



National Capital Region Network FY 2010 Water Resources Monitoring Data Report

Water Chemistry, Nutrient Dynamics, and Surface Water Dynamics Vital Signs

Natural Resource Data Series NPS/NCRN/NRDS—2012/381



ON THE COVER

Tonya Watts, NCRN I&M Hydro Tech, collecting discharge data
Photograph by: NCRN I&M Staff

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October 2012

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies,

The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

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Please cite this publication as:

Pieper J. M., M. E. Norris, and T. Watts. 2012. National Capital Region Network FY 2010 water resources monitoring data report:: water chemistry, nutrient dynamics, and surface water dynamics vital signs. Natural Resource Data Series NPS/NCRN/NRDS—2012/381. National Park Service, Fort Collins, Colorado.

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Executive Summary

Water chemistry is important to maintaining a healthy habitat for many aquatic organisms, wildlife, and humans. Changes in water quality can change system productivity, shift species abundances and distributions, and alter nutrient cycles. Water quality parameters such as pH, specific conductance, dissolved oxygen, and temperature are good measurements that provide an overview of water quality. Water quality monitoring is required to comply with relevant environmental legislation and NPS mandates and to evaluate potential stressors in NCRN waters.

In 2005, the National Capital Region Inventory and Monitoring Network (NCRN) initiated a long-term water quality and quantity monitoring program, funded in part by the Water Resources Division. The program is carried out through monthly sampling at 38 sites within 10 of the NCRN parks. This report focuses on data collected under the Water Chemistry Monitoring Protocol and Surface Water Dynamics Protocol of the NCRN Inventory and Monitoring (I&M) Program (Norris et al. 2011).

Parks monitored for this report include Antietam National Battlefield (ANTI), Catoctin Mountain Park (CATO), Harpers Ferry National Historical Park (HAFE), George Washington Memorial Parkway (GWMP), Manassas National Battlefield Park (MANA), Monocacy National Battlefield (MONO), National Capital Parks – East (NACE), Prince William Forest Park (PRWI), Rock Creek Park (ROCR), and Wolf Trap National Park for the Performing Arts (WOTR). The streams monitored are all part of the Potomac River Watershed. The Potomac is the second largest drainage of the nine major river basins that form the 64,000 square mile Chesapeake Bay watershed.

Introduction

The parks in the National Capital Region Inventory and Monitoring Network (NCRN) lie within the Potomac River watershed with the exception of parts of the Suitland Parkway and Baltimore and Washington Parkway within National Capital Parks – East (NACE), which are located in the Patuxent River watershed.

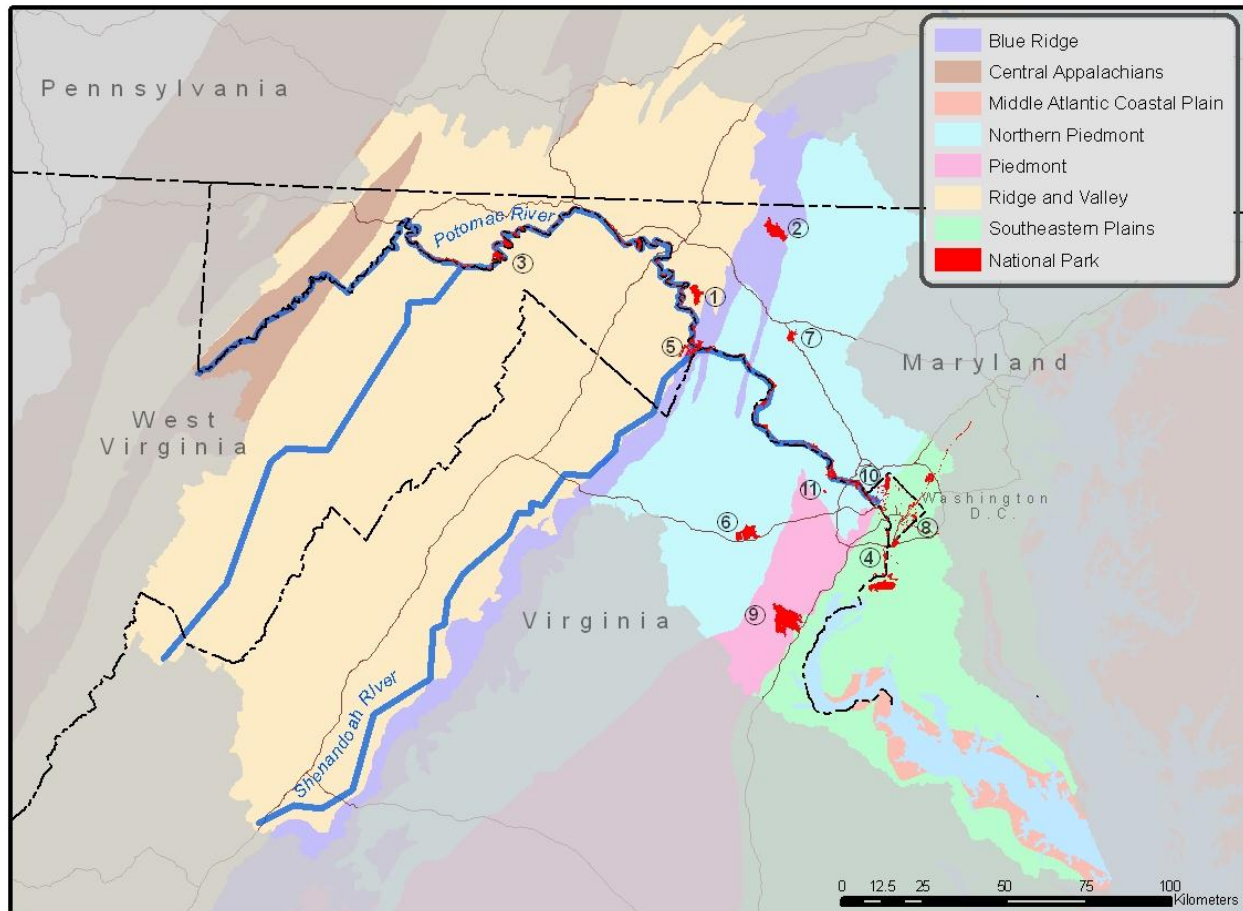


Figure 1: Locations of National Parks (red) in the NCRN. The Potomac River watershed and physiographic regions are highlighted.

1. Antietam National Battlefield (ANTI)
2. Catoctin Mountain Park (CATO)
3. Chesapeake & Ohio Canal National Historical Park (CHOH)
4. George Washington Memorial Parkway (GWMP)
5. Harpers Ferry National Historical Park (HAFE)
6. Manassas National Battlefield Park (MANA)
7. Monocacy National Battlefield (MONO)
8. National Capital Parks–East (NACE)
9. Prince William Forest Park (PRWI)
10. Rock Creek Park (ROCR)
11. Wolf Trap National Park for the Performing Arts (WOTR)

The Potomac River Watershed covers seven physiographic regions: Blue Ridge, Central Appalachians, Middle Atlantic Coastal Plain, Northern Piedmont, Piedmont, Ridge and Valley, and the Southeastern Plains (Figure 1). Though several parks (CHOH, GWMP, HAFE, NACE), are adjacent to the river, the parks do not manage the waters of the Potomac. The Potomac is the second largest drainage of the nine river basins that form the 64,000 square mile Chesapeake Bay watershed. The Chesapeake Bay is the largest estuary in the United States, providing habitat for abundant and diverse wildlife populations and supporting an economy that includes fishing, shipping, and recreation (Burke et al. 1999). The National Park Service is a co-signer of the Chesapeake Bay Agreements for restoration of the Chesapeake Bay.

The NCRN's long-term water monitoring program, funded in part by the Water Resources Division (WRD), is designed to ensure the National Capital Region's (NCR) parks possess science-based information needed for effective natural resource management. To achieve this, we collect data for the following vital signs¹:

- water chemistry
- nutrient dynamics
- surface water dynamics
- physical habitat index
- aquatic macroinvertebrates
- fish

A water chemistry and quantity monitoring protocol was developed by the NCRN which includes the water chemistry, nutrient dynamics, and surface water dynamics vital signs (Norris et al. 2011). The NCRN Biological Stream Survey (BSS) (Norris and Sanders 2009), which includes the physical habitat index (PHI), aquatic macroinvertebrates (BIBI), and fish (FIBI) vital signs was adapted from the Maryland Biological Stream Survey in collaboration with researchers from Frostburg State University and the Maryland Department of Natural Resources (Kazyak et al. 2007). This report includes regional water chemistry, nutrient dynamics and surface water dynamics data. Data analysis on the BSS data will be published every six years when a full survey of the parks is completed. The BSS report is expected in 2014.

¹ Vital signs are selected physical, chemical, and biological elements and processes of park ecosystems that

Objectives of the Water Chemistry and Quantity Monitoring Protocol:

1. Assess variance in temperature, specific conductance, pH, dissolved oxygen (DO), nutrients and acid neutralizing capacity (ANC) in priority streams of the NCRN, on a monthly and seasonal basis as well as over the long term.
2. Assess trends in temperature, specific conductance, pH, DO, nutrients and ANC
3. Assess stream condition by comparing results against thresholds determined a) biologically (determined through literature search), b) according to drinking water standards, c) according to the Environmental Protection Agency (EPA) and state designated use standards, or d) of previous variability.
4. Assess variability of the flow volume (discharge) of surface water in major streams of NCRN parks.
5. Assess trends in the flow volume (discharge) of surface water in major streams of NCRN parks.
6. Assess the availability of sufficient water for ecological, recreational, and aesthetic purposes of the parks.
7. Develop rating curves for a range of environmental conditions, land use, and weather patterns, for each water body (in order to gain an overall understanding of hydrologic systems within the NCRN).

Methods

Although a brief overview of the water quality monitoring methods is provided here, a detailed rational of the sampling design and methods, in addition to Standard Operating Procedures, are provided in the NCRN Water Chemistry and Quantity Monitoring Protocol (Norris et al. 2011).

Sampling Design

The Water Monitoring Program is focused on 1st to 4th order Wadeable, non-tidal freshwater streams in the parks of the NCRN. The sample design for streams is based on stream location bisected by park boundaries. Since water chemistry monitoring sites serve as the pool from which the biological sampling sites are chosen, in-park stream segments less than 75m long (the length used for Maryland Biological Stream Survey sampling) were eliminated. Sampling occurs on those segments of streams that are the furthest downstream and still in park boundaries. Measurements downstream generally reflect conditions in the watershed upstream. It was initially envisioned that once the list of potential monitoring locations was developed; a randomization process would be used to determine which sites would be sampled. However, at this time, resources are sufficient to allow sampling of the full suite of potential sites. During FY 2010, a total of 38 sites were sampled (Table 2).

Table 1: Site Monitored in National Capital Region Network

Site	Watershed	Physiographic Region	State	County	Stream Order
Antietam National Battlefield					
Sharpsburg Creek	Antietam Creek	Ridge and Valley	MD	Washington	1
Catoctin Mountain Park					
Big Hunting Creek	Upper Monocacy River	Blue Ridge	MD	Frederick	2
Owens Creek	Upper Monocacy River	Blue Ridge	MD	Frederick	2
Whiskey Still Run	Upper Monocacy River	Blue Ridge	MD	Frederick	1
George Washington Memorial Parkway					
Minnehaha Creek	Cabin John	Northern Piedmont	MD	Montgomery	2
Mine Run	Difficult Run	Northern Piedmont	VA	Fairfax	2
Pimmit Run	Rock Creek	Northern Piedmont	VA	Arlington	3
Turkey Run	Difficult Run	Northern Piedmont	VA	Fairfax	2
Harpers Ferry National Historical Park					
Flowing Springs Run	North Fork Shenandoah River	Ridge and Valley	WV	Jefferson	2
Manassas National Battlefield					
Youngs Branch	Bull Run	Northern Piedmont	VA	Prince William	3
Monocacy National Battlefield					
Bush Creek	Lower Monocacy River	Northern Piedmont	MD	Frederick	3
Gambrill Mill Run (formerly Visitor's Center Creek)	Lower Monocacy River	Northern Piedmont	MD	Frederick	2
National Capital Parks – East					

Site	Watershed	Physiographic Region	State	County	Stream Order
Henson Creek	Middle Potomac Tidal	Southeastern Plains	MD	Prince Georges	1
Oxon Run	Middle Potomac Tidal	Southeastern Plains	MD	Prince Georges	1
Still Creek	Anacostia River	Southeastern Plains	MD	Prince Georges	1
Unnamed Tributary to Accokeek Creek	Middle Potomac Tidal	Southeastern Plains	MD	Prince Georges	1
Prince William Forest Park					
Carter's Run	Quantico Creek	Southeastern Plains	VA	Prince William	1
Mawavi Run	Quantico Creek	Piedmont	VA	Prince William	1
Mary Bird Branch	Quantico Creek	Southeastern Plains	VA	Prince William	2
North Fork Quantico Creek	Quantico Creek	Southeastern Plains	VA	Prince William	2
Orenda Run	Quantico Creek	Piedmont	VA	Prince William	1
South Fork Quantico Creek	Quantico Creek	Southeastern Plains	VA	Prince William	3
Sow Run	Quantico Creek	Piedmont	VA	Prince William	2
Taylor Run	Quantico Creek	Piedmont	VA	Prince William	1
Rock Creek Park					
Broad Branch	Rock Creek	Northern Piedmont	DC	Washington	2
Dumbarton Oaks	Rock Creek	Northern Piedmont	DC	Washington	1
Fenwick Branch	Rock Creek	Northern Piedmont	DC	Washington	2
Hazen Creek	Rock Creek	Northern Piedmont	DC	Washington	1
Klinge Valley Stream	Rock Creek	Northern Piedmont	DC	Washington	1
Luzon Branch	Rock Creek	Northern Piedmont	DC	Washington	1
Normanstone Creek	Rock Creek	Northern Piedmont	DC	Washington	1
Battery Kemble Creek (formerly Palisades Creek)	Rock Creek	Northern Piedmont	DC	Washington	1
Pinehurst Branch	Rock Creek	Northern Piedmont	DC	Washington	1
Piney Branch	Rock Creek	Northern Piedmont	DC	Washington	1
Rock Creek (below Dumbarton Oaks)	Rock Creek	Northern Piedmont	DC	Washington	4
Soapstone Valley Park Stream	Rock Creek	Southeastern Plains	DC	Washington	1
Wolf Trap National Park for the Performing Arts					
Wolf Trap Creek	Difficult Run	Northern Piedmont	VA	Fairfax	2
Courthouse Creek	Difficult Run	Northern Piedmont	VA	Fairfax	1

No sites are monitored in CHOH at this time. The linear nature of the park and the large number of streams that cross it provide significant challenges to water monitoring. Each individual stream is within the park for only a short distance, and drains only a small portion of the park. Due to these factors the park has little control over the water quality of most of these streams, and each individual stream has a small impact on the park as a whole. Therefore it is difficult to design an appropriate sampling effort that is both affordable and meaningful.

Sampling Frequency and Replication

Currently, all parameters are measured on a monthly basis. The *in situ* measurements (Temperature, pH, DO, specific conductance, salinity) are determined utilizing handheld water chemistry probes. For ANC and nutrients (nitrate, total phosphorus) water samples are collected

and laboratory analysis is conducted. Flow is measured monthly concurrently with other sampling. All parameters are measured monthly as weather and site access permits. Any gaps in sampling data are summarized in the table that follows. Additionally, an equipment failure kept us from gathering depth, flow, and discharge data for October 2009 through the end of December 2009.

Table 2: Sites not sampled during FY2010

December 2009	January 2010	February 2010	September 2010
		ANTI shck	
	CATO owck, whst	CATO whst, owck, bghc	
		GWMP micr, miru, piru, turu	
		HAFE flsp	
		MANA yobr	MANA yobr
		MONO buck, vcck	
		NACE acck, hecr, oxru, stck	
		PRWI caru, maru, mbbr, nfqc, orru, sfqc, soru, taru	
ROCR brbr, duoa, febr, hacr, klva, lubr, nost, phbr, pybr, roc3, svps		ROCR brbr, bake, duoa, febr, hacr, klva, lubr, nost, phbr, pybr, roc3, svps	
		WOTR chck, wotr	
Reason: Sites frozen over following winter storm	Reason: Sites frozen over due to cold temperatures	Reason: Major winter storm closed Federal Government for a week and closed parks for up to 3 weeks	Reason: Stream ran dry

Data Collection and Analysis

Tablet PCs are used as the primary tool for recording field data. A database designed specifically for the NCRN Water Resources vital signs is deployed on the tablet PC and used as a data entry application. All water chemistry data are entered into this system in the field. Additionally, data derived from water samples collected in the field are also entered into this database after the samples have been analyzed in the lab.

All NCRN water monitoring data is entered into NPStoret which is the National Park Service's version of the EPA STORET database. NPStoret is then used to produce all of the graphs used in this report. Water quality parameters at a site will be compared by plotting analyte concentration through time to identify if there is no slope (no change), positive slope (concentration increasing through time), or a negative slope (concentration decreasing through time). Concentrations will also be compared against threshold values that are indicators of degradation. The annual report will focus on the status of the streams in that year. The report will cover the status of the following indicators: air and water temperature, ANC, DO, NO₃, pH, SC, conductivity, salinity, width, depth, flow, and discharge.

Vital Signs

We collect data for water chemistry (temperature, dissolved oxygen [DO], specific conductance, pH, acid neutralizing capacity [ANC]), nutrients (nitrate and total phosphorus), and surface water dynamics (width, depth, discharge, and flow) (Norris et al. 2011). These parameters, which provide information that characterize a waterbody or stream segment, are fundamental components of monitoring and regulatory programs, and are relatively easy to measure with

multi-parameter probes or commercial test kits. The NCRN Water Resources Specialist and Hydrologic Technician collect *in situ* data with handheld meters once a month at every perennial wadeable stream in the parks (Table 3) for temperature, dissolved oxygen, specific conductance, and pH. At the same time samples are collected and brought back to the lab for acid neutralizing capacity, nitrate, and total phosphorus analysis. Parameters are described in detail below.

Table 3: Summary statistics for Vital Signs in NCRN

Parameter	Count	Censored ²	Included in analysis	Minimum	Maximum	Mean	Median	Standard Deviation
Air Temperature (°C)	434	2	432	-6	40.1	15.3	15.0	9.39
Water Temperature (°C)	449	55	394	0.1	29.6	14.3	13.5	6.06
DO (mg/L)	449	55	394	3.2	14.93	9.62	9.60	2.19
Nitrate (mg/L)	458	74	384	0.4	10	2.18	1.70	1.54
Phosphorus (mg/L)	457	70	387	0.06	2.67	0.38	0.29	0.28
ANC (µeq/L)	452	88	364	202	5860	1364	1144	1071
pH	449	55	394	6.05	8.98	7.58	7.60	0.46
Salinity (ppt)	449	55	394	0.01	0.67	0.19	0.17	0.14
Specific conductance (µS/cm)	449	55	394	26.5	1270	386.7	359.0	274.6
Discharge (cfs)	457	225	232	0	79.7	4.74	1.18	10.67
Flow (ft/sec)	278	48	230	0	2.19	0.54	0.41	0.46
Water Depth (ft)	277	45	232	0.01	2.43	0.42	0.37	0.28
Wetted Width (ft)	457	65	392	0	66	12.4	9.2	9.81

² Certain values are automatically censored from data analysis. These are typically instances where no data has been input, or the data has been entered as 'Absent', 'Not Reported', 'Present below Quantification Limits', 'Present above Quantification Limits' or 'Not Detected'.

Acid Neutralizing Capacity (ANC)

ANC is the prime indicator of a waterbody's susceptibility to acid inputs and is a measure of the amount of carbonate and other compounds in the water that neutralize low pH. ANC refers to the alkalinity of an unfiltered water sample (i.e. alkalinity due to both dissolved and suspended matter). The pH of water does not indicate its "buffering capacity," which is controlled by the amounts of alkalinity and acidity present. ANC is typically caused by anions in natural waters that can enter into a chemical reaction with a strong acid. These are primarily the carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) ions. Borates, phosphates, silicates, arsenate, ammonium, and organic ligands (e.g. acetate and propionate) can also contribute to alkalinity when present. It is particularly important to measure ANC in areas where acid mine drainage (e.g. PRWI) or acid precipitation (entire NCR) is a potential concern. Acid sensitive waters generally have specific conductance below 25 $\mu\text{S}/\text{cm}$, acid neutralizing capacity (ANC) below 100 $\mu\text{eq}/\text{L}$ for episodic acidification (50 $\mu\text{eq}/\text{L}$ for chronic acidification), total base cation (calcium, magnesium, sodium, and potassium) concentration below 100 $\mu\text{eq}/\text{L}$, and pH below 6.0. Schindler (1988) states that surface waters with ANC less than or equal to 200 $\mu\text{eq}/\text{L}$ are considered sensitive to acidification. In karst terrain, ANC below 600 $\mu\text{eq}/\text{L}$ CaCO_3 is cause for concern (Weeks et al. 2007). NPS-WRD (National Park Service 1995, 1996, 1997) indicates that surface waters in three parks—Antietam National Battlefield, Chesapeake and Ohio Canal National Historical Park, and Manassas National Battlefield were not susceptible to acidification from atmospheric deposition. However this data ranges in age from 8 to 30 years and circumstances may have changed.

NCRN uses (but does not endorse) Hach Alkalinity Method 8203 (Alkalinity, Phenolphthalein and Total using Sulfuric Acid Method) to determine phenolphthalein and total alkalinity which are used to calculate the acid neutralizing capacity.

Dissolved Oxygen (DO)

DO is a measure of the amount of oxygen in solution. Dissolved oxygen enters the water one of two ways— photosynthesis of plants and directly from the atmosphere via diffusion or mechanical aeration (e.g., waves, waterfalls). The primary losses of DO from water are temperature rise, plant and animal respiration and biochemical oxygen demand (BOD). The DO concentration of surface water is dependent on water temperature and air pressure, and to a lesser extent, the amount of dissolved ions (measured as salinity³ or conductivity). The higher the pressure and cooler the temperature, the more oxygen from the atmosphere can be dissolved into the water until an equilibrium is reached; this is called saturation (Hem 1989). Oxygen has strong daily and seasonal variability. In organically enriched streams, DO is often lowest just before sunrise because plants have not been photosynthesizing and only respiration has been occurring. Conversely, DO increases after sunrise until the sun's angle of incidence is greatest because the rate of photosynthesis is dependent on sunlight. In less enriched streams, this pattern may be less

³ Correction factors for salinity are normally applied after measuring DO.

apparent or absent because stream temperatures are lower at night and thus can contain more dissolved oxygen. Therefore it is important to always monitor a particular site at the same time of day. Because oxygen is sparingly soluble, the balance between sources and sinks can be easily upset leading to oxygen extremes of super saturation or total/near total depletion (U.S. Geological Survey 1980, Stednick and Gilbert 1998, National Park Service 2002).

DO is necessary in aquatic systems for the survival and growth of many aquatic organisms. The presence and amount of dissolved oxygen in surface water also determines the extent to which many chemical and biological reactions will occur (Wilde and Radtke 1998). Low dissolved oxygen is of greatest concern due to detrimental effects on aquatic life. Conditions that generally contribute to low DO levels include warm temperatures, low flows, water stagnation and shallow gradients (streams), organic matter inputs, and high respiration rates. Decay of excessive organic debris that are in the water column from aquatic plants, municipal or industrial discharges, or storm runoff can also cause dissolved oxygen concentrations to be under saturated or depleted. Insufficient DO can lead to unsuitable conditions for aquatic life, and its absence can result in the unpleasant odors associated with anaerobic decomposition.

It is essential that consideration of the natural regimes of DO be included in applying criteria to specific water bodies. Higher absolute concentrations of dissolved oxygen (milligrams/liter) at saturation are achievable in the natural environment under conditions of higher atmospheric pressure, lower temperature, and lower dissolved solids content of the water. Thus, water bodies occurring at higher elevations, subject to a barometric low pressure system, or having warmer temperatures and/or higher dissolved solids content would be expected to contain less dissolved oxygen at saturation. Super saturation of surface water with respect to dissolved oxygen may also result from turbulence associated with high gradient streams or waterfalls. In rocky, high gradient streams, mechanical aeration is often great enough that even streams with highly elevated oxygen demand are at or near saturation levels. In low gradient coastal plain systems, even moderate oxygen demand (referred to as BOD or biochemical oxygen demand) can result in DO levels that are low enough to harm aquatic biota (U.S. Geological Survey 1980, Stednick and Gilbert 1998, National Park Service 2002).

Minimum required DO concentration to support fish varies because the oxygen requirements of fish vary with a number of factors, including the species and age of the fish, prior acclimatization, temperature, and concentration of other substances in the water. The District of Columbia, Maryland, and West Virginia require that DO concentration may not be less than 5.0 mg/L at any time (District Department of the Environment 2010, State of Maryland 2010b, and State of West Virginia 2011). The Commonwealth of Virginia has a 6.0 mg/L DO minimum for natural trout waters (Virginia State Water Control Board 2011).

NCRN uses (but does not endorse) a Yellow Springs Institute (YSI) Professional Plus handheld meter with a polarographic DO probe to measure the percent saturation and concentration of dissolved oxygen.

Nitrate - Nitrogen

Nitrate is the oxidized form of aqueous nitrogen reported as milligrams/liter NO_3 or milligrams/liter $\text{NO}_3 - \text{N}$. Like ammonia, nitrate is one of the dissolved, inorganic forms of

nitrogen most available for biological uptake and the chemical transformation that can lead to eutrophication of water bodies.

Nitrate is a bio-available form of nitrogen which aquatic plants can absorb and incorporate into proteins, amino acids, nucleic acids, and other essential molecules. Nitrate is highly mobile in surface and groundwater and may seep into streams, lakes, and estuaries from groundwater enriched by animal or human wastes and commercial fertilizers. High concentrations of nitrate can enhance the growth of algae and aquatic plants in a manner similar to enrichment in phosphorous and thus cause eutrophication of a water body. Nitrate in drinking water also presents a human health concern particularly to infants (blue-baby syndrome). In most natural waters, inorganic nitrogen as ammonium or nitrate is not the growth-limiting nutrient unless phosphorous is unusually high. Nitrate is typically indicative of agricultural pollution. Nitrate in surface water is considered a nutrient and may occur in dissolved or particulate form resulting from inorganic sources. The dissolved, inorganic forms of nitrogen are most available for biological uptake and chemical transformation. The drinking water standard is 10 mg/L. Nitrate also travels freely through soil and therefore may pollute ground waters.

NCRN uses (but does not endorse) Hach Method 10020 (Nitrate, Chromatropic Acid Method, Test 'N Tube) to determine the concentration of nitrate.

pH

The pH of water directly affects physiological functions of plants and animals and is therefore an important indicator of the health of a water system (U.S. Geological Survey 1980, Stednick and Gilbert 1998). pH is measured to determine the acid/base characteristics of water and is controlled by interrelated chemical reactions that produce or consume hydrogen ions (Hem 1989). The term pH literally means “power of hydrogen.” More hydrogen ions results in a lower pH. The concentration of these ions is measured on a log scale that most commonly ranges from 0 (acid) to 14 (basic/alkaline), so each pH unit increase represents a 10X decrease in hydrogen ion concentration. Pure water has a pH of 7 (neutral), which means that it is equally able to accept or donate hydrogen ions. At $\text{pH} < 7$ (acid), hydrogen ions are more readily donated (Hem 1989, Stednick and Gilbert 1998).

The pH of water is important in the toxicity and solubility of many constituents. The ideal natural range of pH for aquatic life in streams is 6.5 to 9. Freshwaters can vary widely in acidity and alkalinity due to natural causes as well as anthropogenic inputs. Extreme pH values, generally those much below 5 or above 9, are harmful to most organisms (Hem 1989), and the buffering capacity of water is critical to life. Estimating the toxicity of ammonia, aluminum, and some other contaminants requires accurate pH values. Changes in pH affect the dissociation of weak acids or bases, which in turn affects the toxicity of many compounds. For example, hydrogen cyanide toxicity to fish increases with lowered pH; rapid increases in pH increase NH_3 concentrations; and the solubility of metal compounds is affected by pH. Metals mobility is also enhanced by low pH which can have a significant impact to water bodies located in areas contaminated by heavy metals (e.g. mining). The desired range of pH for fish depends upon many other factors such as temperature, DO, and the content of various anions and cations. The importance of pH as a parameter for monitoring is reflected by potential impacts to the life cycle stages of aquatic macroinvertebrates and certain salmonids that can be adversely affected when pH levels above 9.0 or below 6.5 occur. Temporal causes of variation of pH can range from

primary production by fauna and flora (diurnal and seasonal) to fractionation during snowmelt, changes in runoff processes, and changes in atmospheric deposition (monthly and/or seasonal) (MacDonald et al. 1991).

The District of Columbia water quality standards state that the pH of stream water should be between 6.0 and 8.5 (District Department of the Environment 2010). The State of Maryland water quality standards state that the pH should be between 6.5 and 8.5 (State of Maryland 2010b). The Commonwealth of Virginia and the State of West Virginia require pH to be between 6.0 and 9.0 (State of West Virginia 2011, Virginia State Water Control Board 2011).

NCRN uses (but does not endorse) a Yellow Springs Institute (YSI) Professional Plus handheld meter to measure the pH at each site in FY2010.

Specific Conductance, Conductivity, and Salinity

Specific conductance is a temperature corrected measure of the electrical conductivity of an aqueous solution and is directly related to concentration of ionic species. Conductivity is a measure of the capacity of water to conduct an electrical current and is a function of the types and quantities of dissolved, electrically charged substances (ions) in water (Radtke et al. 1998). The conductivity of solutions of ionic species is highly dependent on temperature and may change as much as 3% for each 1°C change. Thus a significant apparent change in conductivity may simply be a function of the water body's diurnal or seasonal temperature change. In addition, corrections made for temperature vary with the charge and abundance of the ionic species present (e.g. Na⁺ versus Ca⁺⁺) so no universally applied algorithm of calculating specific conductance/conductivity is exact. A raw conductivity value is not temperature compensated making it difficult to compare measurements of the same or different water bodies when not at the same temperature (e.g. conducting trend analysis over time). When the raw conductivity measurement of a substance is normalized to unit length and unit cross-section at a specified temperature (e.g. a compensation temperature of 25 °C), it is called specific conductance (U.S. Geological Survey 1980, Stednick and Gilbert 1998, National Park Service 2002). Specific conductance is dependent upon the types and quantities of dissolved substances and is a good indication of total dissolved solids (TDS) and total ion concentration.

The electrical conductivity of a water body has little or no direct effect on aquatic life but because it is essentially due to the sum of all ionic species, its change (increase) may be detrimental if the particular ionic species or groups of ionic species (e.g. specific salts) causing the change is toxic to aquatic life. Specific conductance is useful in estimating the concentration of dissolved solids in water. Electric current is carried by dissolved inorganic solids such as chloride, carbonate, nitrate, sulfate, and phosphate anions (negatively charged particles), as well as sodium, calcium, magnesium, potassium, iron, and aluminum cations (positively charged particles). Common sources of pollution that can affect specific conductance are deicing salts, dust reducing compounds, agriculture (primarily from the liming of fields), and acid mine drainage (AMD) associated with mining operations (U.S. Geological Survey 1980, Stednick and Gilbert 1998, National Park Service 2002). Organic materials such as oils, phenols, alcohols, and sugars do not carry electric current. Small quantities of mineral salts are usually contained in natural inland waters, but in waters polluted by brines and various chemical wastes, salt concentrations may rise to levels harmful to living organisms due to the increase in osmotic pressure. Salinity is often expressed as specific electrical conductance in studies of waters used

for irrigation and fish production. Collectively, all substances in solution exert osmotic pressure on the organisms living in it, which in turn adapt to the condition imposed upon the water by its dissolved constituents. With excessive salts in solution, osmotic pressure becomes so high that water may be drawn from gills and other delicate external organs resulting in cell damage or death of the organism (U.S. Geological Survey 1980, Stednick and Gilbert 1998, National Park Service 2002). The Maryland Biological Stream Survey has found that fish exhibit stress at specific conductance greater than 400 $\mu\text{S}/\text{cm}$ (Morgan and Cushman 2005). In a later analysis of the data, Morgan et al. (2007) found a critical value for conductivity of 247 $\mu\text{S}/\text{cm}$ for the BIBI and 171 $\mu\text{S}/\text{cm}$ for the FIBI.

Salinity refers to the sum of the concentrations of all dissolved ions. It was originally conceived as a measure of the mass of dissolved salts in a given mass of solution. The only reliable way to determine the true or absolute salinity of natural water is to make a complete chemical analysis. However this method is time-consuming and precision is limited. Salinity is normally determined using indirect methods involving the measurement of a physical property such as conductivity, density, sound speed, or refractive index. From an empirical relationship of salinity and the physical property (i.e. conductivity, density, etc.) determined for a standard solution it is possible to calculate salinity. The resultant salinity is no more accurate than the empirical relationship. The precision of the measurement of a physical property will determine the precision in salinity. Although conductivity has the greatest precision (± 0.0002), it responds only to ionic solutes. Density, though less precise ($\pm 3 \times 10^{-6} \text{ g}/\text{cm}^3$), responds to all dissolved solutes (Eaton et al. 2005).

Salinity is a more inclusive term than total dissolved solids (TDS), although for all practical purposes it is the same quantity. In urban areas, the runoff of salts and other deicing compounds applied to roads can significantly elevate the salinity of receiving waters and cause large fluctuations at short time scales. In the United States, 1-15 million tons of road salt are used each year (Benbow and Merritt 2005), primarily in the Northeast and Midwest, and quantities have increased dramatically since 1950 (Jackson and Jobbágy 2005). Kaushal et al. (2005) report chloride concentrations as high as 25% of seawater in some northeastern streams during winter, and the long-term trend is increasing (Allan and Castillo 2007). Freshwater is defined as 0.5 ppt salinity or less. Water with a salinity above 0.5 ppt is considered brackish (Allan and Castillo 2007).

NCRN uses (but does not endorse) a Yellow Springs Institute (YSI) Professional Plus handheld meter to determine the specific conductance, conductivity, and salinity at each site in FY2010.

Surface Water Quantity

Surface water dynamics such as flow or discharge for flowing waterbodies, and stage or level for non-flowing waterbodies, are critical components of surface water dynamics monitoring. The most fundamental of hydrological measurements, which characterize all river and stream ecosystems, is that of discharge, the volume of water flowing through a cross section of a stream channel per unit time. The amount of water flowing past a given point, when combined with the slope of the stream channel, yields an indication of stream power or the ability of the river to do work. This potential energy is dissipated as frictional heat loss on the stream bed and when the stream picks up and moves material. The work performed by the stream is important because it influences the distribution of suspended sediment, bed material, particulate organic matter, and

other nutrients. The distribution of these materials has substantial influence on the distribution of riverine biota (Vannote et al. 1980, Vannote and Minshall 1982, Statzner et al. 1988). In addition, discharge and stream power combine with other basin conditions to influence meander pattern and floodplain dynamics (Leopold et al. 1964, Gore 1996), which are important in providing habitat for flora and fauna.

Streamflow at any point in time is an integration of the streamflow generation and routing mechanisms in the watershed. Streamflow measurements are useful for water quality data comparisons over time, interpretation of water quality data, and calculation of parameter loads. Streamflow monitoring is necessary to calibrate and verify ground-water-flow models. Streamflow measurements are made periodically to define or verify the stage-discharge relation and to define the timing and magnitude of variations in that relation. Understanding the relationship between flow and concentrations and loading helps determine when it is logical to concentrate sampling (Stednick and Gilbert 1998).

Surface water dynamics such as flow are also a key component in calculating chemical and physical loading of a flowing water body for Total Maximum Daily Load (TMDL) studies of various pollutants. Data must be normalized by flow, especially in freshwater streams; because many constituents have strong relationships with flow (trend analysis in running waters is typically difficult unless one calculates flow-adjusted concentrations).

Surface water quantity, or flow regime, can be influenced by human development in and around each park property. A stream or other body of water should have sufficient quantity and quality of water for every day of the year to maintain ecological processes. Height of stream flow varies seasonally under natural conditions, however any extreme variation can be stressful to organisms and damaging to the physical environment (Tarbuck and Lutgens 1984).

Human development can have significant effects upon surface water and hydrologic cycles. Impervious surfaces such as parking lots, streets, sidewalks, and buildings decrease the amount of water that percolates into the soil, thus reducing groundwater recharge and base flow into streams, while simultaneously increasing the velocity and amount of runoff and the likelihood of contaminants and sediment being carried into lakes, rivers, and streams. Lakes, ponds, seeps, and vernal pools are also highly influenced and affected by these types of changes to the hydrologic cycle (Schlosser 1991).

Other human developments include deforestation which disrupts the hydrologic cycle, decreasing the amount of locally available rainfall. Water withdrawal lowers the groundwater table. Impoundments impede flow. It is also possible in an urbanized area to have upstream flow controlled to the point that aquatic systems receive less freshwater (Hackney et al. 1995, Perry and Hershner 1999), which can lead to saltwater incursion in tidal areas. Climate change disrupts weather patterns, either drying the land or not providing precipitation necessary to recharge groundwater. Low flow regime can result in changes in the number, timing, and presence of pools; increase in disease and other pestilence; fish kills; stenothermal and eurythermal changes for fish and herpetofauna; decreased infiltration for groundwater; decreased regeneration for vernal/ephemeral pools; concentration of solutes and particulates; decreased dissolved oxygen; increased surface water temperature; and decreased water quantity.

High flows, from storms or other events, can be due to increased runoff over impervious surfaces. Runoff is also increased through deforestation, because trees are no longer using large amounts of water through evapotranspiration. This increased runoff is frequently channeled into combined sewer outflows that empty directly into streams. High flow regime can result in altered stream morphology, sedimentation, scouring, bank instability and mass wasting, decreased buffer/filter capacity for groundwater, increased water quantity, and dilution of solutes and particulates. With greater than 10% impervious surface in a watershed urban streams lose their stability, additional storm water contributions to annual water level fluctuation passes 20 cm of depth, sensitive macroinvertebrates are replaced by those more tolerant of pollution and hydrologic stress, and the richness of plant and amphibian communities drop off (Watershed Protection Techniques 1994). Dams may raise the local water table level, alter or eliminate seasonal water table fluctuations, and flood or saturate normally mesic or xeric soils (Schneider 1988). Roads may also act as dams and influence the level and fluctuation of the water table in nearby ecosystems (Jeglum 1975, Baxter 1977).

Wetted Width

Wetted width is measured from water's edge to water's edge of a stream. The NCRN has no defined desired value other than >0 feet. Wetted width is used to calculate discharge and determine the number of chemistry readings taken at a site. NCRN staff use a fiberglass 50 meter (reverse side in feet and tenths of feet) tape to measure the wetted width.

Depth

Depth is measured for every flow measurement location and averaged for that transect. Desired values are based on equipment requirements. The instrument requires a minimum of 0.2 feet to function. NCRN uses (but does not endorse) a Sontek Flowtracker wading rod to measure water depth.

Flow

Flow is used to calculate discharge. The NCRN has no defined desired value other than > 0 ft/s. NCRN uses (but does not endorse) a Sontek Flowtracker to measure the depth, flow and discharge.

Discharge

We currently have no defined desired condition value other than >0 cfs. NCRN uses (but does not endorse) a Sontek Flowtracker to measure discharge.

Temperature

Several of the water chemistry parameters are temperature dependent, either in measurement or for the management decision threshold: DO and specific conductance. High temperature can also stress aquatic life particularly those adapted to habitats with cooler temperatures such as trout. Maximum permissible temperature according to all states (Table 5), except West Virginia which does not have a standard, is 32°C (District Department of the Environment 2010, State of Maryland 2010b, State of West Virginia 2011, and Virginia State Water Control Board 2011). Maryland and Virginia specify 20°C for trout waters and/or coldwater aquatic life (State of Maryland 2010b, Virginia State Water Control Board 2011).

NCRN uses (but does not endorse) a Yellow Springs Institute (YSI) Professional Plus handheld meter to determine the temperature at each site.

Total Phosphorous

Phosphorus (measured as PO₄) is frequently a limiting nutrient in aquatic systems. A minor increase in phosphorous concentration can significantly affect water quality by changing the population and community dynamics of algae and diatoms leading to eutrophication (Allan 1995). Phosphorus is singled out as an especially important indicator in the Heinz Center Report (2002) on the state of nation's ecosystems. Sources of phosphorous include sediments, fertilizer application (e.g. irrigation return flow), soaps, and detergents. 0.1 mg/L PO₄ is the published threshold for eutrophication of flowing surface waters for most NCRN parks.

NCRN uses (but does not endorse) Hach Method 8048 (Phosphorus, reactive, PhosVer 3 Method, Low-Range Test 'N Tube) to determine the total phosphorus concentrations for each sample.

Thresholds

The Environmental Protection Agency (EPA) has delegated the authority to administer the Clean Water Act (33 USC 1251) to the States. Within our area, the states have identified their waterbodies and designated their uses. Each state has defined water quality criteria necessary to maintain designated uses.

NCRN has compiled a set of various regulatory and ecological thresholds in regards to the Vital Signs that are monitored (Table 5). Many of these are long established state standards, which require little explanation. Others are regionally established standards that necessitate further understanding.

In regards to Nitrate and Phosphorus thresholds, the Environmental Protection Agency defined and mapped various levels of ecoregions, or areas of relatively homogenized ecosystems (EPA 2000b). These were defined in order to aid in environmental and resource management. For this report, we utilize the delineation of Level III Ecoregions as noted in Table 4.

Table 4: Level III Ecoregions of NCRN parks

Nutrient Ecoregion		Sub-region and associated NCRN parks
IX	Southeastern Temperate Forested Plains and Hills	Southeastern Plains: NACE, CHOH, GWMP
		Piedmont: PRWI
		Northern Piedmont: WOTR, MANA, ROCR, CHOH, MONO, GWMP
XI	Central and Eastern Forested Uplands	Ridge & Valley: CHOH, ANTI
		Blue Ridge: HAFE, CATO, CHOH

Within NCRN, nearly all streams are considered to be warm water streams, with the exception of streams in CATO, which are classified as cold water streams due to the presence of trout. As such, CATO streams are also considered to be trout streams, resulting in a slightly higher threshold for dissolved oxygen.

Weeks et al. 2007 established minimum ecological thresholds for acid neutralizing capacity. The numbers are based on the ability of an ecosystem to handle acidic inputs and are dependent upon the surrounding landscapes. It established that karst landscapes need 600 $\mu\text{eq/L}$ of alkalinity in order to deal with typical acid inputs such as wet deposition (acid rain). Conversely, non-karst landscapes need only 200 $\mu\text{eq/L}$ of alkalinity to handle acidic inputs.

Morgan et al. 2007 established maximum ecological thresholds for specific conductance. As discussed earlier, these thresholds are based on the values in which the concentrations of dissolved ionic species (specific conductance) begin to stress aquatic life. They determined a set of critical values at which the scores of indices of biological integrity (IBIs) would be affected. Fish IBI scores were impacted when specific conductance values exceeded 171 $\mu\text{S/cm}$, while benthic macroinvertebrate IBI scores were impacted when specific conductance values rose above 247 $\mu\text{S/cm}$.

Table 5: Thresholds of Vital Signs. Threshold values indicate the acceptable ranges.

Vital Sign	Threshold	Reference
pH	6.00 – 9.00	District Department of the Environment 2010, State of Maryland 2010b, State of West Virginia 2011, Virginia State Water Control Board 2011
Acid Neutralizing Capacity	> 200 $\mu\text{eq/L}$ (non-karst) > 600 $\mu\text{eq/L}$ (karst)	Weeks et al. 2007
Specific Conductance	< 171 $\mu\text{S/cm}$ (fish) < 247 $\mu\text{S/cm}$ (macros)	Morgan et al. 2007
Salinity	< 0.5 ppt	Allan and Castillo 2007
Nitrate	< 2.0 mg/L NO_3 (Ecoregion IX) < 0.31 mg/L NO_3 (Ecoregion XI)	EPA 2000a
Phosphorus	< 0.037 mg/L P (0.1 mg/L PO_4) (Ecoregion IX) < 0.01 mg/L P (0.03 mg/L PO_4) (Ecoregion XI)	EPA 2000a
Dissolved Oxygen	> 6.0 mg/L (trout streams) > 5.0 mg/L (all other streams)	District Department of the Environment 2010, State of Maryland 2010b, State of West Virginia 2011, Virginia State Water Control Board 2011
Water Temperature	0.0 – 32.0 $^{\circ}\text{C}$ (warm water streams) 0.0 – 20.0 $^{\circ}\text{C}$ (cold water streams)	District Department of the Environment 2010, State of Maryland 2010b, State of West Virginia 2011, Virginia State Water Control Board 2011

Discussion of Findings

Each park will be discussed individually. The NCRN does not yet have enough data to observe seasonal trends. However we evaluate data in reference to water quality thresholds. These measures constitute a snap shot of stream conditions in time, and are not representative of quality over a 24 hour period. All of these measures are influenced to a certain degree by biological activity which follows diurnal and seasonal patterns of temperature and sunlight.

Antietam National Battlefield (ANTI)

The park is located near the town of Sharpsburg in Washington County, Maryland. As part of the Great Valley of the Ridge and Valley physiographic province, the park exhibits classic features of a karst landscape, including disappearing streams and reappearing springs.

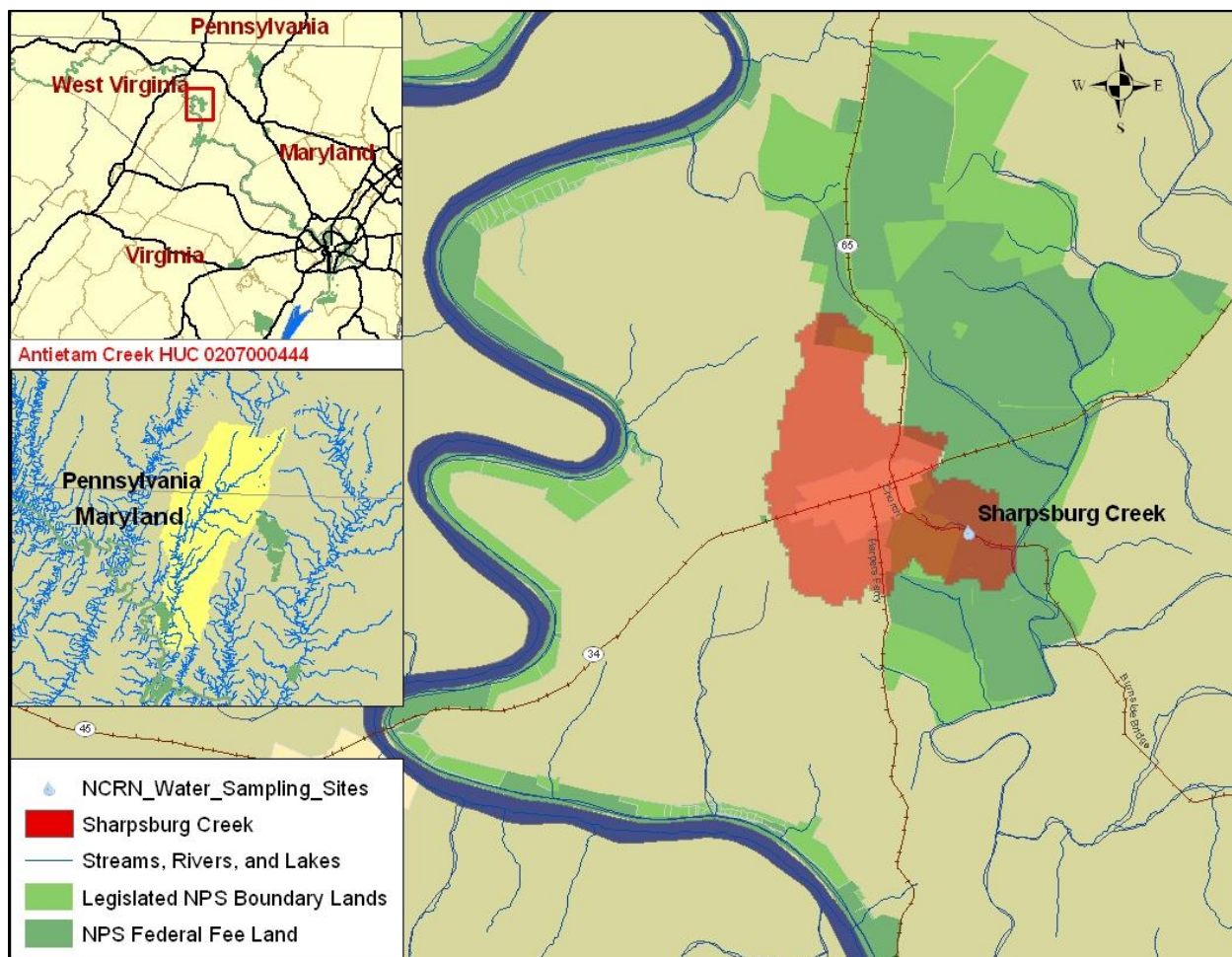


Figure 2: NCRN stream monitoring sites and associated watersheds within ANTI

ANTI is part of the Antietam Creek drainage basin. Antietam Creek passes through ANTI, then through private land and into CHOH before emptying into the Potomac River (Figure 2). Land use within the Antietam Creek drainage basin is 69 percent agriculture, 24 percent forest, and 7 percent urban (National Park Service 1995).

This report discusses data collected October 2009 through September 2010 in Sharpsburg Creek, a perennial tributary of Antietam Creek in the park. Summary statistics for the time period are shown in Table 6. One site was monitored in the park on a monthly basis for dissolved oxygen, pH, specific conductance, temperature, acid neutralizing capacity, nitrate, total phosphorus, depth, wetted width, flow, and discharge.

Table 6: FY2010 Summary statistics for the vital signs data collected at ANTI

Parameter (Units)	Minimum	Maximum	Mean	Median	Standard Deviation
Air Temperature (°C)	-5	30.3	17.6	21.2	12
ANC (µeq/L)	4020	5800	4622	4640	530.8
Discharge (cfs)	0.98	3.09	2.31	---	0.77
DO (mg/L)	8.9	11.9	10.4	10.3	0.9
Flow (ft/sec)	0.9	1.75	1.27	---	0.33
Nitrate (mg/L)	5.8	7.9	6.6	6.6	0.6
pH	8.14	8.4	8.23	8.18	0.10
Salinity (ppt)	0.2	0.31	0.28	0.28	0.03
Specific conductance (µS/cm)	410.2	633.2	570	585	60.8
Total Phosphorus (mg/L)	0.14	0.74	0.34	0.22	0.21
Water Depth (ft)	0.2	0.3	0.24	---	0.05
Water Temperature (°C)	9.6	17.7	14.1	15.1	2.5
Wetted Width (ft)	6.1	11	8.01	7.58	1.37

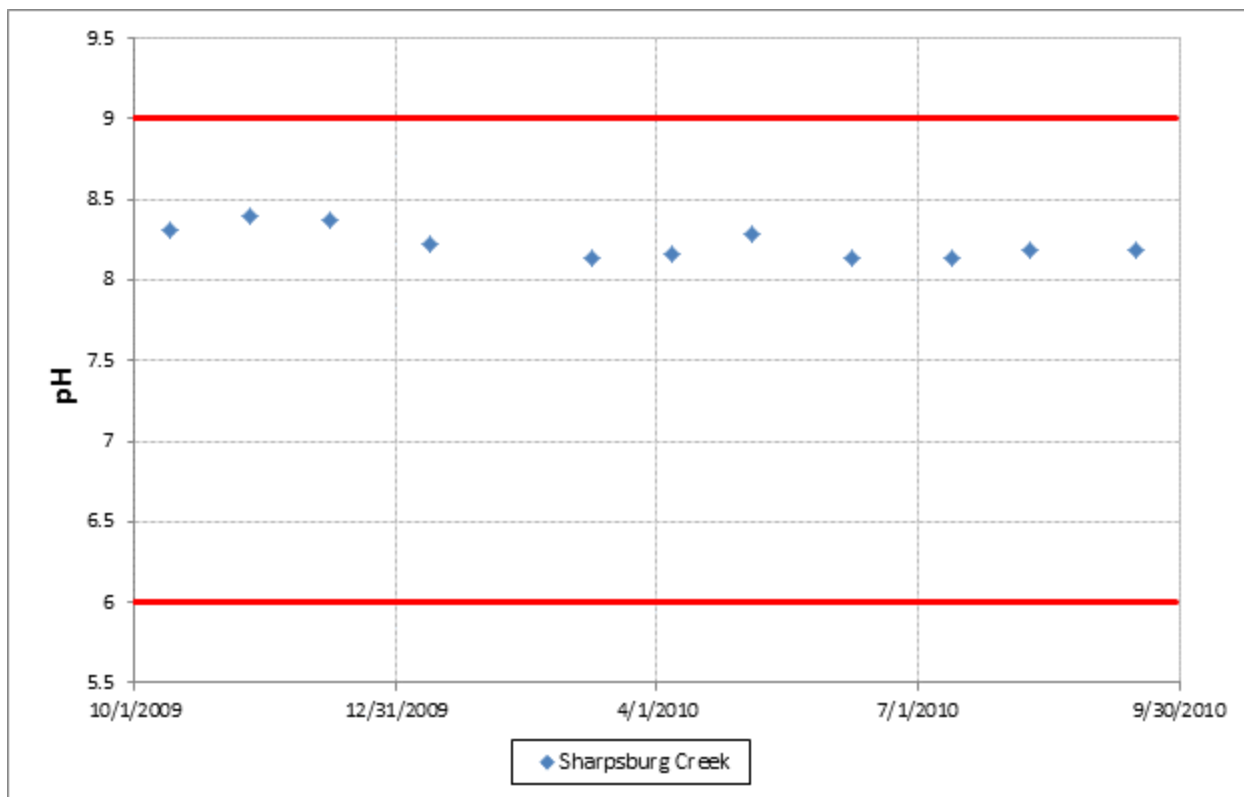


Figure 3: pH in ANTI streams FY 2010.

Both pH (Figure 3) and acid neutralizing capacity (Figure 4) were in the acceptable range. The high values for both parameters are due to the dissolving of rocks within the karst landscape.

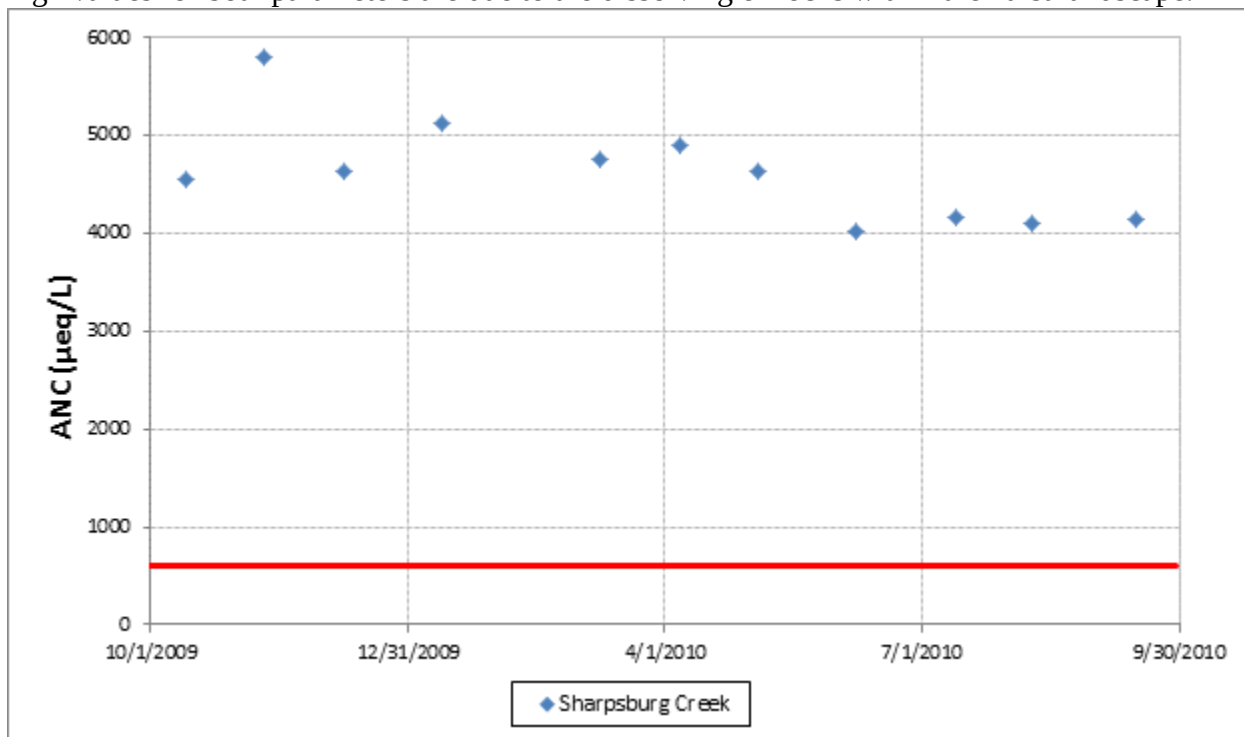


Figure 4: Acid Neutralizing Capacity in ANTI streams FY 2010.

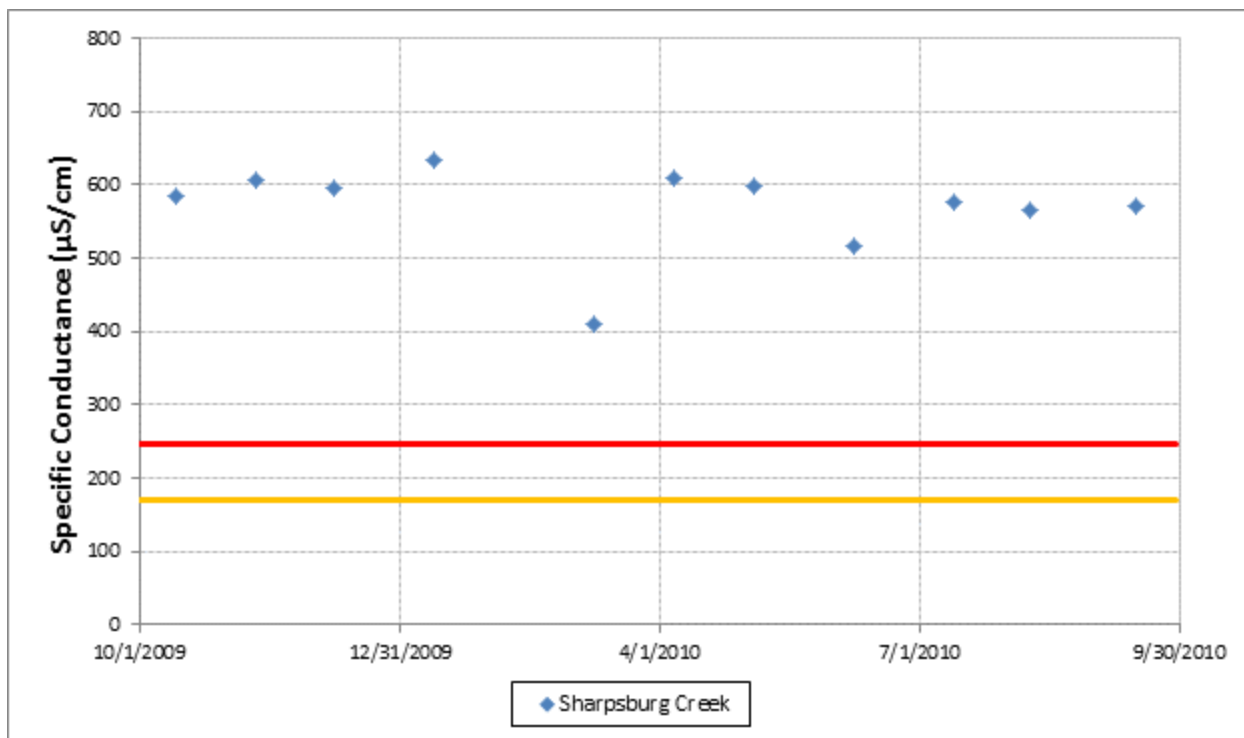


Figure 5: Specific Conductance in ANTI streams FY 2010.

Specific conductance (Figure 5) exceeded ecological thresholds for aquatic life stress (orange = fish threshold; red = macroinvertebrate threshold). Salinity (Figure 6) remained within the acceptable range for fresh water. The higher values for specific conductance are due to the dissolution of rocks in the karst landscape.

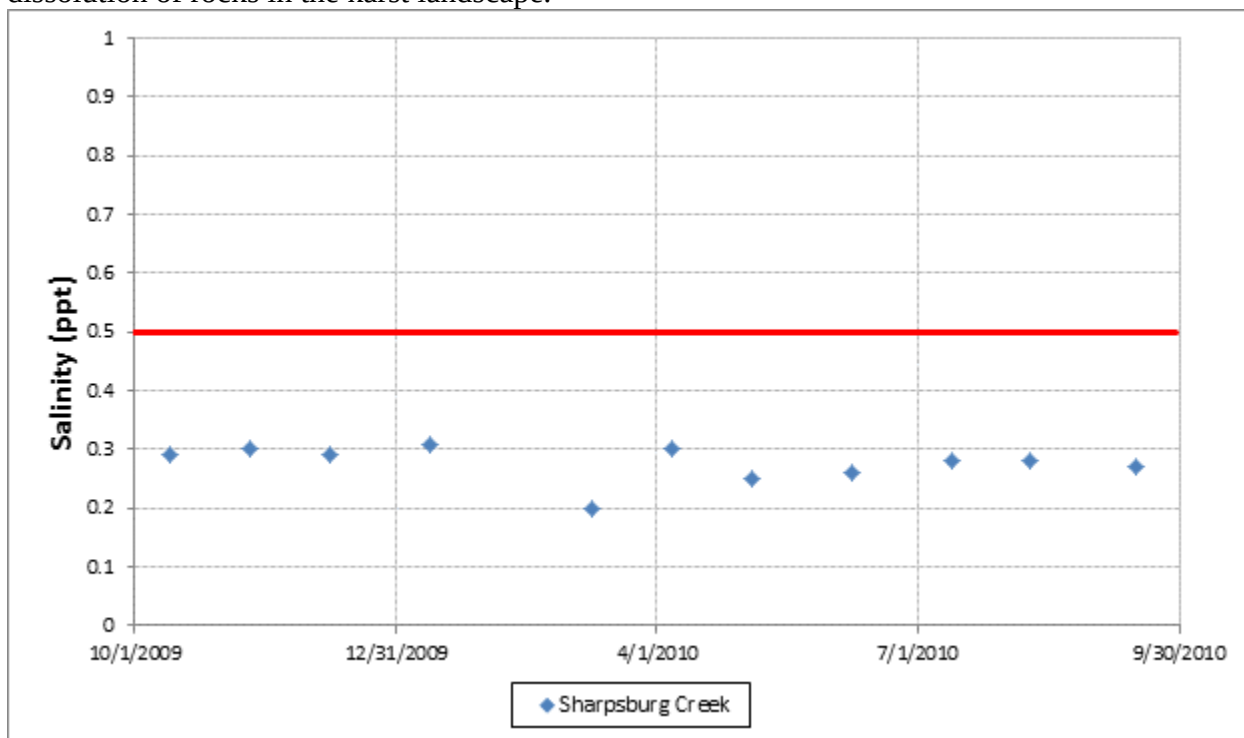


Figure 6: Salinity in ANTI streams FY 2010.

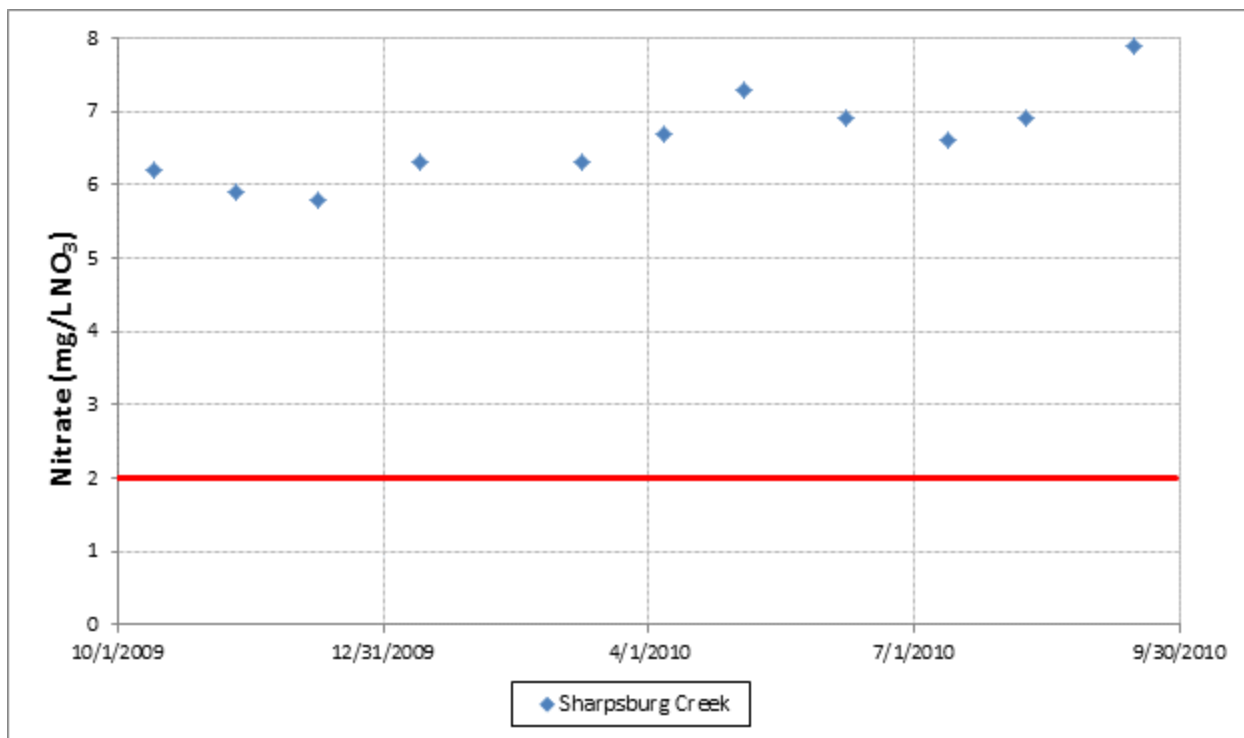


Figure 7: Nitrate in ANTI streams FY 2010.

Nitrate (Figure 7) and Phosphorus (Figure 8) levels consistently exceeded their respective threshold limits..

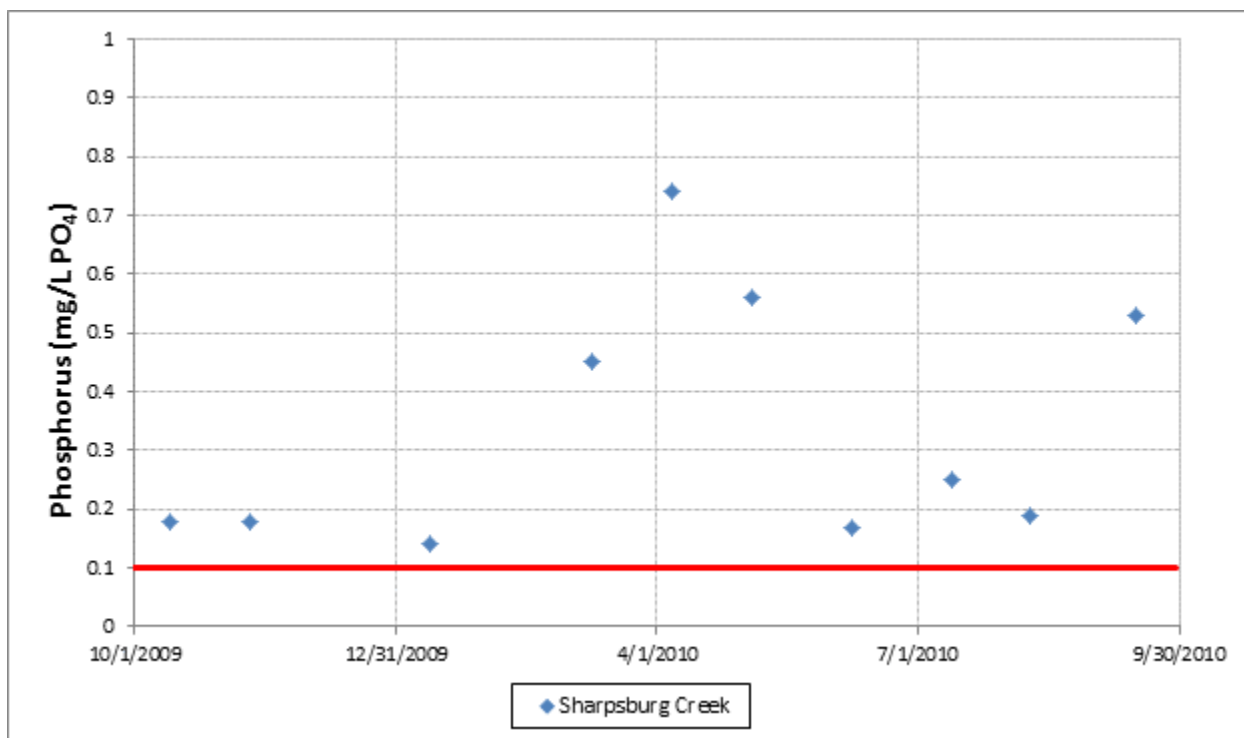


Figure 8: Phosphorus in ANTI streams FY 2010.

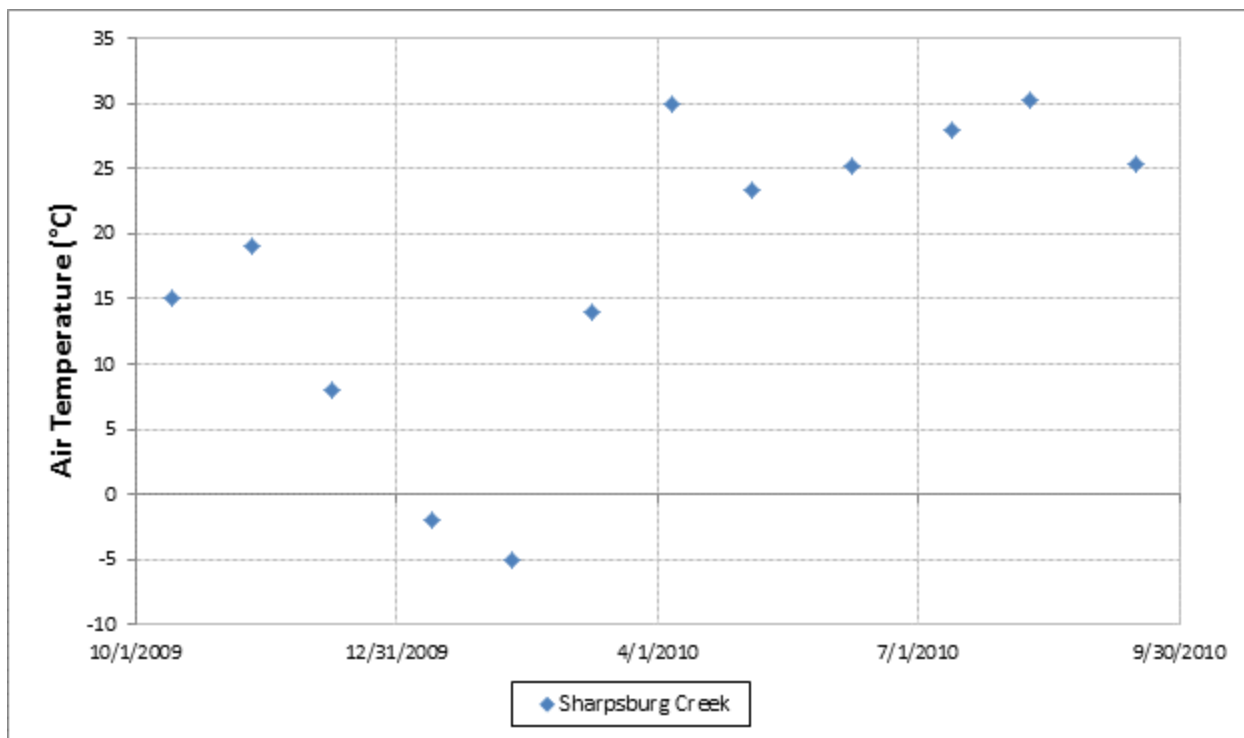


Figure 9: Air Temperature near ANTI streams FY 2010.

Water temperature (Figure 10) exhibits the influence of groundwater, shown by the small range of values and the dissimilarity to Air Temperature (Figure 9).

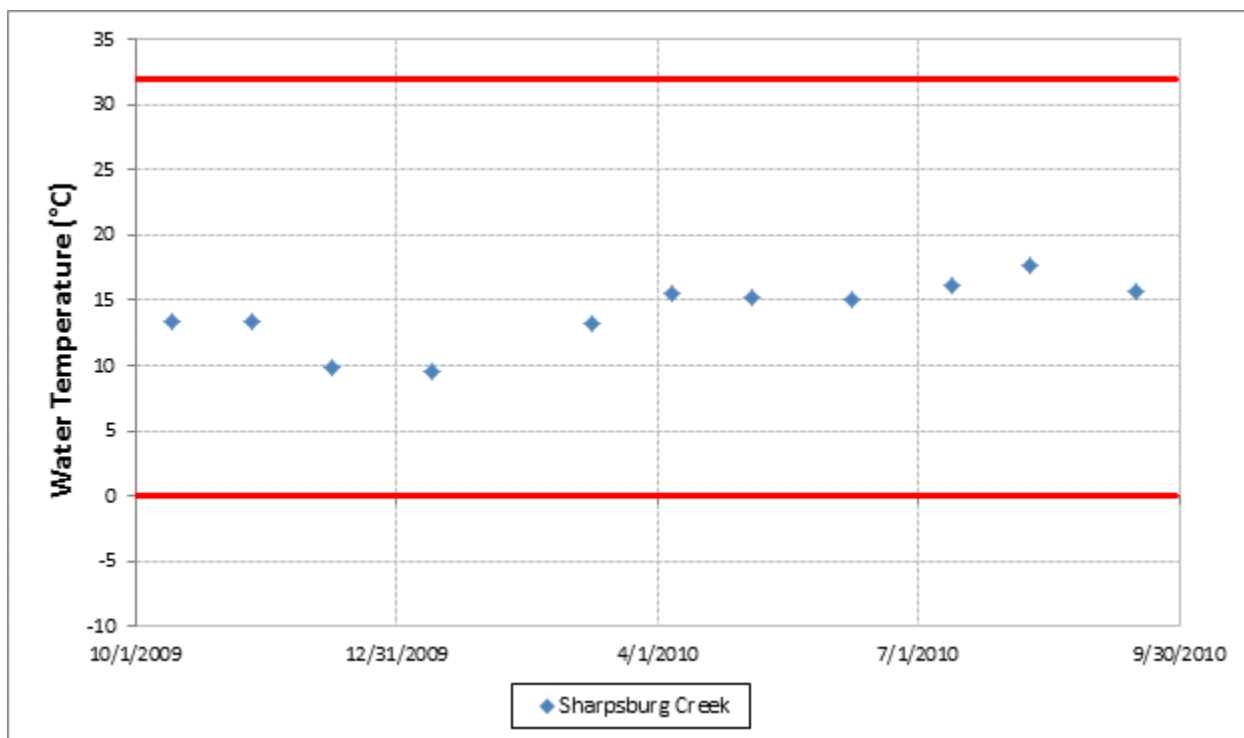


Figure 10: Water Temperature in ANTI streams FY 2010.

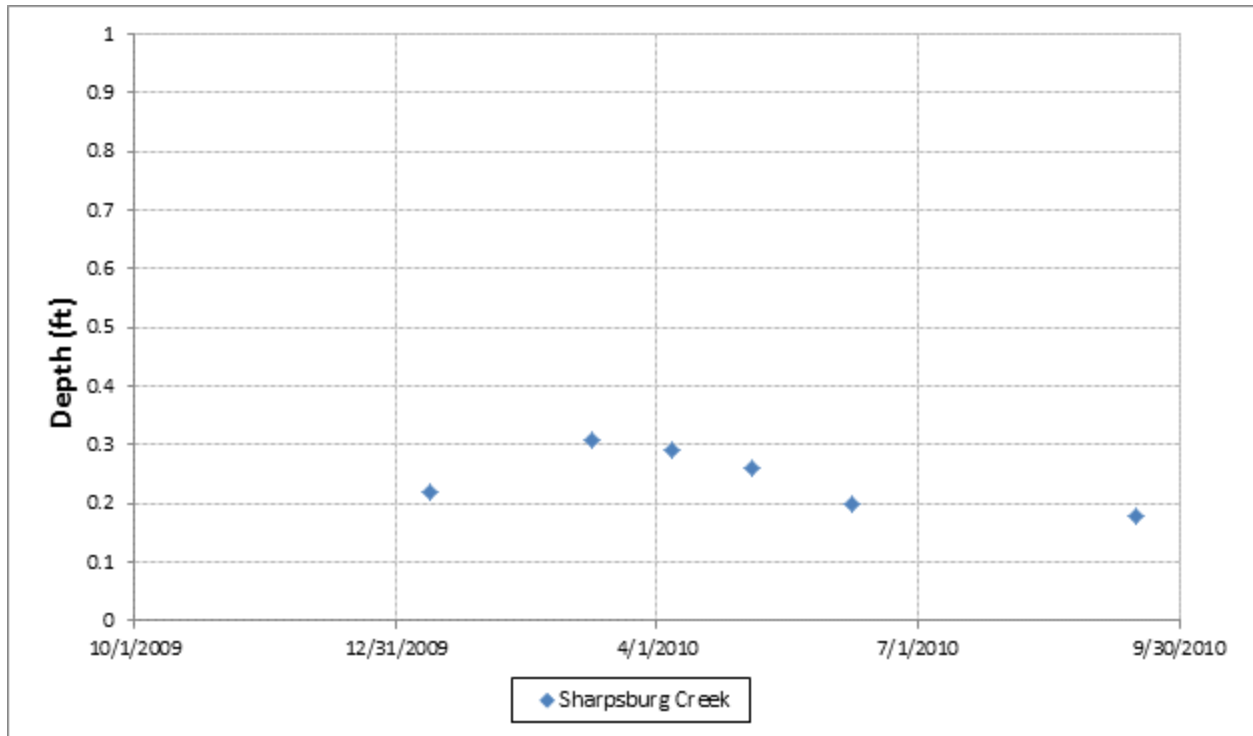


Figure 11: Water depth of ANTI streams FY 2010.

Missing depth data points (Figure 11) from October through December are due to equipment failure.

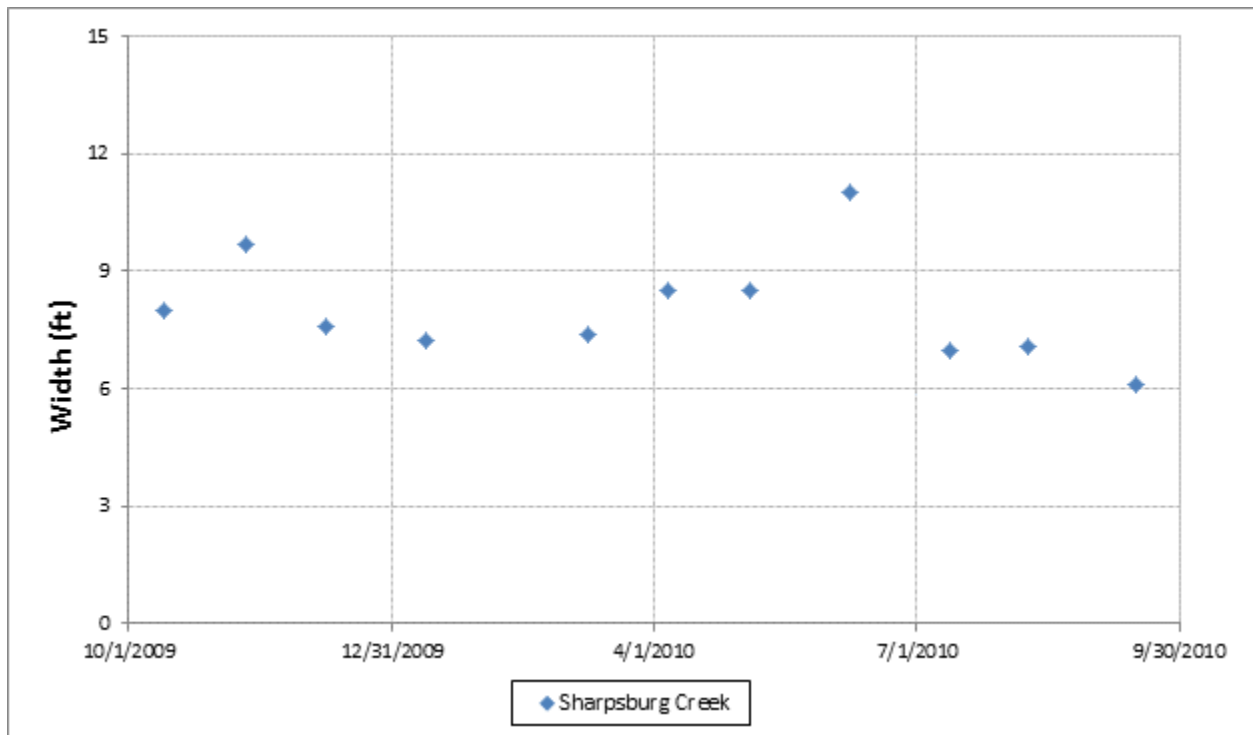


Figure 12: Wetted width of ANTI streams FY 2010.

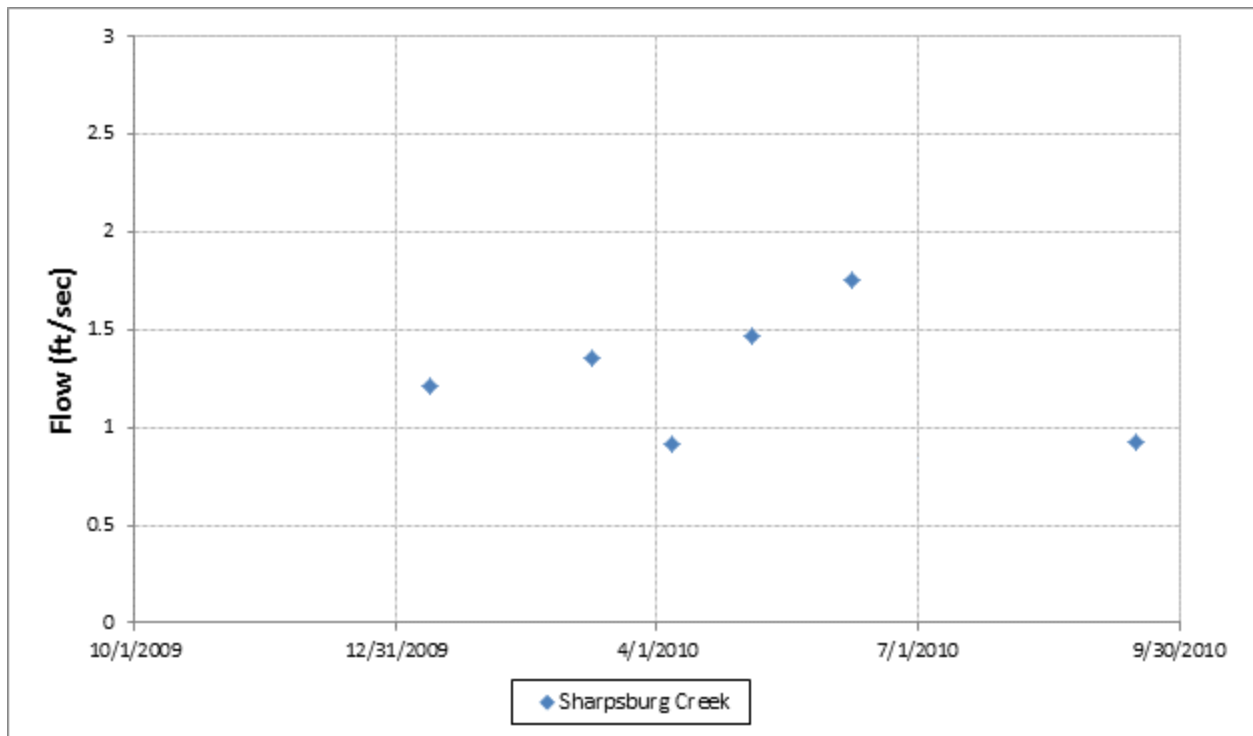


Figure 13: Stream flow in ANTI streams FY 2010.

Missing flow data points (Figure 13) and missing discharge data points (Figure 14) from October through December are due to equipment failure.

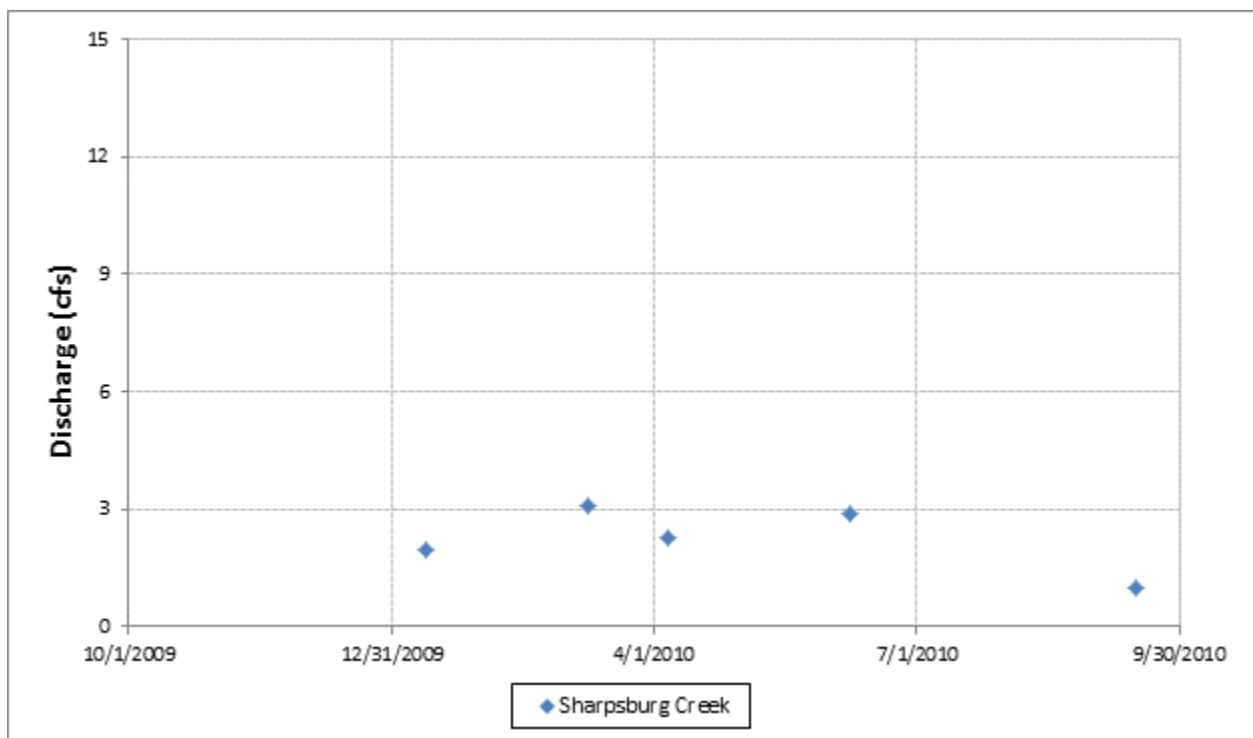


Figure 14: Stream discharge of ANTI streams FY 2010.

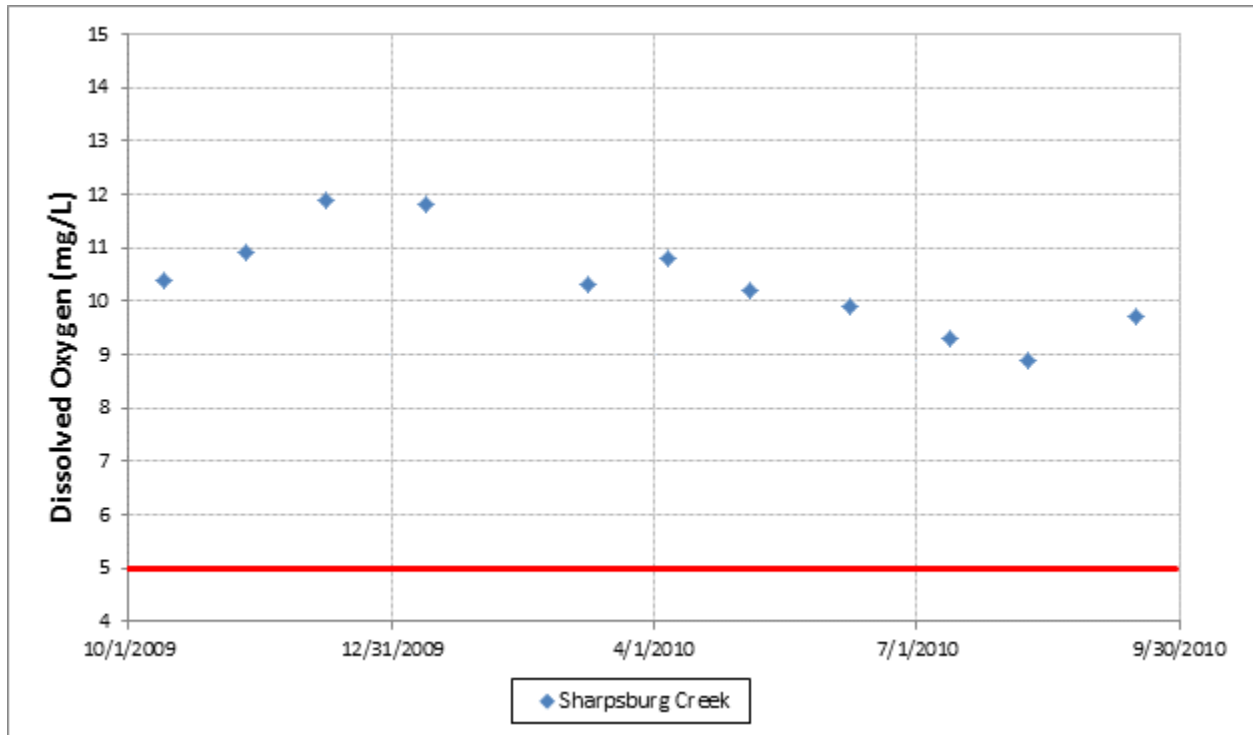


Figure 15: Dissolved Oxygen in ANTI streams FY 2010.

Dissolved oxygen is well within the acceptable range, likely due to groundwater influencing the stream with cooler temperatures.

Catoctin Mountain Park (CATO)

The park encompasses 2,336 ha of forested landscape located in the Blue Ridge Mountains of north-central Maryland. The park is located west of Thurmont in Frederick County. The Blue Ridge in Maryland is a series of forested linear ridges with elevations up to 2000 feet; Catoctin Mountain is a discontinuous ridge that extends from near the Pennsylvania/Maryland border to the Potomac River at Point of Rocks, Maryland. Within the park, which is a small section of the ridge, rock units are highly fractured and folded and range from quartzite along the southeast edge, phyllite and conglomerate in the southeast section, and metarhyolite and metabasalt in the northwest (Hugh Engineers Inc. and R.E. Wright Associates Inc. 1981). These rocks are resistant to erosion and dissolution. Slopes in the park are generally between 10% and 20%, but occur up to 60% (Trombley and Zynjuk 1985).

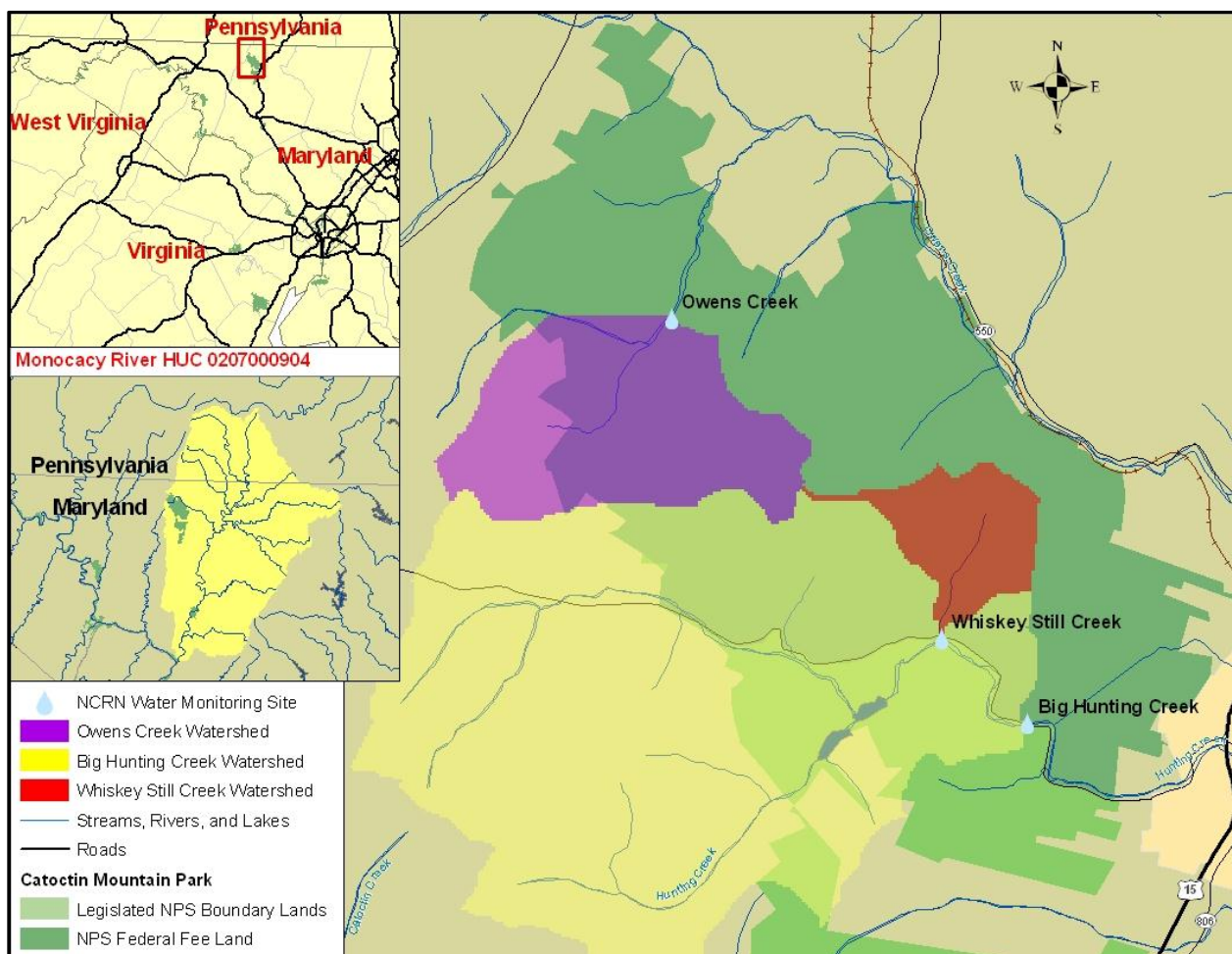


Figure 16: NCRN stream monitoring sites and associated watersheds within CATO

The park area is separated from the main ridge by two streams: Big Hunting Creek to the south and Owens Creek to the west, north, and east (Figure 16). Big Hunting Creek is 41.8 square miles in drainage and 15 miles long. It is a tributary of the Monocacy River. Big Hunting Creek flows in and out of the CATO boundary for roughly 4 miles. The headwaters of Big Hunting Creek are outside of the park, putting this creek at risk for potential problems that cannot be

completely controlled by the park (Means 1995). Before entering the park, Big Hunting Creek runs off farms and lots and along MD Route 77. The national park contains 7% of the creek's drainage basin. Developed areas in the park (Greentop, Round Meadow, Misty Mount, the maintenance yard, the visitor's center, the administration office, Park Central Road, Route 77, and Camp 3) contribute runoff to the creek. Water quality in the creek is very good, with phosphorus the most significant problem (Table 7). Tributaries of Big Hunting Creek include Still Creek, Whiskey Still Run (completely contained within CATO), Hauver Branch (within the state park), and Bear Branch (within Cunningham Falls State Park).

Owens Creek has a 39.8 square mile drainage area and is managed for native brook trout and for naturally reproducing brown trout (Means 1995). The headwaters of Owens Creek begin inside the park. As the creek leaves through the park's north boundary it passes through an agricultural area and flows back into the park. The park contains 14.5% of Owens Creek's watershed, but fewer areas of the park contribute runoff to the creek (Round Meadow, naval housing facilities, Owens Creek Picnic Area, Chestnut Picnic Area, Camp 3, and Owens Creek Campground). A new wastewater treatment plant was located at the head of Owens Creek in the late 1990s. The plant discharges directly into the stream and wetland where Owens Creek originates.

This report discusses data collected October 2009 through September 2010 in Big Hunting Creek, Whiskey Still Run, and Owens Creek. Summary statistics for the time period for all three streams are presented in Table 7. These sites were monitored on a monthly basis for dissolved oxygen, pH, specific conductance, temperature, acid neutralizing capacity, nitrate, total phosphorus, depth, wetted width, flow, and discharge.

Table 7: FY 2010 Summary statistics for the vital signs collected at CATO

Parameter (Units)	Minimum	Maximum	Mean	Median	Standard Deviation
Air Temperature (°C)	-6	27.8	14.5	18.1	11.0
Water Temperature (°C)	2.4	20.7	12.4	13.9	5.1
ANC (µeq/L)	358	880	610	588	142.4
pH	7.44	7.85	7.69	7.67	0.10
Salinity (ppt)	0.03	0.4	0.08	0.07	0.08
Specific conductance (µS/cm)	72.5	179.5	131.2	138.7	27.6
DO (mg/L)	6.8	13.63	10.1	9.8	1.89
Nitrate (mg/L)	0.6	2.5	1.3	1.2	0.4
Total Phosphorus (mg/L)	0.1	0.69	0.33	0.29	0.19
Discharge (cfs)	0.12	24.75	7.56	3.05	8.28
Flow (ft/sec)	0.05	1.26	0.62	0.63	0.42
Water Depth (ft)	0.23	1	0.56	0.60	0.23
Wetted Width (ft)	2	29.58	14.8	16	7.8

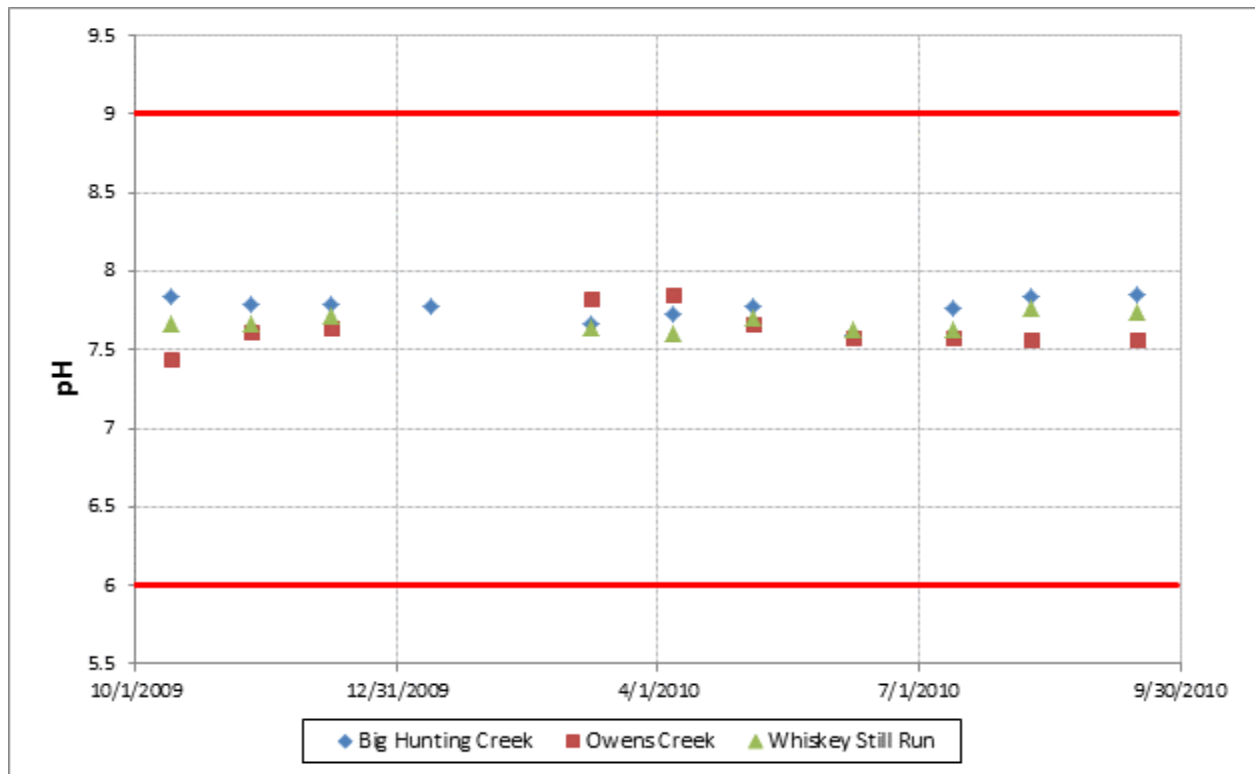


Figure 17: pH in CATO streams FY 2010

Both pH (Figure 17) and acid neutralizing capacity (Figure 18) met threshold expectations.

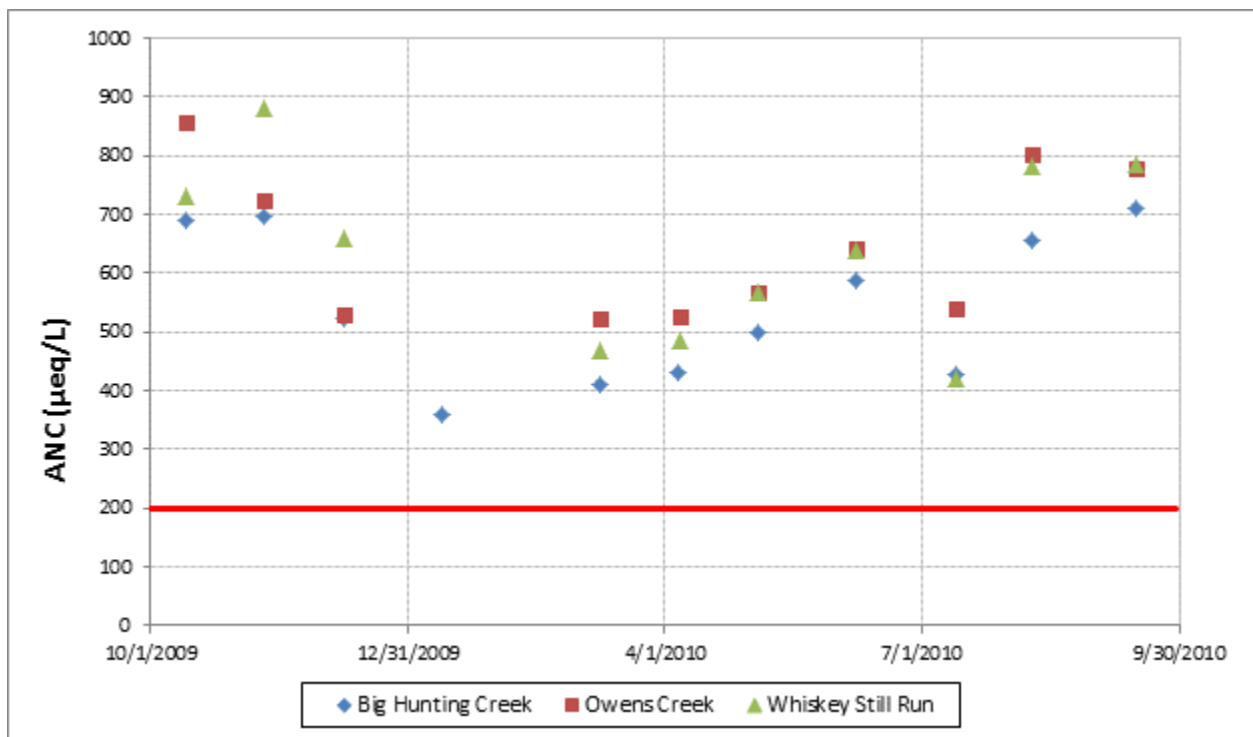


Figure 18: Acid Neutralizing Capacity in CATO streams FY 2010

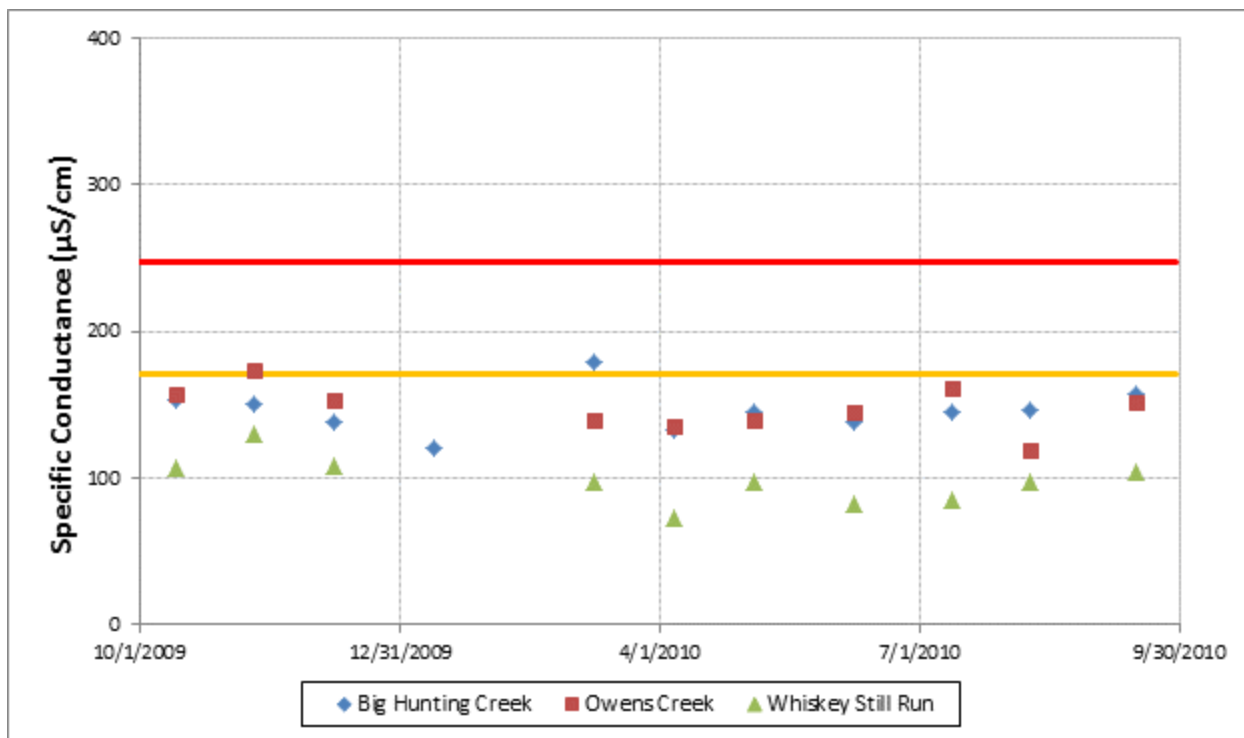


Figure 19: Specific Conductance in CATO streams FY 2010

Specific Conductance (Figure 19) regularly met ecological thresholds for aquatic life stress (orange = fish threshold; red = macroinvertebrate threshold). Salinity (Figure 20) remained under the threshold for freshwater ecosystems.



Figure 20: Salinity in CATO streams FY 2010

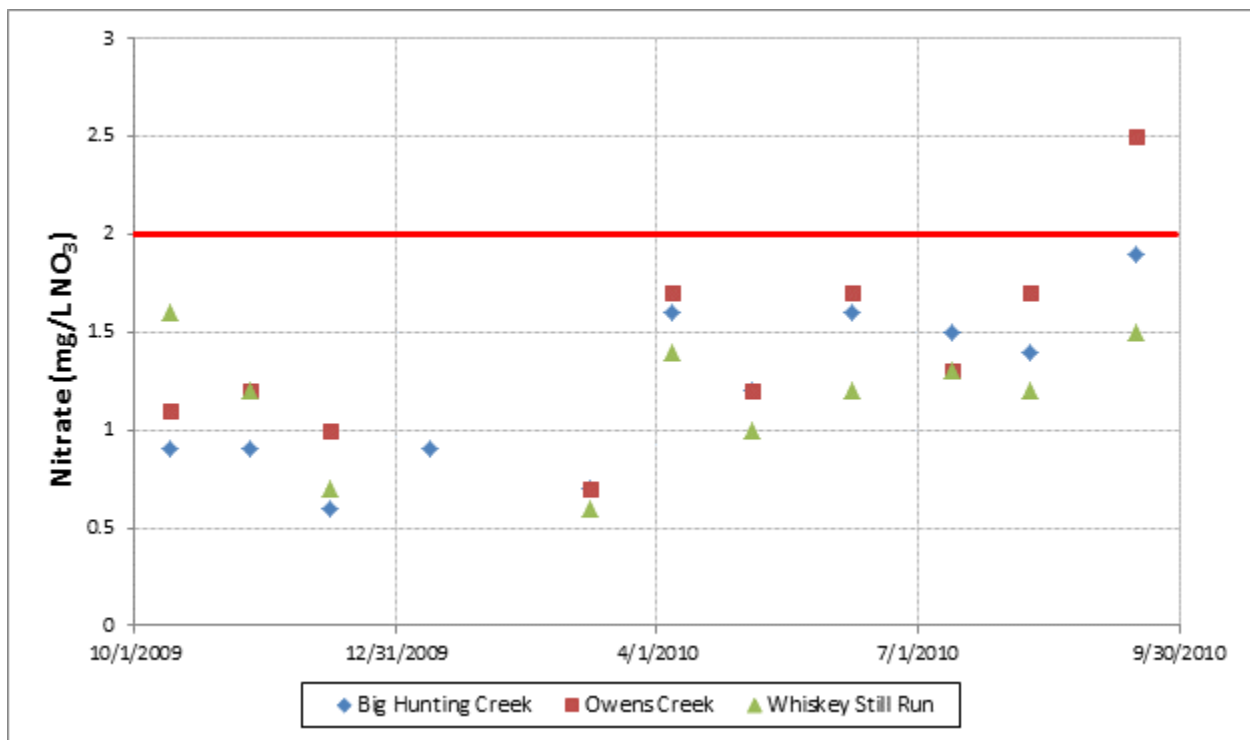


Figure 21: Nitrate in CATO streams FY 2010

Nitrate levels (Figure 21) were consistently acceptable, while Phosphorus levels (Figure 22) regularly exceeded both threshold and eutrophication values.

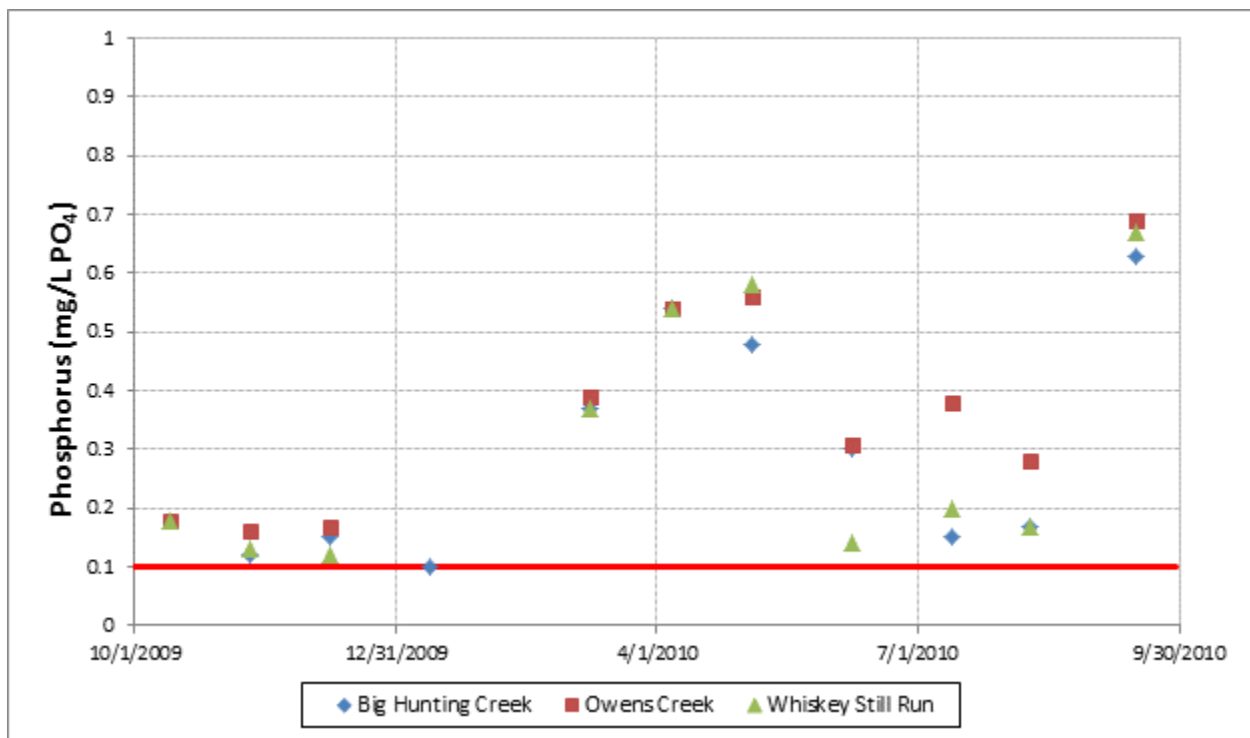


Figure 22: Phosphorus in CATO streams FY 2010

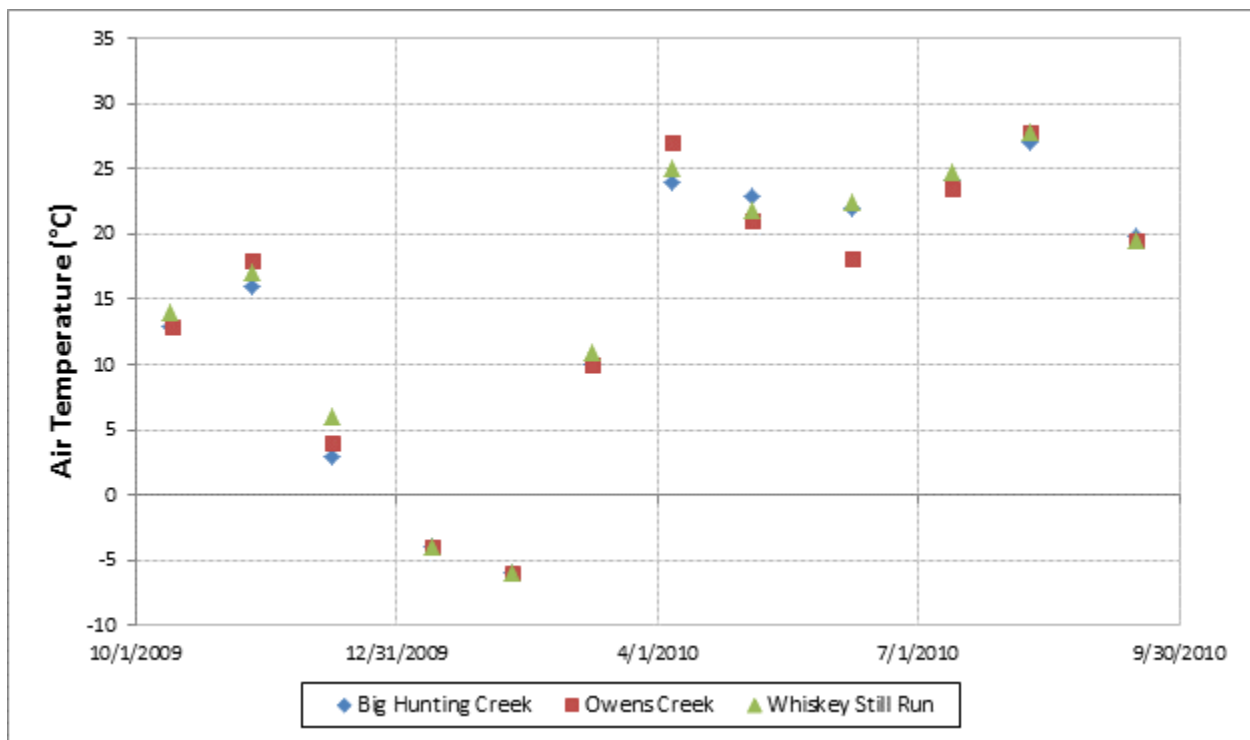


Figure 23: Air Temperature in CATO streams FY 2010

Water temperatures (Figure 24) generally fell within the acceptable range, and were similar to Air temperatures (Figure 23), suggesting that the system is primarily surface-fed.

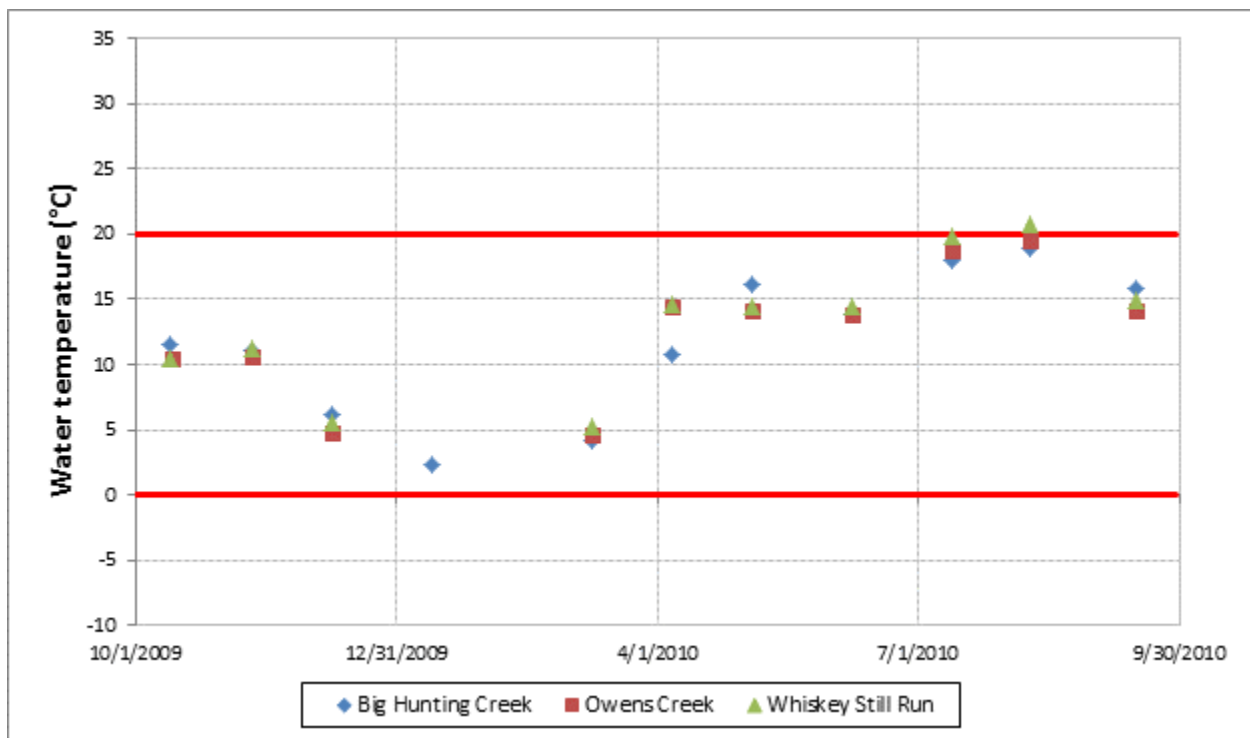


Figure 24: Water Temperature in CATO streams FY 2010

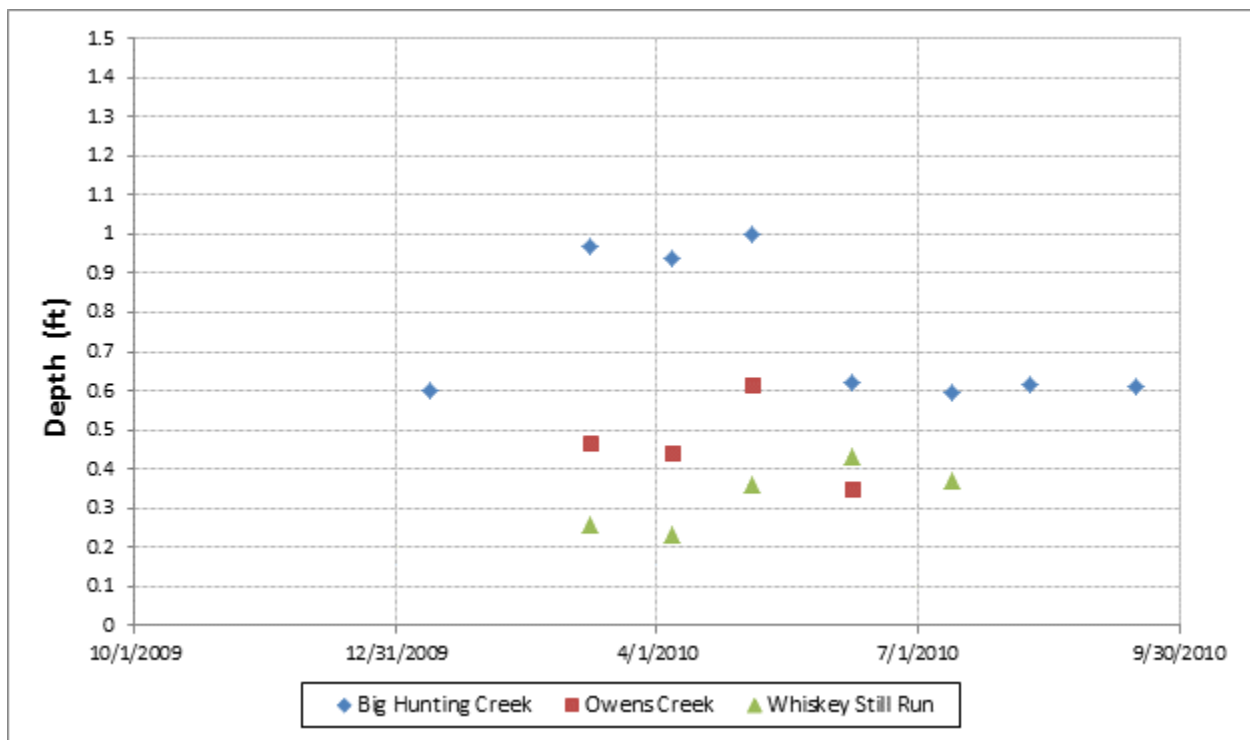


Figure 25: Stream depth in CATO streams FY 2010

Missing depth data points (Figure 25) from October through December are due to equipment failure.

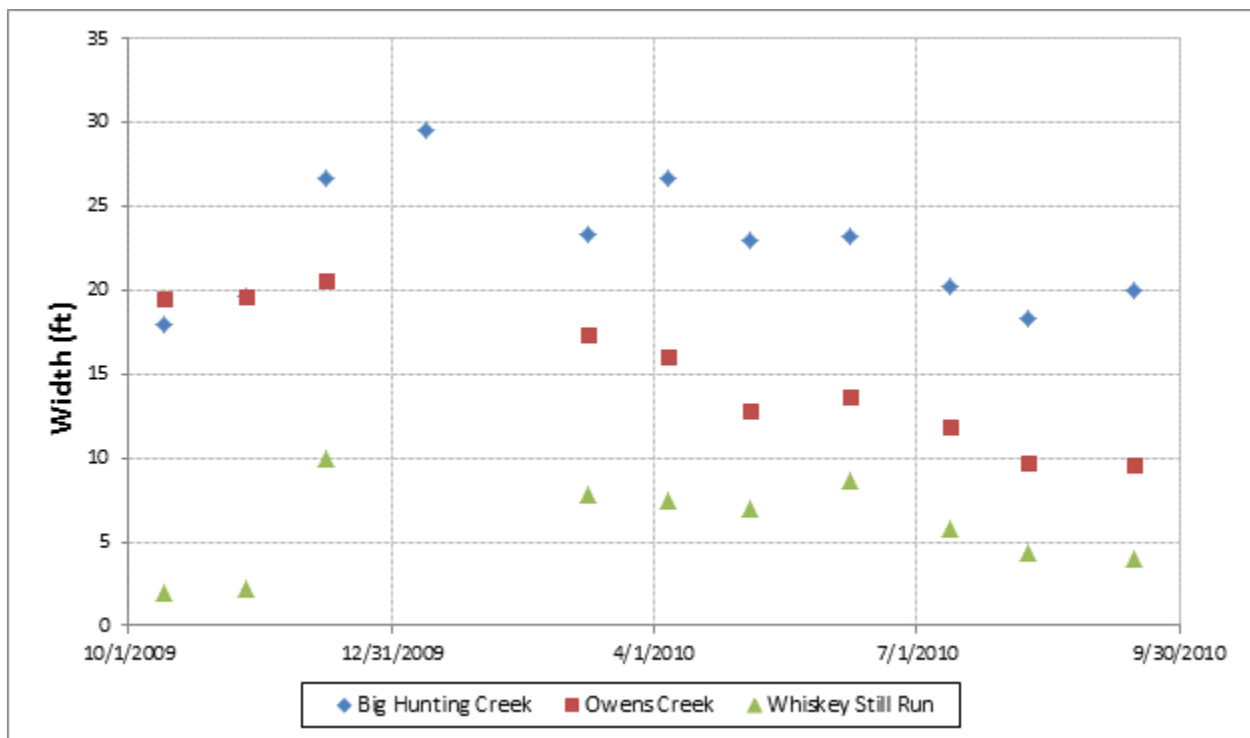


Figure 26: Stream width in CATO streams FY 2010

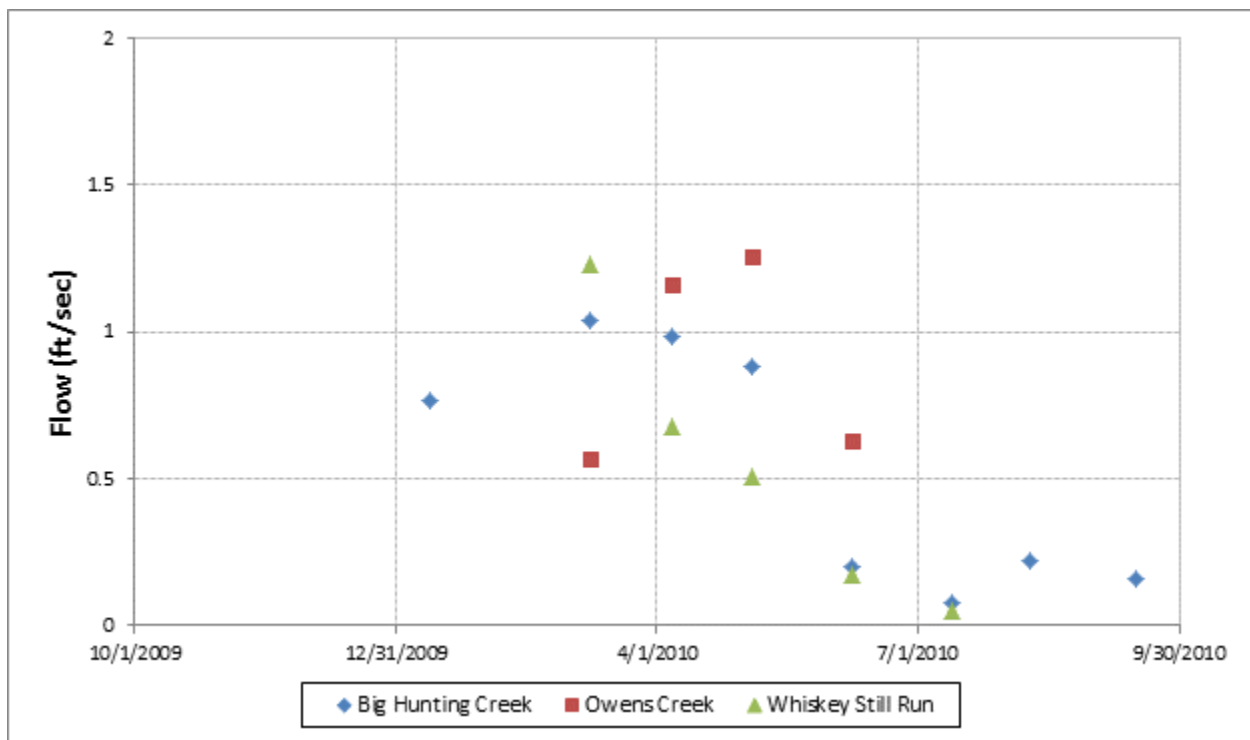


Figure 27: Stream flow in CATO streams FY 2010

Missing flow data points (Figure 27) and missing discharge data points (Figure 28) from October through December are due to equipment failure.

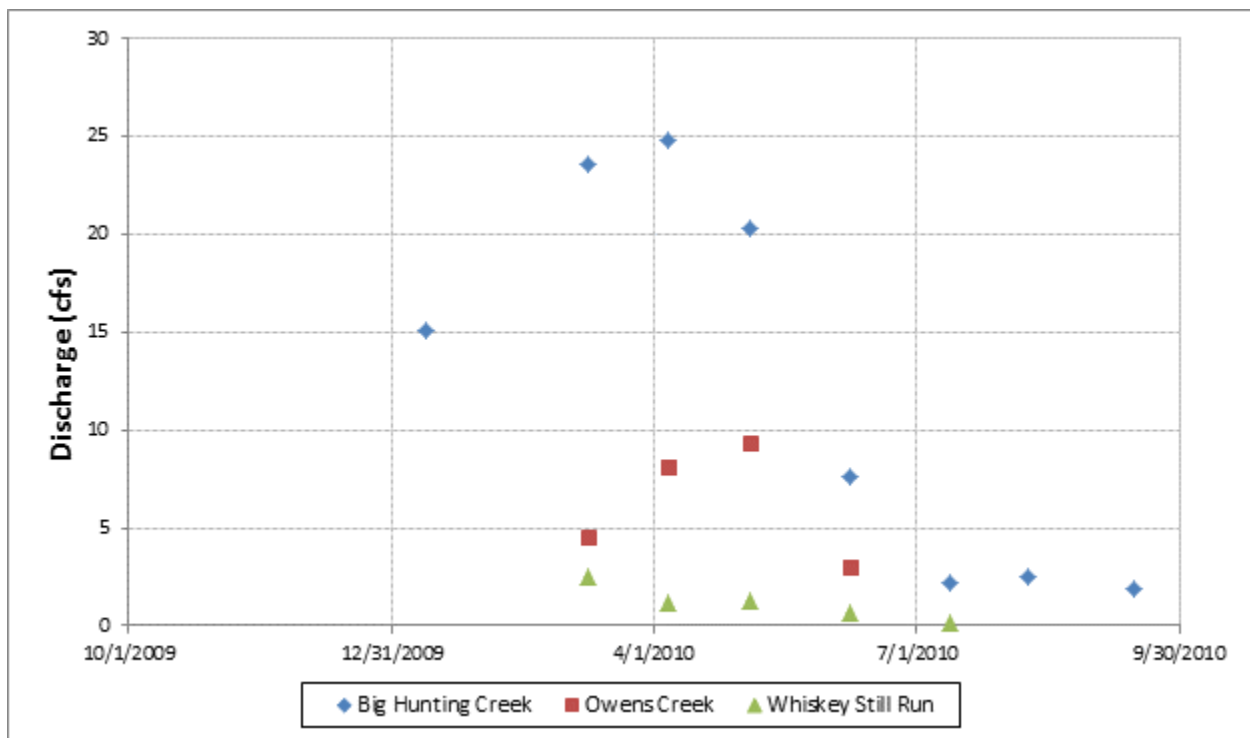


Figure 28: Stream discharge in CATO streams FY 2010

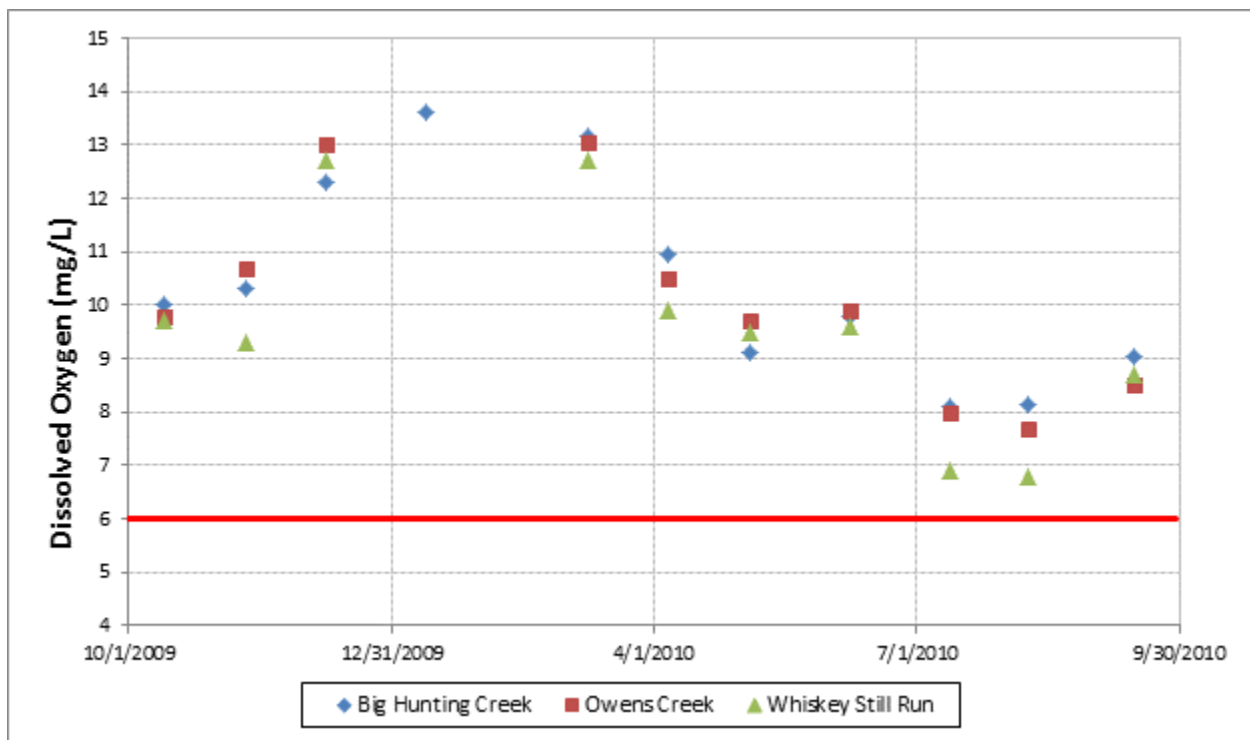


Figure 29: Dissolved Oxygen in CATO streams FY 2010

Dissolved oxygen (Figure 29) is consistently in the acceptable range, and exhibits a typical seasonal pattern.

George Washington Memorial Parkway (GWMP)

The George Washington Memorial Parkway runs through Arlington and Fairfax Counties in Virginia and Montgomery County in Maryland. It also occurs within the Potomac River watershed and Piedmont and Coastal Plain physiographic provinces. All monitoring sites are located in the nontidal portion of GWMP within the Piedmont Physiographic Province.

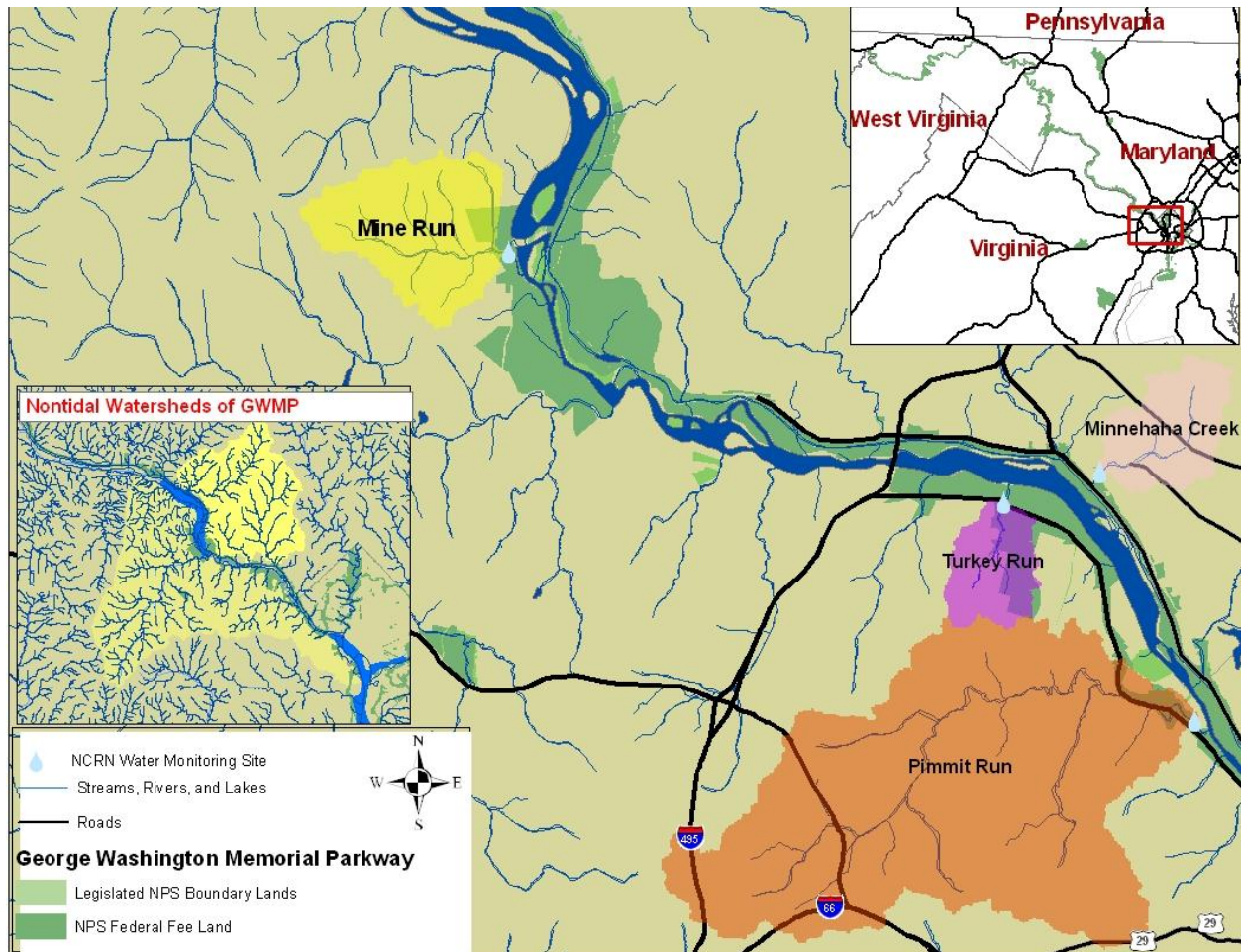


Figure 30: NCRN stream monitoring sites and associated watershed within GWMP

This report discusses data collected October 2009 through September 2010 in Turkey Run, Pimmit Run, Mine Run, and Minnehaha Creek along George Washington Memorial Parkway (Figure 30). Summary statistics for the time period are shown in Table 8.

Table 8: FY 2010 Summary statistics for the vital signs collected at GWMP

Parameter (Units)	Minimum	Maximum	Mean	Median	Standard Deviation
Air Temperature (°C)	-4	28.9	13.9	14	9.3
Water Temperature (°C)	1.9	24.7	13.7	12.6	6.6
ANC (µeq/L)	392	2280	1251	1076	498.1
pH	7.47	8.98	7.78	7.69	0.31
Salinity (ppt)	0.06	0.63	0.20	0.16	0.14
Specific conductance (µS/cm)	128.4	1270	406.2	343.3	282.2
DO (mg/L)	6.9	14.5	10.0	9.9	2.2
Nitrate (mg/L)	1.1	3.6	2.2	2.2	0.6
Total Phosphorus (mg/L)	0.12	2.67	0.40	0.31	0.40
Discharge (cfs)	0.2	16.07	2.72	1.34	3.65
Flow (ft/sec)	0.068	1.66	0.46	---	0.51
Water Depth (ft)	0.25	0.45	0.38	---	0.06
Wetted Width (ft)	1.3	33	14.0	12.8	9.9

Four sites were monitored in the park on a monthly basis from October 2009 to September 2010 for dissolved oxygen, pH, specific conductance, temperature, acid neutralizing capacity, nitrate, and total phosphorus.

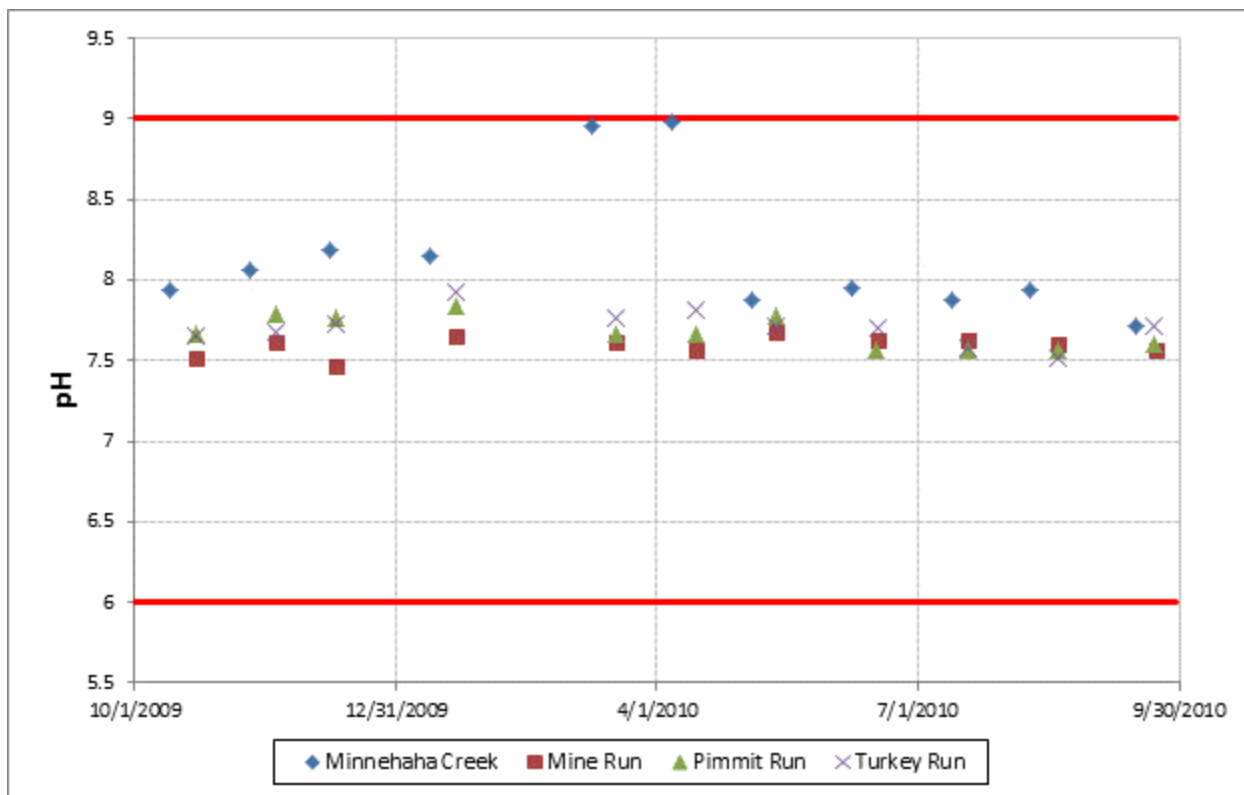


Figure 31: pH in GWMP streams FY 2010

Both pH (Figure 31) and acid neutralizing capacity (Figure 32) met threshold expectations.

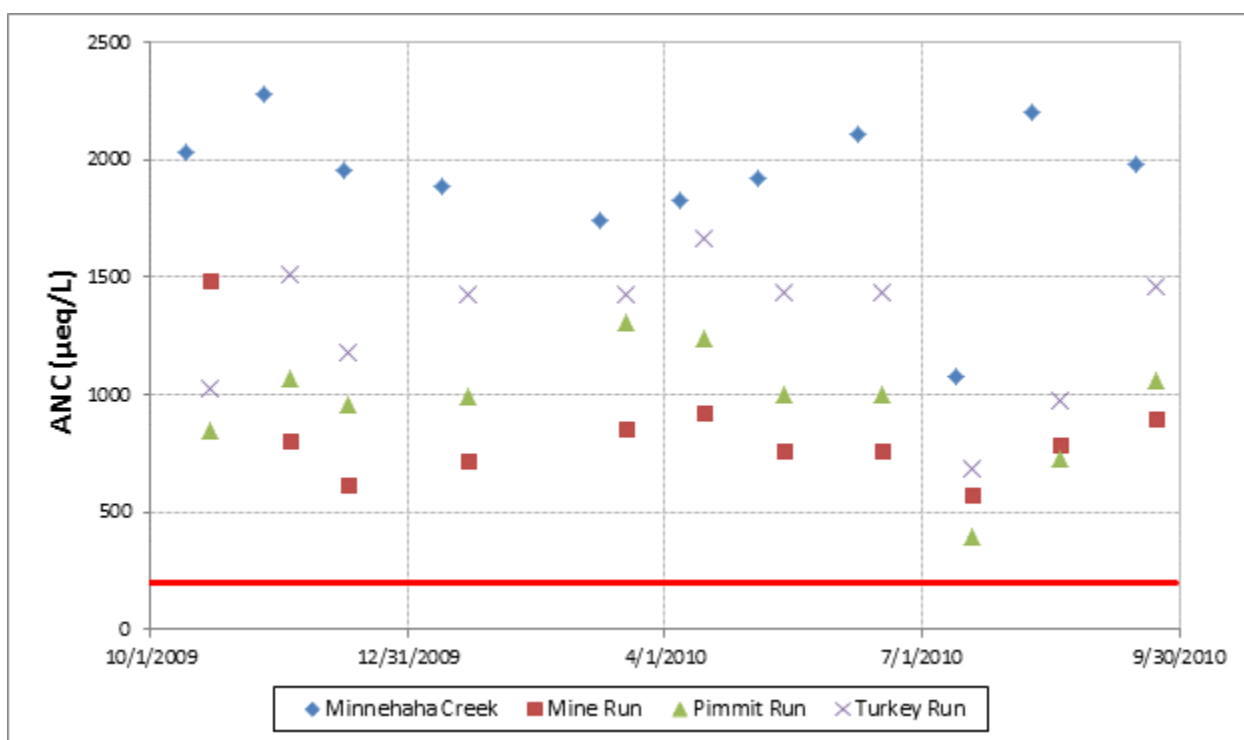


Figure 32: Acid Neutralizing Capacity in GWMP streams FY 2010

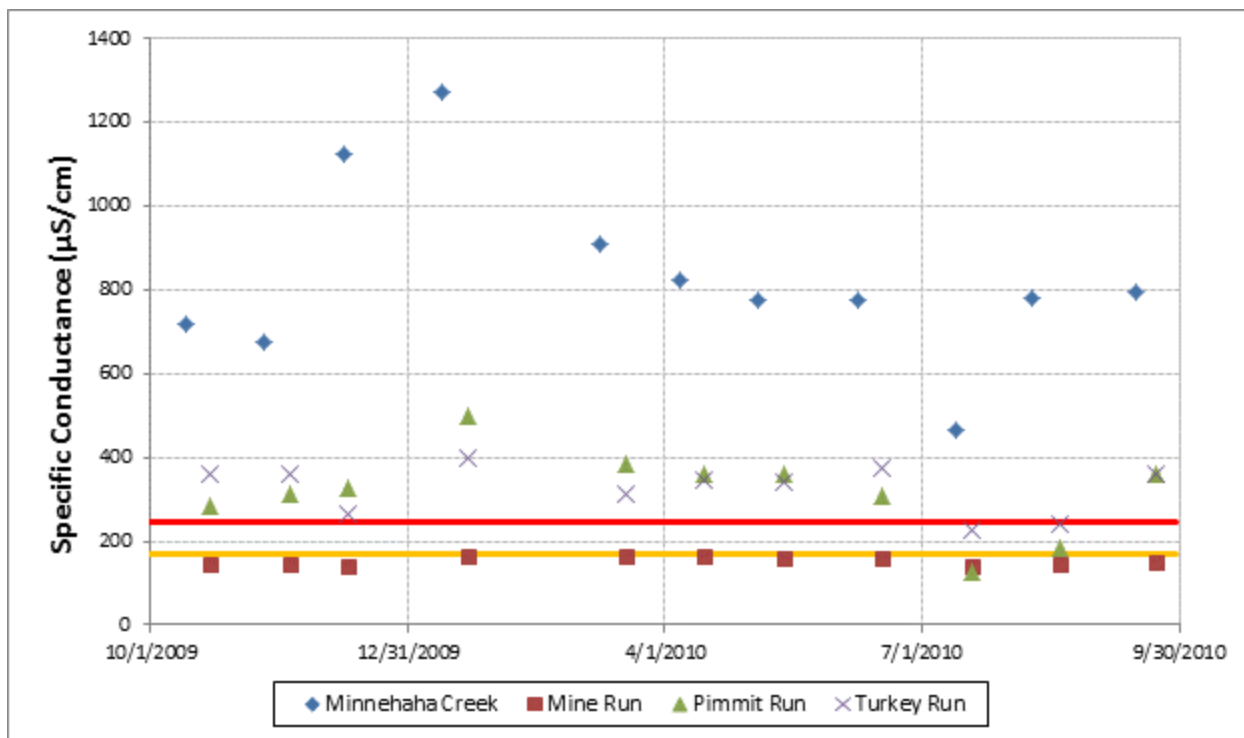


Figure 33: Specific Conductance in GWMP streams FY 2010

Specific conductance (Figure 33) exceeded ecological thresholds for aquatic life stress (orange = fish threshold; red = macroinvertebrate threshold) at all sites except Mine Run. Salinity (Figure 34) was consistently below the threshold for fresh water, except a few instances on Minnehaha Creek during the winter (likely road salt).

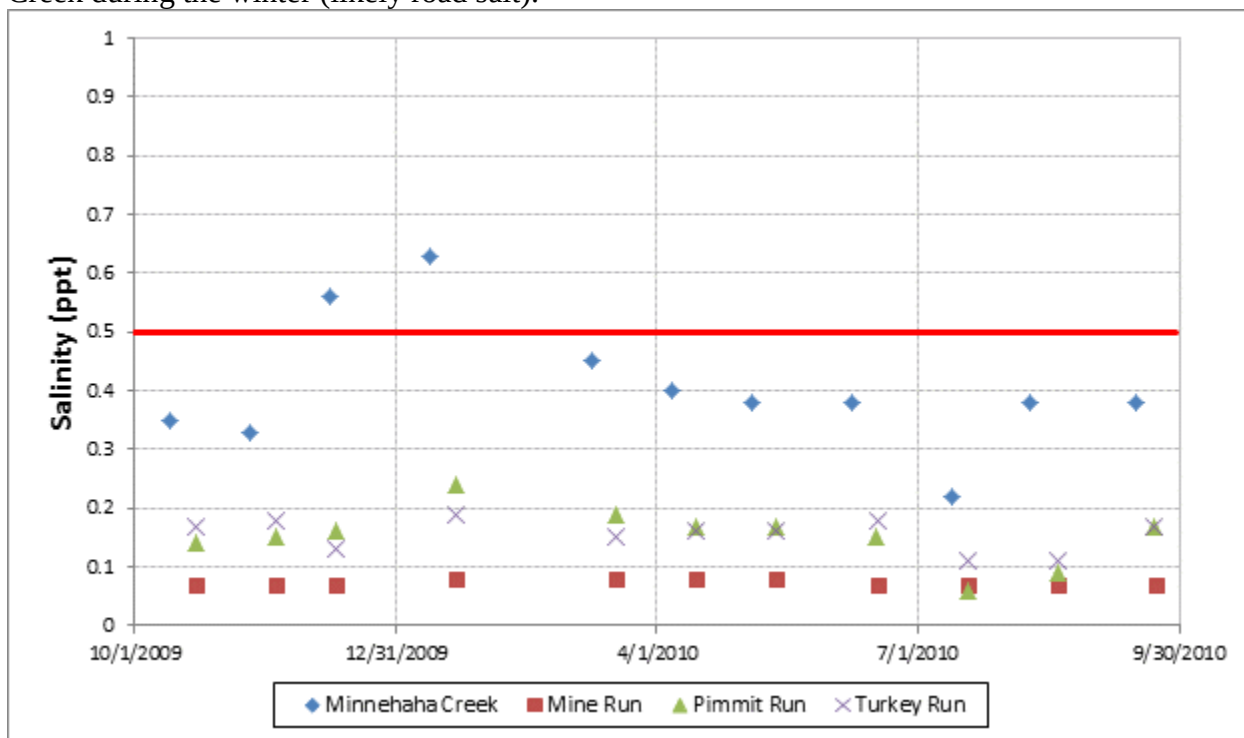


Figure 34: Salinity in GWMP streams FY 2010

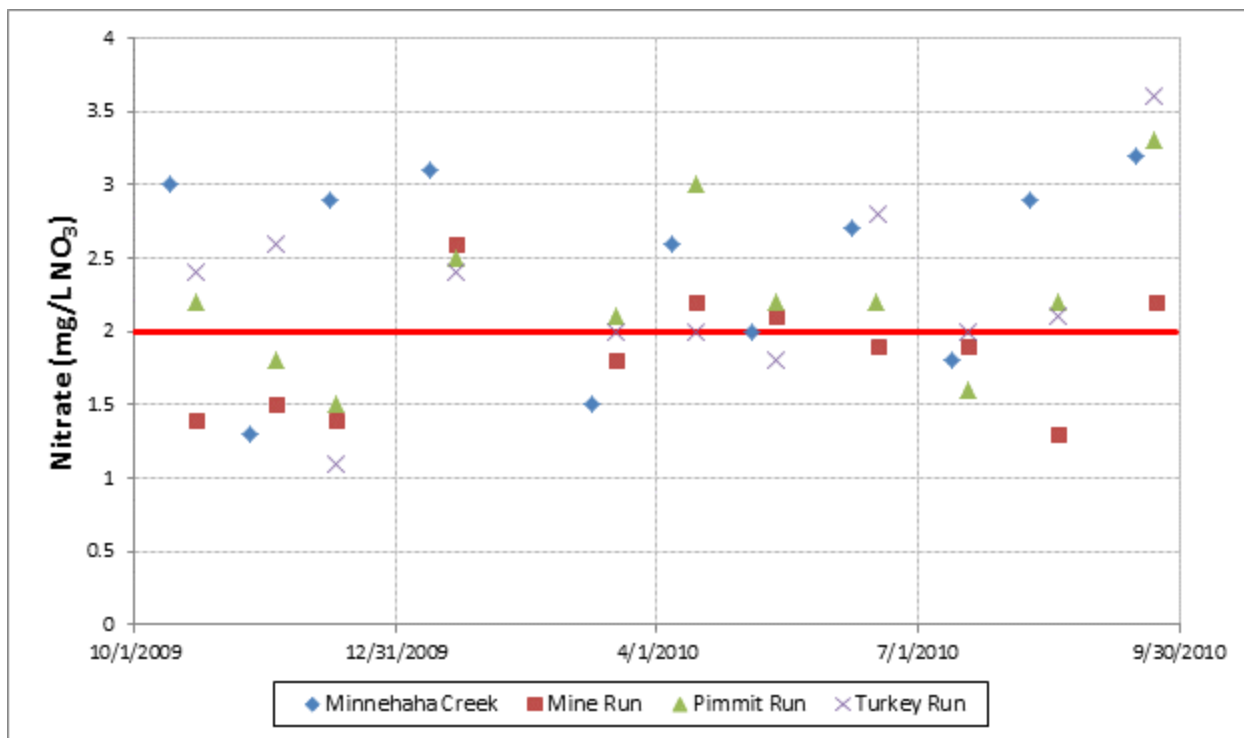


Figure 35: Nitrate in GWMP streams FY 2010

Nitrate levels (Figure 35) are nearly equally split between meeting or exceeding threshold limits, with no discernible pattern. Phosphorus levels (Figure 36) consistently exceed threshold and eutrophication values.

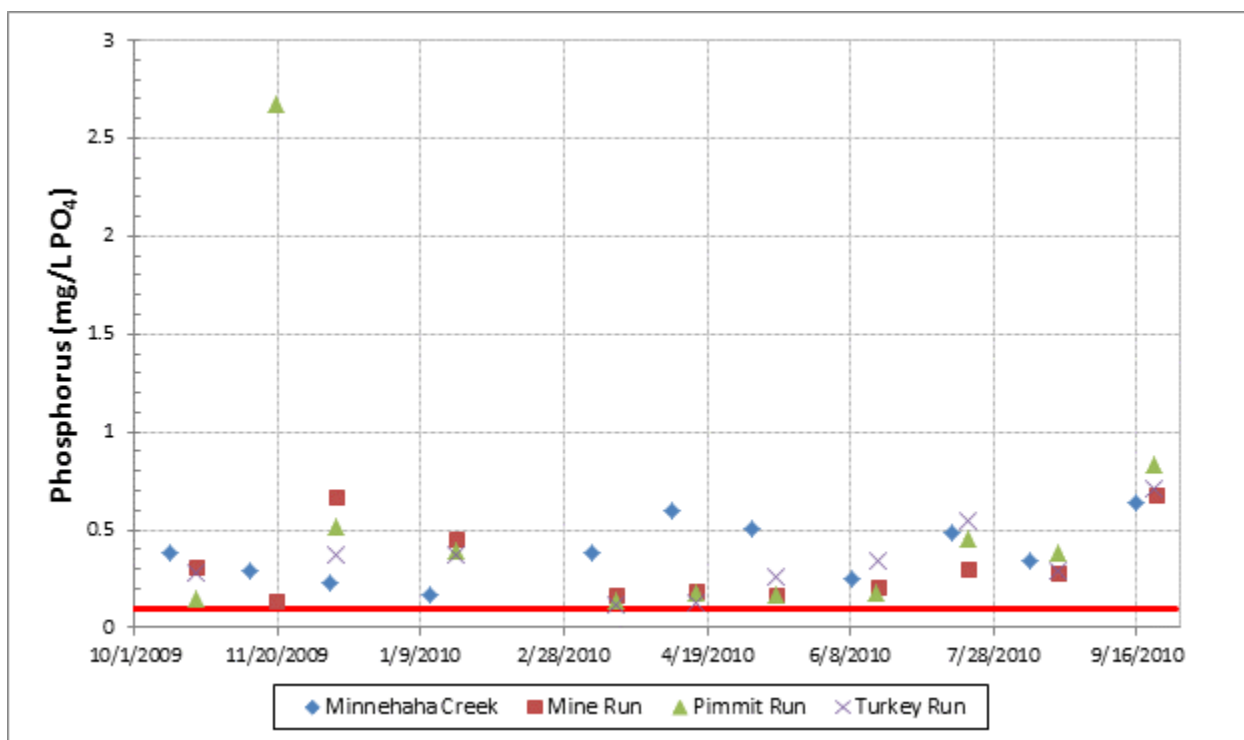


Figure 36: Phosphorus in GWMP streams FY 2010

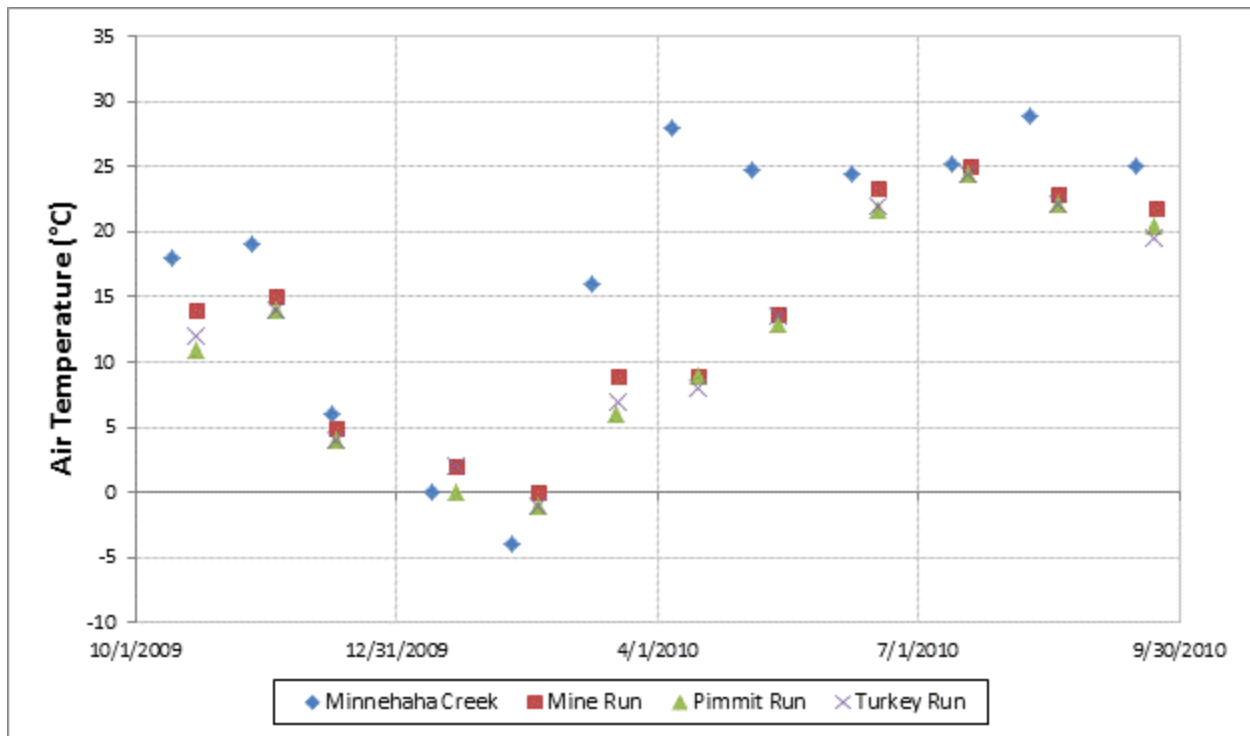


Figure 37: Air Temperature in GWMP streams FY 2010

Water temperatures (Figure 38) always fell within the threshold range, and followed similarly to Air temperatures (Figure 37), suggesting that the streams are primarily surface-fed.

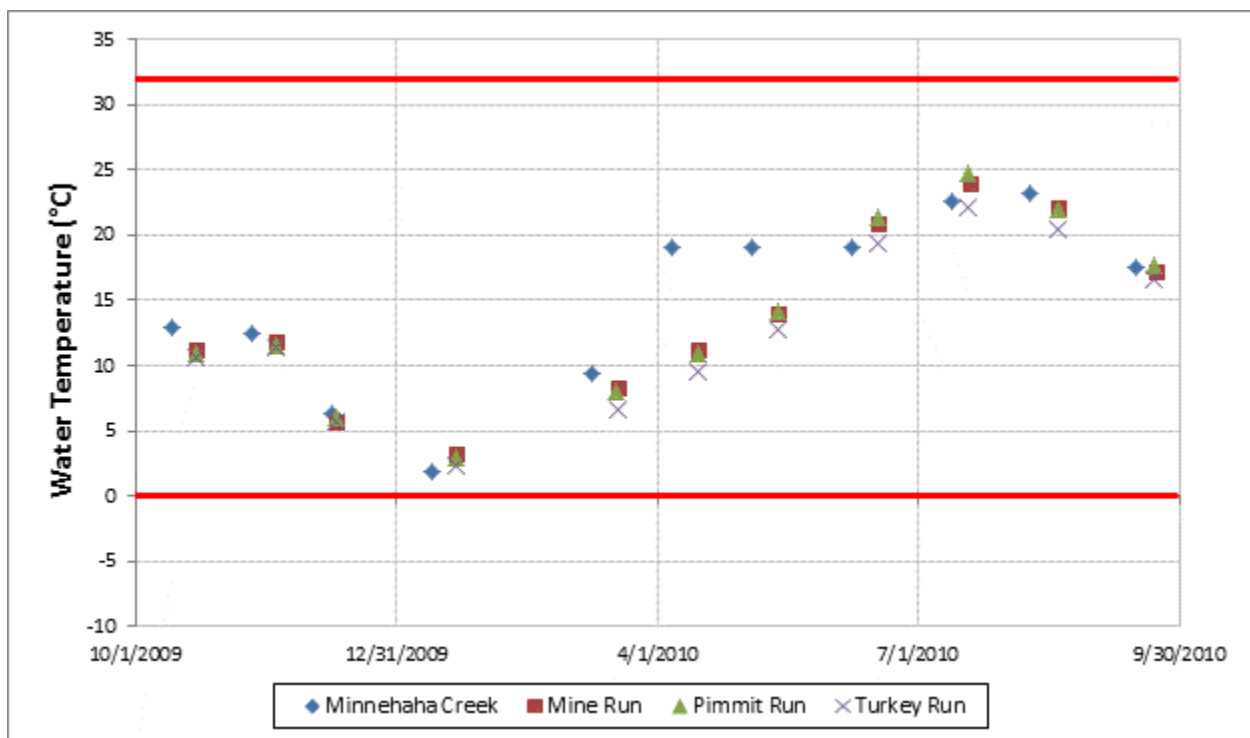


Figure 38: Water Temperature in GWMP streams FY 2010

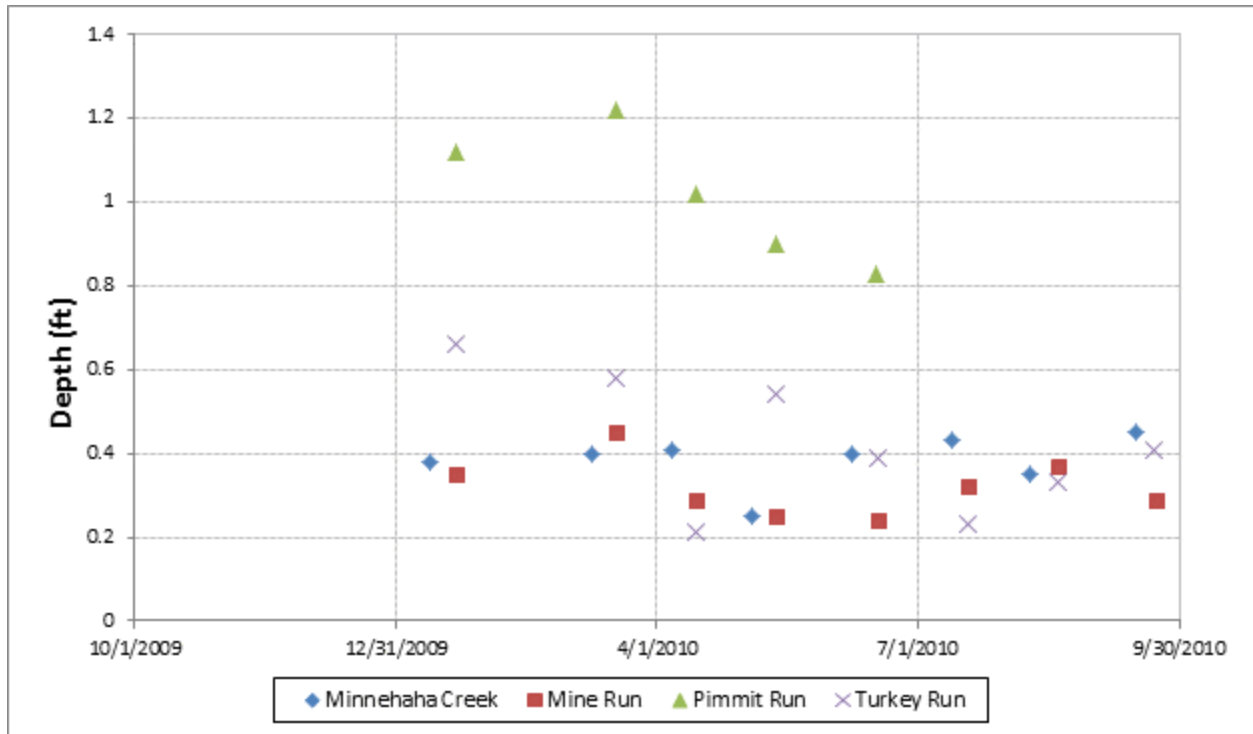


Figure 39: Stream depth in GWMP streams FY 2010

Missing depth data points (Figure 39) from October through December are due to equipment failure.

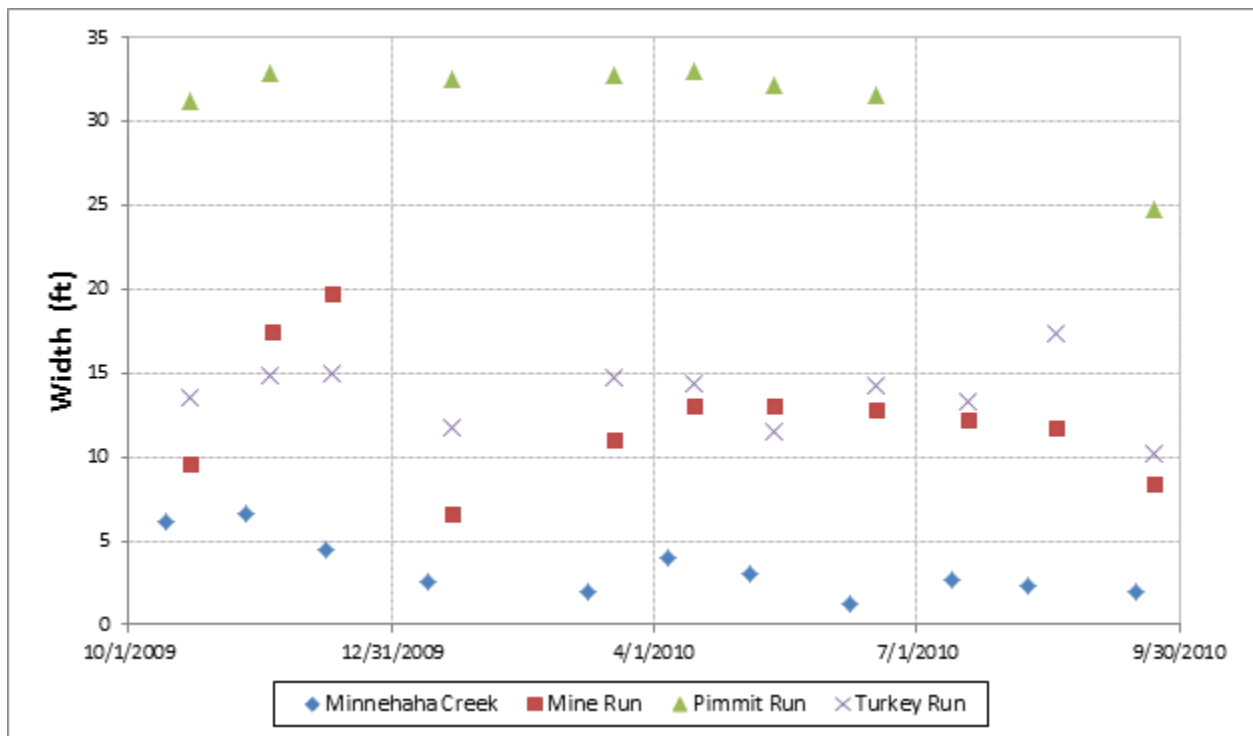


Figure 40: Stream width in GWMP streams FY 2010

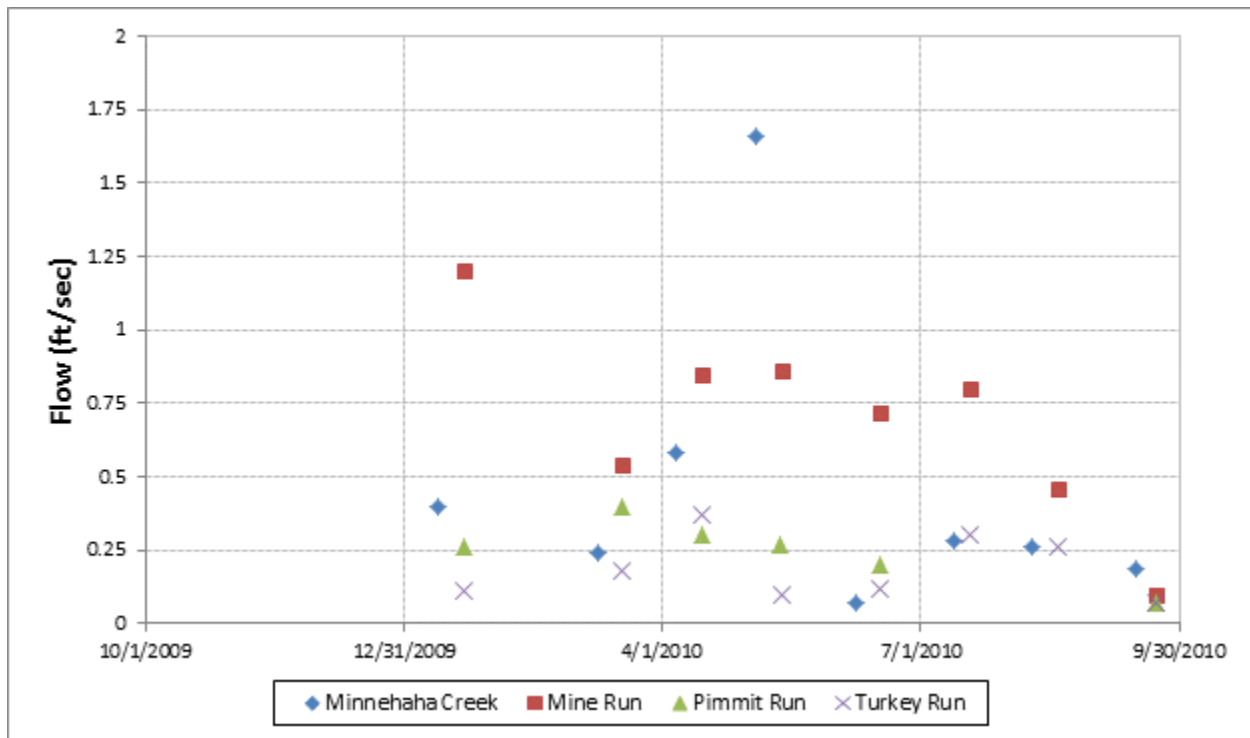


Figure 41: Stream flow in GWMP streams FY 2010

Missing flow data points (Figure 41) and missing discharge data points (Figure 42) from October through December are due to equipment failure.

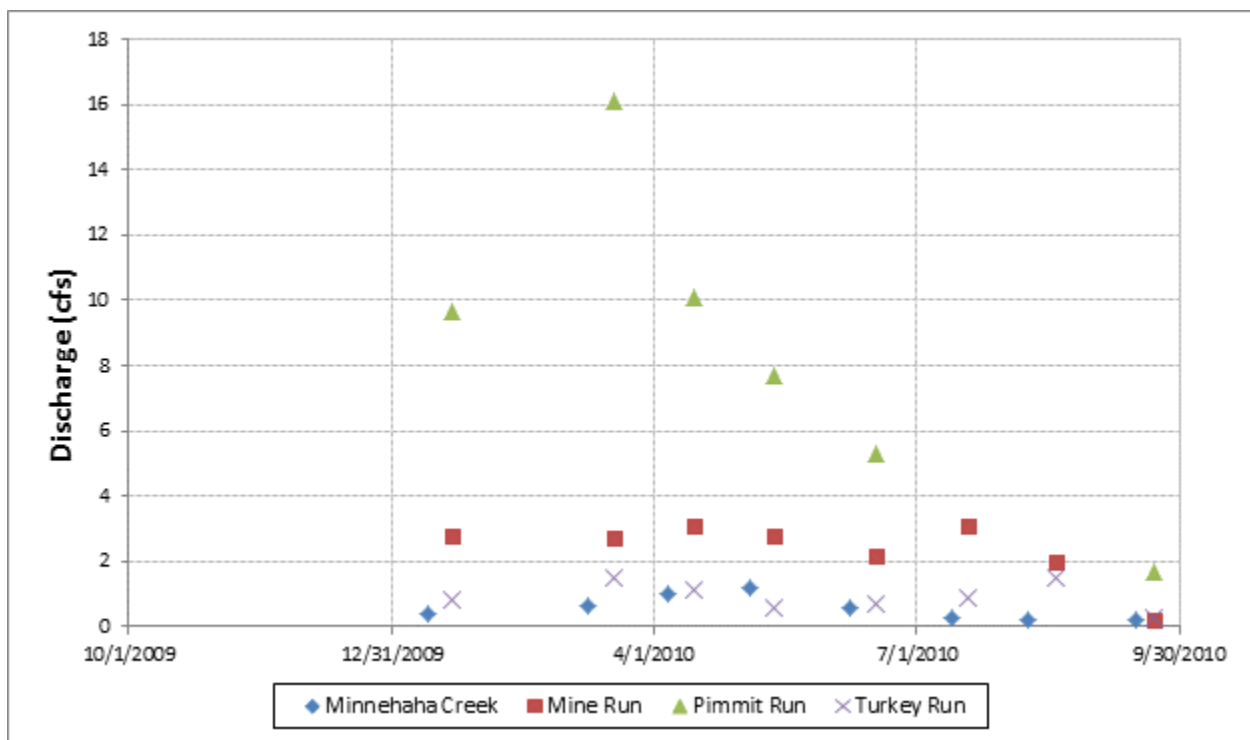


Figure 42: Stream discharge in GWMP streams FY 2010

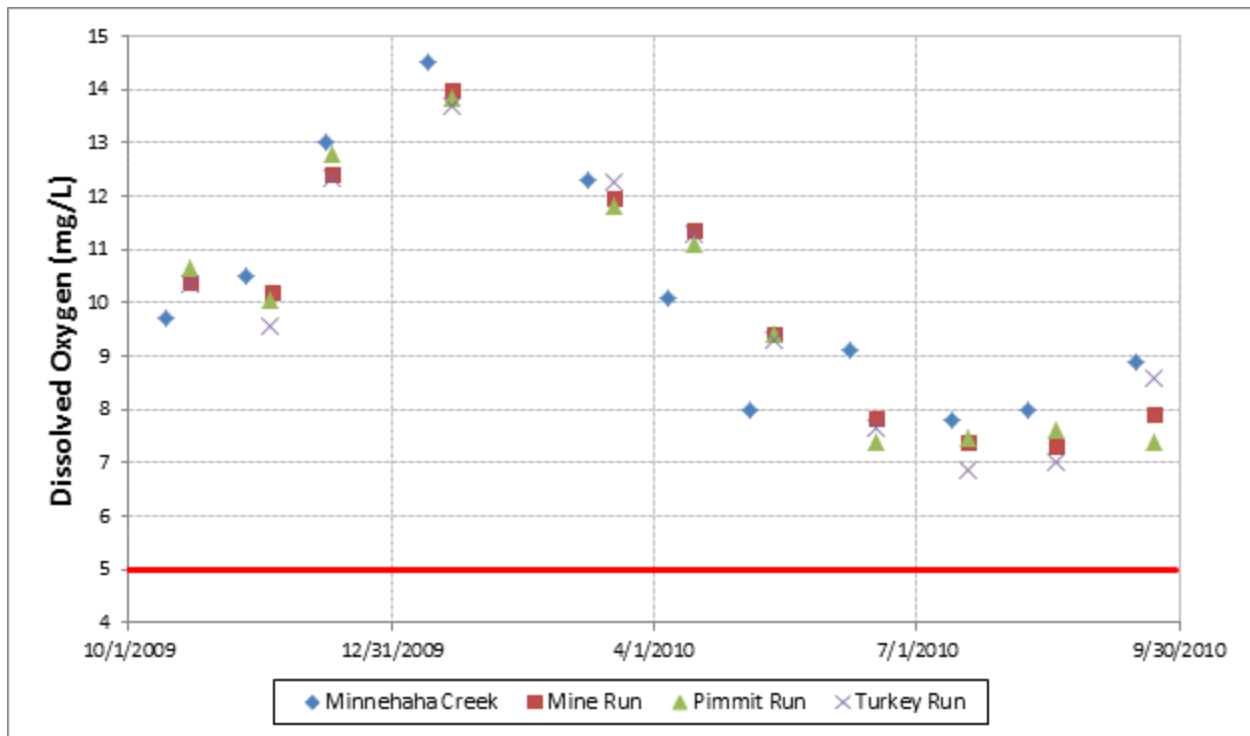


Figure 43: Dissolved Oxygen in GWMP streams FY 2010

Dissolved oxygen (Figure 43) consistently met threshold expectations, and displays a typical seasonal pattern.

Harpers Ferry National Historical Park (HAFE)

Harpers Ferry is located in the Great Valley of the Ridge and Valley Physiographic Province, within the Shenandoah and Potomac River watersheds. It stretches across Jefferson County, West Virginia; Loudoun County, Virginia; and Frederick County, Maryland.

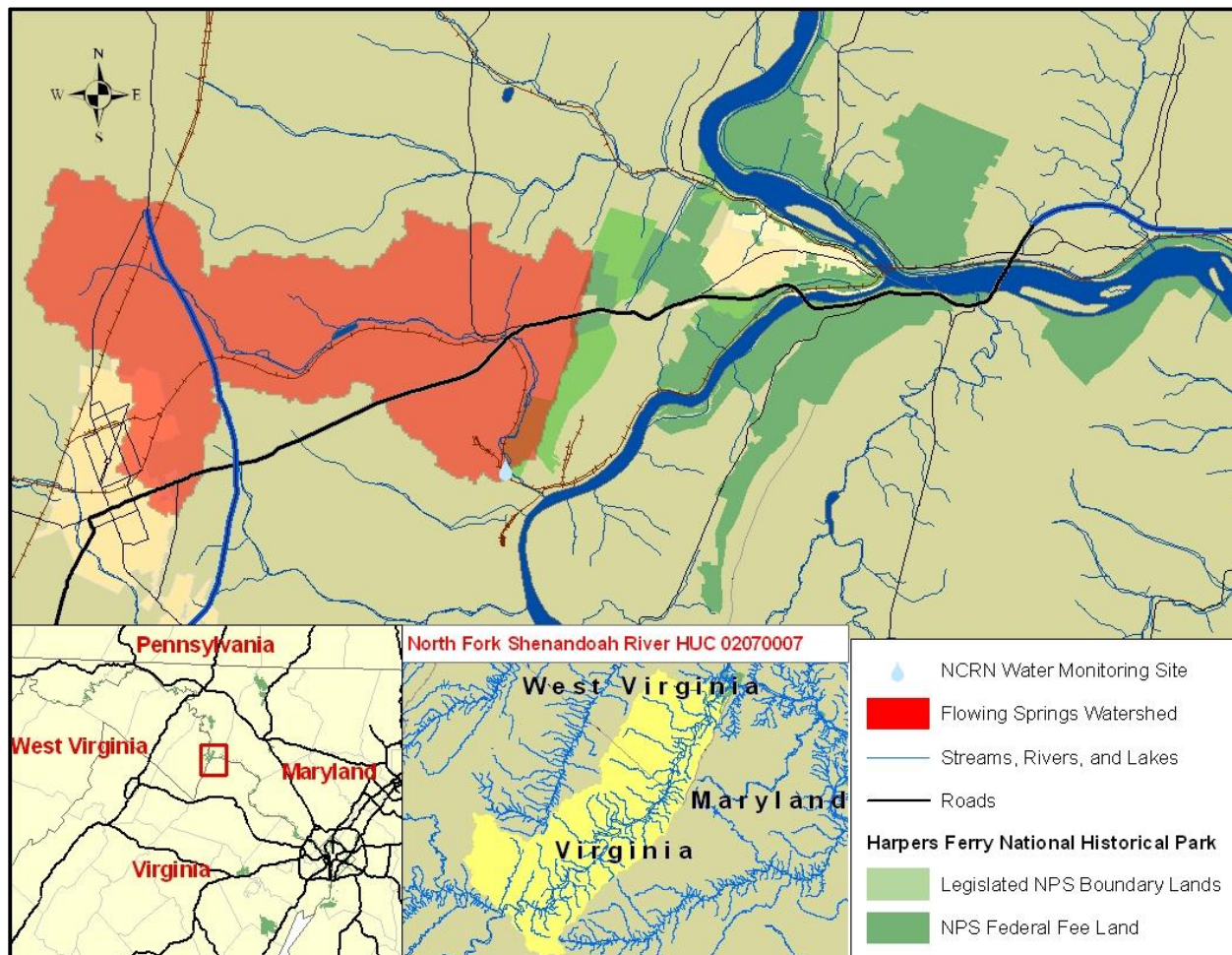


Figure 44: NCRN stream monitoring sites and associated watersheds within HAFE

The Potomac and Shenandoah Rivers run through the park but are not considered part of the Harpers Ferry. There are some small tributaries that cross the park. Elk Run, for example, is the major water supply for the town and a 500-foot section runs through the park before it empties into the Potomac River. A short portion of Piney Run crosses the park before it also enters the Potomac. The only stream with any appreciable length on park property that would be affected by park management is Flowing Springs, which winds for about one mile along the park before it enters the Shenandoah. Wetlands/waterways are impacted by development including roads and possibly de-icing salts used in the winter.

This report discusses data collected October 2009 through September 2010 in Flowing Springs Creek. Summary statistics for the time period are presented in Table 9. One site was monitored

on a monthly basis for dissolved oxygen, pH, specific conductance, temperature, acid neutralizing capacity, nitrate, total phosphorus, depth, wetted width, flow, and discharge.

Table 9: FY 2010 Summary statistics for the vital signs collected at HAFE

Parameter (Units)	Minimum	Maximum	Mean	Median	Standard Deviation
Air Temperature (°C)	-5	32	18.5	22.1	12.5
Water Temperature (°C)	2.8	24.5	15.1	18.1	7.1
ANC (µeq/L)	4200	5860	4962	4920	548.8
pH	8.04	8.42	8.24	8.20	0.12
Salinity (ppt)	0.28	0.39	0.33	0.32	0.04
Specific conductance (µS/cm)	574.6	798	682.9	669	74.7
DO (mg/L)	7.2	12.9	9.1	9	1.8
Nitrate (mg/L)	2.2	5.2	3.6	3.7	1.0
Total Phosphorus (mg/L)	0.15	1.12	0.46	0.39	0.28
Discharge (cfs)	2.29	11.34	5.61	---	3.76
Flow (ft/sec)	1.07	2.19	1.56	---	0.46
Water Depth (ft)	0.3	0.49	0.38	---	0.06
Wetted Width (ft)	5.8	13.2	8.7	8.3	2.6

Agriculture takes place in much of the park to replicate the historical Civil War landscape. The agriculture lease agreements allow for fertilizer and pesticide applications and some fields are leased for livestock grazing. These are potential sources of nitrate and phosphorus. Other sources include acid rain and atmospheric deposition as well as background levels in groundwater.

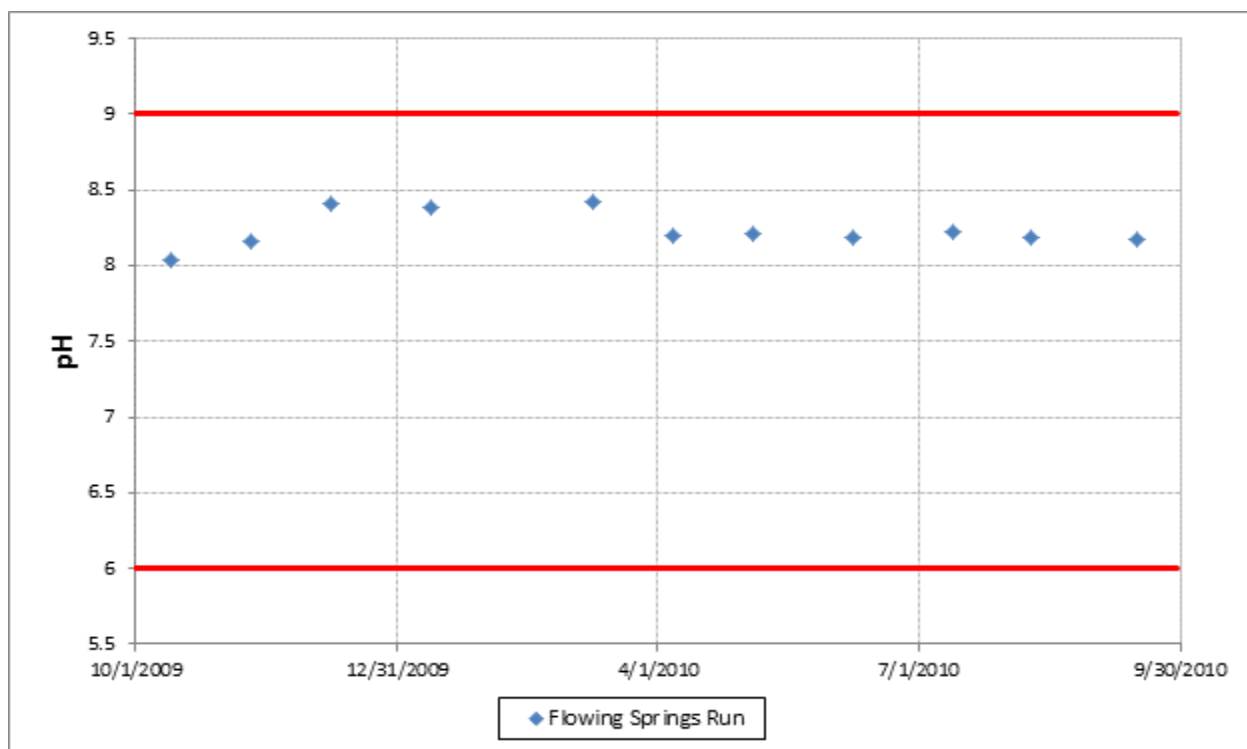


Figure 45: pH in HAFE streams FY 2010

Both pH (Figure 45) and acid neutralizing capacity (Figure 46) met threshold expectations. The high values for both parameters are due to the dissolving of rocks within the karst landscape.

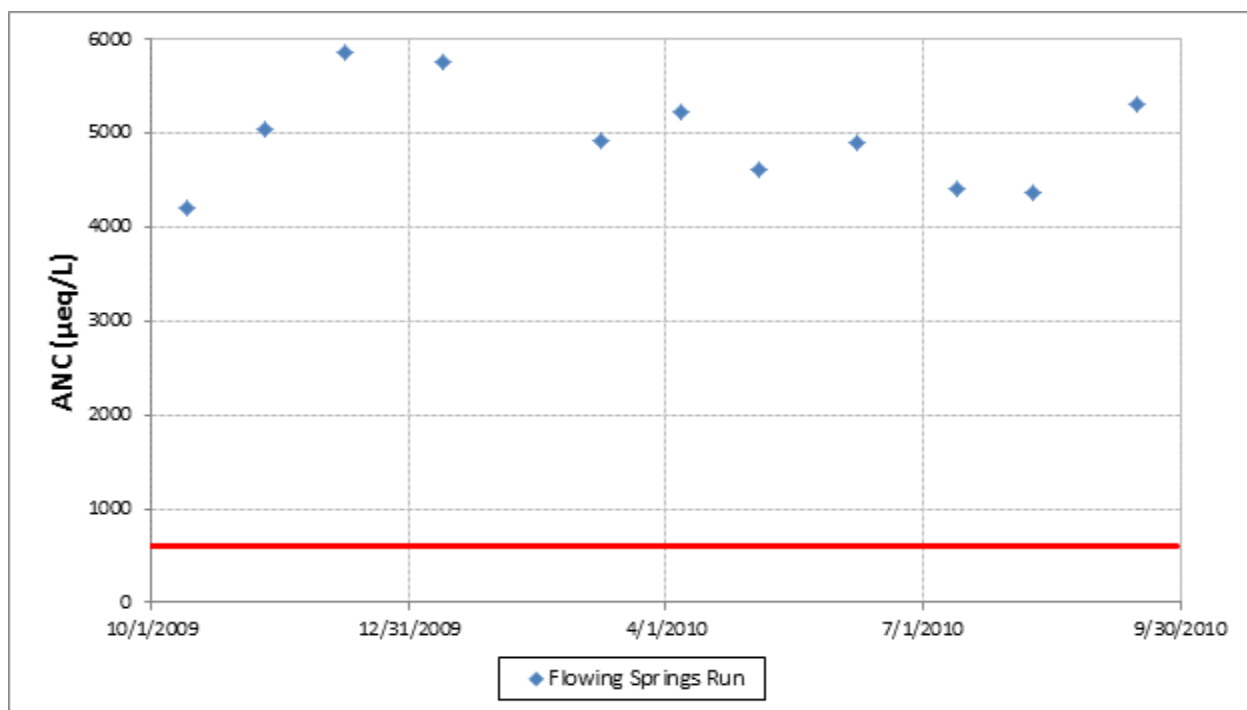


Figure 46: Acid Neutralizing Capacity in HAFE streams FY 2010

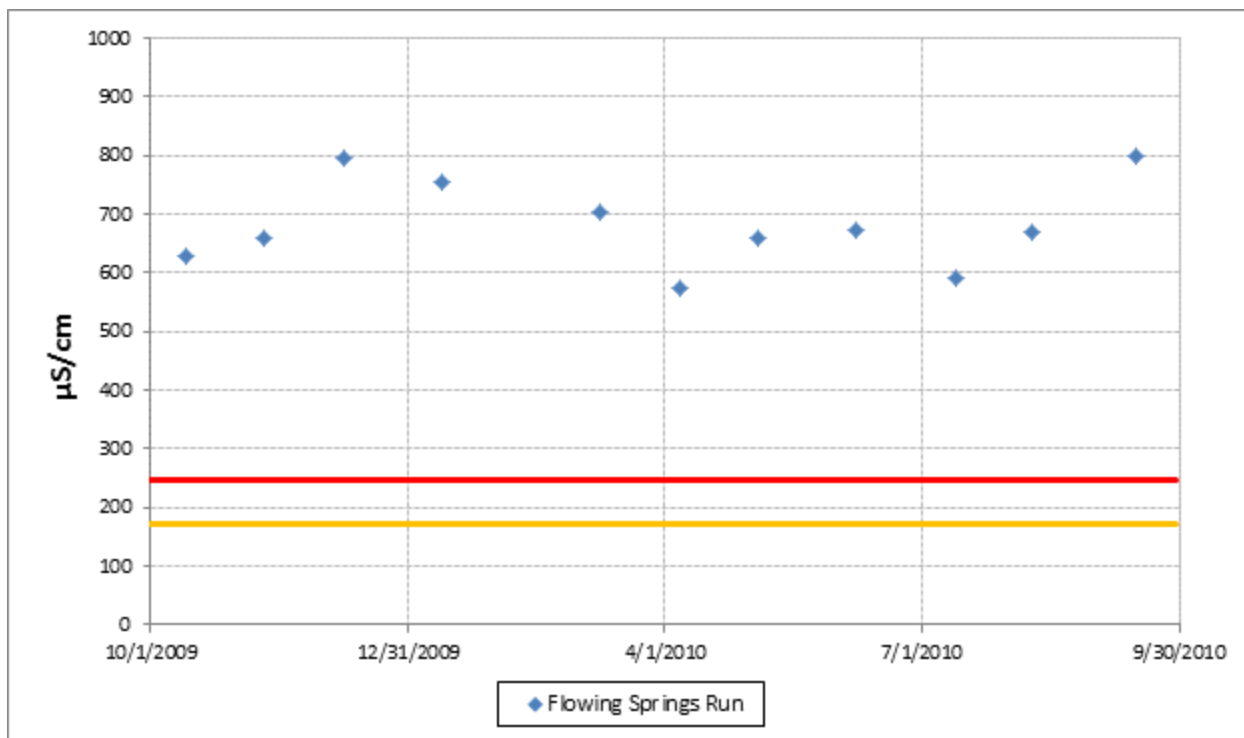


Figure 47: Specific Conductance in HAFE streams FY 2010

Specific conductance (Figure 47) exceeded ecological thresholds for aquatic life stress (orange = fish threshold; red = macroinvertebrate threshold). Salinity (Figure 48) remained below the threshold for fresh water. The overall higher values for specific conductance are due to the dissolution of rocks in the karst landscape.

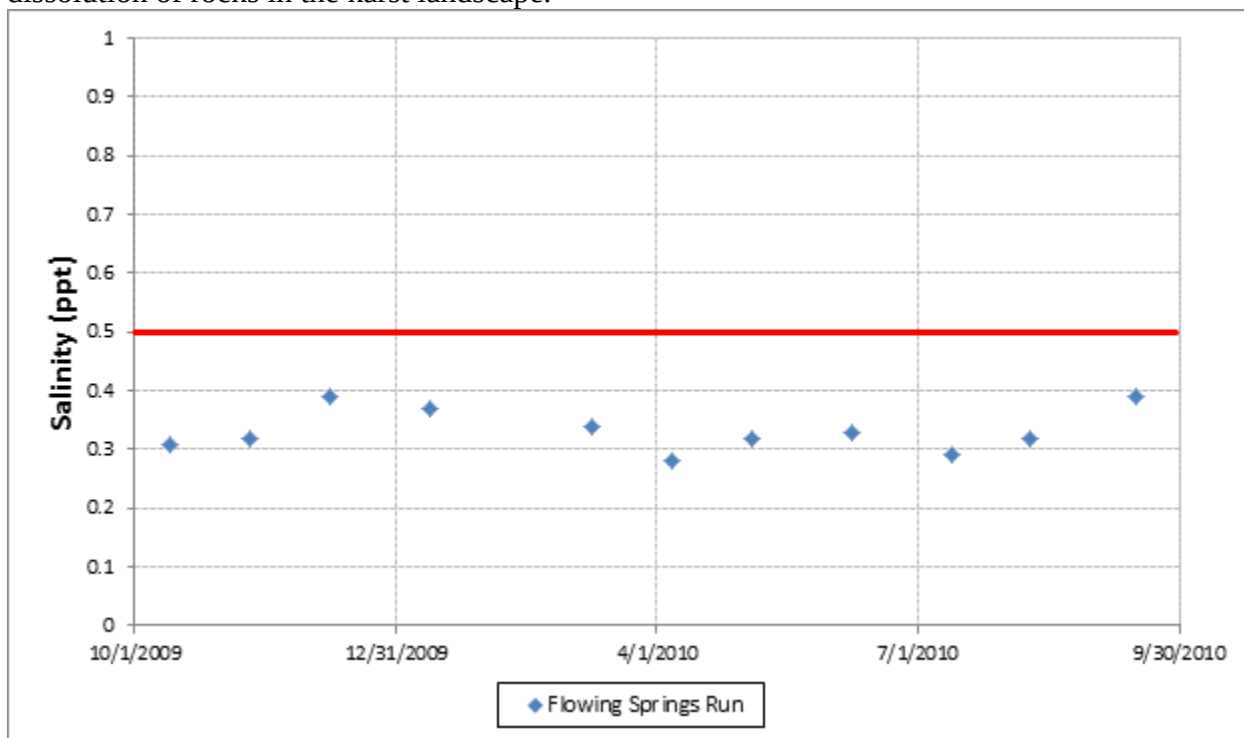


Figure 48: Salinity in HAFE streams FY 2010

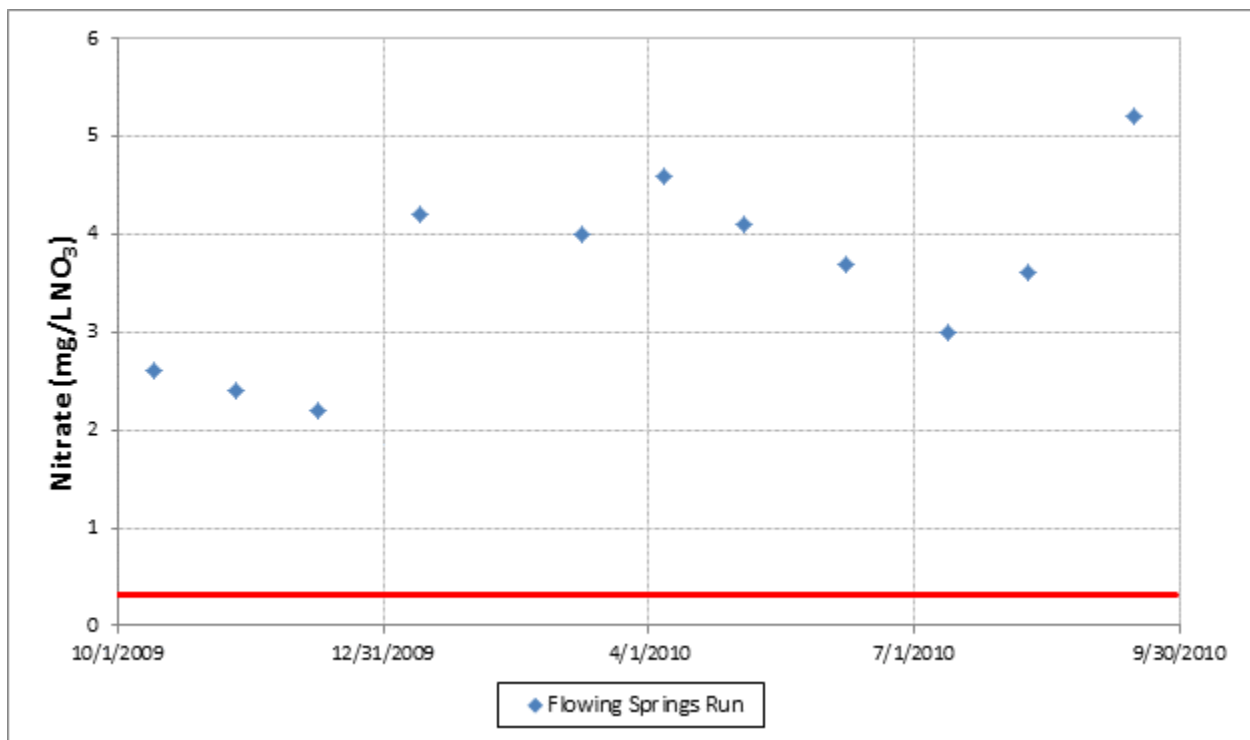


Figure 49: Nitrate in HAFE streams FY 2010

Nitrate (Figure 49) and Phosphorus (Figure 50) levels consistently exceeded their respective threshold levels.

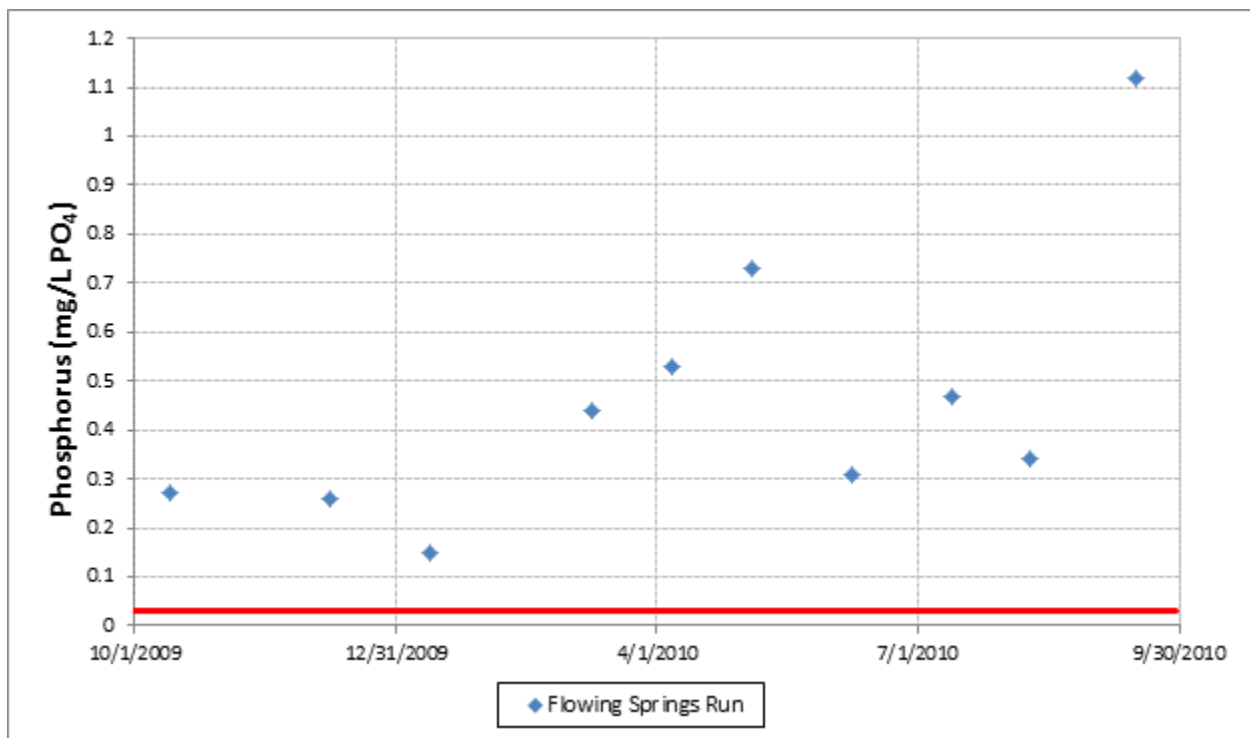


Figure 50: Phosphorus in HAFE streams FY 2010

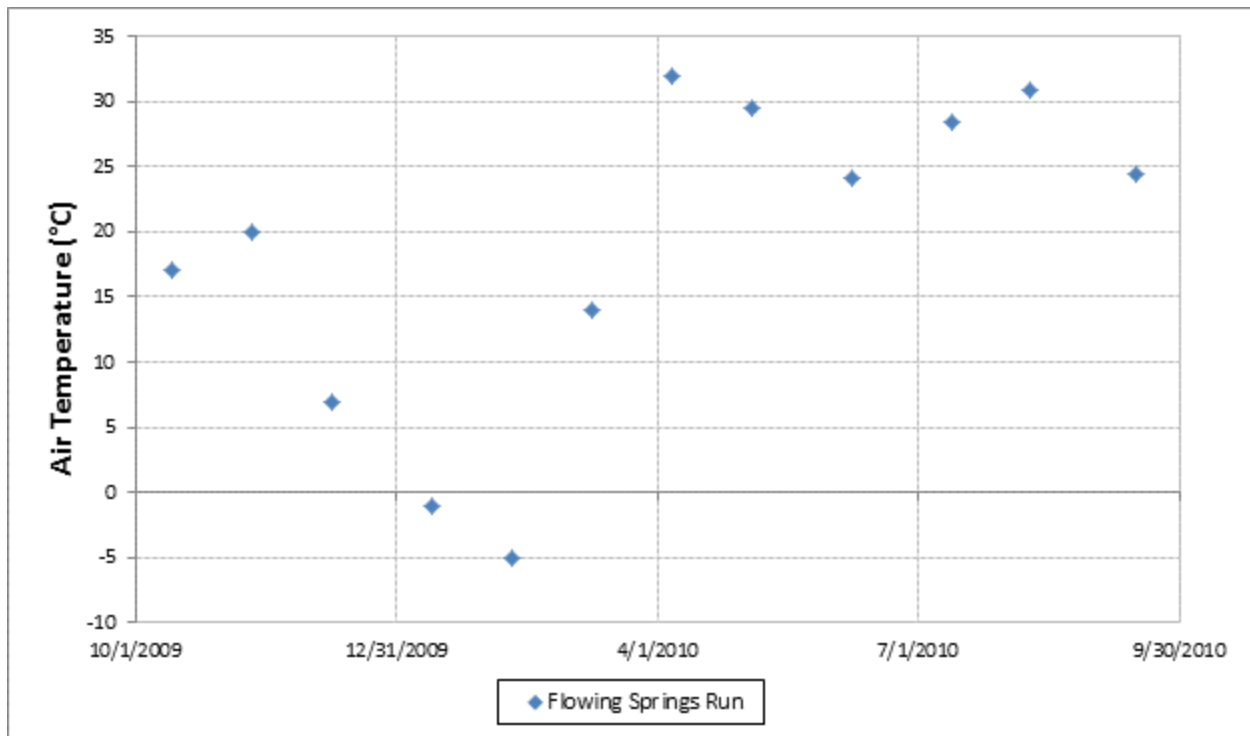


Figure 51: Air Temperature in HAFE streams FY 2010

Water temperatures (Figure 52) were within the threshold range and generally follow Air temperature (Figure 51), suggesting that Flowing Springs Run is surface-fed.

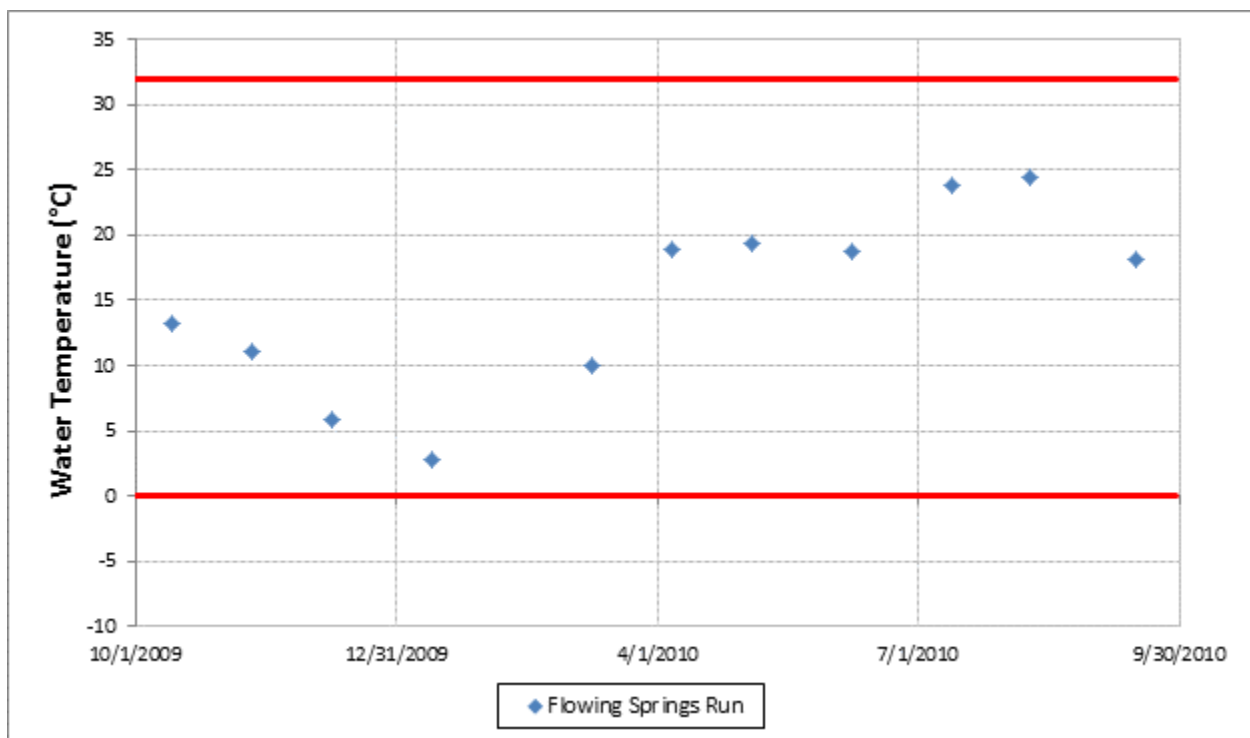


Figure 52: Water Temperature in HAFE streams FY 2010

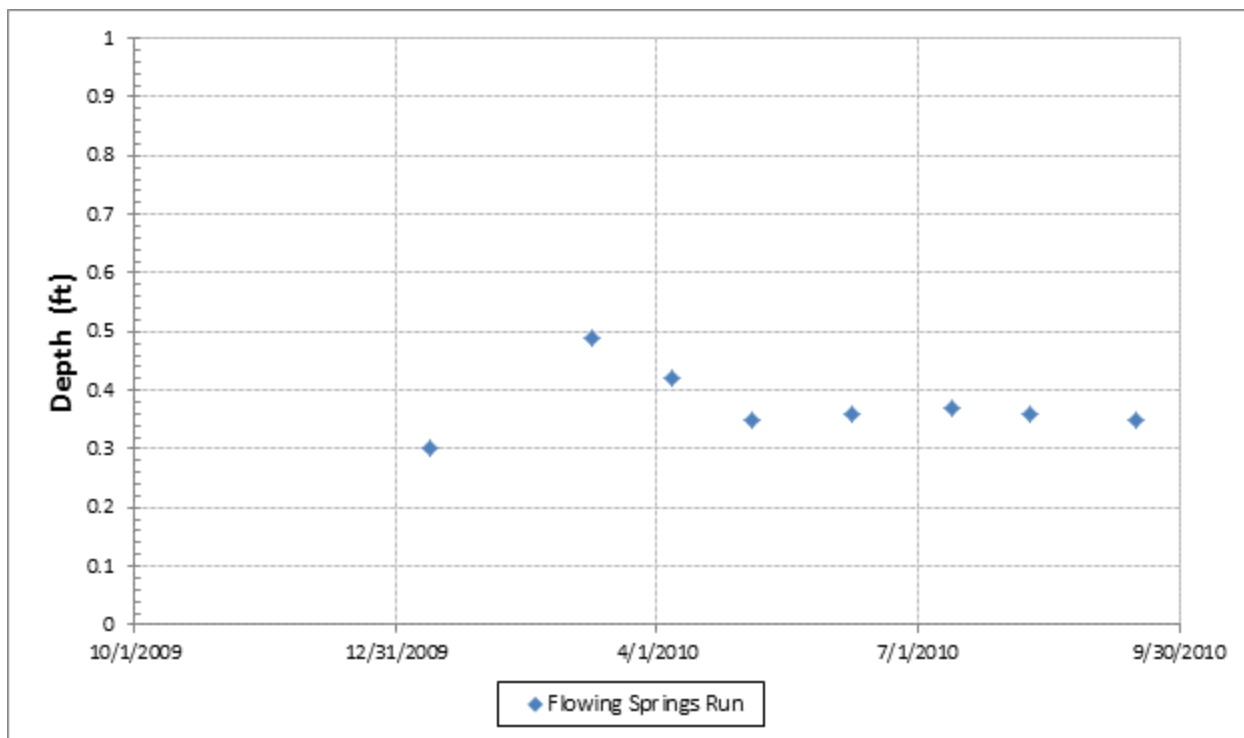


Figure 53: Stream depth in HAFE streams FY 2010

Missing depth data points (Figure 53) from October through December are due to equipment failure.

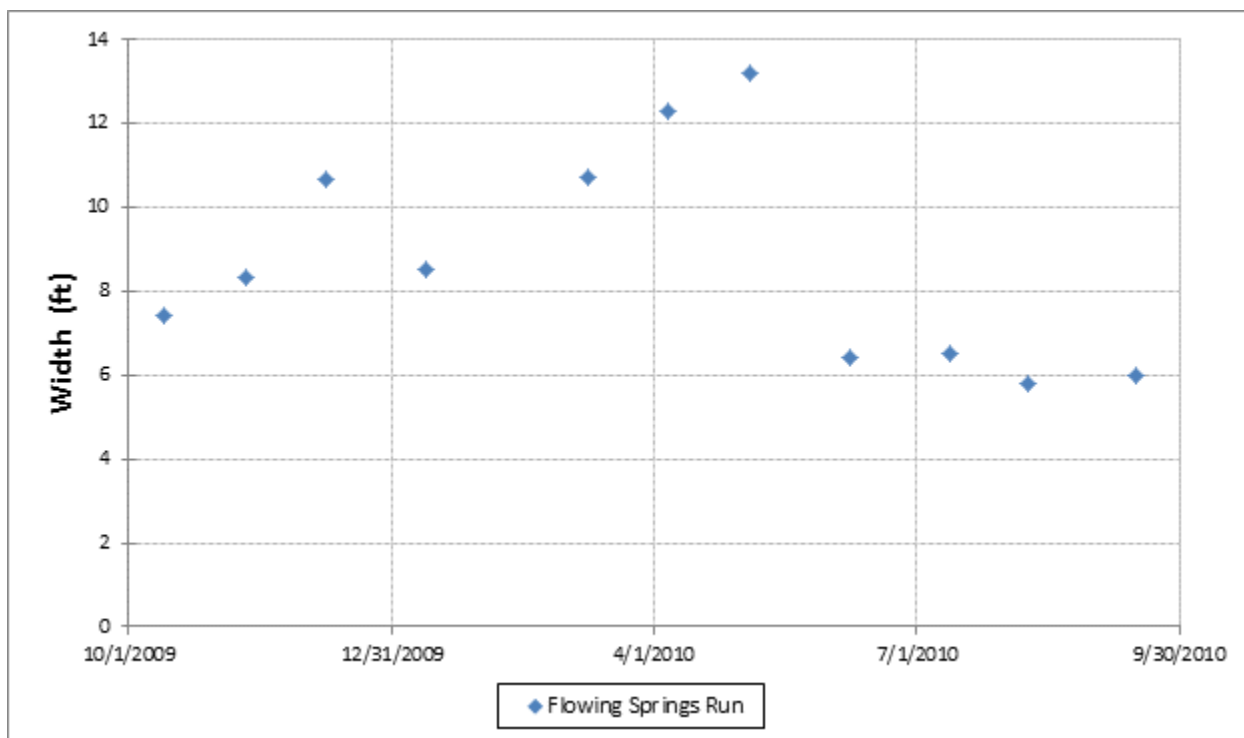


Figure 54: Stream width in HAFE streams FY 2010

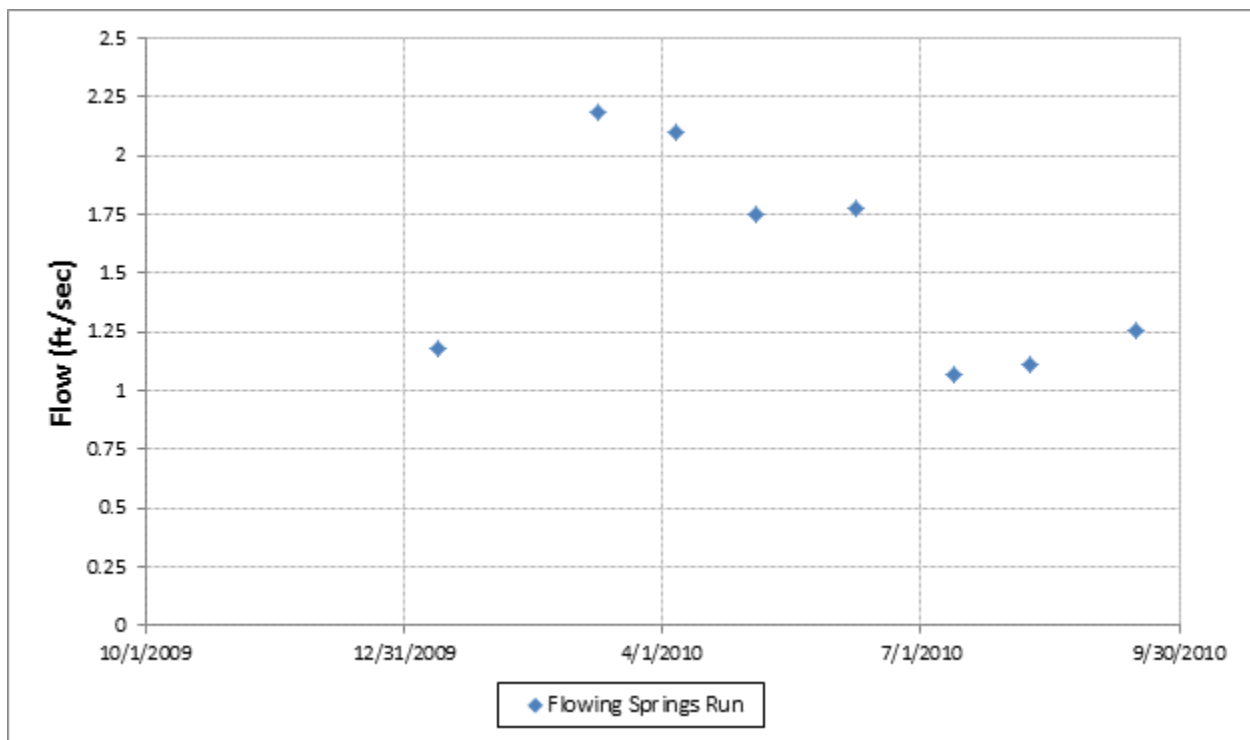


Figure 55: Stream flow in HAFE streams FY 2010

Missing flow data points (Figure 55) and missing discharge data points (Figure 56) from October through December are due to equipment failure.

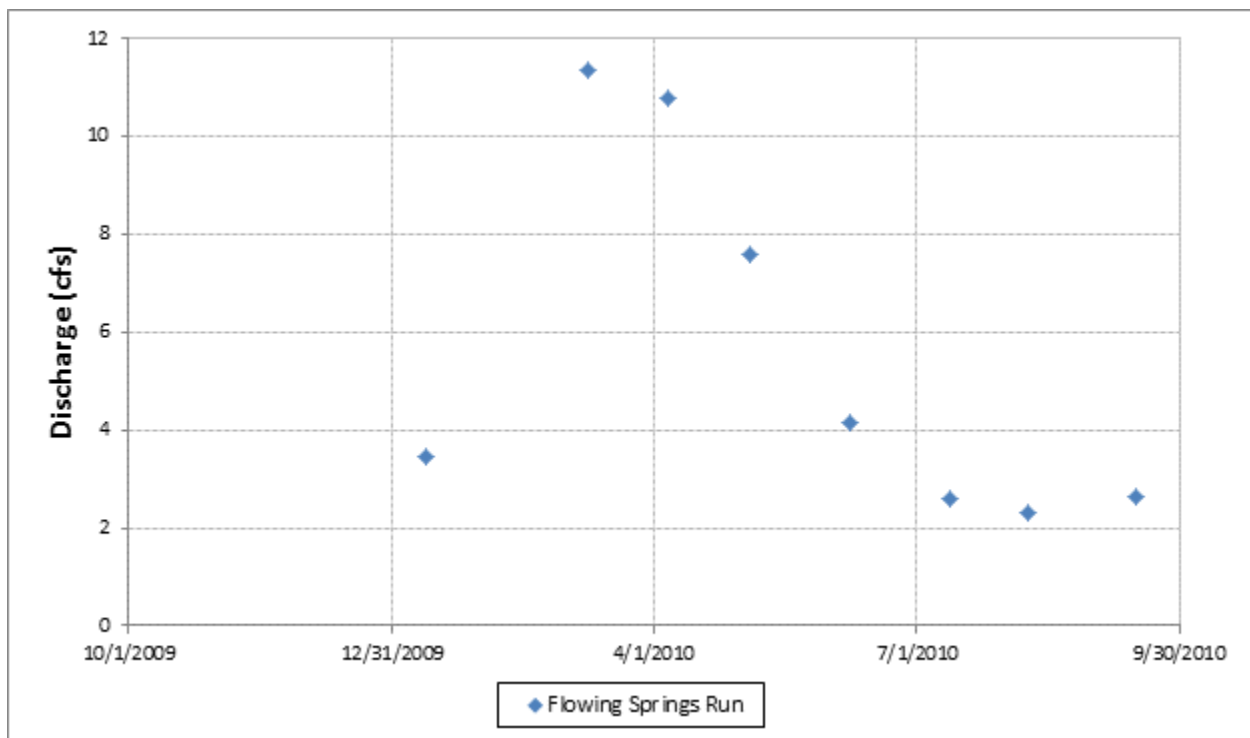


Figure 56: Stream discharge in HAFE streams FY 2010

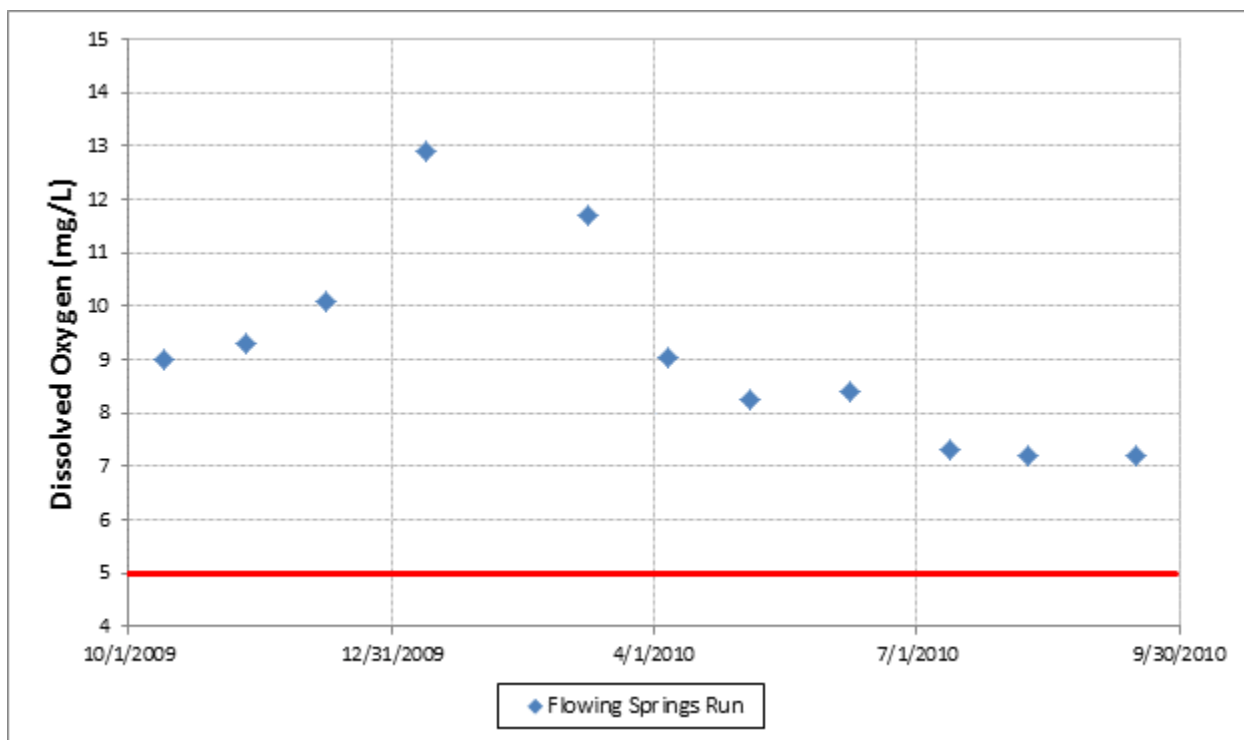


Figure 57: Dissolved Oxygen in HAFE streams FY 2010

When measured, dissolved oxygen (Figure 57) is well above the threshold limit, likely due to groundwater influencing the stream with cooler temperatures.

Manassas National Battlefield Park (MANA)

Manassas National Battlefield Park was established in 1940. The 2,064 ha park is located approximately 72 km southwest of Washington, D.C. in Manassas County, Virginia within the Piedmont physiographic province. The Piedmont is characterized by a gently rolling topography of deeply weathered bedrock, with some solid outcrop. MANA is characterized by gently rolling hills with a patchwork of open fields and forests with riparian vegetation along the streams. A variety of igneous, metamorphic, and sedimentary rocks make up the bedrock of MANA. Most streams are of moderate slope with rock or bedrock bottoms (Fenneman 1938, Thornbury 1968, Blomquist et al. 1996, William & Mary 2000). Many of MANA's streams are lined with a dark red siltstone. The park contains about 16 miles of named streams and several unnamed watercourses. The eastern boundary of the park is Bull Run. Young's Branch is a tributary of Bull Run and most of its watershed is contained within the battlefield (Figure 58).

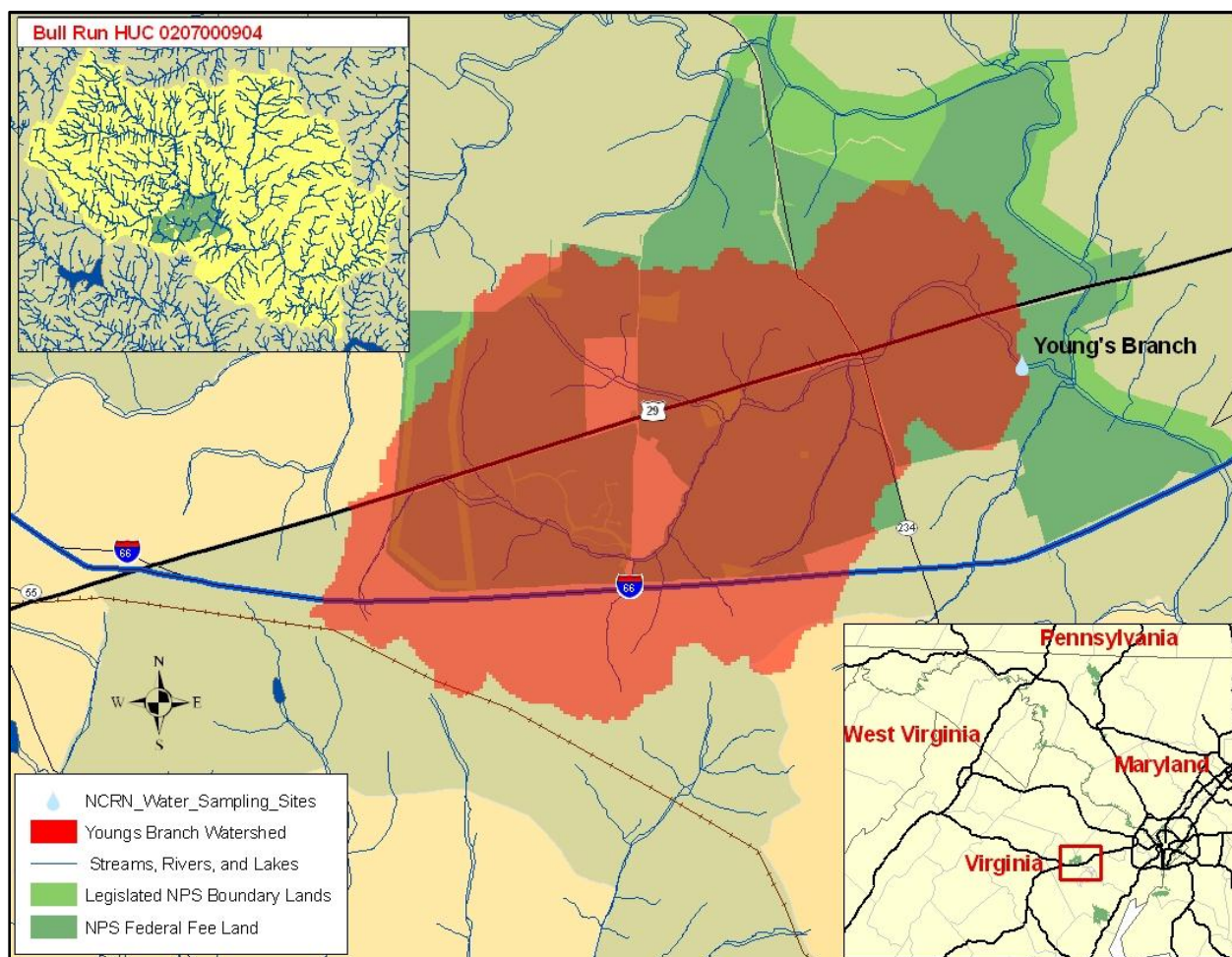


Figure 58: NCRN stream monitoring sites and associated watersheds within MANA

This report discusses data collected October 2009 through September 2010 in Youngs Branch. Summary statistics for the time period are presented in Table 10. The site was monitored on a

monthly basis for dissolved oxygen, pH, specific conductance, temperature, acid neutralizing capacity, nitrate, total phosphorus, depth, wetted width, flow, and discharge.

Table 10: FY 2010 Summary statistics for the vital signs collected at MANA

Parameter (Units)	Minimum	Maximum	Mean	Median	Standard Deviation
Air Temperature (°C)	-3	25.3	13.2	11.1	9.1
Water Temperature (°C)	2.0	24.1	12.9	10.6	8.0
ANC (µeq/L)	776	2200	1485	1652	542.5
pH	7.48	7.82	7.60	7.56	0.12
Salinity (ppt)	0.14	0.39	0.24	0.24	0.09
Specific conductance (µS/cm)	285	779.3	492.7	487.4	170.6
DO (mg/L)	4.1	13.7	8.7	9.17	3.28
Nitrate (mg/L)	0.6	1.8	1.2	1.05	0.4
Total Phosphorus (mg/L)	0.1	0.49	0.28	0.22	0.14
Discharge (cfs)	0	18.82	4.21	---	7.15
Flow (ft/sec)	0	0.68	0.15	---	0.23
Water Depth (ft)	0.25	0.7	0.51	---	0.14
Wetted Width (ft)	0	32.7	23.4	25.2	8.4

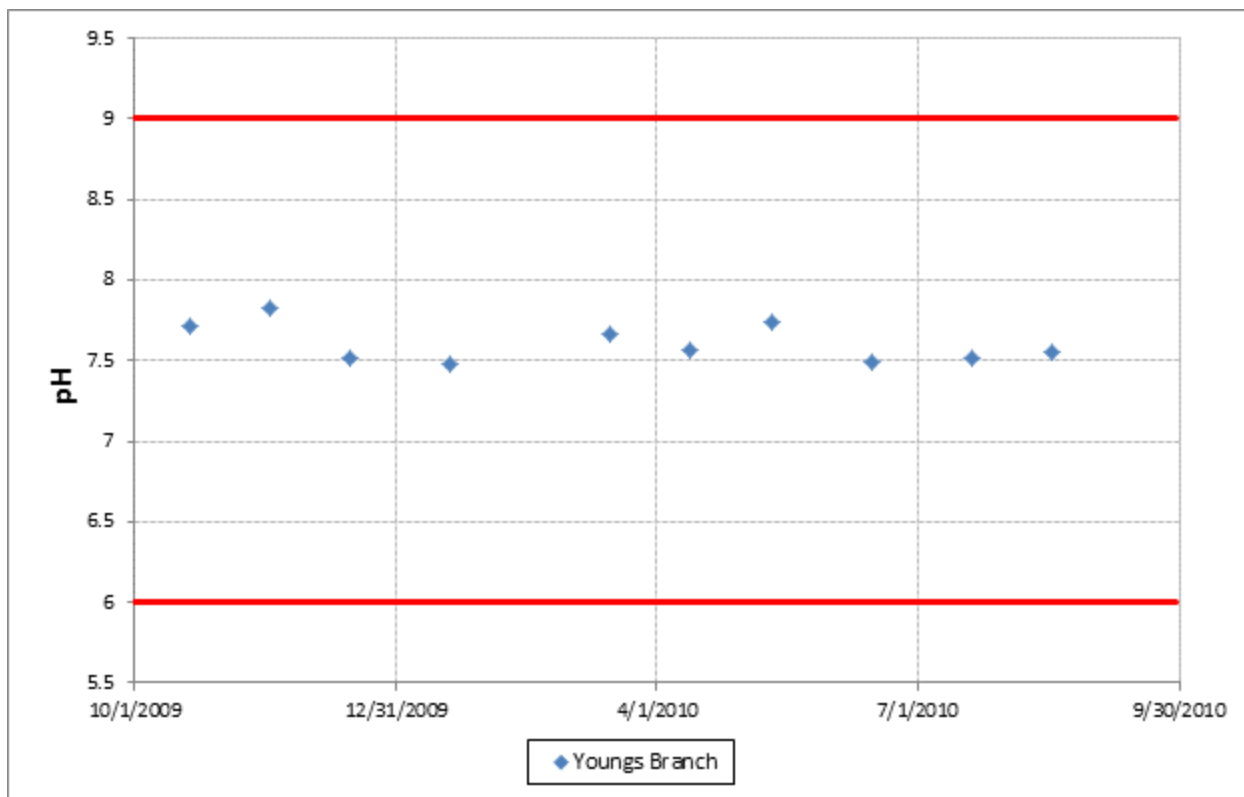


Figure 59: pH in MANA streams FY 2010

Both pH (Figure 59) and acid neutralizing capacity (Figure 60) met threshold expectations.

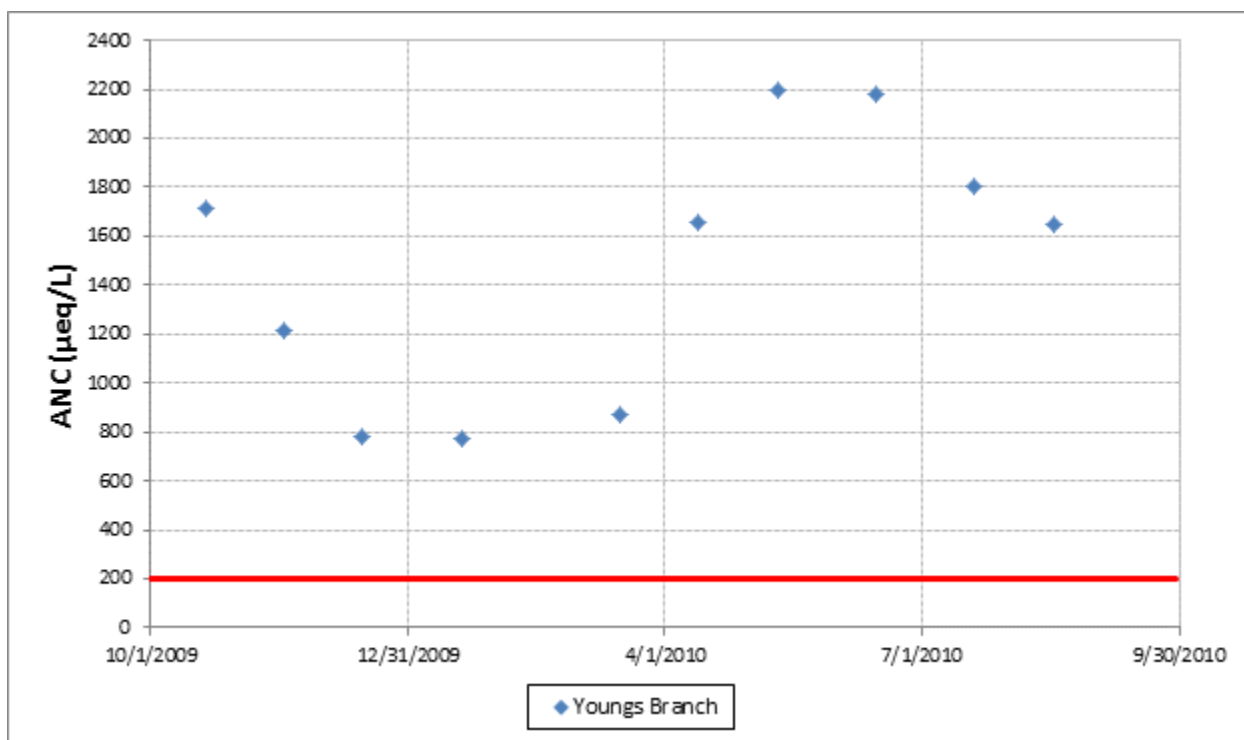


Figure 60: Acid Neutralizing Capacity in MANA streams FY 2010

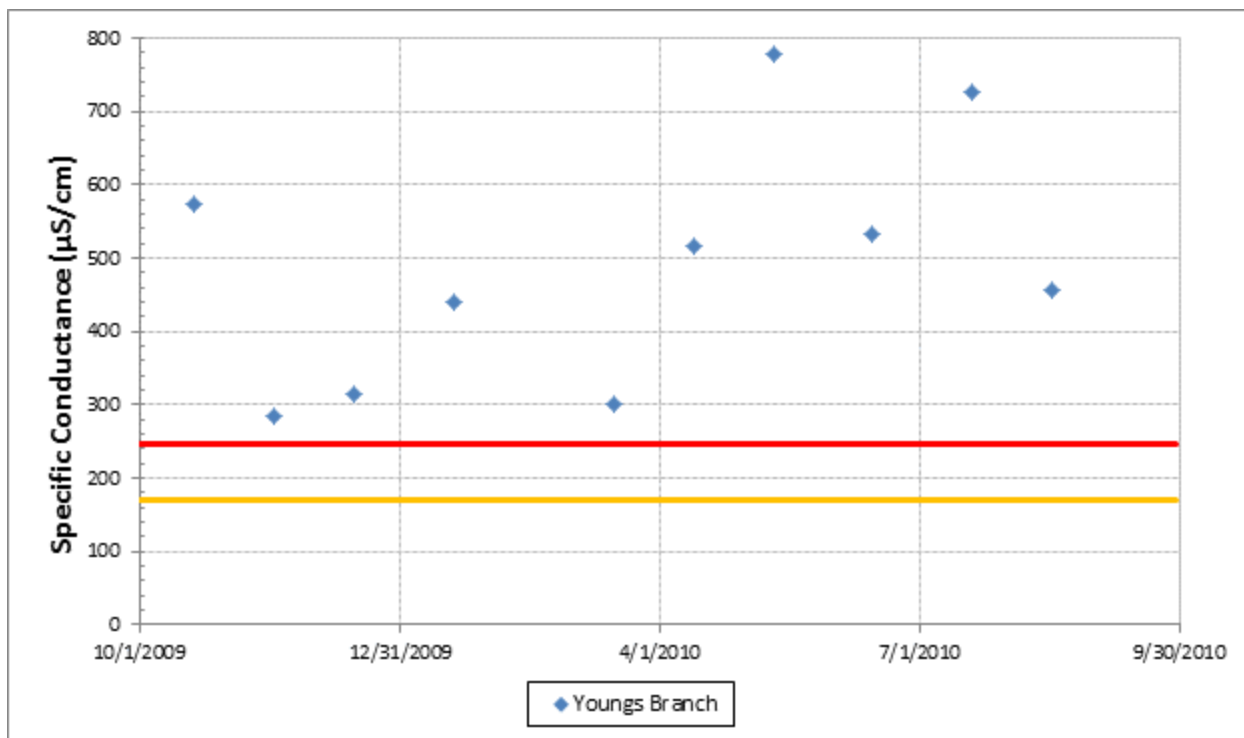


Figure 61: Specific Conductance in MANA streams FY 2010

Specific conductance (Figure 61) exceeded ecological thresholds for aquatic life stress (orange = fish threshold; red = macroinvertebrate threshold). Salinity (Figure 62) remained under the threshold for freshwater ecosystems.

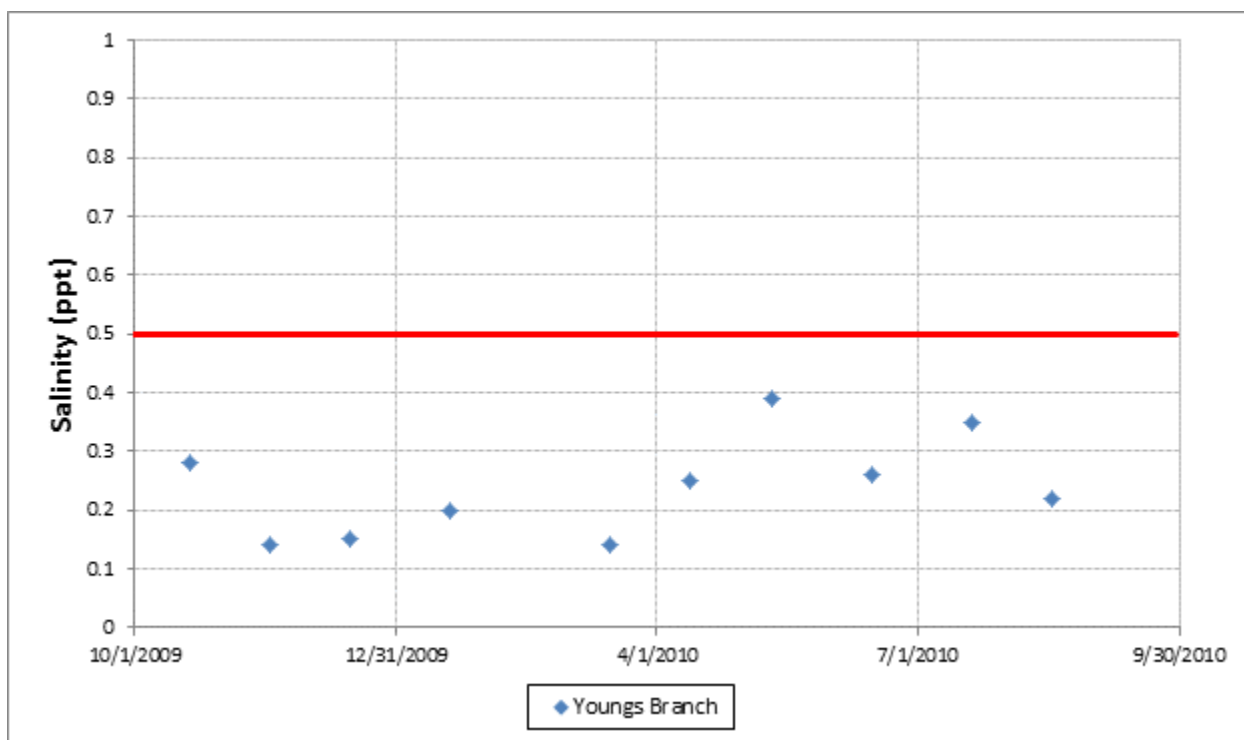


Figure 62: Salinity in MANA streams FY 2010

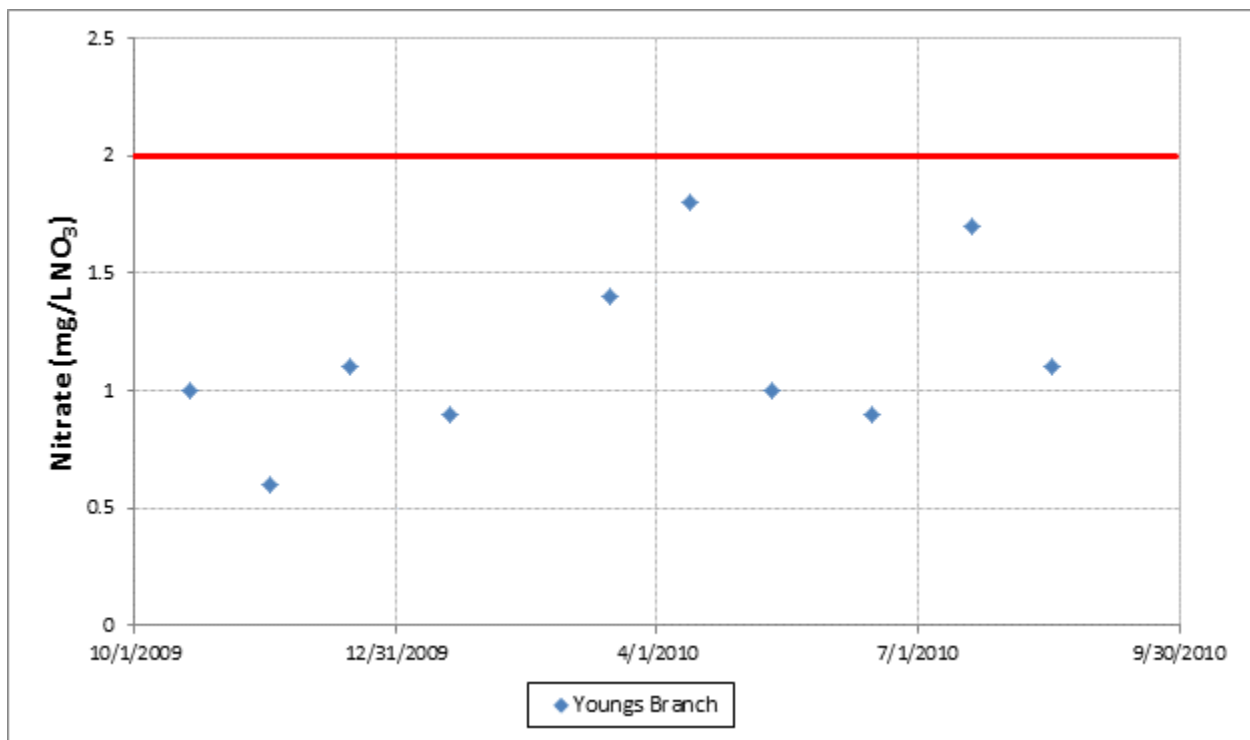


Figure 63: Nitrate in MANA streams FY 2010

Nitrate levels (Figure 63) were consistently below threshold, while phosphorus levels (Figure 64) regularly exceeded both threshold and eutrophication values.

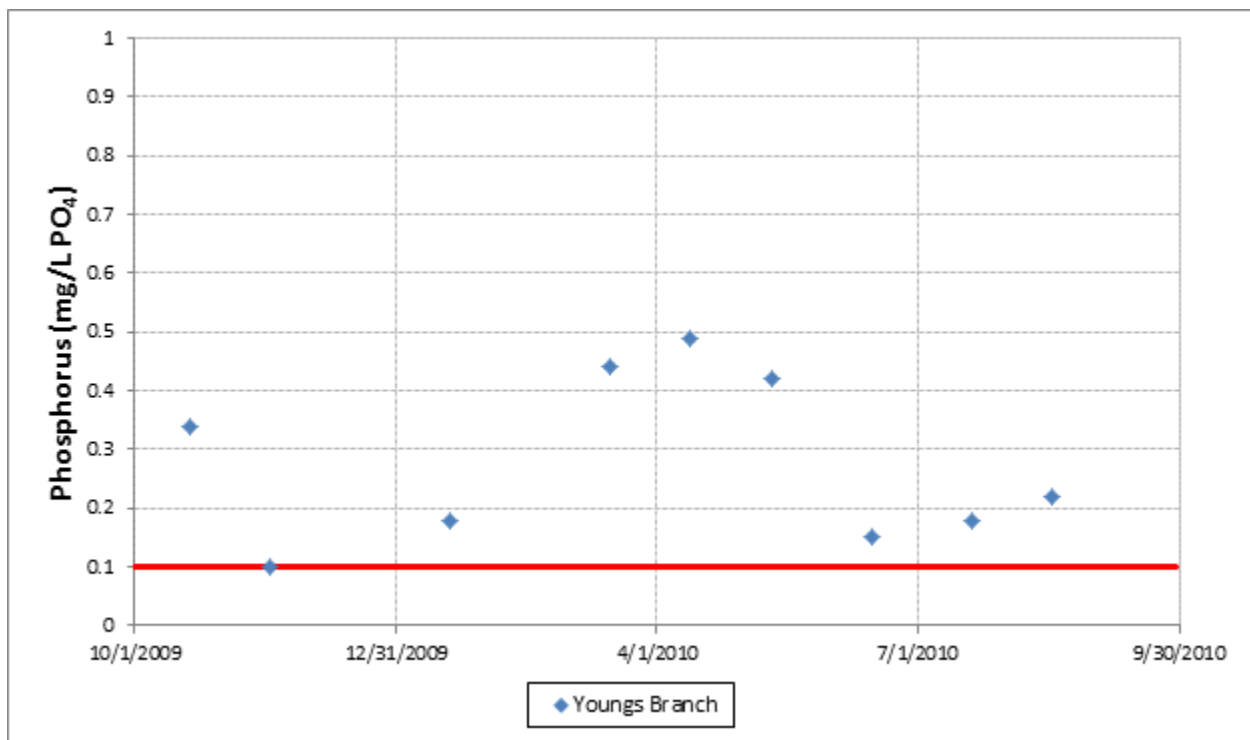


Figure 64: Phosphorus in MANA streams FY 2010

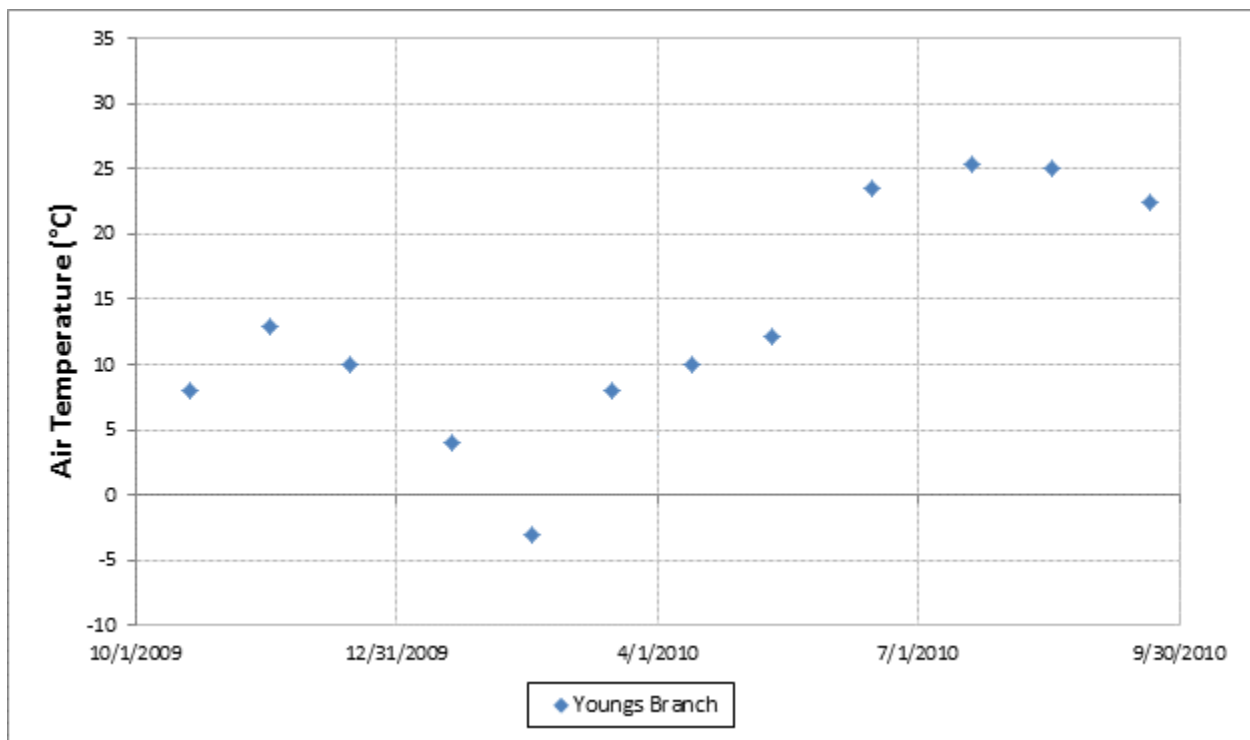


Figure 65: Air Temperature in MANA streams FY 2010

Water temperatures (Figure 66) always fell within the threshold range, and followed similarly to Air temperatures (Figure 65), suggesting that the streams are primarily surface-fed.

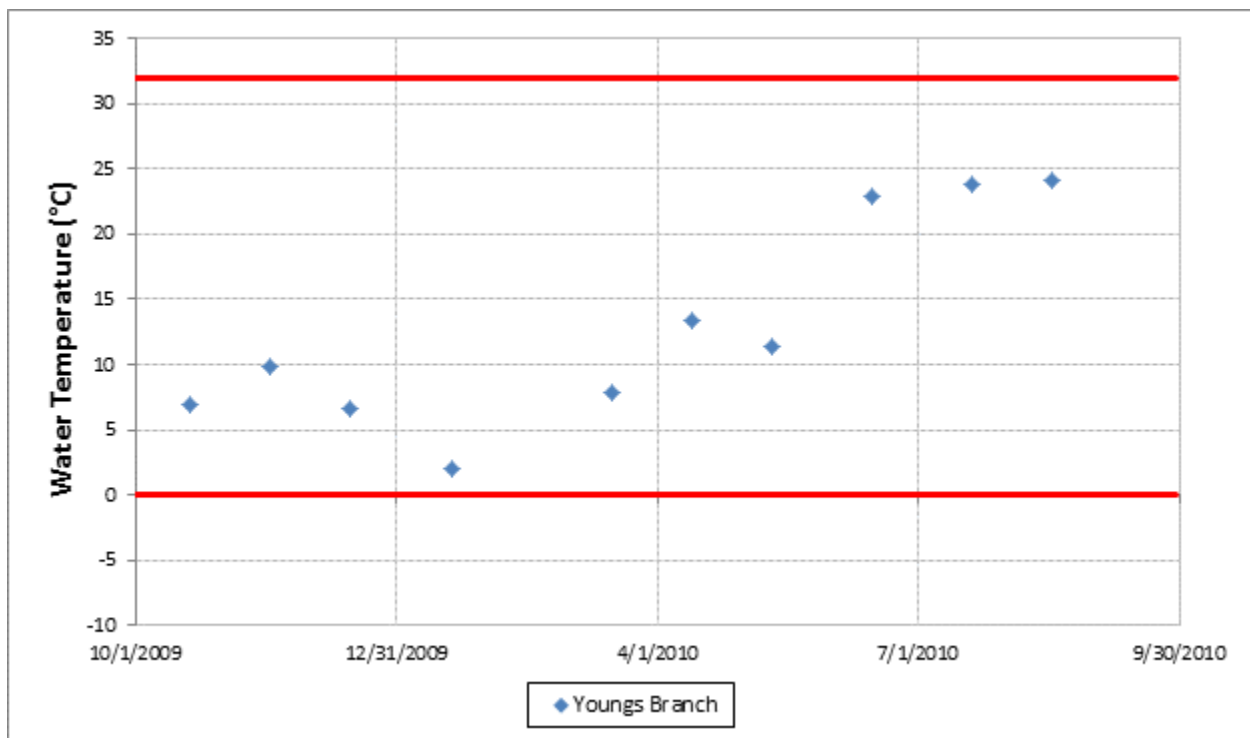


Figure 66: Water Temperature in MANA streams FY 2010

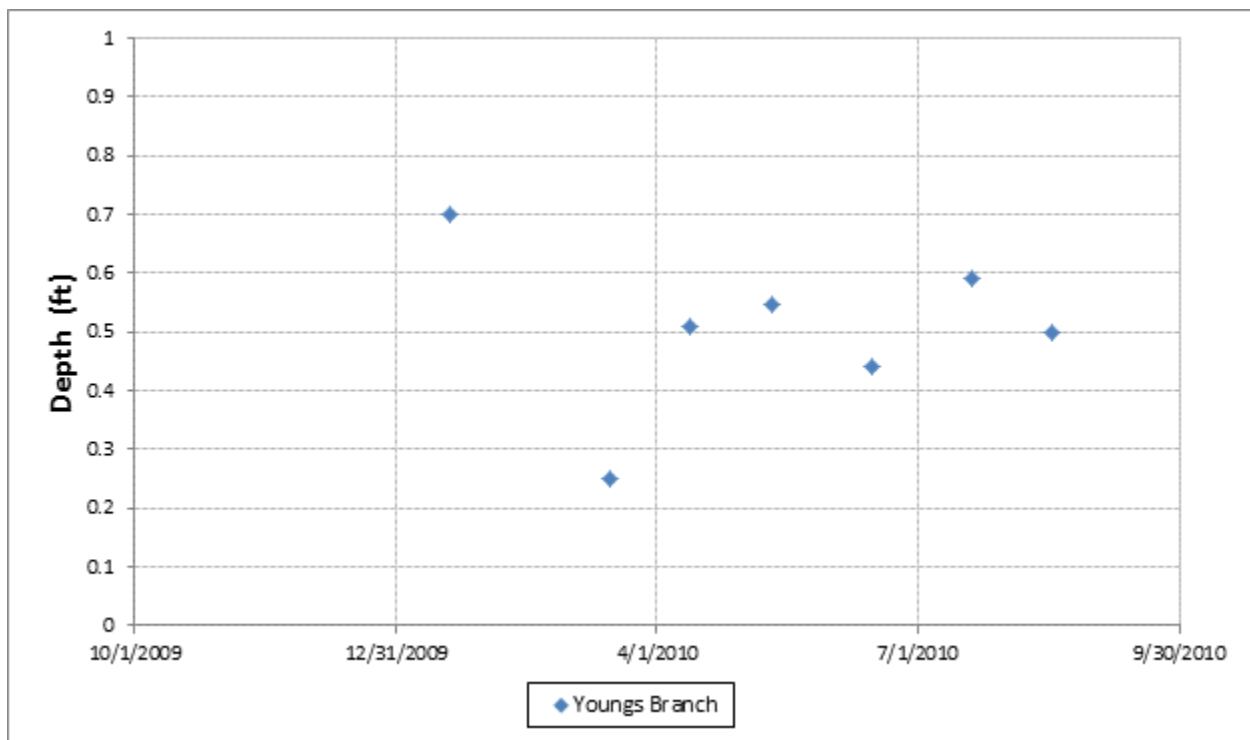


Figure 67: Stream depth in MANA streams FY 2010

Missing depth data points (Figure 67) from October through December are due to equipment failure.

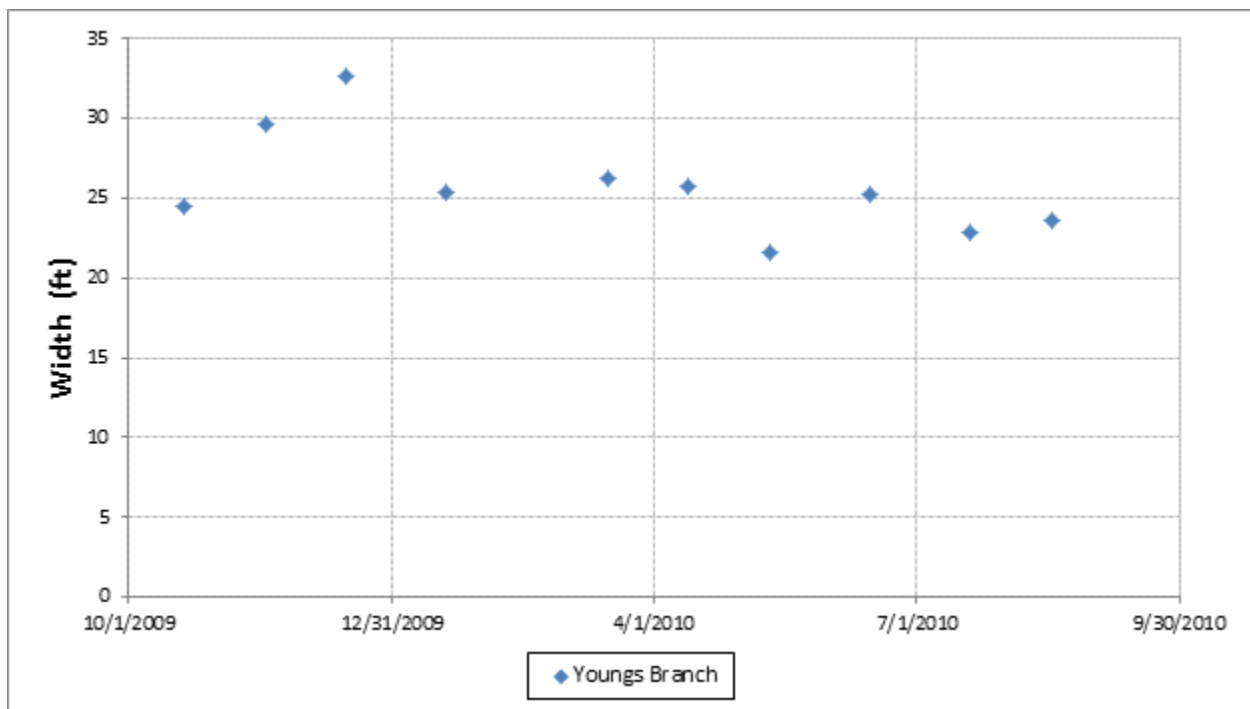


Figure 68: Stream width in MANA streams FY 2010

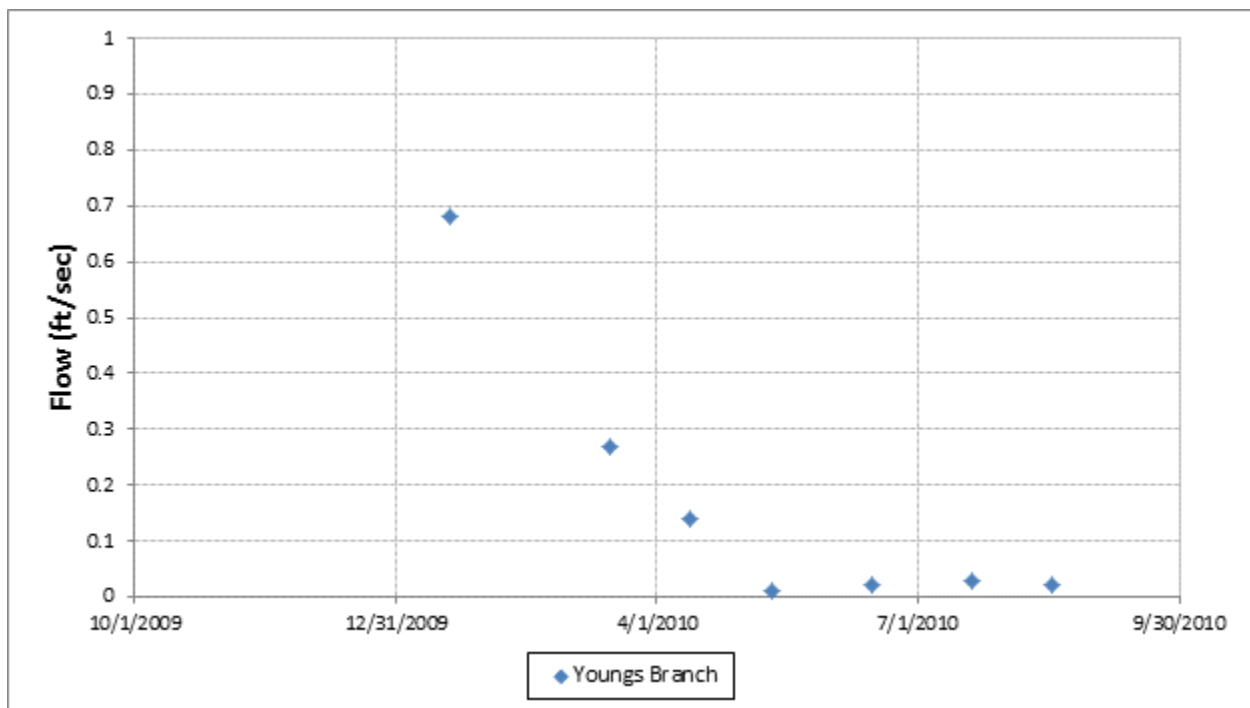


Figure 69: Stream flow in MANA streams FY 2010

Missing flow data points (Figure 69) and missing discharge data points (Figure 70) from October through December are due to equipment failure.

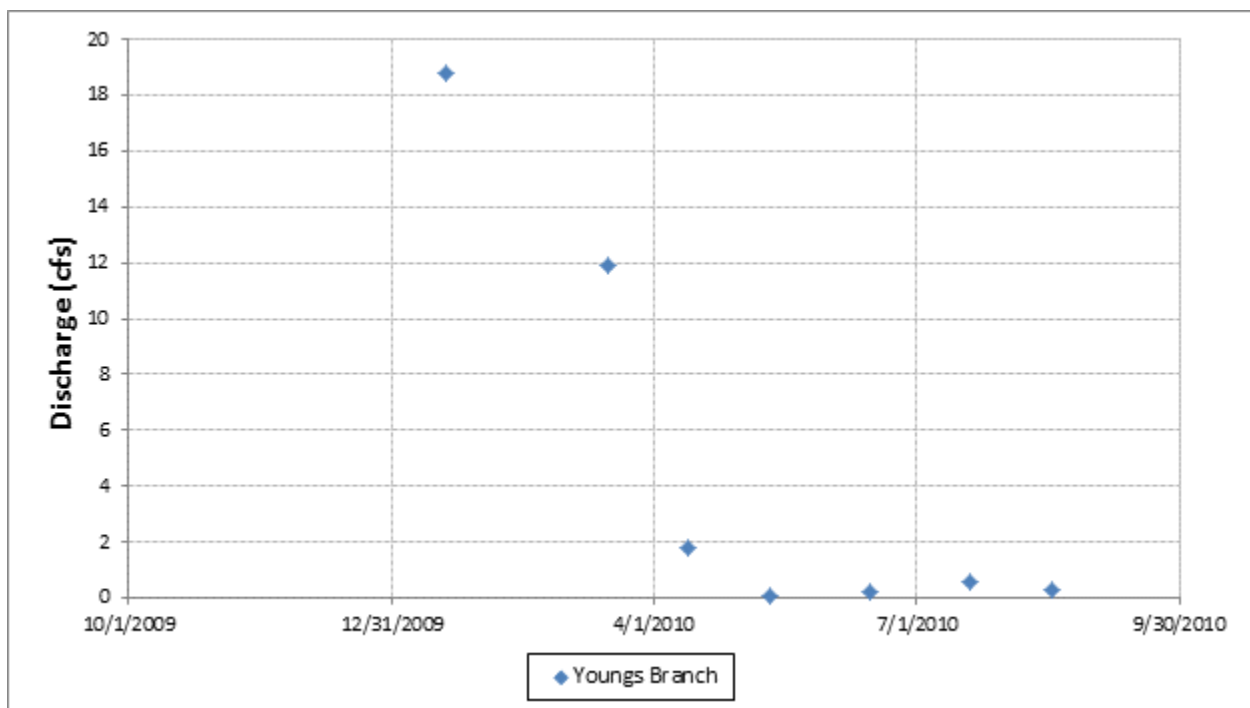


Figure 70: Stream discharge in MANA streams FY 2010

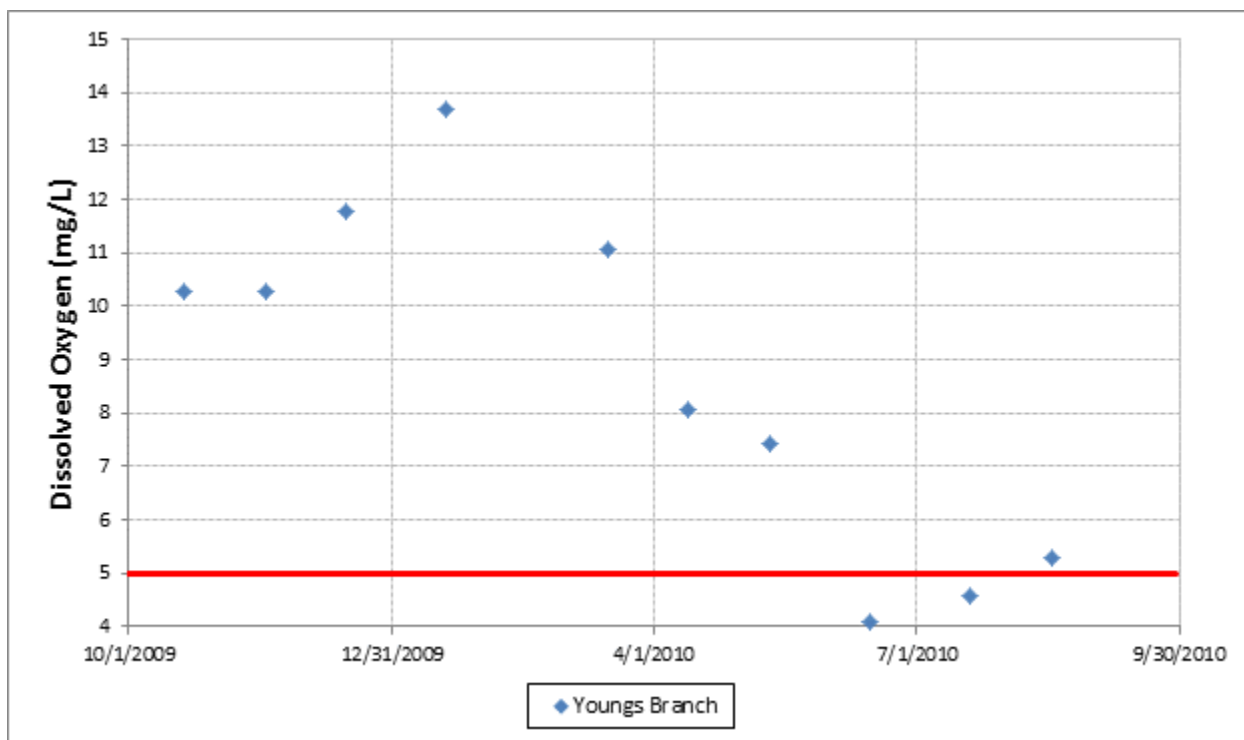


Figure 71: Dissolved Oxygen in MANA streams FY 2010

Dissolved oxygen (Figure 71) was typically above the threshold, except for 2 instances during summer of 2010. This is likely caused by the stagnation of water due to low flows.

Monocacy National Battlefield (MONO)

Monocacy National Battlefield is located near the town of Urbana in Frederick County, Maryland along the eastern side of the Frederick Valley within the Northern Piedmont physiographic province. The landscape of MONO consists of the broad Monocacy River valley bordered by ridges of resistant geology. The river is confined to the west side of the Frederick Valley and tends to flow along the west base of the resistant ridges. These ridges, like Brooks Hill, are underlain by plunging anticlines of hard rock. Uplift and erosion has produced “valley and ridge” topography, with linear ridges and intervening valleys. To the west of the battlefield, the landscape is a broad, open valley underlain by carbonate rocks that are susceptible to chemical erosion producing the local karst features (i.e., sinkholes and springs). To the east, the landscape is an elevated plateau underlain by fine-grained metamorphic rocks. Most of the battlefield is on the flat land which consists of terrace deposits overlying rocks of the Frederick Formation, just north of Interstate Highway 270 (Southworth and Denenny 2005). MONO is underlain by limestone bedrock which has developed karst topography. The karst topography affects water quality in the park.

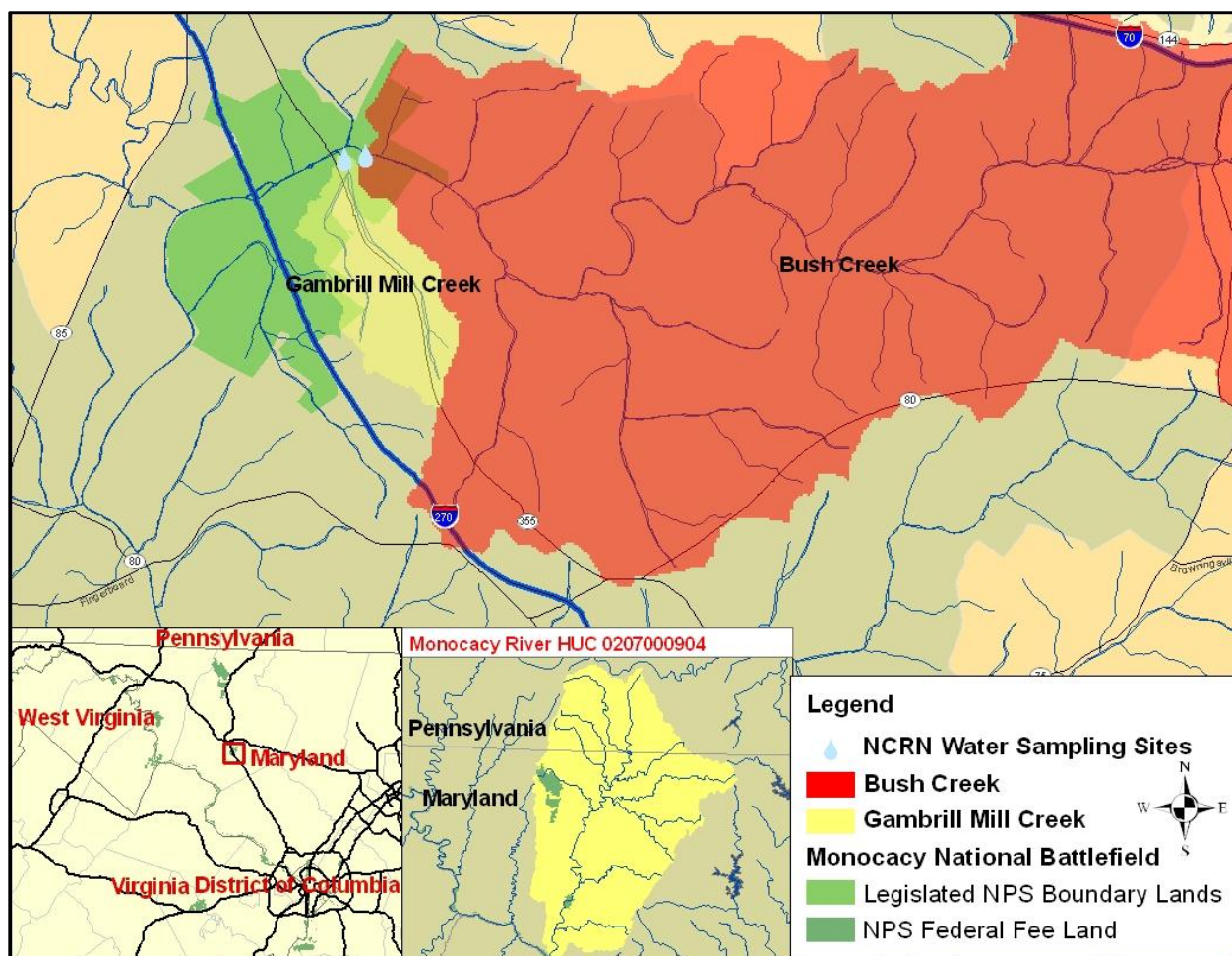


Figure 72: NCRN stream monitoring sites and associated watersheds within MONO

Streams in MONO are all part of the Lower Monocacy River drainage (Figure 72) that drains 194,700 acres before emptying into the Potomac River (Maryland Department of Natural Resources 2003). The Monocacy River is the largest tributary in Maryland of the Potomac River (Monocacy Scenic River Local Advisory Board 1990). The perennial streams in the park are Bush Creek and Thomas Farm Creek/Gambrill Mill Creek. Three ephemeral streams, Best Farm Creek, Harding's Run, and an unnamed drainage also feed into the river. The Monocacy River flows directly through and along the boundary of the national battlefield for approximately 2.5 miles. Approximately 0.8 miles of Bush Creek passes through the north central part of the national battlefield. Bush Creek, the largest tributary in the park is a "moderately narrow, rapidly flowing creek with a cobble/gravel bottom with scoured sections of banks and cobble beds from periodic high flows" (Motivans 1995). As the creek nears its confluence with the river, the stream channel becomes incised and much of the stream bank is undercut.

Agriculture is the dominant land use within the Bush Creek watershed with approximately a third of the watershed still forested. Given the long history of human habitation and agricultural land use in the region, streams are far from pristine; however, much of lower Bush Creek and its tributaries appear to be in reasonably good condition at present.

This report discusses data collected October 2009 through September 2010 in Bush Creek and Gambrill Mill Run. Summary statistics for the time period in two streams are presented in Table 11. Two sites were monitored on a monthly basis for dissolved oxygen, pH, specific conductance, temperature, acid neutralizing capacity, nitrate, total phosphorus, depth, wetted width, flow, and discharge.

Much of the park is maintained as agriculture to replicate the historical Civil War landscape. The agriculture lease agreements allow for fertilizer and pesticide applications and some fields are leased for livestock grazing. These are probably among the sources of the nitrate and phosphorus. Other sources include acid rain and atmospheric deposition as well as background levels in groundwater.

Table 11: FY 2010 Summary statistics for the vital signs collected at MONO

Parameter (Units)	Minimum	Maximum	Mean	Median	Standard Deviation
Air Temperature (°C)	-4	25.1	12.6	15	9.8
Water Temperature (°C)	0.1	22.4	13.1	14.9	6.6
ANC (µeq/L)	960	3816	1806	1600	801.5
pH	7.63	8.23	7.91	7.89	0.15
Salinity (ppt)	0.14	0.31	0.20	0.19	0.05
Specific conductance (µS/cm)	302.3	628	416.7	391.3	101.1
DO (mg/L)	6.9	14.7	10.5	9.5	2.7
Nitrate (mg/L)	2.3	10	4.6	4.1	1.9
Total Phosphorus (mg/L)	0.11	0.66	0.32	0.27	0.16
Discharge (cfs)	0.9	79.7	24.7	16.2	25.8
Flow (ft/sec)	0.27	1.58	0.87	0.71	0.49
Water Depth (ft)	0.21	0.96	0.49	0.41	0.24
Wetted Width (ft)	0	36.5	18.6	11.8	13.2

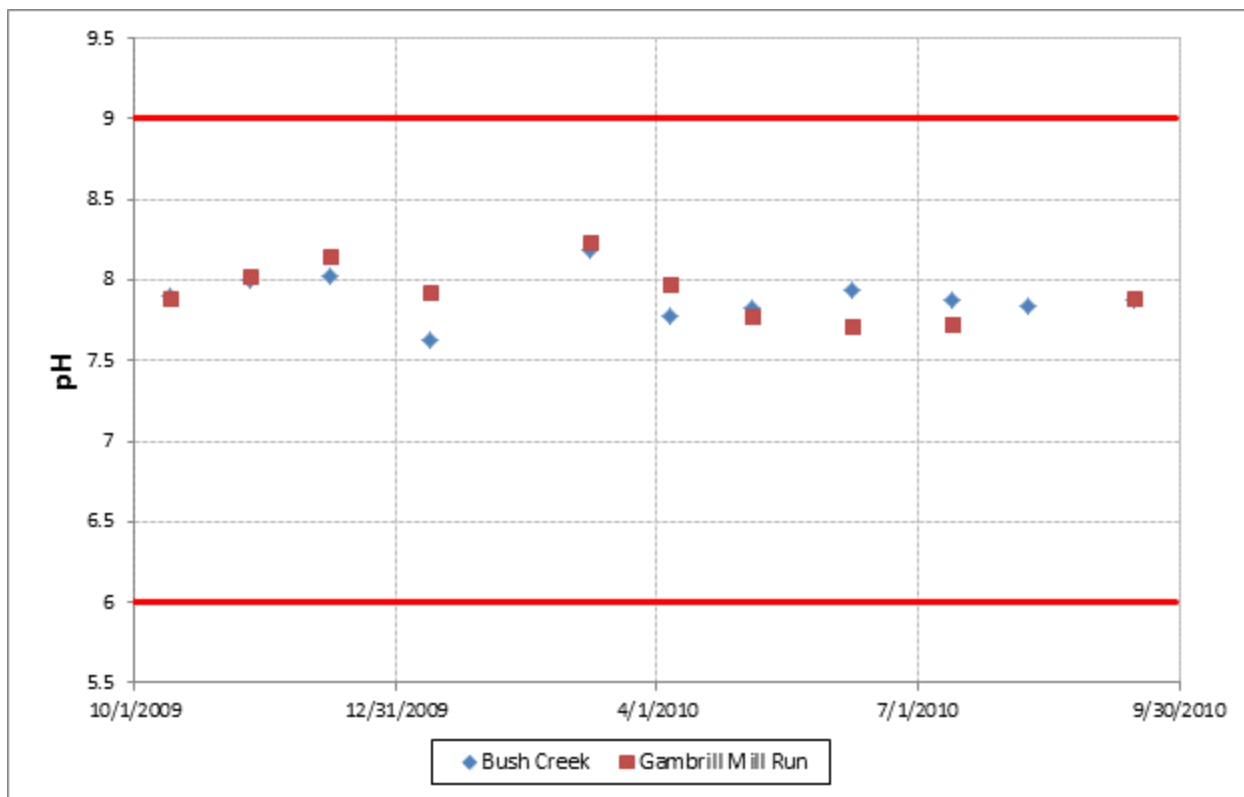


Figure 73: pH in MONO streams FY 2010

Both pH (Figure 73) and acid neutralizing capacity (Figure 74) met threshold expectations.

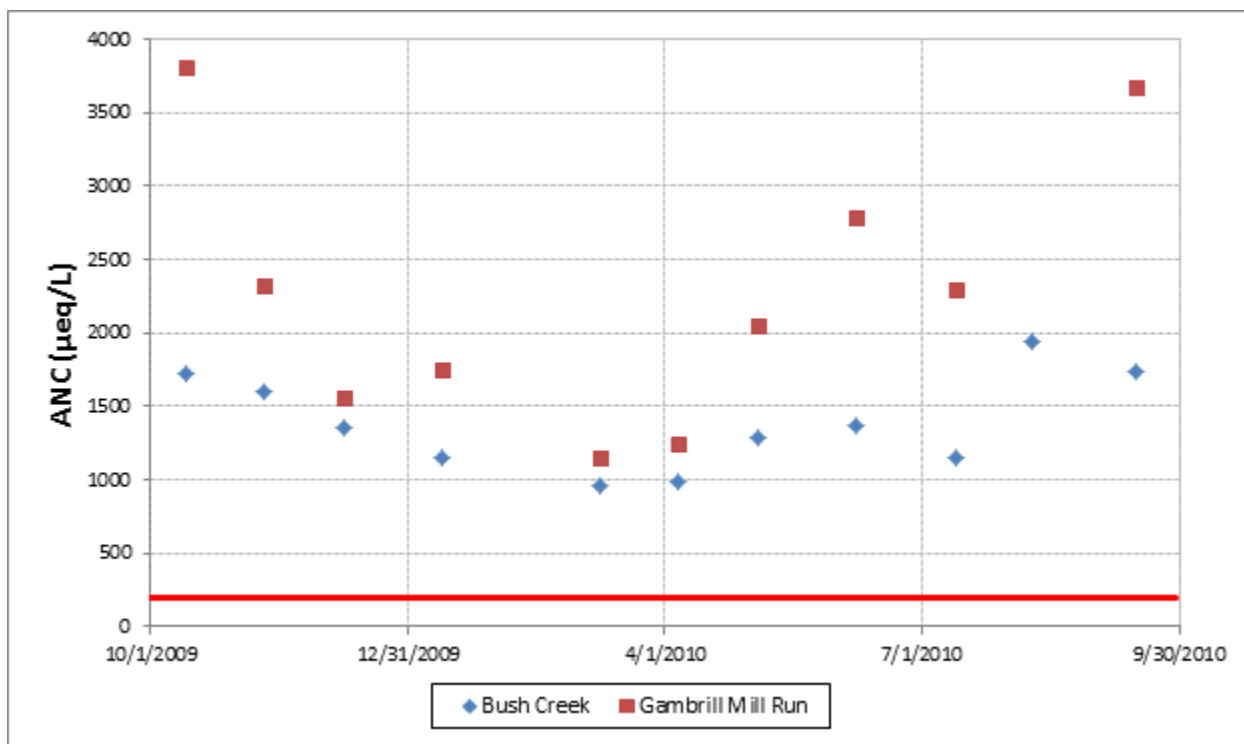


Figure 74: Acid Neutralizing Capacity in MONO streams FY 2010

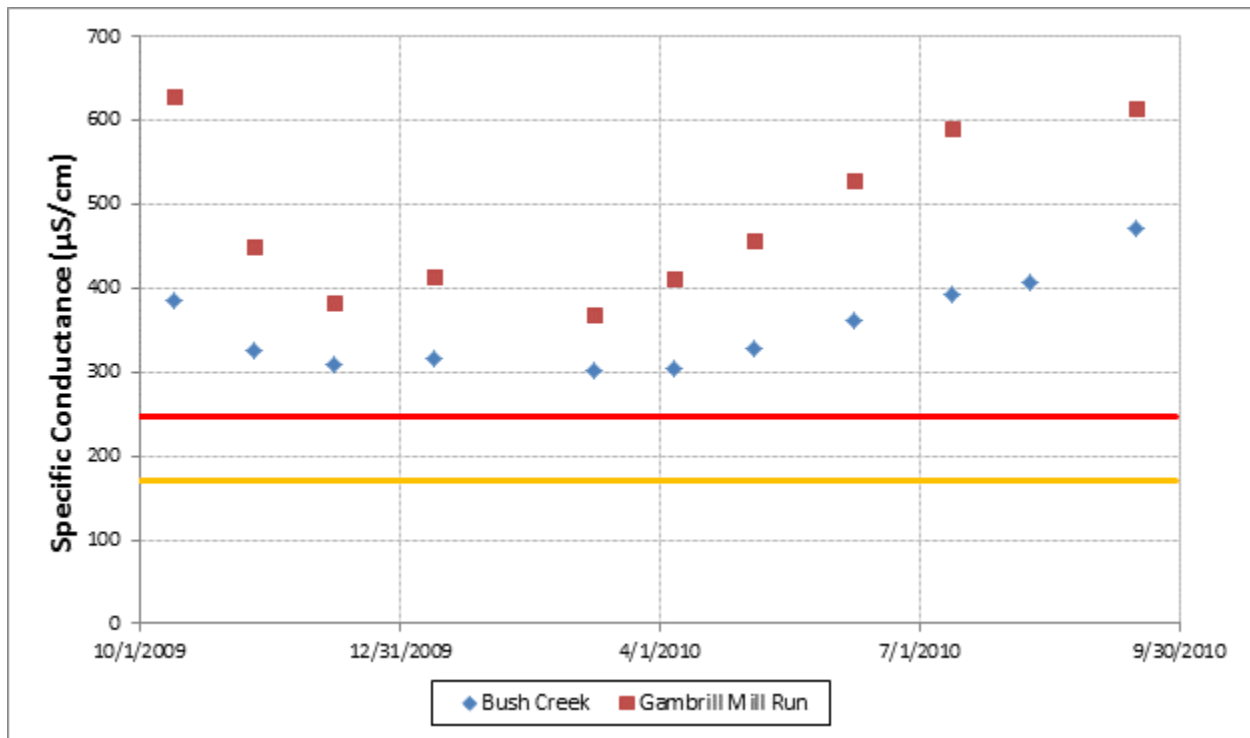


Figure 75: Specific Conductance in MONO streams FY 2010

Specific conductance (Figure 75) exceeded ecological thresholds for aquatic life stress (orange = fish threshold; red = macroinvertebrate threshold). Salinity (Figure 76) remained below the threshold for fresh water.

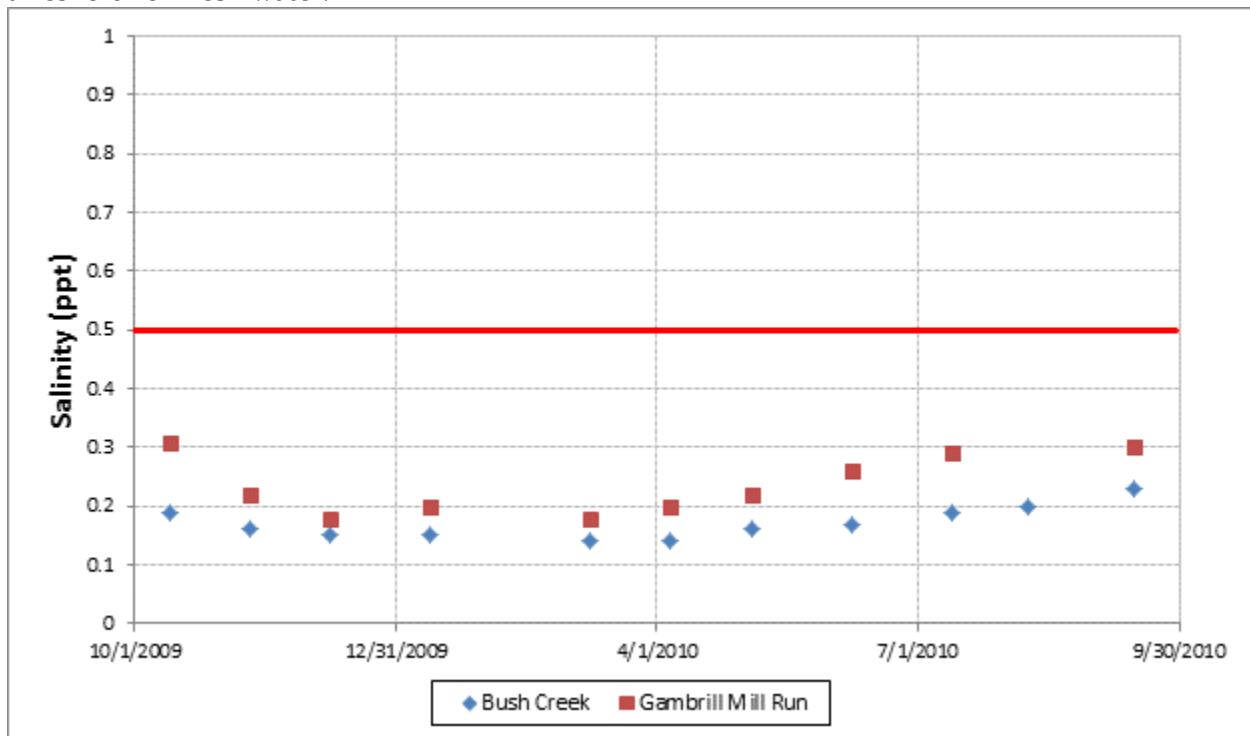


Figure 76: Salinity in MONO streams FY 2010

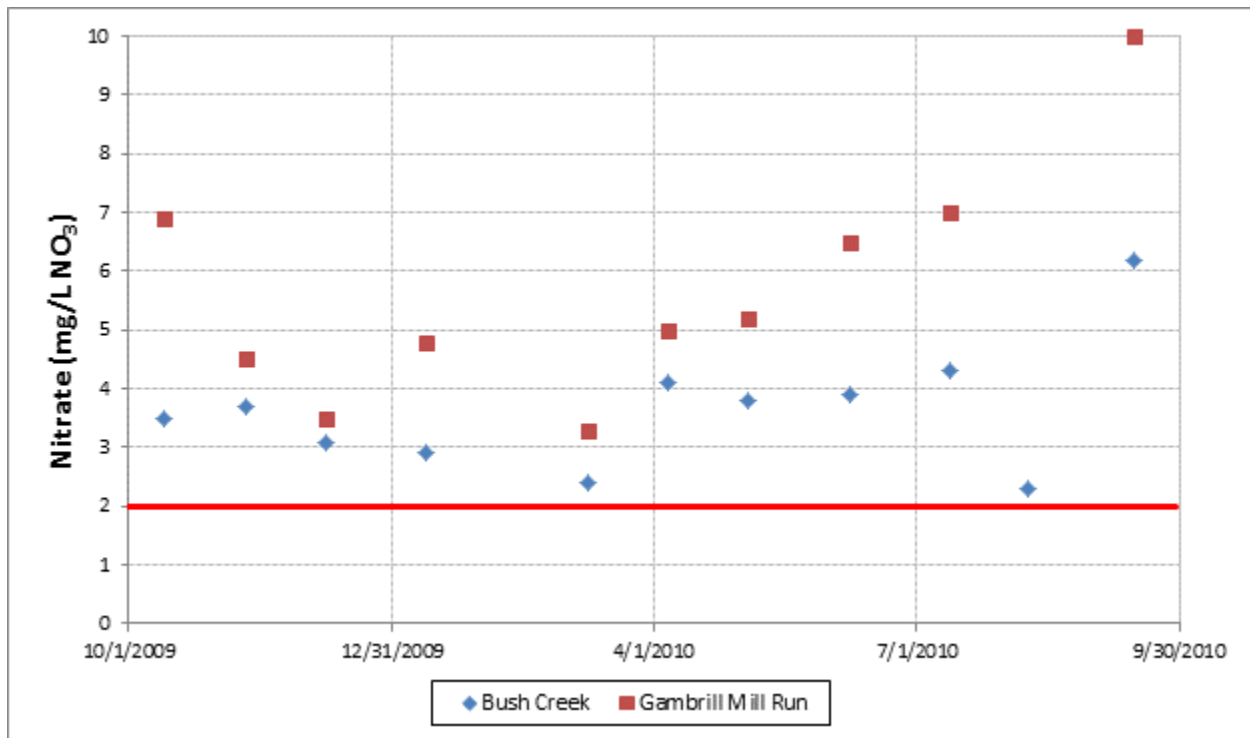


Figure 77: Nitrate in MONO streams FY 2010

Nitrate (Figure 77) and Phosphorus (Figure 78) levels consistently exceeded threshold limits, as well as, eutrophication values.

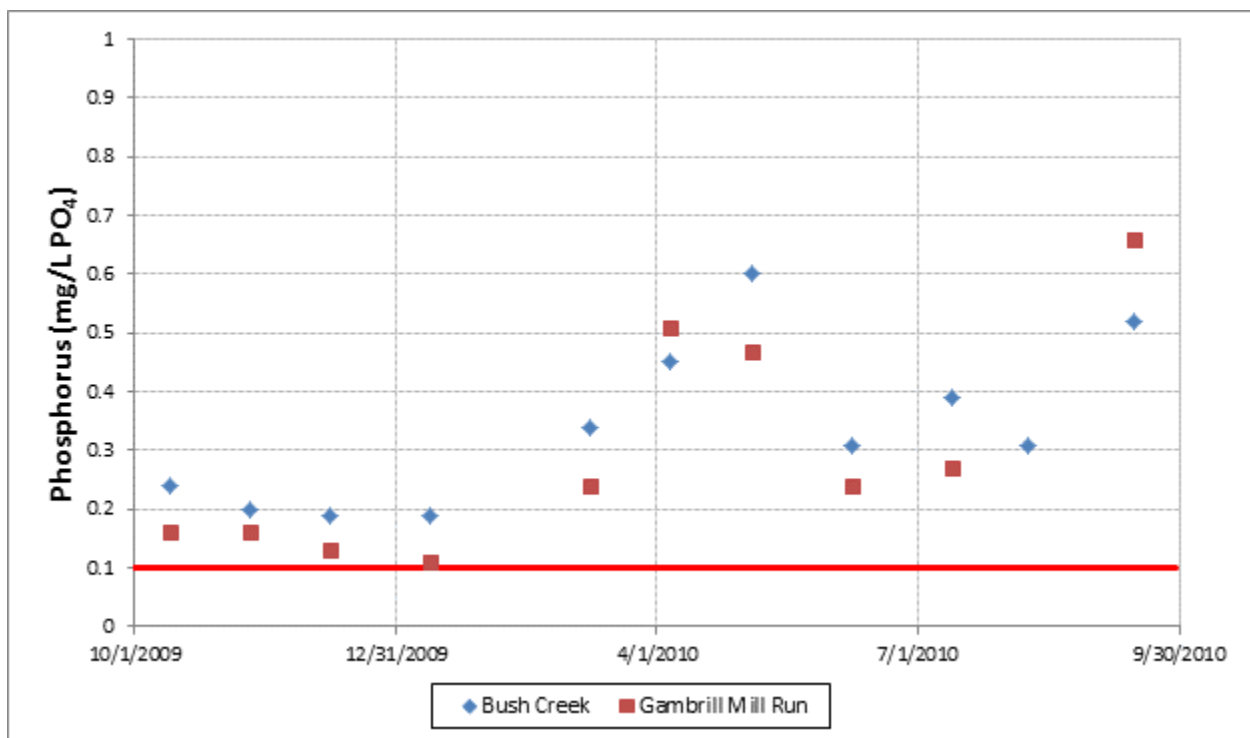


Figure 78: Phosphorus in MONO streams FY 2010

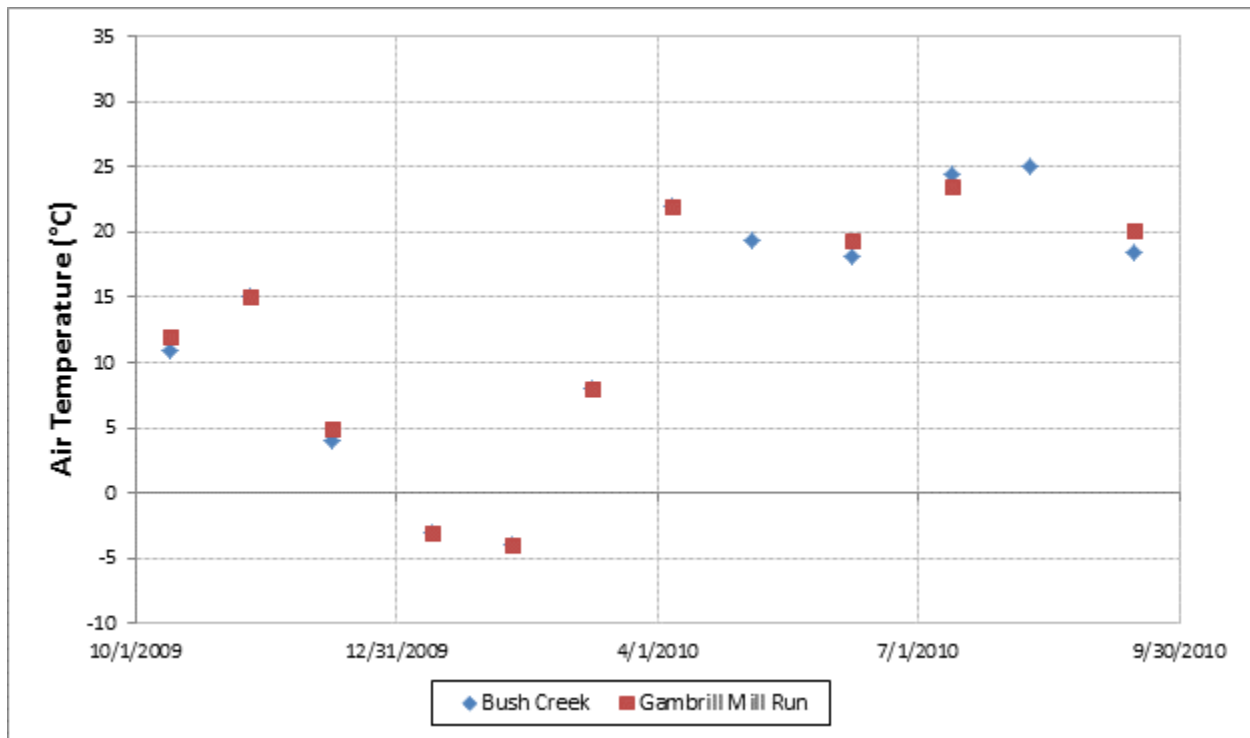


Figure 79: Air Temperature in MONO streams FY 2010

Water temperatures (Figure 80) always fell within the threshold range, and followed similarly to Air temperatures (Figure 79), suggesting that the streams are primarily surface-fed.

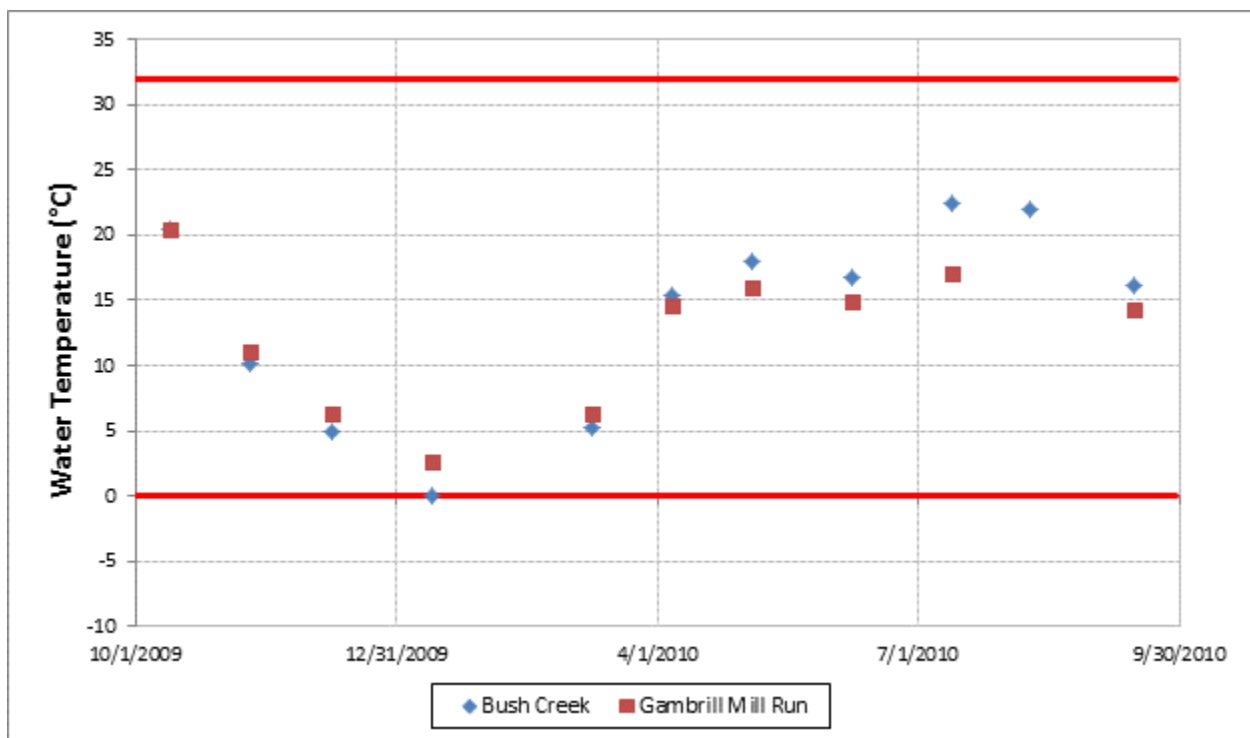


Figure 80: Water Temperature in MONO streams FY 2010

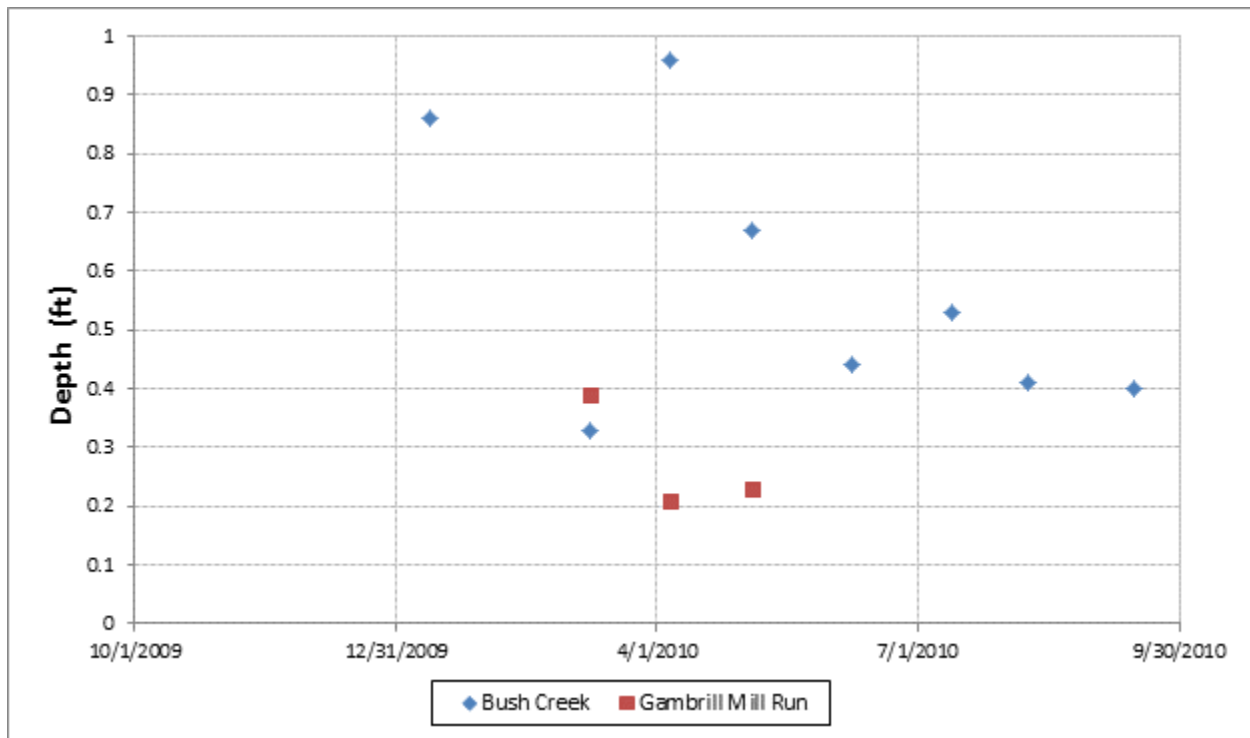


Figure 81: Stream depth in MONO streams FY 2010

Missing depth data points (Figure 81) from October through December are due to equipment failure.

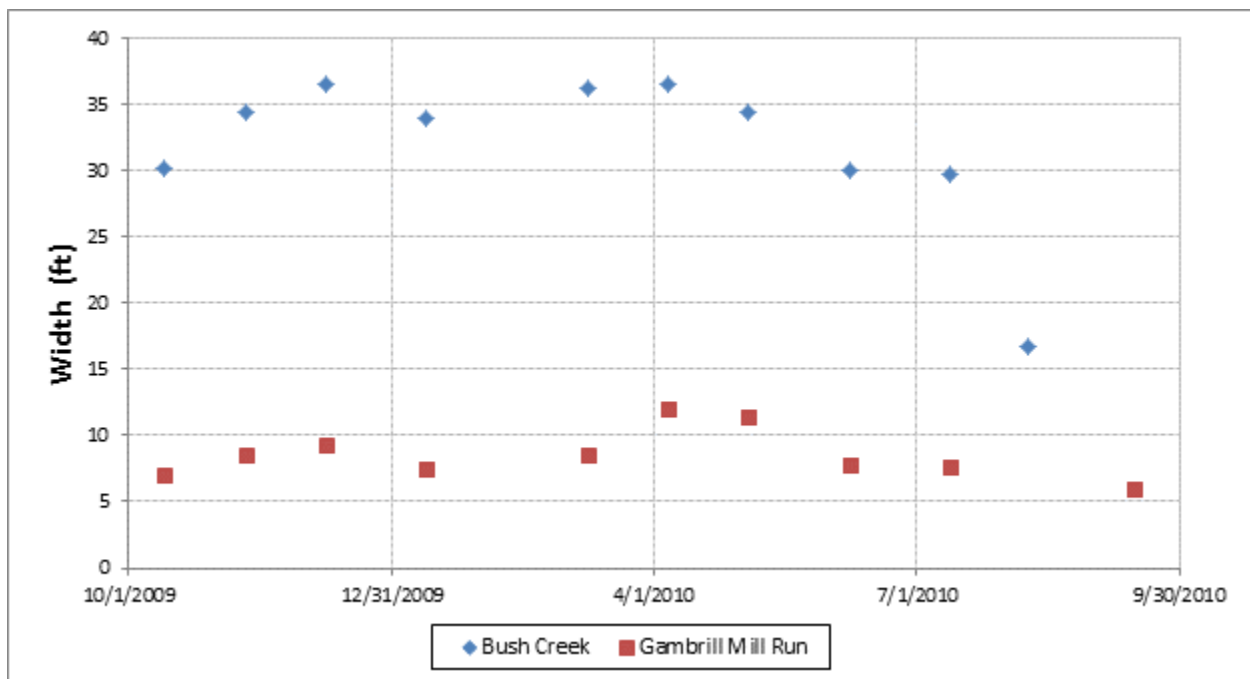


Figure 82: Stream width in MONO streams FY 2010

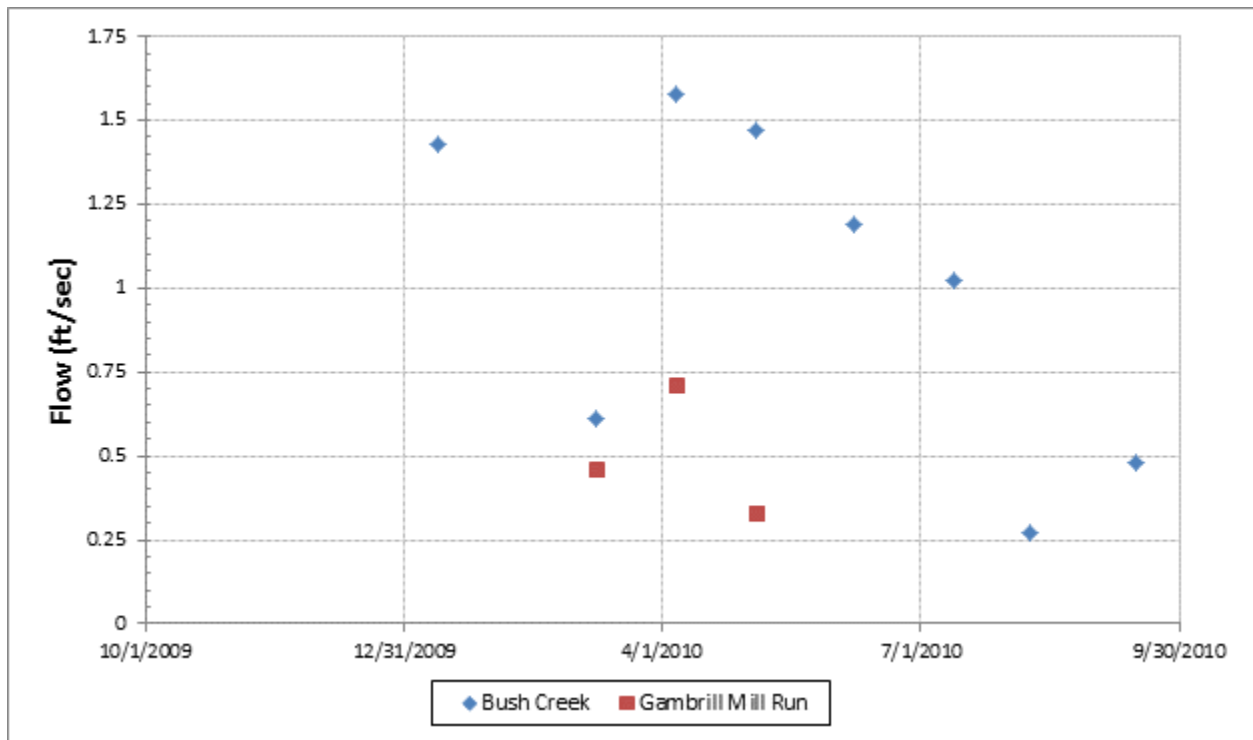


Figure 83: Stream flow in MONO streams FY 2010

Missing flow data points (Figure 83) and missing discharge data points (Figure 84) from October through December are due to equipment failure.

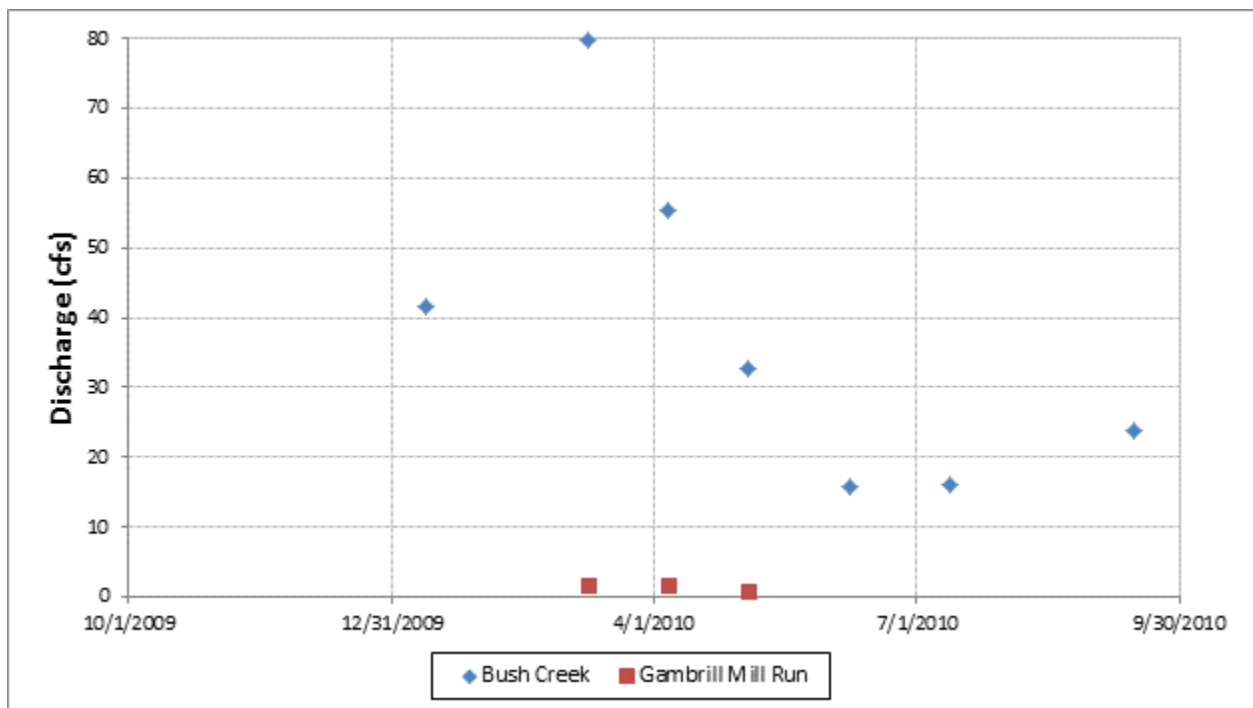


Figure 84: Stream discharge in MONO streams FY 2010

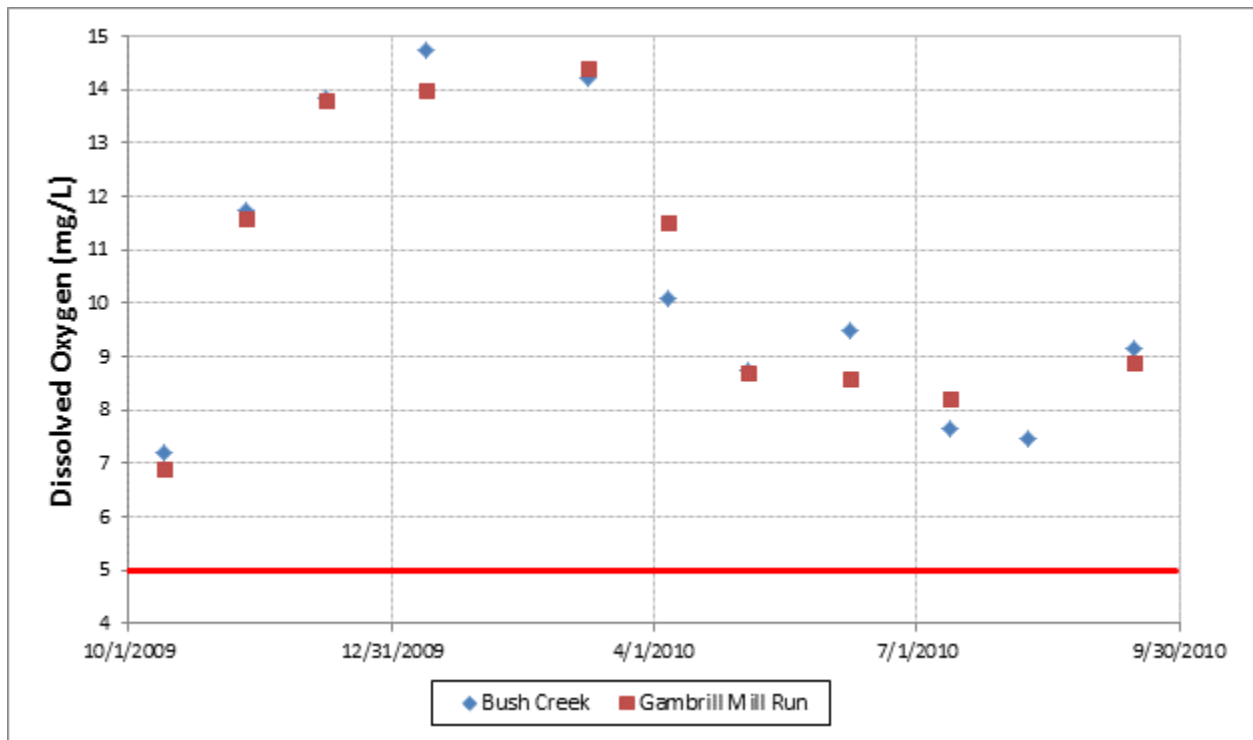


Figure 85: Dissolved Oxygen in MONO streams FY 2010

When measured, dissolved oxygen (Figure 85) is well above the threshold limit.

National Capital Parks-East includes 11 major park areas covering 4,378 ha within the District of Columbia and three nearby counties in Maryland. The park lies entirely within the upper Coastal Plain physiographic province and is managed for a variety of natural, cultural, and recreational resources. Most of the park units are within the Potomac River Watershed, with the exception of parts of Suitland Parkway and Baltimore and Washington Parkway which are in the Patuxent River watershed. All water monitoring sites are located in the Potomac River Watershed.



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Table 12: FY 2010 Summary statistics for the vital signs collected at NACE

Parameter (Units)	Minimum	Maximum	Mean	Median	Standard Deviation
Air Temperature (°C)	-2	40.1	15.5	15	10.5
Water Temperature (°C)	2	29.6	14.5	13.9	7.3
ANC (µeq/L)	604	1804	997.5	954	302.7
pH	7.11	8.65	7.62	7.48	0.40
Salinity (ppt)	0.07	0.38	0.19	0.19	0.07
Specific conductance (µS/cm)	143.8	788	392.1	399.4	141.8
DO (mg/L)	5.85	14	9.88	9.93	2.18
Nitrate (mg/L)	0.4	2.3	1.2	1.3	0.49
Total Phosphorus (mg/L)	0.11	0.65	0.25	0.22	0.11
Discharge (cfs)	0.2	12.3	2.73	1.85	2.87
Flow (ft/sec)	0.09	1.52	0.49	0.43	0.35
Water Depth (ft)	0.08	0.5	0.35	0.38	0.10
Wetted Width (ft)	0	39.3	13.5	14.5	8.36

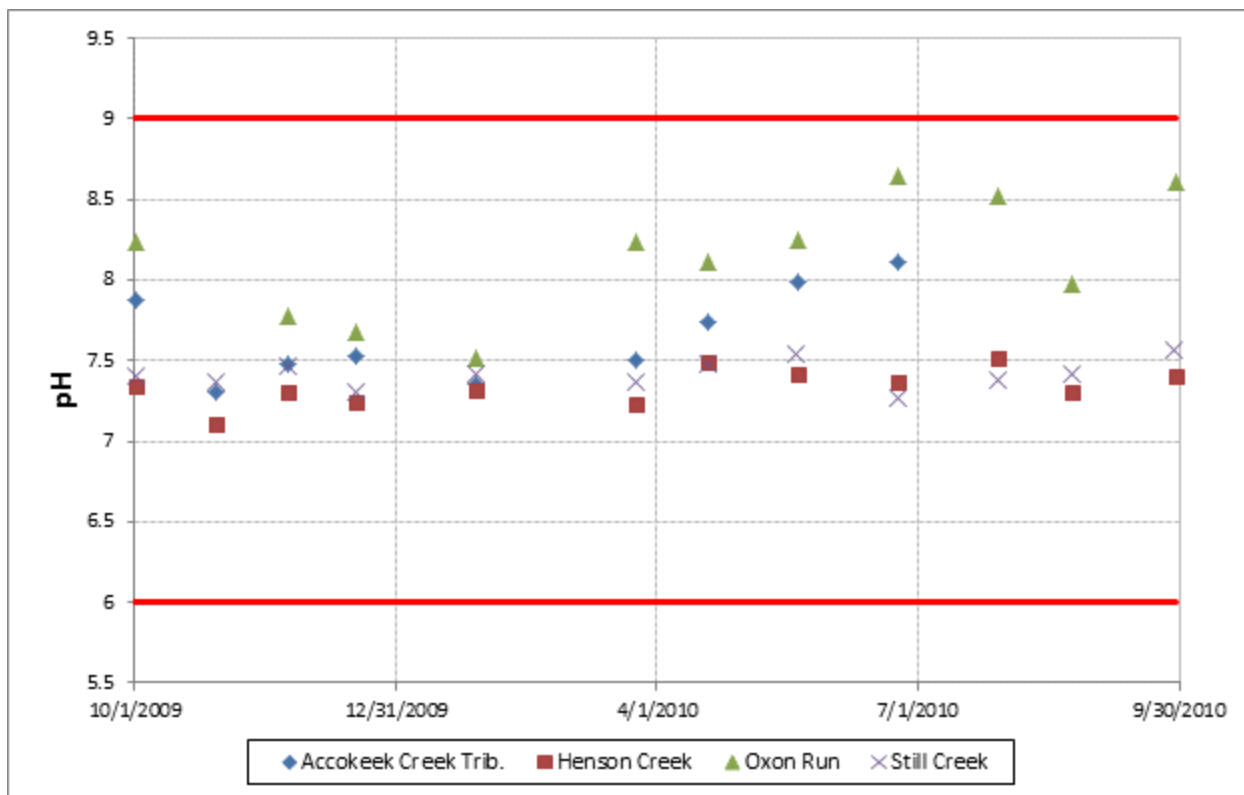


Figure 87: pH in NACE streams FY 2010

Both pH (Figure 87) and acid neutralizing capacity (Figure 88) were in the acceptable range.

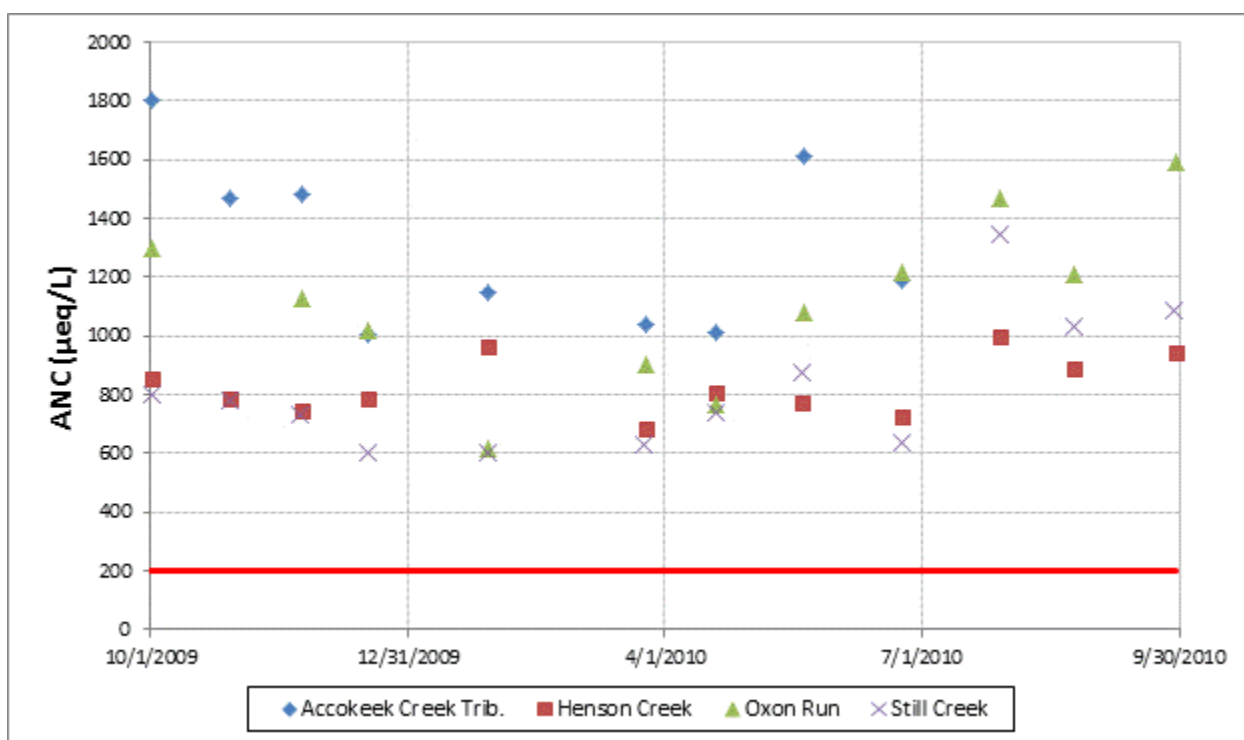


Figure 88: Acid Neutralizing Capacity in NACE streams FY 2010

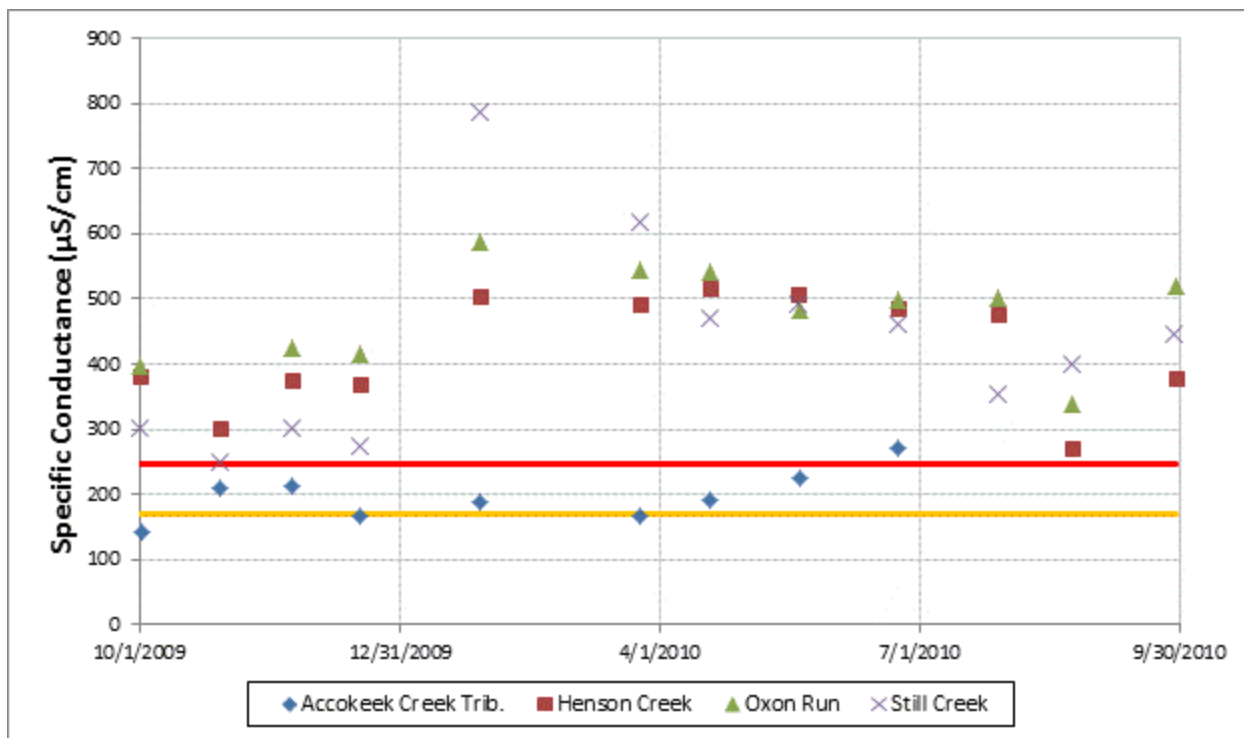


Figure 89: Specific Conductance in NACE streams FY 2010

Specific conductance (Figure 89) exceeded ecological thresholds for aquatic life stress (orange = fish threshold; red = macroinvertebrate threshold) at all sites except the tributary to Accokeek Creek, which fell between the thresholds. Salinity (Figure 90) was consistently within the acceptable range for fresh water.

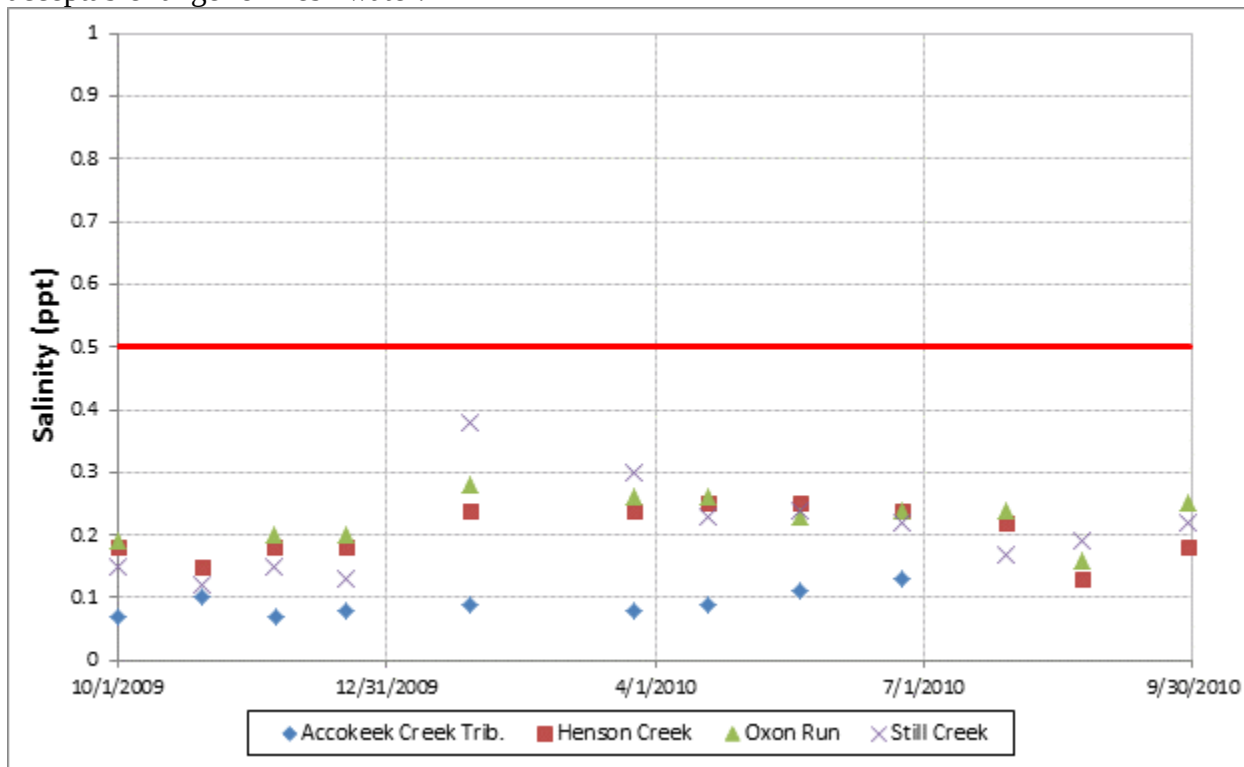


Figure 90: Salinity in NACE streams FY 2010

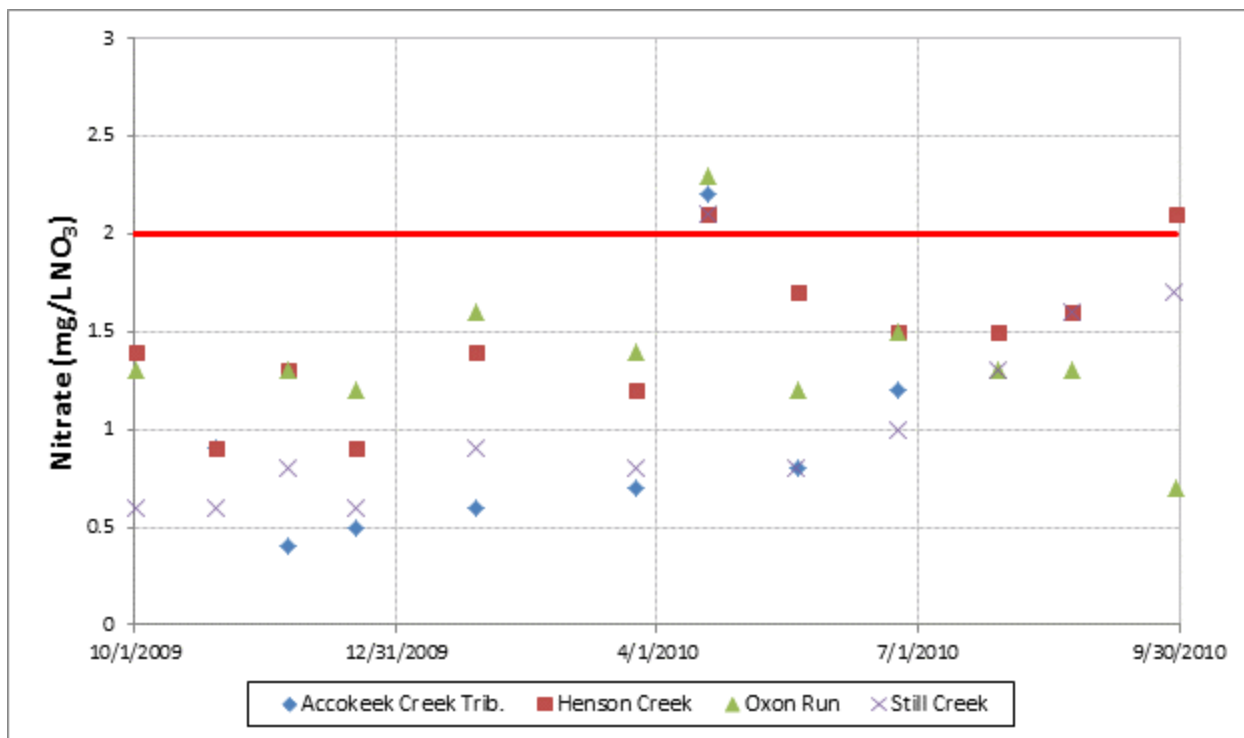


Figure 91: Nitrate in NACE streams FY 2010

Nitrate levels (Figure 91) were consistently within the acceptable range, with a handful of exceedances. Phosphorus levels (Figure 92) regularly exceeded the threshold value.

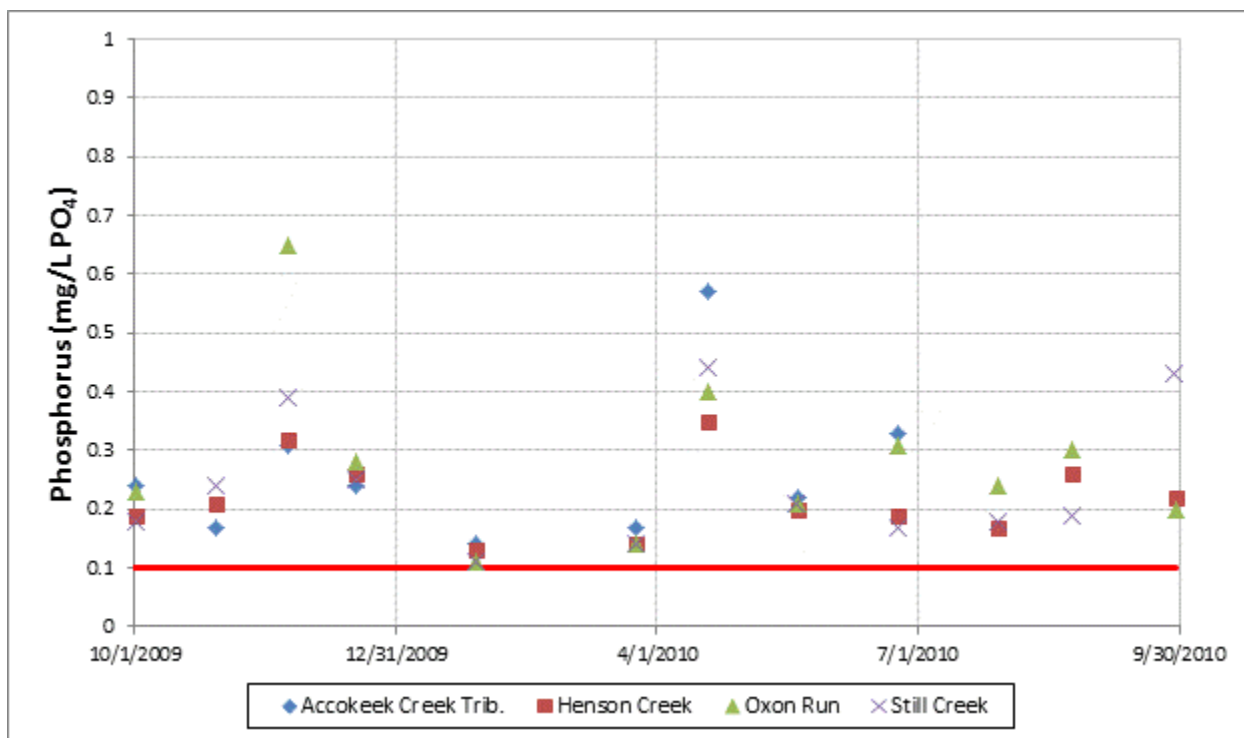


Figure 92: Phosphorus in NACE streams FY 2010

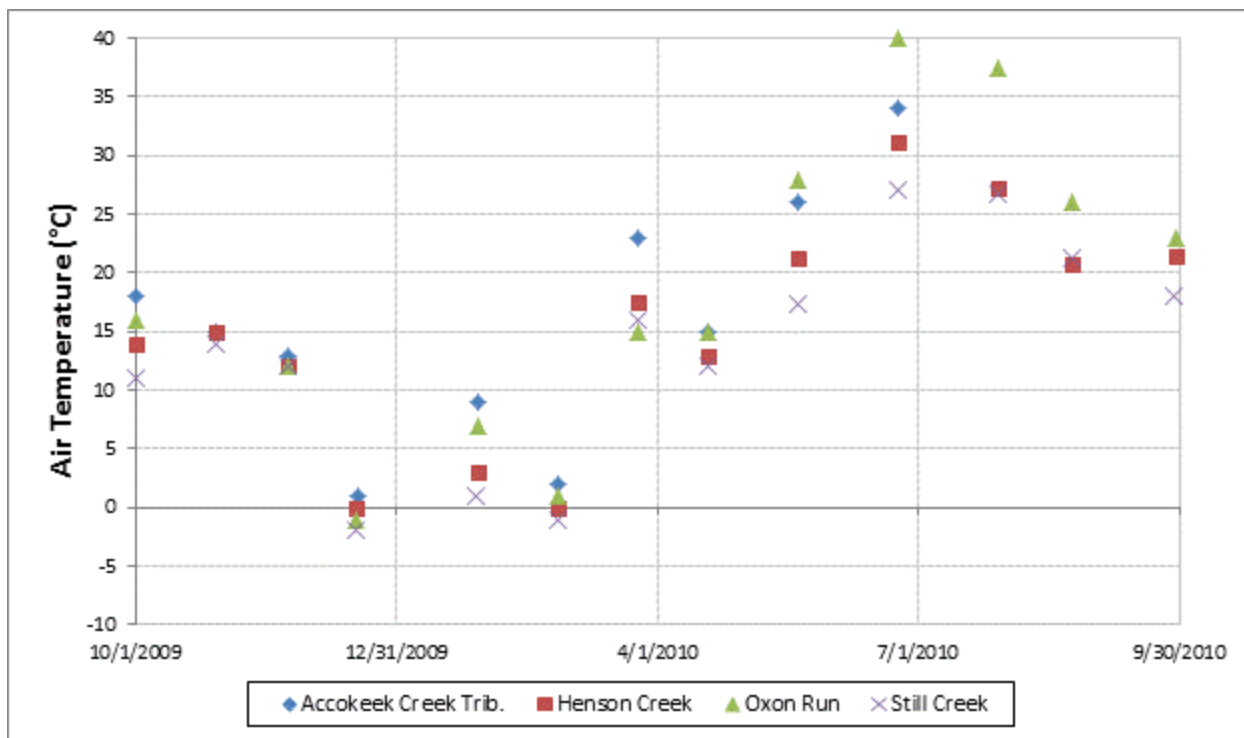


Figure 93: Air Temperature in NACE streams FY 2010

Water temperatures (Figure 94) always fell within the acceptable range, and followed air temperatures (Figure 93), suggesting that the streams are primarily surface-fed.



Figure 94: Water Temperature in NACE streams FY 2010

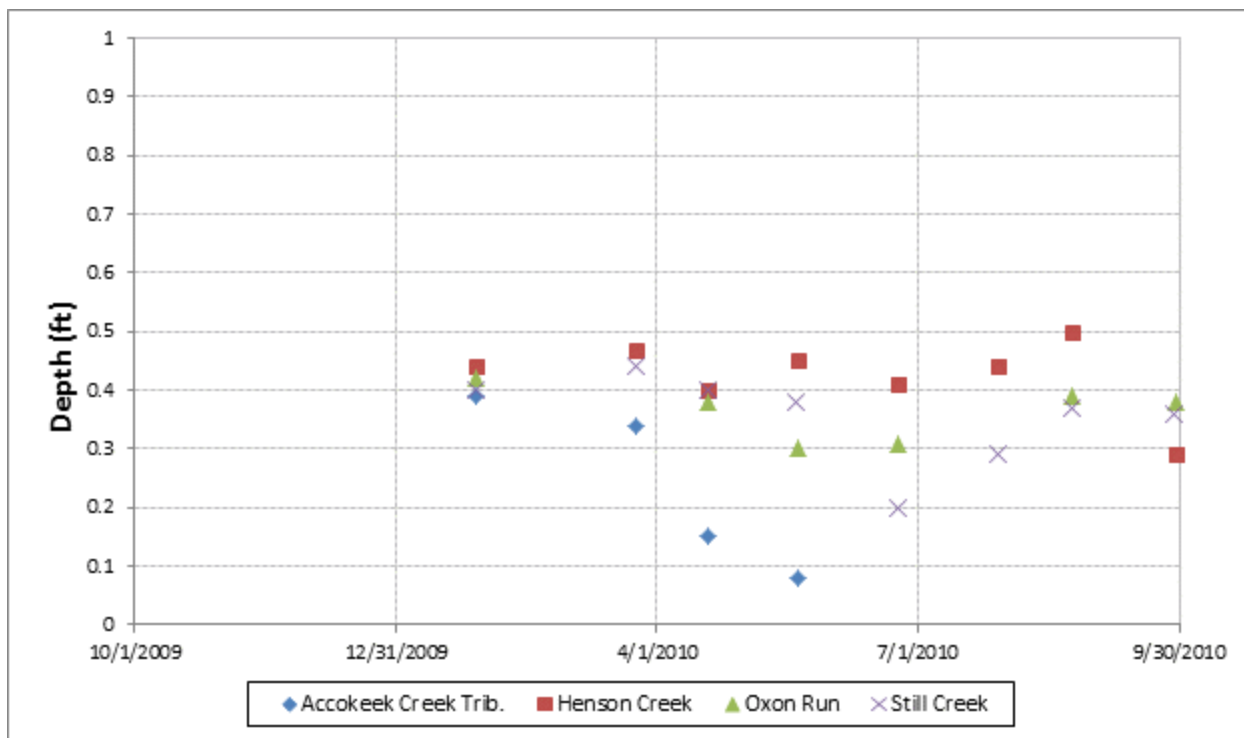


Figure 95: Stream depth in NACE streams FY 2010

Missing depth data points (Figure 95) from October through December are due to equipment failure.

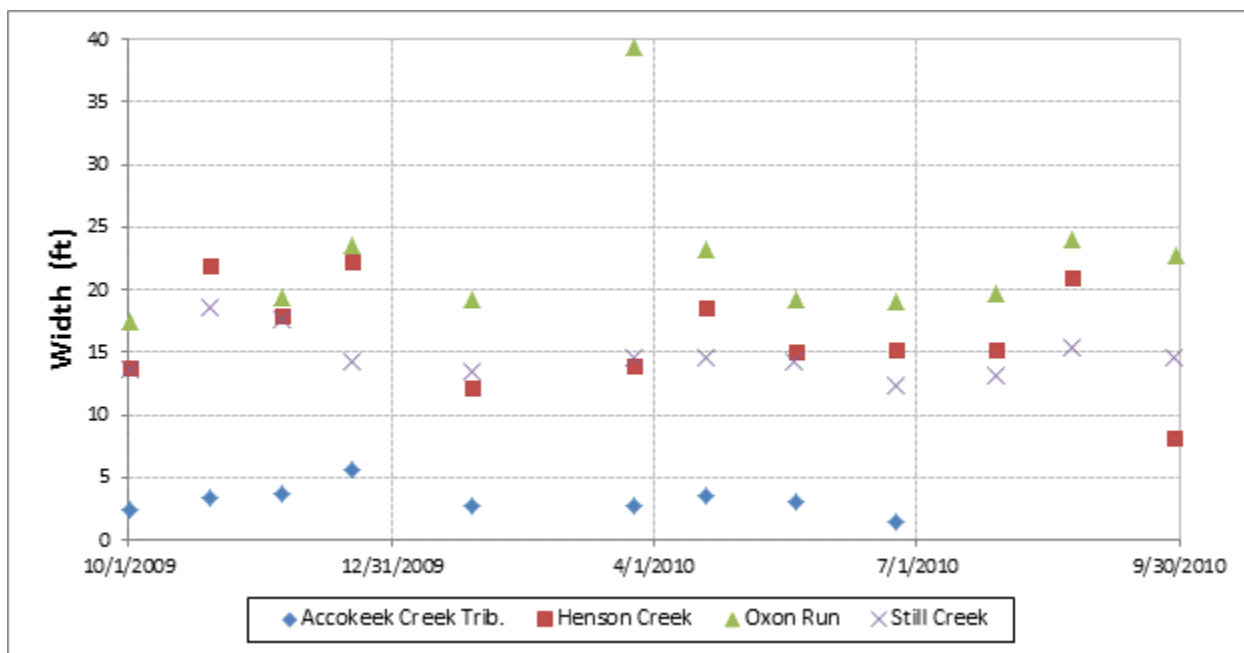


Figure 96: Stream width in NACE streams FY 2010

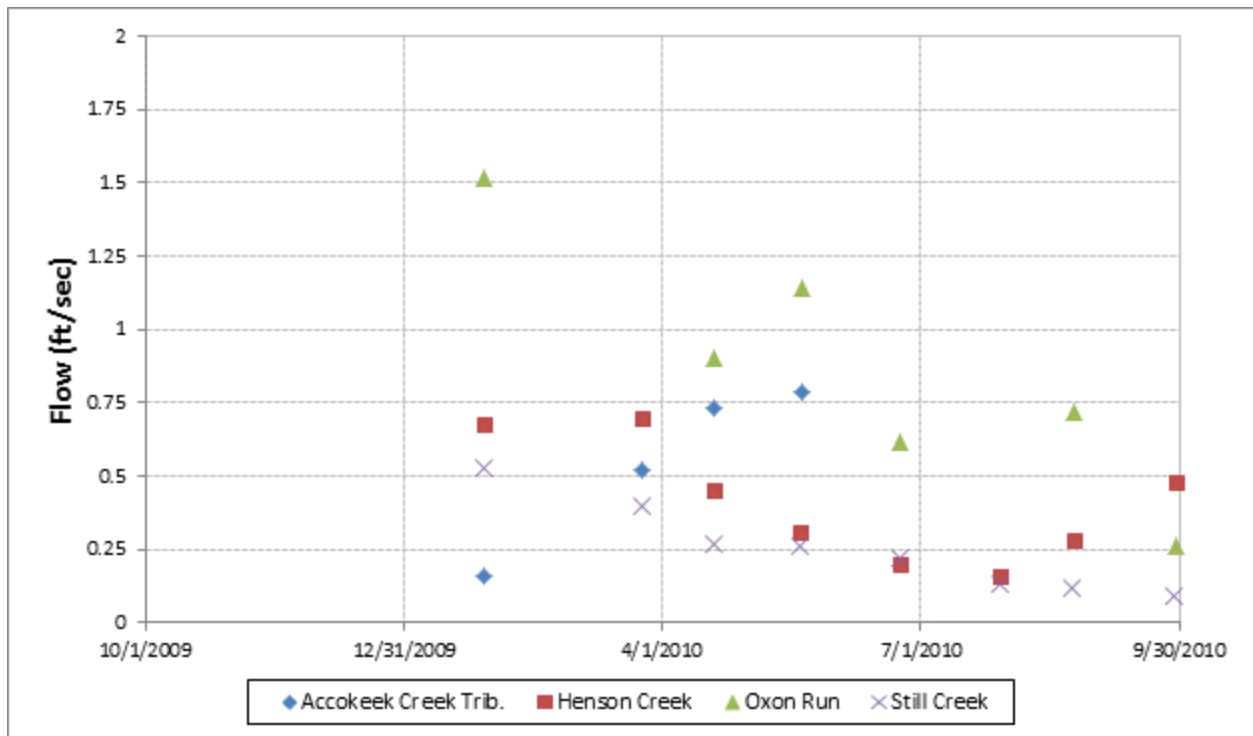


Figure 97: Stream flow in NACE streams FY 2010

Missing flow data points (Figure 97) and missing discharge data points (Figure 98) from October through December are due to equipment failure.

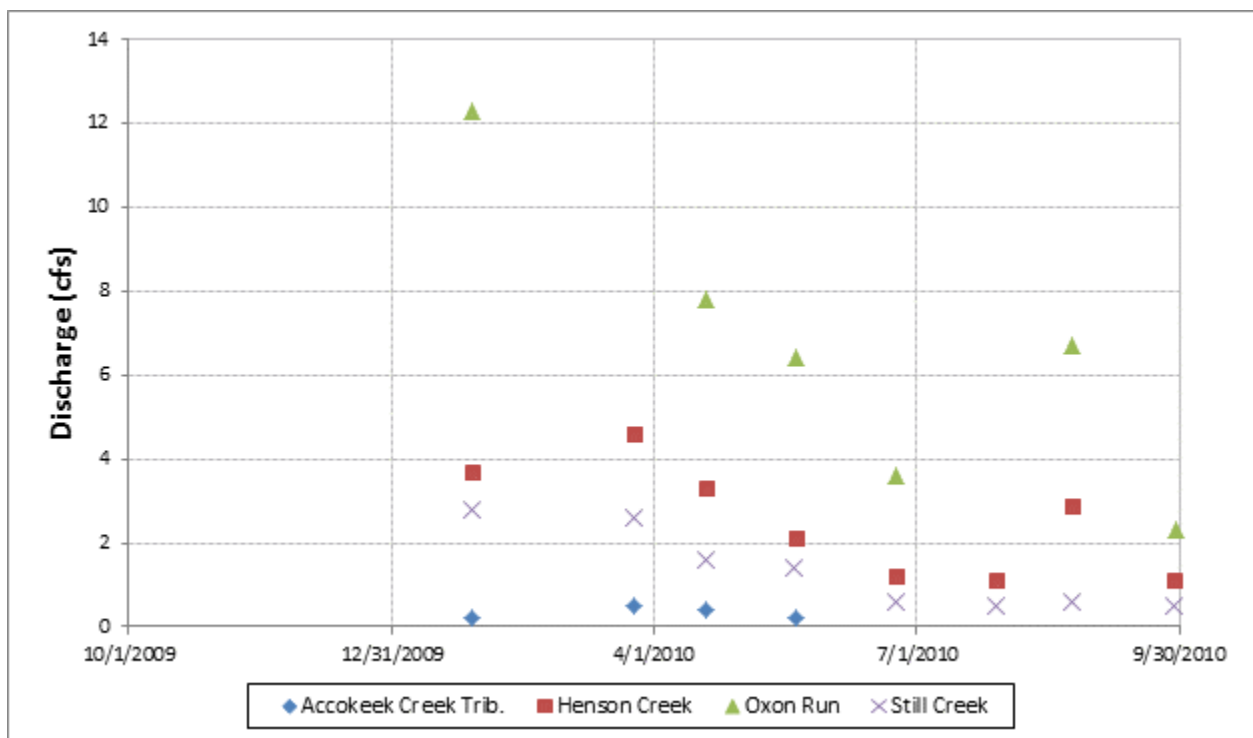


Figure 98: Stream discharge in NACE streams FY 2010

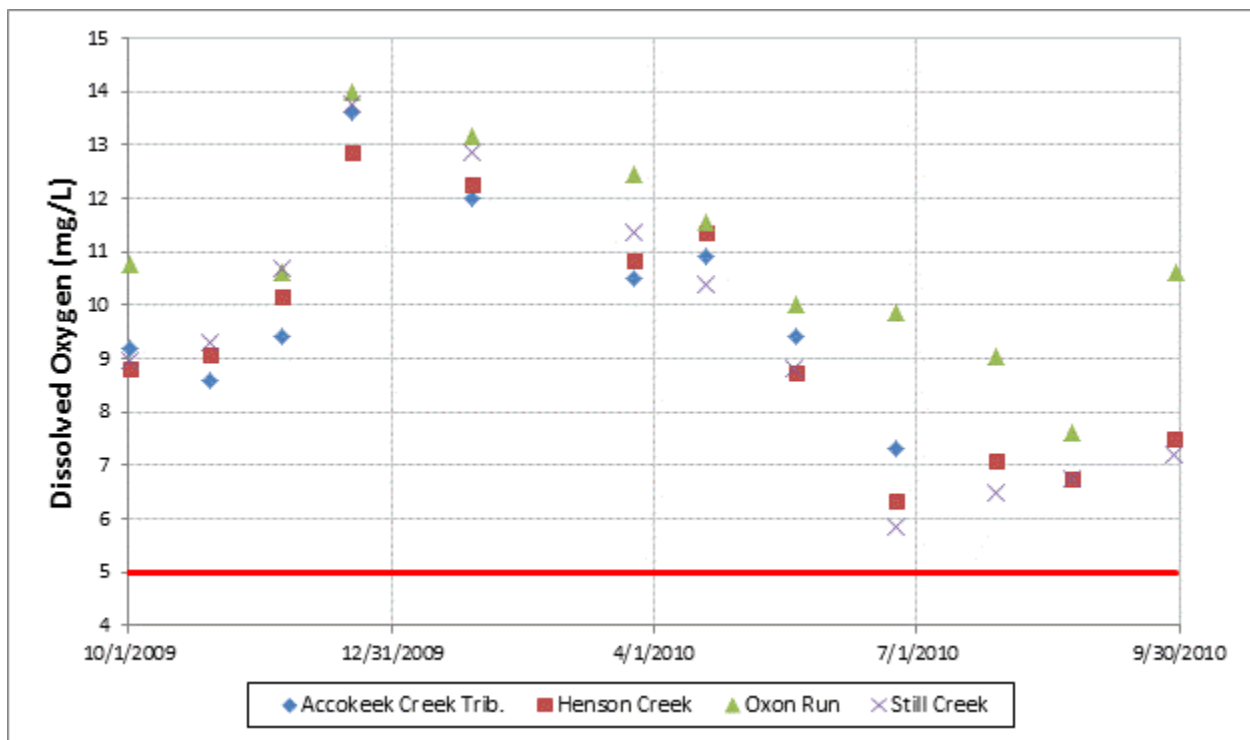


Figure 99: Dissolved Oxygen in NACE streams FY 2010

Dissolved oxygen (Figure 99) was consistently acceptable, and displayed a typical seasonal pattern.

Prince William Forest Park (PRWI)

The park is located in Prince William and Stafford Counties, Virginia straddling the Piedmont and Coastal Plain physiographic regions. Prince William contains portions of two stream systems: Quantico Creek and Chopawamsic Creek (Figure 100). The 30-square mile watershed of Quantico Creek is almost entirely forested. The headwaters of South Fork Quantico Creek, 9 square miles, lie within Quantico Marine Corps Base, while 4 square miles of watershed are in private ownership. The remaining 17 square miles of the watershed lay within the 7,518 ha Prince William Forest Park. Thus, the park has the unique opportunity to preserve and protect a large portion of this ecosystem. Because the park includes two physiographic provinces (Piedmont and Coastal Plain) and lies in the transition zone between northern and southern climates, it exhibits a wide range of habitat and vegetative communities. It is currently the only natural area in the National Park System that contains a significant expanse of piedmont forest.

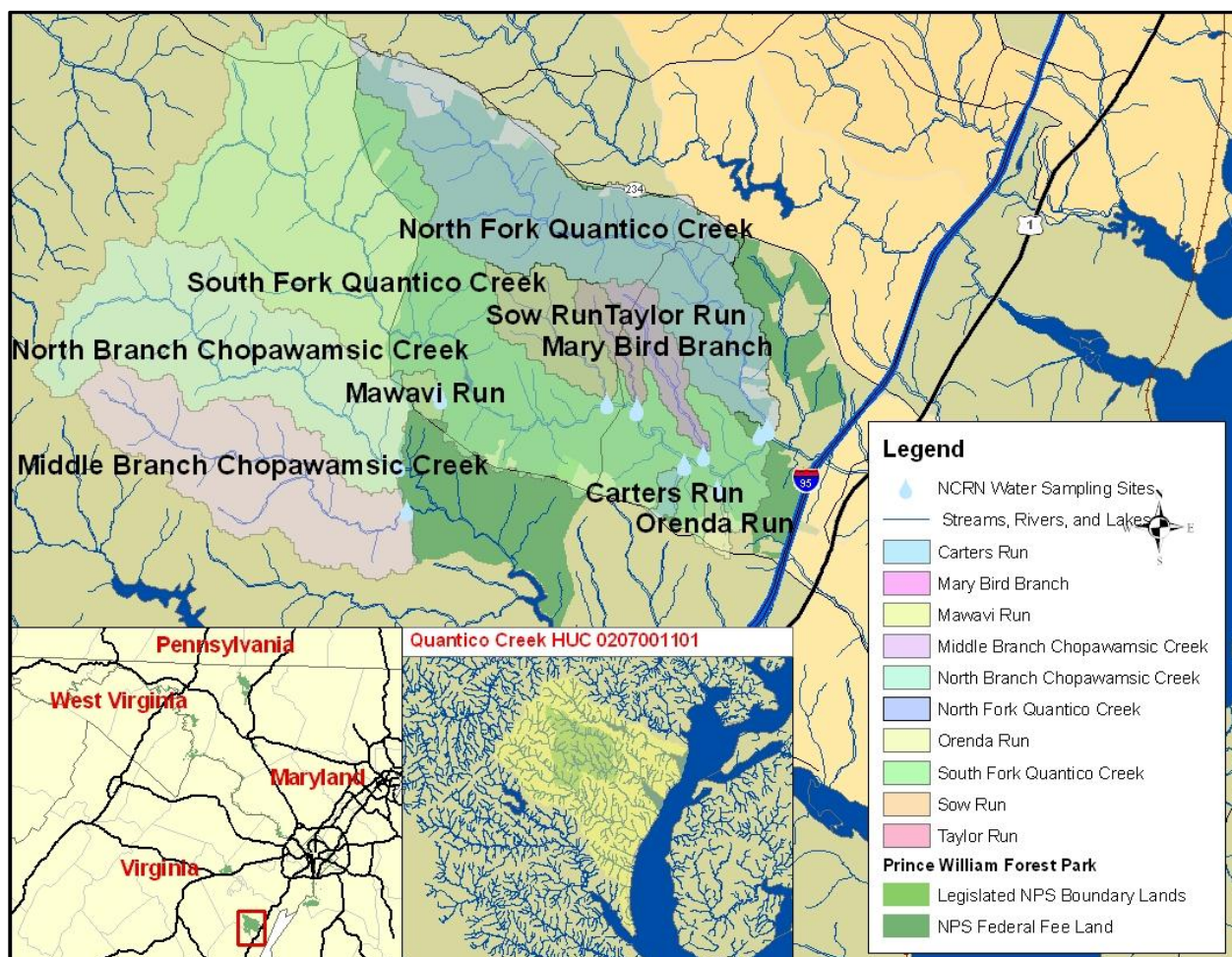


Figure 100: NCRN stream monitoring sites and associated watersheds in PRWI

This report discusses data collected October 2009 through September 2010 for North Fork Quantico Creek, South Fork Quantico Creek, Sow Run, Mary Bird Branch, Mawavi Run, Taylors Run, Carters Run, and Orenda Run. Summary statistics for the time period are shown in Table 13.

Table 13: FY 2010 Summary Statistics for the vital signs collected at PRWI

Parameter (Units)	Minimum	Maximum	Mean	Median	Standard Deviation
Air Temperature (°C)	-3	29.8	15.9	14	8.5
ANC (µeq/L)	202	604	328	309	103.1
DO (mg/L)	6.3	13.3	9.6	10	1.9
Nitrate (mg/L)	0.4	1.8	0.9	1	0.3
pH	6.05	7.4	6.95	7.05	0.33
Salinity (ppt)	0.01	0.23	0.04	0.03	0.03
Specific conductance (µS/cm)	26.5	485	78.4	63.7	56.3
Total Phosphorus (mg/L)	0.08	0.54	0.24	0.2	0.12
Water Temperature (°C)	4.2	26.5	13.9	11.5	6.3
Discharge (cfs)	0.03	23.98	2.66	0.59	5.28
Flow (ft/sec)	0.02	1.44	0.53	0.42	0.41
Water Depth (ft)	0.01	1	0.36	0.3	0.19
Wetted Width (ft)	0	30.3	6.8	5	5.8

Eight sites were monitored in the park on a monthly basis for dissolved oxygen, pH, specific conductance, temperature, acid neutralizing capacity, nitrate, total phosphorus, width, depth, flow and discharge. North Branch Chopawamsic Creek and Middle Branch Chopawamsic Creek were dropped due to issues with accessibility (accessible only through Marine Corps Base – Quantico).

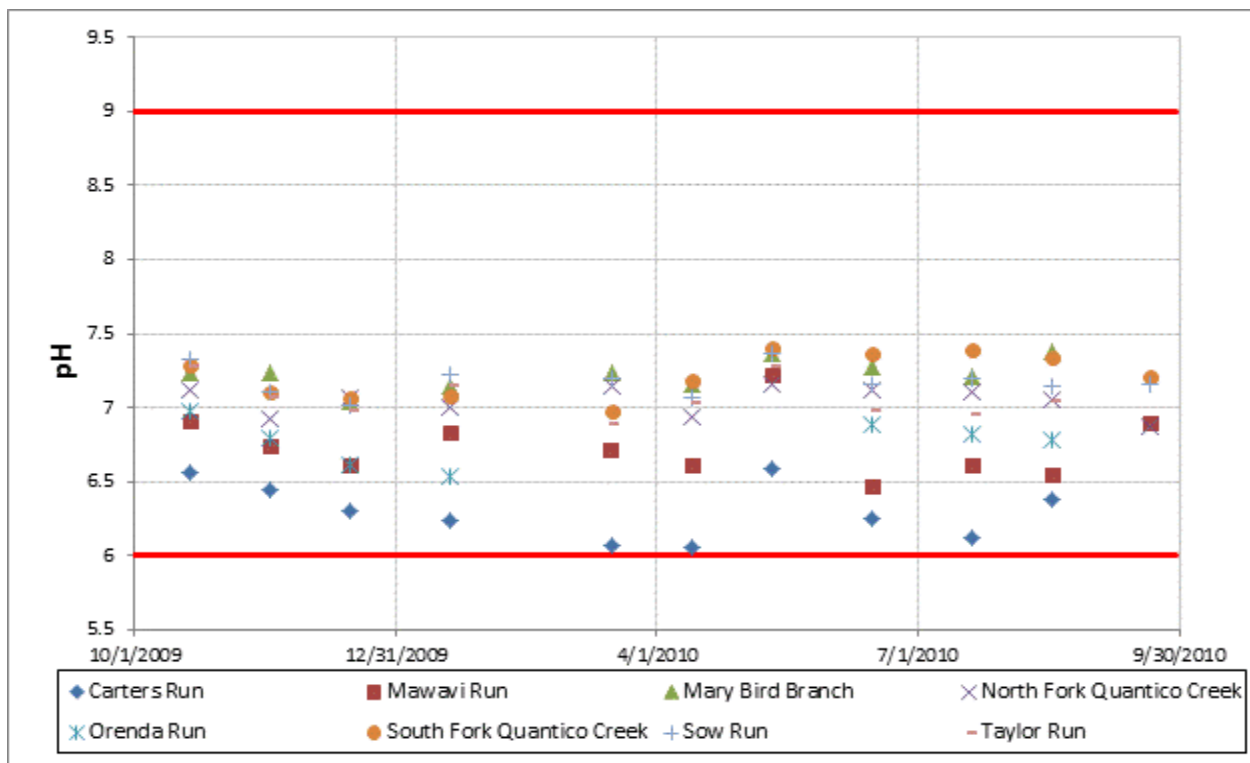


Figure 101: pH in PRWI streams FY 2010

All sites at PRWI fell within the acceptable range for pH (Figure 101), albeit at low values. However, several sites had insufficient acid neutralizing capacity (Figure 102), including Carters Run, which never met threshold. It is not displayed in the graph due to the fact that the threshold ($> 200 \mu\text{eq/L}$) is the lower quantification limit for the testing procedure.

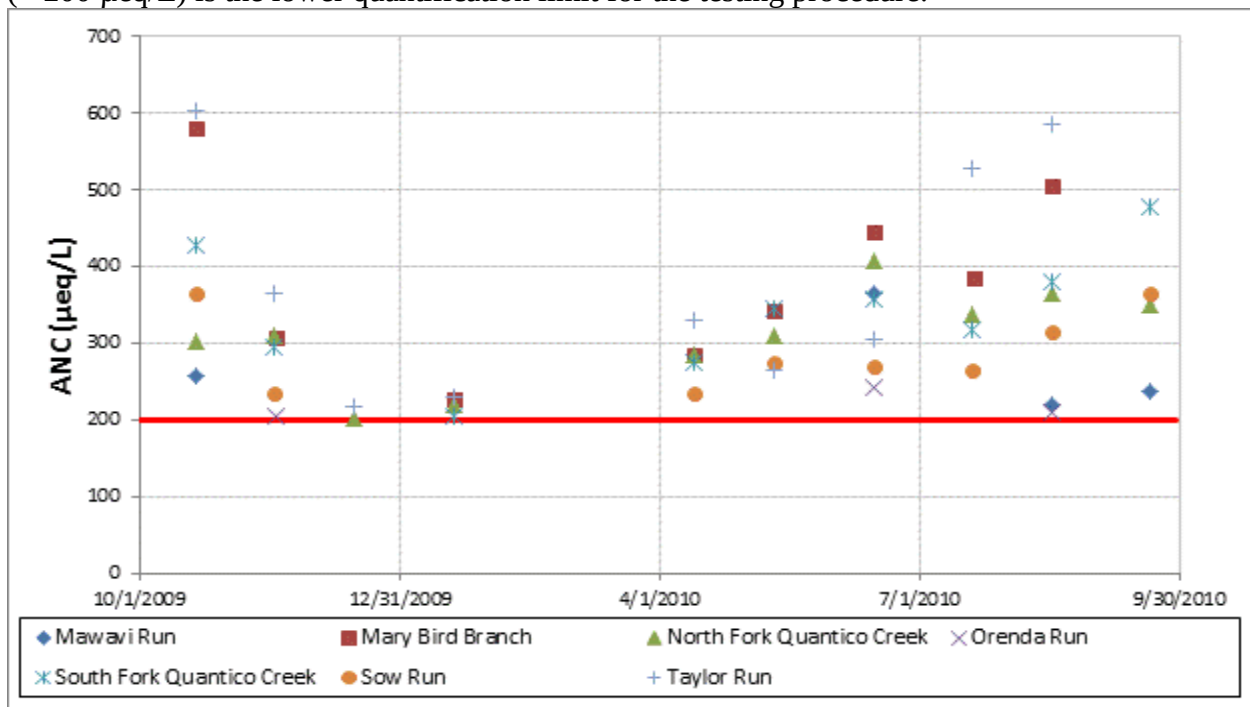


Figure 102: Acid Neutralizing Capacity in PRWI streams FY 2010

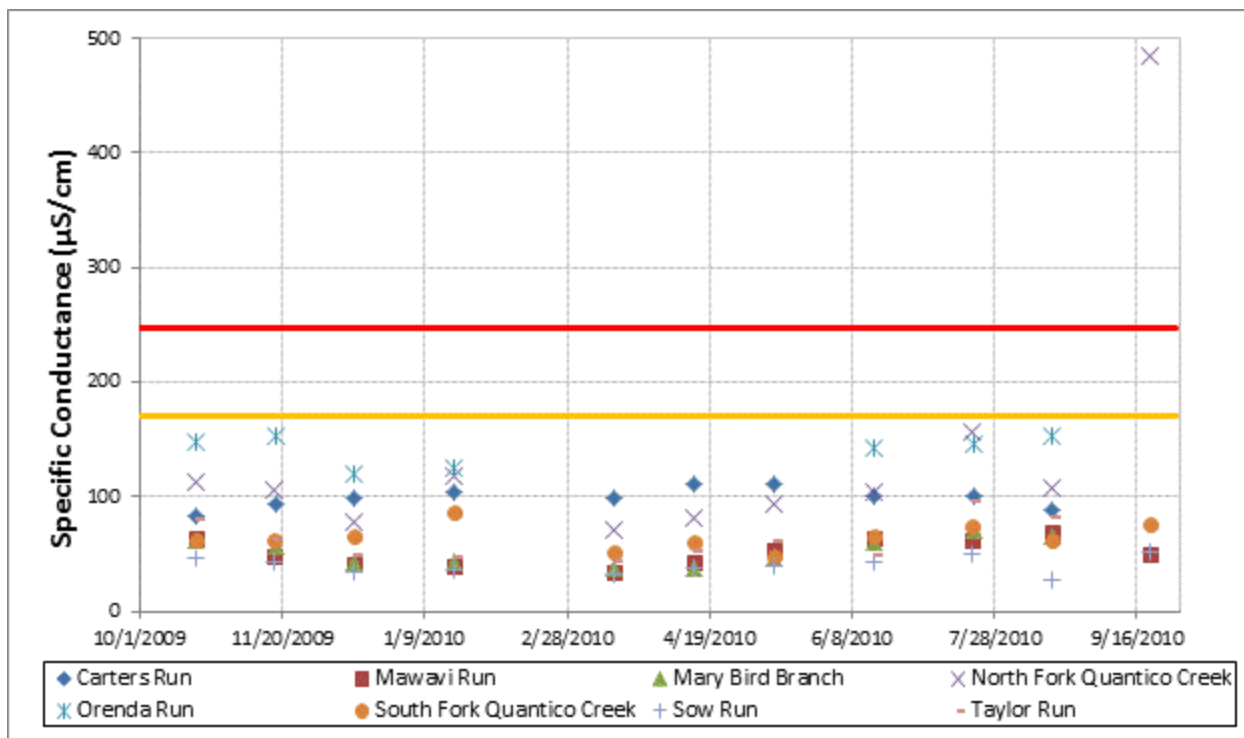


Figure 103: Specific Conductance in PRWI streams FY 2010

Specific Conductance (Figure 103) met ecological requirements for aquatic life stress (orange = fish threshold; red = macroinvertebrate threshold), except for a single instance of North Fork Quantico Creek exceeding the ecological threshold for specific conductance. Salinity (Figure 20) remained under the threshold for freshwater ecosystems.

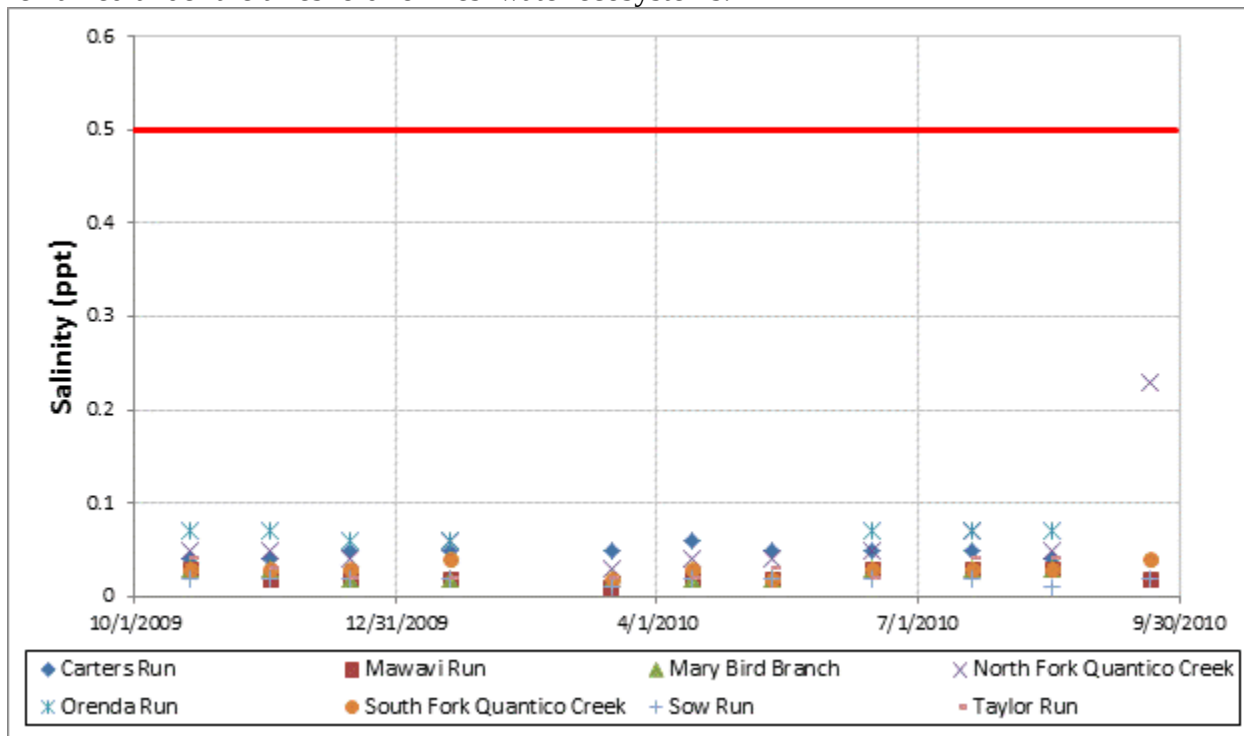


Figure 104: Salinity in PRWI streams FY 2010

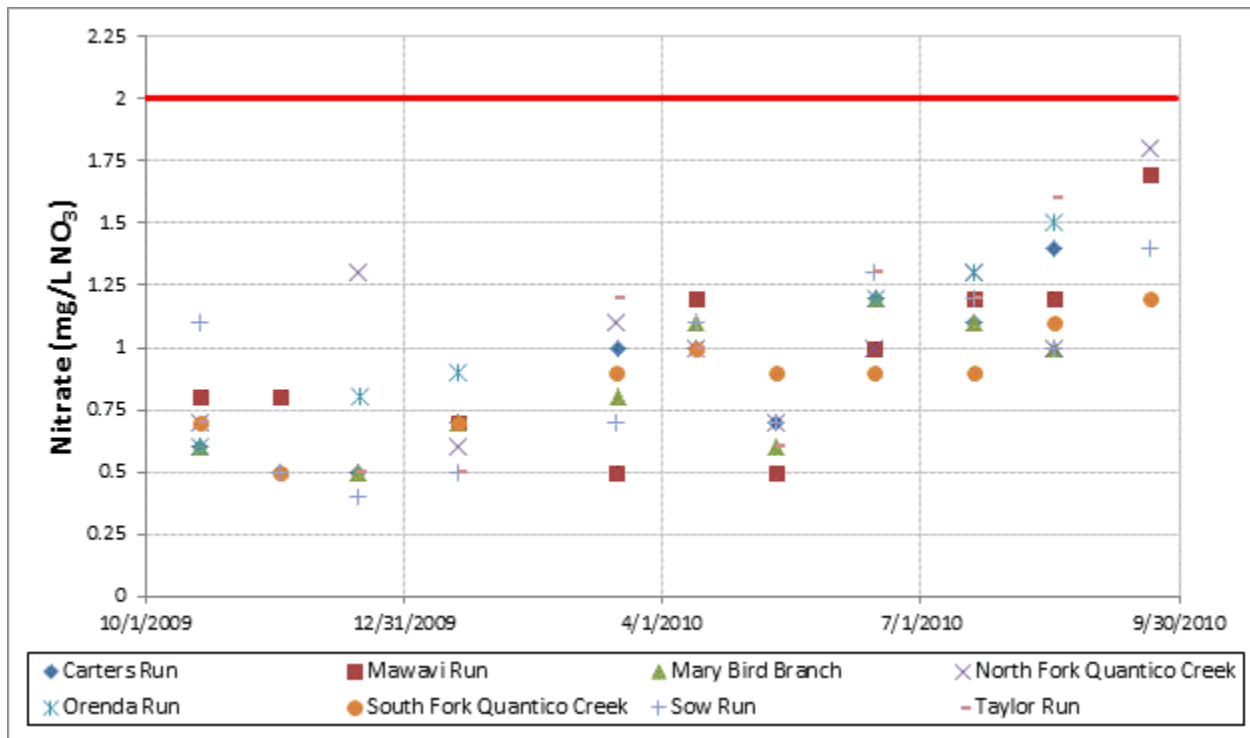


Figure 105: Nitrate in PRWI streams FY 2010

Nitrate levels (Figure 105) were consistently acceptable, while phosphorus levels (Figure 106) regularly exceeded the threshold value.

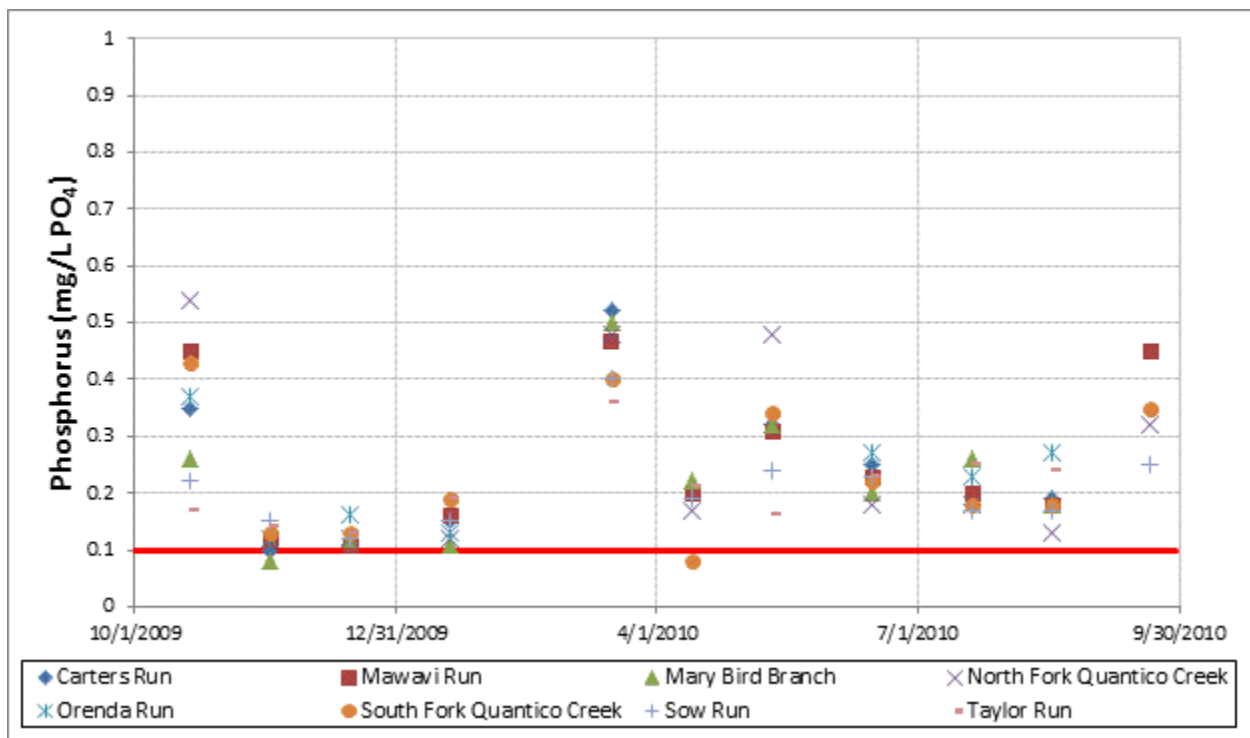


Figure 106: Phosphorus in PRWI streams FY 2010

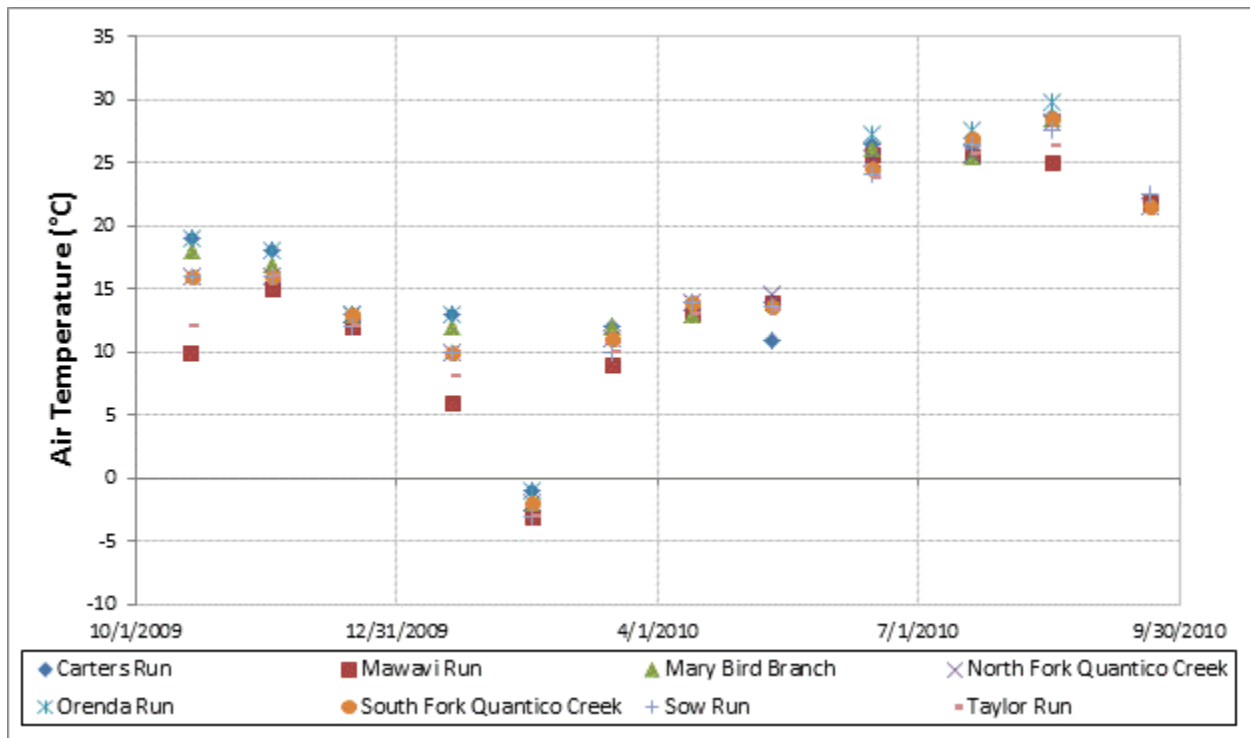


Figure 107: Air Temperature in PRWI streams FY 2010

Water temperatures (Figure 108) always fell within the acceptable range, and followed the same pattern as air temperatures (Figure 107), suggesting that the streams are primarily surface-fed.

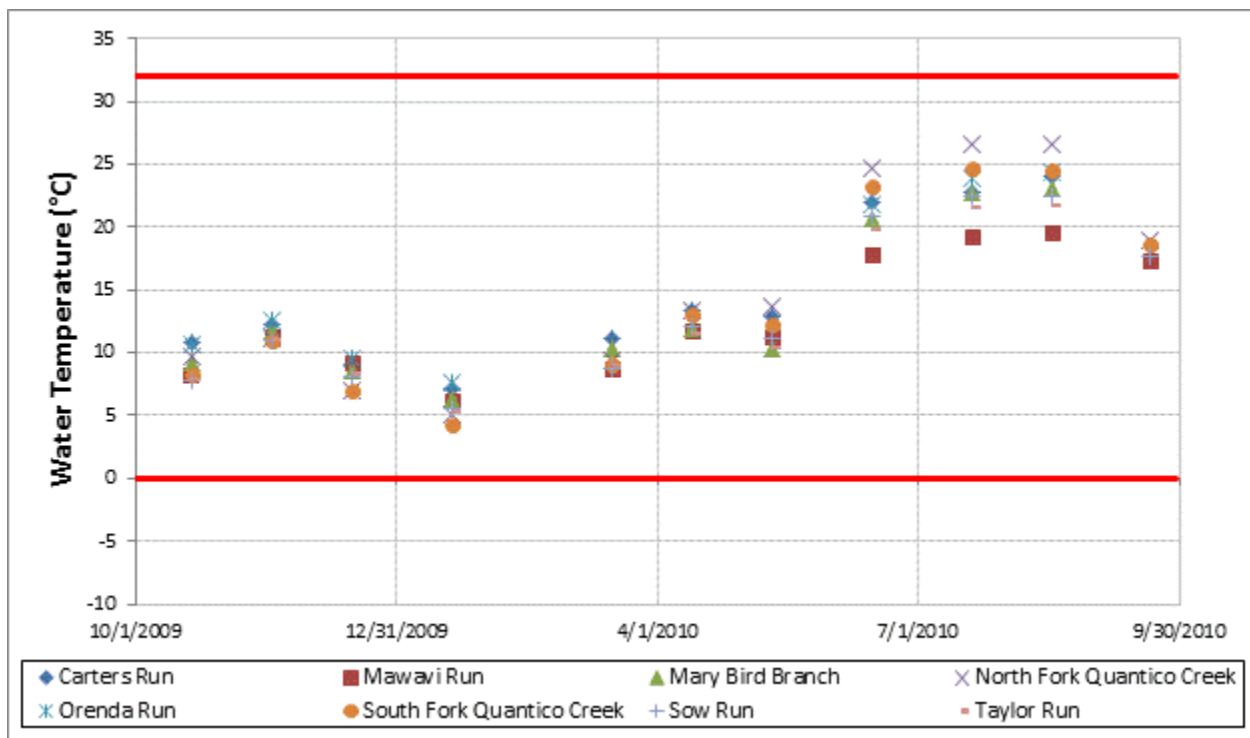


Figure 108: Water Temperature in PRWI streams FY 2010

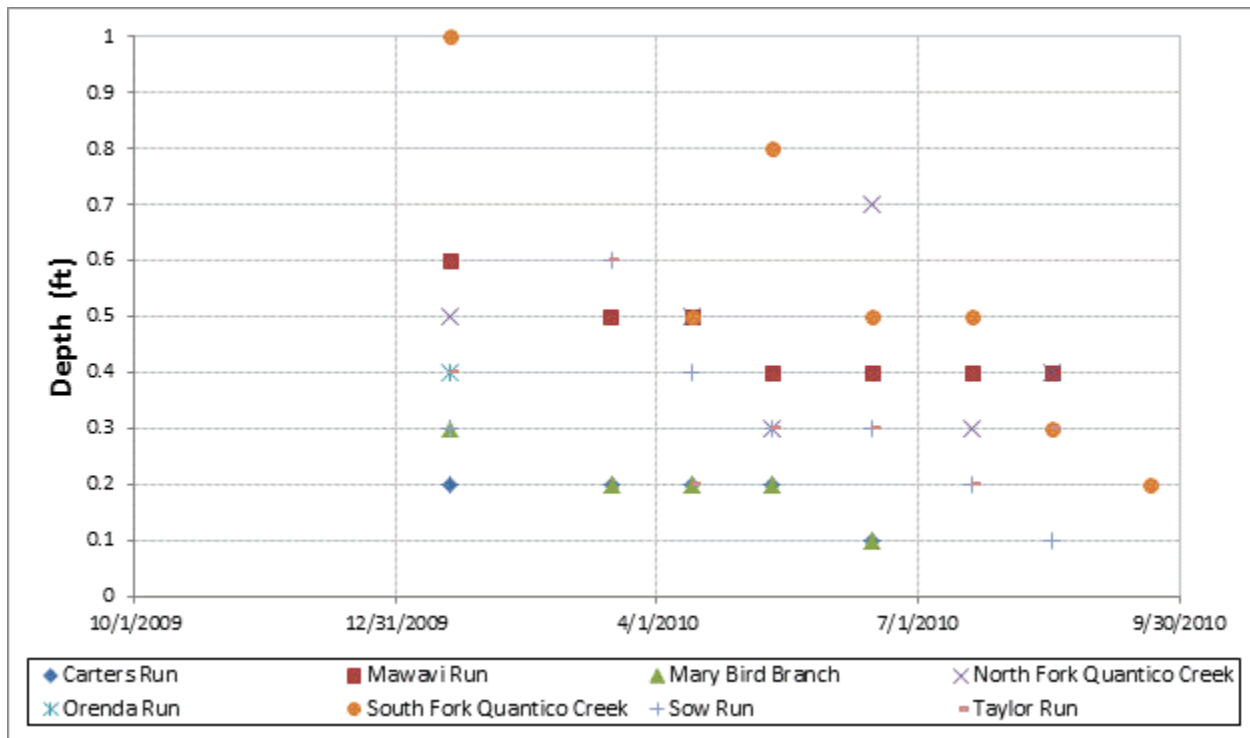


Figure 109: Stream depth in PRWI streams FY 2010

Missing depth data points (Figure 109) from October through December are due to equipment failure.

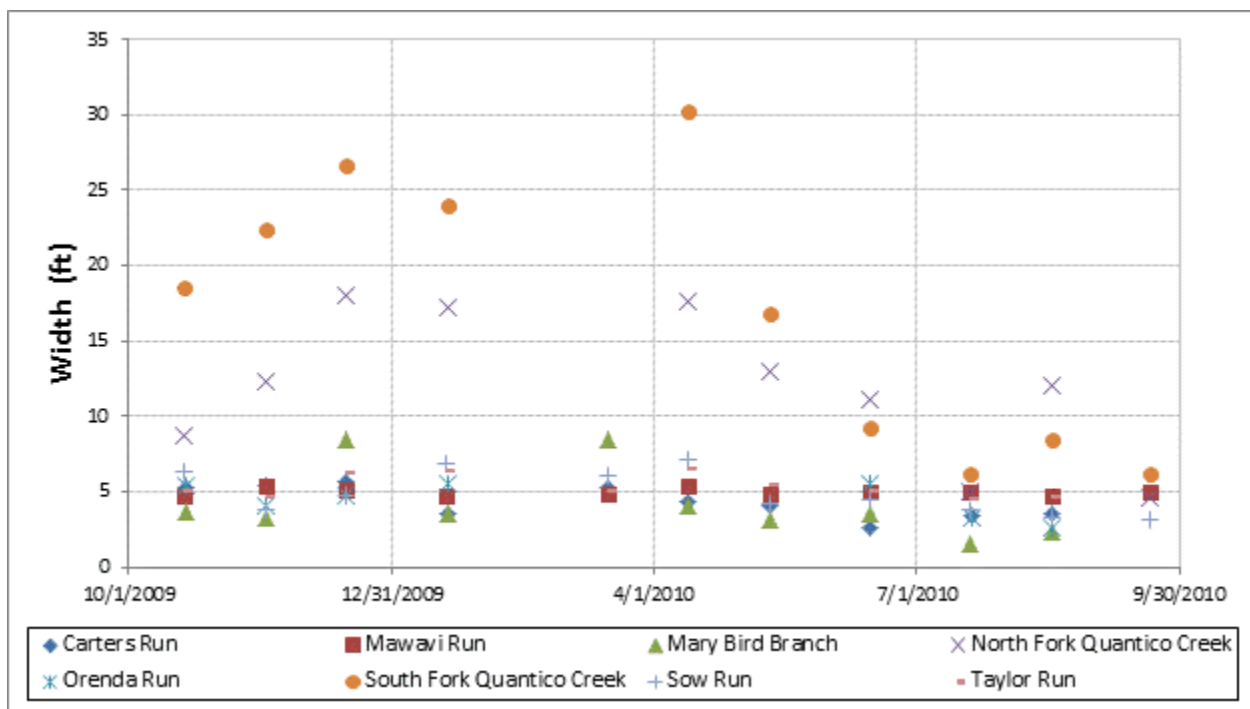


Figure 110: Stream width in PRWI streams FY 2010

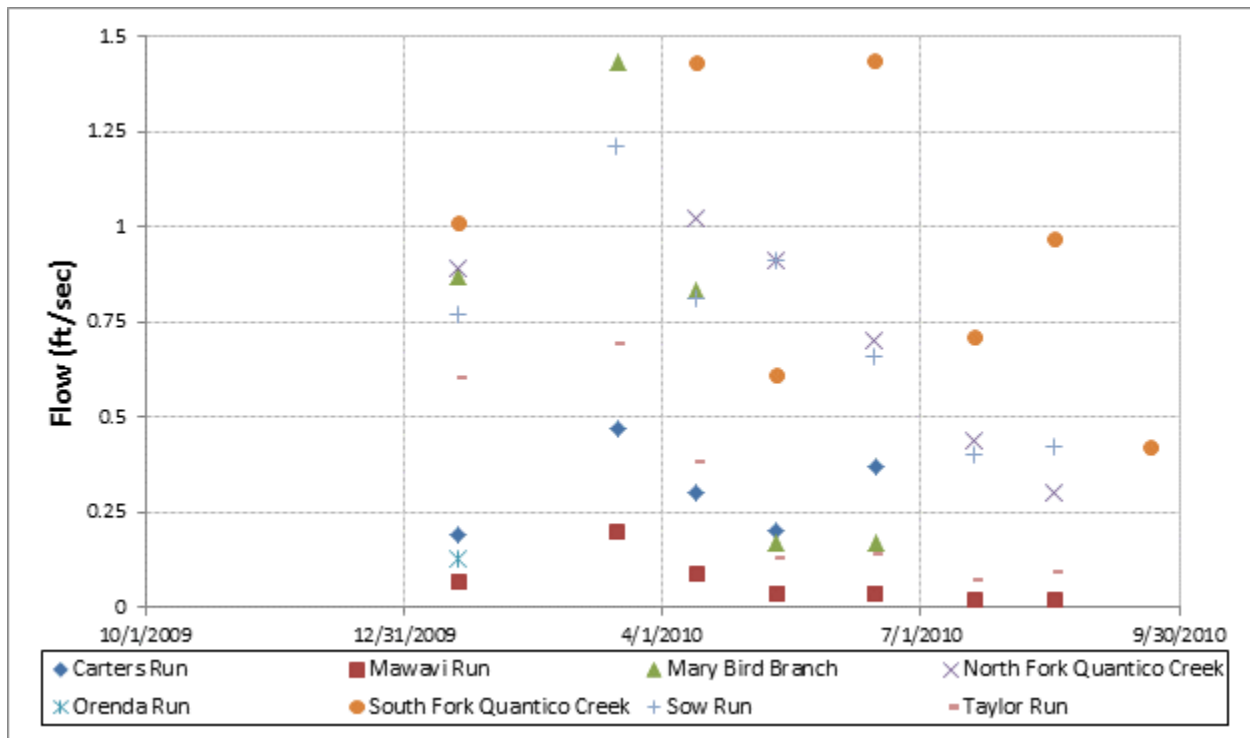


Figure 111: Stream flow in PRWI streams FY 2010

Missing flow data points (Figure 111) and missing discharge data points (Figure 112) from October through December are due to equipment failure.

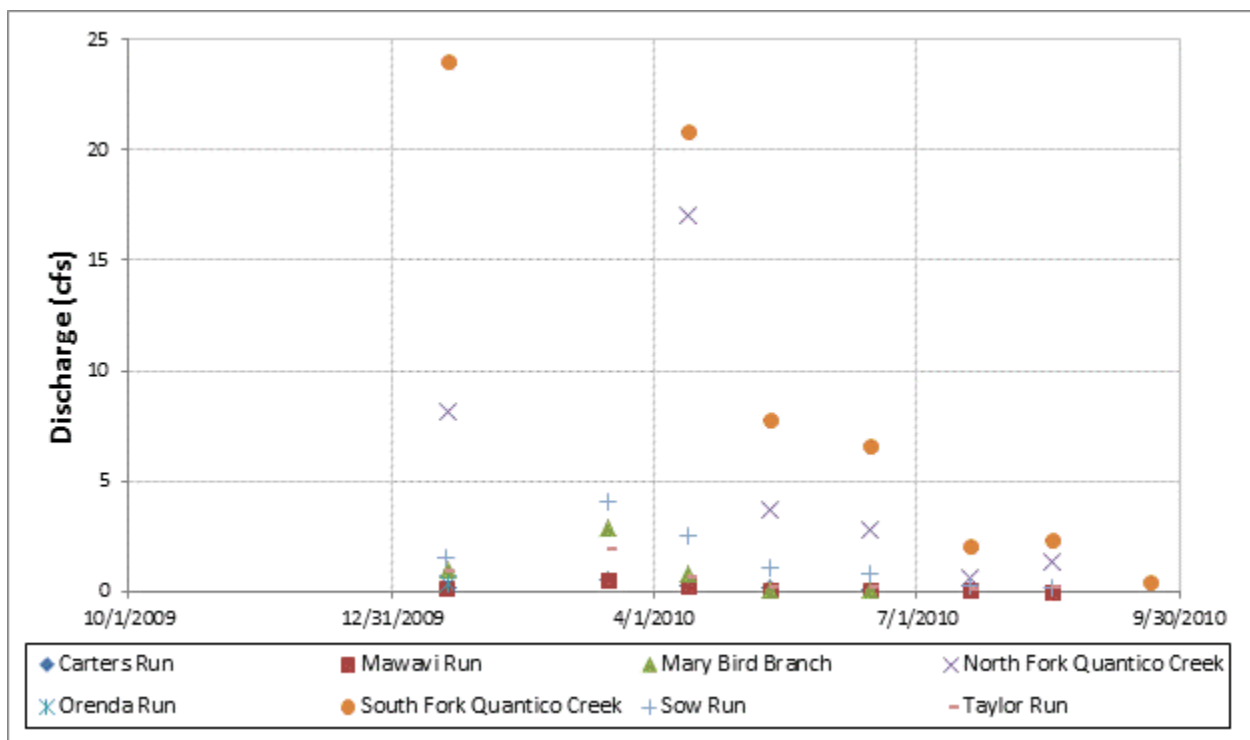


Figure 112: Stream discharge in PRWI streams FY 2010

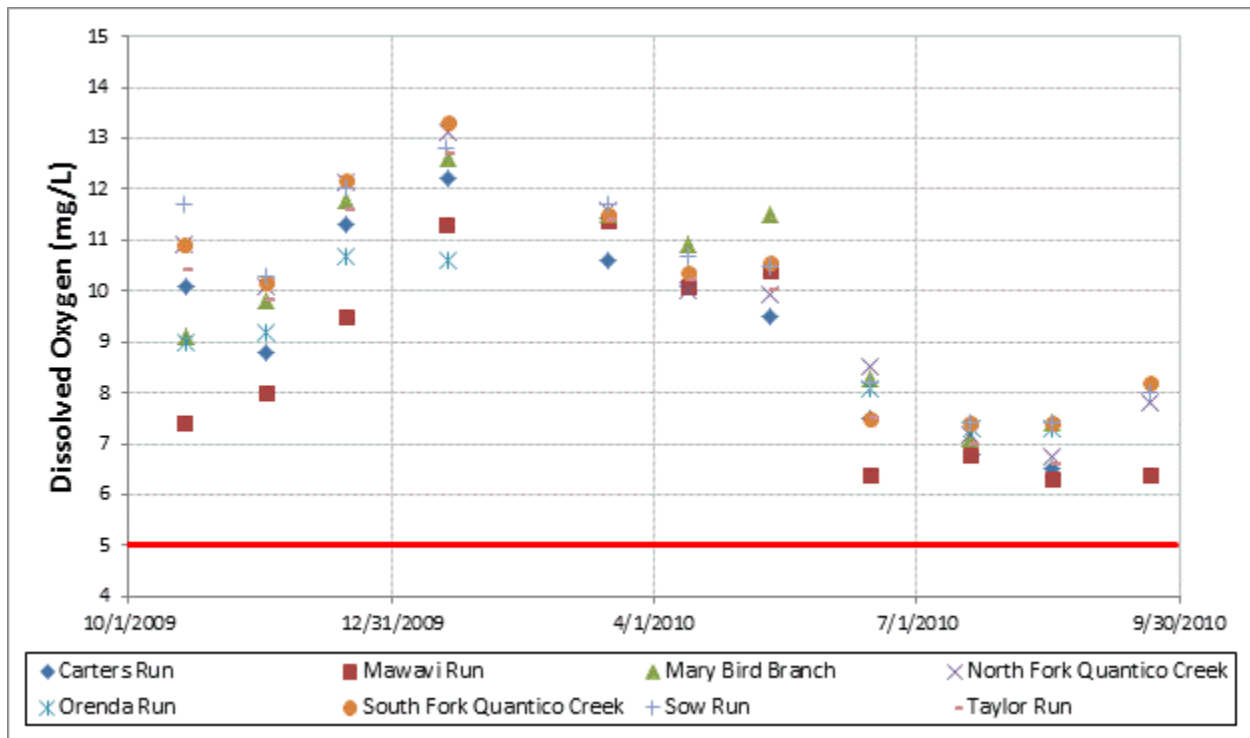


Figure 113: Dissolved Oxygen in PRWI streams FY 2010

Dissolved oxygen (Figure 113) was consistently acceptable, and displayed a typical seasonal pattern.

Rock Creek Park (ROCR)

The park is located in Washington, DC within the Potomac River Watershed and the Piedmont and Coastal Plain physiographic provinces. Rock Creek originates near Laytonsville in Montgomery County, MD. Approximately 10 miles of its total length of 33 miles are located within the District of Columbia (Figure 114). Rock Creek becomes a fourth-order stream at the confluence of Rock Creek with the North Branch of Rock Creek, north of Rockville, Maryland. It remains a fourth-order stream for the remainder of its length. Except for the narrow extension of parkland into Maryland that is under Montgomery County administration, Rock Creek Park represents a largely isolated natural system surrounded by urban areas, which have significantly impacted the park. These effects include flooding and pollution in park streams, introductions of invasive non-native species into natural areas, extirpations or reductions of sensitive native species, and the artificial inflation of populations of a few native species that adversely affect other native plants and wildlife (Carruthers et al. 2009).

This report discusses data collected October 2009 through September 2010 for Fenwick Branch, Pinehurst Branch, Luzon Branch, Soapstone Valley Stream, Broad Branch, Hazen Creek, Piney Branch, Klinge Valley Creek, Normanstone Creek, Dumbarton Oaks Stream, Rock Creek, and Battery Kemble Creek. Summary statistics for the time period for all eleven streams are shown in Table 14.

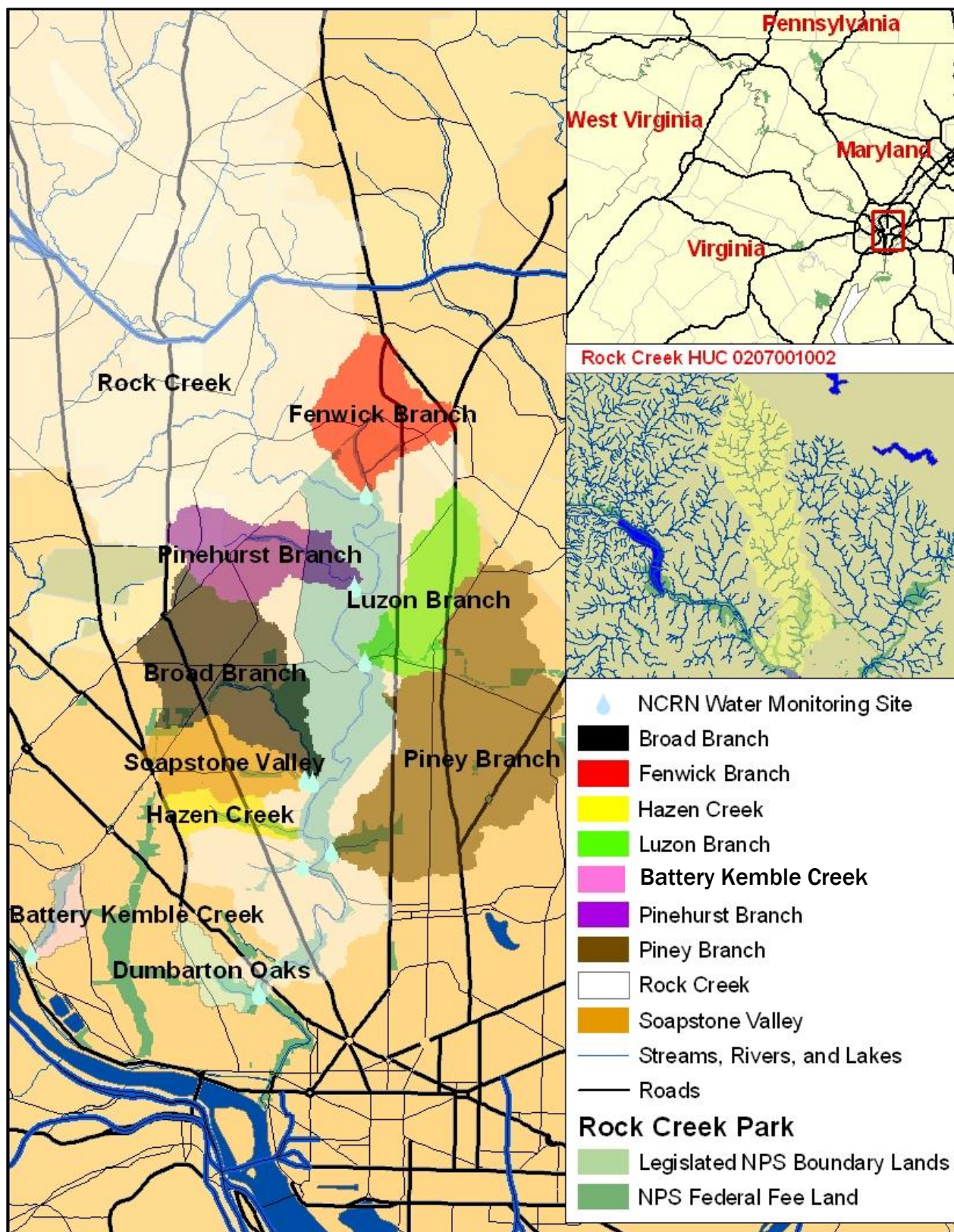


Figure 114: NCRN stream monitoring sites and associated watersheds within ROCK

Table 14: FY 2010 Summary statistics for the vital signs collected at ROCR

Parameter (Units)	Minimum	Maximum	Mean	Median	Standard Deviation
Air Temperature (°C)	-4	30.3	15.8	14	8.6
Water Temperature (°C)	2.8	25.2	15.5	13.9	5.1
ANC (µeq/L)	624	2424	1576	1592	428.4
pH	7.2	8.68	7.76	7.71	0.30
Salinity (ppt)	0.05	0.67	0.30	0.31	0.12
Specific conductance (µS/cm)	121.9	1178	609.7	644	242.1
DO (mg/L)	3.2	14.93	9.13	8.8	2.2
Nitrate (mg/L)	0.4	5.6	2.7	2.6	1.3
Total Phosphorus (mg/L)	0.06	1.81	0.56	0.54	0.30
Discharge (cfs)	0.06	77.93	4.34	0.65	13.1
Flow (ft/sec)	0.03	1.58	0.39	0.34	0.31
Water Depth (ft)	0.07	2.43	0.43	0.27	0.44
Wetted Width (ft)	1.7	66	13.2	8.6	11.8

Twelve sites were monitored in the park on a monthly basis for dissolved oxygen, pH, specific conductance, temperature, acid neutralizing capacity, nitrate, total phosphorus, width, depth, flow, and discharge. Rock Creek at Edgewater Stables was replaced with Rock Creek at Dumbarton Oaks as the downstream point on Rock Creek. Rock Creek above Fenwick Branch was dropped in 2009 because of the inability to safely wade across it.

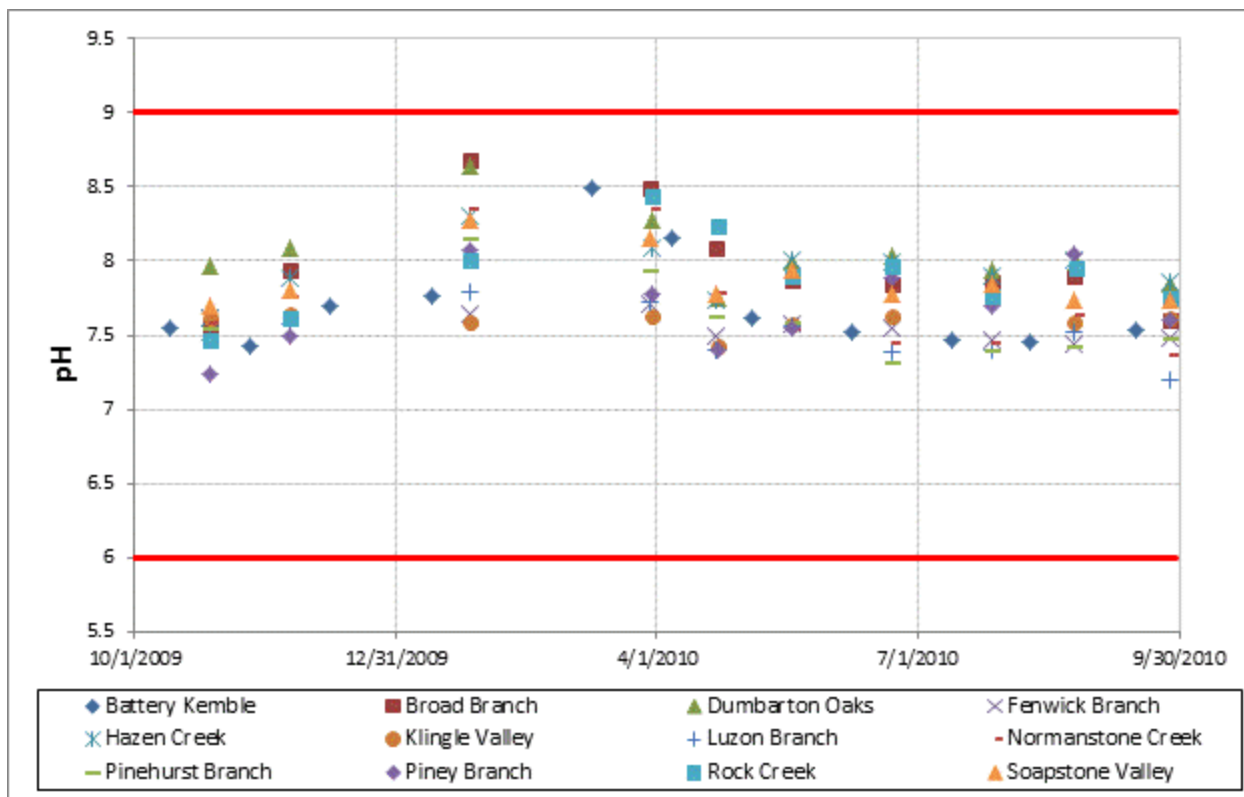


Figure 115: pH in ROCR streams FY 2010

Both pH (Figure 115) and acid neutralizing capacity (Figure 116) were within the acceptable range.

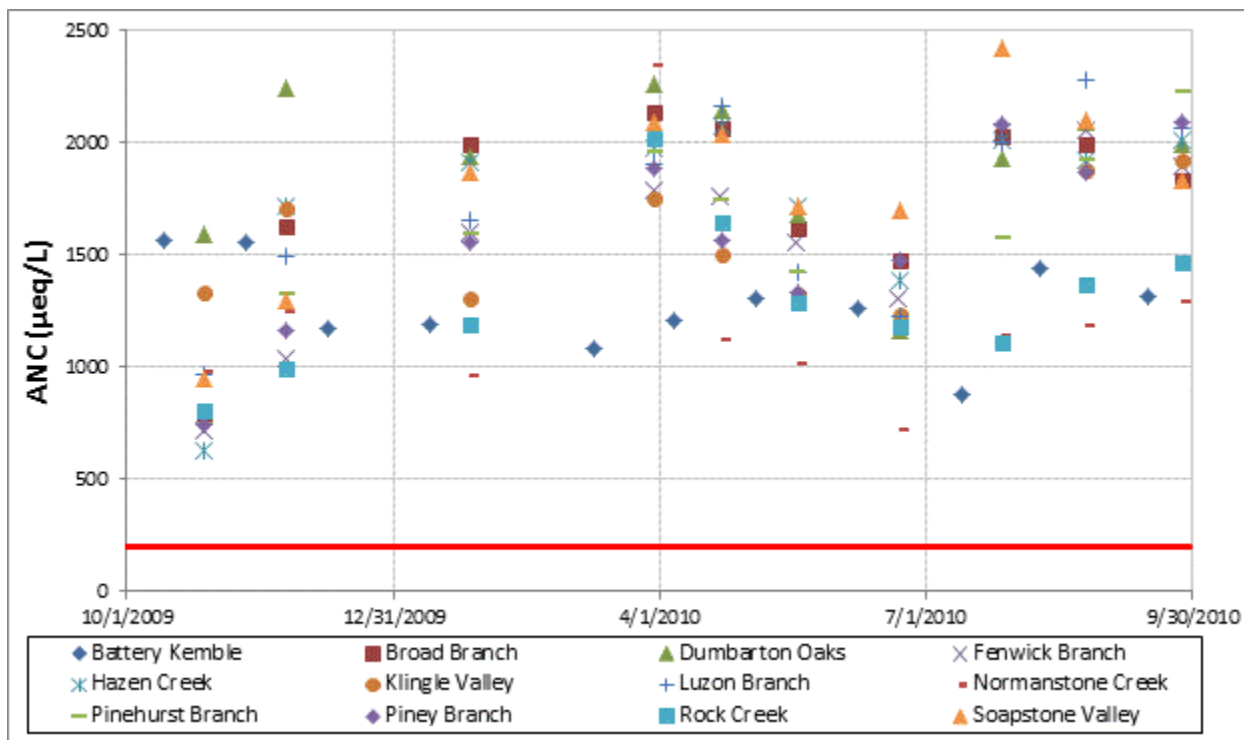


Figure 116: Acid Neutralizing Capacity in ROCR streams FY 2010

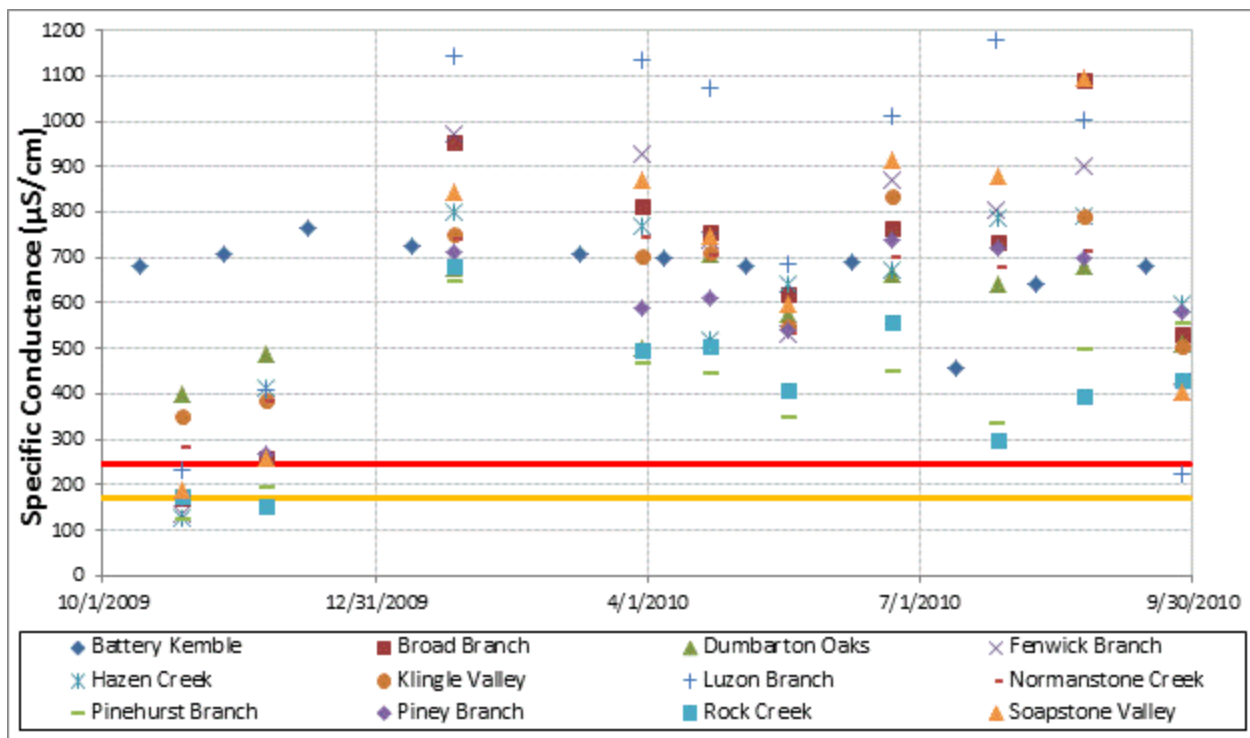


Figure 117: Specific Conductance in ROCR streams FY 2010

Specific conductance (Figure 117) exceeded ecological thresholds for aquatic life stress (orange = fish threshold; red = macroinvertebrate threshold) at all sites except a handful of instances during the wet season. Salinity (Figure 118) was consistently within the acceptable range for fresh water, except for several instances at Luzon Branch (cause unknown).

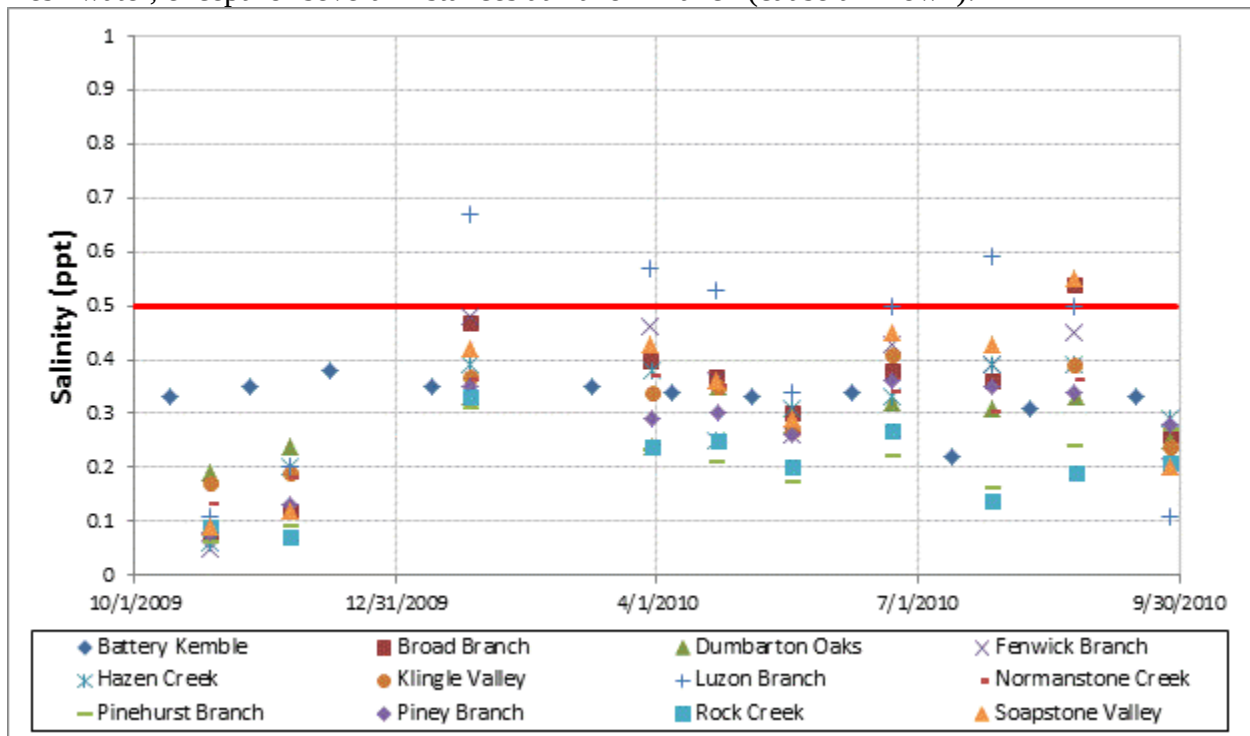


Figure 118: Salinity in ROCR streams FY 2010

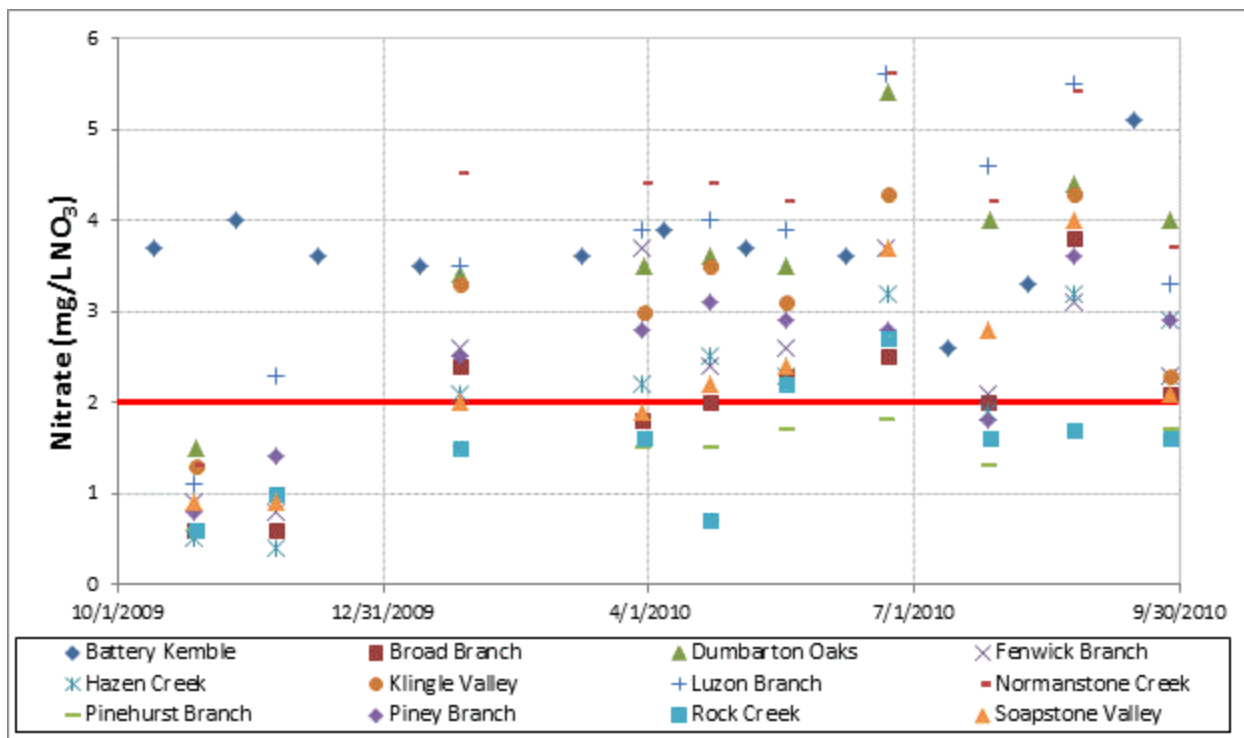


Figure 119: Nitrate in ROCR streams FY 2010

Nitrate levels (Figure 119) mostly exceeded the acceptable range,, but were occasionally below the threshold, with no discernible pattern. Phosphorus levels (Figure 120) consistently exceed threshold and eutrophication values.

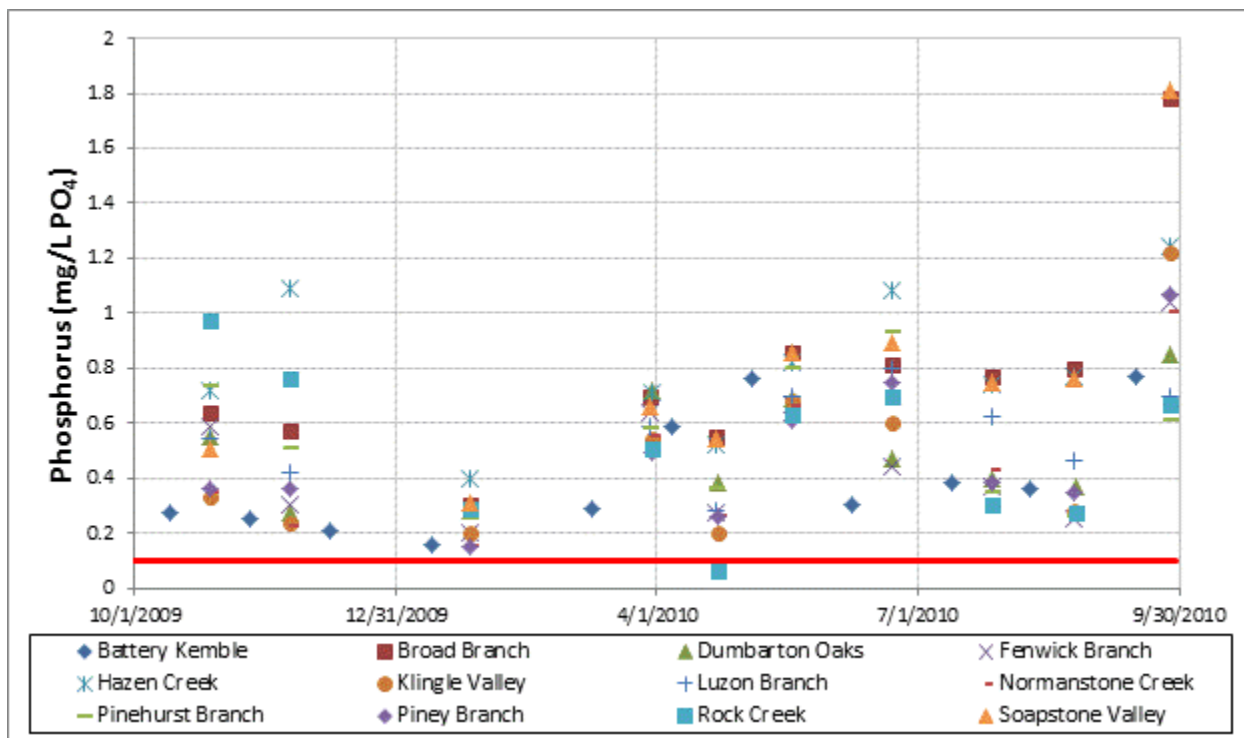


Figure 120: Phosphorus in ROCR streams FY 2010

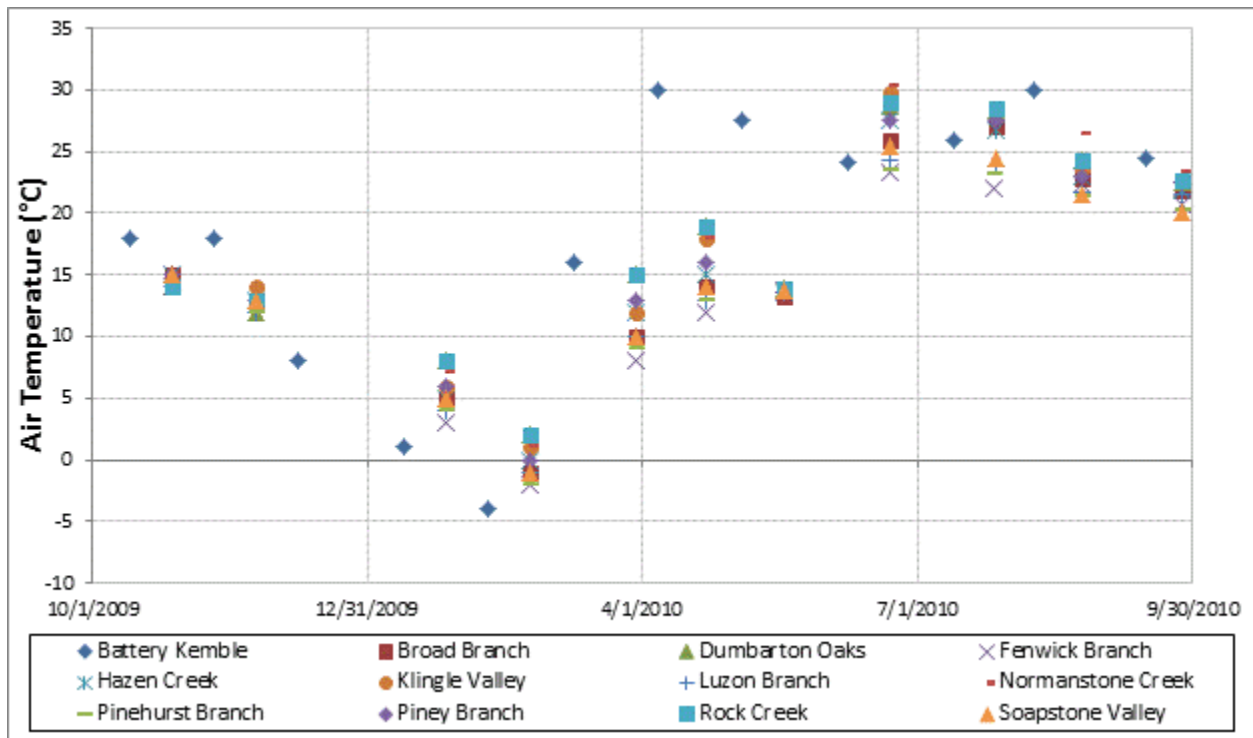


Figure 121: Air Temperature in ROCR streams FY 2010

Water temperatures (Figure 122) always fell within the threshold range, and followed a similar pattern as air temperatures (Figure 121), suggesting that the streams are primarily surface-fed.

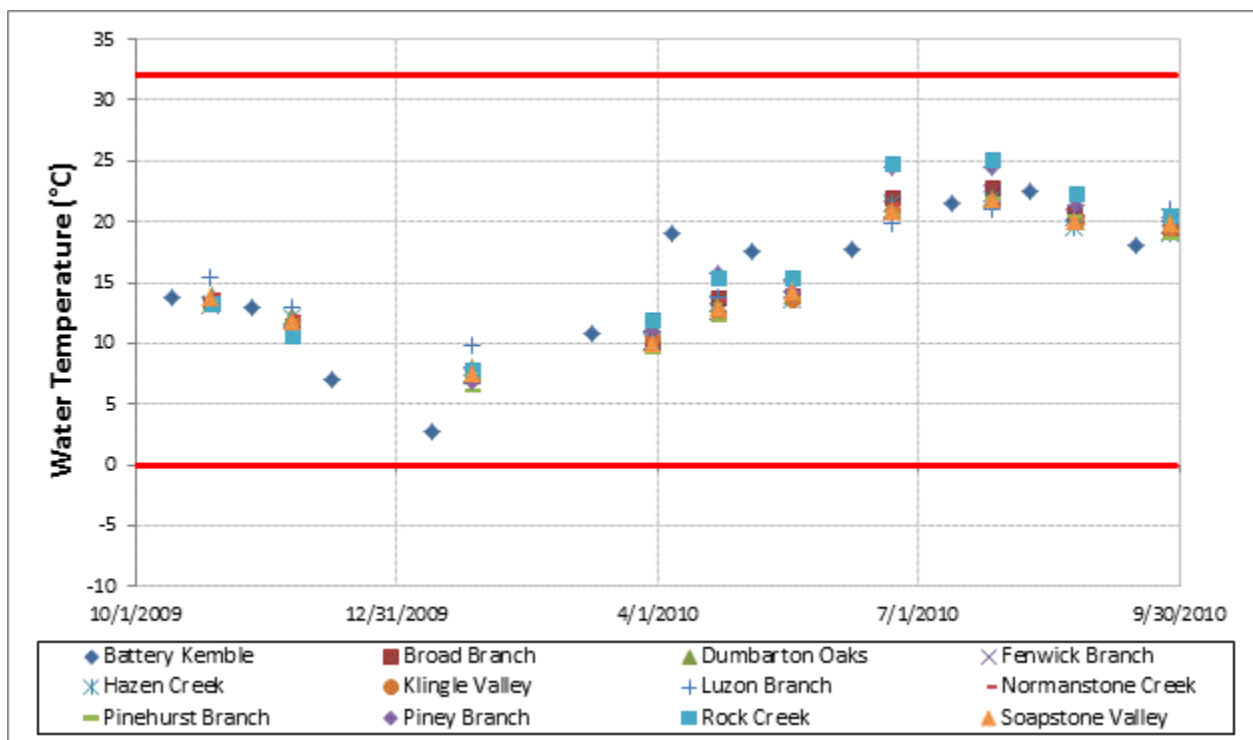


Figure 122: Water Temperature in ROCR streams FY 2010

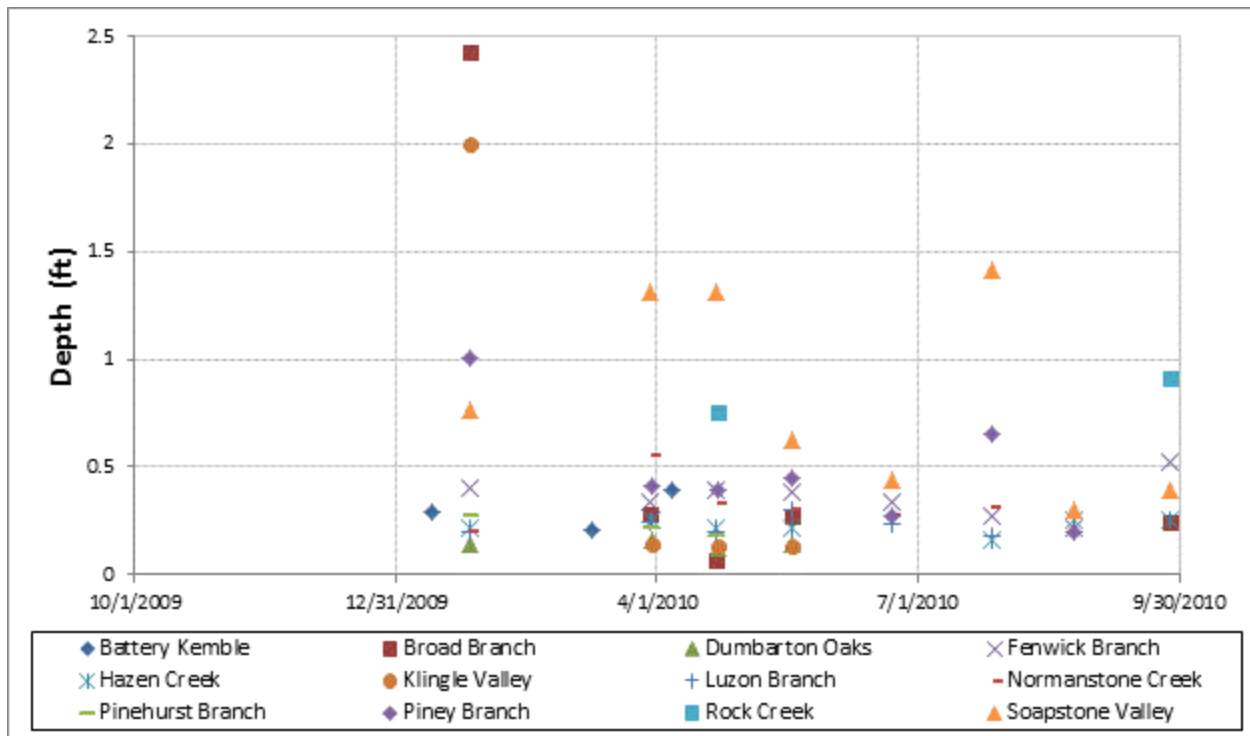


Figure 123: Depth in ROCR streams FY 2010

Missing depth data points (Figure 123) from October through December are due to equipment failure.

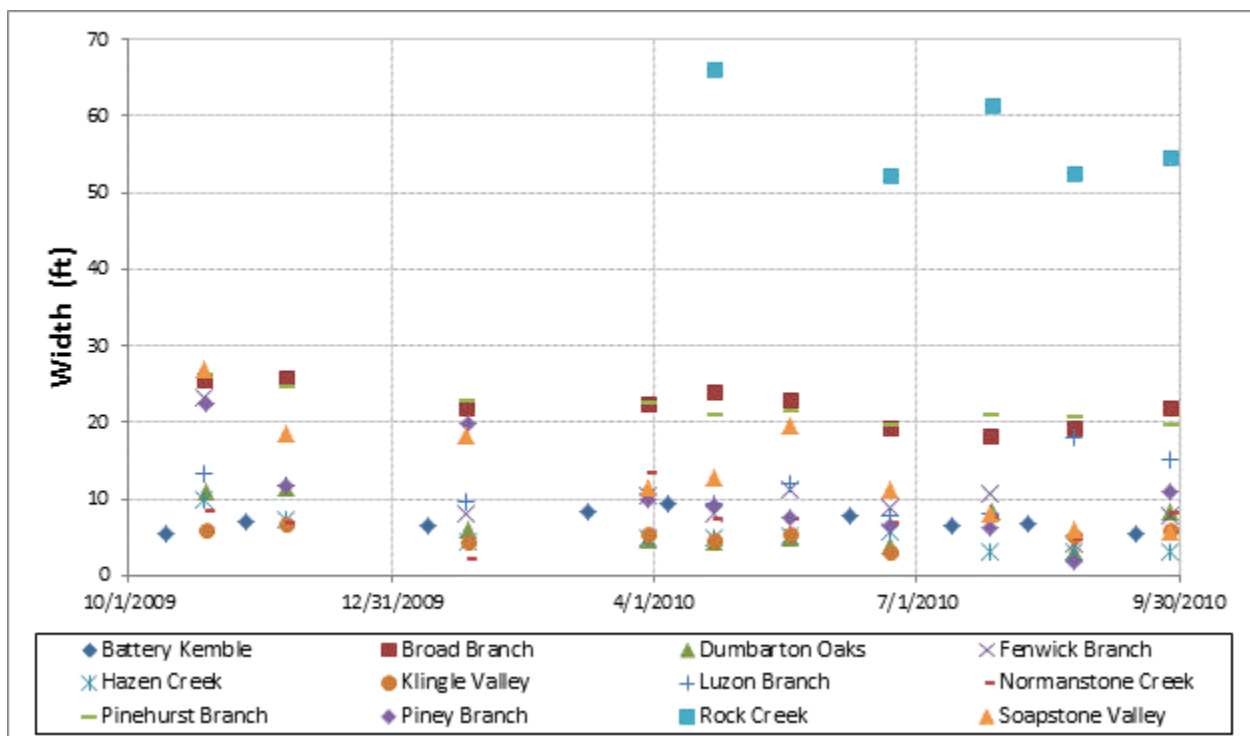


Figure 124: Width in ROCR streams FY 2010

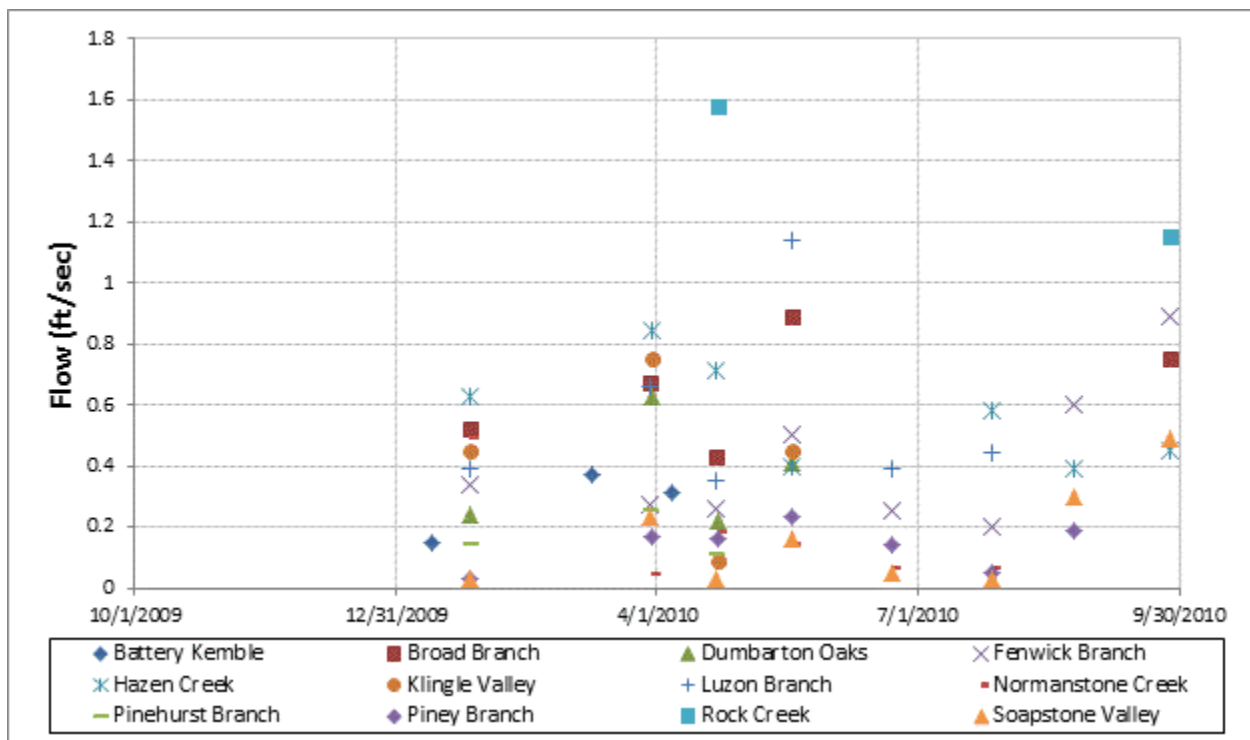


Figure 125: Flow in ROCR streams FY 2010

Missing flow data points (Figure 125) and missing discharge data points (Figure 126) from October through December are due to equipment failure.

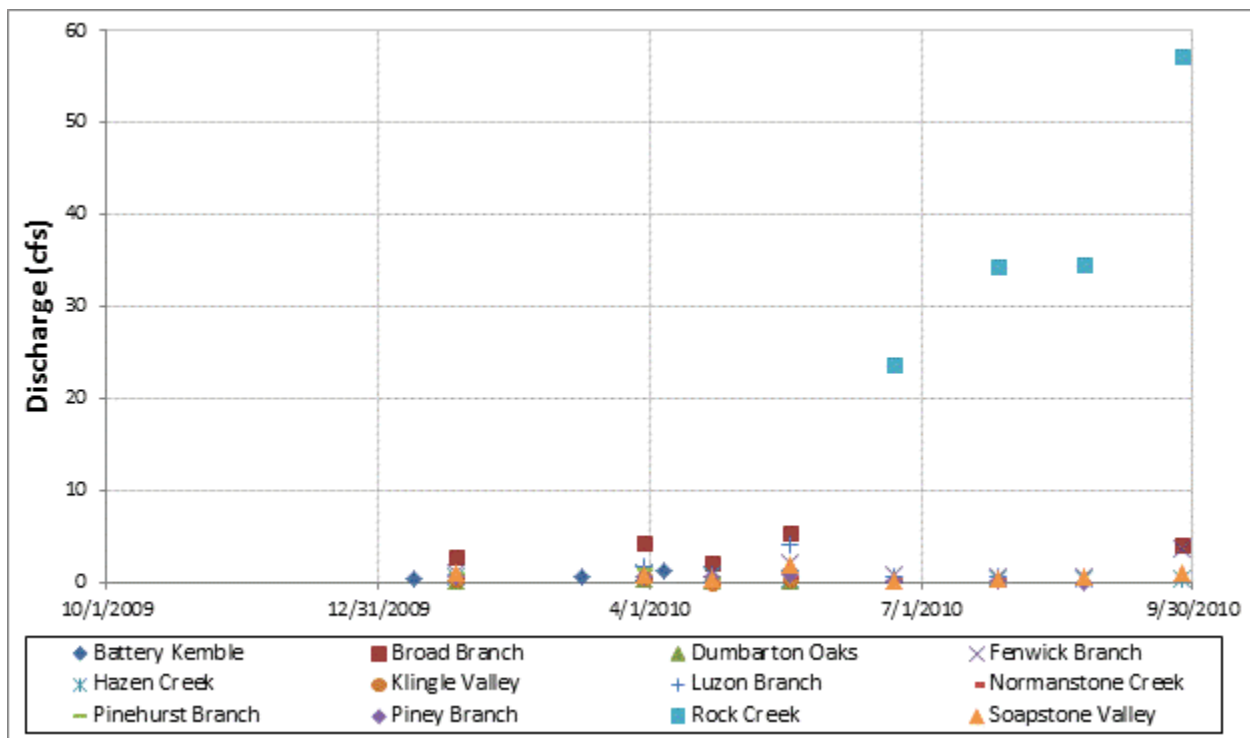


Figure 126: Discharge in ROCR streams FY 2010

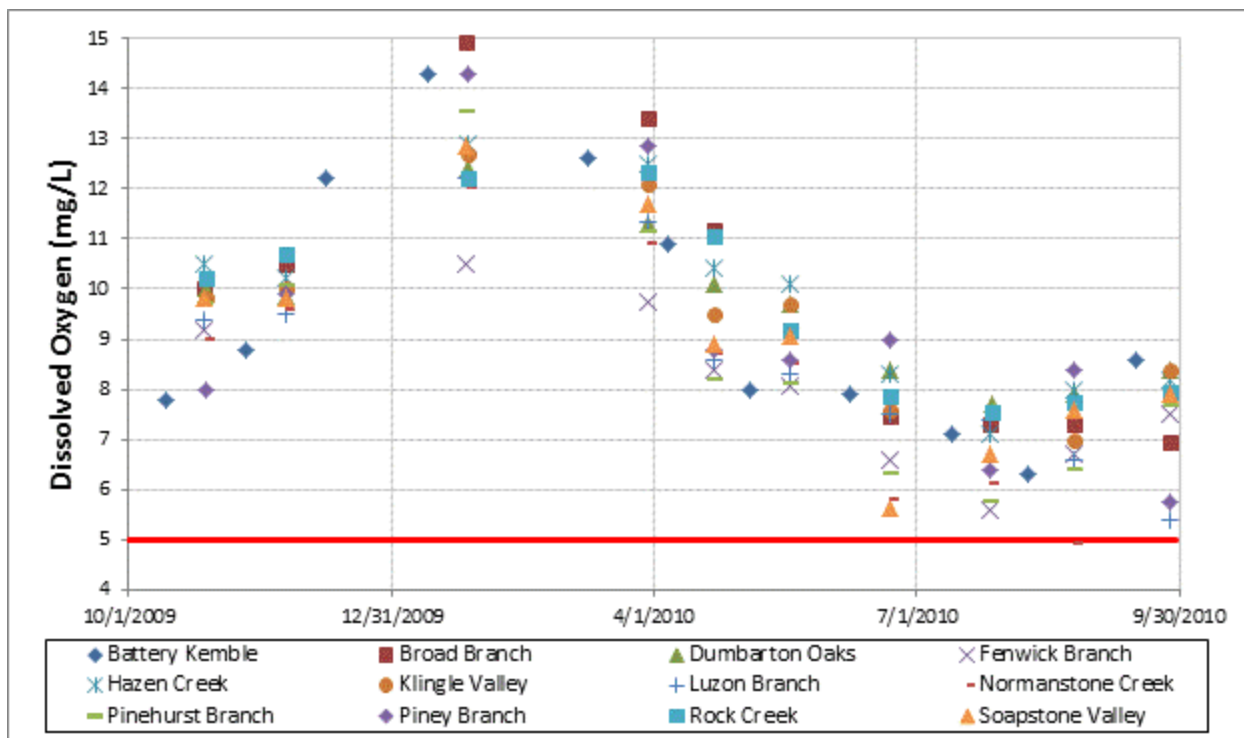


Figure 127: Dissolved Oxygen in ROCR streams FY 2010

Dissolved oxygen (Figure 113) was consistently acceptable, and displayed a typical seasonal pattern.

Wolf Trap National Park for the Performing Arts (WOTR)

Wolf Trap National Park for the Performing Arts is located in Fairfax County, Virginia within the Potomac River Watershed and the Piedmont physiographic province. Within the boundaries of the park are streams, meadows and wooded areas. The park's three streams, Old Court House Branch, Wolf Trap Creek, and Wolf Trap Run (Figure 128), and their riparian forest are among the park's most important natural resources. Water quality is a major concern for the park. Stream bank erosion has occurred due to increased development around the park. The erosion may threaten the maintenance yard in the future. This erosion has led to sediment deposition. Runoff from the Dulles Toll Road may have detrimental effects. Streams are also impacted by fertilizer runoff from the park's landscaping, parking lot runoff, and runoff from salt storage in the maintenance yard.

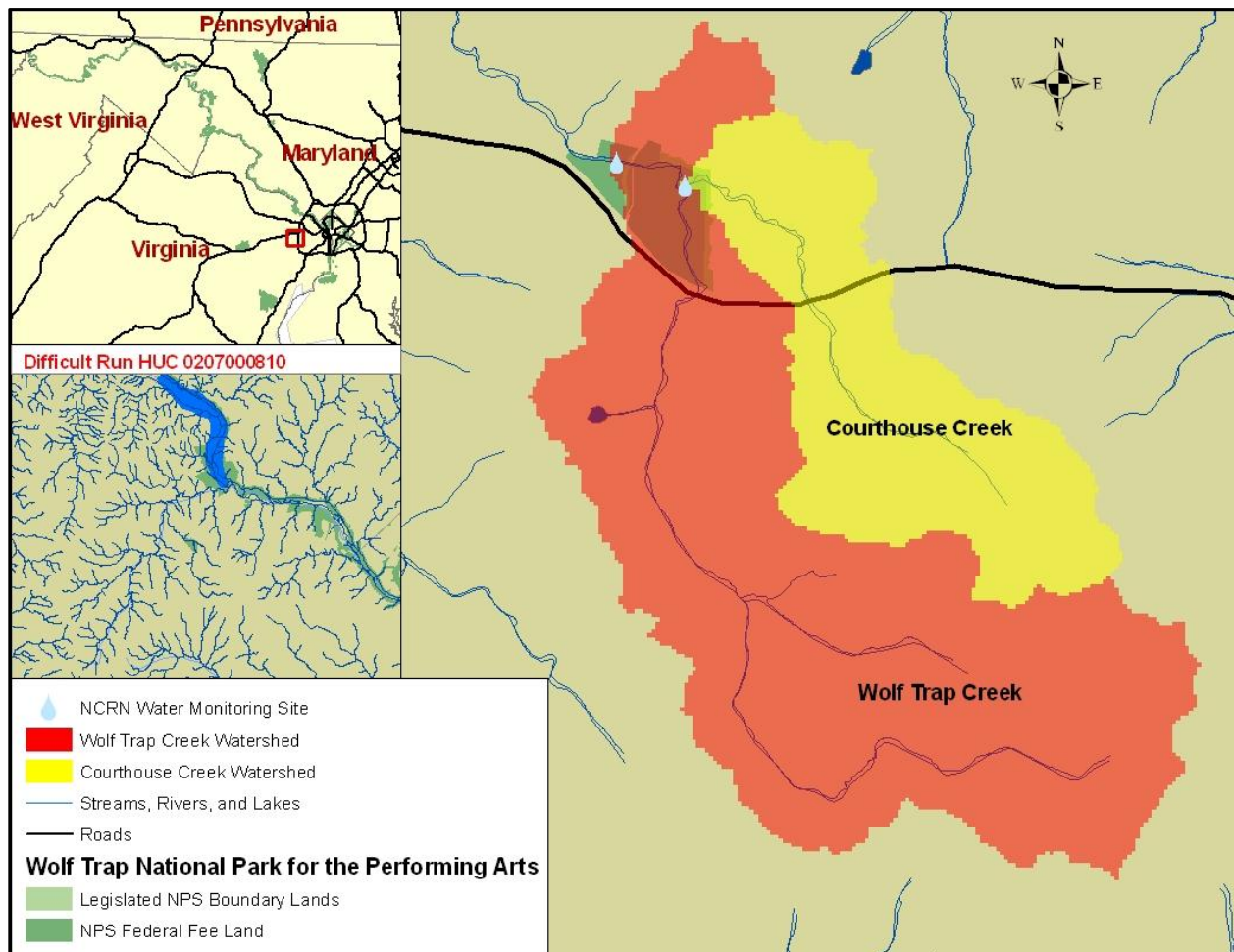


Figure 128: NCRN stream monitoring sites and associated watersheds within WOTR

Table 15: FY 2010 Summary statistics for vital signs collected at WOTR

Parameter (Units)	Minimum	Maximum	Mean	Median	Standard Deviation
Air Temperature (°C)	1	29.2	15.2	14.5	9.2
Water Temperature (°C)	3.7	24.4	13.8	12.1	6.4
ANC (µeq/L)	286	960	670.8	708	164.4
pH	6.93	7.59	7.29	7.30	0.17
Salinity (ppt)	0.06	0.33	0.15	0.14	0.06
Specific conductance (µS/cm)	123.2	685.2	309.2	292.1	126.8
DO (mg/L)	7.25	13.8	10.1	9.8	2.17
Nitrate (mg/L)	1.2	2.8	1.9	1.8	0.45
Total Phosphorus (mg/L)	0.1	0.61	0.25	0.23	0.13
Discharge (cfs)	0.56	8.7	3.21	2.21	2.57
Flow (ft/sec)	0.16	1.9	0.65	0.49	0.53
Water Depth (ft)	0.27	0.7	0.41	0.36	0.13
Wetted Width (ft)	6	21.5	12.4	11.9	4.54

This report discusses data collected October 2009 through September 2010 in Wolf Trap Creek and Courthouse Creek. Summary statistics for the time period for both stream sampling sites are presented in Table 15. Two sites were monitored on a monthly basis for dissolved oxygen, pH, specific conductance, temperature, acid neutralizing capacity, nitrate, total phosphorus, depth, wetted width, flow and discharge.

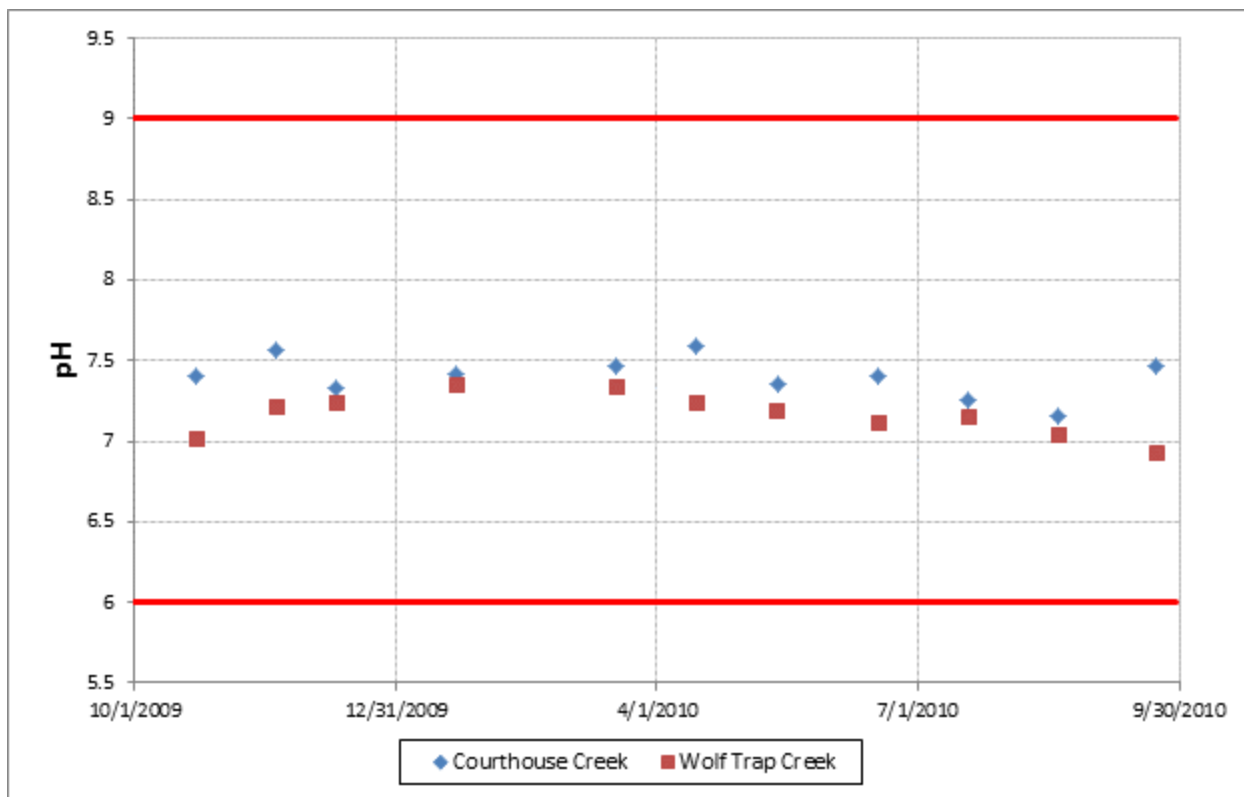


Figure 129: pH in WOTR streams FY 2010

Both pH (Figure 129) and acid neutralizing capacity (Figure 130) were in the acceptable range.

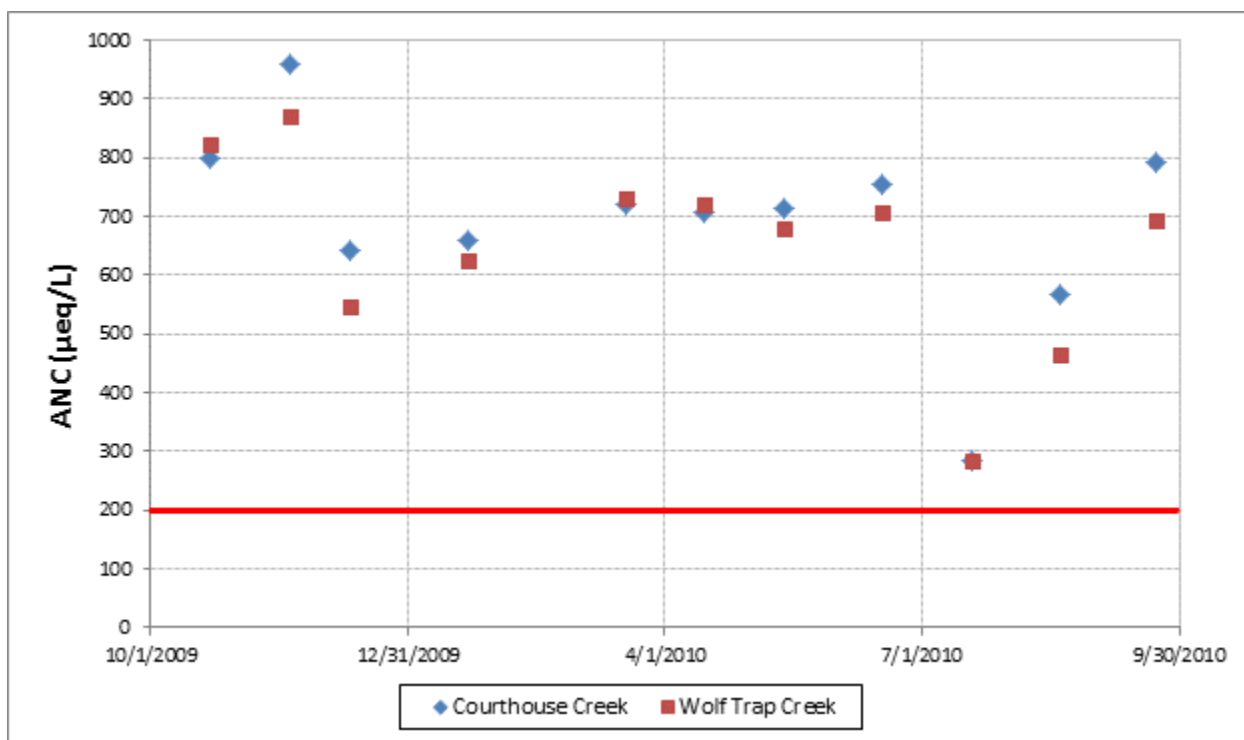


Figure 130: Acid Neutralizing Capacity in WOTR streams FY 2010

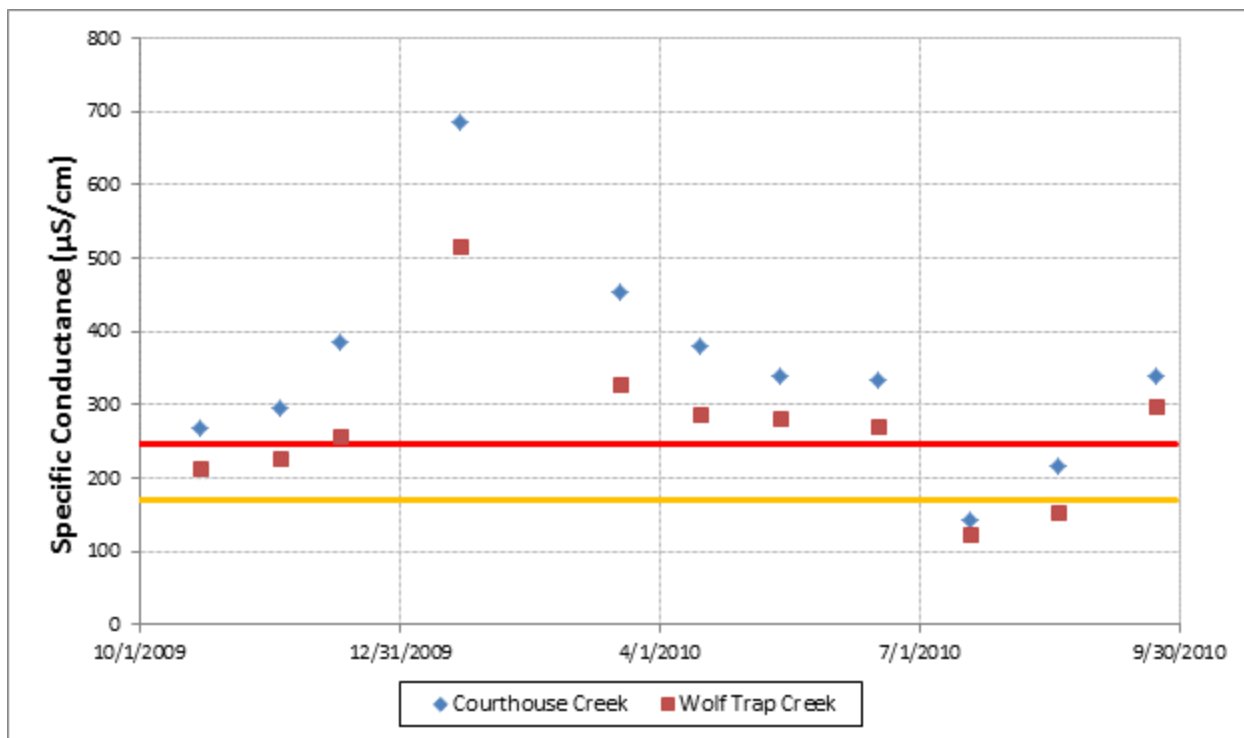


Figure 131: Specific Conductance in WOTR streams FY 2010

Specific conductance (Figure 131) typically exceeded ecological thresholds for aquatic life stress (orange = fish threshold; red = macroinvertebrate threshold) at all sites except a handful of instances. Salinity (Figure 132) was consistently acceptable for fresh water.

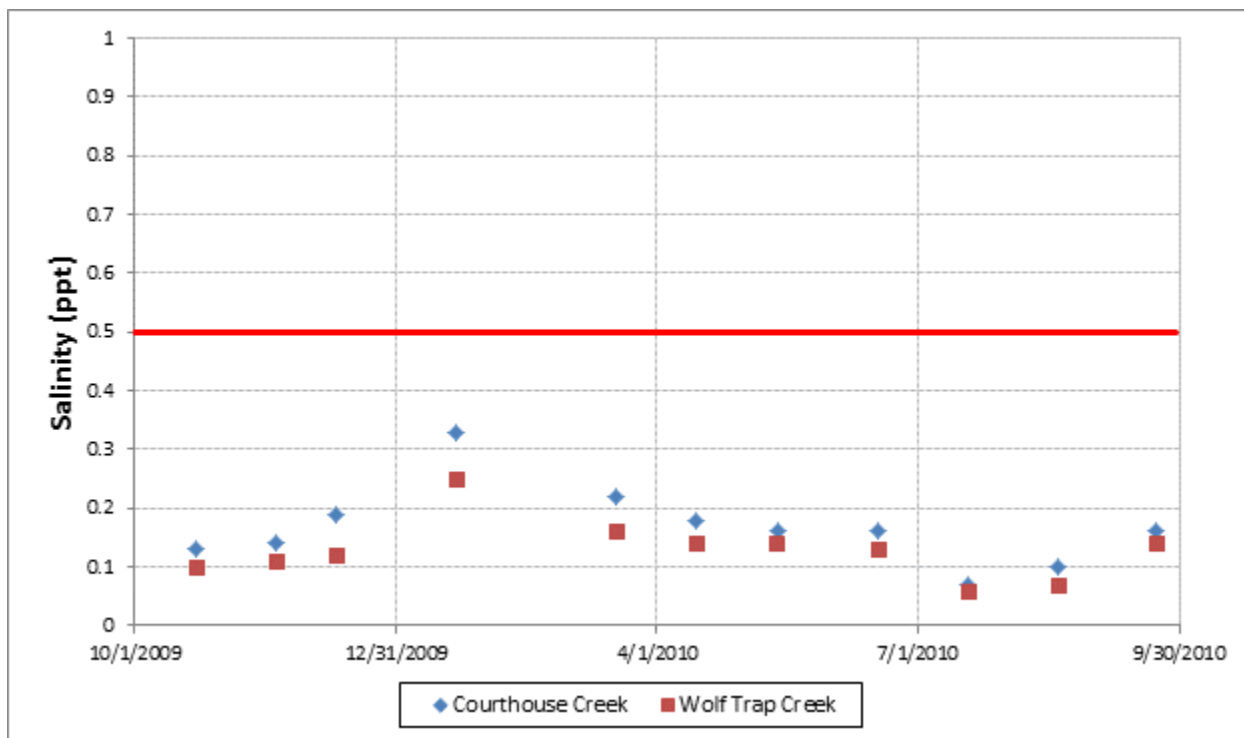


Figure 132: Salinity in WOTR streams FY 2010

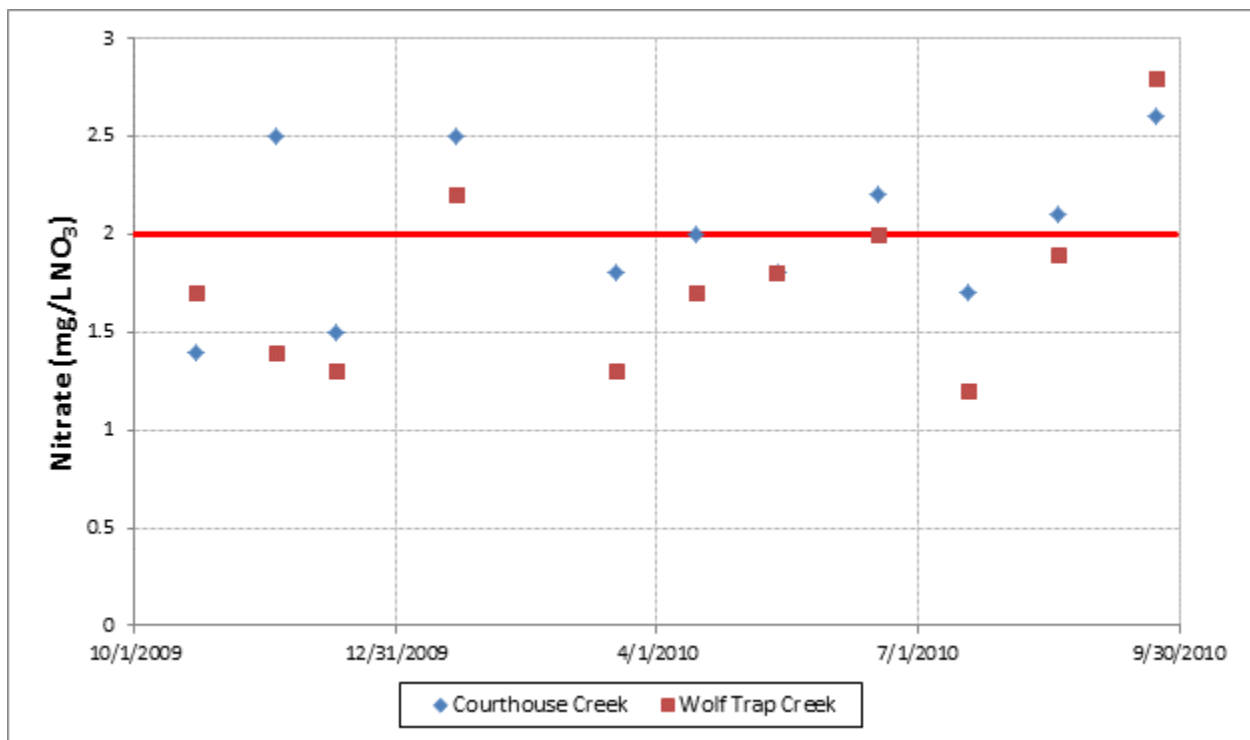


Figure 133: Nitrate in WOTR streams FY 2010

Nitrate levels (Figure 133) were nearly equally split between meeting or exceeding threshold limits, with no discernible pattern. Phosphorus levels (Figure 134) consistently exceed threshold and eutrophication values.

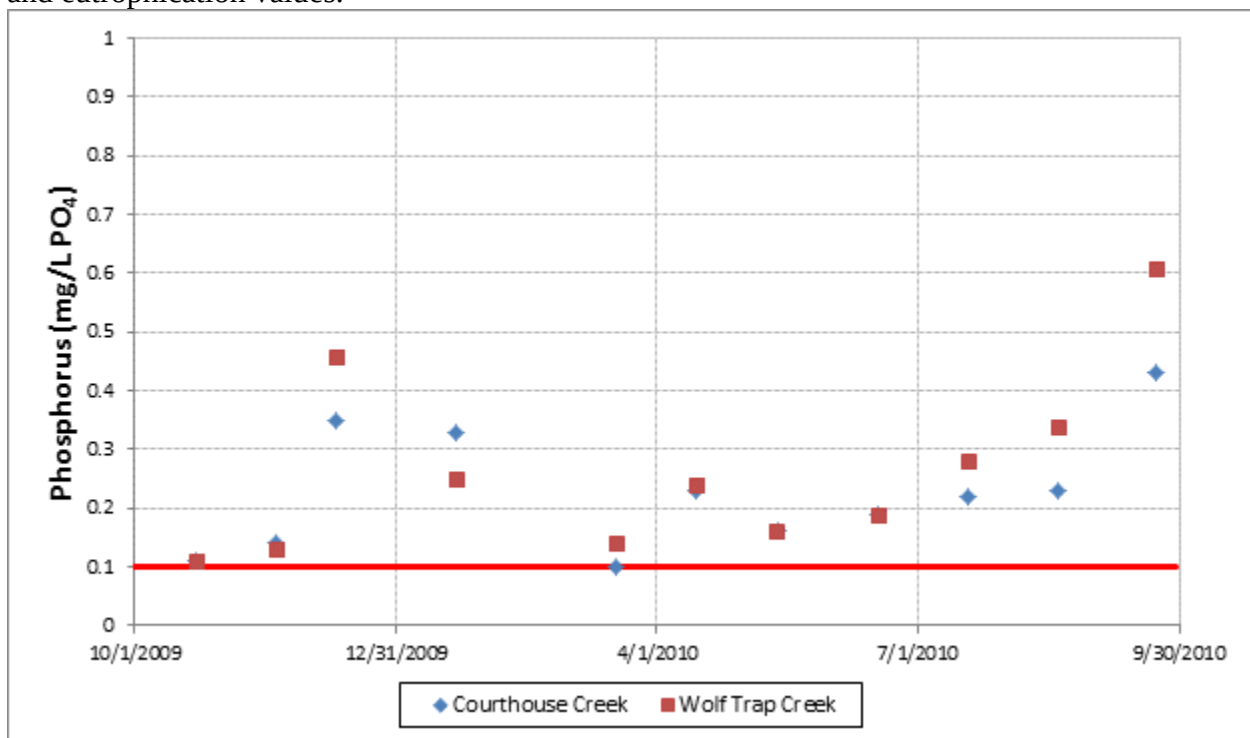


Figure 134: Phosphorus in WOTR streams FY 2010

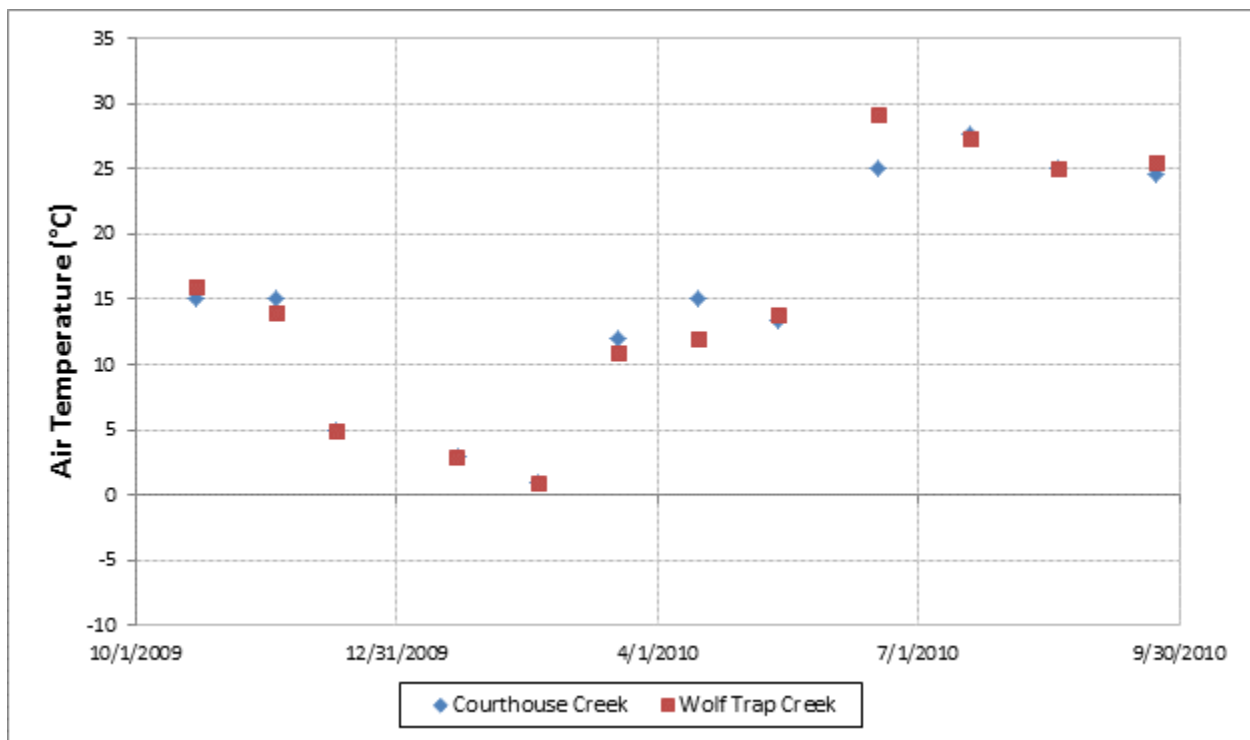


Figure 135: Air Temperature in WOTR streams FY 2010

Water temperatures (Figure 136) always fell within the acceptable range, and followed the same pattern as air temperatures (Figure 135), suggesting that the streams are primarily surface-fed.

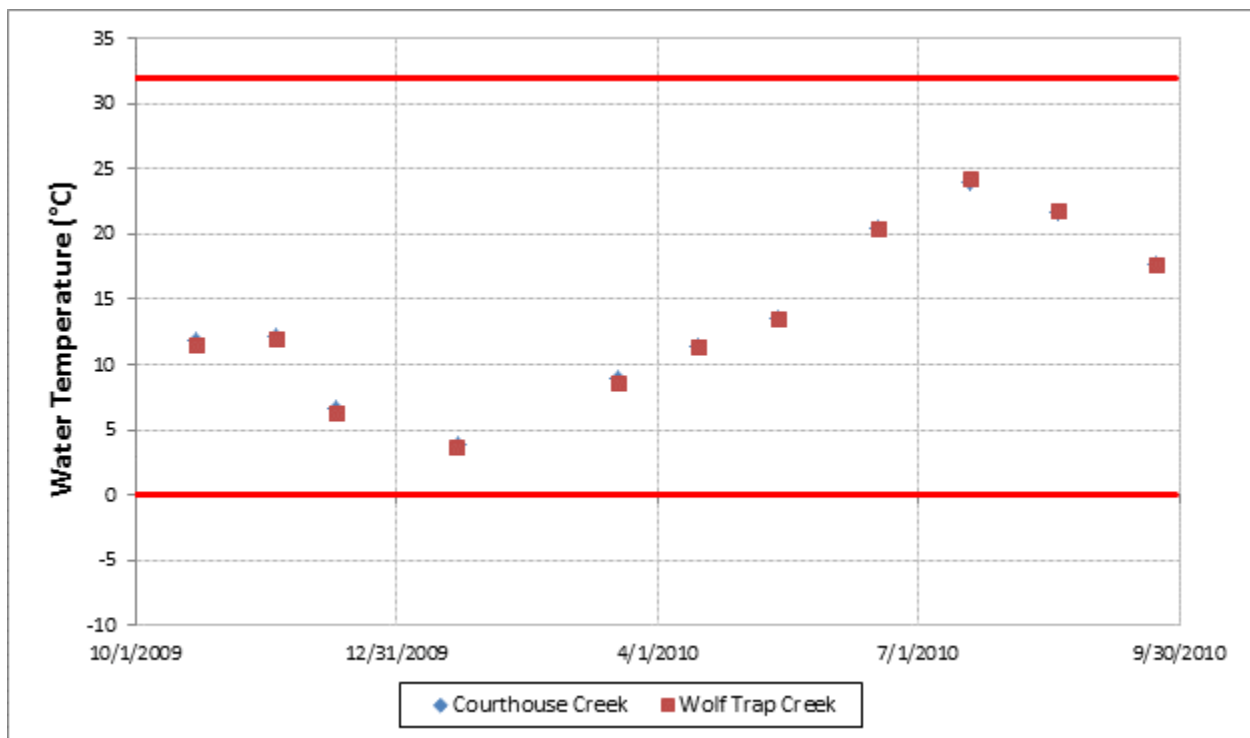


Figure 136: Water Temperature in WOTR streams FY 2010

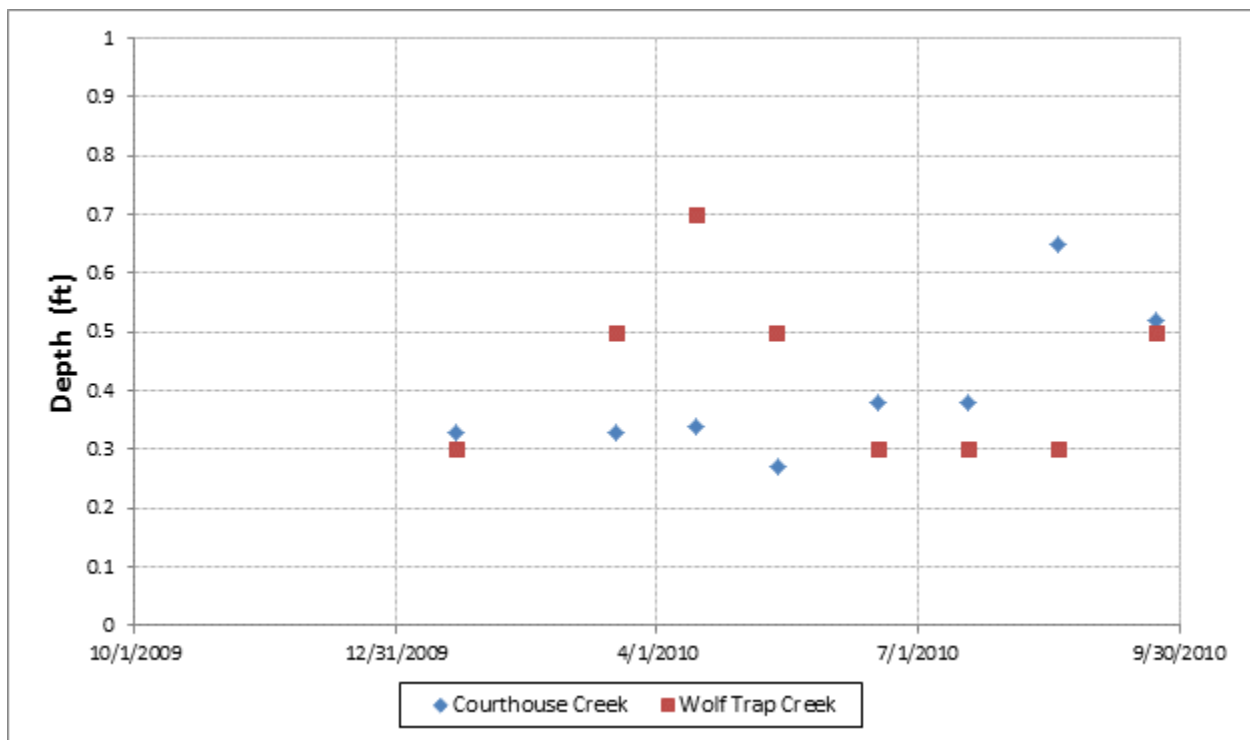


Figure 137: Stream depth in WOTR streams FY 2010

Missing depth data points (Figure 137) from October through December are due to equipment failure.

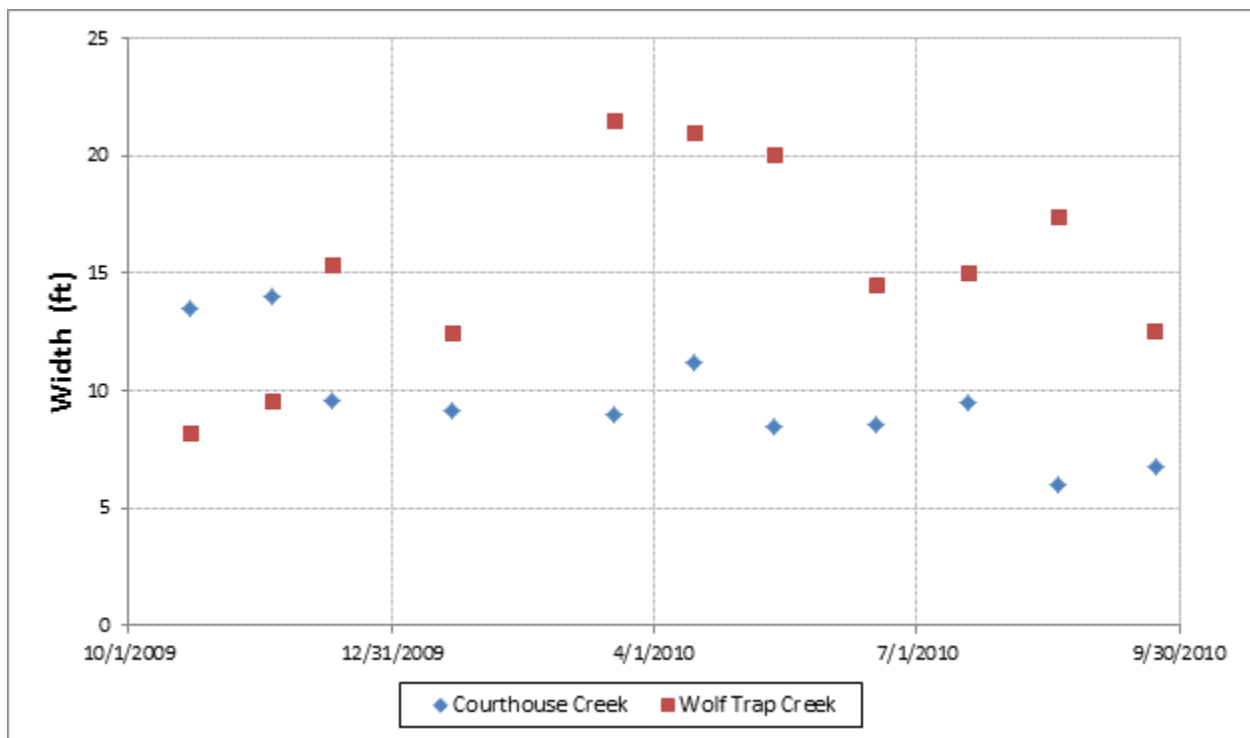


Figure 138: Stream width in WOTR streams FY 2010

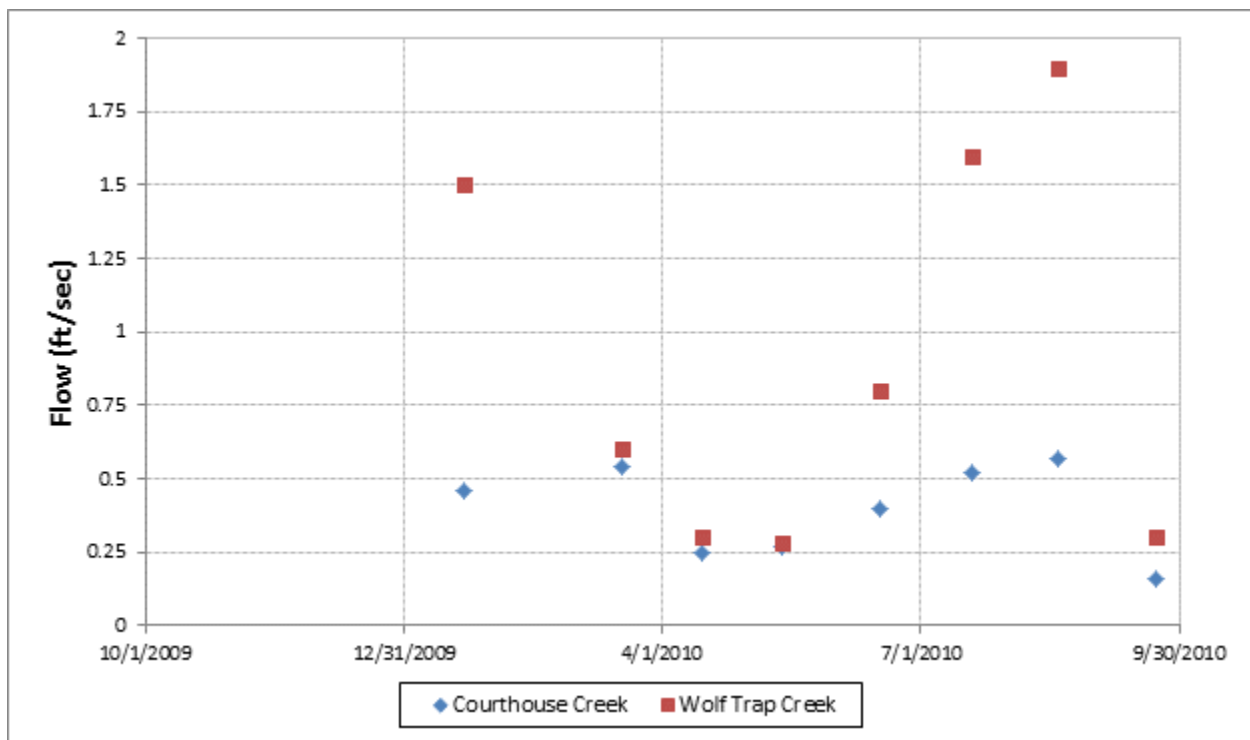


Figure 139: Stream flow in WOTR streams FY 2010

Missing flow data points (Figure 139) and missing discharge data points (Figure 140) from October through December are due to equipment failure.

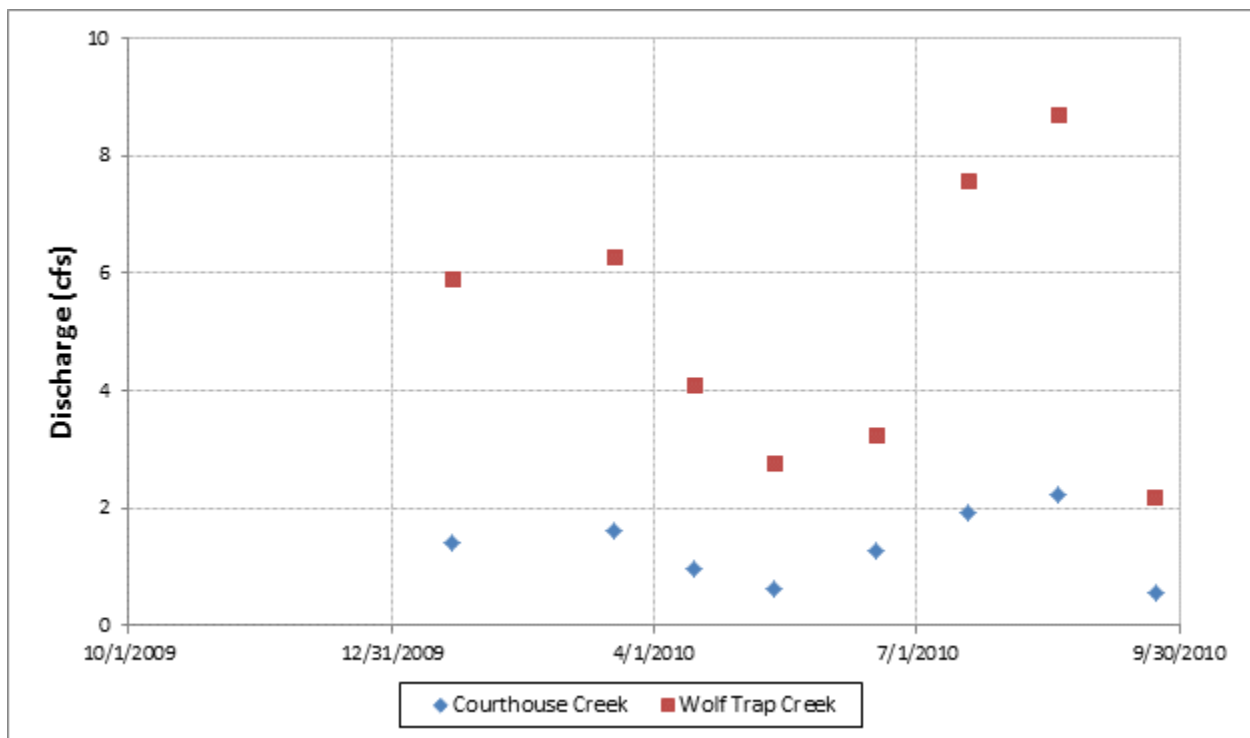


Figure 140: Stream discharge in WOTR streams FY 2010

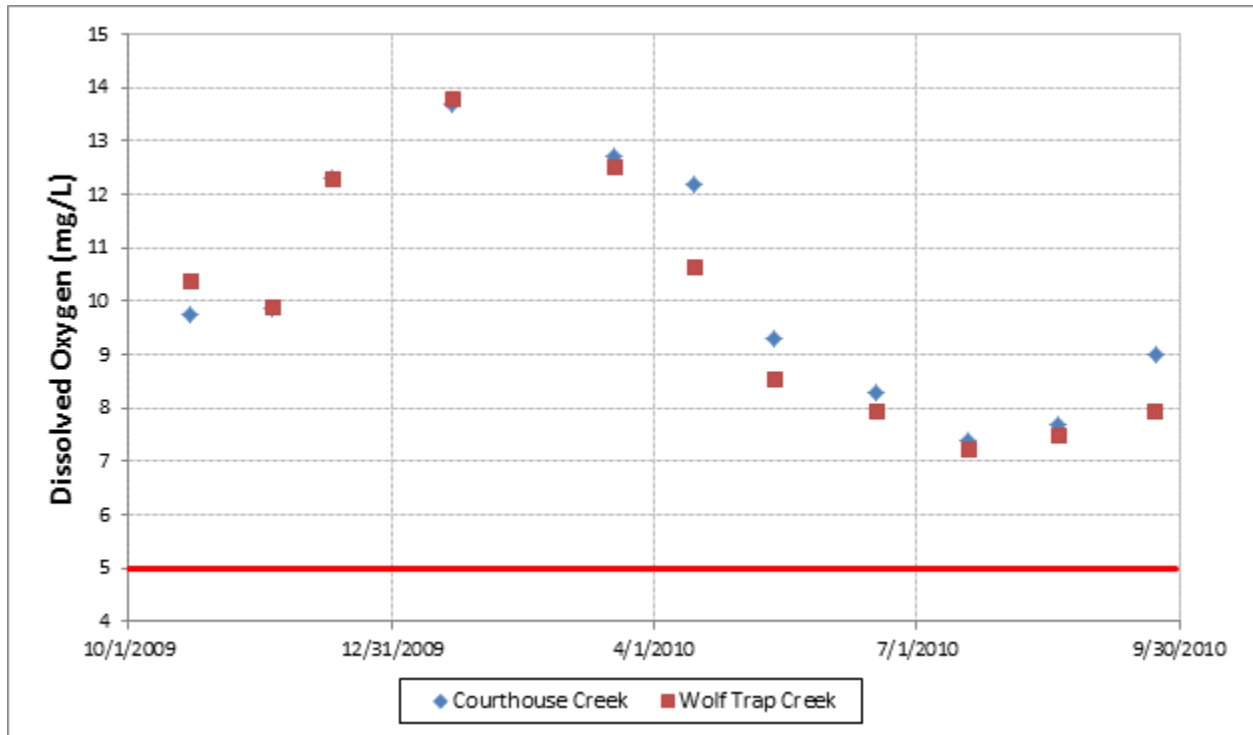


Figure 141: Dissolved Oxygen in WOTR streams FY 2010

Dissolved oxygen (Figure 141) was consistently acceptable, and displayed a typical seasonal pattern.

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NPS 800/117240, October 2012

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