.521	1.03	0.94	0.69	1.42
Nitrite (mg/L)	0.008	0	0.03	0.0054	0	0.02	0.0116	0	0.04
pH (SU)	7.74	7.5	8.2	8.12	7.5	9.3	7.50	7.3	7.7
Phosphorus (mg/L)	0.012	0	0.06	0.012	0	0.06	0.042	0	0.15
Soluble Reactive Phosphorus (mg/L)	0.012	0	0.06	0.012	0	0.06	0.034	0	0.11
TKN (mg/L)	0.38	0.204	0.564	0.35	0.14	0.52	0.46	0.29	0.812
TSS (mg/L)	7.80	4	10	7.20	2	14	10.20	3	16

PARAMETER	11WCT			12WCT			13WCT		
	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
Ammonia (mg/L)	**0.09**	0	**0.19**	**0.036**	0	**0.08**	**0.08**	**0.05**	**0.14**
BOD (mg/L)	**1.94**	**1.7**	**2**	**1**	0	**2**	**3.74**	**3**	**4.7**
Chloride (mg/L)	**57.16**	**17.9**	**71.7**	**83.74**	**18.9**	**136**	**52.96**	**18.5**	**82.3**
E. coli (MPN/100mL)	**254.28**	**14.89**	**591.3**	**569.48**	**260.5**	**925.9**	**394.05**	**54.7**	**815.6**
Nitrate (mg/L)	**0.80**	**0.464**	**1.82**	**1.09**	**0.59**	**1.3**	**1.40**	**0.412**	**3.5**
Nitrite (mg/L)	**0.0178**	0	**0.06**	**0.0086**	0	**0.04**	**0.114**	0	**0.5**
pH (SU)	**7.52**	**7.1**	**7.9**	**7.76**	**7.6**	**8**	**7.70**	**7.6**	**7.9**
Phosphorus (mg/L)	**0.032**	0	**0.1**	**0.064**	0	**0.12**	**0.14**	**0.11**	**0.16**
Soluble Reactive Phosphorus (mg/L)	**0.012**	0	**0.06**	**0.058**	0	**0.1**	**0.044**	0	**0.1**
TKN (mg/L)	**0.60**	**0.27**	**1.036**	**0.46**	**0.353**	**0.724**	**1.10**	**0.874**	**1.46**
TSS (mg/L)	**12.80**	**6**	**26**	**8.20**	**4**	**12**	**37.20**	**22**	**51**

Table 5 indicates which sites had exceedances of WQC or comparison values for the parameters sampled.

Table 5. Exceedances of Water Quality Criteria or Comparison Values.

Site ID	Stream	Road	Exceeds WQC or comparison value
2WCT	Buck Creek	Canal	Ammonia; E. coli; nitrate and nitrite; TKN; pH
3WCT	Buck Creek	Ivanrest	Ammonia; E. coli; nitrate and nitrite; TKN
4WCT	Buck Creek	Burlingame	Ammonia; E. coli; nitrate and nitrite; TKN
5WCT	Heyboer Drain	Division	Ammonia; E. coli; nitrate and nitrite; TKN
6WCT	Buck Creek	Clay	Ammonia; E. coli; nitrate and nitrite; TKN
7WCT	Crippen Drain	Division	Ammonia; E. coli; nitrate and nitrite; TKN
8WCT	Buck Creek	68th	Ammonia; E. coli; nitrate and nitrite; TKN
9WCT	Buck Creek Ext. Drain	68th	Ammonia; E. coli; nitrate and nitrite; TKN
10WCT	Buck Creek	76th	Ammonia; E. coli; nitrate and nitrite; phosphorus; TKN
11WCT	Buck Creek	92nd	Ammonia; E. coli; nitrate and nitrite; phosphorus; TKN
12WCT	Buck Creek	104th	Ammonia; E. coli; nitrate and nitrite; phosphorus; TKN
13WCT	Buck Creek	Division	Ammonia; E. coli; nitrate and nitrite; phosphorus; TKN

Stream Discharge and Pollutant Loading

Concurrent to water chemistry (concentration) sampling, discharge was measured at the same 12 sampling sites to calculate pollutant loading. Stream stage was recorded at each site during discharge monitoring to develop a relationship between the two variables (Appendix C). An effort was made to measure discharge proximate in time to the concentration sampling, but was not always possible.

The stream gage plates at 3WCT and 6WCT were knocked down during the winter of 2015/2016. As a result, the stage heights were not monitored during the subsequent water chemistry sampling and discharge measurement activities. However, the stage heights were estimated to generate the 3WCT and

6WCT stage/discharge graphs. The estimated stage values were established by comparing stream depth data collected during discharge measurements before and after the gage plates were knocked down.

The water chemistry data and stream discharge corresponding to the stage height at the time of sample collection were utilized to calculate the loading values for each parameter. The average, minimum and maximum loading data for each monitoring location are summarized in Table 6. In general, the loading values increased downstream as a direct result of increased discharge, with the exception of loading values for 3WCT and 6WCT. However, the average loading data for 3WCT and 6WCT are based on only one and three water quality sampling event data sets, respectively, since the stream stage elevations were unknown during several of the quarterly sampling events.

Table 6. Buck Creek Pollutant Loading (3rd Qtr 2015 - 4th Qtr 2016)

PARAMETER	2WCT (5 events)			3WCT (1 event)			4WCT (4 events)		
	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
Ammonia (mg/sec)	**25**	0	**68**	**22**	**22**	**22**	**51**	**30**	**74**
Chloride (mg/sec)	**136,062**	**16,565**	**281,708**	**13,377**	**13,377**	**13,377**	**90,367**	**10,959**	**154,058**
E. coli (MPN/sec)	**$2.2x10^6$**	**532,818**	**$7.8x10^6$**	**$1.0x10^6$**	**$1.0x10^6$**	**$1.0x10^6$**	**$3.0x10^6$**	**597,123**	**$6.6x10^6$**
Nitrate (mg/sec)	**1,325**	**265**	**2,374**	**850**	**850**	**850**	**830**	**475**	**1,127**
Nitrite (mg/sec)	**9.4**	0	**34**	0	0	0	**9.6**	0	**25**
Phosphorus (mg/sec)	**17**	0	**86**	0	0	0	**17**	0	**68**
Soluble Reactive Phosphorus (mg/sec)	**17**	0	**86**	0	0	0	**17**	0	**68**
TKN (mg/sec)	**563**	**94**	**1,076**	**180**	**180**	**180**	**295**	**127**	**580**
TSS (mg/sec)	**8,411**	**1,699**	**14,725**	**1,478**	**1,478**	**1,478**	**3,848**	**1,218**	**6,570**

PARAMETER	5WCT (5 events)			6WCT (3 events)			7WCT (5 events)		
	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
Ammonia (mg/sec)	**13**	**5.1**	**24**	**48**	**24**	**70**	**0.7**	0	**3.1**
Chloride (mg/sec)	**26,891**	**1,784**	**42,051**	**74,751**	**46,839**	**116,609**	**4,141**	**1,223**	**9,974**
E. coli (MPN/sec)	**969,152**	**263,803**	**$2.3x10^6$**	**$5.2x10^6$**	**$4.2x10^6$**	**$7.1x10^6$**	**510,303**	**124,266**	**$2.1x10^6$**
Nitrate (mg/sec)	**205**	**110**	**297**	**563**	**243**	**832**	**129**	**25**	**367**
Nitrite (mg/sec)	**2.2**	0	**6.0**	**9.9**	0	**17**	**2.3**	0	**11**
Phosphorus (mg/sec)	**2.4**	0	**12**	**20**	0	**60**	**0.1**	0	**0.7**
Soluble Reactive Phosphorus (mg/sec)	**2.4**	0	**12**	**20**	0	**60**	**0.1**	0	**0.7**
TKN (mg/sec)	**74**	**15**	**132**	**252**	**144**	**394**	**20**	**5.8**	**58**
TSS (mg/sec)	**549**	**306**	**902**	**5,253**	**2,359**	**10,052**	**242**	**23**	**442**

PARAMETER	8WCT (5 events)			9WCT (4 events)			10WCT (5 events)		
	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
Ammonia (mg/sec)	**50**	**17**	**121**	**2.7**	**1.4**	**3.7**	**14**	**6.7**	**24**
Chloride (mg/sec)	**59,995**	**7,691**	**110,668**	**2,117**	**974**	**4,429**	**14,680**	**3,116**	**26,108**
E. coli (MPN/sec)	**$1.9x10^6$**	**442,295**	**$7.5x10^6$**	**137,288**	**32,689**	**648,531**	**397,048**	**158,433**	**900,941**
Nitrate (mg/sec)	**615**	**143**	**1,178**	**34**	**12**	**61**	**197**	**66**	**402**
Nitrite (mg/sec)	**8.6**	0	**36**	**0.2**	0	**0.7**	**2.6**	0	**9.8**
Phosphorus (mg/sec)	**8.0**	0	**40**	0	0	0	**7.2**	0	**26**
Soluble Reactive Phosphorus (mg/sec)	**8.0**	0	**40**	0	0	0	**5.9**	0	**19**

TKN (mg/sec)	**277**	**43**	**547**	**14**	**5.2**	**27**	**96**	**39**	**230**
TSS (mg/sec)	**5,295**	**1,586**	**12,148**	**291**	**91**	**511**	**2,090**	**516**	**4,531**

	11WCT (5 events)			**12WCT (5 events)**			**13WCT (5 events)**		
PARAMETER	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
Ammonia (mg/sec)	**3.7**	0	**13**	**0.4**	0	**0.7**	**1.1**	**0.4**	**1.9**
Chloride (mg/sec)	**7,554**	**201**	**30,049**	**1,244**	**321**	**2,467**	**916**	**120**	**1,862**
E. coli (MPN/sec)	**46,747**	**5,481**	**156,635**	**73,40**	**44,259**	**158,328**	**34,680**	**12,912**	**127,480**
Nitrate (mg/sec)	**170**	**1.3**	**763**	**21**	**5.8**	**63**	**32**	**2.7**	**112**
Nitrite (mg/sec)	**0.9**	0	**4.2**	**0.1**	0	**0.4**	**1.0**	0	**3.3**
Phosphorus (mg/sec)	**0.5**	0	**2.2**	**0.9**	0	**2.0**	**2.1**	**0.9**	**3.8**
Soluble Reactive Phosphorus (mg/sec)	**0.4**	0	**2.2**	**0.8**	0	**1.7**	**0.6**	0	**1.9**
TKN (mg/sec)	**100**	**2.0**	**434**	**8.5**	**3.6**	**23**	**20**	**5.7**	**47**
TSS (mg/sec)	**2,452**	**23**	**10,896**	**145**	**68**	**374**	**599**	**163**	**1,536**

Hydrolab DataSonde

The Hydrolab Data Sonde 4A was installed at monitoring station 2WCT. The frequency of data downloads, equipment maintenance and water quality sensor calibrations ranged from one to two weeks. The data collected during the two week period in 2015 did not meet the project quality control objectives due to dissolved oxygen and temperature sensor malfunctions. As a result, the 2015 data were not part of the data evaluation. The pH sensor malfunctioned on a few occasions during the 2016 monitoring period. The Hydrolab operational summary for data collected in 2016 is provided below in Table 7.

Hydrolab Data Sonde 4a Operational Period: April 15, 2016 – August 26, 2016				
Parameter	Data Set (days)	Mean Ave. Value	Minimum Value	Maximum Value
Water Temperature (degrees F)	120.04	64.5	47.3	76.5
Specific Conductivity (uS/cm)	120.04	934	222	1,209
Total Dissolved Solids (mg/L)	120.04	598	142	774
Dissolved Oxygen (mg/L)	120.04	5.8	2.9	11.1
Dissolved Oxygen Saturation (%)	120.04	62.3	30.9	106.4
pH (SU)	101.33	7.8	5.8	9.2

The following graphs of the 2016 Hydrolab data are provided in Appendix D:

- Water Temperature vs. Dissolved Oxygen Concentration
- Precipitation vs. Dissolved Oxygen % Saturation
- Precipitation vs. Specific Conductivity
- Precipitation vs. Total Dissolved Solids
- Precipitation vs. pH

Hourly precipitation data was obtained from the Michigan Celery Cooperative automated weather monitoring station in Hudsonville, Michigan, which is part of the Enviro-weather Weather Station Network. The Hydrolab was programmed to record the water quality parameters every 15 minutes. An hourly mean average was calculated for each water quality parameter for graphing purposes. The general results of each parameter are as follows:

1. **Temperature** results for 2016 were fairly consistent with the 2015 data collected with the Hobo temperature data logger at monitoring station 2WCT. A daily cyclic pattern was usually observed during periods of no precipitation. The minimum daily water temperature occurred between approximately 8:00 am to 10:00 am. The maximum daily water temperature occurred late afternoon to early evening. Short term water temperature spikes routinely occurred during and immediately following a rainfall event.
2. **Dissolved Oxygen** concentrations generally exhibited a daily cyclic pattern. The peak dissolved oxygen concentrations typically occurred early afternoon. The minimum dissolved oxygen concentrations occurred during overnight shortly after midnight. The daily cyclic trend appears to be driven primarily by the water temperature since dissolved oxygen concentration is inversely related to water temperature. However, daily fluctuations in the water temperature are not the sole source of the cyclic nature of dissolved oxygen since the daily maximum and minimum water temperatures do not mirror the minimum and maximum dissolved oxygen values. The observed offset between the maximum and minimum cycles of water temperatures and dissolved oxygen concentrations is likely a result day time sun exposure and associated oxygen production from plant and algae photosynthesis. During evening hours, the plants and algae in turn consume oxygen. Only 13.9% of the dissolved oxygen data was at, or greater than, the Michigan minimum dissolved oxygen water quality standard of 7.0 mg/L.
3. **Dissolved Oxygen Percent Saturation** represents the amount of oxygen dissolved in water relative to the maximum amount of dissolved oxygen that could be present based on the corresponding water temperature, salinity and atmospheric pressure. The dissolved oxygen percent saturation values sometimes exceed 100% in streams due to rapidly tumbling water (i.e. aeration) or discharge of relatively cool groundwater into the stream. Dissolved oxygen percent saturation values within the range of 80% to 120% are considered excellent for fish and aquatic organisms. Values less than 60% or greater than 125% are considered harmful and indicative of degraded water quality. Approximately 59.6% of the dissolved oxygen data was above the minimum 60% saturation threshold. Less than 1% of the data fell within the range considered excellent for fish and aquatic organisms.
4. **Conductivity** is a measure of the ability of water to conduct an electrical current. The conductivity of most waters typically ranges from 10 to 1,000 uS/cm. Specific conductivity values were generally at the high end of the typical range for most waters during extended dry periods when most, if not all, of the surface water in the stream originates from groundwater discharge. Significant decreases in specific conductivity occurred during or immediately following most precipitation events, which is an indicator of a significant volume of low conductivity surface water runoff entering the stream corridor.

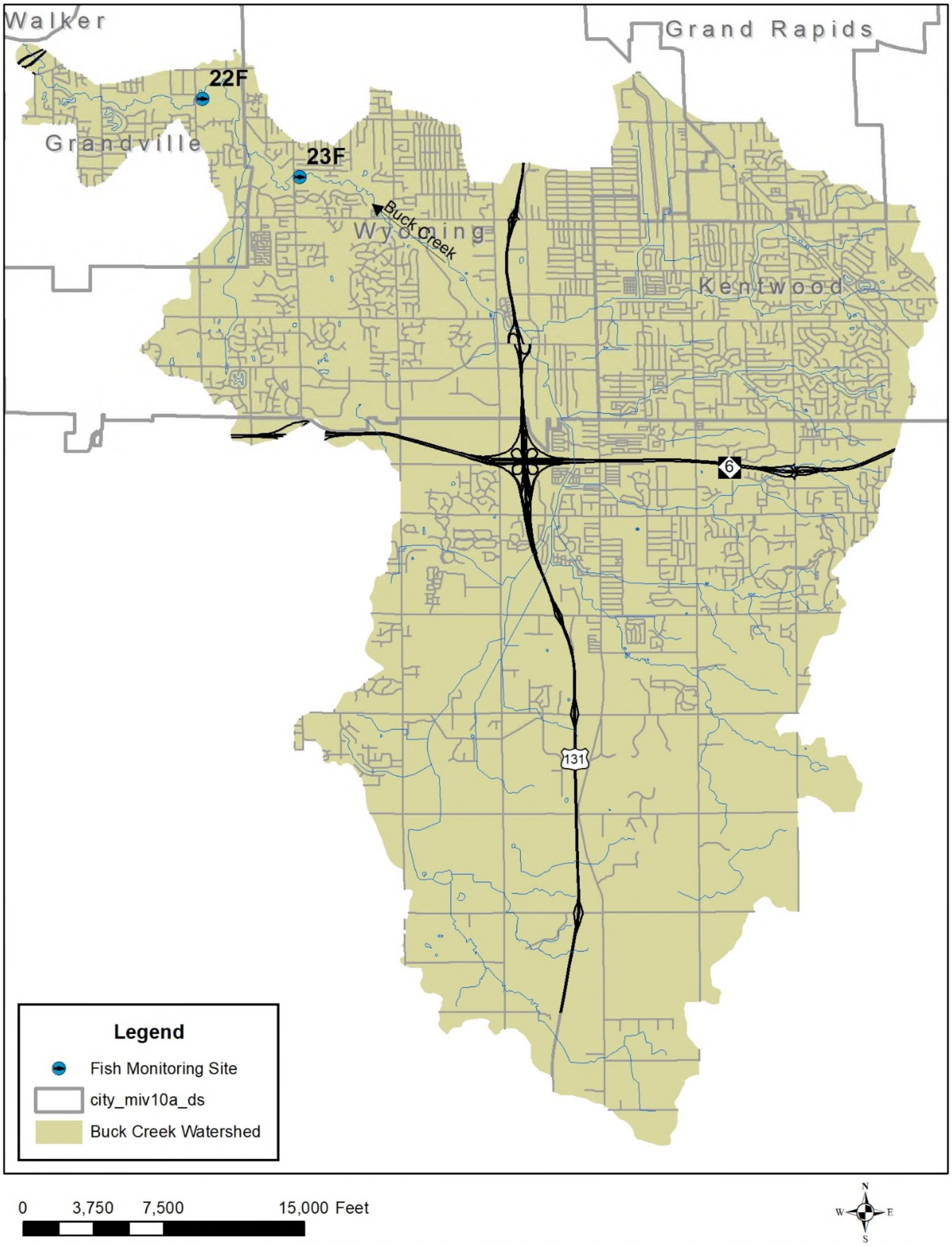
5. **Total Dissolved Solids** are directly related to conductivity. Typical dissolved solids include sodium, calcium, magnesium, bicarbonate, chloride and agricultural related nutrients such as nitrate, phosphate and sulfate. The Hydrolab total dissolved solids data are calculated from the specific conductivity data. Therefore, the total dissolved solids graph is essentially identical to the specific conductivity graph. Total dissolved solids for healthy lakes and streams commonly range from 50 to 250 mg/L. Approximately 97.5% of the total dissolved solids data exceed 250 mg/L. The elevated total dissolved solids is likely due to elevated chlorides in groundwater, since quarterly laboratory data are indicative of an increasing chloride concentration trend heading downstream, and the highest total dissolved solids concentrations occur during baseflow conditions. The most likely source of chlorides is the use of road salt during the winter months.

6. The pH data generally exhibited a slight daily cyclic pattern (i.e. approximately 0.2 SU) that appears to correlate with water temperature fluctuations. The pH values peaked during late afternoon or early evening at maximum water temperature. In contrast, pH values were generally at a minimum during morning hours when water temperatures were also at a daily minimum. However, the pH fluctuations are not driven by water temperature since pH is inversely related to water temperature in pure water. Therefore, the daily increase in pH is likely associated with daytime photosynthesis by plants and algae. Conversely, the drop in pH levels during the evening hours is likely associated with aquatic organism respiration and associated increase in dissolved carbon dioxide concentration. Notable short-term drops in pH may correlate with significant rainfall events. The rainfall correlation is likely associated with surface runoff, which is significant based on the specific conductivity and total dissolved solids trends. Approximately 98.4% of the pH data fell within the Michigan pH water quality range of 7.0 to 9.0 SU.

Biology

Fish surveys were completed on the mainstem of Buck Creek at the Grandville Cemetery (22F) and at Lemery Park (23F), on October 13 and 14, 2015 (Figure 6). Conditions were optimal for completing the survey, with relatively low, clear water.

At the cemetery site, a total of 136 trout were captured, measured, marked and released on October 13 (Appendix E). The following day, 107 brown trout, 48 of which had been marked, were captured, resulting in a population estimate of 1,549 trout per mile of stream (420 trout/acre). Trout ranged from three to 15 inches in size, with about 22% of fish being at least eight inches in length, the legal size for harvest. Most trout (56%) were six to eight inches in length. Four trout were under five inches and presumed to be wild based upon their small size relative to the initial size of stocked trout. About 7% of the trout collected were presumed to be at least two years of age, based upon their larger size. Twenty-one other species of fish were collected at the site, with a diverse mix of cold, cool and warmwater species. White sucker was the dominant species.



SCHREMS WEST MICHIGAN TROUT UNLIMITED	PO Box 230094 Grand Rapids, MI 49523	BUCK CREEK SAMPLING SITES		FIGURE NO.
		Schrems TU - BUCK CREEK CMI	SES-15-27 08/30/17	6

At Lemery Park, only six brown trout and three rainbow trout were captured during the marking run – too few to complete a reliable population estimate. Brown trout were, on average, larger in size than those at the cemetery and likely greater than one year old. Only nine species of fish were collected and the community was dominated by approximately equal numbers of white sucker, round goby, mottled sculpin and johnny darter. Overall, numbers and diversity of fish seemed low for the relatively high-quality habitat.

Relative to other brown trout streams in the region, and disregarding the numbers of fish stocked, the size of the trout population in Buck Creek (420/acre) appears to be comparable. Bear Creek (Kent County) had an estimated 350 trout/acre (Bear Creek is not stocked), Coldwater River had around 315 trout/acre and Tyler Creek (Kent County) averaged about 800 trout/acre during fish surveys conducted over the past five years (SES, unpublished).

Procedure No. 51 physical habitat assessments were also conducted at these two sites (Table 7). At Lemery Park, epifaunal habitat is relatively abundant and diverse in the form of woody debris and vegetation. Substrate is impacted by fine sediments, though a bit of gravel and manmade riffles do exist. Deep holes with overhanging banks and debris jams provide excellent cover. Flow appears to be very flashy and, along with excess sedimentation, appears to be the primary reason for degradation of this site. The stream corridor is quite natural on the north bank and upstream of the maintained park area. Within the park, parking lot runoff and erosion from foot traffic are evident.

The Grandville Cemetery is bordered by residential development on the upstream side, and associated impacts to the riparian corridor are prevalent. The southern stream bank, however, is in natural condition and contains many mature trees that help shade the stream. Overall, the habitat at the cemetery is slightly better than that at Lemery Park. A nice combination of riffles, runs and both shallow and deep pools are present. Overhanging vegetation and woody debris harbored many fish. The stream appears to be flashy here as well, but is better equipped to handle high flows due to accessible floodplains. The impacts of fine sediment are not as profound as the park site.

Table 7. Physical habitat summary (P51) at two Buck Creek fish sampling sites, 2016.

	Buck Creek		Buck Creek
	Lemery Park		Grandville Cemetery
HABITAT METRIC			
Substrate and Instream Cover			
Epifaunal Substrate/ Avail Cover	15		16
Embeddedness	9		12
Velocity/Depth Regime	12		12
Channel Morphology			
Sediment Deposition	9		11
Flow Status - Maint. Flow Volume	6		7
Flow Status - Flashiness	2		3
Channel Alteration	15		15
Frequency of Riffles/Bends	14		15
Riparian and Bank Structure			
Bank Stability (L)	6		7
Bank Stability (R)	6		7
Vegetative Protection (L)	5		8
Vegetative Protection (R)	5		4
Riparian Veg. Zone Width (L)	3		9
Riparian Veg. Zone Width (R)	9		2
TOTAL SCORE (200):	116		128
HABITAT RATING:	GOOD		GOOD
	(SLIGHTLY		(SLIGHTLY
	IMPAIRED)		IMPAIRED)

Discussion

The goals of this project were to establish baseline conditions, to collect water chemistry data and compare them to regional standards, and to determine if Buck Creek is meeting its coldwater fishery designation. Based upon the data collected, Buck Creek is impacted by a variety of issues, but somehow maintains high enough water quality to harbor trout and other coldwater species in portions of the watershed.

Water chemistry parameters including *E. coli,* ammonia, nitrate and nitrite and Total Kjeldahl Nitrogen, appear to be problems throughout the watershed, since they exceed WQC or regional comparison values. Phosphorus is a major pollutant in the upper watershed. Elevated chlorides are likely associated with road salt applications during the winter months, which typically increases groundwater concentrations in the spring. The data are also supported by the Hydrolab specific conductivity and total dissolved solids data collected near the mouth of Buck Creek (2WCT). Specifically, the conductivity and total dissolved solids peak during dry weather conditions when groundwater influx represent the source of water the stream.

E. coli bacteria, which are associated with fecal contamination and typically indicate presence of other pathogens, bacteria and viruses, appears to be one of the pollutants of greatest concern. *E. coli* concentrations throughout the Buck Creek Watershed exceed WQC, meaning that the stream is not meeting its designated uses of partial and/or full body contact recreation and should not be used for these purposes. The highest values were found within the most urbanized areas of the watershed. The communities where the elevated levels of *E. coli* occurred have sewer use ordinances that mandate connection to the sanitary sewer system. Thus it is very unlikely that illicit connections exist where human sewage could be contributing to Buck Creek. Additionally, all MS4 communities in the Lower Grand River Watershed have conducted illicit discharge monitoring at least once in the last five years. Therefore, it is more likely that the *E. coli* source are from sources other than humans.

E. coli Recommendations:

- *Sources of E. coli should be identified to determine appropriate remediation for this pollutant. This work should be coordinated with MDEQ to ensure that methods and temporal aspects of sampling are acceptable.*
- *Future E. coli monitoring should be conducted to evaluate success of any BMP implementation.*

Excessive nutrients, particularly nitrates, appear to be a ubiquitous problem in Buck Creek. All sites had nitrate/nitrite and TKN values that exceed EPA ambient water quality criteria recommendations. Ammonia levels were also elevated throughout Buck Creek. The nitrate/nitrite and ammonia nutrients had the highest concentration during the summer (June and August) sampling events, indicating that fertilizer runoff is a likely contributor. The TKN results were consistently high throughout the watershed and did not appear to seasonally fluctuate as dramatically as the nitrate/nitrite and ammonia results did. The ammonia, nitrate/nitrite and TKN values remained relatively consistent between the urban and rural areas.

Another nutrient, phosphorus, exceeded WQC in the more rural areas of the watershed, where levels were six times higher than the urban sites, with the most downstream site (13WCT) having an average value that was 13 times higher than those in the urban area. Seasonality does not seem to play a part in the phosphorus concentrations as almost no fluctuation was seen within each site. It is presumed that agricultural inputs are responsible for the phosphorus pollution. Excessive phosphorus can fuel nuisance growth of algae and macrophytes, which are both readily apparent in the stream south of Byron Center Road.

Nutrient recommendations:

- *Determine sources and causes of phosphorus pollution in the upper watershed.*
- *Continue nutrient sampling as part of normal watershed monitoring.*
- *Work with the Grand River watershed groups to develop and/or use educational programs about fertilizer, both in the rural and urban areas.*
- *Follow-up sampling should be conducted to determine the extent of the nutrient problems, and to determine if exceedances may be related to excessive runoff during precipitation events and/or baseflow concentrations.*

The water temperature data collected for this study represents the most significant effort to thermally classify Buck Creek and its tributaries. In contrast to Hanshue and Harrington (2011), results of this study indicate that the headwaters are warm, but the water cools as it nears the lower portions of the watershed. Despite warm water associated with agricultural land use in the upper watershed and high-density urban development in the rest of the watershed, the stream cools enough from groundwater contribution (i.e. baseflow) and contains a fish community to be considered a designated coldwater stream (DNR) from approximately 84th Street downstream to Ivanrest. Mean July water temperatures were used to classify this stream reach as "cold-transitional". This portion of Buck Creek is meeting its use as a designated coldwater stream, pursuant to Part 4 of the WQC.

Buck Creek (2WCT) and Cutlerville Drain (17T) nearly meet the requirements of cold-transitional streams. Conversely, Buck Creek at Ivanrest (3WCT) and Carlisle Drain (19T) are pushing the upper limit for trout and slight warming, or a warmer than average summer, could make these stream reaches too warm. At several sites, the maximum July water temperatures could negatively impact trout populations, especially if colder water refuges, such as springs or groundwater seeps, are scarce or not accessible. Sharps Creek (18T) appears to be especially important for protection since it was the coldest site in the study area.

Not only are stream temperatures favorable for trout, fish surveys confirmed their presence (along with associated coldwater species) and indicate that Buck Creek is meeting its coldwater designation at the Grandville Cemetery. Based only upon population estimates derived from fish surveys, and not considering the numbers of fish stocked, etc., the size of the trout population at the Grandville Cemetery appears to be consistent with those of other, similarly sized, streams in the region.

Despite having cooler water than the cemetery site, the data indicate that the trout population is depressed near Lemery Park. Though, the few trout captured during electrofishing surveys were, on average, larger in size and likely survived multiple years in the stream. Anglers do report good fishing for large brown trout in this reach. It is possible that the habitat near Lemery Park, with sandy substrate, and more deep holes and runs than the cemetery, favors lower numbers of larger trout.

Data collected during this study indicates that environmental factors are conducive to trout survival for at least a single season. It is also evident from the survey data that some trout are surviving year-round, some for multiple years. Anecdotal evidence from anglers indicates that Buck Creek provides the environment necessary to grow low to moderate numbers of large trout; however, data also supports the suggestion that the coldwater fishery is threatened by water temperature in several reaches and impaired near Lemery Park.

In addition to elevated water temperature, reasons for threats or impairments to the coldwater fishery might include degraded water quality and/or physical habitat. Results of monitoring indicate that the stream is flashy and impacted by excessive sediment. Hydrolab data shows that levels of dissolved oxygen and total dissolved solids are far from ideal for supporting a high-quality aquatic community, and could be limiting the survival of sensitive aquatic species. The role of elevated levels of nutrients and, chlorides, is unclear.

Coldwater Recommendations:

- *Explore opportunities to implement best management practices throughout the watershed, with emphasis at the aforementioned sites, to cool the stream.*
- *Planting/Protecting riparian vegetation is obviously important. Large-scale removal of vegetation, especially along the south and west streambanks, should be discouraged. Local ordinances could be used to protect stream corridors.*
- *Wetland restoration or other "pre-treatment" of stormwater runoff would be beneficial. Direct runoff of stormwater during summer storms, especially from hot surfaces such as roofs and asphalt, can increase stream temperatures dramatically.*
- *Continue monitoring to decipher impacts of summer air temperature and precipitation on water temperature.*
- *All sources of sediment should be identified and sediment input should be quantified. Priority areas include those sites that show impacts to stream habitat. Known sources should be stabilized as soon as possible.*

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APPENDIX A

WATER TEMPERATURE AT BUCK CREEK SAMPLING STATIONS

Score based on Mean and Peak July Temperatures							
Min July Temp (Deg F)	**Max July Temp (Deg F)**	**Category**	**Thrive Species**	**Base Score for Mean Temp**	**Score Modifier for Peak Temp**	**Min July Temp (Deg C)**	**Max July Temp (Deg C)**
50.00	55.00	Cold	Population is nearly all Coldwater Species. All Trout Tolerate	8	0	10.00	12.78
55.00	59.00	Cold	Population is nearly all Coldwater Species. Brook Trout Thrive. All trout tolerate	9	0	12.78	15.00
59.00	63.50	Cold	Population is nearly all coldwater species. All Trout Thrive.	10	2	15.00	17.50
63.50	65.00	Cold-Transitional	Fish community is mostly coldwater fish. All Trout Thrive.	9	2	17.50	18.33
65.00	67.00	Cold-Transitional	Fish community is mostly coldwater fish. All Trout Thrive.	8	0	18.33	19.44
67.00	70.00	Cool	Fish community is mostly warmwater, but some coldwater fish are present. Trout will Tolerate.	6	-1	19.44	21.11
70.00	72.00	Warm	The fish community is nearly all warmwater fish. Trout will marginally Tolerate.	4	-2	21.11	22.22
72.00	75.00	Warm	The fish community is nearly all warmwater fish. Trout will marginally Tolerate.	2	-4	22.22	23.89
75.00		Warm	Warmwater fish. Lethal for all but some large trout.	1	-5	23.89	-17.78

1DS

Based on July Data

DNR Designation

Cool

MITU July Score

1

MITU Summer Score (Jun, Jul, Aug)

1.67

	Mean Temp °F	Min Temp °F	Max Temp °F	Std Dev
Jan				
Feb				
Mar				
Apr				
May				
Jun	65.21	56.41	73.85	3.37
Jul	69.61	61.98	76.33	3.39
Aug	70.27	64.94	76.54	2.68
Sep				
Oct				
Nov				
Dec				

2WCT

Based on July Data

DNR Designation

Cool

MITU July Score

2

MITU Summer Score (Jun, Jul, Aug)

4.33

	Mean Temp °F	Min Temp °F	Max Temp °F	Std Dev
Jan				
Feb				
Mar				
Apr				
May				
Jun	64.40	63.13	65.83	0.91
Jul	67.49	60.35	74.51	3.07
Aug	67.05	59.79	74.68	3.34
Sep	64.51	56.12	73.00	4.20
Oct	55.75	50.93	60.52	2.46
Nov				
Dec				

3WCT

Based on July Data

DNR Designation

Cold-Transitional

MITU July Score

4

MITU Summer Score (Jun, Jul, Aug)

6.00

	Mean Temp °F	Min Temp °F	Max Temp °F	Std Dev
Jan				
Feb				
Mar				
Apr				
May				
Jun	63.63	62.53	64.59	0.53
Jul	66.78	60.30	72.05	2.74
Aug	66.43	59.87	72.57	3.12
Sep	64.04	55.60	73.30	4.08
Oct	55.67	51.02	60.43	2.32
Nov				
Dec				

4WCT

Based on July Data

DNR Designation

Cold-Transitional

MITU July Score

6

MITU Summer Score (Jun, Jul, Aug)

6.67

	Mean Temp °F	Min Temp °F	Max Temp °F	Std Dev
Jan				
Feb				
Mar				
Apr				
May				
Jun	62.79	60.39	65.27	1.60
Jul	65.69	57.89	71.58	3.22
Aug	65.41	58.46	72.61	3.34
Sep	63.37	54.47	74.16	4.11
Oct	55.87	51.28	61.42	2.41
Nov				
Dec				

5WCT

Based on July Data

DNR Designation

Cool

MITU July Score

1

MITU Summer Score (Jun, Jul, Aug)

2.00

	Mean Temp °F	Min Temp °F	Max Temp °F	Std Dev
Jan				
Feb				
Mar				
Apr				
May				
Jun	65.02	57.12	74.81	3.86
Jul	67.89	58.20	79.08	4.03
Aug	68.87	61.80	78.03	3.23
Sep	64.23	56.86	74.73	3.56
Oct	59.40	50.49	74.94	4.04
Nov				
Dec				

6WCT

Based on July Data

DNR Designation

Cold-Transitional

MITU July Score

4

MITU Summer Score (Jun, Jul, Aug)

6.33

	Mean Temp °F	Min Temp °F	Max Temp °F	Std Dev
Jan				
Feb				
Mar				
Apr				
May				
Jun	62.67	59.87	65.79	1.95
Jul	65.03	57.33	72.96	3.54
Aug	64.54	57.94	73.65	3.48
Sep	62.77	53.82	73.56	4.09
Oct	55.80	51.15	61.25	2.58
Nov				
Dec				

7WCT

Based on July Data

DNR Designation

Warm

MITU July Score

0

MITU Summer Score (Jun, Jul, Aug)

0.33

	Mean Temp °F	Min Temp °F	Max Temp °F	Std Dev
Jan				
Feb				
Mar				
Apr				
May				
Jun	68.25	56.69	81.55	6.11
Jul	70.82	57.94	84.14	5.29
Aug	70.52	60.95	84.23	4.65
Sep	64.82	54.73	78.43	4.71
Oct	58.83	48.09	72.83	4.44
Nov				
Dec				

8WCT

Based on July Data

DNR Designation

Cold-Transitional

MITU July Score

6

MITU Summer Score (Jun, Jul, Aug)

7.00

	Mean Temp °F	Min Temp °F	Max Temp °F	Std Dev
Jan				
Feb				
Mar				
Apr				
May				
Jun	63.04	60.90	65.62	1.36
Jul	65.29	58.67	71.45	2.81
Aug	64.71	58.80	72.87	2.92
Sep	62.85	53.91	72.01	4.01
Oct	53.59	50.93	57.72	1.84
Nov				
Dec				

9WCT

Based on July Data

DNR Designation

Cold-Transitional

MITU July Score

5

MITU Summer Score (Jun, Jul, Aug)

6.67

	Mean Temp °F	Min Temp °F	Max Temp °F	Std Dev
Jan				
Feb				
Mar				
Apr				
May				
Jun	61.95	57.51	66.56	3.10
Jul	64.28	54.56	74.51	4.65
Aug	63.28	55.47	75.55	4.26
Sep	61.47	51.28	73.52	4.50
Oct	55.12	47.29	75.94	5.94
Nov				
Dec				

10WCT

Based on July Data

DNR Designation

Cold-Transitional

MITU July Score

4

MITU Summer Score (Jun, Jul, Aug)

6.33

	Mean Temp °F	Min Temp °F	Max Temp °F	Std Dev
Jan				
Feb				
Mar				
Apr				
May				
Jun	63.47	60.82	66.09	1.76
Jul	65.92	58.67	73.90	3.20
Aug	64.33	57.72	73.73	3.02
Sep	61.92	53.21	72.14	3.92
Oct	55.69	48.27	73.30	5.67
Nov				
Dec				

11WCT

Based on July Data

DNR Designation

Warm

MITU July Score

0

MITU Summer Score (Jun, Jul, Aug)

1.33

	Mean Temp °F	Min Temp °F	Max Temp °F	Std Dev
Jan				
Feb				
Mar				
Apr				
May				
Jun	68.87	65.87	71.70	1.95
Jul	71.86	63.30	80.98	3.58
Aug	70.33	61.59	79.35	3.63
Sep	66.37	55.13	78.21	4.94
Oct	55.83	47.91	72.74	5.69
Nov				
Dec				

12 WCT

Based on July Data

DNR Designation

Warm

MITU July Score

0

MITU Summer Score (Jun, Jul, Aug)

0.67

	Mean Temp °F	Min Temp °F	Max Temp °F	Std Dev
Jan				
Feb				
Mar				
Apr				
May				
Jun	68.32	62.83	74.38	3.68
Jul	71.59	60.39	83.11	5.10
Aug	70.18	59.14	83.29	4.70
Sep	66.51	52.38	80.98	6.06
Oct	55.32	47.20	73.90	6.37
Nov				
Dec				

13WCT

Based on July Data

DNR Designation

Warm

MITU July Score

0

MITU Summer Score (Jun, Jul, Aug)

0.67

	Mean Temp °F	Min Temp °F	Max Temp °F	Std Dev
Jan				
Feb				
Mar				
Apr				
May				
Jun	68.32	62.83	74.38	3.68
Jul	71.59	60.39	83.11	5.10
Aug	70.18	59.14	83.29	4.70
Sep	66.51	52.38	80.98	6.06
Oct	55.32	47.20	73.90	6.37
Nov				
Dec				

15T

Based on July Data

DNR Designation

Cool

MITU July Score

1

MITU Summer Score (Jun, Jul, Aug)

1.67

	Mean Temp °F	Min Temp °F	Max Temp °F	Std Dev
Jan				
Feb				
Mar				
Apr				
May				
Jun	66.43	60.09	74.81	3.08
Jul	69.78	59.87	80.45	4.03
Aug	70.60	63.95	78.78	2.93
Sep	65.02	57.12	76.59	3.91
Oct	59.20	49.25	75.46	4.52
Nov				
Dec				

16T

Based on July Data

DNR Designation

Cool

MITU July Score

1

MITU Summer Score (Jun, Jul, Aug)

1.00

	Mean Temp °F	Min Temp °F	Max Temp °F	Std Dev
Jan				
Feb				
Mar				
Apr				
May				
Jun				
Jul	69.60	60.13	77.64	3.89
Aug	69.46	60.78	78.73	3.67
Sep	66.58	55.13	76.77	5.00
Oct	56.54	50.18	64.29	2.99
Nov				
Dec				

17T

Based on July Data

DNR Designation

Cool

MITU July Score

2

MITU Summer Score (Jun, Jul, Aug)

4.00

	Mean Temp °F	Min Temp °F	Max Temp °F	Std Dev
Jan				
Feb				
Mar				
Apr				
May				
Jun	64.72	62.45	66.94	1.49
Jul	67.61	58.80	74.99	3.48
Aug	67.30	59.27	75.77	3.25
Sep	64.93	52.12	75.33	5.09
Oct	51.44	46.97	56.34	2.74
Nov				
Dec				

18T

Based on July Data

DNR Designation

Cold-Transitional

MITU July Score

8

MITU Summer Score (Jun, Jul, Aug)

8.33

	Mean Temp °F	Min Temp °F	Max Temp °F	Std Dev
Jan	35.92	33.78	39.03	1.49
Feb	36.43	32.89	42.02	2.40
Mar	42.89	32.84	54.13	4.82
Apr	48.45	36.80	62.02	6.15
May	57.25	47.60	68.44	5.41
Jun	62.38	55.47	68.36	2.68
Jul	64.22	58.24	68.36	2.44
Aug	64.67	59.87	69.09	2.28
Sep	62.65	57.51	68.27	3.00
Oct	52.69	46.75	57.55	2.65
Nov	46.84	39.41	56.25	4.10
Dec	42.38	35.83	49.43	2.81

19T

Based on July Data

DNR Designation

Cold-Transitional

MITU July Score

3

MITU Summer Score (Jun, Jul, Aug)

3.33

	Mean Temp °F	Min Temp °F	Max Temp °F	Std Dev
Jan				
Feb				
Mar				
Apr				
May				
Jun	63.57	54.87	77.25	4.76
Jul	65.64	56.34	77.12	4.40
Aug	65.67	55.69	75.42	4.23
Sep	61.85	54.65	71.88	3.33
Oct	58.56	50.62	76.11	3.42
Nov				
Dec				

20T

Based on July Data

DNR Designation

Cool

MITU July Score

1

MITU Summer Score (Jun, Jul, Aug)

3.00

	Mean Temp °F	Min Temp °F	Max Temp °F	Std Dev
Jan				
Feb				
Mar				
Apr				
May				
Jun	65.60	62.11	69.39	2.31
Jul	67.97	57.64	76.85	4.06
Aug	67.42	58.50	76.51	3.68
Sep	64.83	52.99	76.07	5.04
Oct	55.69	47.47	73.17	5.63
Nov				
Dec				

21T

Based on July Data

DNR Designation

Cool

MITU July Score

1

MITU Summer Score (Jun, Jul, Aug)

1.33

	Mean Temp °F	Min Temp °F	Max Temp °F	Std Dev
Jan				
Feb				
Mar				
Apr				
May				
Jun	66.36	56.69	83.74	4.58
Jul	69.59	57.33	79.66	4.67
Aug	70.11	61.21	78.25	3.56
Sep	64.91	56.21	75.64	4.21
Oct	58.31	49.34	76.03	3.98
Nov				
Dec				

22T

Based on July Data

DNR Designation

Cool

MITU July Score

1

MITU Summer Score (Jun, Jul, Aug)

3.00

	Mean Temp °F	Min Temp °F	Max Temp °F	Std Dev
Jan				
Feb				
Mar				
Apr				
May				
Jun	63.60	59.57	69.13	2.33
Jul	69.64	59.96	80.40	4.32
Aug	70.79	64.42	77.34	2.91
Sep	66.13	57.72	76.85	3.82
Oct	60.01	50.40	75.29	3.81
Nov				
Dec				

23T

Based on July Data

DNR Designation

Cool

MITU July Score

1

MITU Summer Score (Jun, Jul, Aug)

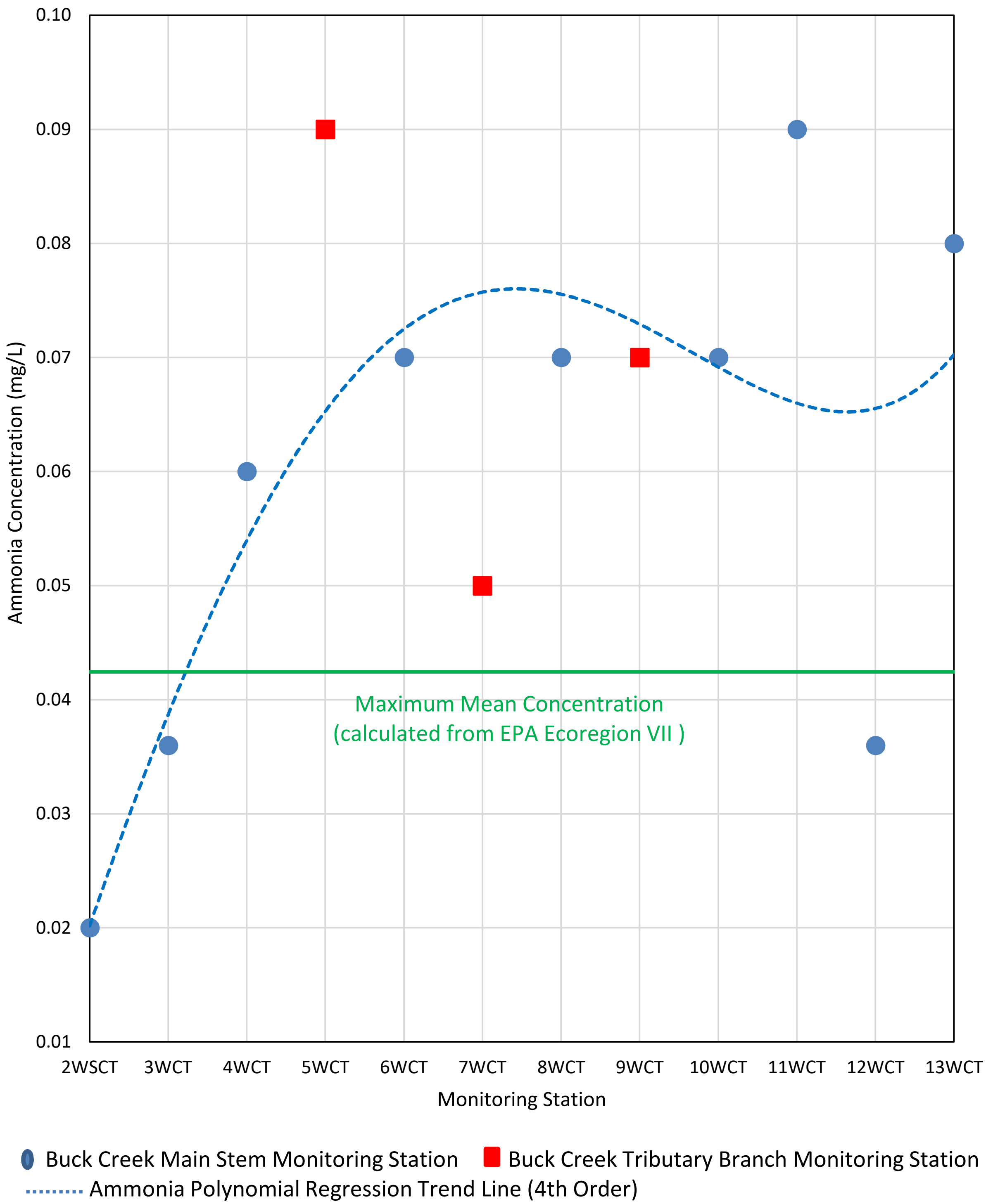
2.67

	Mean Temp °F	Min Temp °F	Max Temp °F	Std Dev
Jan				
Feb				
Mar				
Apr				
May				
Jun	64.21	58.20	71.06	2.93
Jul	67.41	59.14	78.21	3.70
Aug	70.72	63.22	79.08	3.45
Sep	65.22	58.63	72.31	2.90
Oct	60.43	50.80	76.51	3.12
Nov				
Dec				

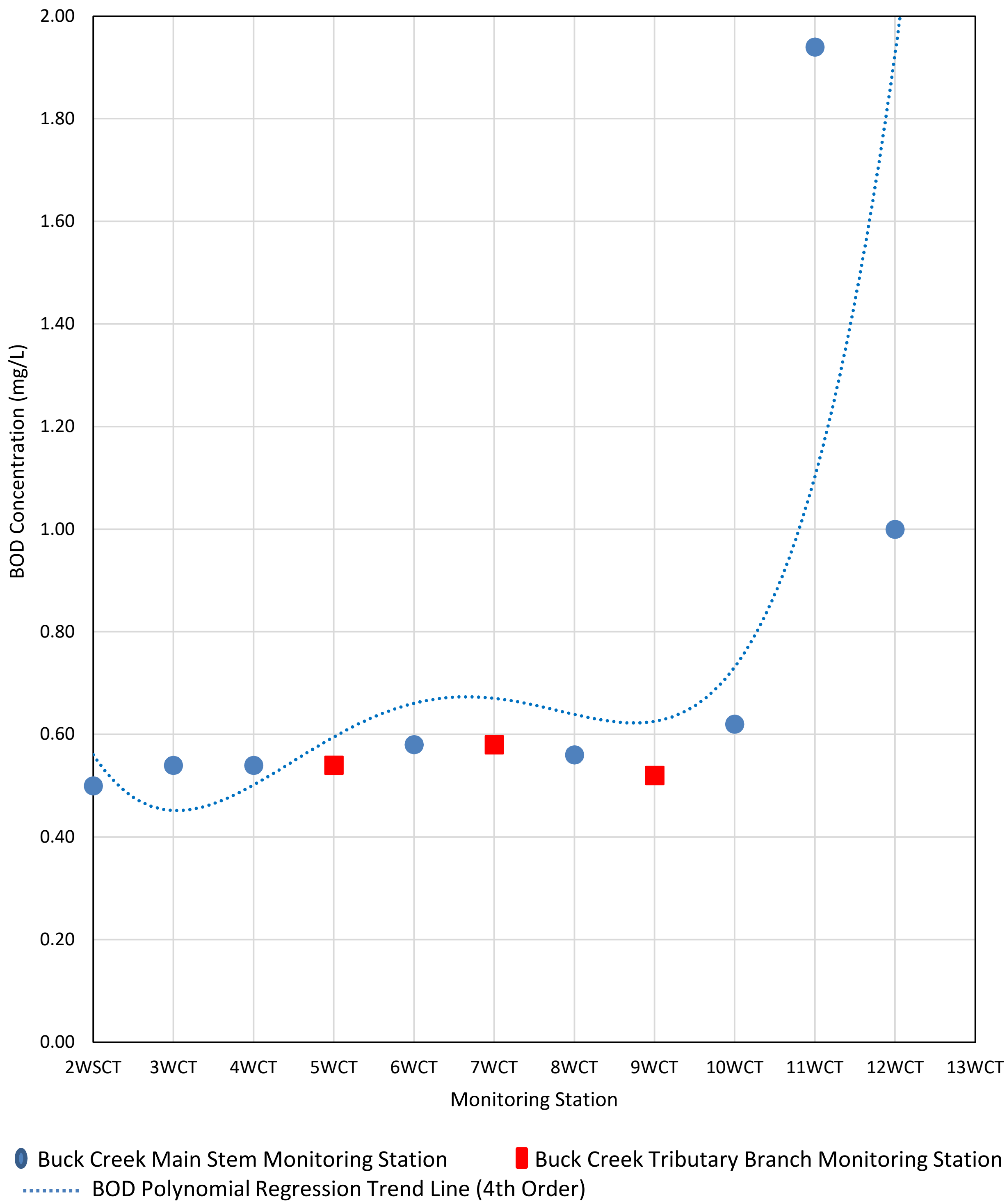
APPENDIX B

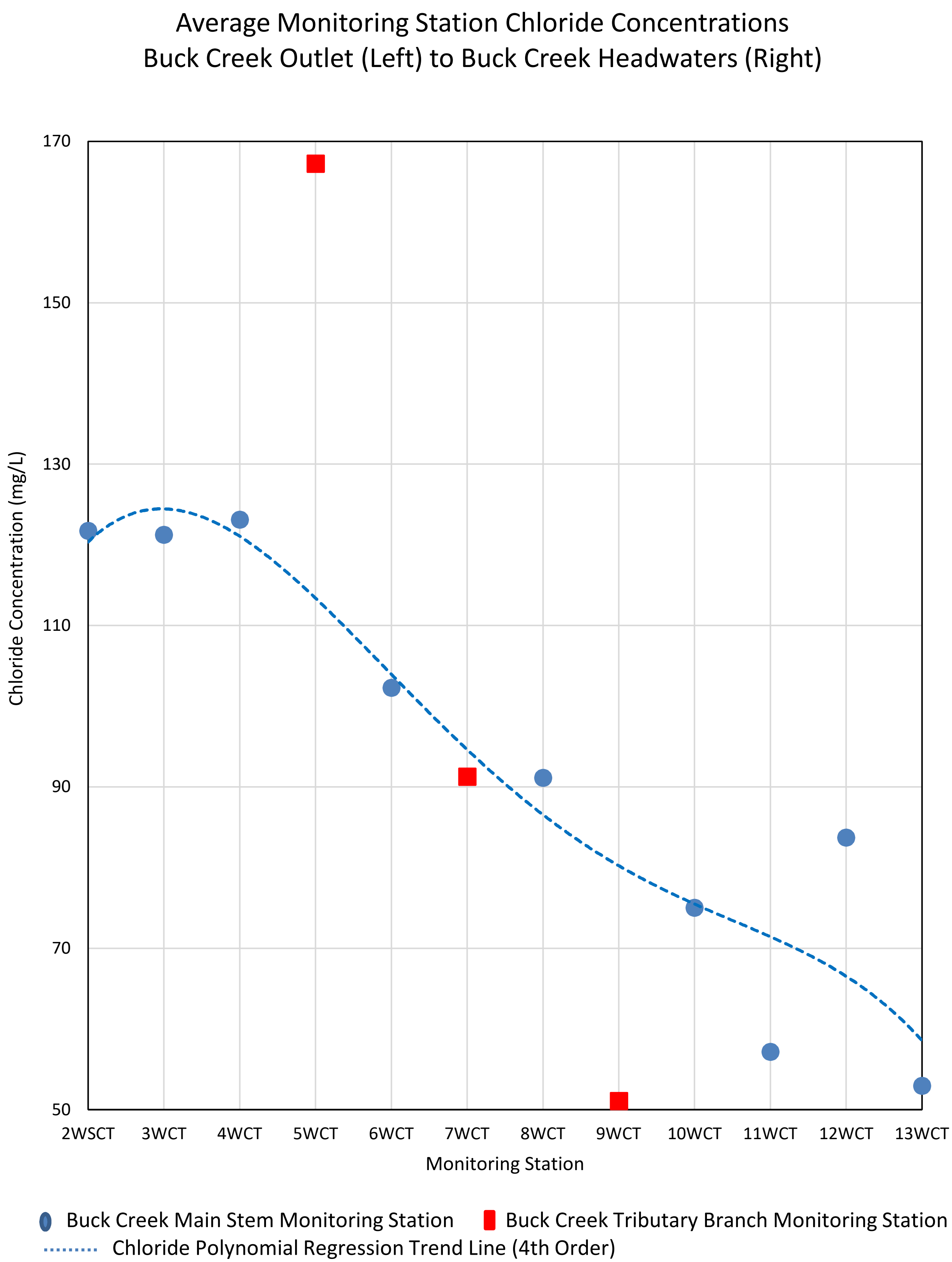
WATER CHEMISTRY GRAPHS

Average Monitoring Station Ammonia Concentrations
Buck Creek Outlet (Left) to Buck Creek Headwaters (Right)

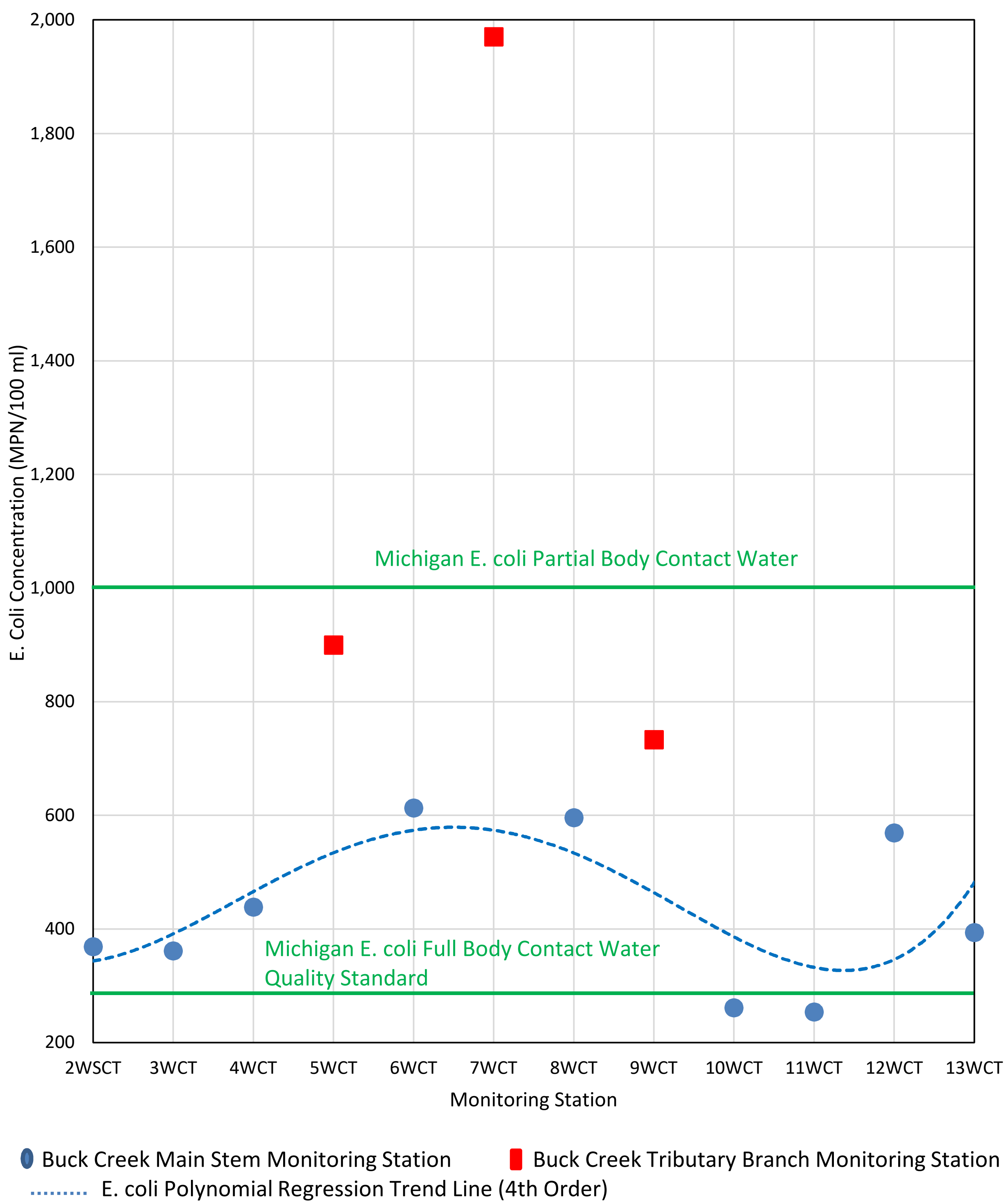


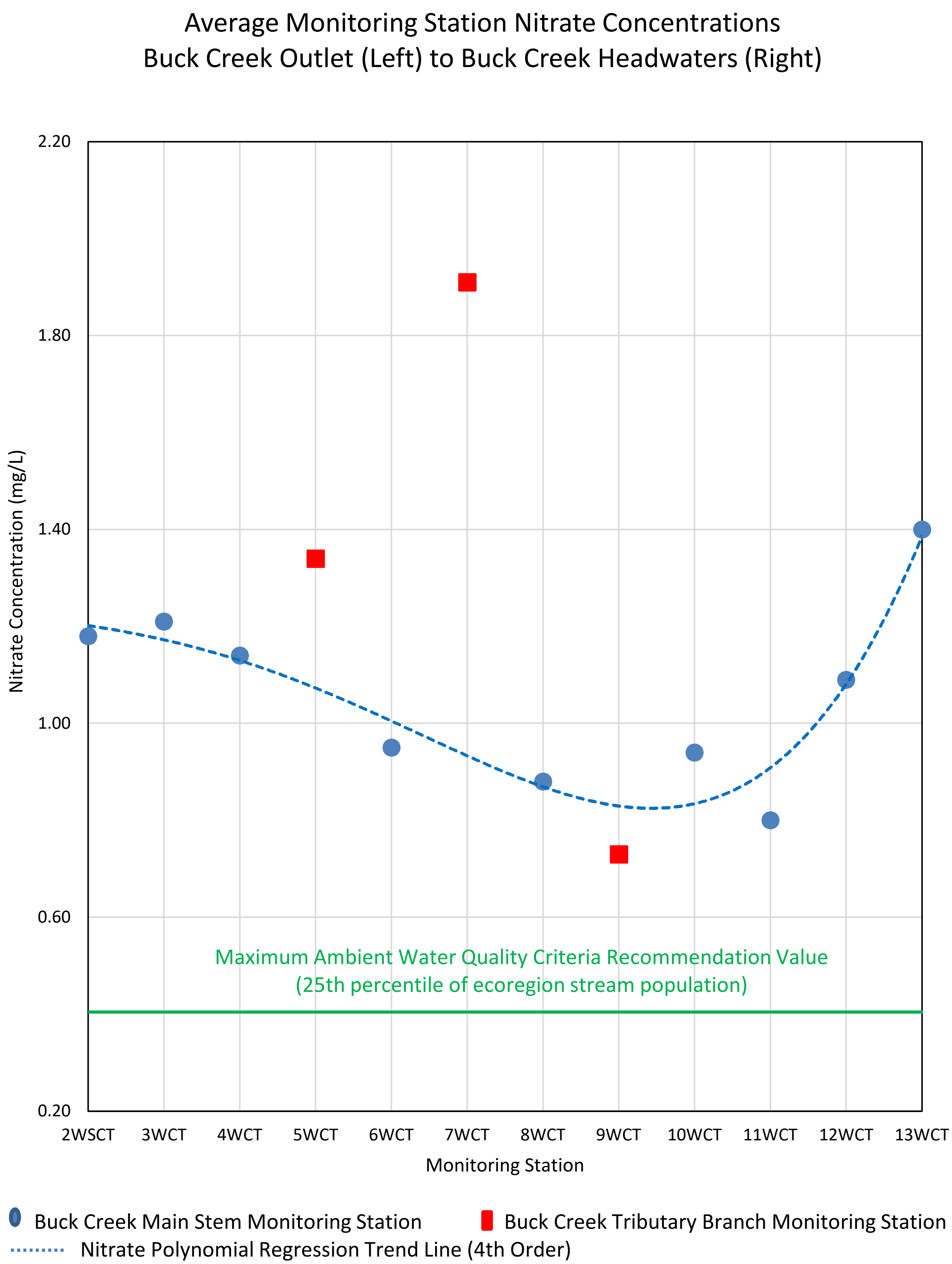
Average Monitoring Station BOD Concentrations
Buck Creek Outlet (Left) to Buck Creek Headwaters (Right)

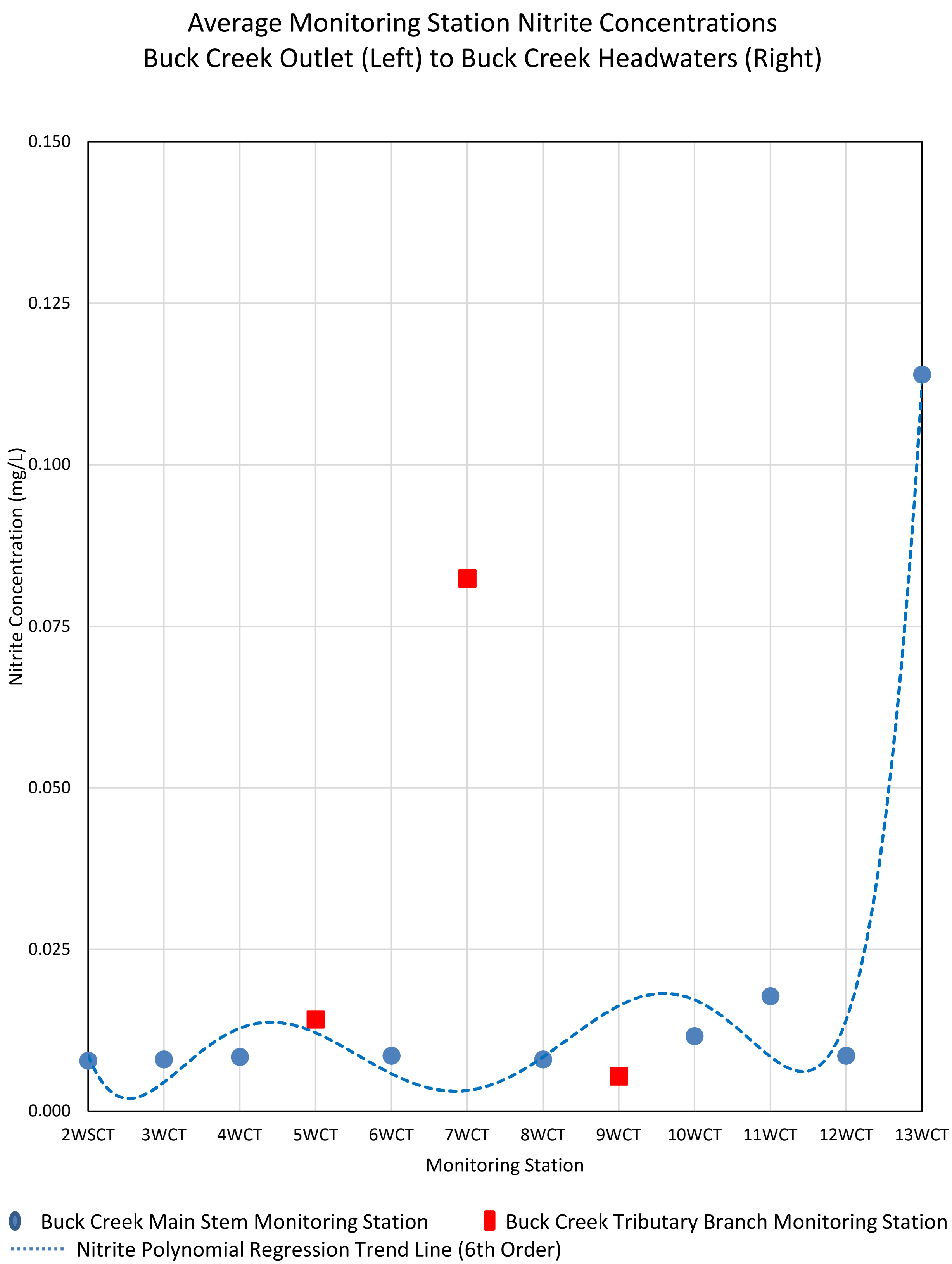


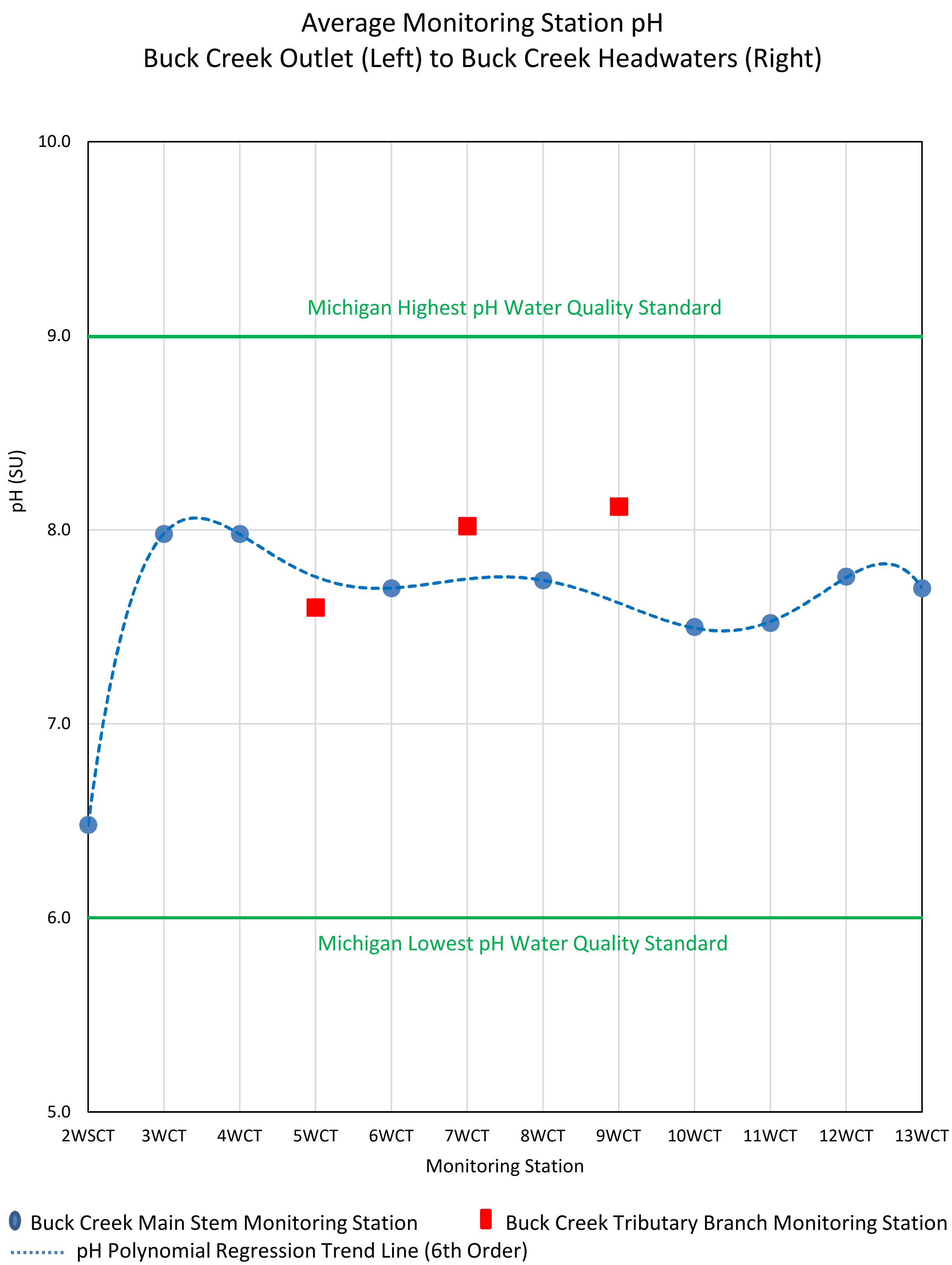

Average Monitoring Station Chloride Concentrations
Buck Creek Outlet (Left) to Buck Creek Headwaters (Right)
170
150
130
110
90
70
50
Chloride Concentration (mg/L)
2WSCT
3WCT
4WCT
5WCT
6WCT
7WCT
8WCT
9WCT
10WCT
11WCT
12WCT
13WCT
Monitoring Station
Buck Creek Main Stem Monitoring Station
Buck Creek Tributary Branch Monitoring Station
Chloride Polynomial Regression Trend Line (4th Order)

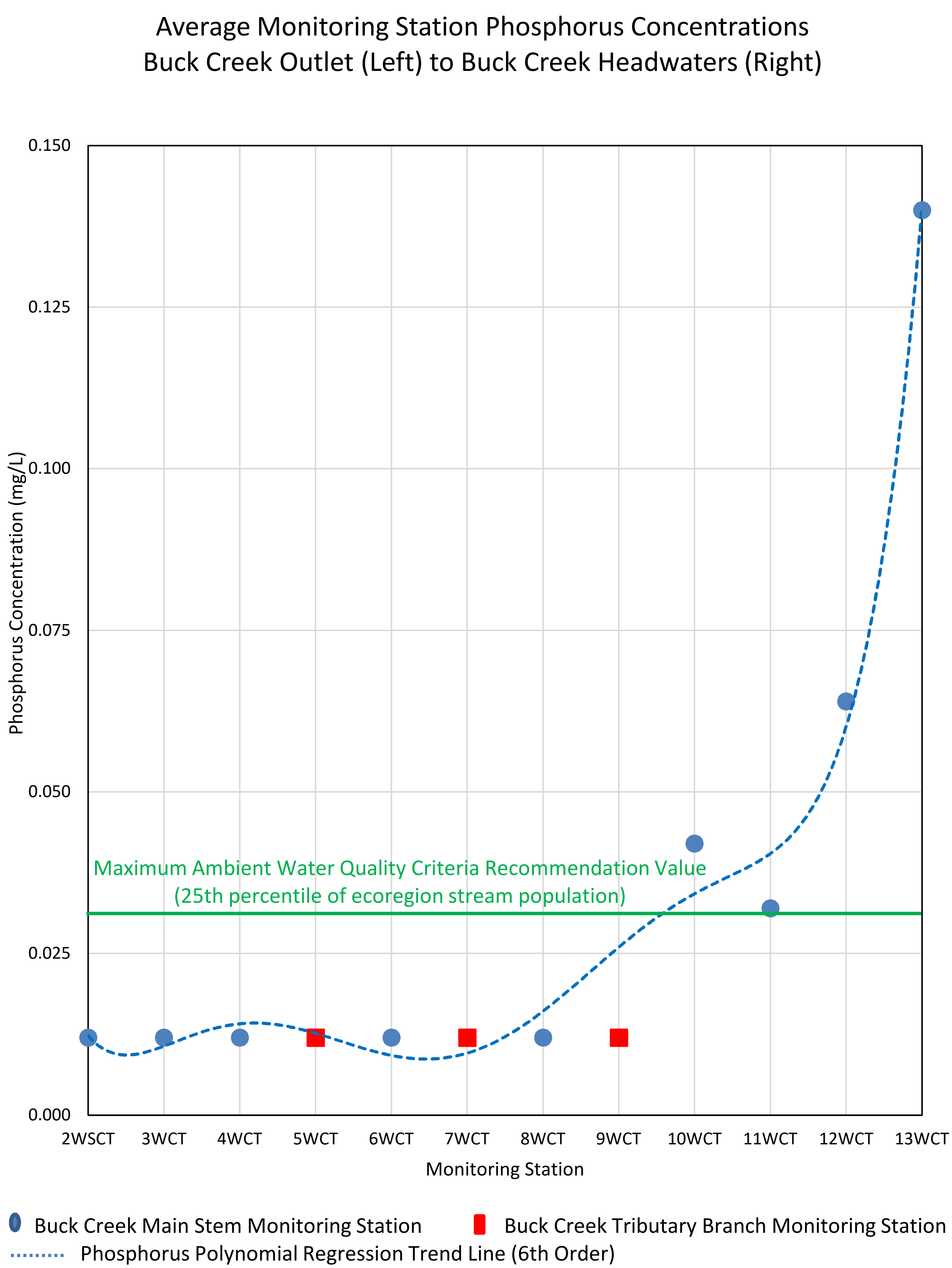
Average Monitoring Station E. Coli Values
Buck Creek Outlet (Left) to Buck Creek Headwaters (Right)



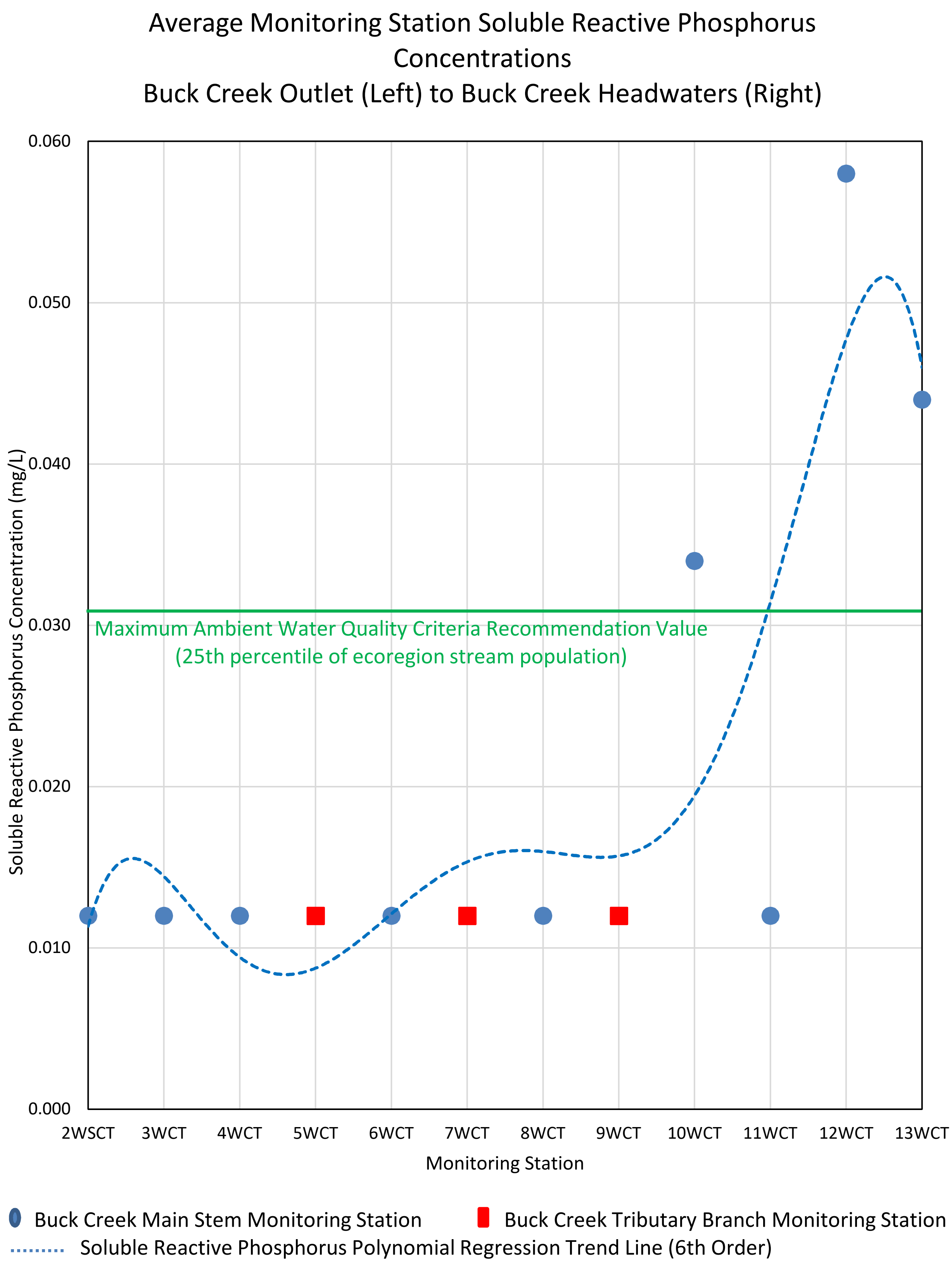

Average Monitoring Station Nitrate Concentrations
Buck Creek Outlet (Left) to Buck Creek Headwaters (Right)
2.20
1.80
1.40
1.00
0.60
0.20
Nitrate Concentration (mg/L)
Maximum Ambient Water Quality Criteria Recommendation Value
(25th percentile of ecoregion stream population)
2WSCT
3WCT
4WCT
5WCT
6WCT
7WCT
8WCT
9WCT
10WCT
11WCT
12WCT
13WCT
Monitoring Station
Buck Creek Main Stem Monitoring Station
Buck Creek Tributary Branch Monitoring Station
Nitrate Polynomial Regression Trend Line (4th Order)

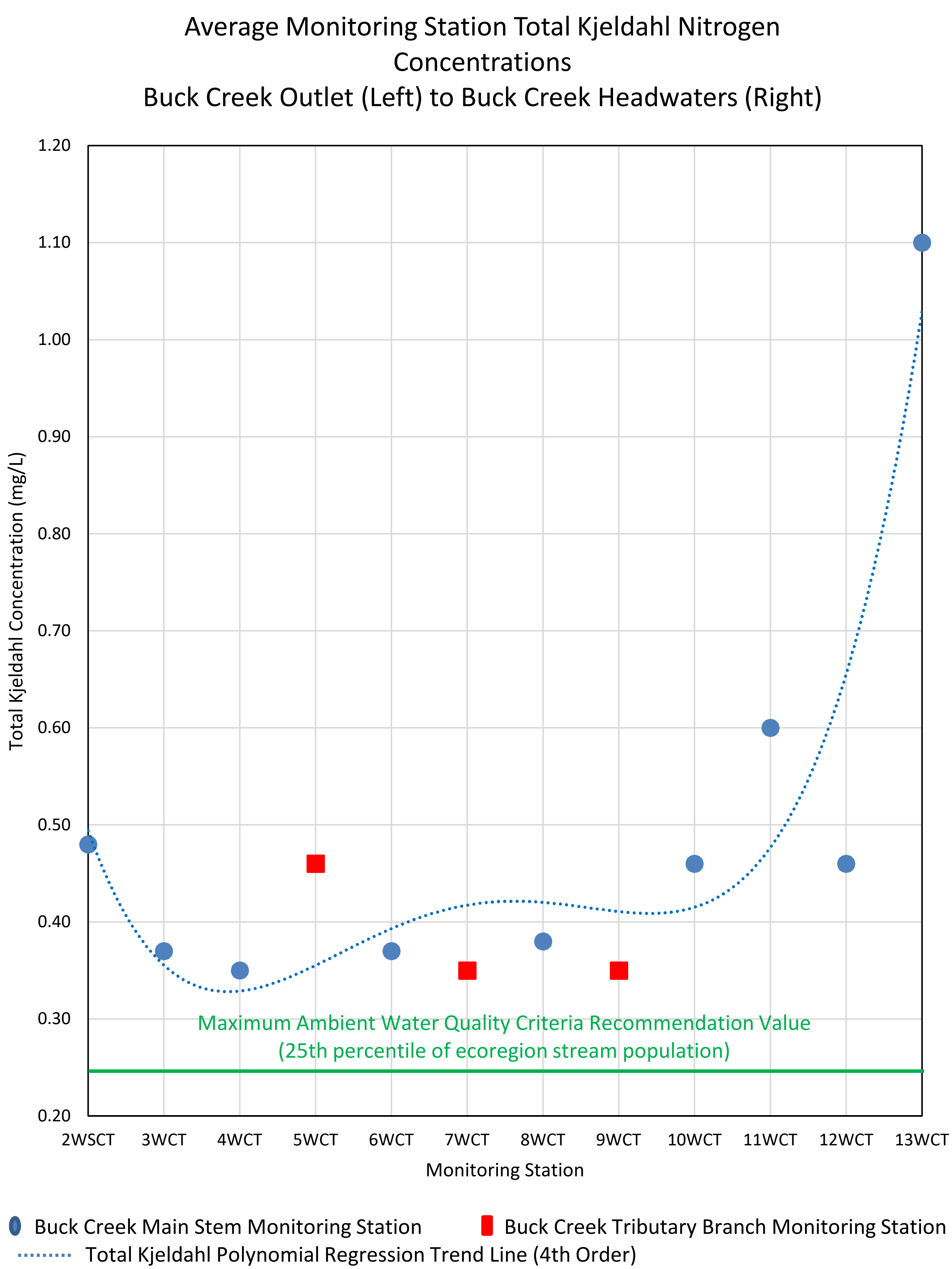

Average Monitoring Station Nitrite Concentrations
Buck Creek Outlet (Left) to Buck Creek Headwaters (Right)
Nitrite Concentration (mg/L)
0.150
0.125
0.100
0.075
0.050
0.025
0.000
2WSCT
3WCT
4WCT
5WCT
6WCT
7WCT
8WCT
9WCT
10WCT
11WCT
12WCT
13WCT
Monitoring Station
Buck Creek Main Stem Monitoring Station
Buck Creek Tributary Branch Monitoring Station
Nitrite Polynomial Regression Trend Line (6th Order)

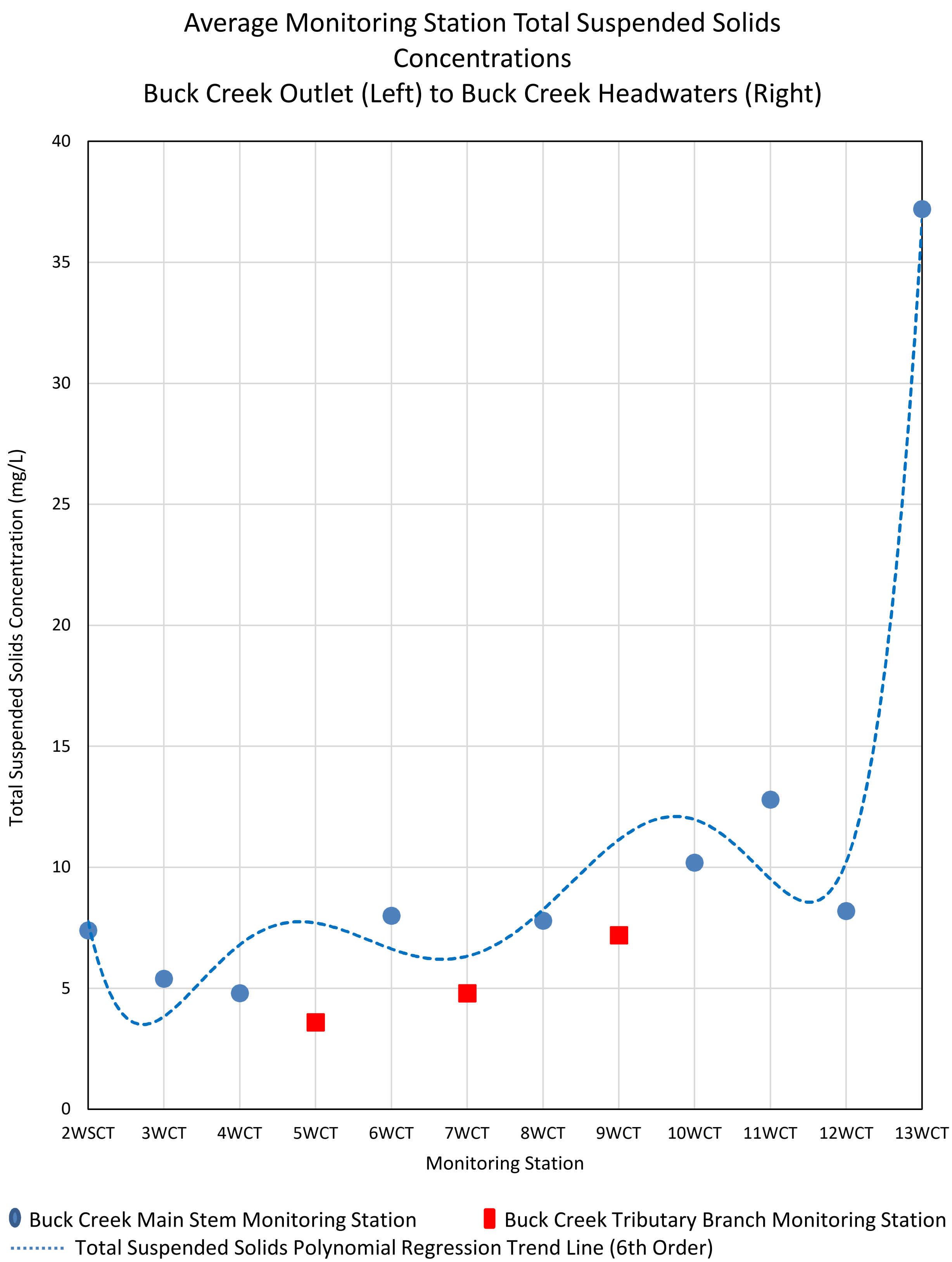

Average Monitoring Station pH
Buck Creek Outlet (Left) to Buck Creek Headwaters (Right)
10.0
9.0
8.0
7.0
6.0
5.0
pH (SU)
Michigan Highest pH Water Quality Standard
Michigan Lowest pH Water Quality Standard
2WSCT
3WCT
4WCT
5WCT
6WCT
7WCT
8WCT
9WCT
10WCT
11WCT
12WCT
13WCT
Monitoring Station
Buck Creek Main Stem Monitoring Station
Buck Creek Tributary Branch Monitoring Station
pH Polynomial Regression Trend Line (6th Order)



Average Monitoring Station Phosphorus Concentrations
Buck Creek Outlet (Left) to Buck Creek Headwaters (Right)
0.150
0.125
0.100
0.075
0.050
0.025
0.000
Phosphorus Concentration (mg/L)
Maximum Ambient Water Quality Criteria Recommendation Value
(25th percentile of ecoregion stream population)
2WSCT
3WCT
4WCT
5WCT
6WCT
7WCT
8WCT
9WCT
10WCT
11WCT
12WCT
13WCT
Monitoring Station
Buck Creek Main Stem Monitoring Station
Buck Creek Tributary Branch Monitoring Station
Phosphorus Polynomial Regression Trend Line (6th Order)

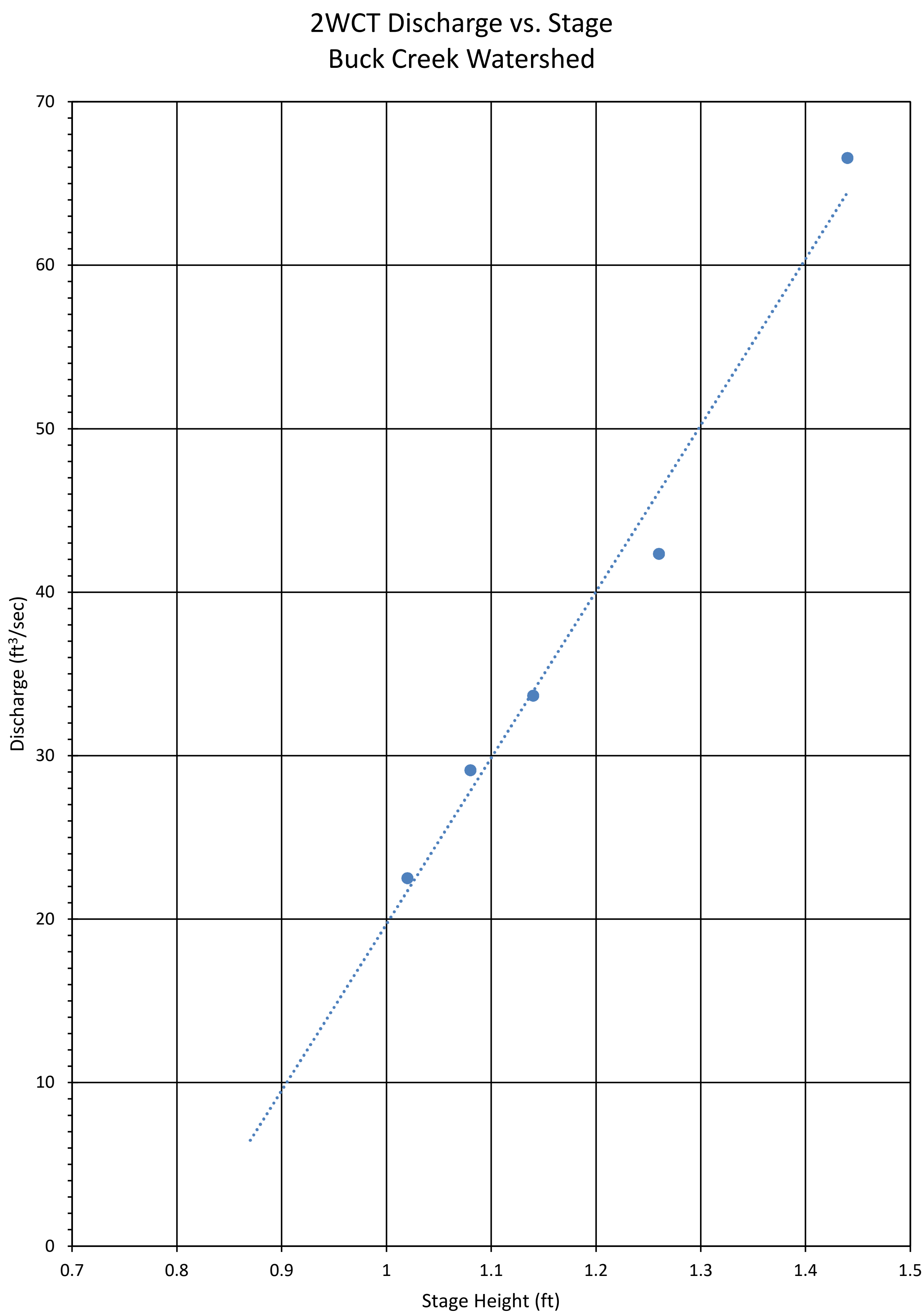

Average Monitoring Station Soluble Reactive Phosphorus Concentrations
Buck Creek Outlet (Left) to Buck Creek Headwaters (Right)
0.060
0.050
0.040
0.030
0.020
0.010
0.000
Soluble Reactive Phosphorus Concentration (mg/L)
Maximum Ambient Water Quality Criteria Recommendation Value
(25th percentile of ecoregion stream population)
2WSCT
3WCT
4WCT
5WCT
6WCT
7WCT
8WCT
9WCT
10WCT
11WCT
12WCT
13WCT
Monitoring Station
Buck Creek Main Stem Monitoring Station
Buck Creek Tributary Branch Monitoring Station
Soluble Reactive Phosphorus Polynomial Regression Trend Line (6th Order)

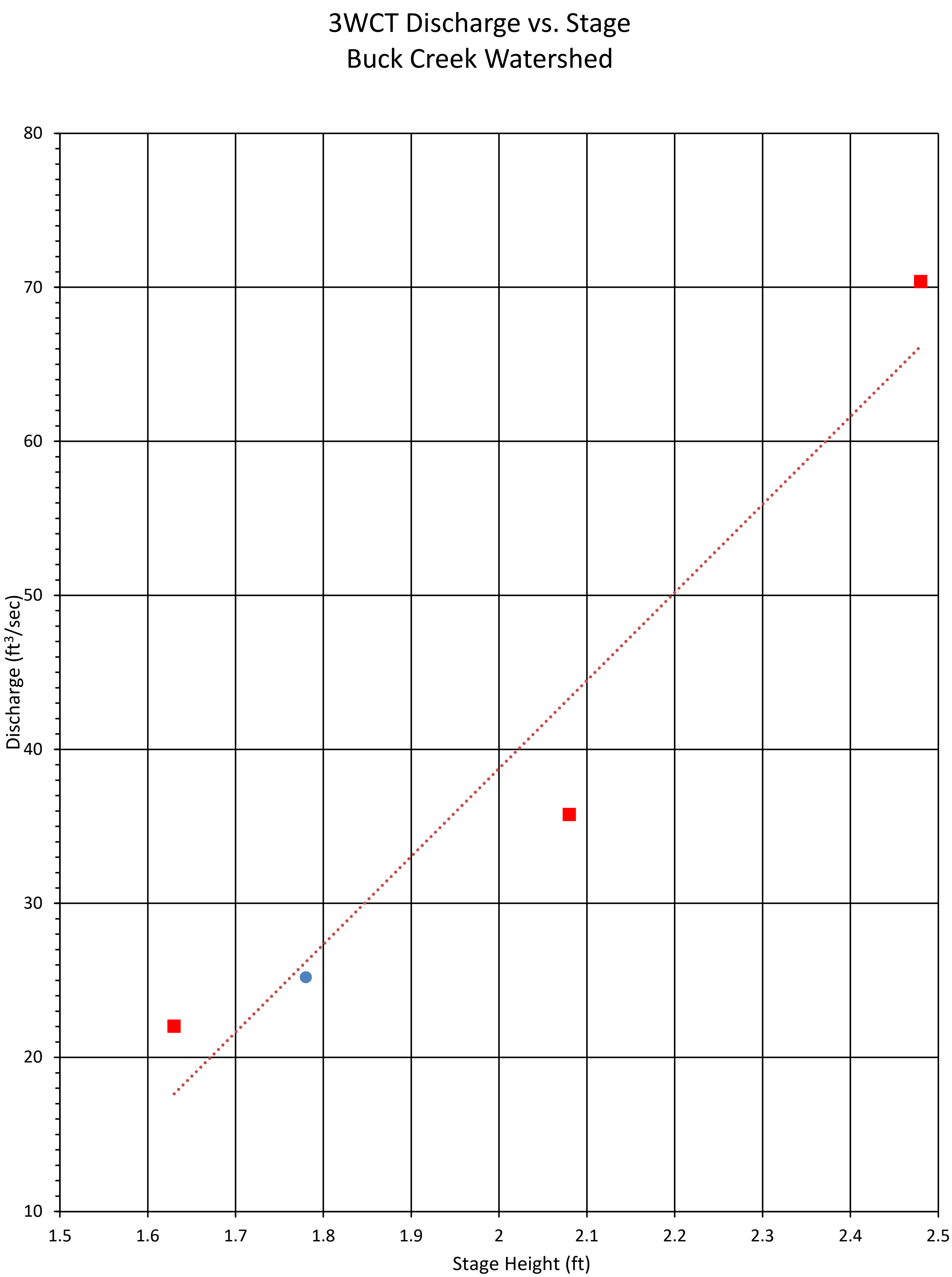

Average Monitoring Station Total Kjeldahl Nitrogen Concentrations
Buck Creek Outlet (Left) to Buck Creek Headwaters (Right)
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
Total Kjeldahl Concentration (mg/L)
Maximum Ambient Water Quality Criteria Recommendation Value
(25th percentile of ecoregion stream population)
2WSCT
3WCT
4WCT
5WCT
6WCT
7WCT
8WCT
9WCT
10WCT
11WCT
12WCT
13WCT
Monitoring Station
Buck Creek Main Stem Monitoring Station
Buck Creek Tributary Branch Monitoring Station
Total Kjeldahl Polynomial Regression Trend Line (4th Order)


Average Monitoring Station Total Suspended Solids Concentrations
Buck Creek Outlet (Left) to Buck Creek Headwaters (Right)
Total Suspended Solids Concentration (mg/L)
0
5
10
15
20
25
30
35
40
2WSCT
3WCT
4WCT
5WCT
6WCT
7WCT
8WCT
9WCT
10WCT
11WCT
12WCT
13WCT
Monitoring Station
Buck Creek Main Stem Monitoring Station
Buck Creek Tributary Branch Monitoring Station
Total Suspended Solids Polynomial Regression Trend Line (6th Order)

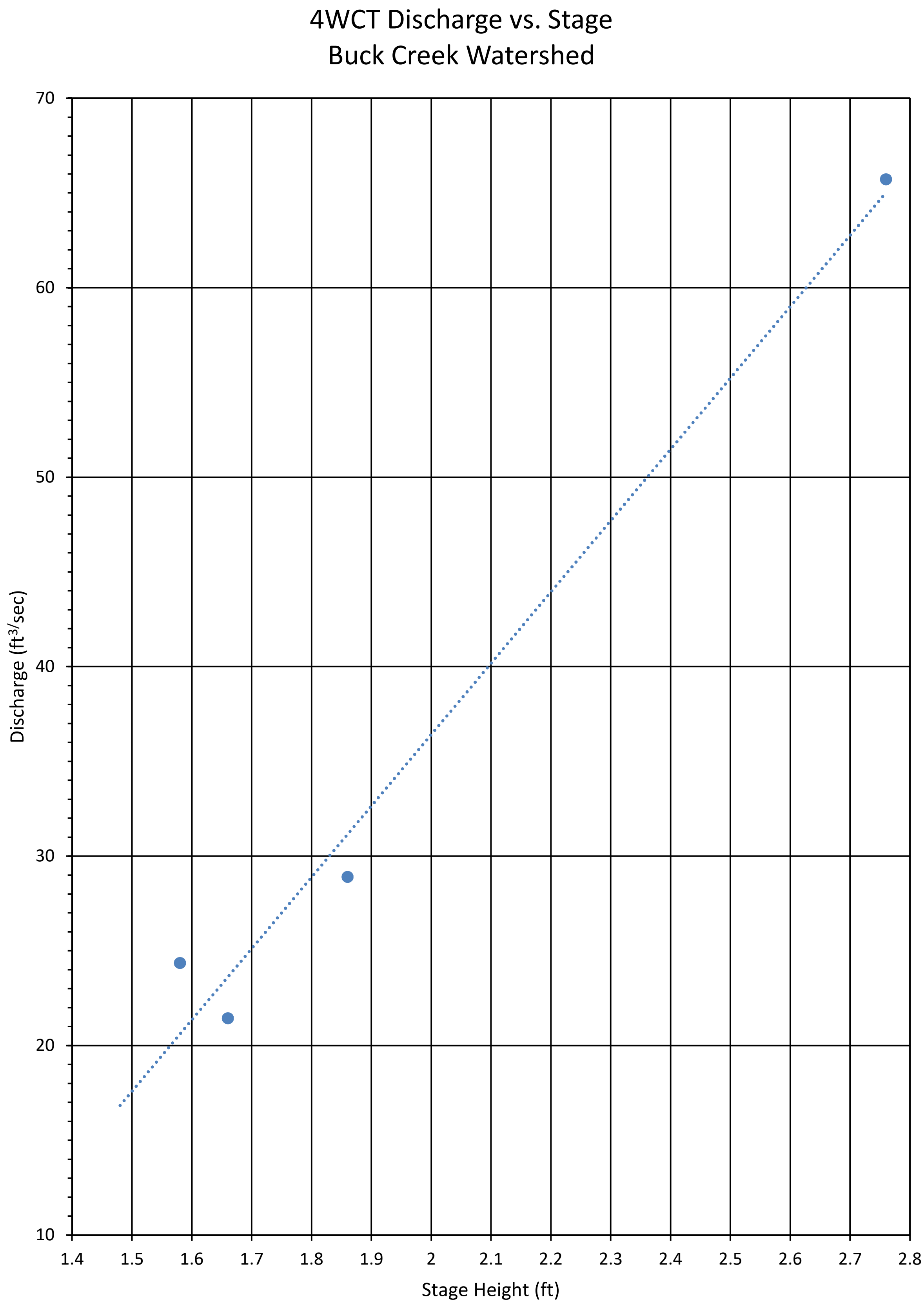
APPENDIX C

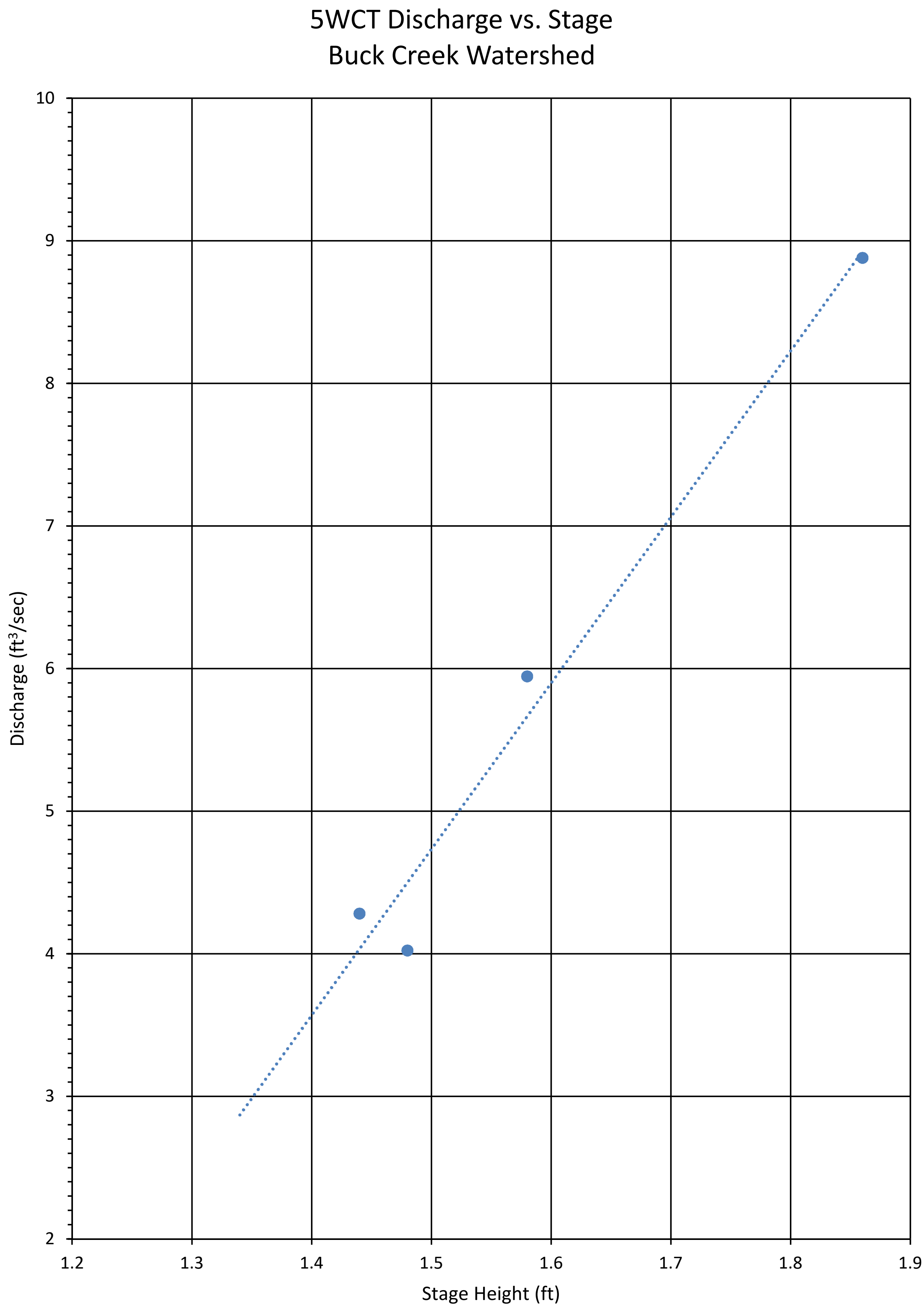
DISCHARGE VS. STREAM STAGE RELATIONSHIPS

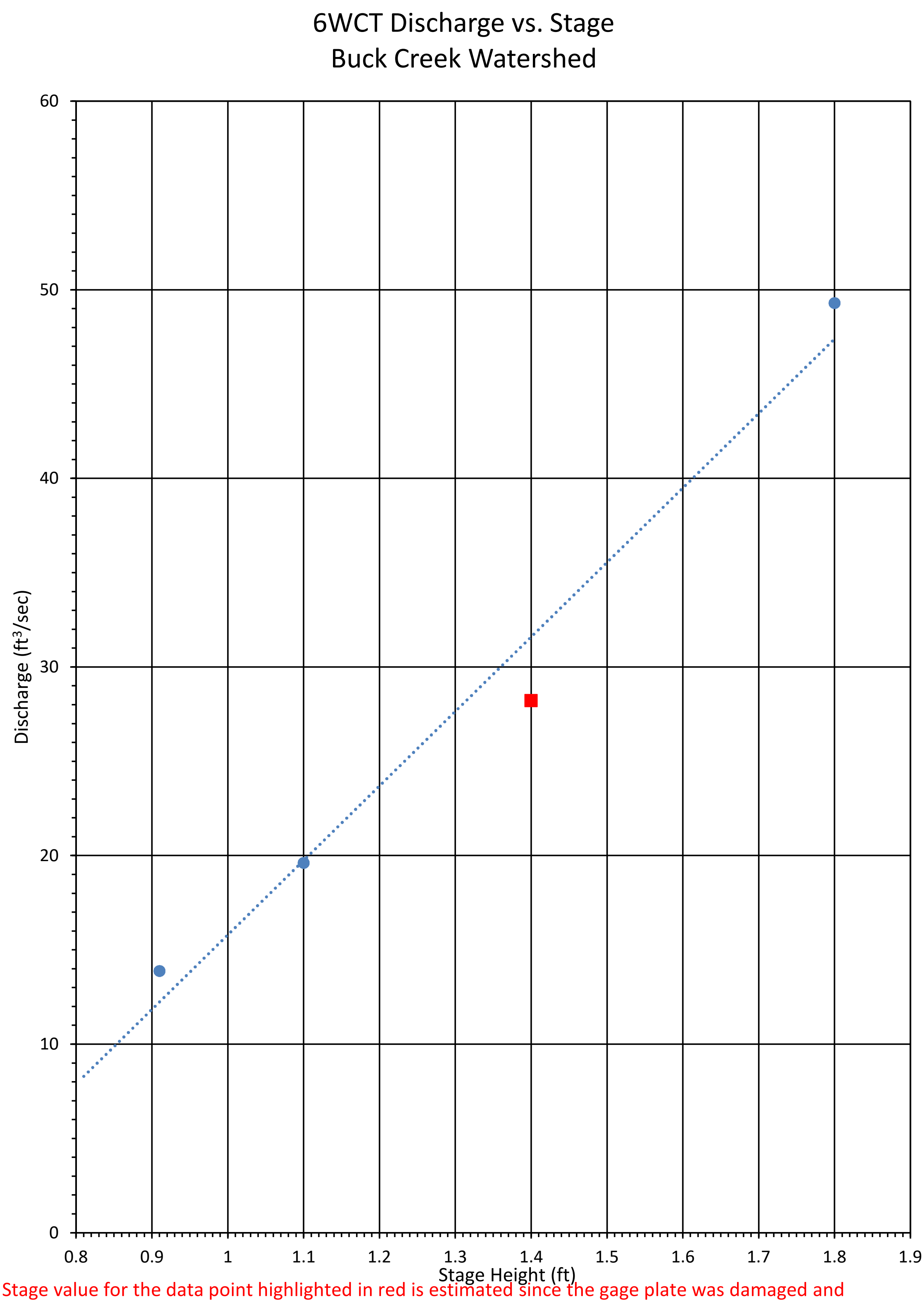

2WCT Discharge vs. Stage
Buck Creek Watershed
Discharge (ft³/sec)
Stage Height (ft)
0
10
20
30
40
50
60
70
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
1.5



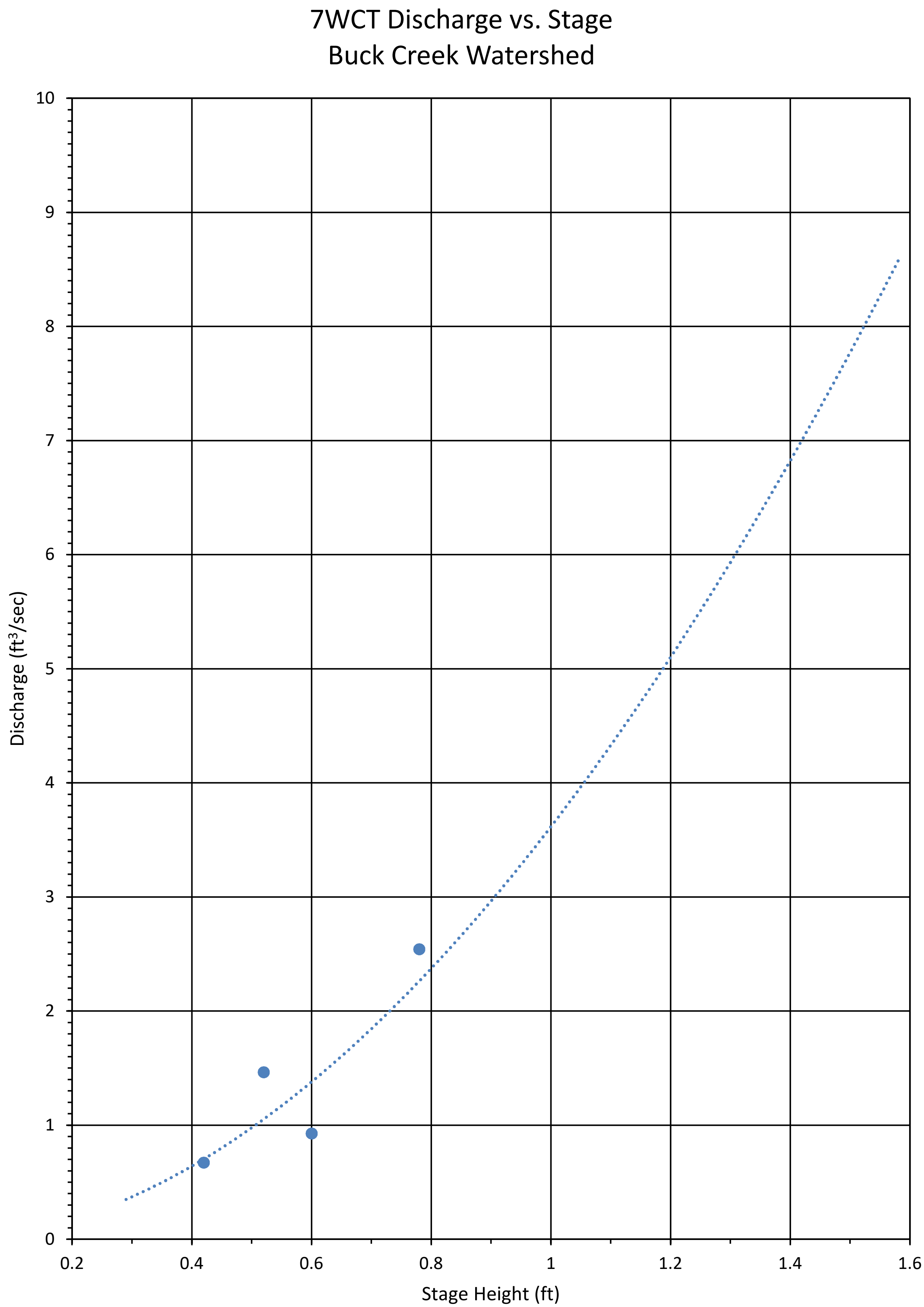
The stage values for data points highlighted in red are estimated since the gage plate was damaged and subsequently reinstalled.

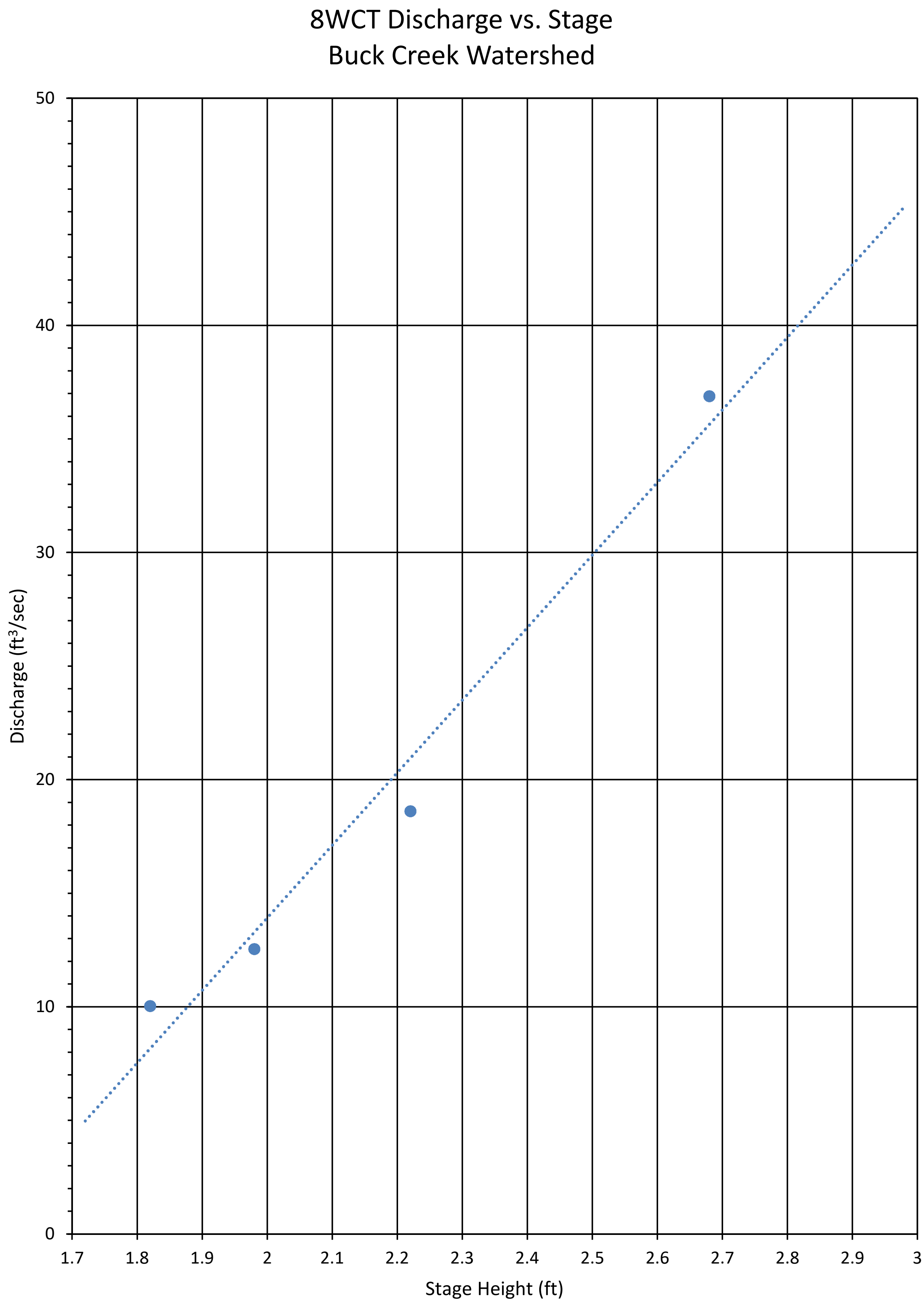

4WCT Discharge vs. Stage
Buck Creek Watershed
Discharge (ft³/sec)
Stage Height (ft)
70
60
50
40
30
20
10
1.4
1.5
1.6
1.7
1.8
1.9
2
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8

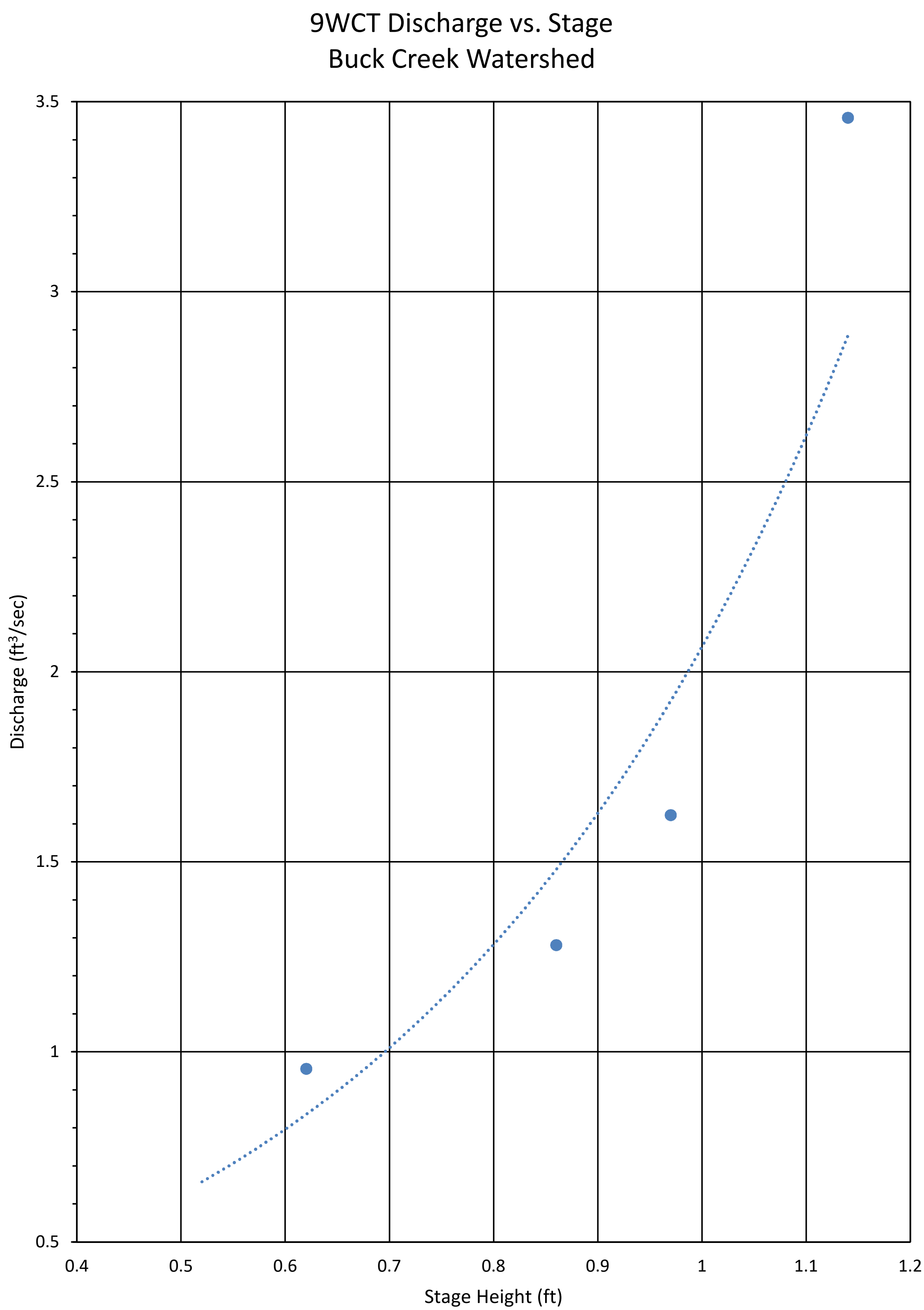

5WCT Discharge vs. Stage
Buck Creek Watershed
Discharge (ft³/sec)
Stage Height (ft)
10
9
8
7
6
5
4
3
2
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9

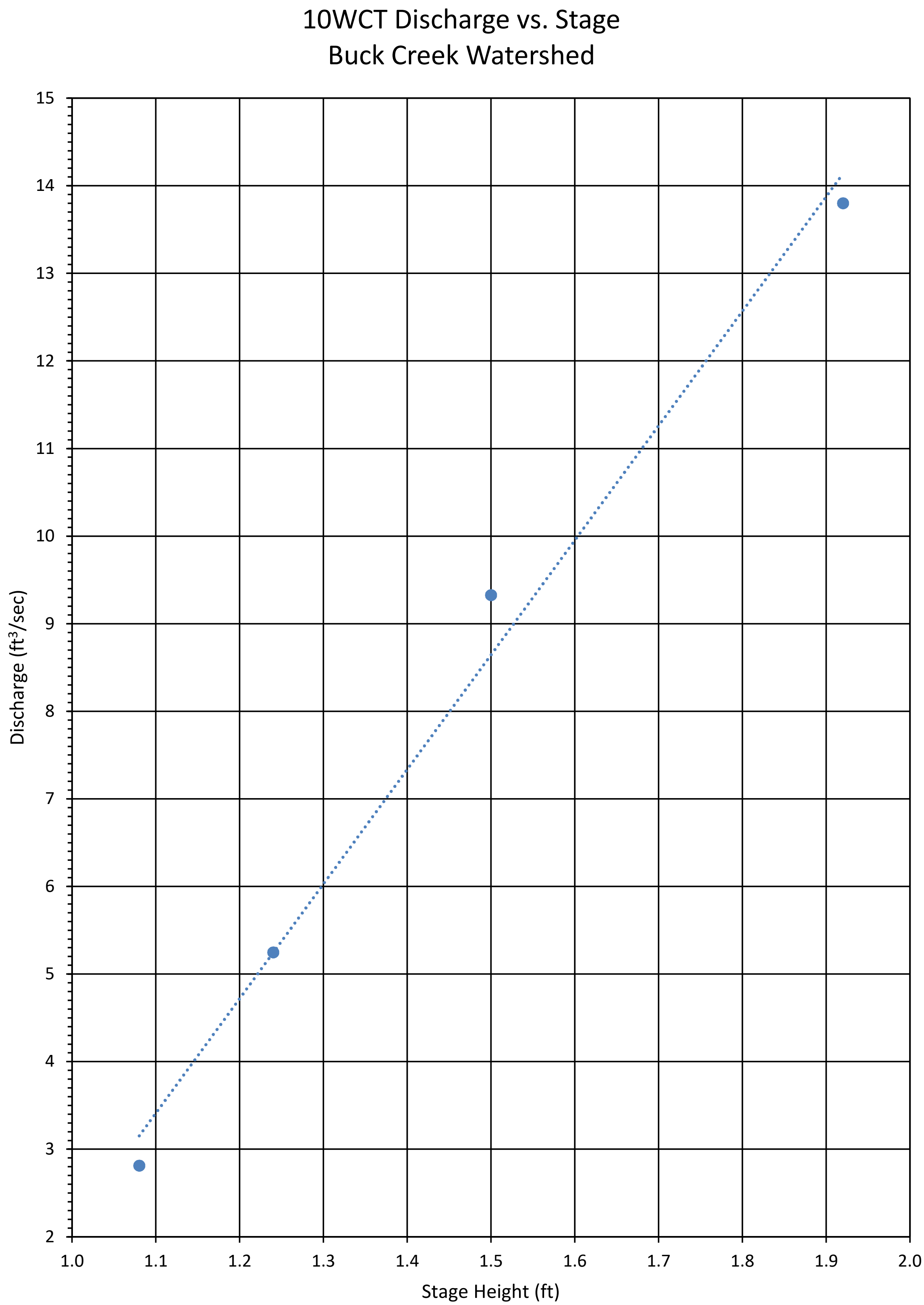


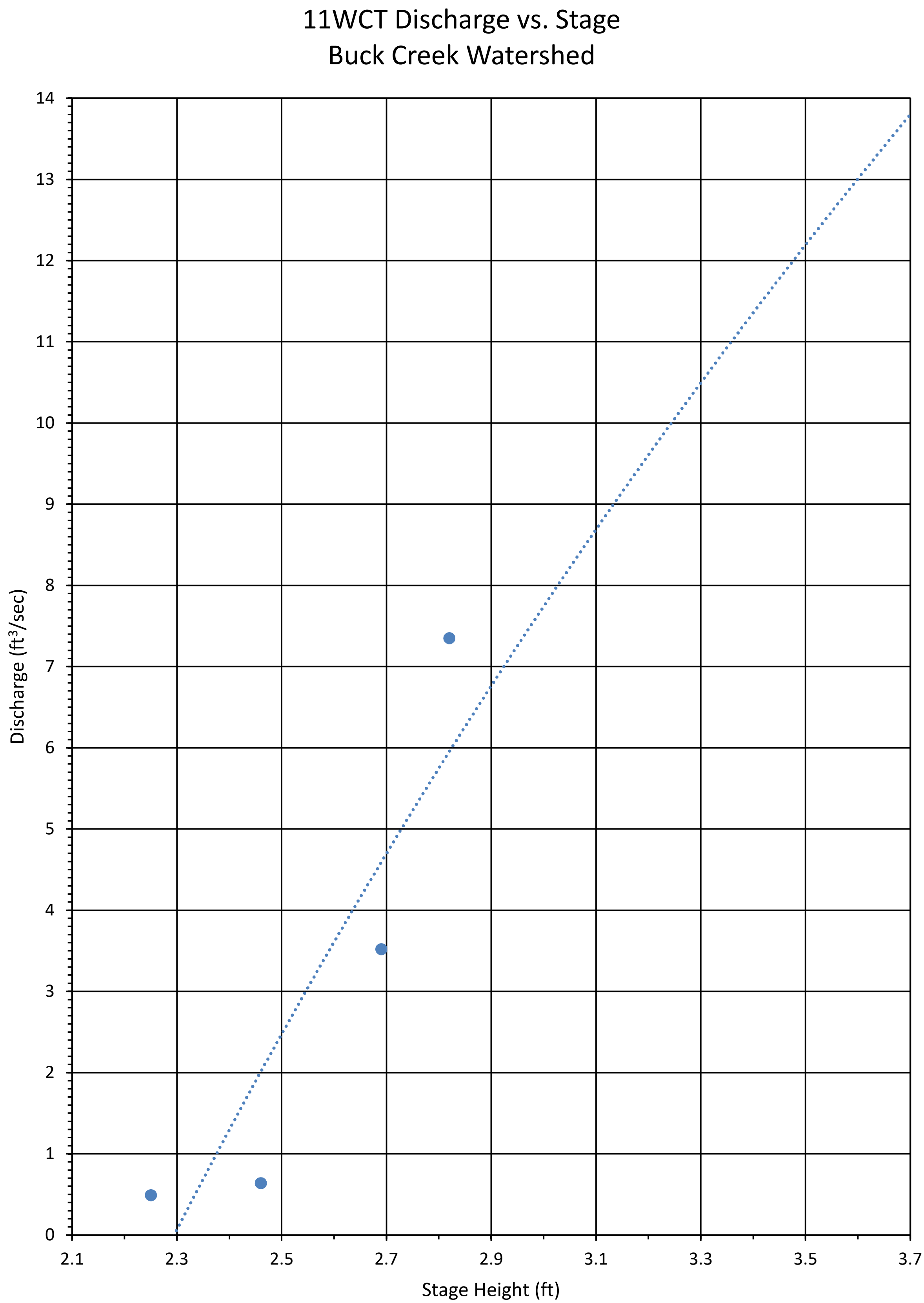
Stage value for the data point highlighted in red is estimated since the gage plate was damaged and subsequently reinstalled.

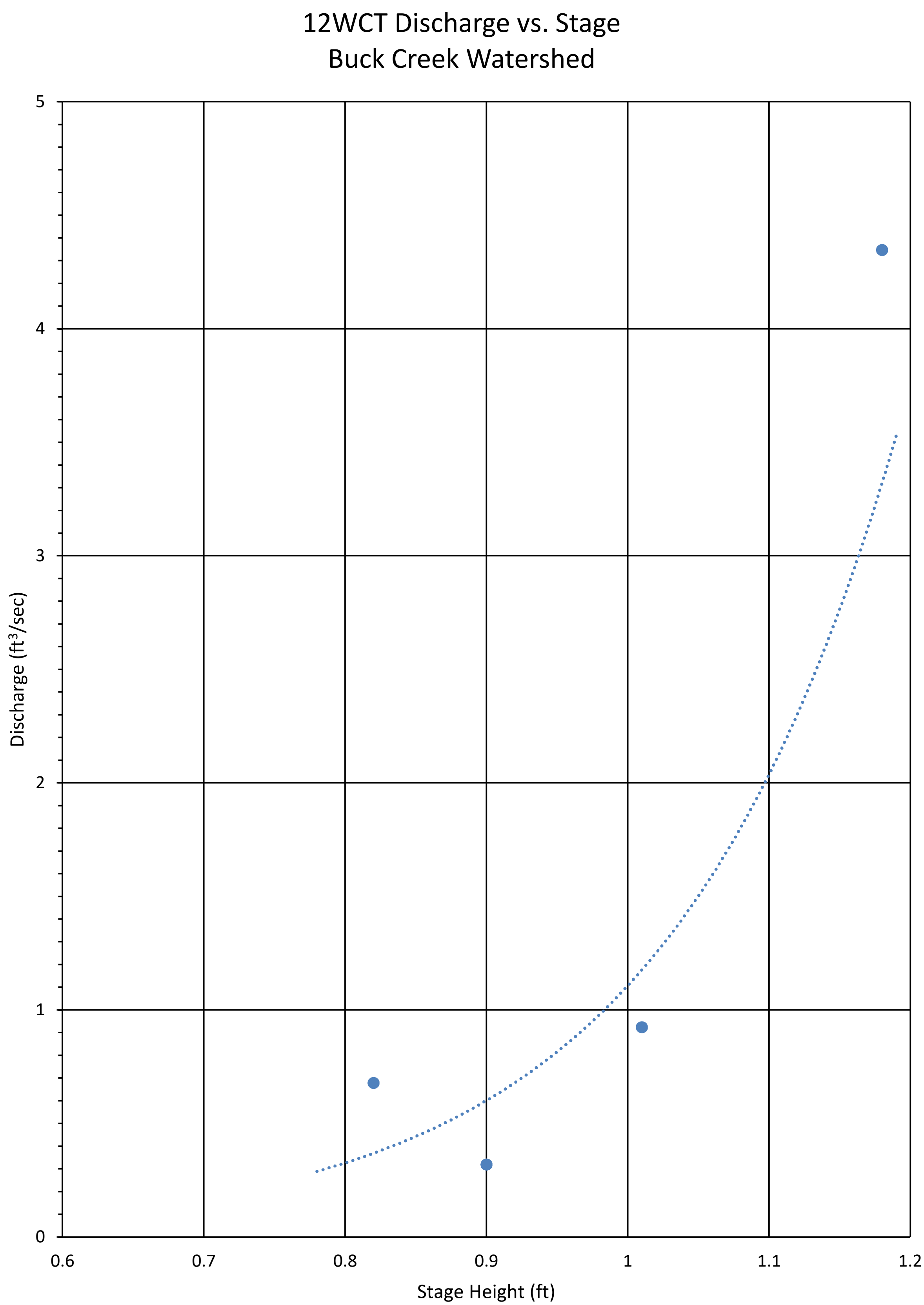

7WCT Discharge vs. Stage
Buck Creek Watershed
Discharge (ft³/sec)
Stage Height (ft)
0
1
2
3
4
5
6
7
8
9
10
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6

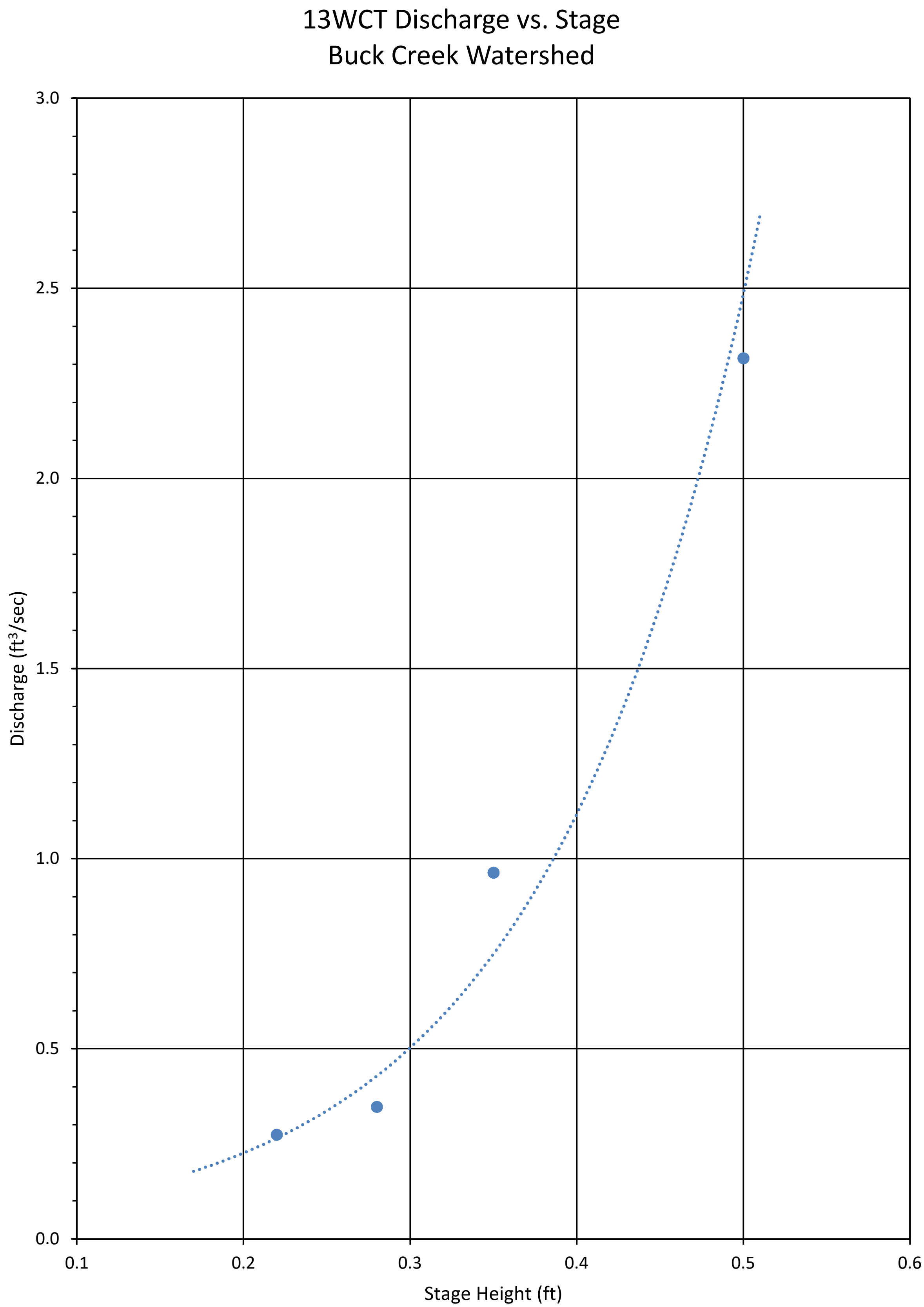

8WCT Discharge vs. Stage
Buck Creek Watershed
Discharge (ft³/sec)
Stage Height (ft)
0
10
20
30
40
50
1.7
1.8
1.9
2
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3


9WCT Discharge vs. Stage
Buck Creek Watershed
3.5
3
2.5
2
1.5
1
0.5
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
Discharge (ft³/sec)
Stage Height (ft)


10WCT Discharge vs. Stage
Buck Creek Watershed
Discharge (ft³/sec)
Stage Height (ft)
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0

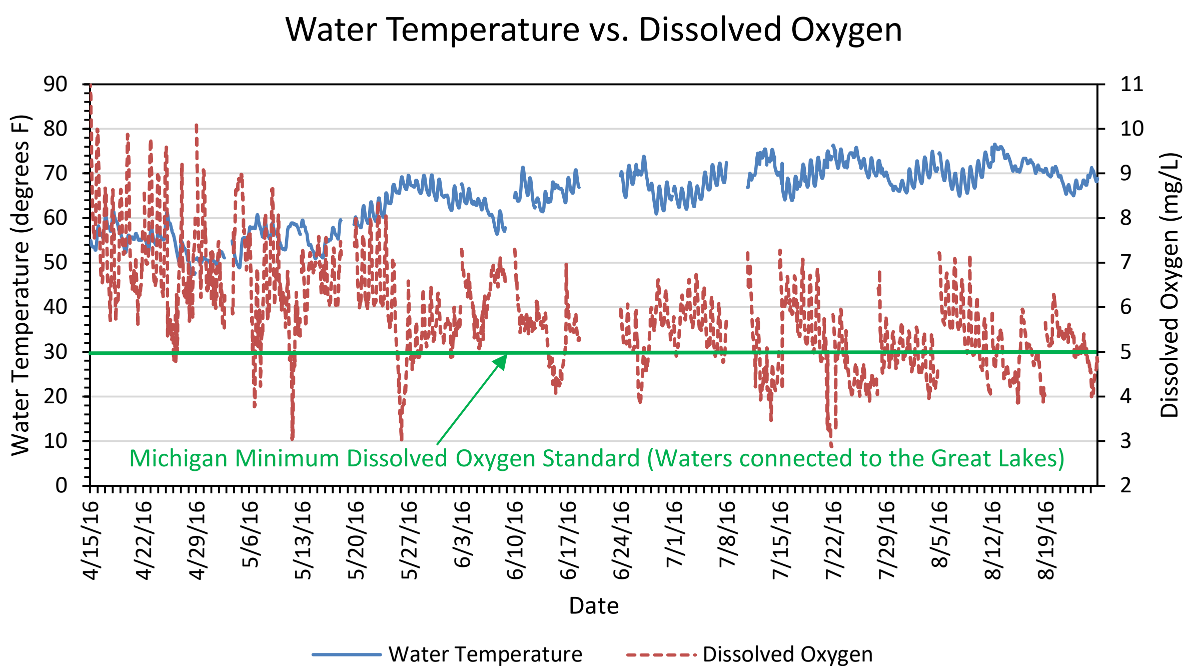

11WCT Discharge vs. Stage
Buck Creek Watershed
Discharge (ft^3/sec)
Stage Height (ft)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
2.1
2.3
2.5
2.7
2.9
3.1
3.3
3.5
3.7


12WCT Discharge vs. Stage
Buck Creek Watershed
Discharge (ft3/sec)
5
4
3
2
1
0
0.6
0.7
0.8
0.9
1
1.1
1.2
Stage Height (ft)

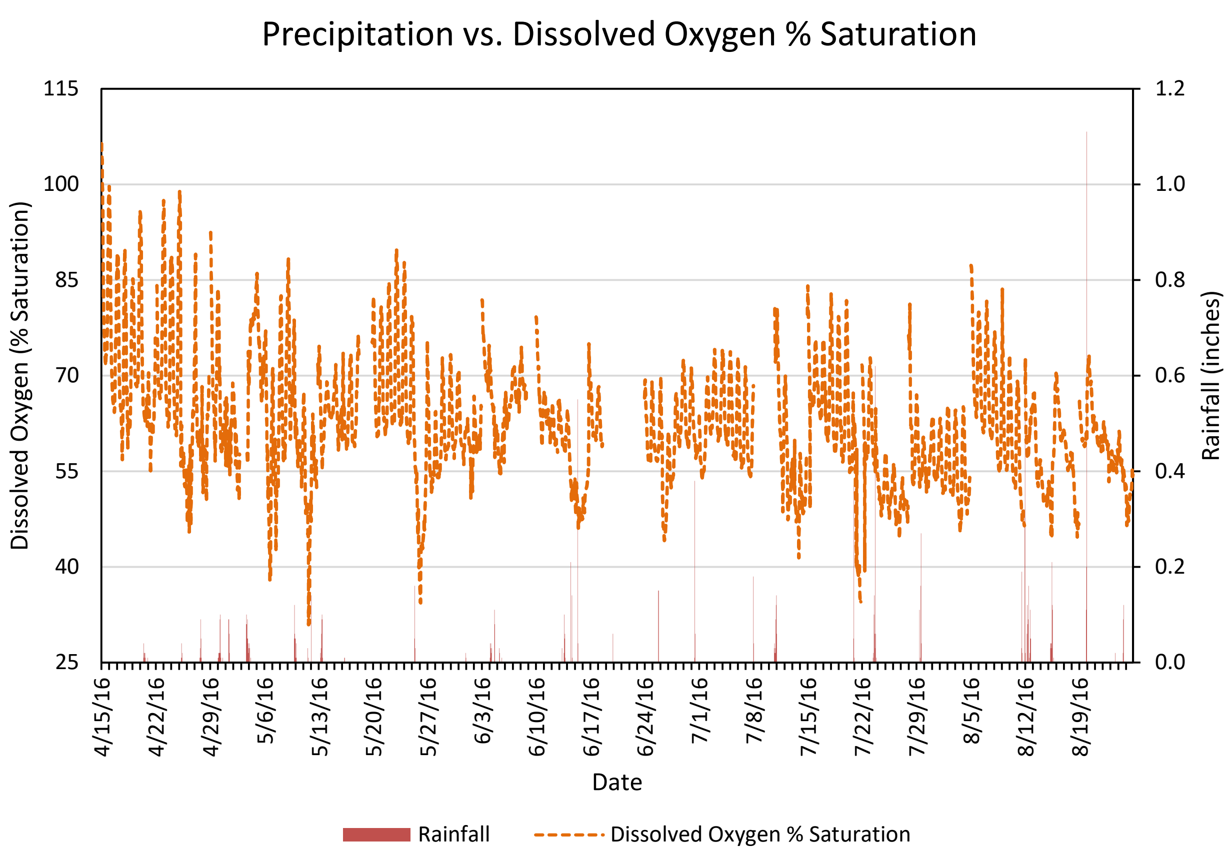

13WCT Discharge vs. Stage
Buck Creek Watershed
Discharge (ft³/sec)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Stage Height (ft)

APPENDIX D

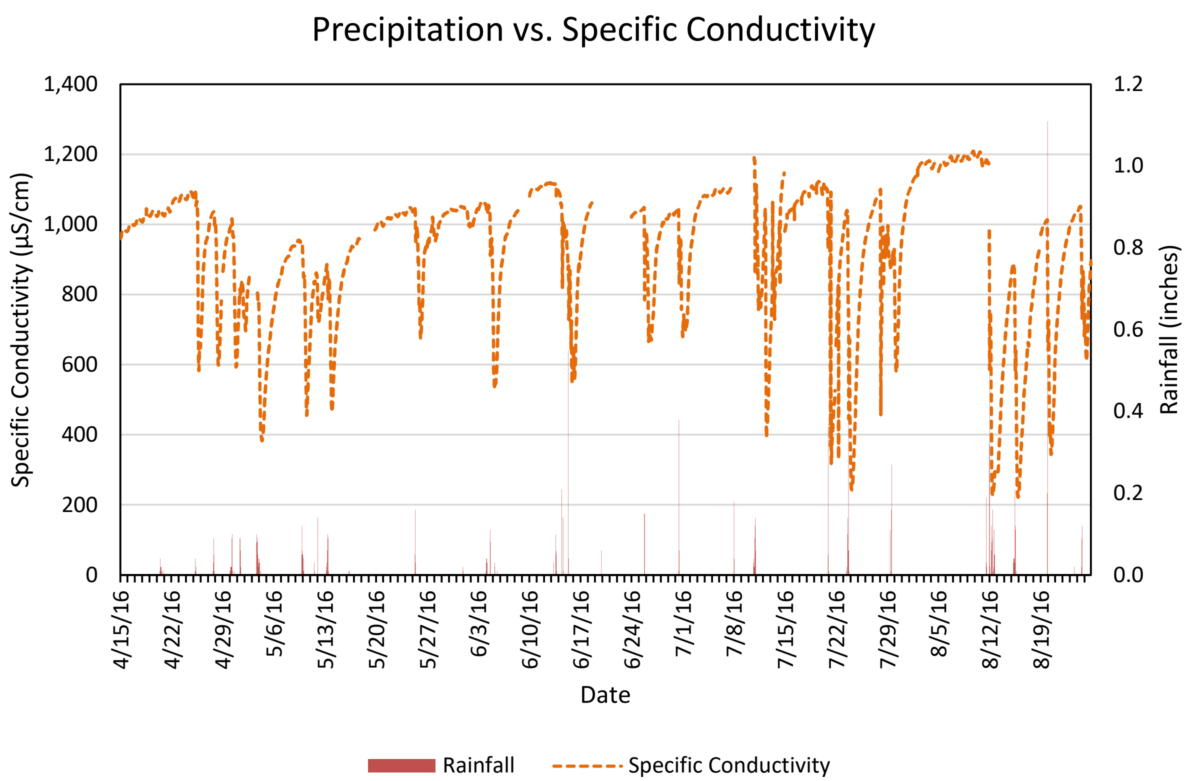
HYDROLAB DATASONDE GRAPHS

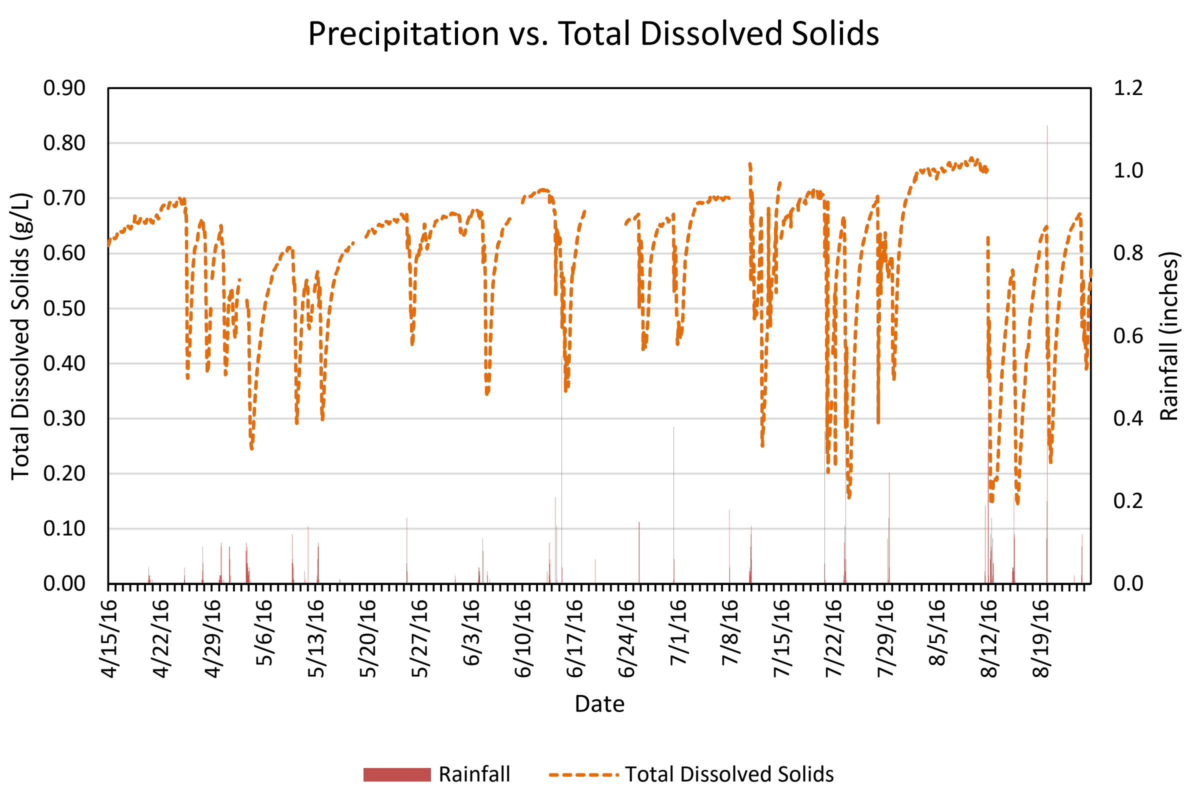


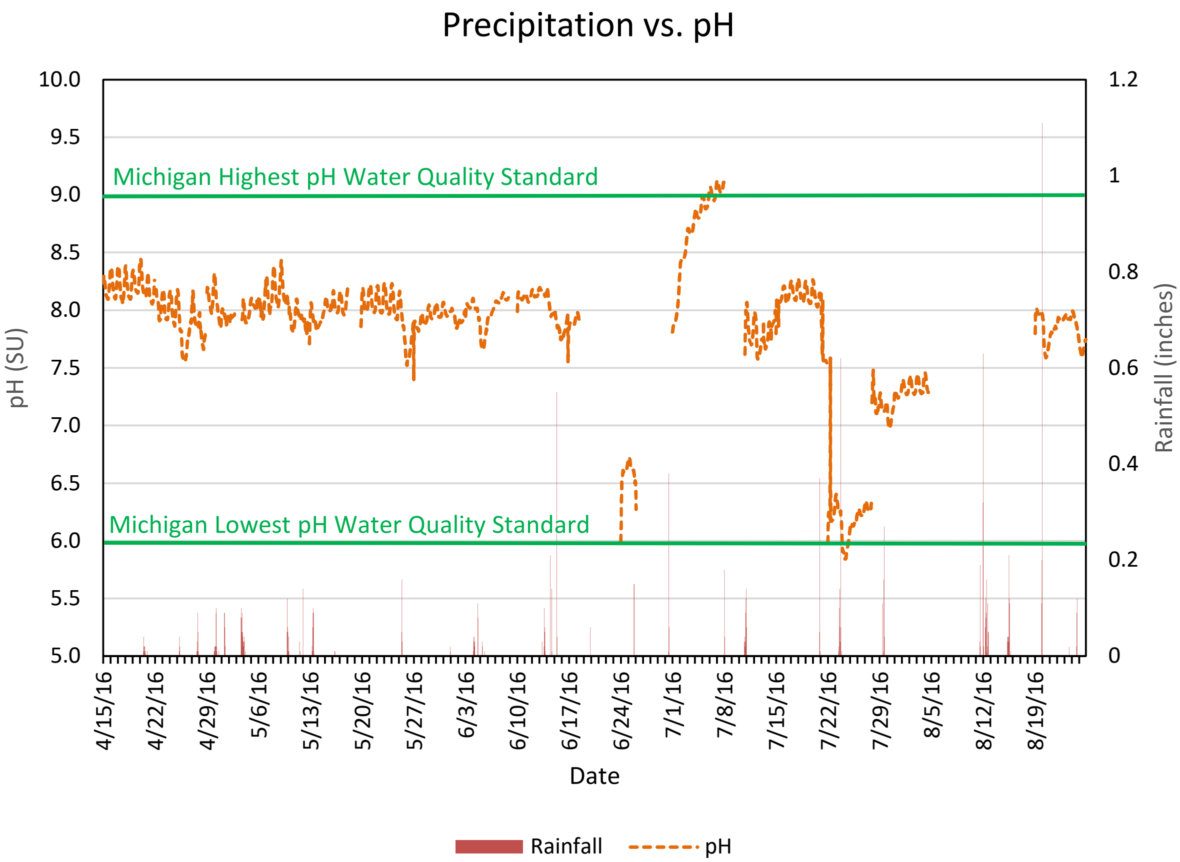
Water Temperature vs. Dissolved Oxygen
Water Temperature (degrees F)
Dissolved Oxygen (mg/L)
Michigan Minimum Dissolved Oxygen Standard (Waters connected to the Great Lakes)
90
80
70
60
50
40
30
20
10
0
11
10
9
8
7
6
5
4
3
2
4/15/16
4/22/16
4/29/16
5/6/16
5/13/16
5/20/16
5/27/16
6/3/16
6/10/16
6/17/16
6/24/16
7/1/16
7/8/16
7/15/16
7/22/16
7/29/16
8/5/16
8/12/16
8/19/16
Date
Water Temperature
Dissolved Oxygen



Precipitation vs. Dissolved Oxygen % Saturation
Dissolved Oxygen (% Saturation)
Rainfall (inches)
115
100
85
70
55
40
25
1.2
1.0
0.8
0.6
0.4
0.2
0.0
4/15/16
4/22/16
4/29/16
5/6/16
5/13/16
5/20/16
5/27/16
6/3/16
6/10/16
6/17/16
6/24/16
7/1/16
7/8/16
7/15/16
7/22/16
7/29/16
8/5/16
8/12/16
8/19/16
Date
Rainfall
Dissolved Oxygen % Saturation


Precipitation vs. Specific Conductivity
Specific Conductivity (µS/cm)
1,400
1,200
1,000
800
600
400
200
0
Rainfall (inches)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
4/15/16
4/22/16
4/29/16
5/6/16
5/13/16
5/20/16
5/27/16
6/3/16
6/10/16
6/17/16
6/24/16
7/1/16
7/8/16
7/15/16
7/22/16
7/29/16
8/5/16
8/12/16
8/19/16
Date
Rainfall
Specific Conductivity


Precipitation vs. Total Dissolved Solids
Total Dissolved Solids (g/L)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Rainfall (inches)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
4/15/16
4/22/16
4/29/16
5/6/16
5/13/16
5/20/16
5/27/16
6/3/16
6/10/16
6/17/16
6/24/16
7/1/16
7/8/16
7/15/16
7/22/16
7/29/16
8/5/16
8/12/16
8/19/16
Date
Rainfall
Total Dissolved Solids


Precipitation vs. pH
Michigan Highest pH Water Quality Standard
Michigan Lowest pH Water Quality Standard
pH (SU)
Rainfall (inches)
Date
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
1.2
1
0.8
0.6
0.4
0.2
0
4/15/16
4/22/16
4/29/16
5/6/16
5/13/16
5/20/16
5/27/16
6/3/16
6/10/16
6/17/16
6/24/16
7/1/16
7/8/16
7/15/16
7/22/16
7/29/16
8/5/16
8/12/16
8/19/16
Rainfall
pH

APPENDIX E

FISH SURVEYS

Michigan Dept. of Natural Resources **Population Estimate**
Fisheries Division

Water: Buck Creek
County: Kent Site TRS:

Site: Grandville Cemetery Date: Mark 10/13/2015 Recap. 10/14/2015

Gear: Barge, 2 probes Formula: Chapman-Petersen Acres: 0.70 Length (ft.): 1,000.00 No/mile= 1,548.7
Min. legal/acceptable size: 8.0
Species: Brown trout Estimated: no./acre: 419 Lb./acre: 66.41 %L-A by no.: 21.71 by lb.: 45.99

Inch	No.	Recapture run		Estimates				No.	Estimates by age group**								
group*	marked	recaps	unmarked	No.	95% limits	Variance	Lb.	aged	0+	1+	2+	ac	3+	4+	5+	6+	7+
0				0	0	0.00	0.00		0	0	0		0	0	0	0	0
1				0	0	0.00	0.00		0	0	0		0	0	0	0	0
2				0	0	0.00	0.00		0	0	0		0	0	0	0	0
3	1			1	0	0.00	0.02		0	0	0		0	0	0	0	0
4	1		2	5	4	5.00	0.16		0	0	0		0	0	0	0	0
5	20	9	8	37	11	29.24	2.15		0	0	0		0	0	0	0	0
6	40	12	18	97	33	269.75	9.37		0	0	0		0	0	0	0	0
7	36	12	19	90	30	227.19	13.41		0	0	0		0	0	0	0	0
8	19	9	7	33	9	20.64	7.16		0	0	0		0	0	0	0	0
9	7	2	4	18	11	30.11	5.36		0	0	0		0	0	0	0	0
10	4	2		4	0	0.00	1.64		0	0	0		0	0	0	0	0
11	3			3	0	0.00	1.62		0	0	0		0	0	0	0	0
12	3	1		3	0	0.00	2.08		0	0	0		0	0	0	0	0
13	1			1	0	0.00	0.87		0	0	0		0	0	0	0	0
14				0	0	0.00	0.00		0	0	0		0	0	0	0	0
15	1	1	1	2	0	0.00	2.65		0	0	0		0	0	0	0	0
16				0	0	0.00	0.00		0	0	0		0	0	0	0	0
17				0	0	0.00	0.00		0	0	0		0	0	0	0	0
18				0	0	0.00	0.00		0	0	0		0	0	0	0	0
19				0	0	0.00	0.00		0	0	0		0	0	0	0	0
20				0	0	0.00	0.00		0	0	0		0	0	0	0	0
21				0	0	0.00	0.00		0	0	0		0	0	0	0	0
22				0	0	0.00	0.00		0	0	0		0	0	0	0	0
23				0	0	0.00	0.00		0	0	0		0	0	0	0	0
24				0	0	0.00	0.00		0	0	0		0	0	0	0	0
25				0	0	0.00	0.00		0	0	0		0	0	0	0	0
Total	136	48	59	293	48	582	46.49										

blacknose dace
bluegill
burbot
central mudminnow
coho
common shiner
creek chub
emerald shiner
green sunfish
hyrbid sunfish
johnny darter
largemouth bass
logperch
longnose dace
mottled sculpin
northern pike
redhorse sp.
round goby
smallmouth bass
white sucker
yellow perch