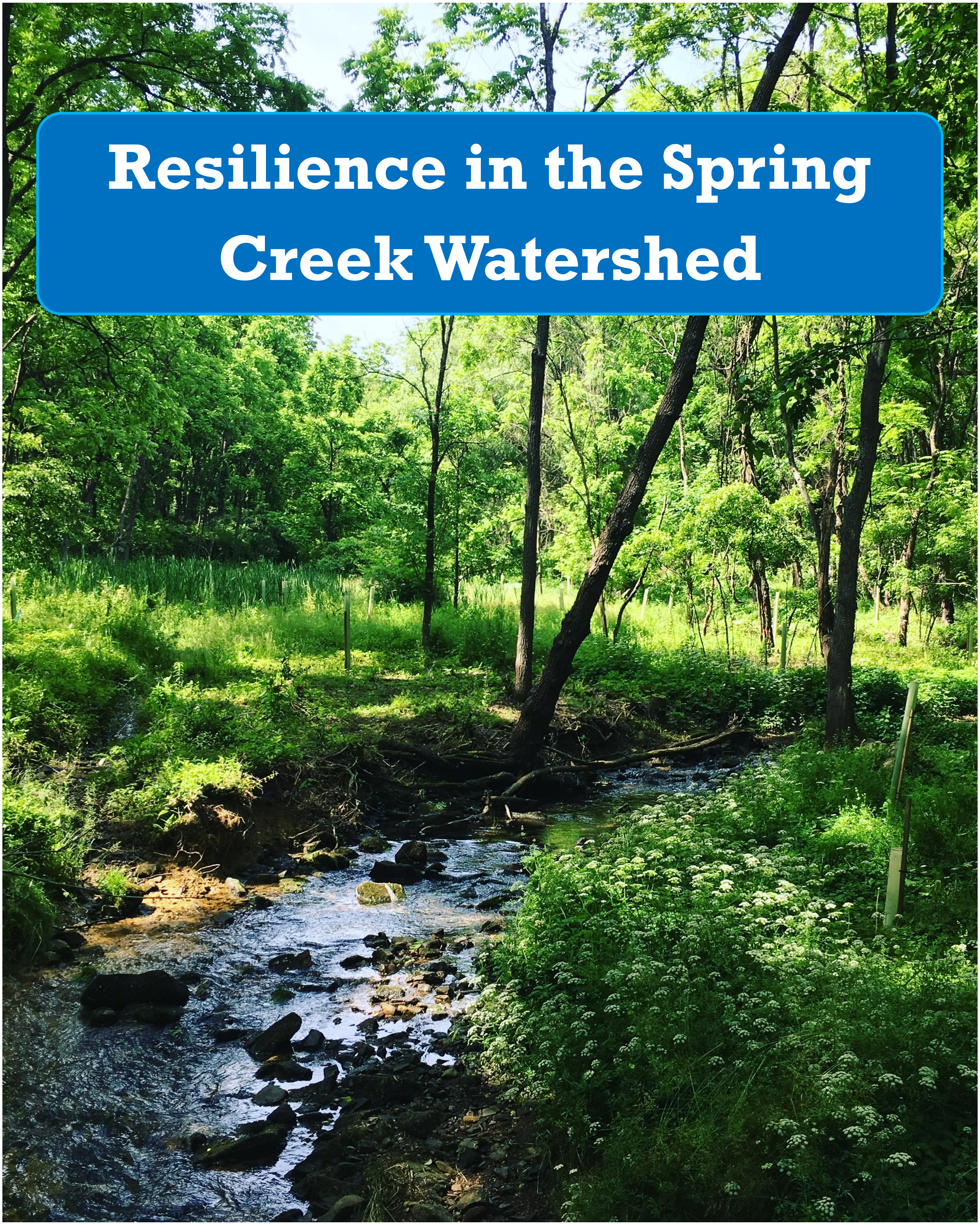


Resilience in the Spring Creek Watershed

KEYSTONE Water Resources CENTER

The Spring Creek Water Resources Monitoring Project (WRMP) is conducted in partnership with the Keystone Water Resources Center, a publicly-funded non-profit organization with the mission of collecting scientifically useful data on the water resources of Pennsylvania and making those data available to the public. The following municipalities and organizations provide financial support for the WRMP to collect the necessary data for establishing long-term water resource data trends within the Spring Creek basin:

Bellefonte Borough

Benner Township

College Township

Ferguson Township

Halfmoon Township

Patton Township

University Area Joint Authority

Penn State University

Spring Township

Spring Township Water Authority

State College Borough

State College Borough Water Authority

Spring Creek Chapter of Trout Unlimited

Table of Contents

Introduction

Sources of Resilience in the Spring Creek Watershed

Monitoring Methods and 2019 Data

Introduction

What is Watershed Resilience?

"Over time, all watersheds experience a variety of disturbance events such as fires and floods. Resilient watersheds have the ability to recover promptly from such events and even be renewed by them." –USFS/USDA

Fig 1. Debris pile-up after large flooding event on Spring Creek near Fisherman's Paradise.

Due to current climate change predictions for potential increases in frequency and intensity of extreme weather events, the concept of understanding, maintaining and restoring resilience within our landscapes and watersheds is a growing field of interest. Resilience can be broadly defined as the ability of a system to recover from an outside disturbance. In other words, a resilient system will not significantly change after a disturbance but rather return to its pre-disturbance state within a relatively short period of time. Watersheds are often faced with outside disturbances that can potentially impact their stability. Natural disturbances can include floods (Figure 1), droughts, vegetative die-off and wildfires, while anthropogenic land use changes can also cause disturbances. All of these disturbances can disrupt streambank stability and subsequently degrade water quality and aquatic life. Additionally, extreme flood events can alter stream channel structure and extreme droughts can greatly increase stream temperatures and also potentially result in aquatic and vegetation stress or die offs. However, inherent watershed characteristics can provide resilience to many of these disturbances.

Natural Sources of Resilience

Fig 2. Vegetated riparian zone along Slab Cabin Run. Source: PSU

Within a watershed, vegetative growth can provide an important source of resilience. Plant root systems help maintain soil structure and subsequently the ability of soil to both absorb and retain water. Plants also take in nutrients and can slow the flow of runoff during storm events. In particular, riparian cover along stream banks and within flood plains provides the most critical sources of resilience for a healthy stream (Figure 2). Larger trees and shrubs in the riparian and flood zones of a river provide stability for the streambank, further slow flood waters and trap sediment. Additionally, riparian cover provides shade, a critical buffer to increases in stream temperature during summer months.

Fig 3. Blue Spring in Boalsburg, PA emerging directly from the subsurface.

Groundwater inputs into streams through seeps and springs, which have an average temperature of around 50°F in this region, can also provide a source of water as well as a thermal buffer during times of drought. The potential for higher discharge rates and subsequent increased thermal capacity and stream velocity to reduce a stream's sensitivity to direct radiation and air temperature has been well documented (Webb at al., 2008; Hofmeister et al., 2015; Hannah & Garner, 2015). Regardless of groundwater contribution, larger streams in general are less sensitive to reduced riparian cover. However, groundwater contribution can both increase discharge rates and temperature buffering capacity through the addition of cooler groundwater.

Another major source of resilience in watersheds is the presence of wetlands. Wetlands can help in reducing the impacts of floods as well as in providing a source of water during periods of drought. During extreme flood events, wetlands provide an area for excess water, sediment and nutrients to accumulate.

Threats to Resilience - Land Development

While many of these sources of resilience are found in undisturbed watersheds, human development has greatly changed the landscape of many watersheds in a way that can both alter natural sources of resilience and amplify the intensity of disturbances like floods and drought.

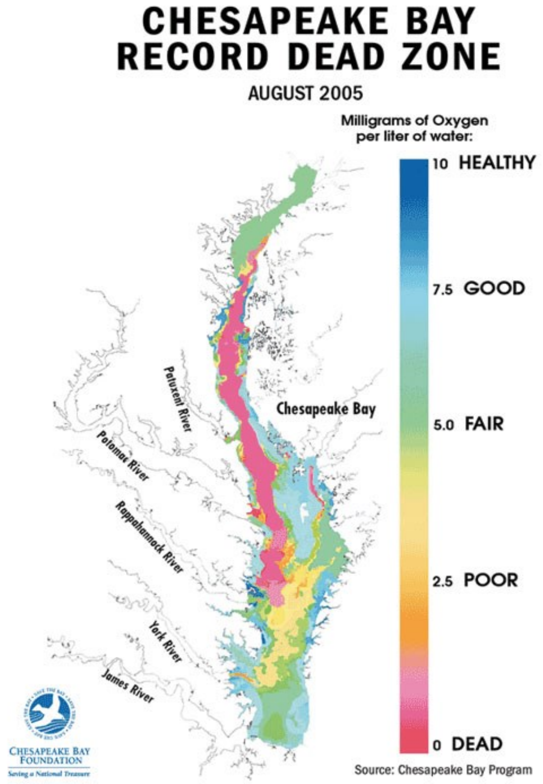
One major impact of development on watershed resilience is the potential for much larger floods following storm events. Cities, neighborhoods, parks and roads all require infrastructure that removes vegetation from the landscape and often replaces it with impervious surfaces like pavement. Because rainfall cannot penetrate impervious surfaces to infiltrate the soil or be absorbed by plants, much of that rainfall becomes surface runoff that will likely end up in a stream thereby increasing total flood water volume. Additionally, urbanized areas around streams often do not take into account the natural floodplain of a stream so in order to accommodate floods and urban/suburban infrastructure, streams are often channelized and connected to a network of stormwater drainage systems (Figure 4). In addition to the removal of floodplains and the replacement of vegetation with impervious surfaces,

Fig 4. Slab Cabin Run flooding where it is channelized to go under Route 26 in College Township.

many wetlands have also been drained in order to accommodate urban/suburban development as well as agriculture. Therefore, human changes to the landscape have increased the potential for larger flood events with less potential for the landscape to naturally infiltrate and store water. Large floods can cause severe damage to streambanks and stream channels and therefore disrupt habitat for aquatic species.

Another major impact of development on watershed resilience is the potential for increased thermal and physiochemical pollution. Similar to increased potential for floods, pollution in runoff can result from decreased natural vegetation and increased urban, suburban and agricultural land-use. Surface runoff from both agricultural and urban/suburban areas picks up sediment and chemical pollutants, such as metals, oils, greases, pesticides, fertilizers, and other organic compounds, before entering streams. Additionally, during summer months, runoff from impervious surfaces can pick up heat from the pavement. Solar radiation transfers heat to paved sidewalks, roads and parking lots. When rain contacts these surfaces, heat is transferred from the paved surface to the water. During summer months, experiments have shown rain can cool paved surfaces by more than 20°F while runoff from asphalt averages 9°F warmer than runoff from lawns or agricultural soils (Thompson et al., 2008). Because of this temperature difference, one of the largest non-point source contributors of thermal pollution in urban areas is runoff during summer storm events, particularly preceded by full or partial sun exposure (Herb et al., 2008).

All aquatic lifeforms have a range of tolerance to water temperature, nutrients and other chemical levels, so changes in these levels can alter populations of aquatic species. Surface runoff with excess nutrients can lead to eutrophication, a process where algae grows so densely that light cannot penetrate through its surface. The lack of sunlight reduces other plant life and dissolved oxygen levels to a level that most aquatic life cannot survive. Eutrophication and expansive dead zones, areas where fish, crabs and other aquatic life can no longer survive, are an urgent problem in the Chesapeake Bay (Figure 5). Eutrophication is a common example of a watershed changing from a pre-disturbance state to a new, post-disturbance state, the opposite of watershed resilience.



Source: Chesapeake Bay Program

Fig 5. Record dead zone in the Chesapeake Bay. Source: Chesapeake Bay Foundation

The last major potential for human development to impact watershed resilience is through increased water withdrawals and inputs because as populations increase within a watershed so too does water consumption. Water is needed for personal, commercial, industrial, power generation and agricultural uses. All of the residential and commercial water is then treated and generally is discharged back into the watershed at a downstream location with at a higher temperature and chemical constituent level due to water heaters, softeners and the inability of and lack of necessity for cost effective filtration systems to remove every chemical.

Threats to Resilience - Climate Change

Fig 6. Spring Creek flooding in Talleyrand Park in 2018. Source: Centre Daily Times

Just as changes in landscape development can impact natural sources of resilience, so too can climate change. Models predict increased frequency of large storm events in the Northeast Region of the United States, including the Spring Creek Watershed (Stocker et al., 2013). 2018 was the wettest year on record in Pennsylvania and Spring Creek experienced many large floods (Figure 6). Frequent and high peak flows can erode stream channels and banks and increase sediment and nutrient levels within the stream (Boothe and Jackson, 1997; Paul and Meyer, 2001). Sediment is a critical water quality issue in the United States that can cause both ecological and economic disasters through decreases in stream biodiversity and impacts on flood control measures and water storage areas (Simon et al., 1999; Gauge et al., 2004).

Increases in air temperature can lead to soil moisture droughts in Pennsylvania that could also alter the resilience of watersheds. Warm air temperatures increase surface evaporation rates as well as transpiration rates, the rate at which plants utilize water in the soils. This combination of increased water uptake and evaporation with increased air temperatures could potentially amplify the thermal effects of droughts on streams. When the thermal regime within a stream is significantly altered even just during summer months, shifts in aquatic populations can occur.

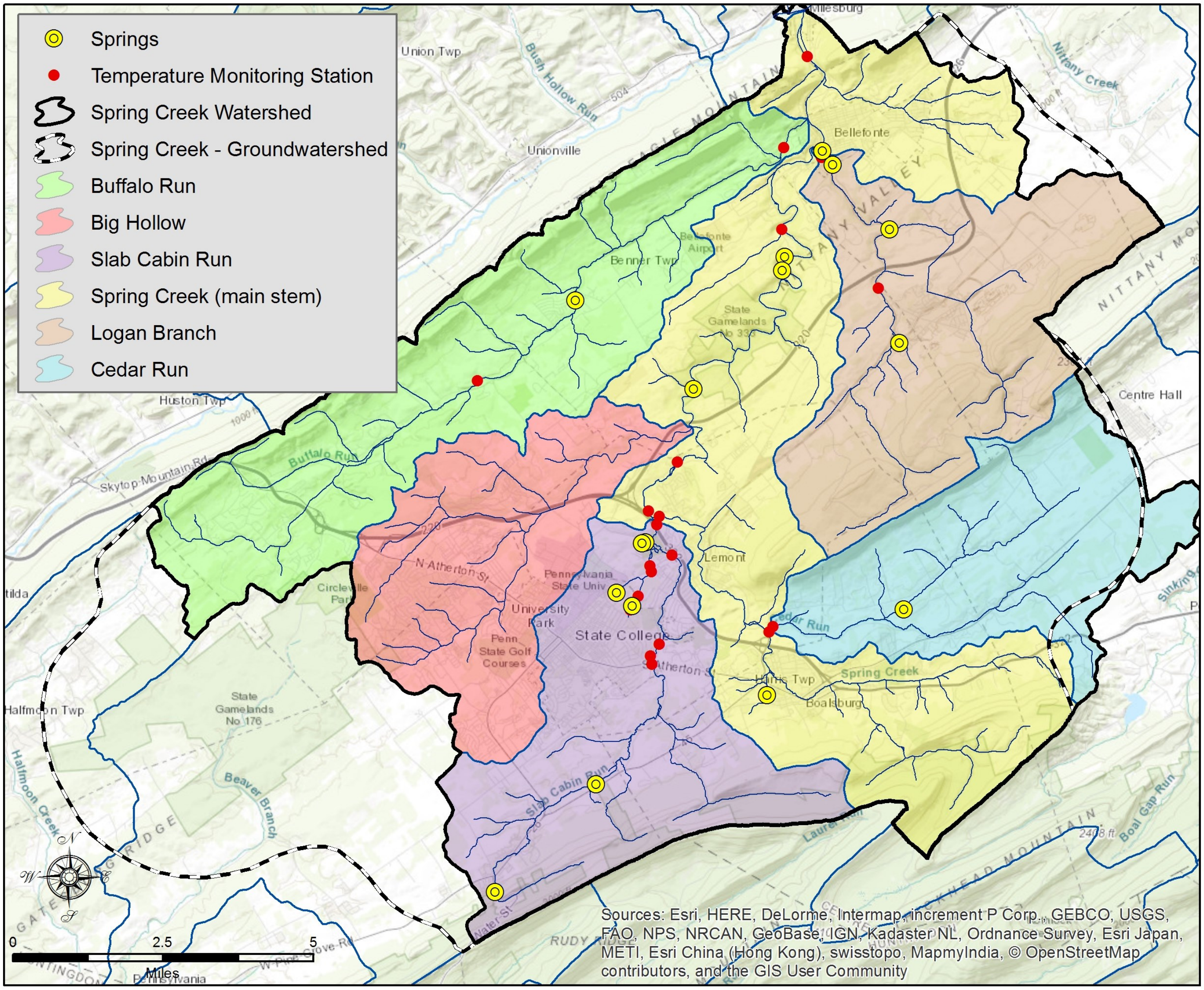
Best Management Practices—Protecting Resilience

In order to address the adverse effects of human development on watersheds, many communities, government agencies, and organizations implement and/or mandate watershed restoration projects and best management practices (BMPs) designed to reduce both natural and human impacts. These types of management practices can include restoring riparian buffers, building infrastructure to store stormwater run-off as well as in-stream habitat and stream structure restoration projects. The following section describes some of the BMPs used within the Spring Creek Watershed.

Sources of Resilience in the Spring Creek Watershed

Groundwater Inputs

The valleys within the Spring Creek Watershed are characterized as karst terrain, which consists of carbonate (limestone and dolomite bedrock), which have many large springs from underground aquifers that directly discharge groundwater into streams as well as areas where groundwater diffuses through the streambed into the streamflow (Fulton et al., 2005). There are at least seven large springs in the watershed that each contribute 1.4 cubic feet per second of outflow directly into Spring Creek and its tributaries (Figure 7, Carline et al., 2011). In addition to large springs, numerous sink holes in the watershed allow surface water to directly enter the aquifer where it can be cooled. These inputs help moderate sea-



Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Fig 7. Large springs within the Spring Creek Watershed sonal stream temperature changes by maintaining cooler stream temperatures in the summer and warmer temperatures during the winter (Tague et al., 2007). A water budget analysis of the Spring Creek Watershed discovered that approximately 85 percent of the total annual flow through the main stem of Spring Creek at Milesburg was contributed by groundwater (Giddings, 1974). With large groundwater inputs, streams may experience much less sensitivity to atmospheric and anthropogenic factors and maintain temperature ranges much closer to groundwater temperature.

However, some reaches of streams within the watershed receive more groundwater input than others. For example, Thompson Spring provides much of the baseflow to Thompson Run, which maintains seasonal temperatures much closer to groundwater temperature than other streams of similar size like the middle and upper reaches of Slab Cabin Run. Figure 11 shows that the Upper Slab Cabin Run monitoring station exhibits a much higher range of daily average temperature than the Lower Thompson Run Monitoring Station.

Not only does groundwater help to maintain lower seasonal variation in Thompson Run, this input also mitigates the immediate impact of urban development. The entire Thompson Run watershed is covered in approximately 50% impervious surface and the flow path of the stream was actually channelized and redirected due to business development along Route 26. The stream receives a great deal of surface runoff during storms, particularly from Walnut Run and Route 26, which is reflected in the high, variable peaks of maximum stream temperature during warm months (Figure 8). The large amount of cool water entering the stream quickly restores stream temperatures back to a healthy level thereby providing a natural source of thermal resilience to potential impacts from urban development.

Groundwater inputs can also provide thermal resilience during times of drought by providing a critical

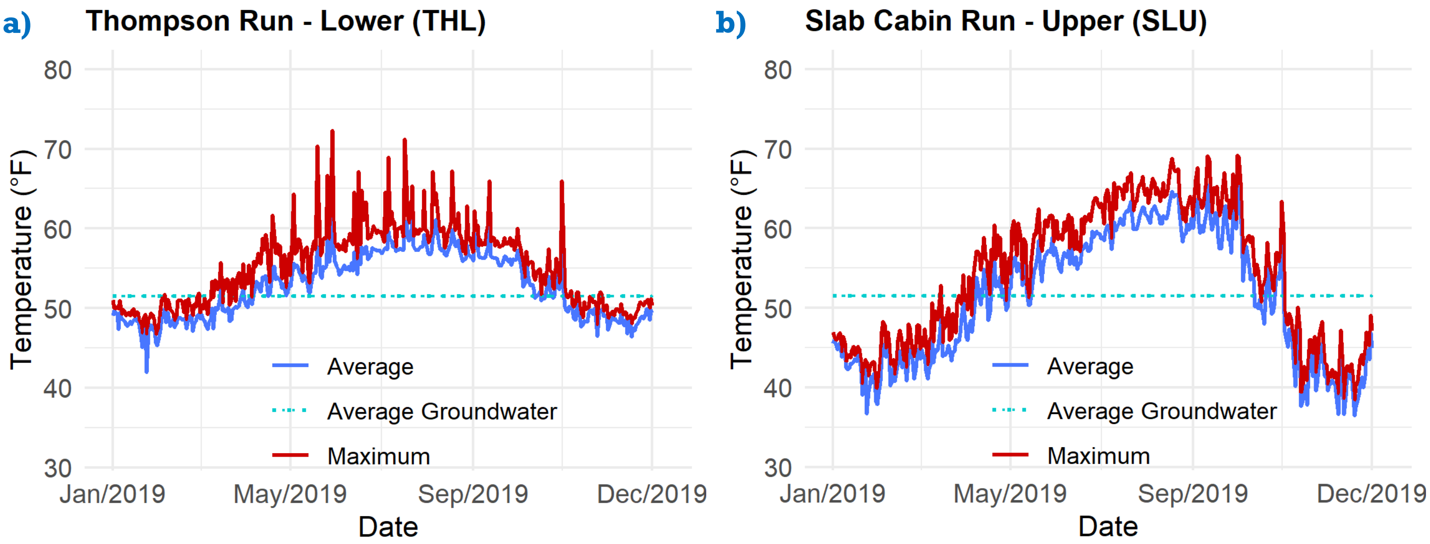


Fig 8. Daily average and maximum temperatures in 2019 for the Lower Thompson Run and Upper Slab Cabin Run monitoring stations.

source of cool water. In 2016, the Spring Creek Watershed experienced a prolonged drought in the summer. Upper reaches of Slab Cabin Run essentially stopped flowing. Figure 9 outlines daily average, maximum and median stream temperatures at the Upper Slab Cabin Run and Lower Logan Branch monitoring stations during this period of drought. During the summer of 2016, when air temperatures rose and water levels fell, stream temperature in Slab Cabin Run rose substantially above median levels with maximum temperatures exceeding the lethal temperature for trout survival on some days before the streamflow became too low to monitor. On the other hand, the Lower Logan Branch station, which receives substantial groundwater, maintained average and maximum stream temperatures levels near median levels. Groundwater input provided critical, cool water to maintain healthy stream flows and temperatures. This impact can also be seen in lower reaches of Slab Cabin Run, after its confluence with Thompson Run, where in 2016, maximum stream temperatures never rose above the lethal threshold for trout.

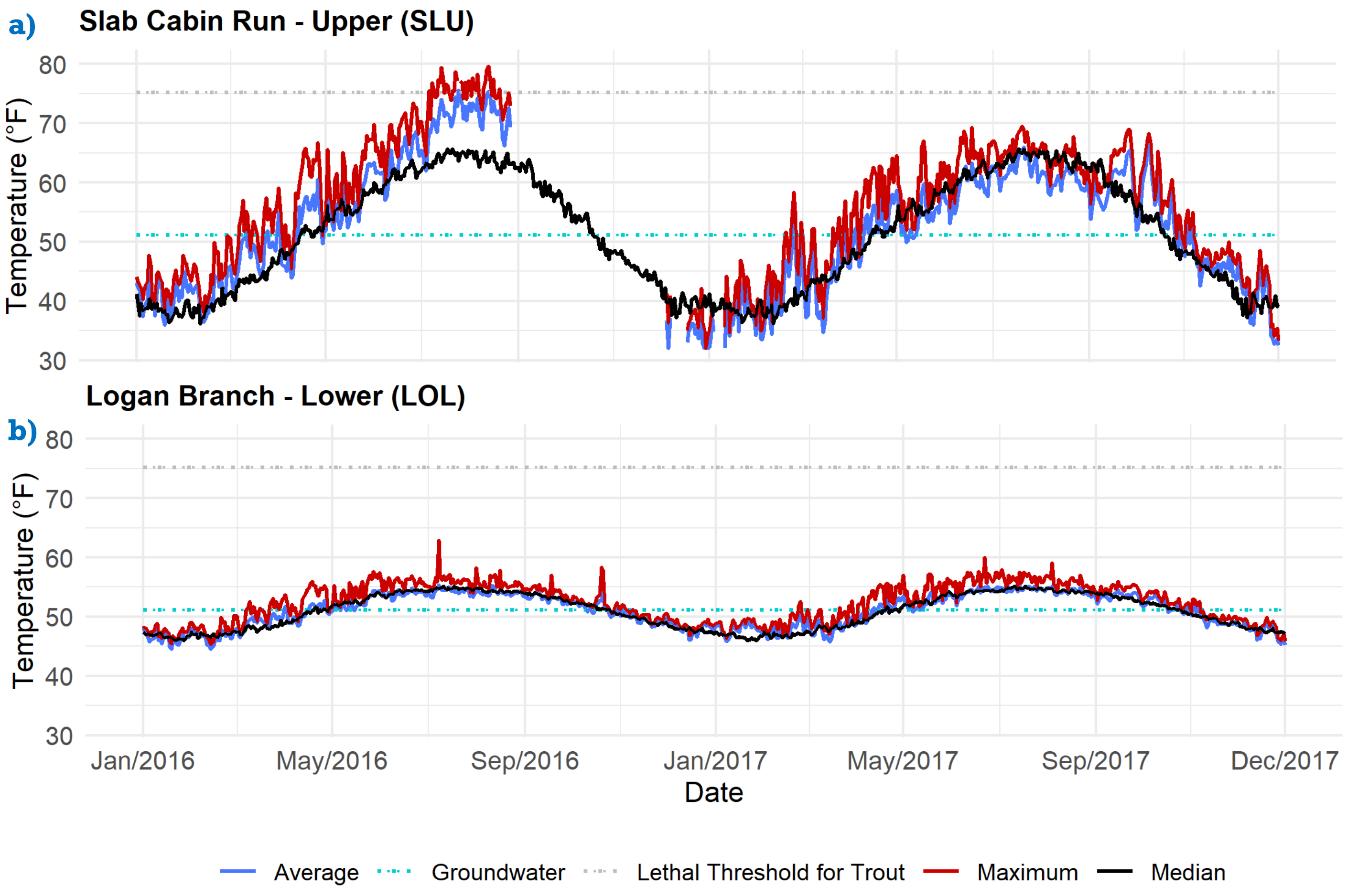


Fig 9. Daily average and maximum temperatures in 2016-17 for the Upper Slab Cabin Run and Lower Logan Branch monitoring stations.

Best Management Practices to Reduce Pollution

A number of national, state and local mandates help to ensure that the possible impacts of human activities and land development are reduced. For example, the EPA's Chesapeake Bay Pollution Reduction Plan has led to the Pennsylvania Watershed Implementation Plan that outlines all of the best management practices that can be implemented in order to meet pollution reduction goals set by the EPA. These best management practices address issues such as stormwater and agricultural runoff as well as industrial water releases. At the local level, all of the municipalities in the Spring Creek Watershed address watershed issues in some way. The Spring Creek Watershed Commission, which is made up of representatives from each municipality, ensures that local governing bodies are educated on current watershed issues. Some examples of local mandates include riparian buffer requirements, sourcewater protection regulations near wells and critical areas of groundwater recharge, proper well and wellhead construction protocols, ridgetop protection ordinances and conservation subdivisions to ensure rural communities preserve natural environmental features and vegetative cover (Figure 10).

Fig 10. An example of conservation subdivision.

Land conservation can also be achieved through conservation easements that limit or completely block development in critical areas of the watershed. In the Spring Creek Watershed, these types of easements are mostly managed and held by ClearWater Conservancy.

Riparian Buffers & Stream Restoration

Riparian buffer planting is a common and very useful BMP implemented in the Spring Creek Watershed. Riparian buffer restoration can help to stabilize stream banks, slow the flow of surface runoff into streams as well as provide shade, food and habitat for many species of wildlife. A number of government and NGO partners work together to implement stream and riparian buffer restoration projects in the Spring Creek Watershed. The most active organizations include the Spring Creek Chapter of Trout Unlimited, ClearWater Conservancy, the US Fish and Wildlife Service and the Centre County Conservation District. While the first three organizations are critical in implementing projects, the Conservation District is the organization that ensures that pollution reduction plans are in place with education and assistance particularly in the agricultural sector.

Since 1990, the Spring Creek Chapter of TU has implemented over 30 projects that have restored approximately 22 acres of habitat. These projects alone reduce the amount of nitrogen and phosphorus leaving the watershed by 14,000 and 3,350 pounds annually (Figure 11). In addition to on-land restoration, stream restoration can also stabilize streambanks and channels, in turn creating habitat for wildlife and reducing erosion and its impact on water quality. In the fall of 2019, the Spring Creek Chapter of TU, in partnership with other organizations, installed a major restoration project on the main stem of Spring Creek around the Houserville monitoring station. Figure 12 shows how a portion of this stream restoration project restored the streambank and floodplain to help reduce further erosion and sedimentation.

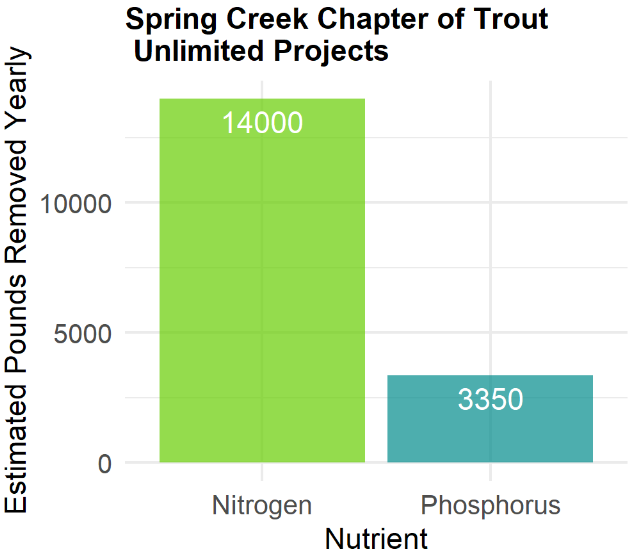


Fig 11. Estimated yearly nitrogen and phosphorus reductions in the Spring Creek Watershed due to projects implemented by TU and partners

ClearWater Conservancy is another local, non-profit organization that conserves and restores critical areas in the watershed. Its Riparian Conservation Program began in 2004 and has installed over 95 acres of riparian buffers in the Spring Creek Watershed. All of these projects help to improve resilience to flooding and pollution carried in surface runoff (Figure 13).

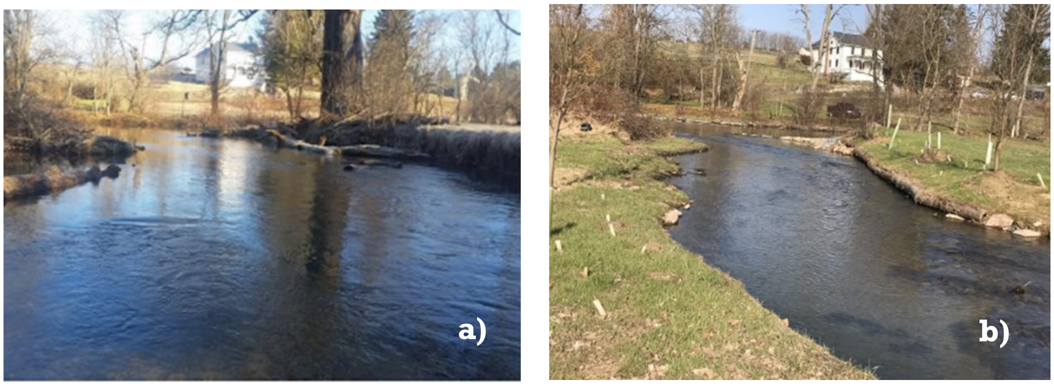


Fig 12. Before (a) and after (b) photos of a portion of the stream restoration done on Spring Creek in 2019 by TU

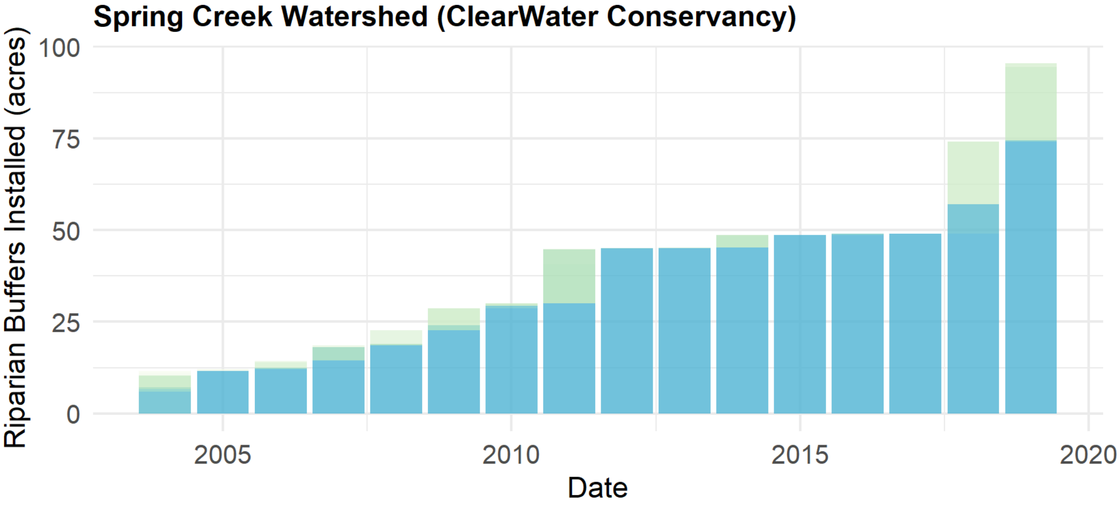


Fig 13. Cumulative acres of riparian buffers installed by ClearWater Conservancy and partners. Green bars represent new projects for that year.

Flood Resilience through Stormwater Management

Green infrastructure, reduced impervious surfaces and other types of stormwater infrastructure can be an adaption tool for water resources in Pennsylvania (Shortle etl al, 2015). These types of infrastructure help to reduce surface runoff and increase infiltration in areas where stormwater can be filtered or retained, thus reducing the overall impacts of storm events by lowering the overall risk of flooding through management of the stormwater flow paths and decreasing water quality impacts.

In the Spring Creek Watershed all designated urban areas (Figure 14) require an MS4 (municipal separate storm sewer system) permit. An MS4 is a municipal separate storm sewer system, which means that the stormwater system can be managed separately from sewer systems. College, Harris, Ferguson and Patton Townships, the Borough of State College and Penn State University are all designated by the Pennsylvania Department of Environmental Protection (DEP) to implement stormwater management programs. Collectively, these municipalities and the university form the MS4 Partnership, which is a group that addresses the local stormwater issues they face. All MS4s must meet specific goals to reduce the amount of sediment and nutrients that directly flow into streams. Permits and plans outline specific projects that will be implemented in their governing area. Some examples of stormwater control measures in the watershed include retention ponds, underground storage facilities, rain gardens and constructed wetlands.

The Penn State's University Park campus has one of the most extensive stormwater collection systems that includes over 73 miles of storm drains ranging in size from 6" to 72" in diameter, more than all of the local municipalities combined. Approximately 69% of the total area owned by the university is managed by a stormwater management facility.

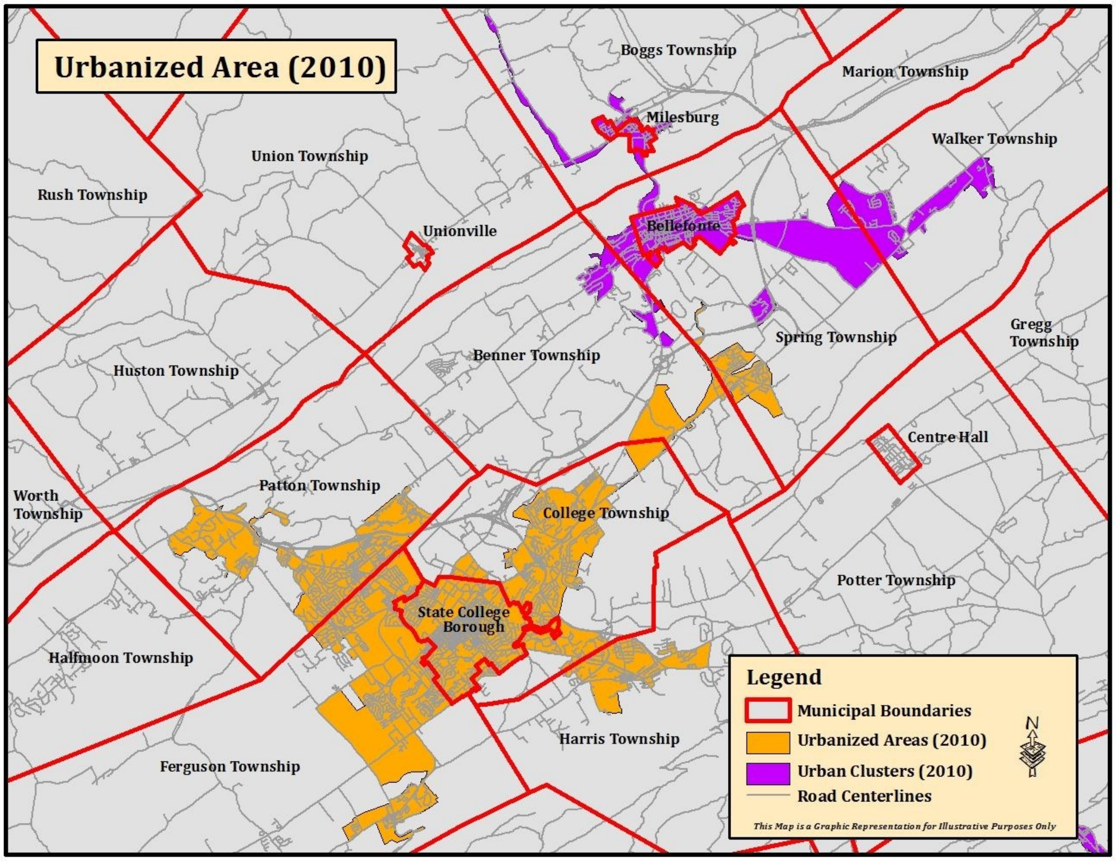


Fig 14. Designated urbanized areas that form the MS4 partnership. Source: MS4 Partners

Drought Resilience through Wastewater Recycling and Recharge

Fig 15. UAJA's beneficial reuse water being used to irrigate a fairway at Centre Hills Country Club (Source: MS4 partners)

Both Penn State University and the University Area Joint Authority practice wastewater recycling to help reduce water consumption and increase the potential for groundwater recharge in the Spring Creek Watershed. The University Area Joint Authority (UAJA) is the largest wastewater treatment facility in the watershed and serves much of the Centre Region and upper sections of the watershed. UAJA treats approximately five million gallons of wastewater each day on average. The majority of this treated water is discharged into the main stem of Spring Creek and contributes to a small portion of its total flow (<5%). Additionally, UAJA recycles approximately nine percent of wastewater into beneficial reuse water (Figure 15).

Beneficial reuse of wastewater can positively impact watersheds in many ways by reducing the need for groundwater withdrawals as well as helping maintain healthy stream flows. While the UAJA's beneficial reuse project is required to meet drinking water standards, it is still classified as non-potable water and therefore must be used for non-potable purposes. For example, the Centre Hills Country Club uses beneficial reuse water to irrigate their golf course. Slab Cabin Run at Kissinger Meadow is permitted to receive direct discharges of reuse water. This section of stream receives on average 450,000 gallons (0.70 cfs) of recycled water per day, which aids in augmenting stream flow and may increase resilience of the stream to droughts.

Fig 16. Corn irrigation with recycled wastewater at the living filter (Source: PSU)

Rather than discharge treated wastewater directly into streams, Penn State applies treated effluent to the land at the Living Filter (Figure 16). The campus also has plans to build a reuse system designed to recycle 300,0000 to 500,000 gallons of water per day. Historically, Penn State discharged treated water into Thompson Run at the Duck Pond. In 1983, this discharge was redirected to the Living Filter to be sprayed onto fields. Currently, an estimated 1.7 million gallons of water is returned to the aquifer each day through groundwater recharge at the Living Filter (sustainability.psu.edu/water).

Discussion

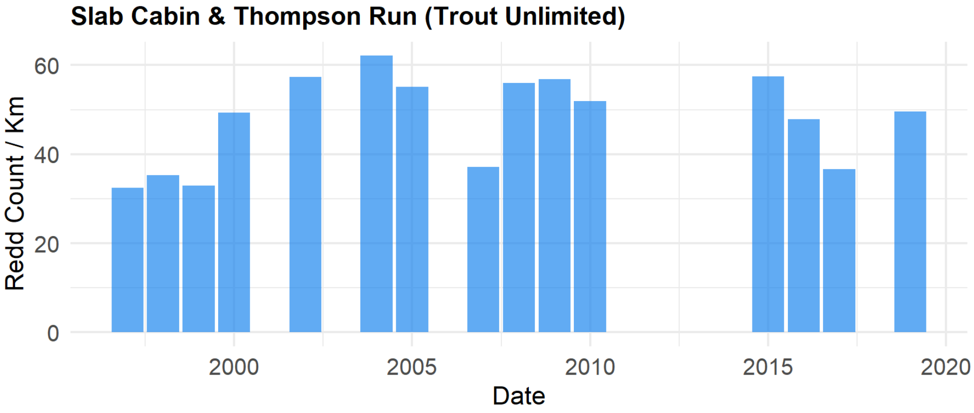


Fig 17. Density of redds in Slab Cabin and Thompson Run (Source: TU)

According to the Centre Region Planning Agency, in 2014 approximately 26 percent of the Spring Creek Watershed was developed land yet trout populations remain stable. Trout populations generally decline when urban development reaches 6 percent and cannot persist at levels greater than 11 percent (Wang et al., 2003). However, wild brown trout populations generally increased substantially between 1980 and 2006 (Table 1). Reproducing populations seem to be maintained in smaller tributaries as well. The Spring Creek Chapter of TU conducts redd, trout spawning bed, counts each year to determine the number of trout reproducing in Slab Cabin and Thompson Run (Figure 17). This data shows that over the last 20 years, trout have continued to spawn in the watershed at similar rates despite increased urban and suburban development. The watershed's natural resilience to droughts and thermal impacts through large groundwater inputs is critical in maintaining healthy trout populations. Additionally, government mandates and local efforts from non-profit organizations and the Penn State University help to maintain and restore resilience through restoration projects and best management practices to deal with runoff. In order to continue to maintain trout and other aquatic populations in the face of continued development and a changing climate, these efforts will need to continue in the future.

Table 1: Density (#/ha) of wild brown trout in six sections of Spring Creek. Values for age 0 represent total captured in electrofishing. Values for age 1+ are based on population estimates. (Table 7 from Carline et al. 2011)

	1980		1988		2000		2006	
Section	Age 0	Age 1 and older	Age 0	Age 1 and older	Age 0	Age 1 and older	Age 0	Age 1 and older
2	1,399	291	348	861	233	1,144	114	1,034
4	358	310	416	927	1,278	255	61	368
6	78	453	173	678			20	527
13	378	609	241	1,327	456	1,302	213	1,563
15	20	56	180	827	332	1,172	40	798
16	9	6	230	728	111	1,418	22	1,131
Median	218	301	236	844	332	1,172	51	916

WRMP Monitoring Methods

&

2019 Data

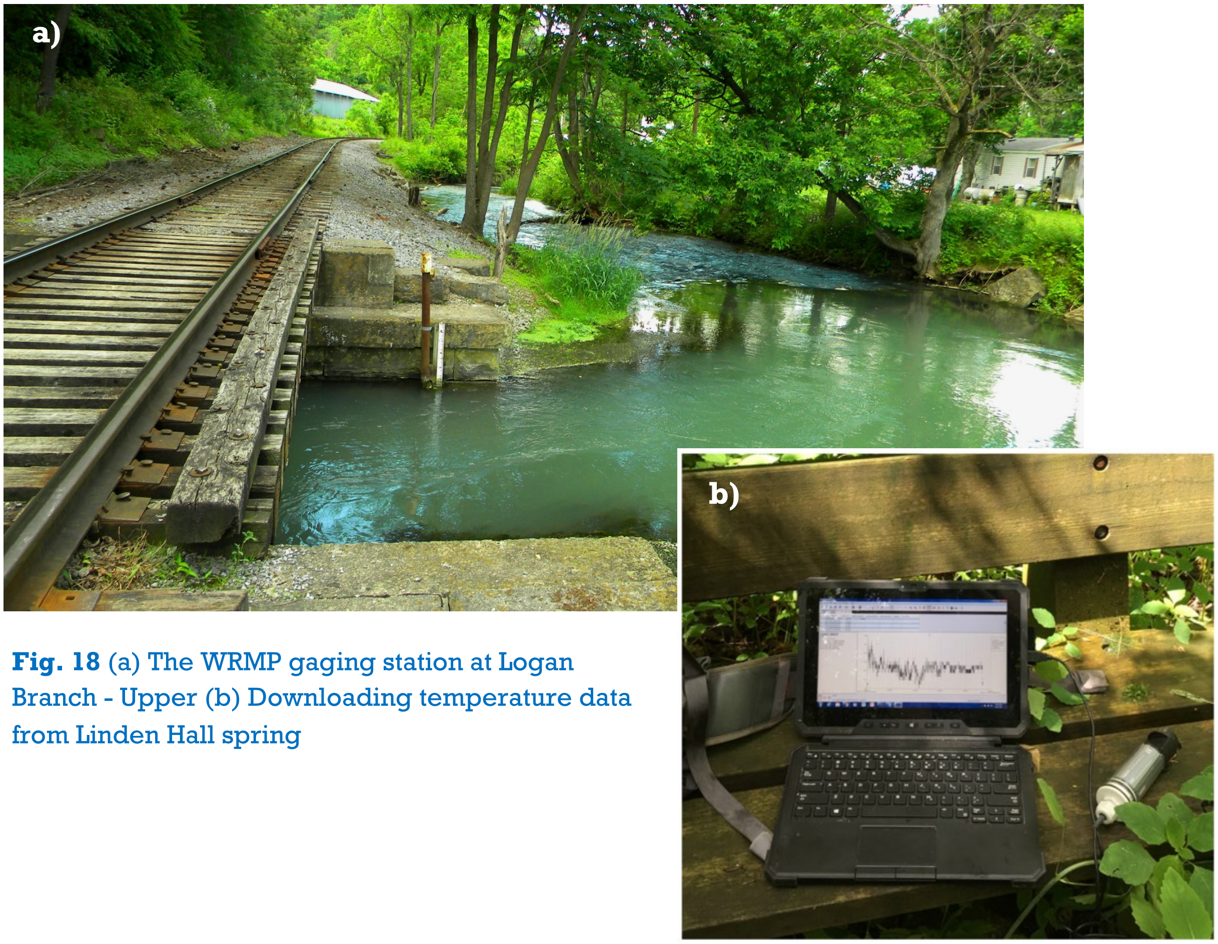


Fig. 18 (a) The WRMP gaging station at Logan Branch - Upper (b) Downloading temperature data from Linden Hall spring

Continuous Water Temperature Monitoring

Water temperature is measured continuously at 18 stream stations (Figure 19) and 8 spring stations (Figure 20 on page 18) with submersible Onset Computer Corporation Optic Stowaway TidBitv2 data loggers. Eleven of these stream temperature monitoring stations are co-located with WRMP gaging stations and three are co-located with existing USGS gaging stations on Spring Creek. Temperature is recorded hourly at all stations except for the Thompson Run and Middle Walnut Run station. Temperature is recorded every five minutes at these stations because past data have shown that temperatures can fluctuate rapidly at these locations during storm events.

Temperature loggers are installed based on the EPA's Best Practices for Continuous Monitoring of Temperature and Flow in Wadeable Streams. Loggers are housed in PVC units and anchored to the stream bed or other large object such as a rock, tree root or cement wall. Data is downloaded from the loggers every four weeks. Loggers are additionally checked during low flow periods to ensure they are fully submersed in the stream or spring.

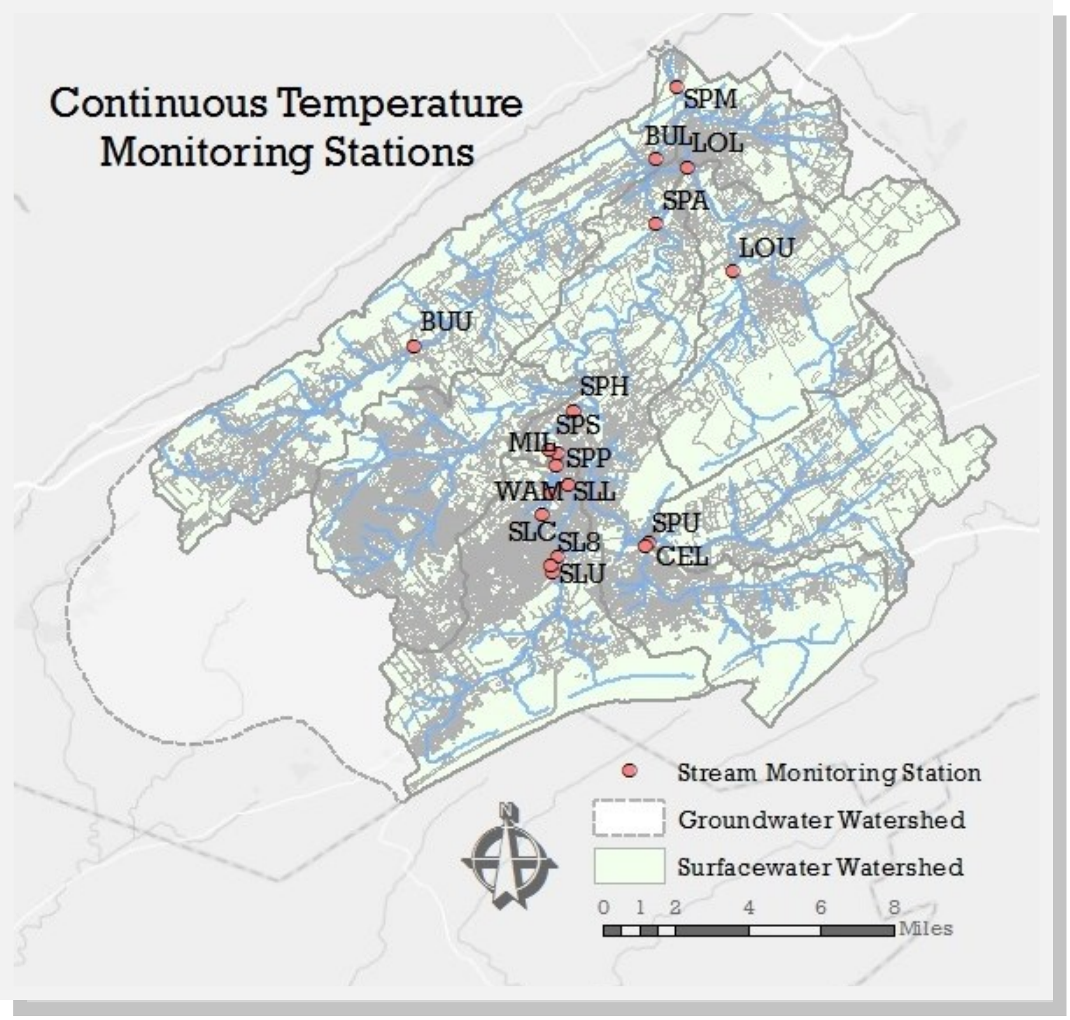
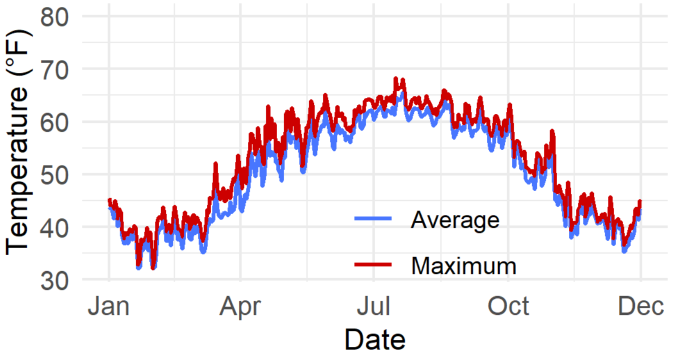
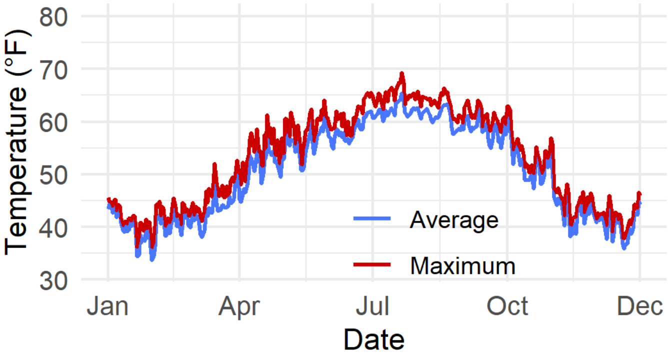
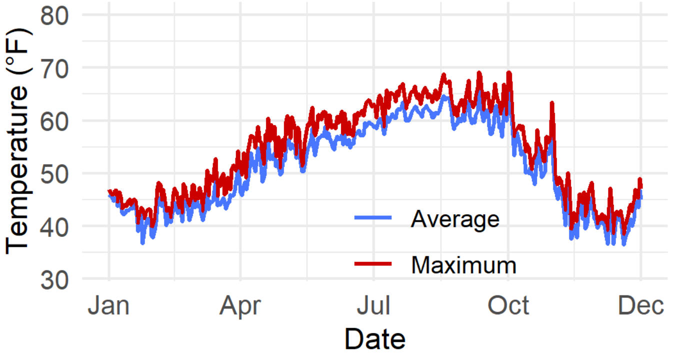


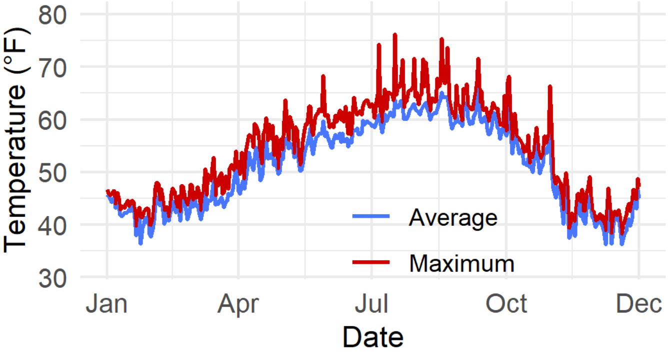
Fig. 19 Continuous stream temperature monitoring stations managed by the WRMP

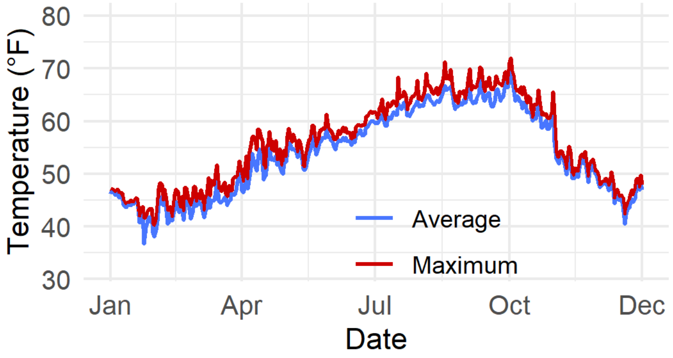
2019 Stream Temperature Data

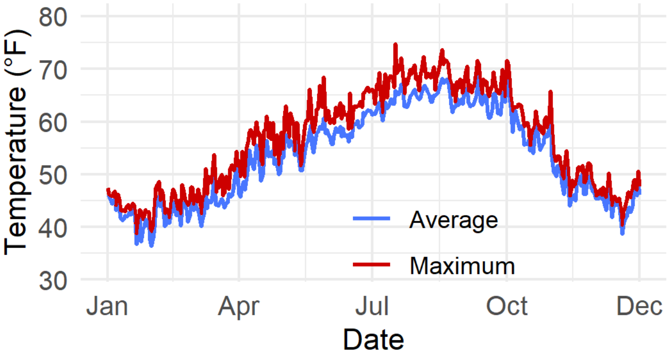

Buffalo Run - Upper (BUU)

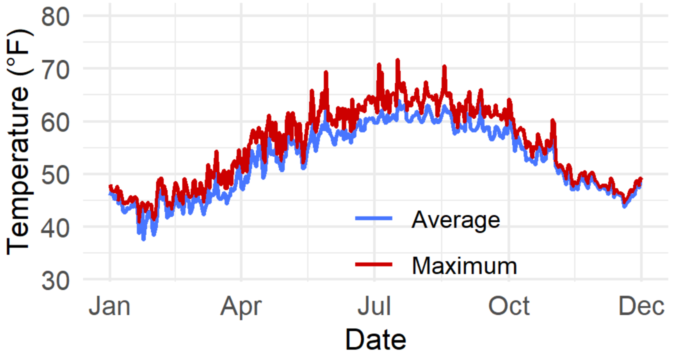

Buffalo Run - Lower (BUL)

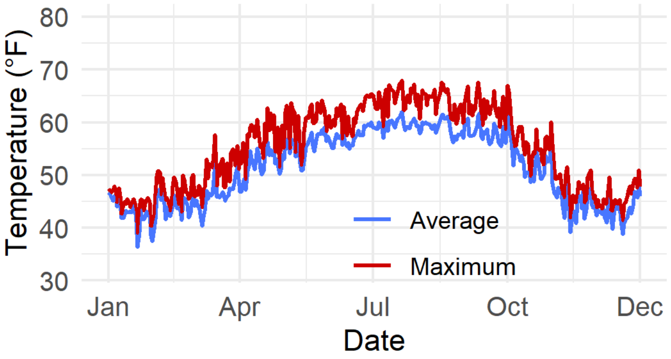

Slab Cabin Run - Upper (SLU)

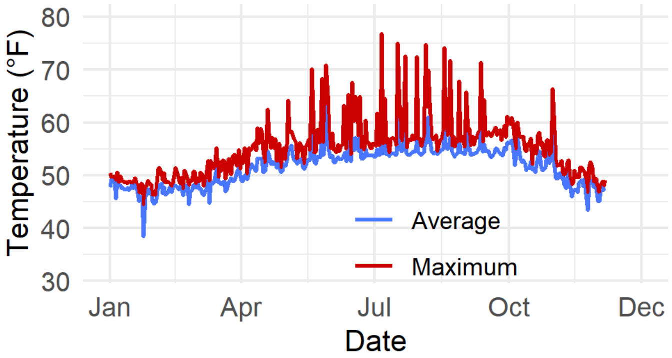

Slab Cabin Run - Super 8 (SL8)

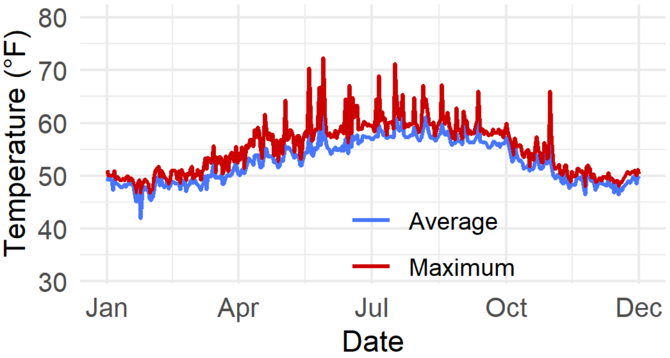

Slab Cabin Run - Kissinger Meadow (SLC)

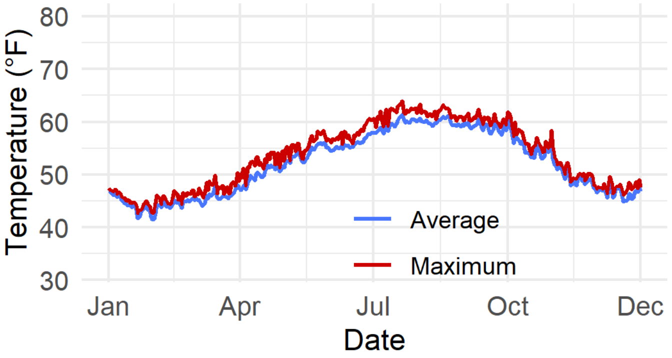

Slab Cabin Run - Lower (SLL)

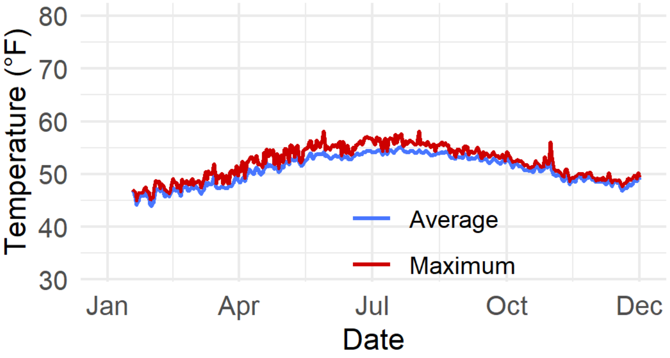

Slab Cabin Run - Millbrook Marsh (MIL)

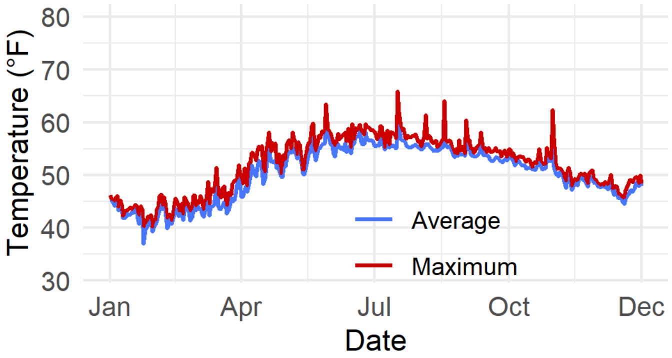

Cedar Run - Lower (CEL)

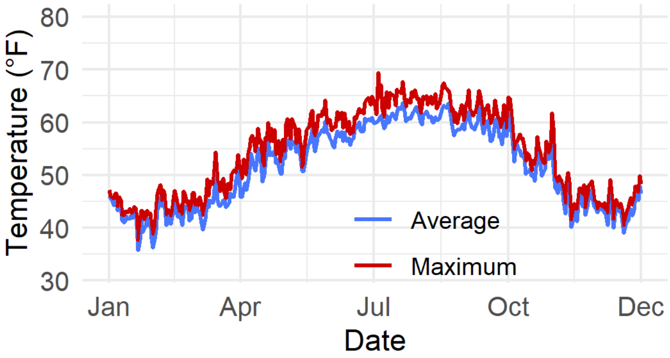

Walnut Run - Middle (WAM)

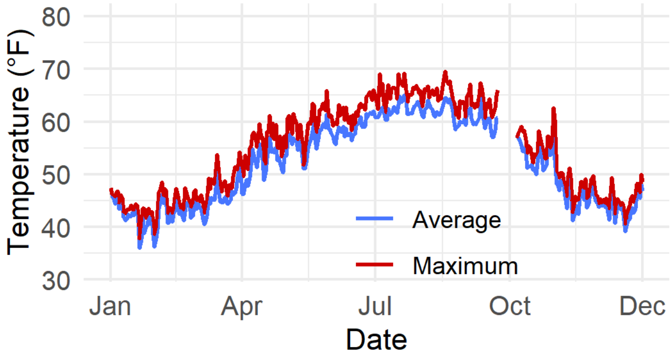

Thompson Run - Lower (THL)

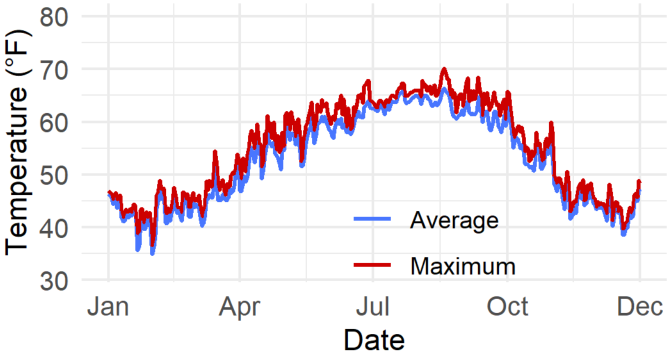

Logan Branch - Upper (LOU)


Logan Branch - Lower (LOL)

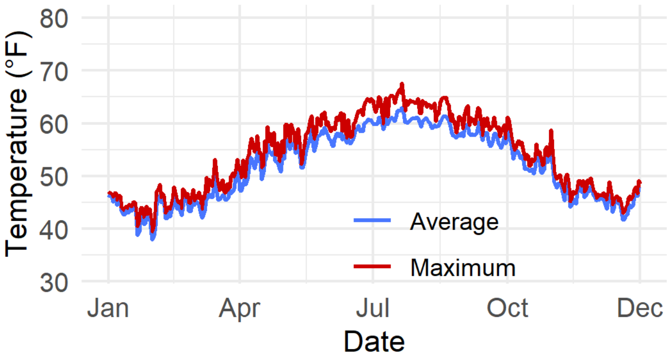

Spring Creek - Upper (SPU)


Spring Creek - Spring Creek Park (SPP)


Spring Creek - Houserville (SPH)


Spring Creek - Axemann (SPA)

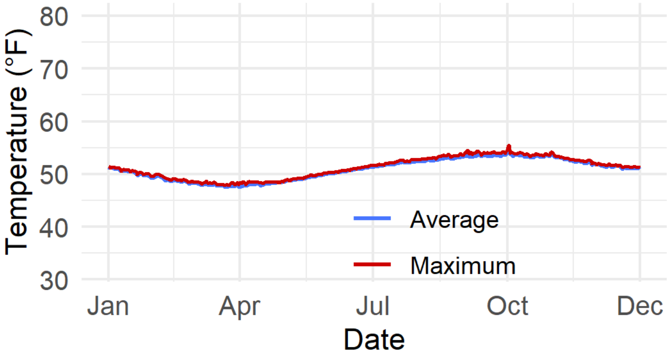
Spring Creek - Milesburg (SPM)



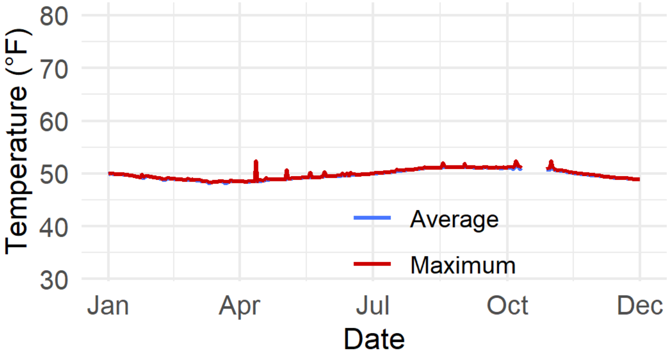
2019 stream temperatures were fairly normal. There were no major droughts, floods or temperature extremes. Seasonal variations between locations are reflective of the level of groundwater contributing to that stream's baseflow. The Lower Logan Branch station shows the least amount of variation due to steady groundwater inputs. High peak termpatures in Walnut and Thompson Runs indicate higher levels of stormwater runoff.

2019 Spring Temperature Data

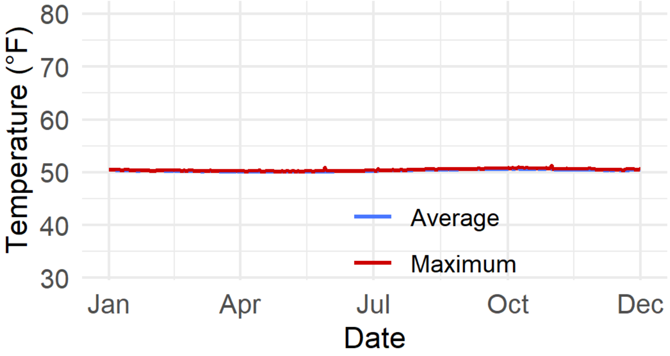
Windy Hill Spring (WIS)



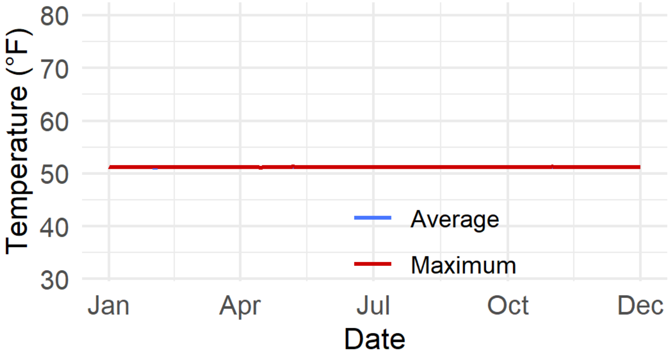
Blue Spring (BLS)



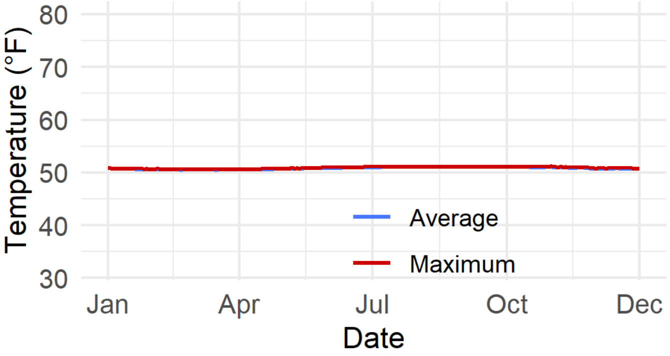
Linden Hall Spring (LIS)



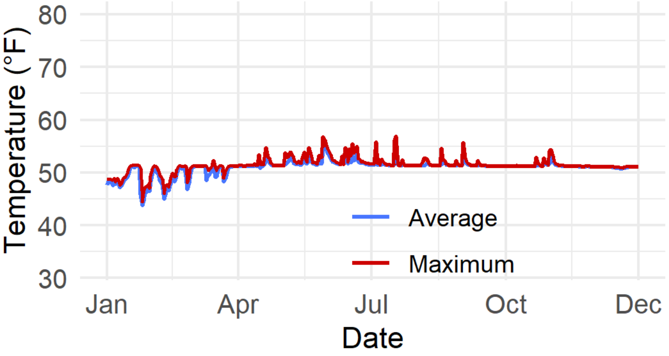
Walnut Spring (WAS)

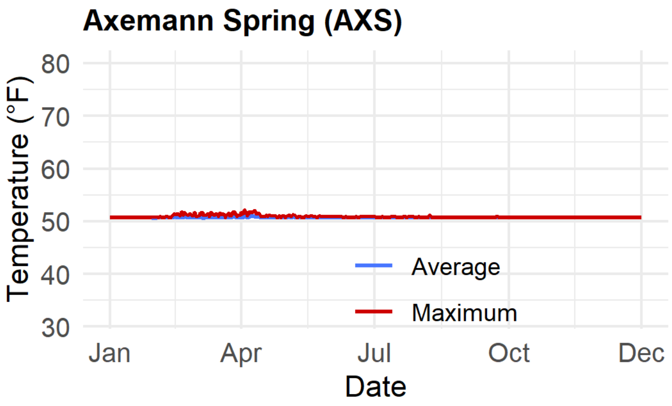


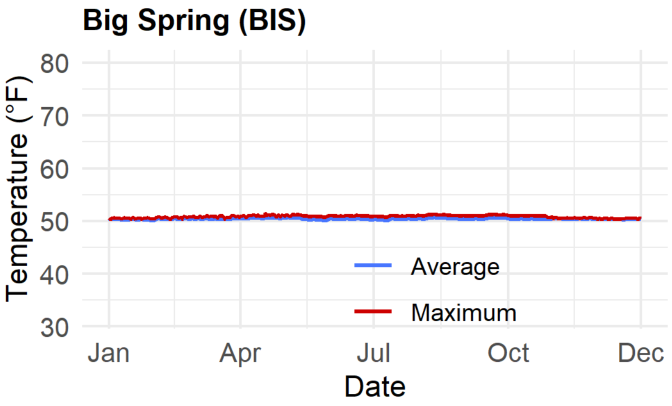
Continental Courts Spring (COS)



Benner Spring (BES)







The WRMP began monitoring spring temperature in 2018. The data reveal that most springs maintained steady temperatures around the average temperature of groundwater (approximately 50°F). Benner Spring experienced some peaks and drops in temperature when surface runoff mixed with the spring water around the temperature logger. Additionally, the Windy Hill Spring and Blue Spring data indicate that temperature at that location follows a seasonal pattern, which could mean that the locations are seeps that are impacted by seasonal fluctuations in air temperatures.

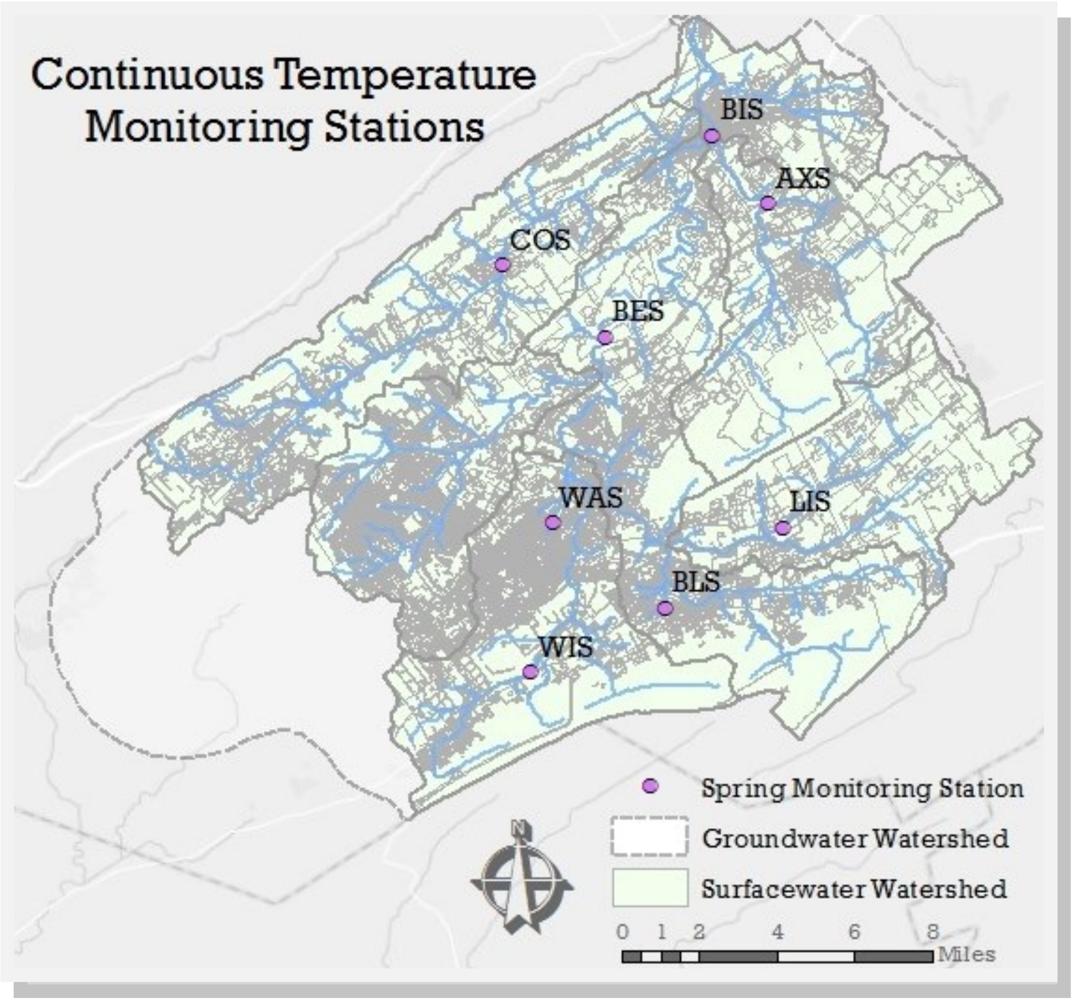


Fig. 20 Continuous spring temperature monitoring stations managed by the WRMP

Continuous Stream Stage and Discharge Monitoring

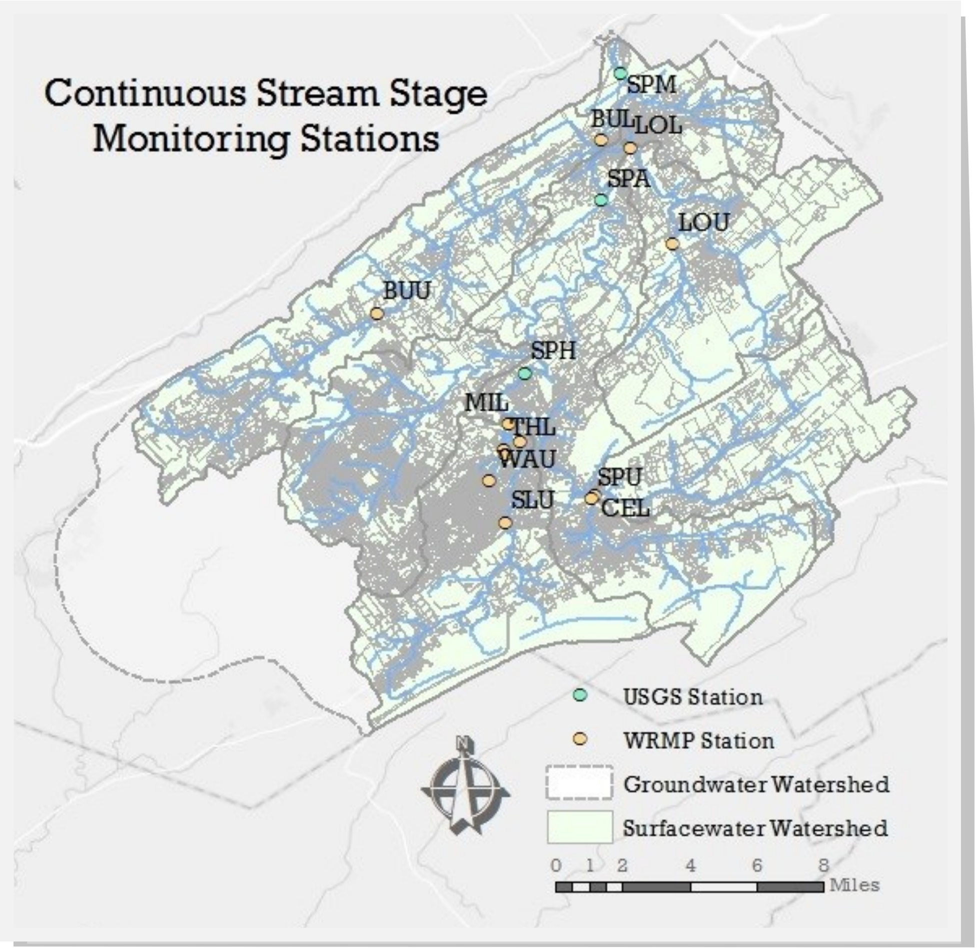


Fig. 21 USGS and WRMP stream stage monitoring stations

The WRMP operates 12 stream monitoring stations with one site on the main stem of Spring Creek and 11 tributary sites located throughout the stream's five major sub-basins (Figure 21). The sites are representative of land use practices across the watershed. There are three USGS-operated stream gages on the main stem of Spring Creek. Stations are equipped with continuous water level, or stage, loggers.

Stream stage is digitally recorded every 30 minutes for all gaging stations except Lower Thompson Run and two stations on Walnut Run, where stream stage is recorded every 5 minutes due to rapid fluctuations in stage level during storm events. Rating curves are developed and maintained at each of these sites to convert stream stage into discharge rates (Figure 22).

2019 discharge rates began higher than median rates due to heavy precipitation in 2018. Spring and early summer storms caused frequent peaks in discharge rates. Less precipitation in the late summer and fall is fairly common for the region, which resulted in flows near and below median levels.

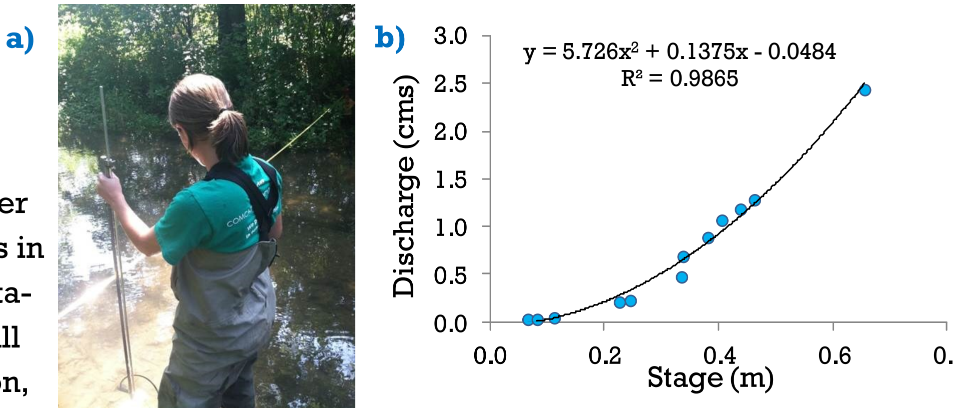
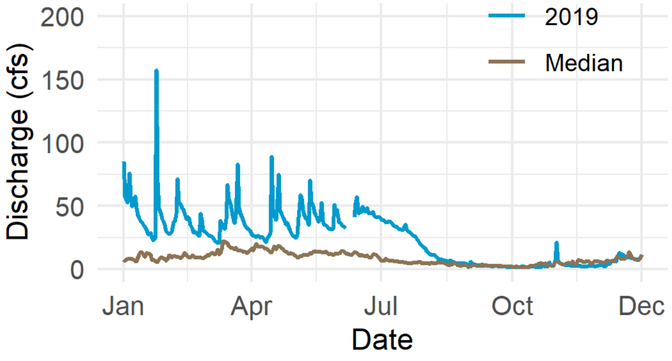
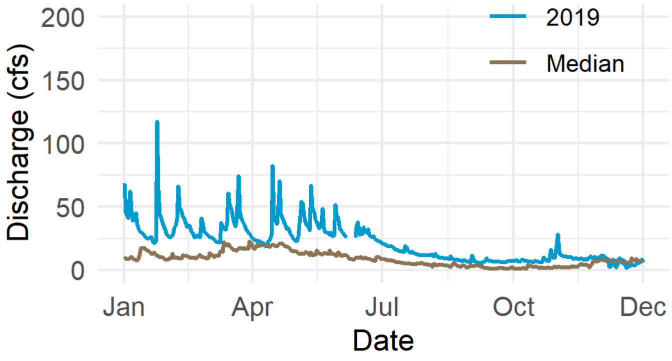


Fig. 22 (a) Manual discharge measurement being taken to develop a (b) rating curve at Slab Cabin Run - Upper (SLU)

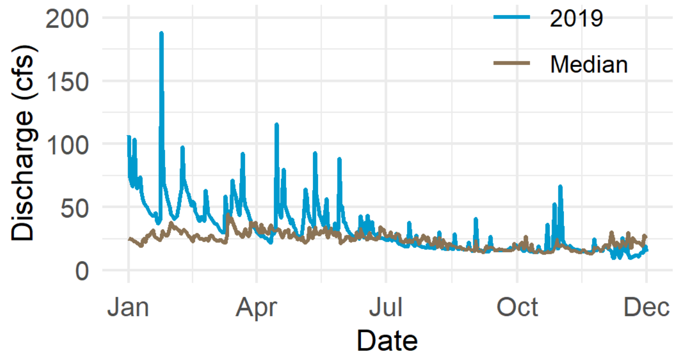
2019 Discharge Data



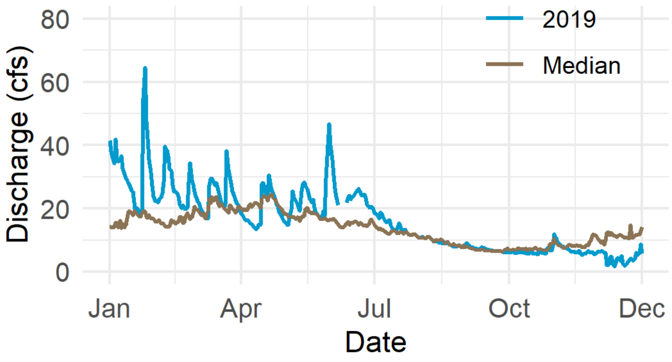
Slab Cabin Run - Upper (SLU)



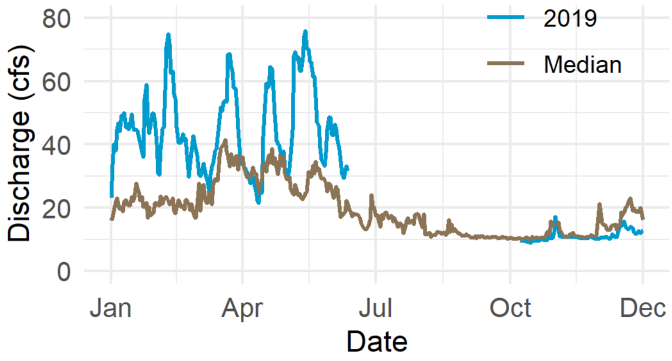
Slab Cabin Run - Lower (SLL)



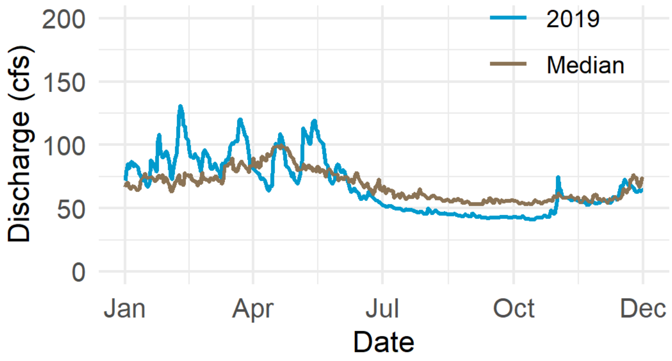
Slab Cabin Run - Millbrook Marsh (MIL)



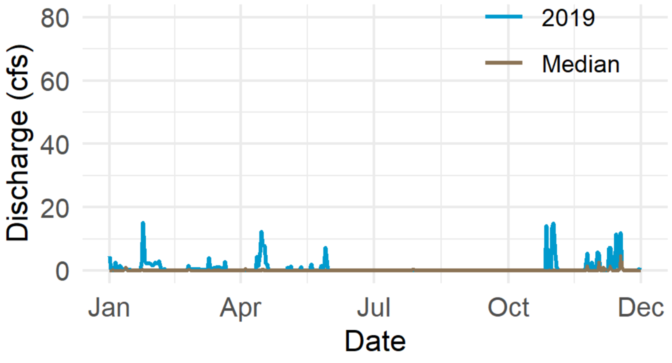
Cedar Run - Lower (CEL)



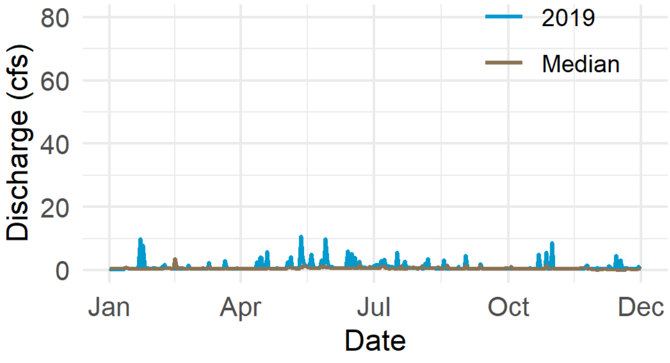
Logan Branch - Upper (LOU)



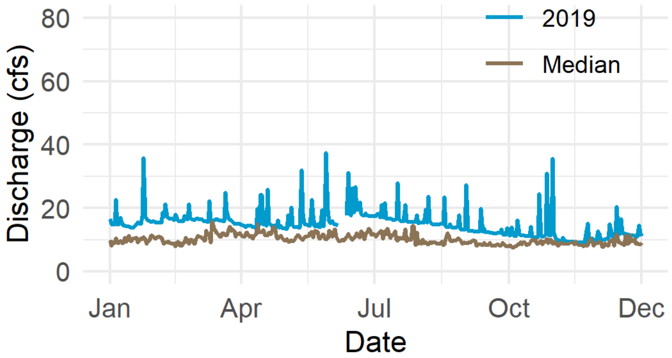
Logan Branch - Lower (LOL)

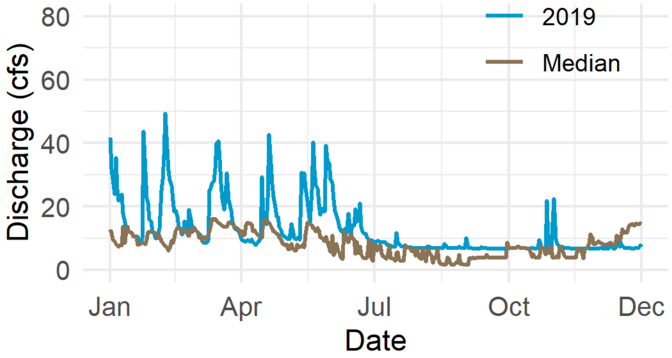


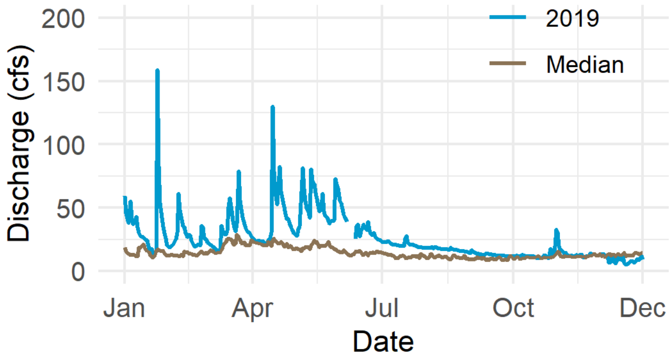
Walnut Run - Upper (WAU)

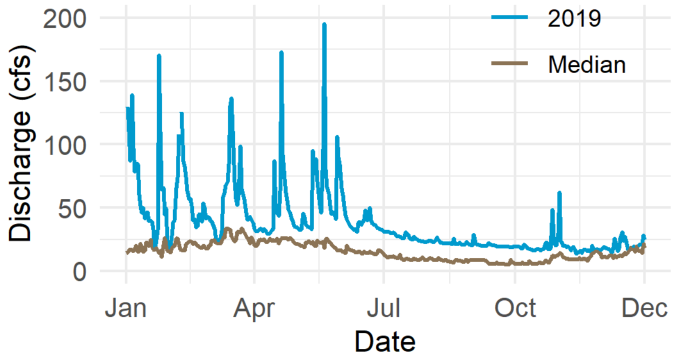


Walnut Run - Lower (WAL)

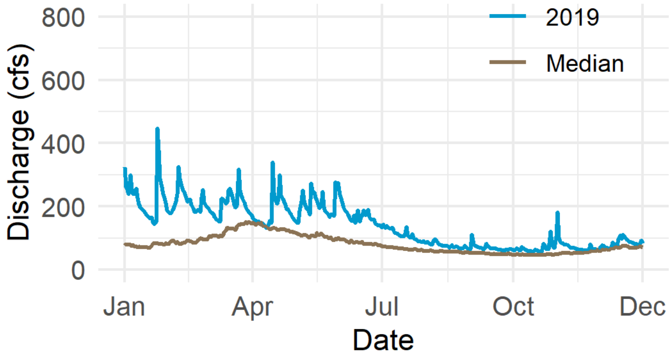

Thompson Run - Lower (THL)

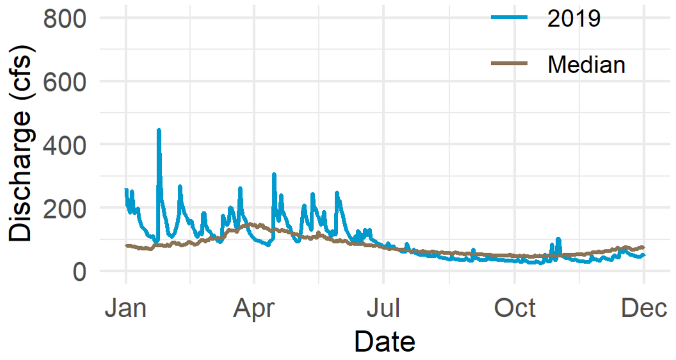

Buffalo Run - Upper (BUU)

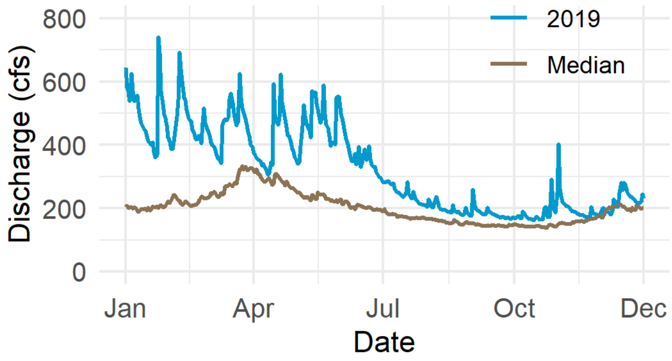

Spring Creek - Upper (SPU)


Buffalo Run - Lower (BUL)

2019 USGS Discharge Data


Spring Creek - Axemann (SPA)


Spring Creek - Houserville (SPH)


Spring Creek - Milesburg (SPM)

Quarterly Water Quality Sampling

WRMP staff and volunteers collect water samples from 15 stream sites and 8 springs on a quarterly basis (spring, summer, fall and winter) during baseflow conditions (Figure 23). The water samples are analyzed for chemical and nutrient content by the Pennsylvania Department of Environmental Protection Analytical Laboratories. Coliform analysis is conducted for spring samples by the University Area Joint Authority laboratory.

2019 data showed similar quality levels as most years except for increased aluminum levels in most stream sites but particularly Buffalo Run—Valley View. Both Thompson Run and Walnut Spring have elevated sodium, chloride and conductivity levels due to higher level of stormwater runoff with high salt concentrations. Nitrate concentrations are typically highest in the Axemann Spring.

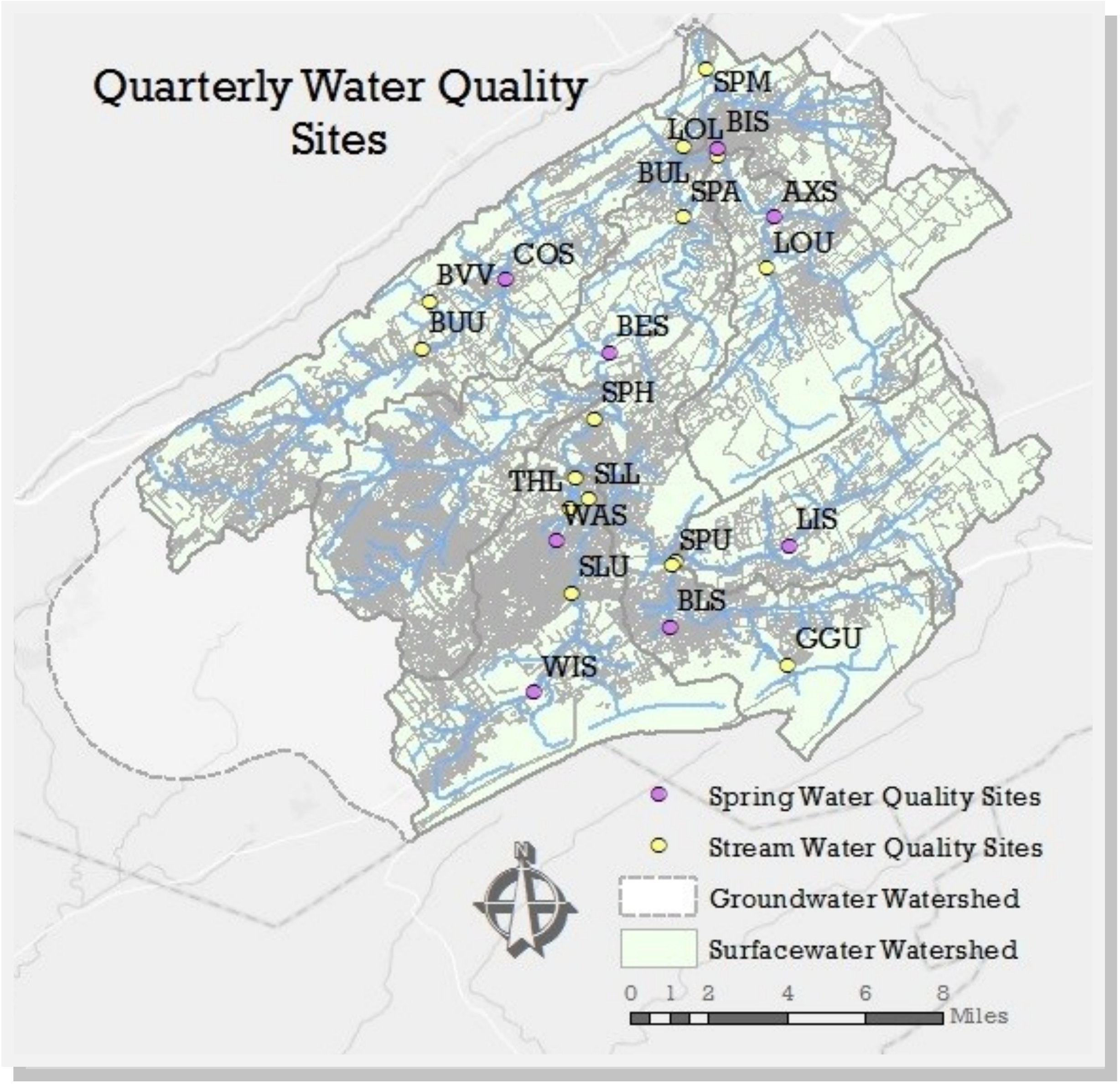
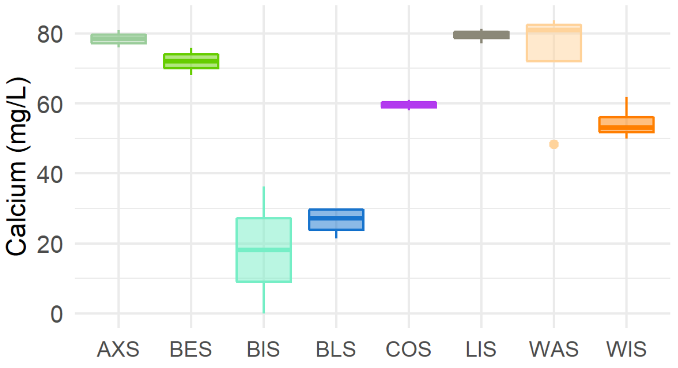
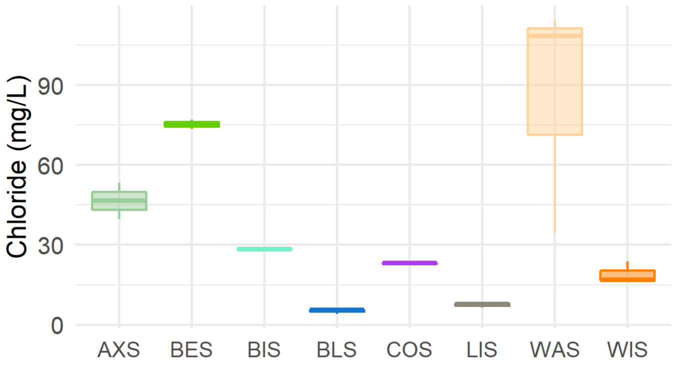


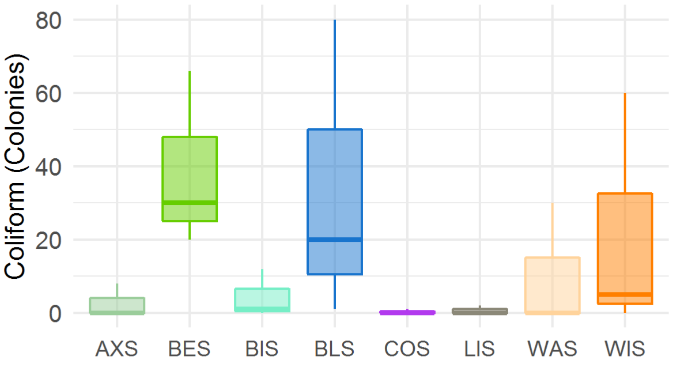
Fig. 23 Stream and spring water quality sampling locations

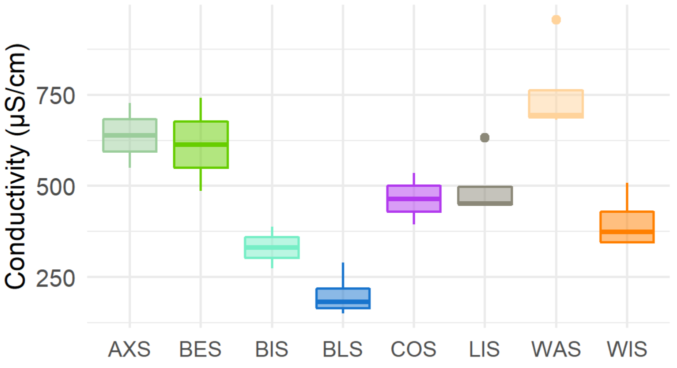
2019 Spring Water Quality Data

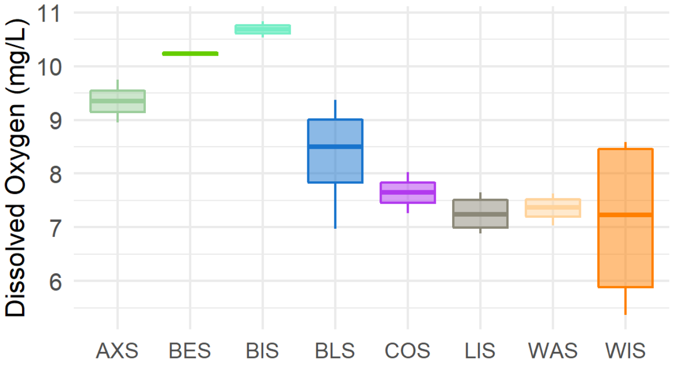
Physiochemical Parameters

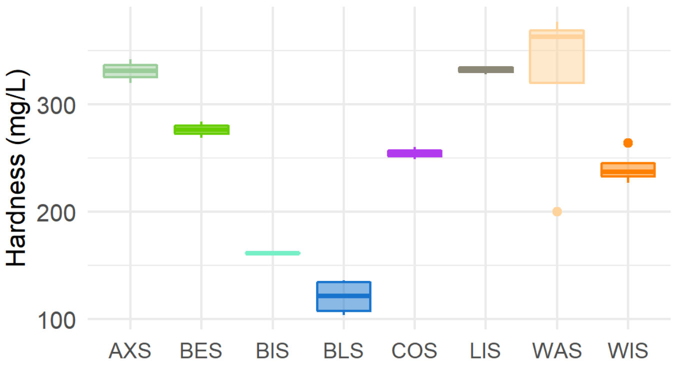


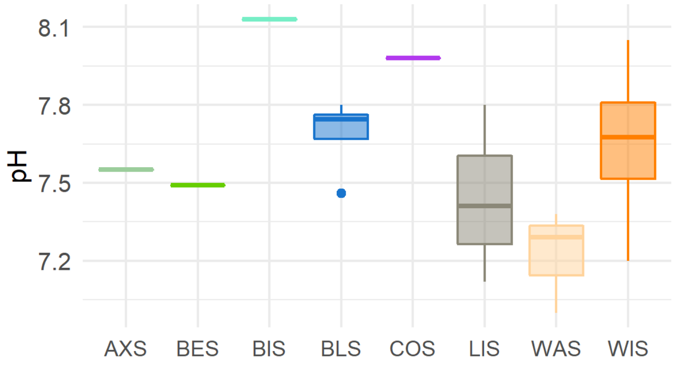


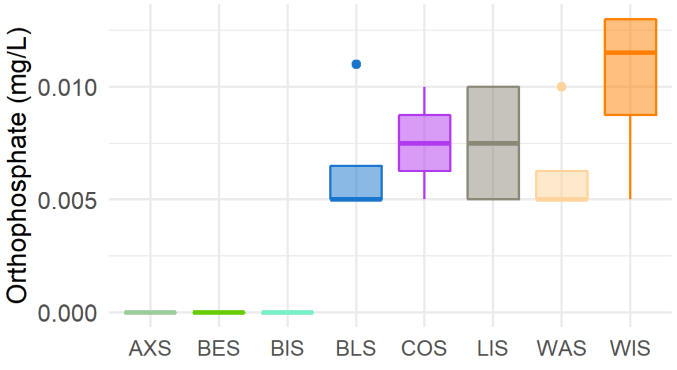


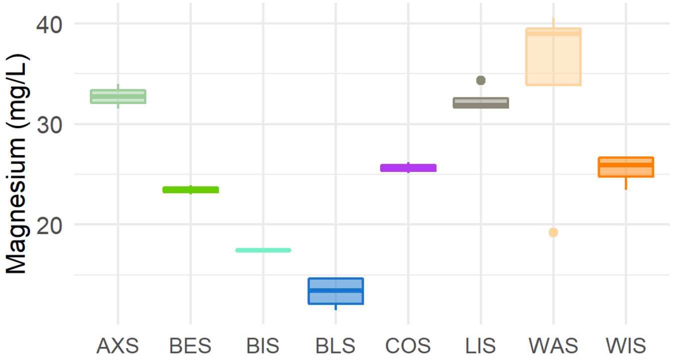


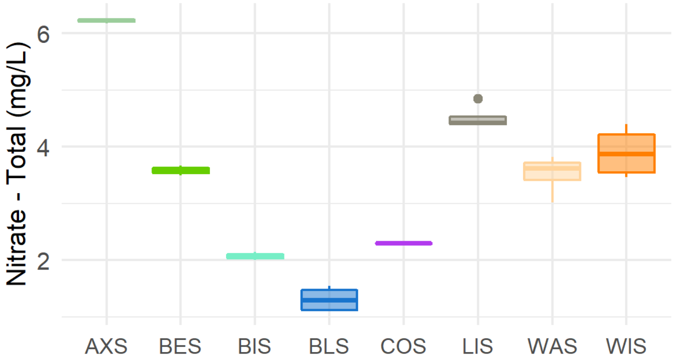


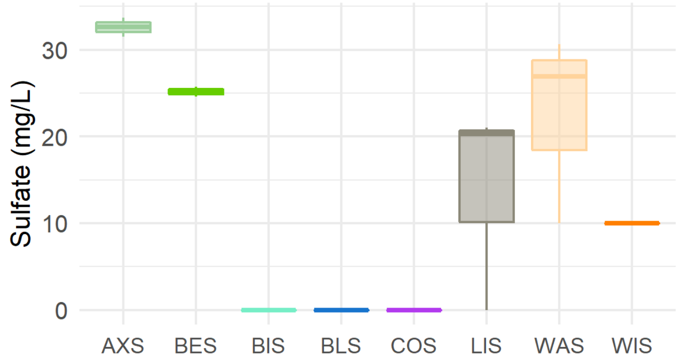


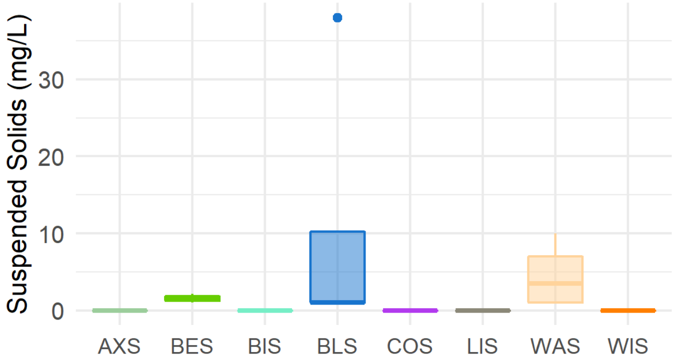


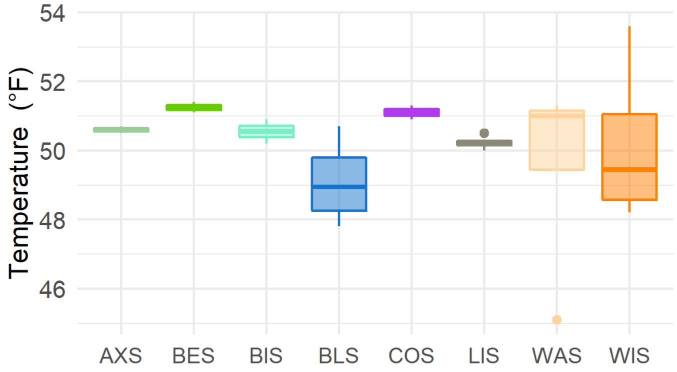


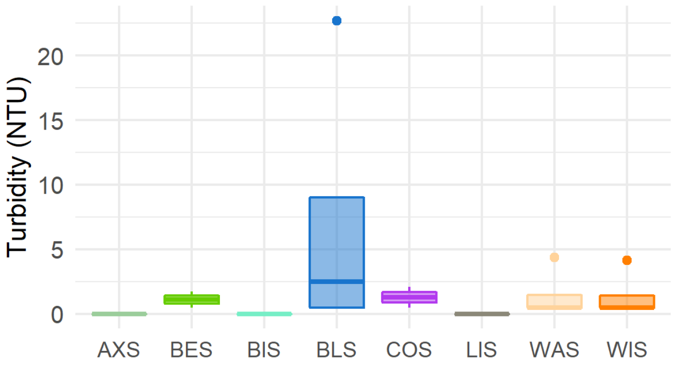








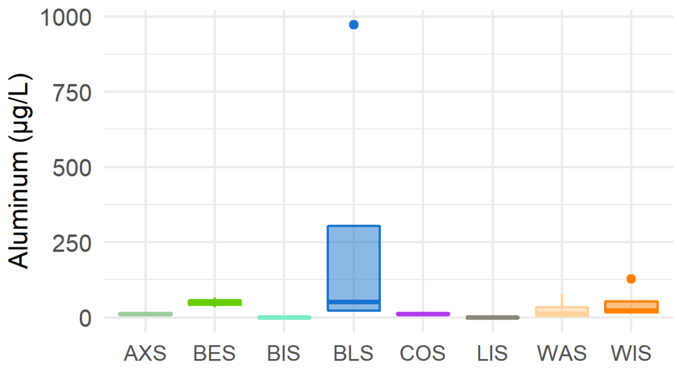


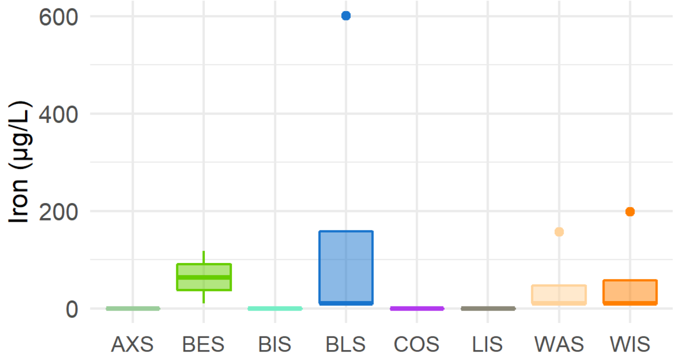


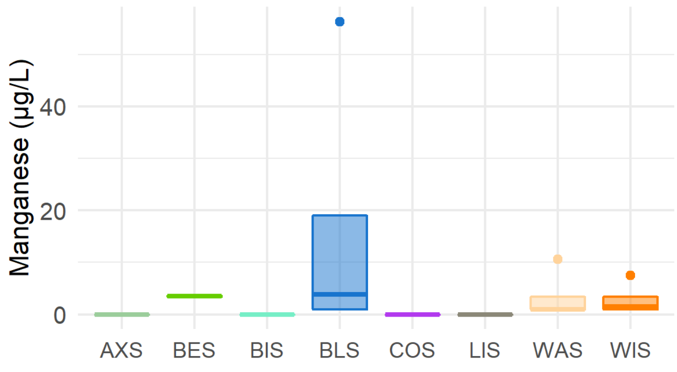
2019 Spring Water Quality Data

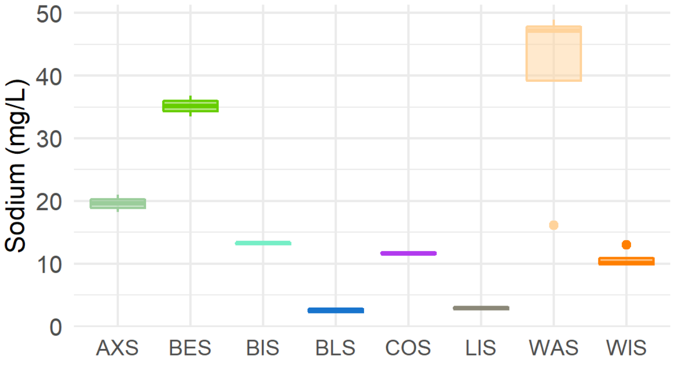
Metals—Total

Concentrations of nickel, lead, copper, chromium, cadmium and zinc were all non-detectable, so plots of these parameters are not included.



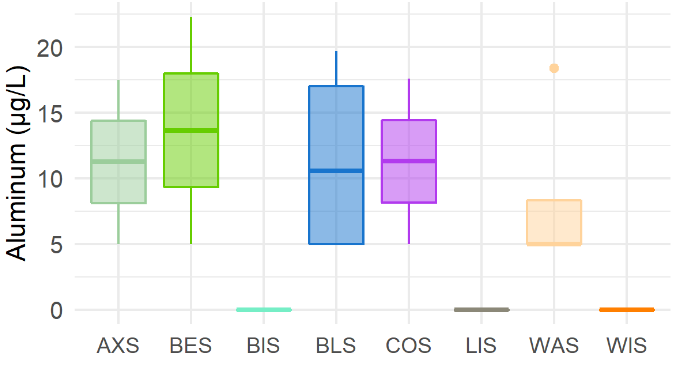


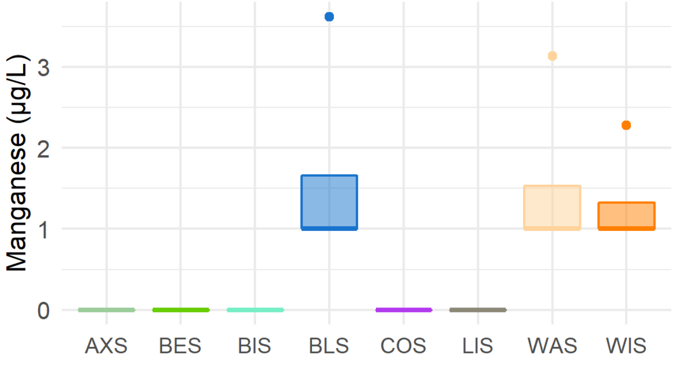


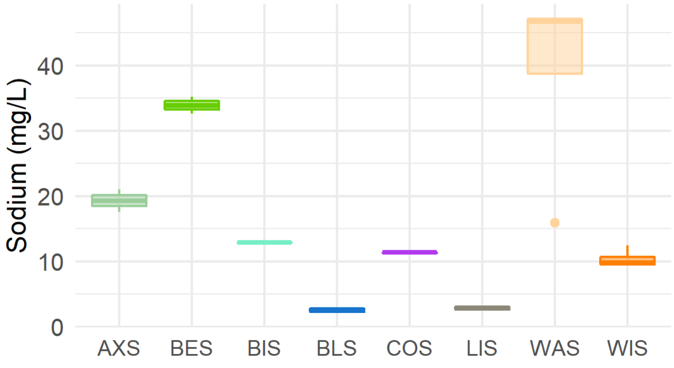


2019 Spring Water Quality Data

Metals—Dissolved

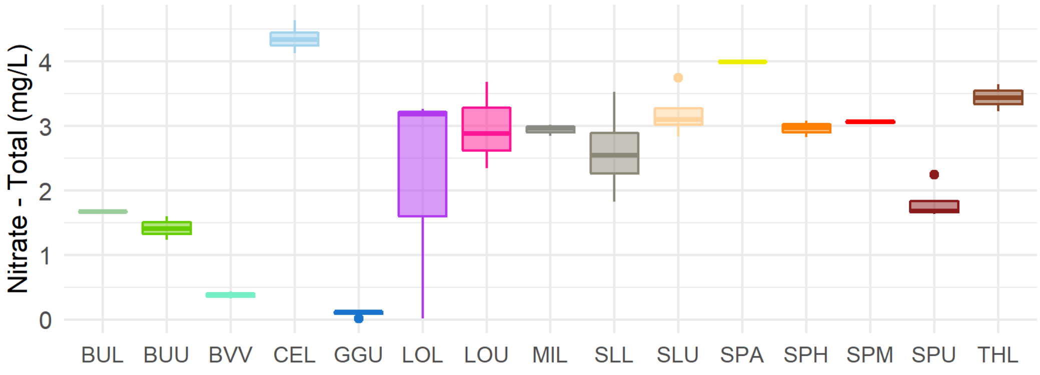


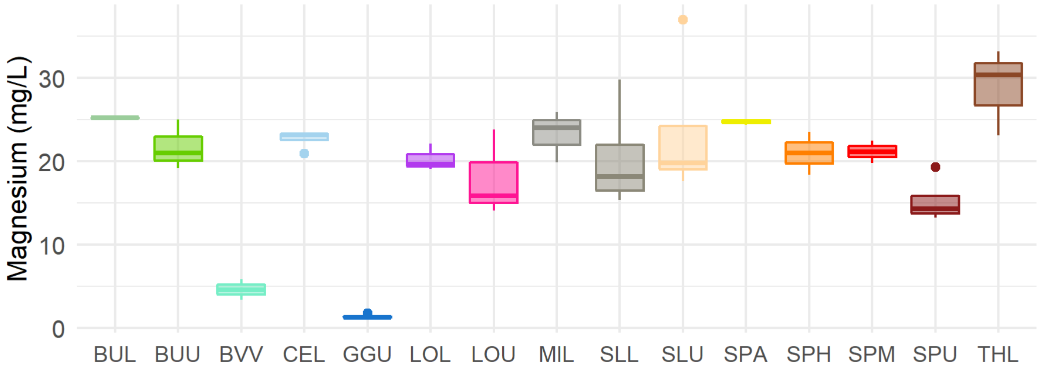


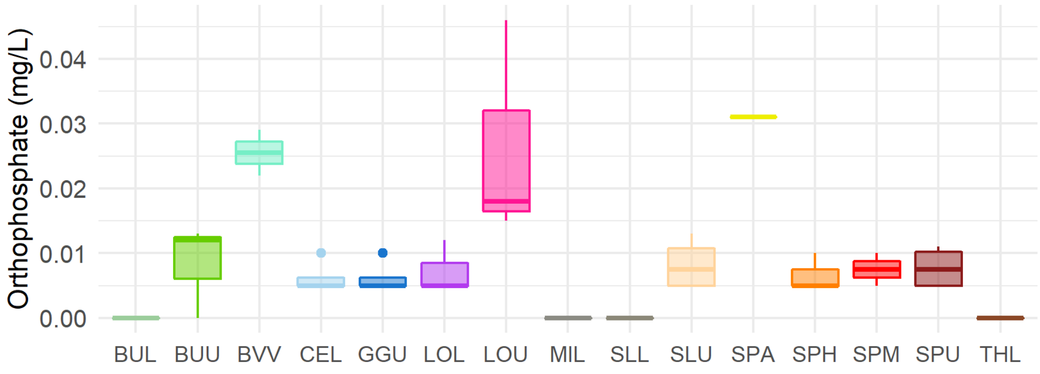


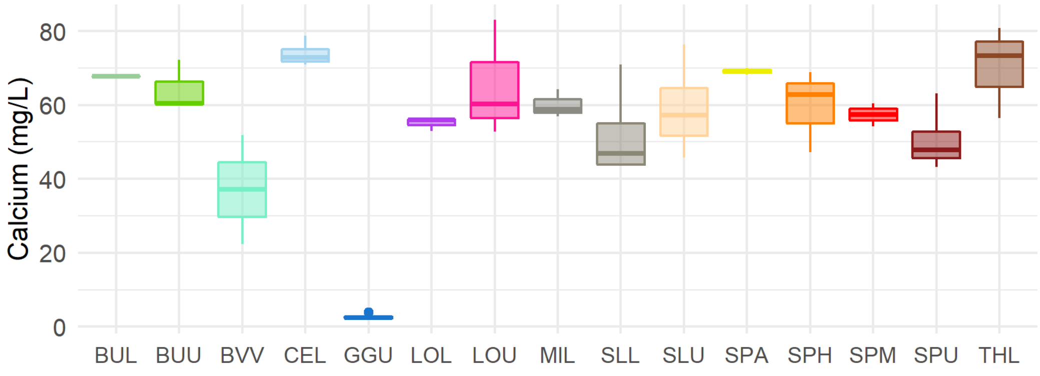
2019 Stream Water Quality Data

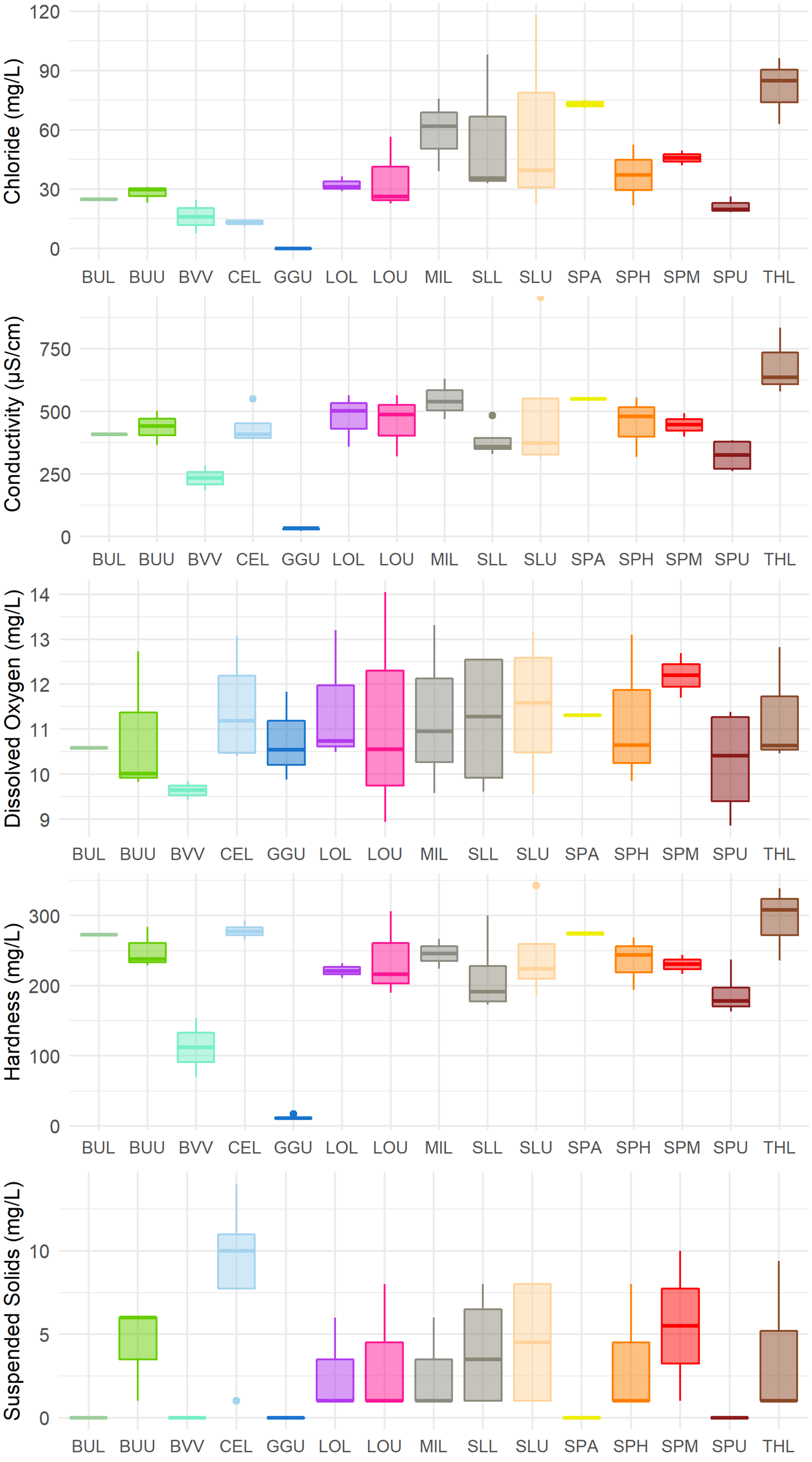
Physiochemical Parameters

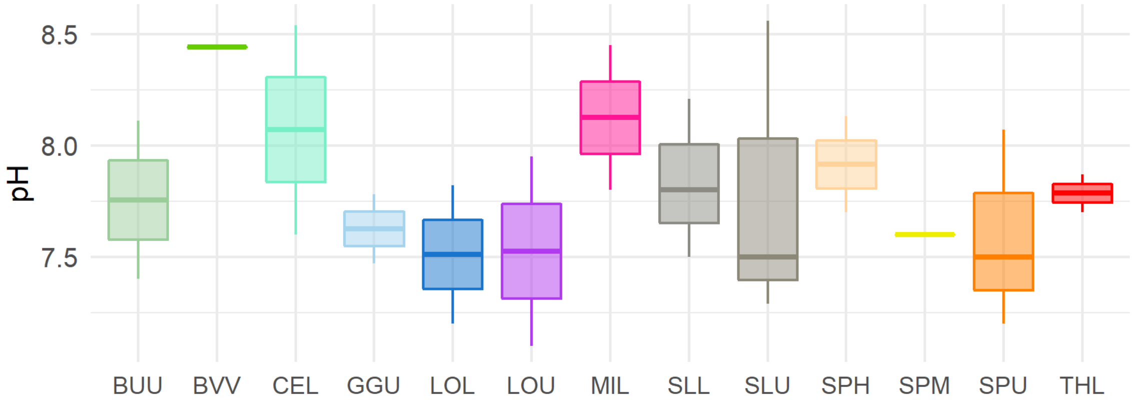


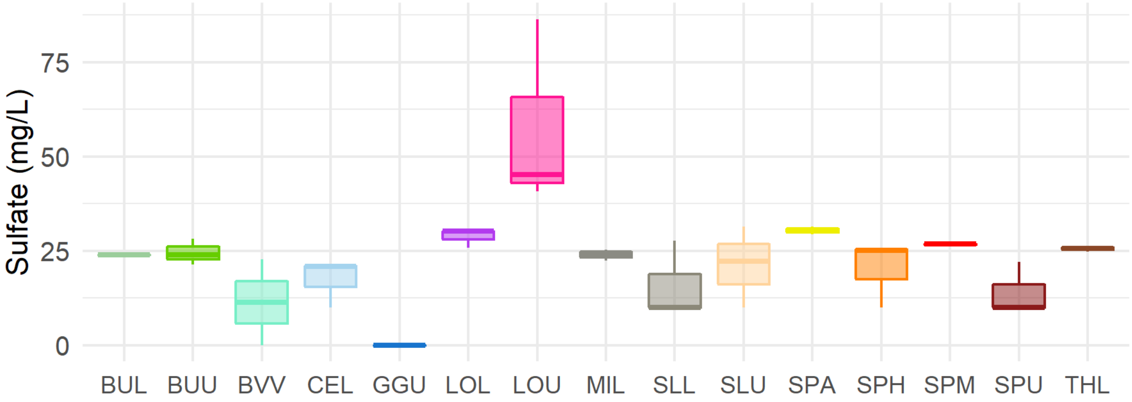


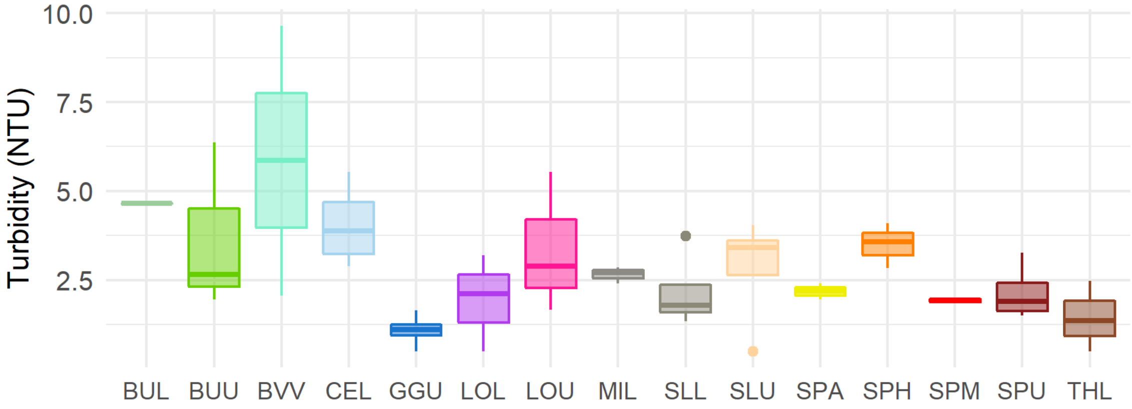


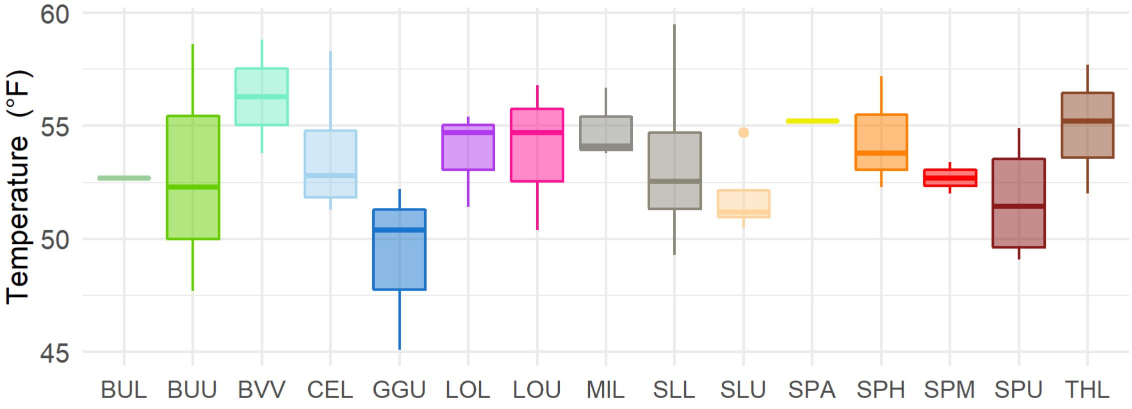



Chloride (mg/L)
0
30
60
90
120
BUL BUU BVV CEL GGU LOL LOU MIL SLL SLU SPA SPH SPM SPU THL
Conductivity (µS/cm)
0
250
500
750
BUL BUU BVV CEL GGU LOL LOU MIL SLL SLU SPA SPH SPM SPU THL
Dissolved Oxygen (mg/L)
9
10
11
12
13
14
BUL BUU BVV CEL GGU LOL LOU MIL SLL SLU SPA SPH SPM SPU THL
Hardness (mg/L)
0
100
200
300
BUL BUU BVV CEL GGU LOL LOU MIL SLL SLU SPA SPH SPM SPU THL
Suspended Solids (mg/L)
0
5
10
BUL BUU BVV CEL GGU LOL LOU MIL SLL SLU SPA SPH SPM SPU THL


pH
8.5
8.0
7.5
BUU
BVV
CEL
GGU
LOL
LOU
MIL
SLL
SLU
SPH
SPM
SPU
THL


Sulfate (mg/L)
75
50
25
0
BUL
BUU
BVV
CEL
GGU
LOL
LOU
MIL
SLL
SLU
SPA
SPH
SPM
SPU
THL

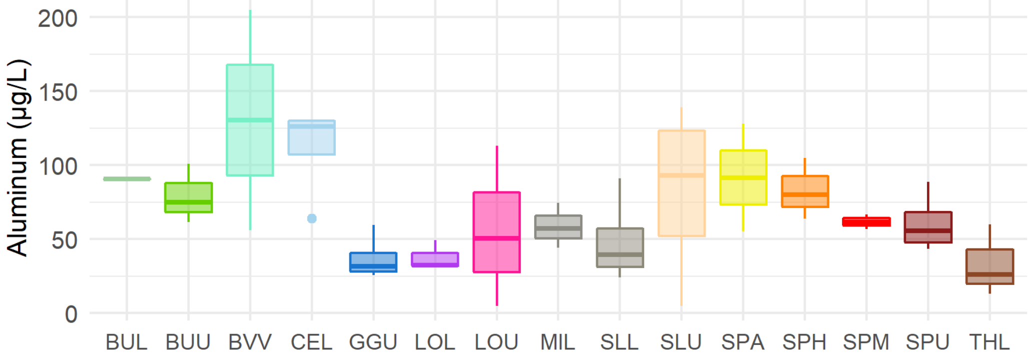

Turbidity (NTU)
10.0
7.5
5.0
2.5
BUL
BUU
BVV
CEL
GGU
LOL
LOU
MIL
SLL
SLU
SPA
SPH
SPM
SPU
THL

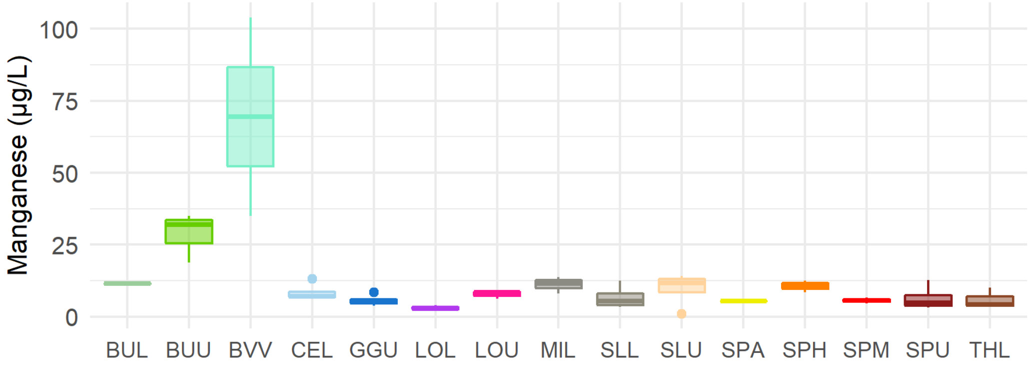

Temperature (°F)
60
55
50
45
BUL
BUU
BVV
CEL
GGU
LOL
LOU
MIL
SLL
SLU
SPA
SPH
SPM
SPU
THL

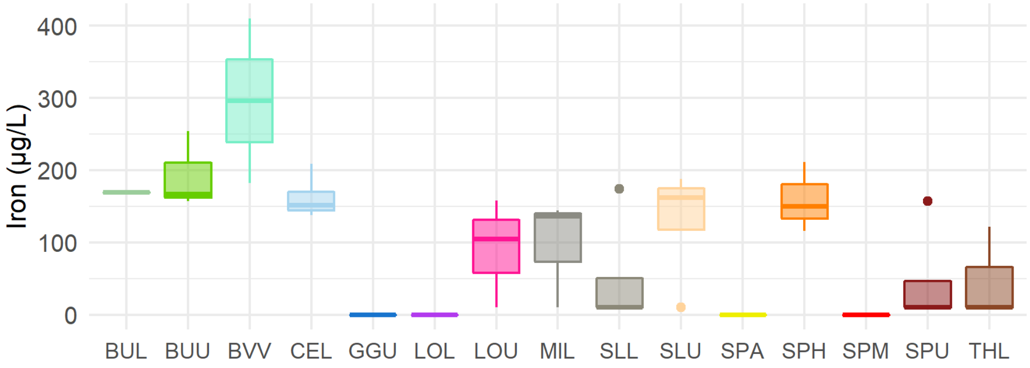
2019 Stream Water Quality Data

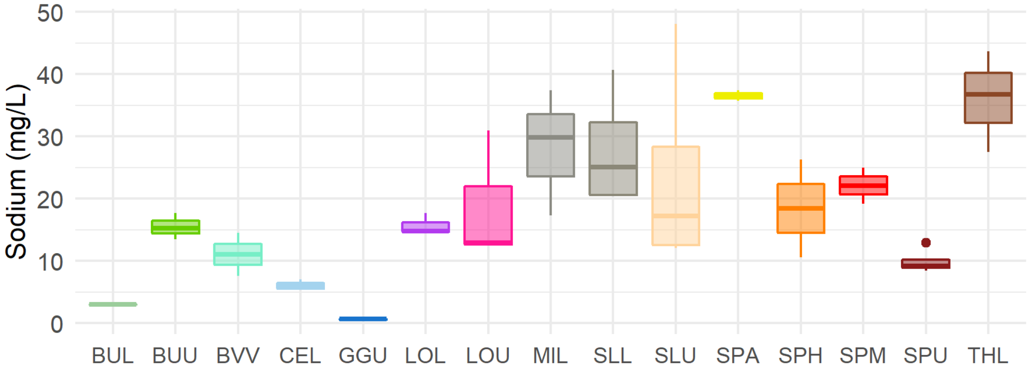
Metals—Total

Concentrations of nickel, lead, copper, chromium, cadmium and zinc were all non-detectable, so plots of these parameters are not included.



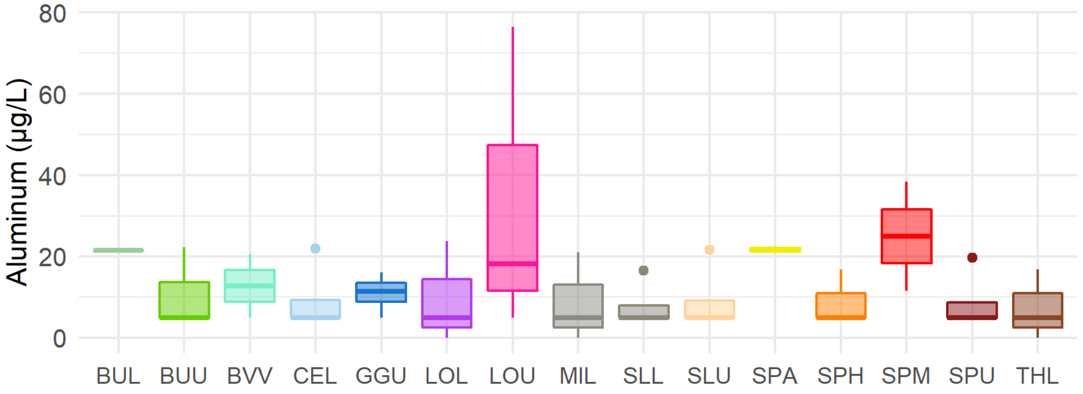


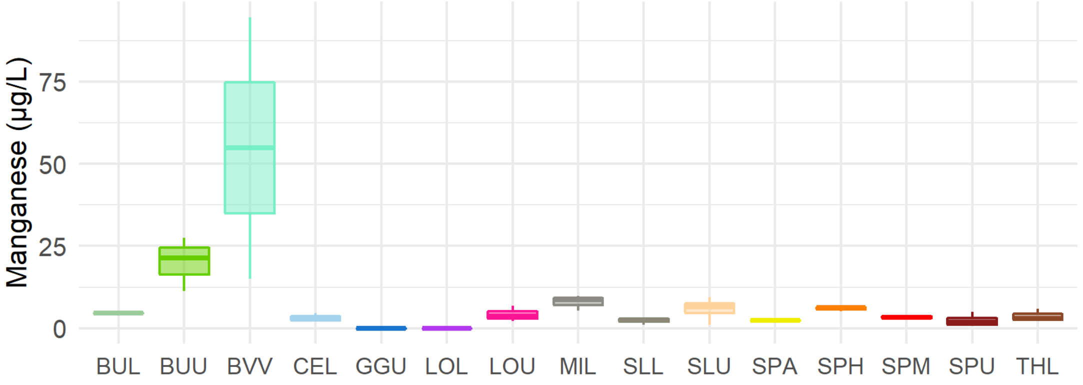


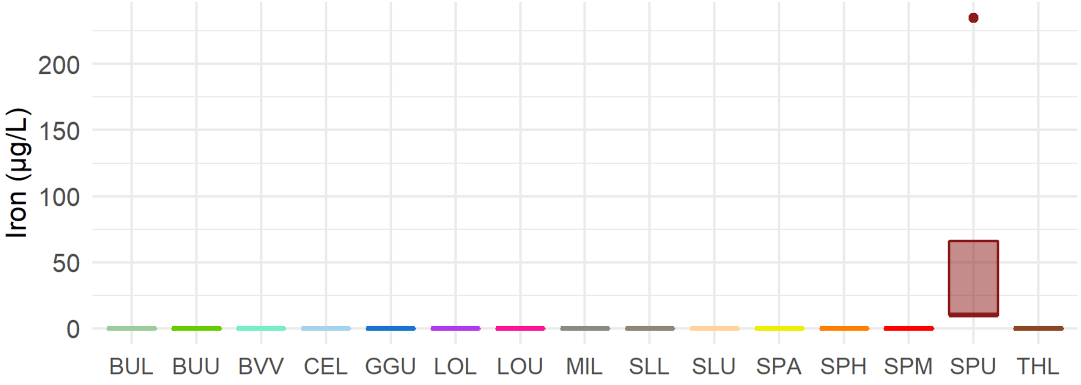


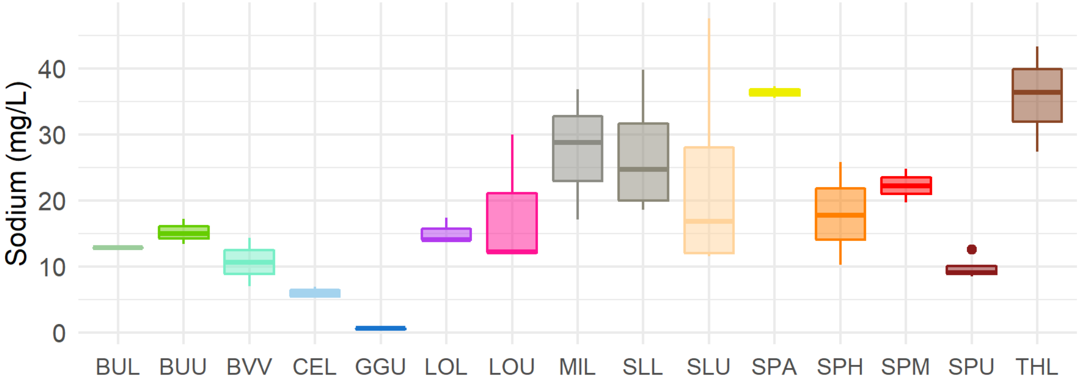
2019 Stream Water Quality Data

Metals—Dissolved









Groundwater Elevation Monitoring

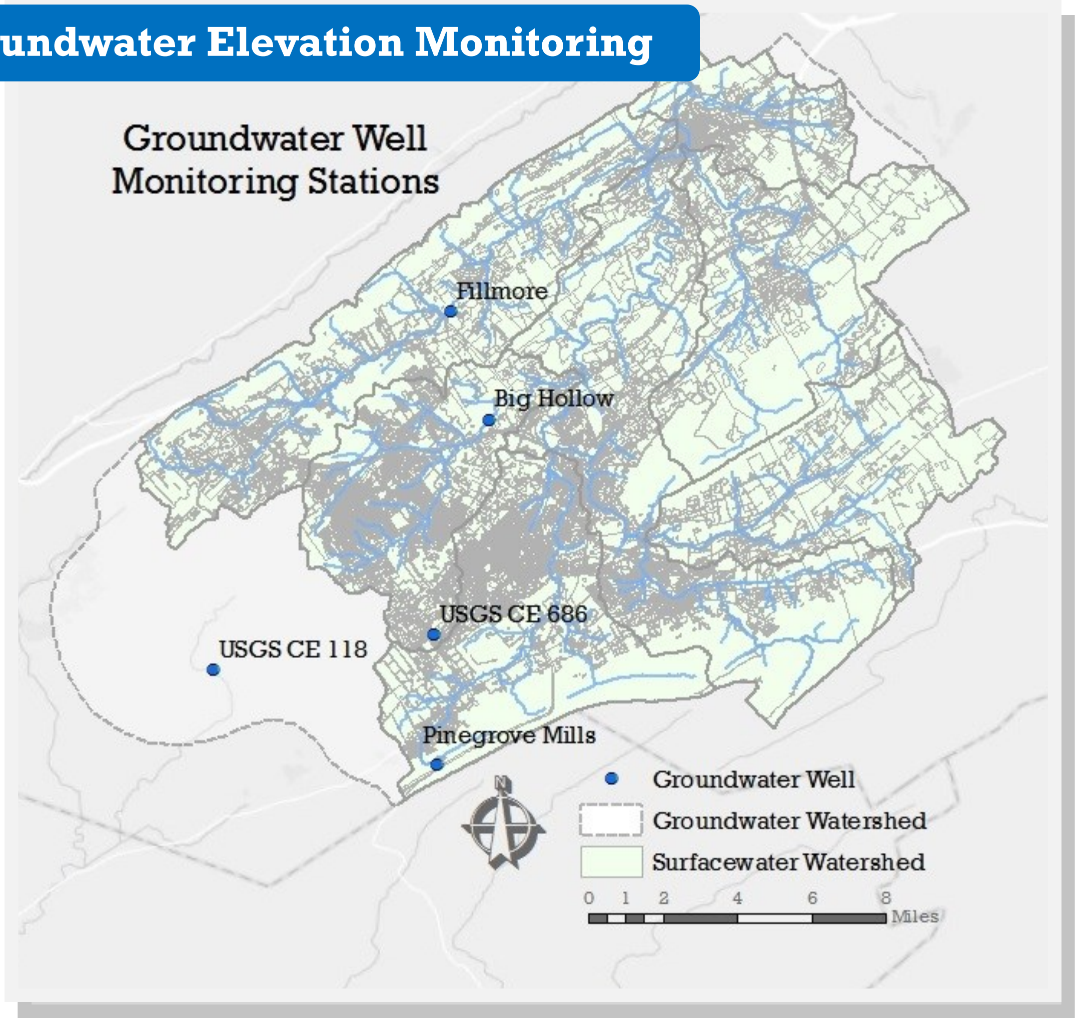
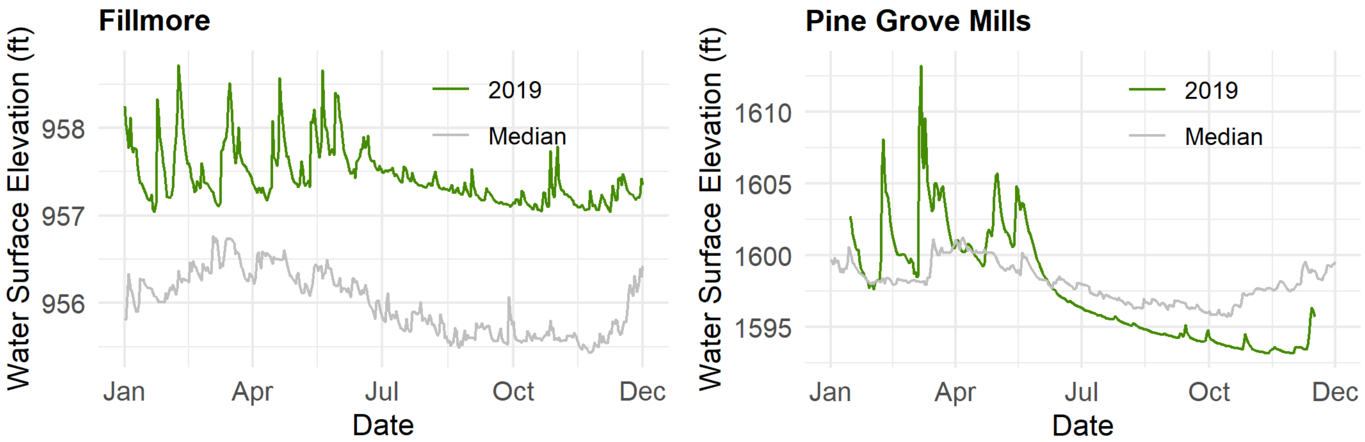
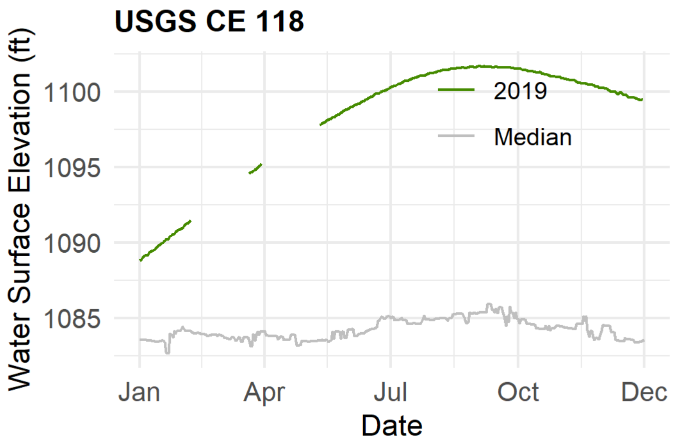


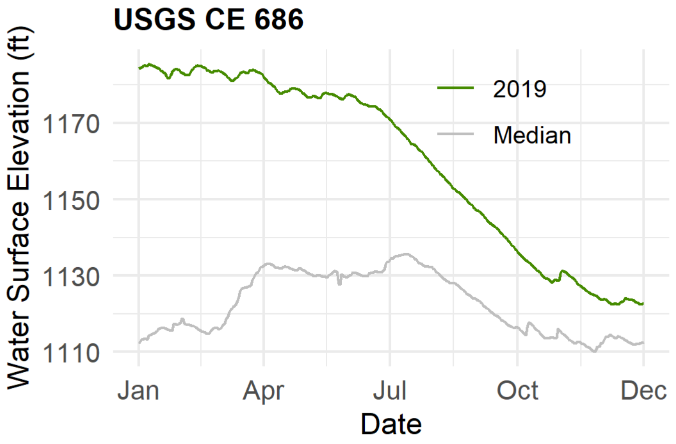
Fig. 24 Groundwater well locations maintained by the WRMP and the USGS

At the three wells comprising the WRMP groundwater monitoring network, water surface elevation is recorded every 3 hours with digitally-recording pressure transducers. Two USGS groundwater wells are also located in the watershed (Figure 24). In 2019, groundwater levels typically decreased in the second half of the year, indicating a lack of rainfall. The USGS well CE 118 continued to increase throughout the first half of the year due to deep soils and much slower response time to precipitation.



2019 USGS Groundwater Data





Data Quality and Requests

To assure the consistency and quality of data collected as part of the WRMP, the Keystone Water Resources Center Board of Directors and the Pennsylvania State University developed a set of standardized procedures for data collection, sample processing and database maintenance. The WRMP has been working directly with the Department of Environmental Protection to update this protocol and become quality assured by their Bureau of Clean Water. A detailed description of these methods may be found in the WRMP's protocol. To review this document, please contact the Water Resources Specialist at lexie@keystonewaterresources.org.

All data requests can be made through the Keystone Water Resources Center Website (www.keystonewaterresources.org) or by directly contacting Lexie Buck, the Water Resources Specialist at lexie@keystonewaterresources.org.

References

Booth, D. B., & Jackson, C. R. (1997). URBANIZATION OF AQUATIC SYSTEMS: DEGRADATION THRESHOLDS, STORMWATER DETECTION, AND THE LIMITS OF MITIGATION. *Journal of the American Water Resources Association*, *33*(5), 1077–1090. https://doi.org/10.1111/j.1752-1688.1997.tb04126.x

Carline, R .F., Dunlap, R.L., Detar, J.E., and B.A. Hollender. 2011. The Fishery of Spring Creek: A watershed under siege. Pennsylvania Fish and Boat Commission, Technical Report 1, Harrisburg, PA.

Fulton, J.W., Koerkle, E.H., McAuley, S.S., Hoffman, S.S. and L.F. Zarr. 2005. Hydrogeologic setting and conceptual hydrologic model of the Spring Creek basin, Centre County, Pennsylvania, June 2005. U.S. Geologic Survey, Scientific Investigations Report 2005-5091, Reston, Virgnia.

Gage, M. S., Spivak, A., & Paradise, C. J. (2004). Effects of Land Use and Disturbance on Benthic Insects in Headwater Streams Draining Small Watersheds North of Charlotte, NC. *Southeastern Naturalist*, *3*(2), 345–358. Retrieved from JSTOR.

Giddings, M.T. 1974. *Hydrologic Budget of Spring Creek Drainage Basin, Pennsylvania.* Unpublished Doctoral Dissertation. The Pennsylvania State University.

Hannah, D.M. and G. Garner. 2015. River water temperature in the United Kingdom: Changes over the 20th century and possible changes in the 21st century. *Progress in Physical Geology*. 39 (1): 68-92.

Herb, William & Janke, Ben & Mohseni, Omid & Stefan, Heinz. (2008). Thermal Pollution of Streams by Runoff From Paved Surfaces. Hydrological Processes. 22. 987 - 999. 10.1002/hyp.6986.

Hofmeister, K.L., Cianfrani, C.M. and W.C. Hession. 2015. Complexities in the stream temperature regime of a small mixed-use watershed in Blacksburg, VA. *Ecological Engineering*. 78:101-111.

Paul, M. J., & Meyer, J. L. (2001). Streams in the Urban Landscape. *Annual Review of Ecology and Systematics*, *32*(1), 333–365. https://doi.org/10.1146/annurev.ecolsys.32.081501.114040

Shortle, J., Abler, D., Blumsack, S., Britson, A., Fang, K., Kemanian, A., … Yetter, S. (2015). *Pennsylvania Climate Impacts Assessment Update*. 199.

Simon, A., Curini, A., Darby, S. E., & Langendoen, E. J. (2000). Bank and near-bank processes in an incised channel. *Geomorphology*, *35*(3–4), 193–217. https://doi.org/10.1016/S0169-555X(00)00036-2

Tague, C., Farrell, M., Grant, G., Lewis, S. and S. Rey. 2007. Hydrogeologic controls on summer stream temperatures in the McKenzie River Basin, Oregon. *Hydrologic Processes*. 21: 3288-3300.

Thompson, Anita & Kim, Kyunghyun & Vandermuss, Anthony. (2008). Thermal Characteristics of Stormwater Runoff From Asphalt and Sod Surfaces. JAWRA Journal of the American Water Resources Association. 44. 10.1111/j.1752-1688.2008.00226.x.

Webb, B.W., Hannah, D.M., Moore, R.D., Brown, L.E., and F. Nobilis. 2008. Recent advances in stream and river temperature research. Hydrological Processes. 22: 902-918.

KEYSTONE
Water
Resources
CENTER

208 South Spring Street

Bellefonte, PA 16823

lexie@keystonewaterresources.org

(814) 380-9244