Evaluation of Pollution Sources to Lake Glenville
June 2019 – December 2019

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Executive Summary

Routine water quality assessments on 6 streams in the Upper Little Tennessee River Basin in the Lake Glenville area have been conducted. Quarterly monitoring of 6 sites was conducted between June 2019 and December 2019 (referred to as Year 3); one site was monitored for each of the following streams: Hurricane Creek, Mill Creek, Pine Creek, Cedar Creek, Norton Creek, and Glenville Creek. The data demonstrate that water quality of the streams vary spatially and temporally, suggesting the influence of climate and the effects of land use activities within the area on water quality. Typically, water discharge and volume were lowest during the summer compared to the spring and fall, which is likely an influencing factor in overall water quality in the monitored streams. A quarterly sampling event was not conducted in March 2020 (winter) due to the impacts of the COVID-19 pandemic.

Results demonstrate that nutrient concentrations are influenced by land use patterns, specifically as they relate to soil erosion and runoff. However, orthophosphate concentrations were lower during Year 3 compared to those observed from June 2018 - March 2019 (referred to as Year 2). Nitrate concentrations were higher in Year 3 than in Year 2, but Year 3 nitrate concentrations were lower than those observed in Year 1 of this study. Based on analysis of spatial and temporal trends, overall water quality in the 6 monitored streams near Lake Glenville is acceptable and within established ambient water quality standards. Continued monitoring can allow for the evaluation of the stability of seasonal variation and evaluate the effectiveness of Best Management Practices (BMPs).

Based on the results in this study, none of the monitored streams discharging into Lake Glenville have exhibited pollutant levels that would significantly affect lake water quality. The influence of runoff and soil erosion on stream water quality may continue to be investigated but results of this study do not allow for the direct attribution of *E. coli* or nutrients to specific land use practices. It is probable that any decline in lake water quality is related to activities directly in and around the lake rather than to pollution inputs from the monitored streams.

Key Findings

- Land use patterns, water discharge and volume, and climate influence stream water quality
- Nutrient concentrations were lower or comparable in Year 3 to those observed in previous years of study.
- No monitored stream exhibited pollution levels that would significantly affect the water quality of Lake Glenville

Introduction

The Little Tennessee River Basin includes most of Graham, Macon, Swain, and Jackson Counties along with small portions of Cherokee and Clay Counties. The basin encompasses 1,797 square miles which includes the Cullasaja, Nantahala, Tuckasegee, and Cheoah Rivers. Approximately 90% of the land is forested land with less than 5% consisting of urban or developed land use patterns, which are concentrated in and around Franklin, Sylva, Cullowhee, Highlands, Bryson City, and Robbinsville. More than half of the land in the basin is in the Great Smoky Mountains National Park or the Nantahala National Forest.

The Little Tennessee River basin is further classified into Upper and Lower portions. Lake Glenville is located in the Upper Little Tennessee River basin (HUC 06010202). Six streams within the Upper Little Tennessee River basin that discharge into Lake Glenville were monitored by the Environmental Health Program at Western Carolina University from June 2019 to December 2019 to assess overall water quality and identify sources of impairment (Table 1).

Table 1. Lake Glenville monitoring sites

H-1	Hurricane Creek at Norton Road bridge crossing
N-1	Norton Creek at North Norton Road bridge crossing
M-1	Mill Creek at bridge 0.2 miles downstream from North Norton Road bridge crossing
P-1	Pine Creek at Pine Creek Road bridge crossing
C-1	Cedar Creek at Bee Tree Road bridge crossing
G-1	Glenville Creek at Tator Knob Road culvert crossing

Materials and Methods

Water samples were collected quarterly from June 2019 to December 2019 by the Environmental Health Program at Western Carolina University. Collected water samples were transported to WCU and analyzed for the following parameters: pH, ammonia (NH_3) nitrate (NO_3^-) orthophosphate (PO_4^{3}), total suspended solids (TSS), turbidity, conductivity, and alkalinity. Discharge measurements from the US Geological Survey (USGS) gauging station on Little Tennessee River at Prentiss (USGS 03500000) were used to determine relative discharge for the sites in the Lake Glenville area. Although gauging stations only truly represent the streams on which they are located, the discharge measurements collected by this gauge station are assumed to be a reliable method for determining the influence of discharge on water quality at each stream site. Specific details regarding sample collection, transport, and laboratory analysis methodology are available in Appendix A.

Statistical analyses were performed in an effort to (1) characterize the water quality of each stream site in relation to established water quality standards and (2) identify the effects of precipitation, stream water level, seasonality, land use, and temporal trends on water quality.

Results and Discussion

This discussion is based on data collected between June 2019 and December 2019. Summary statistics for data collected during this time period are available in Appendix B. Mean concentrations of each analyzed parameter by stream and season are available in Appendix C.

Trends in water quality become more evident with every year of continuous monitoring and contribute to a shaper image of conditions present in streams and watersheds. Continued collection of water quality data over time allows for the identification of changing conditions and areas of concern, which can contribute to financially and politically sound decision making for effective water resource management.

It is important and necessary to compare sites within the mountain area to understand how water quality from each stream ranks within the region. With this information local governments, organizations, and individuals can compare areas with similar problems or successes and exchange information regarding remediation or protection plans. It will also be helpful to note improvements or deteriorations in stream water quality over time as a result of changes in population density, industrial development, topography, and land use patterns. Each of these factors must be taken into consideration when comparing stream water quality. A discussion of the stream sites relative to specific water quality parameters follows.

Analysis of the effects of stream water level, temporal changes, and seasonality on water quality parameters at individual sites has been included in this discussion. These analyses were used to determine if changes in concentrations or levels of a parameter change in relation to discharge, time, and season. Trends observed in these data and interpretations of what may have contributed to those trends are suggested.

Acidity and Alkalinity

pH is used to measure acidity and is an important water quality parameter because it has the potential to seriously affect aquatic ecosystems. Slight fluctuations in pH can interfere with the reproduction of aquatic organisms or result in their death. The ambient water quality standard for pH is between 6.0 and 9.0, although natural pH in area streams generally ranges from 6.5-7.5. Values below 6.5 may indicate the effects of acid precipitation or other acidic inputs, and values above 7.5 may indicate the influence of industrial discharge. Spatial trends in pH demonstrate slight variability but no average pH reading below 6.5 or above 7.5 was observed in any stream during Year 3 (Figure 1). Examination of seasonal pH demonstrates subtle variability between seasons but there are no statistically significant seasonal trends related to pH at the stream sites. (Figure 2). There are no statistically significant differences in annual pH at stream sites (Figure 3).

Monitoring results from 2007-2019 demonstrated an overall trend of increasing pH for all streams since the initiation of routine monitoring by the Friends of Lake Glenville, and these results continue to indicate an increasing trend in pH (Figure 4). The increasing trend in pH may be the result of emission and discharge controls from power plants, resulting in reduced acid deposition. However, it is important to note that pH in all streams observed during since 2007 has been within the ambient water quality standard for pH. Annual stream discharge variations are not a factor, as they are not accounted for in trend analysis.

Figure 1. Mean pH levels at each monitoring site, June 2019 – December 2019

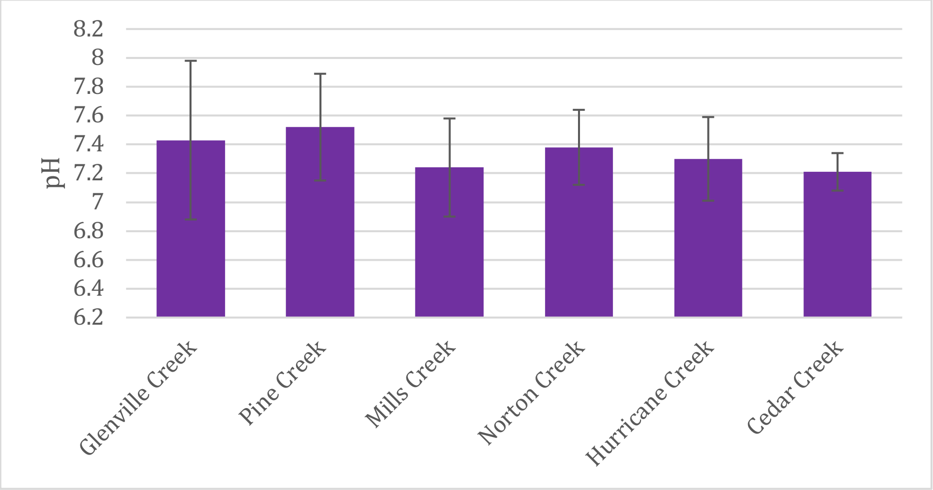


Figure 2. Mean pH at each monitoring site by season, June 2019 – December 2019

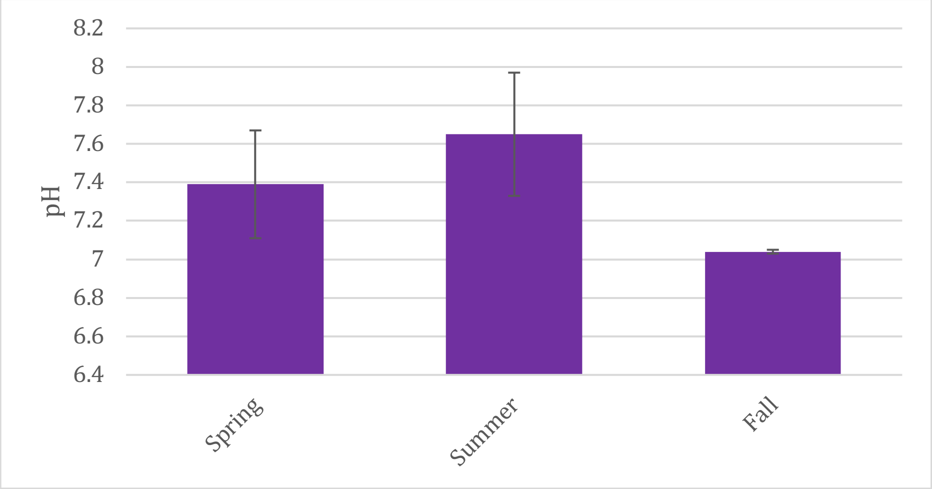


Figure 3. Mean pH at each monitoring site by year

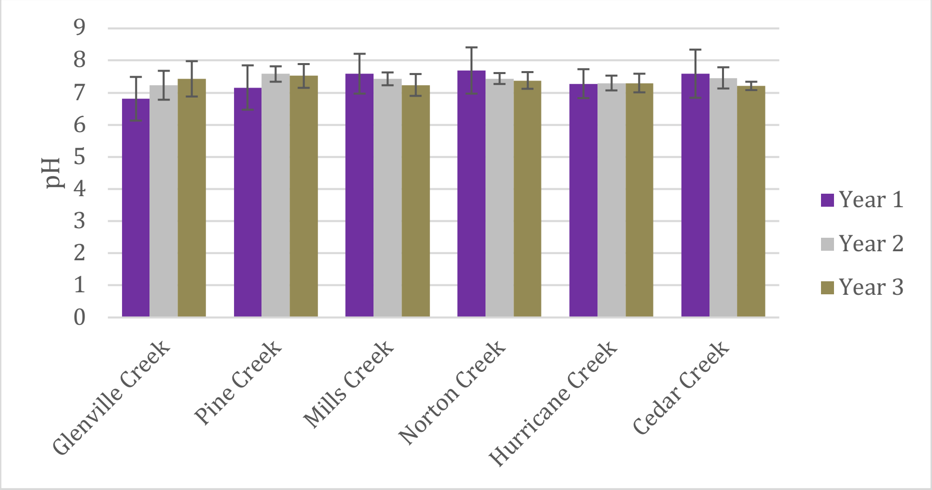
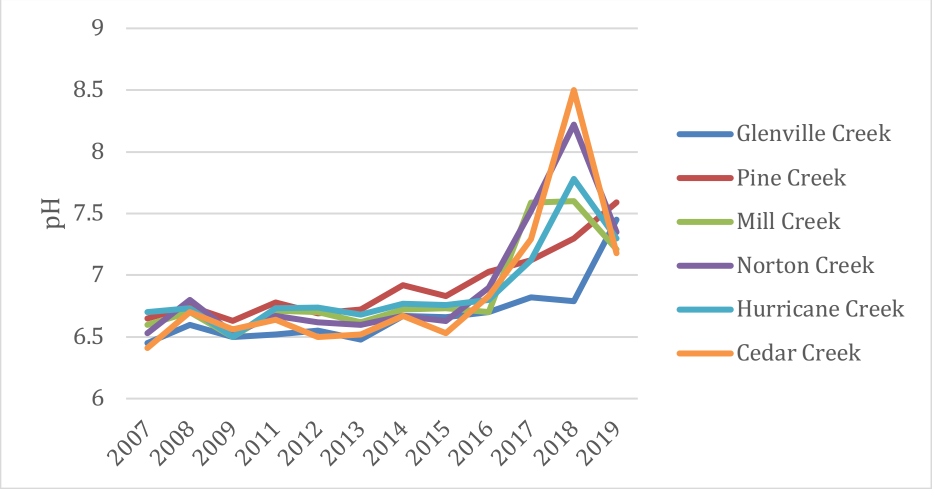


Figure 4. Mean pH at each monitoring site by year, 2007-2019



Alkalinity is the measure of the pH buffering capacity of a water or soil. High alkalinity waters are generally better protected against acid inputs from sources such as acid rain, organic matter, and industrial effluent. Waters with an alkalinity below 30mg/L are considered to have low alkalinity. The observed mean alkalinity concentrations demonstrate low alkalinity in all monitored streams during all seasons in 2019 (Figures 5 and 6). These low levels are largely the result of bedrock, soils, and precipitation patterns in the Glenville area. The Glenville area streams also exhibit lower levels of pollutants compared to many other area streams, and pollutants can also affect alkalinity levels. While no extreme high or low pH levels were observed at any site, minimum alkalinity concentrations at several sites have been almost exhausted.

Low alkalinity concentrations have been consistently observed in since 2007. Examination of temporal trends in alkalinity demonstrates variability over time, specifically decreases in mean alkalinity concentrations in all streams since the initiation of the study in 2007. With the exception of Glenville Creek, all streams exhibited a sharp decrease in alkalinity concentrations from 2016 to 2018, followed by an increase in alkalinity concentrations in 2019 (Figure 7). With the exception of Glenville Creek, all streams demonstrated an increase in alkalinity between Year 1 and Year 3 of this study (Figure 8) which may contribute to the observed improved stability of stream pH during Year 3.

Figure 5. Mean alkalinity concentration by site, June 2019 – December 2019

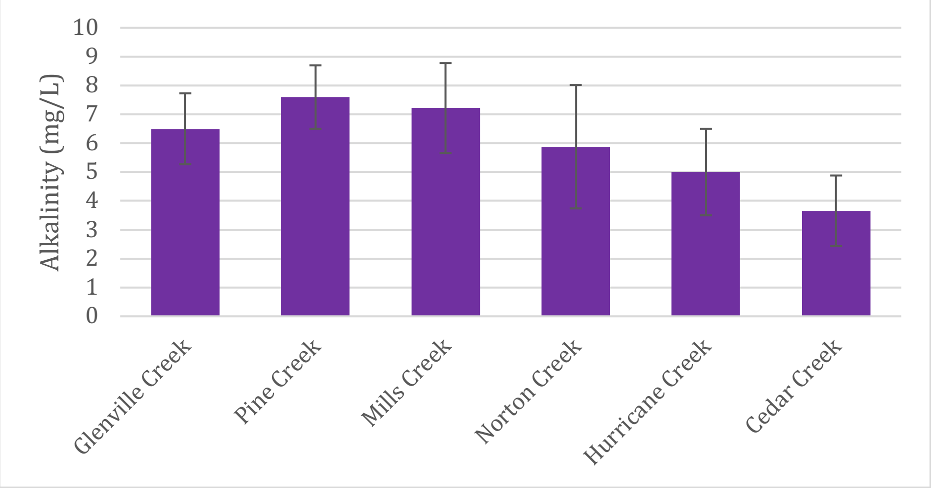


Figure 6. Mean alkalinity concentration by season, June 2019 – December 2019

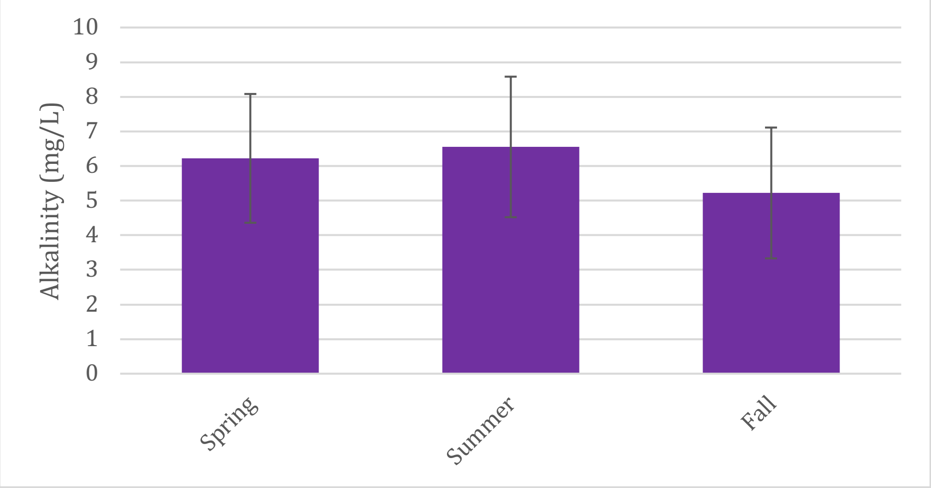


Figure 7. Mean alkalinity concentration at each monitoring site by year, 2007-2019

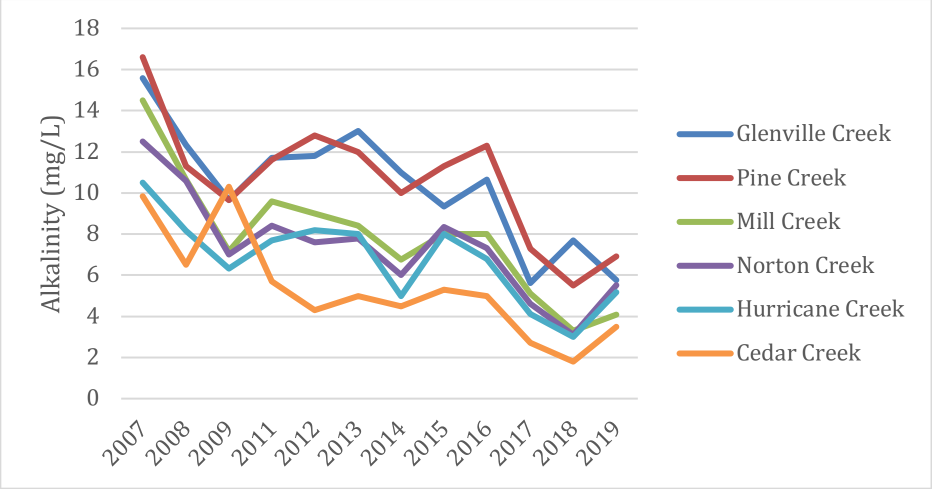
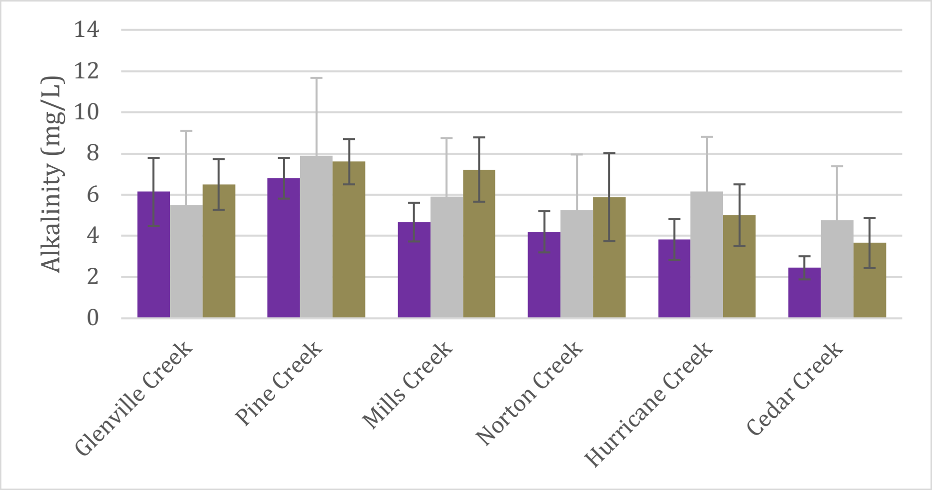


Figure 8. Mean alkalinity concentration at each monitoring site by year



Turbidity and Total Suspended Solids (TSS)

Turbidity is a measure of visual water clarity and of the presence of suspended particulate matter. Turbidity is an important parameter for assessing the viability of a stream for trout propagation. Trout eggs can withstand only slight amounts of silt before hatching is impaired. Fish that are dependent on sight for locating food are also at a great disadvantage when water clarity declines. To minimize the likelihood of such negative impacts, the standard for trout-designated waters is 10 NTU and the standard to protect other aquatic life is 50 NTU. Mean turbidity measurements in all streams were below the 10 NTU trout-designated water standard (Figure 9).

Temporal trends in turbidity demonstrate a decrease from 2018 to 2019 and from Year 2 to Year 3 in Glenville, Mill, and Norton Creeks (Figures 10 and 11). These decreases may be the result of dilution due to increased discharge and the presence of buffer vegetation to prevent the introduction of turbidity constituents to receiving waters. Average discharge at the Little Tennessee River at Prentiss gauging station increased during the three-year study period, from an average of 250 cubic feet per second (cfs) in 2017 to 600 cfs in 2019. Increases in turbidity concentrations in Pine, Hurricane, and Cedar Creeks during Year 3 were not statistically elevated compared to Years 1 and 2 turbidity concentrations. Turbidity concentrations and average discharge during the spring were higher than what was observed in summer and fall, suggesting the influence of water flow on soil erosion and the introduction of turbidity constituents. Mean turbidity measurements during all seasons were below the 10 NTU trout-designated water standard (Figure 12).

Figure 9. Mean turbidity at each monitoring site, June 2019 – December 2019

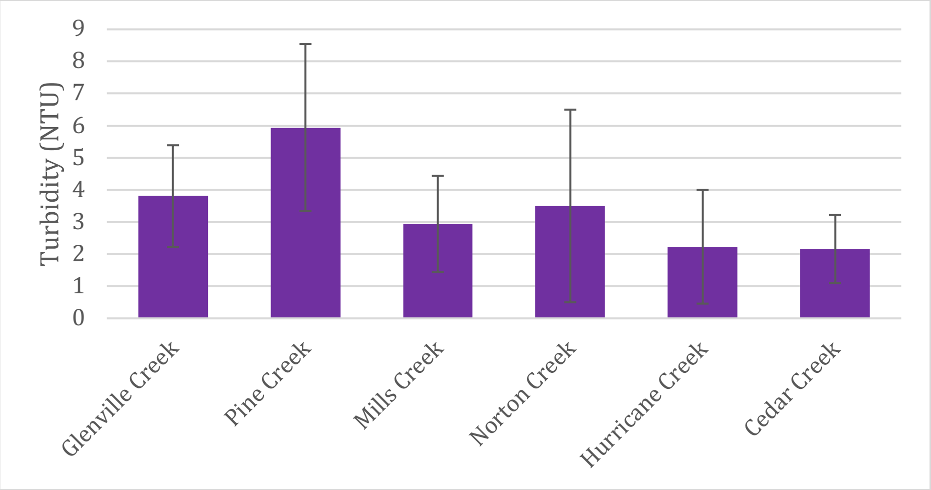


Figure 10. Mean turbidity concentration at each monitoring site by year, 2007-2019

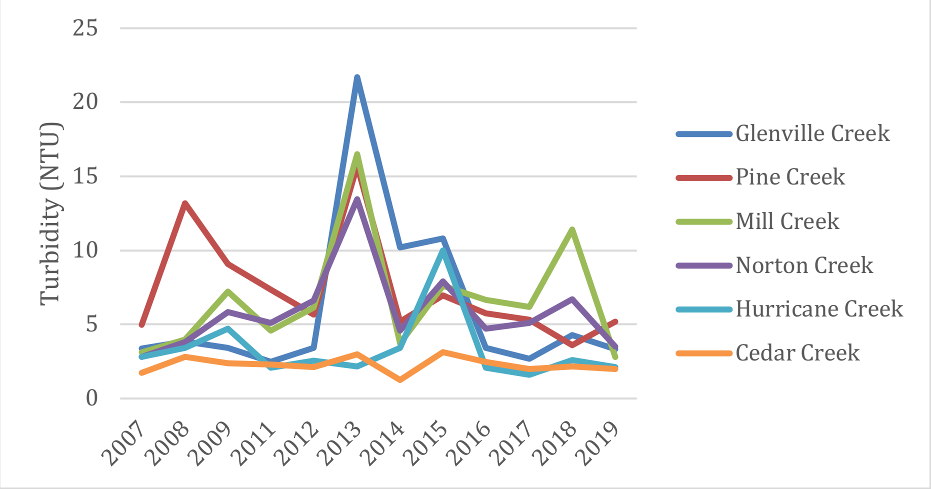


Figure 11. Mean turbidity at each monitoring site by year

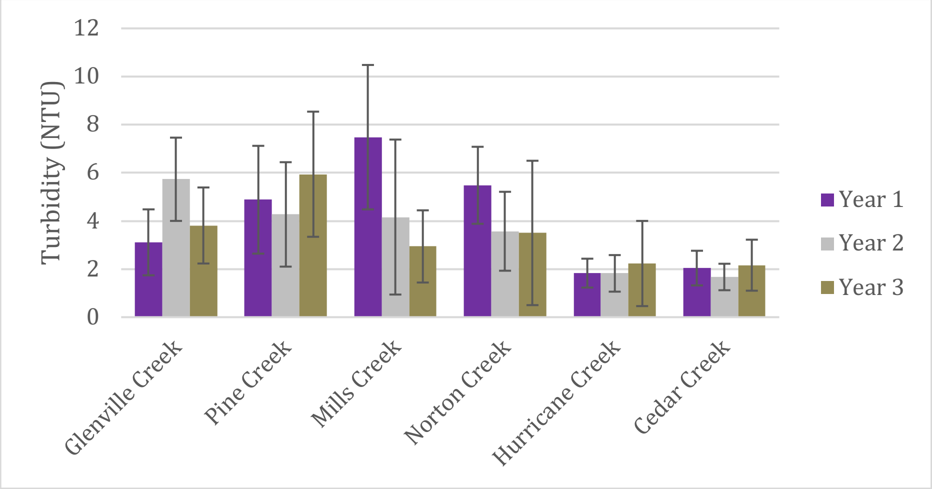
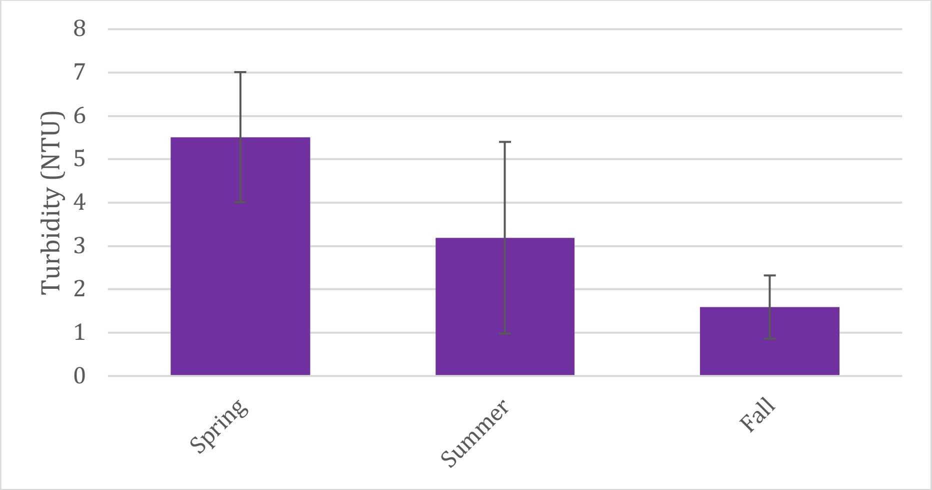


Figure 12. Mean turbidity by season, June 2019 – December 2019



TSS quantifies solids by weight and is heavily influenced by a combination of stream discharge and land disturbances. Mountain streams in undisturbed forested areas such as those in the Little Tennessee River Basin tend to remain clear even after moderately heavy rainfall events. Areas with disturbed soil may have elevated TSS concentrations even after relatively light rainfall. Suspended solids settle to the streambed where they can bury and destroy benthic macroinvertebrates, the absence of which reduces ecosystem diversity. Although there is no legal standard for TSS, concentrations below 30mg/L are generally considered low. All monitoring streams exhibited low TSS concentrations (Figure 13). The undisturbed forested areas and presence of vegetated riparian zones likely influenced the low turbidity and TSS concentrations.

Temporal trends demonstrate continued decreases in TSS since 2015 in all streams (Figure 14). The nonsignificant increases in TSS concentrations observed for Glenville, Pine, Mill, and Norton Creeks during Year 3 (Figure 15) may be due to the influence precipitation and runoff events that introduced TSS immediately prior to one of the quarterly sampling events. Approximately 0.5 inches of precipitation fell on the day prior to the June 2019 sampling event resulting in TSS concentrations higher than those observed previously. Increased water volume was also observed at Glenville and Pine Creeks during the December 2019 sampling event, where water elevations were above the defined banks of Glenville and Pine Creeks. While the streams were not considered to be flooded, the contact between the elevated water and exposed soil along stream banks likely contributed to increased TSS concentrations in those streams at the time. Seasonal trends in TSS are similar to those of turbidity as mean TSS concentrations during all season is considered to be low (Figure 16).

Figure 13. Mean TSS concentration at each monitoring site, June 2019 – December 2019

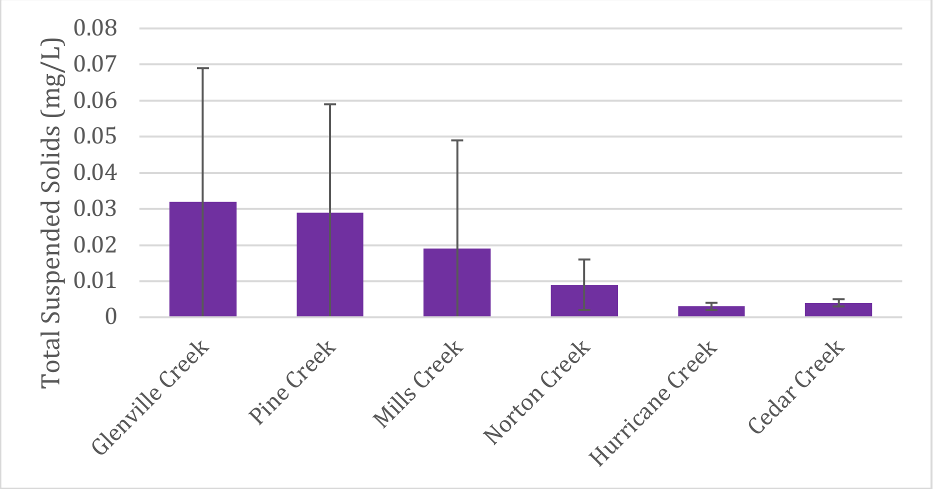


Figure 14. Mean TSS concentration at each monitoring site by year, 2007-2019

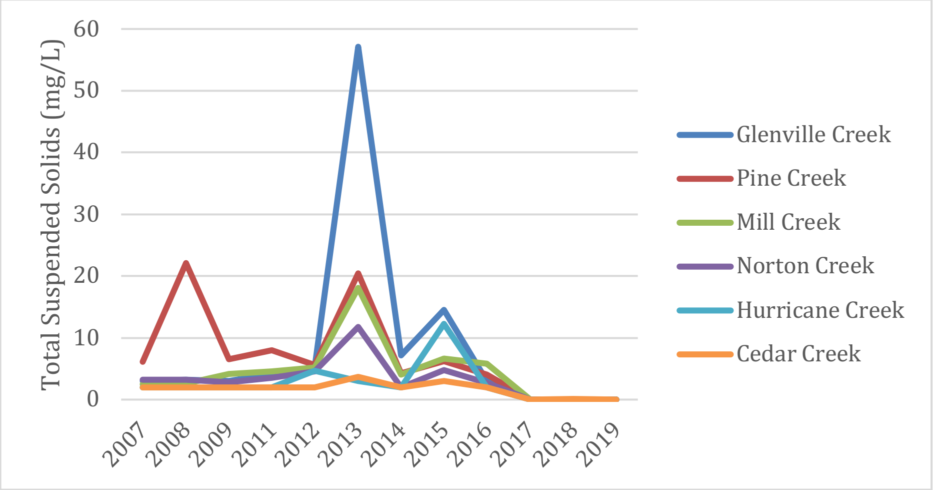


Figure 15. Mean TSS concentration at each monitoring site by year

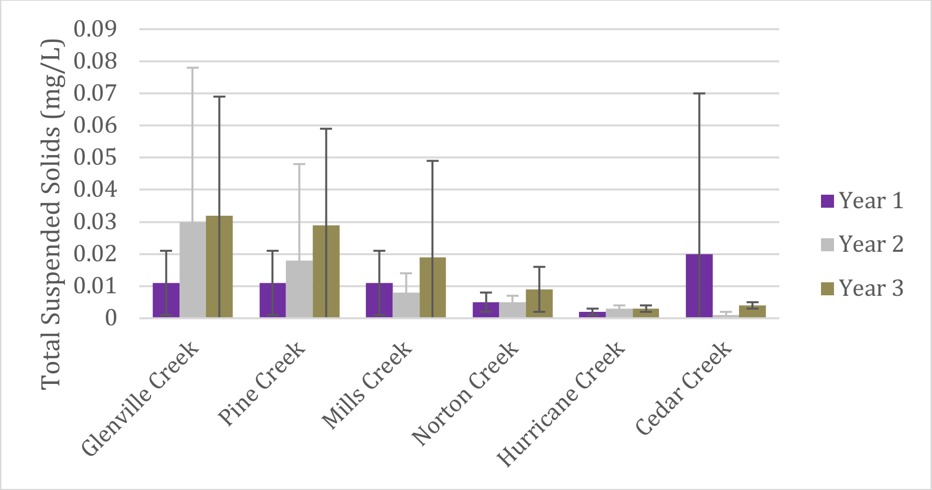
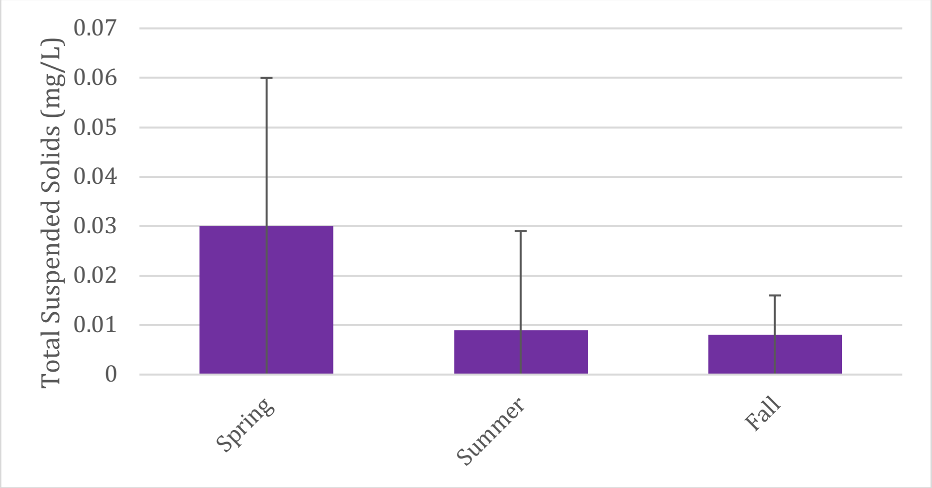


Figure 16. Mean TSS concentration by season, June 2019 – December 2019



Conductivity

Conductivity is used to measure the ability of water to conduct an electrical current. Samples containing dissolved solids and salts will form ions that conduct an electrical current and the concentration of dissolved ions in a sample determines conductivity. Inorganic dissolved solids such as chloride, nitrate, phosphate, calcium, sulfate, iron, sodium, and aluminum will affect conductivity levels and local geologic conditions will influence the types and extent of dissolved ions. Elevated levels of conductivity are most often seen in streams receiving wastewater discharge, urban runoff, or eroded soils.

The observed conductivity levels at each monitoring site are expected considering the undisturbed forested landscape and clay soils (Figure 17). Pine, Mill, and Hurricane Creeks demonstrate increases in conductivity levels from 2018 to 2019 although it is important to note that observed conductivity is not worrisome (Figure 18). Most sites displayed their highest conductivity levels during the spring which coincides with higher TSS concentrations and turbidity, suggesting that soil erosion and runoff may be contributing ions resulting in increased conductivity. Only Norton Creek displayed a significant increase in conductivity in Year 3 (Figure 20).

Figure 17. Mean conductivity at each monitoring site, June 2019 – December 2019

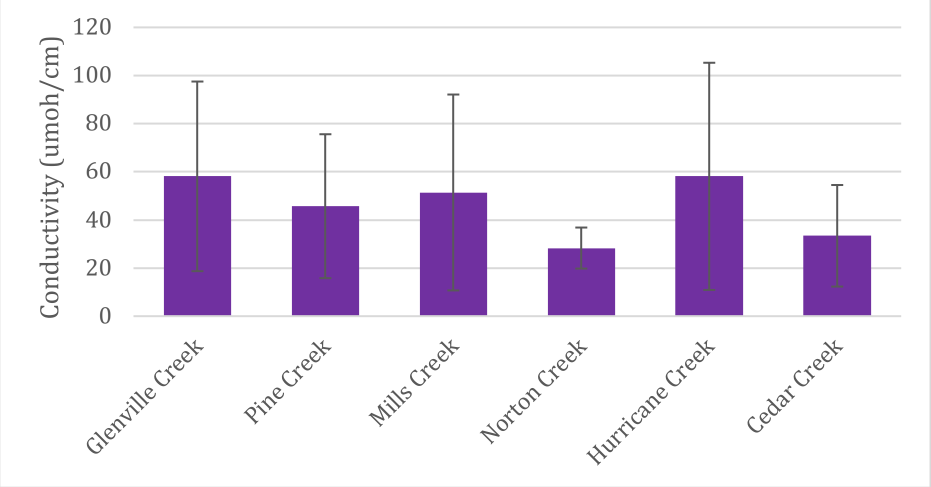


Figure 18. Mean conductivity at each monitoring site by year, 2007-2019

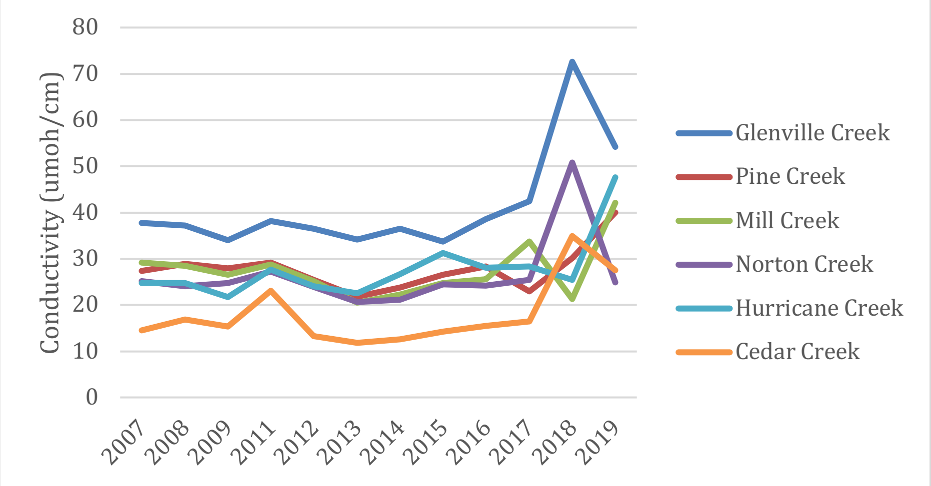


Figure 19. Mean conductivity by season, June 2019 – December 2019

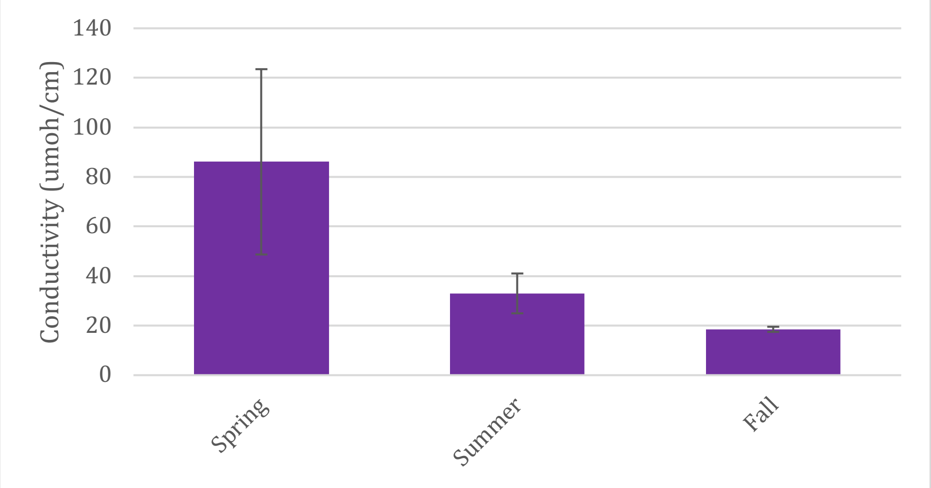
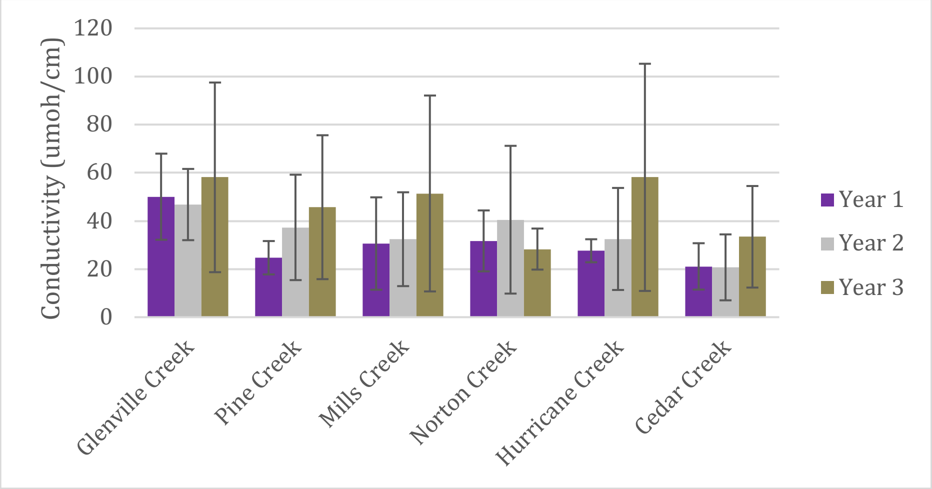


Figure 20. Mean conductivity at each monitoring site by year



Nutrients (Orthophosphate [PO4^{3-}], Ammonia [NH3^{+}], and Nitrate [NO^{3-}])

Phosphorous is an essential nutrient for aquatic plants and algae, and is typically the limiting nutrient in most aquatic systems thereby restricting plant growth in an ecosystem. Phosphorous is introduced into water systems from soil, wastewater treatment systems, failing septic systems, and runoff from fertilized land. Excessive phosphorous stimulates plant growth and may result in eutrophication, a condition that can result in dissolved oxygen depletion in an aquatic ecosystem. Orthophosphate is the amount of phosphorous that is immediately available to plants or algae for biological assimilation. Generally, orthophosphate levels below 0.05 mg/L are sufficient to prevent eutrophication.

There is no legal water quality standard for orthophosphate, but the Environmental Protection Agency (EPA) nutrient criteria for total phosphorous in rivers and streams in this ecoregion is 0.01 mg/L. Although orthophosphate is only one component of total phosphorous, observed concentrations at Glenville, Pine, Mill, and Norton Creeks exceed the EPA nutrient criteria for total phosphorous. However, all streams continue to exhibit significantly decreased orthophosphate concentrations in Year 3 compared to Years 1 and 2 (Figures 21 and 22). Strong correlations are observed between orthophosphate concentrations, and TSS concentrations and turbidity, suggesting that soil erosion and runoff are likely contributing orthophosphate to the streams (Figures 23 and 24).

The average orthophosphate concentrations observed during the study period across all streams, while elevated, do not appear to be contributing to eutrophication based on observed dissolved oxygen concentrations and the absence of visual algal blooms. Orthophosphate concentrations were highest in the summer and this observation was expected due to concentration of nutrients in the water column as a result of reduced water discharge (Figure 5). The highest orthophosphate concentrations in Year 3 were observed in the summer when the average discharge was at its lowest (108 cfs) as indicated by the Prentiss gauging station on the Little Tennessee River. Higher discharge during the fall likely diluted orthophosphates in the water column as the average discharge increased to 379 cfs and orthophosphate concentrations significantly decreased. The decrease in orthophosphate concentrations in all streams during 2019 is an indicator of successful BMPs and warrants additional monitoring to evaluate their continued effectiveness (Figure 26).

Figure 21. Mean orthophosphate concentration at each monitoring site, June 2019 – December 2019

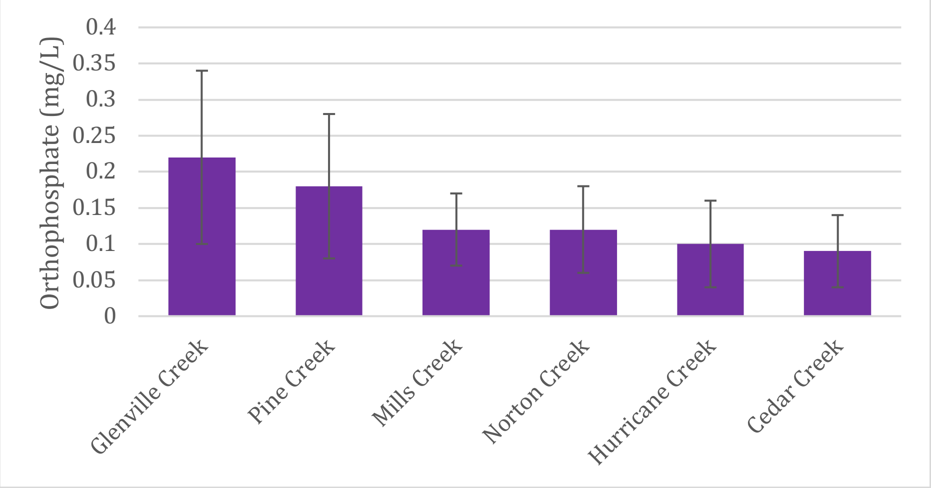


Figure 22. Mean orthophosphate concentration at each monitoring site by year

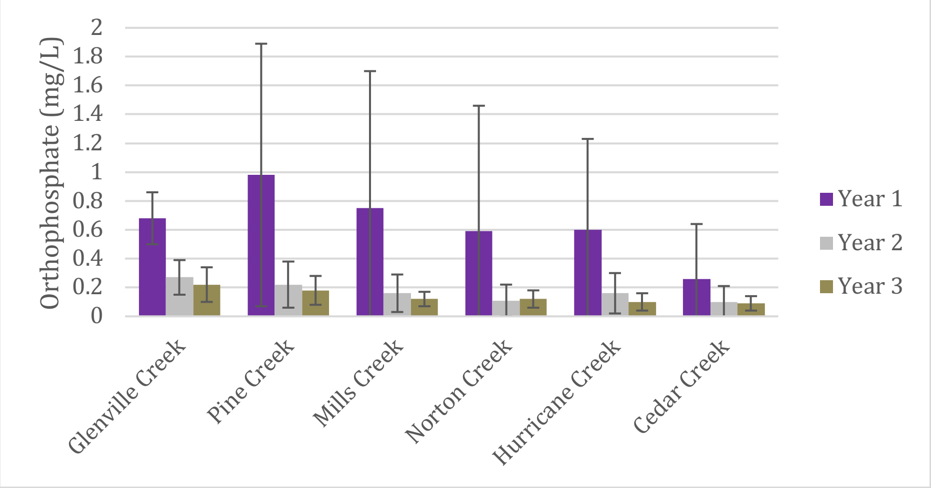


Figure 23. Correlation between orthophosphate and TSS, June 2019 – December 2019

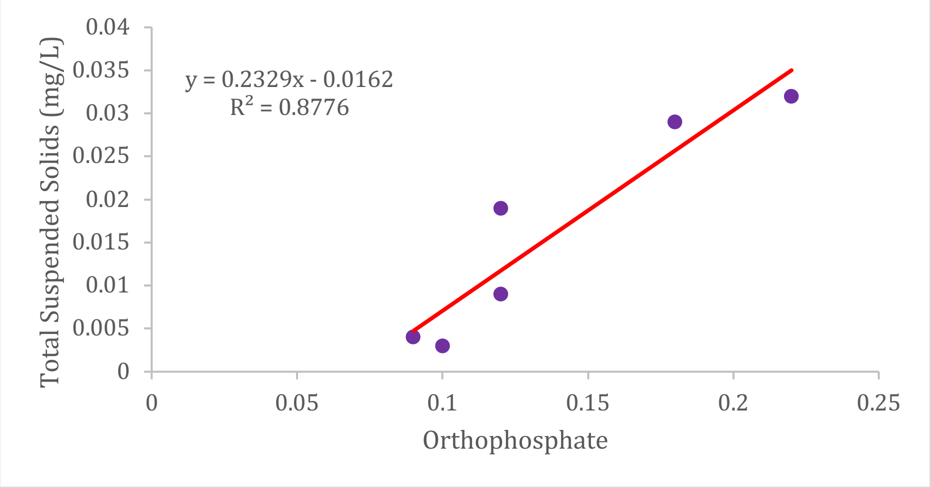


Figure 24. Correlation between orthophosphate and turbidity, June 2019 – December 2019

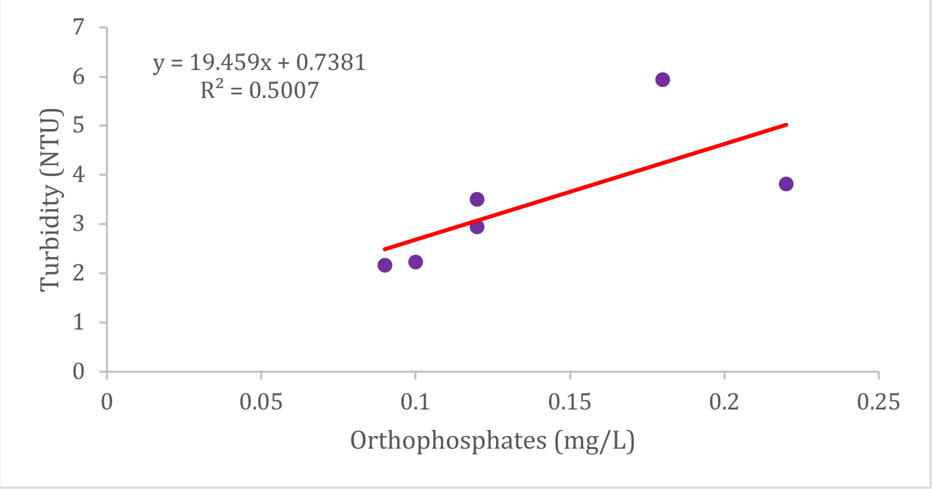


Figure 25. Mean orthophosphate concentration by season, June 2019 – December 2019

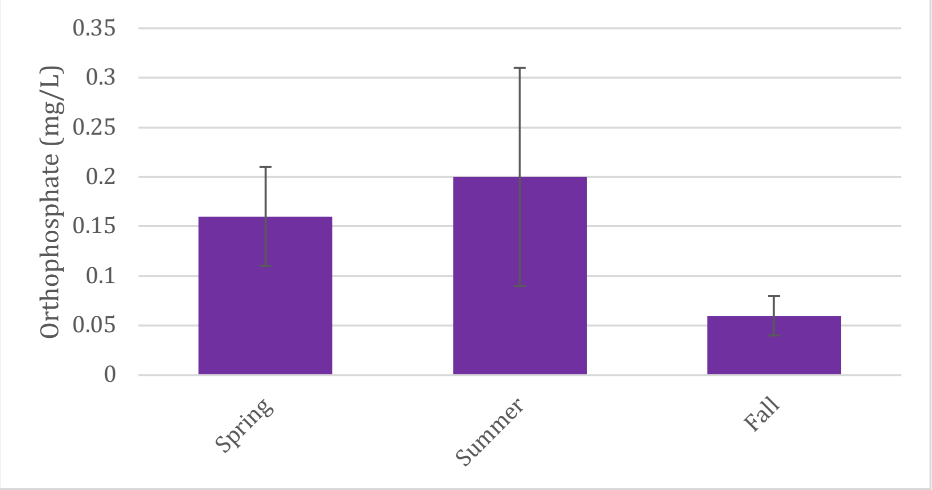
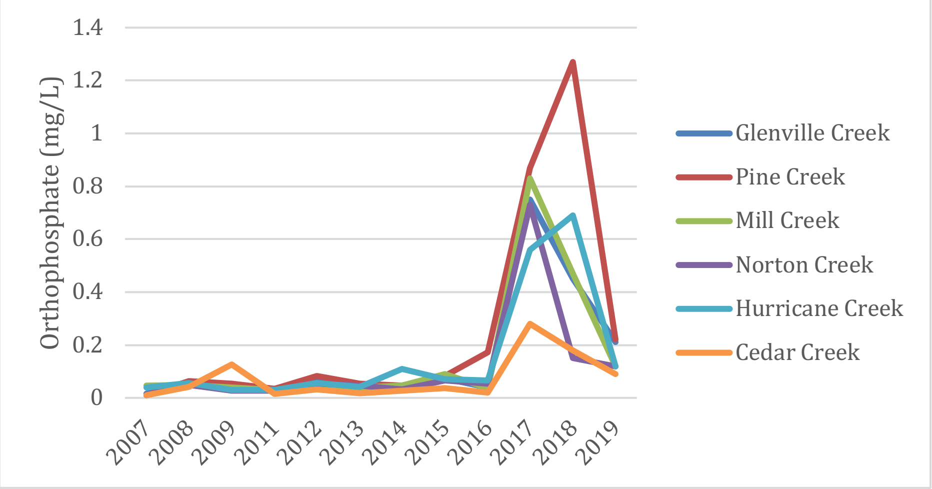


Figure 26. Mean orthophosphate concentration at each monitoring site by year, 2007-2019



Ammonia is contained in decaying plant and animal remains and microbial decomposition of these organic wastes can release ammonia. The most common sources of ammonia are agricultural runoff, livestock farming, septic drainage, and sewage treatment plants. The ambient concentration of ammonia in water is approximately 0.10 mg/L but concentrations are heavily influenced by water temperature and pH. Ammonia concentrations in Mill and Cedar Creeks exceed this "norm" but no stream exceeded the ambient total ammonia toxicity standard of 1.9 mg/L (Figures 27 and 28). Additionally, ammonia concentrations appear to be slightly influenced by seasonality and discharge. The spring and summer exceed the ambient ammonia concentration of 0.10mg/L but no season exceeds the ambient total ammonia toxicity standard of 1.9 mg/L (Figure 29). Mean ammonia concentrations were comparable across Years 1 – 3 of this study for all streams and continue to be below the ambient total ammonia toxicity standard (Figure 30). Ammonia concentrations also demonstrate a weak inverse correlation with nitrate concentrations, suggesting the activity of nitrifying bacteria that convert ammonia to nitrate as part of the nitrogen cycle.

Figure 27. Mean ammonia concentration at each monitoring site, June 2019 – December 2019

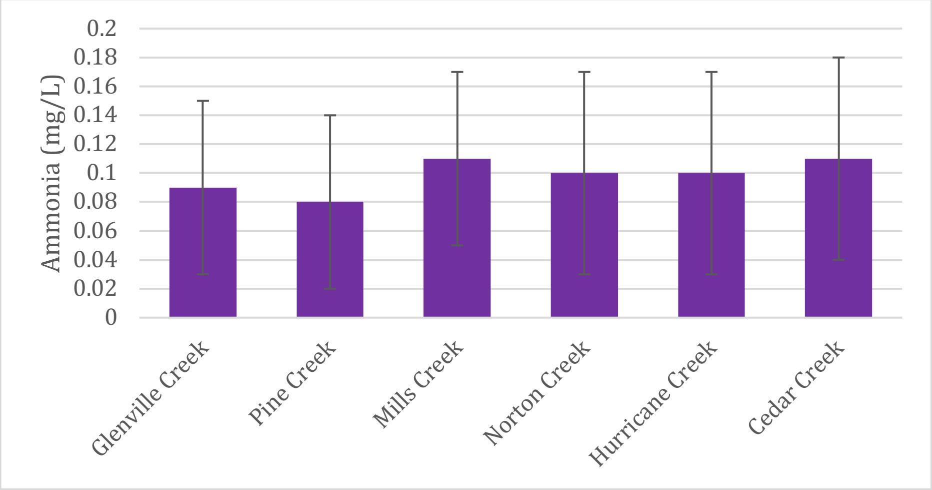


Figure 28. Mean ammonia concentration at each monitoring site by year, 2007-2019

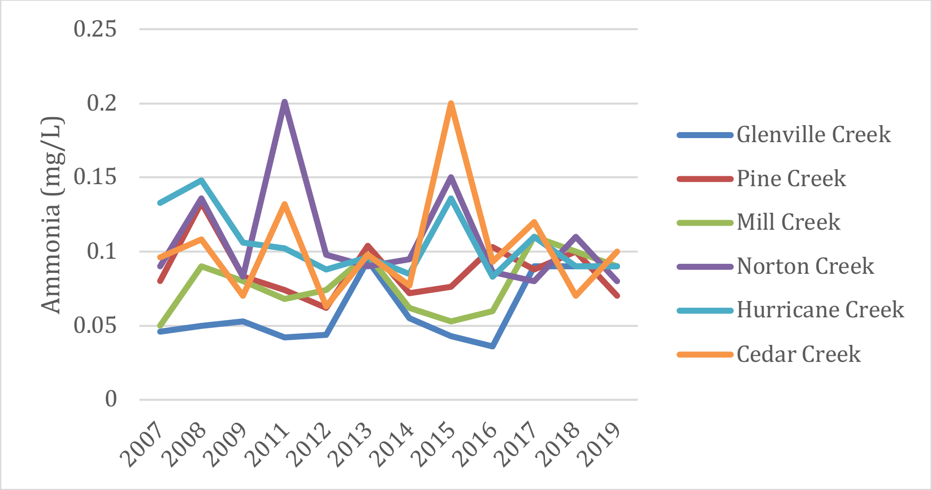


Figure 29. Mean ammonia concentration by season, June 2019 – December 2019

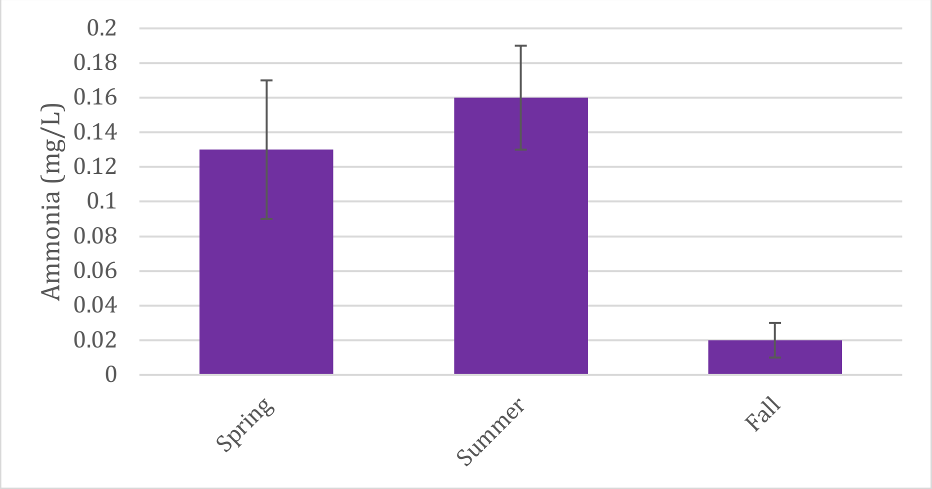
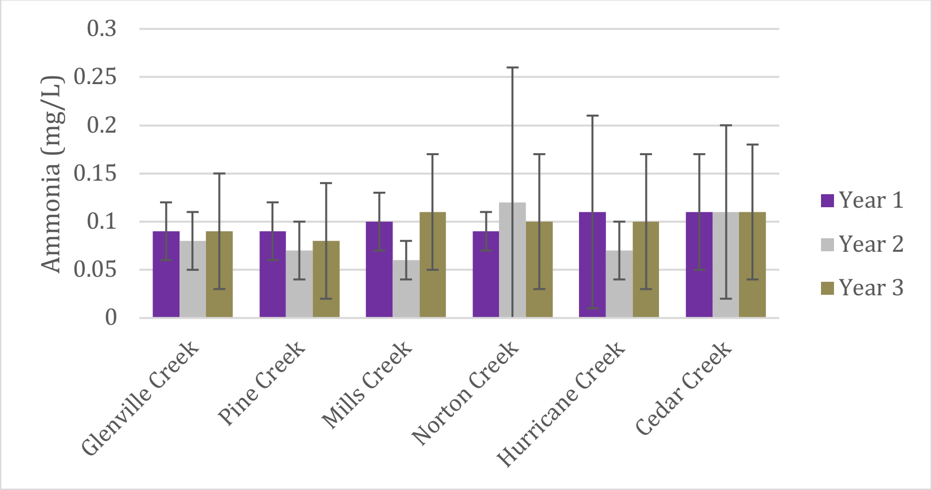


Figure 30. Mean ammonia concentration at each monitoring site by year



Like phosphorous, nitrate serves as an algal nutrient and can contribute to excessive plant growth and eutrophication. Common sources of nitrate include septic drainage and fertilizer runoff. The ability of nitrate to more readily dissolve in water contributes to its increased likelihood of traveling in surface waters. As a result, nitrate is a good indicator of sewage or animal waste input. The ambient standard to protect aquatic ecosystems is 10mg/L and observed concentrations at all monitored sites are well below this ambient standard (Figure 31). However, the EPA nutrient criterion for total nitrogen in rivers and streams in this ecoregion is 0.31 mg/L. Although nitrate is only one component of total nitrogen, observed concentrations in all streams exceeded this EPA nutrient criterion for total nitrogen, thus making it more susceptible to eutrophication.

Nitrate concentrations increased in all streams from Year 2 to Year 3 of this study in all streams except Cedar Creek (Figure 32). However, it is important to point out that the nitrate concentrations observed in Year 3 are still lower than those observed during Year 1 of the study and since their highest observed concentrations in 2017 (Figures 32 and 33). Observed nitrate concentrations slightly correlate with TSS and turbidity concentrations suggesting that, like orthophosphate concentrations, soil erosion and runoff may be contributing sources of nitrate. Nitrate concentrations were generally lowest during the spring and summer months when the average discharge was reduced (Figure 34). Nitrate concentrations do not appear to be contributing to eutrophication based on observed dissolved oxygen concentrations and the absence of visual algal blooms.

Figure 31. Mean nitrate concentration at each monitoring site, June 2019 – December 2019

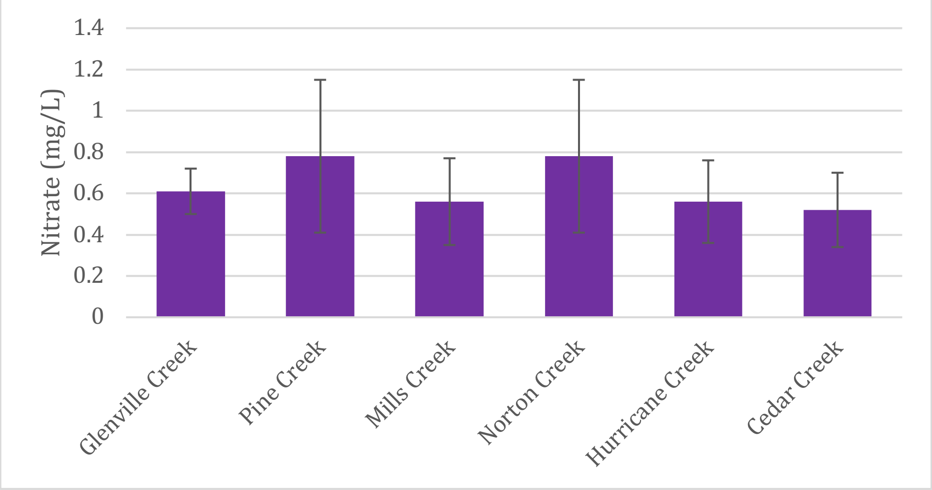


Figure 32. Mean nitrate concentration at each monitoring site by year, 2007-2019

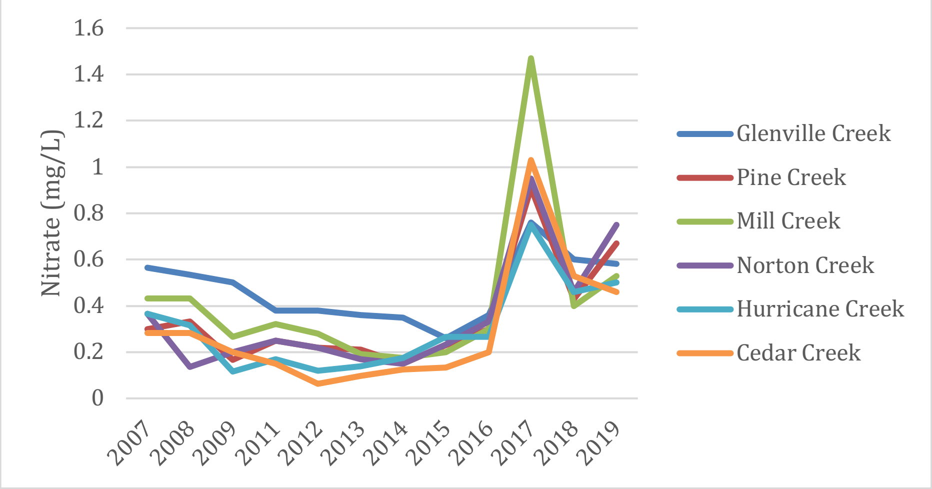


Figure 33. Mean nitrate concentration at each monitoring site by year

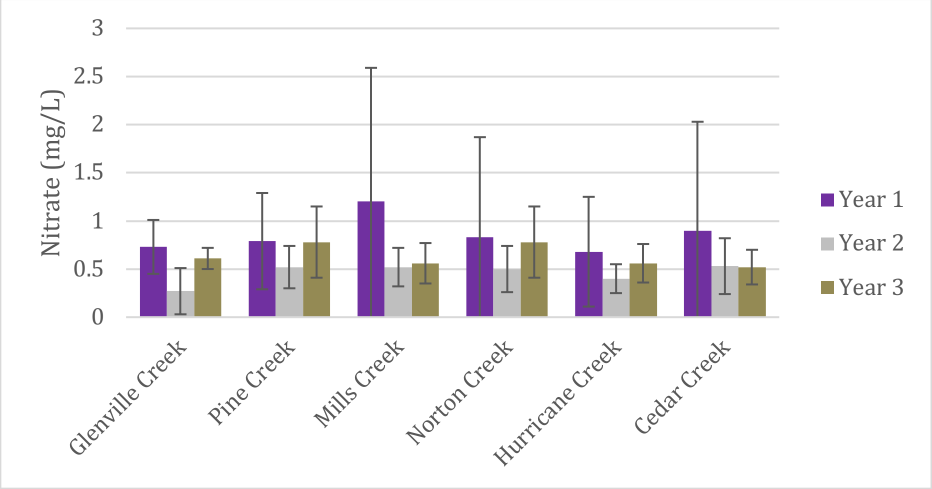
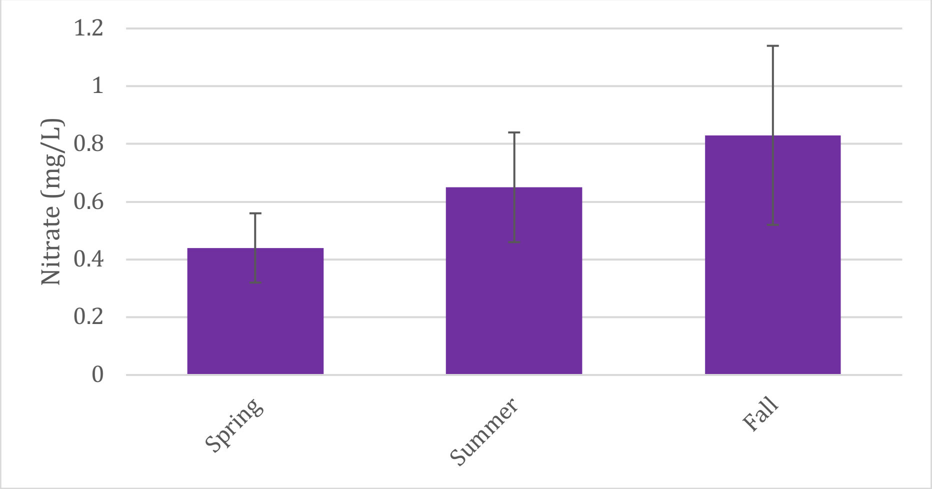


Figure 34. Mean nitrate concentration by season, June 2019 – December 2019



E. coli

The potential presence of fecal pathogens in surface water is determined based on a surrogate measurement if fecal indicator organisms, including *E. coli*. The recreational standard for *E. coli* in the State of North Carolina is 200 CFU/100ml. Mean *E. coli* concentrations for all monitored streams except Pine Creek were below this standard (Figure 35) and the mean *E. coli* concentration in all streams was above this standard during the spring (Figure 36). The presence of livestock and active agricultural activities upstream of Pine Creek and in Gem Creek, which discharges into Pine Creek, may be contributing to the observed *E. coli* concentrations but the results of this study do not definitively determine *E. coli* source. All streams except Glenville Creek demonstrated increases in *E. coli* concentrations from Year 2 to Year 3 of this study. Except for Pine Creek, these increases are below the recreational *E. coli* standard and may be the result of increased precipitation and runoff events (Figure 37). *E. coli* concentrations in surface waters have been shown to be influenced in part by seasonality and discharge, and future sampling events should continue to monitor *E. coli* to identify the influence of temporal effects on fecal pollution in the streams discharging into Lake Glenville.

Figure 35. Mean E. coli concentration at each monitoring site, June 2019 – December 2019

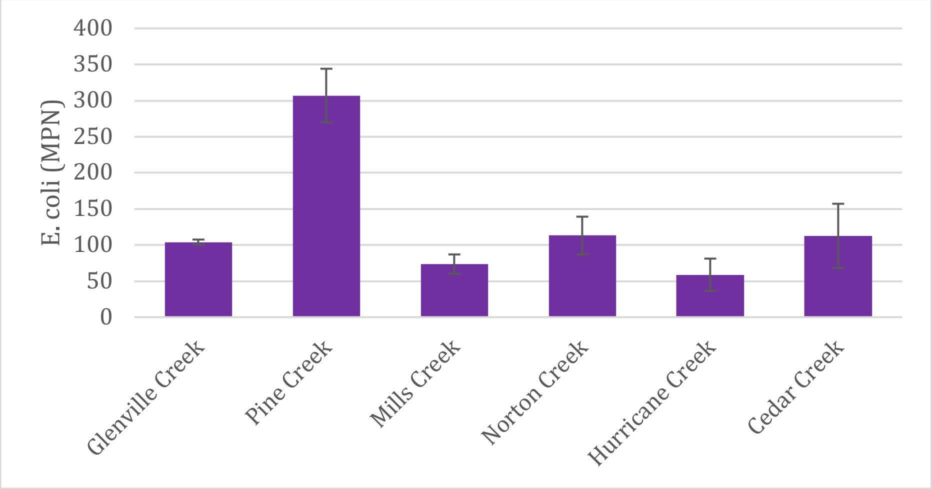


Figure 36. Mean E. coli concentration by season, June 2019 – December 2019

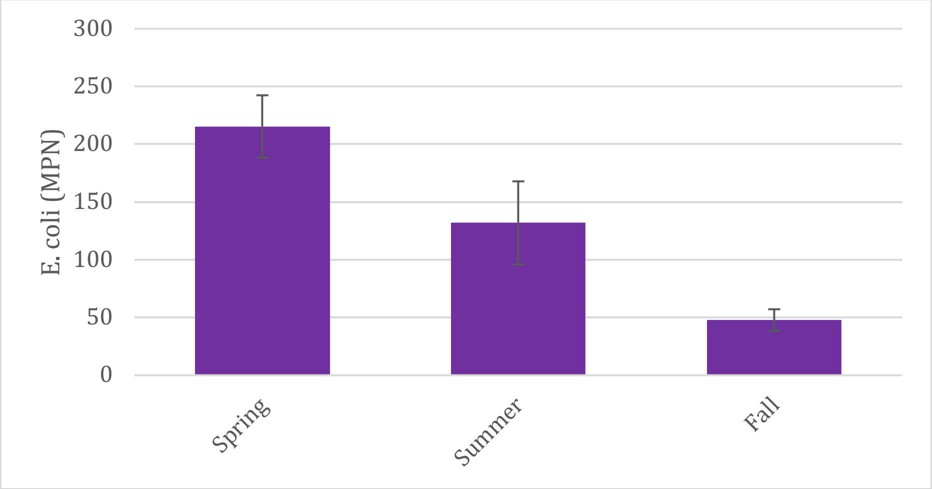
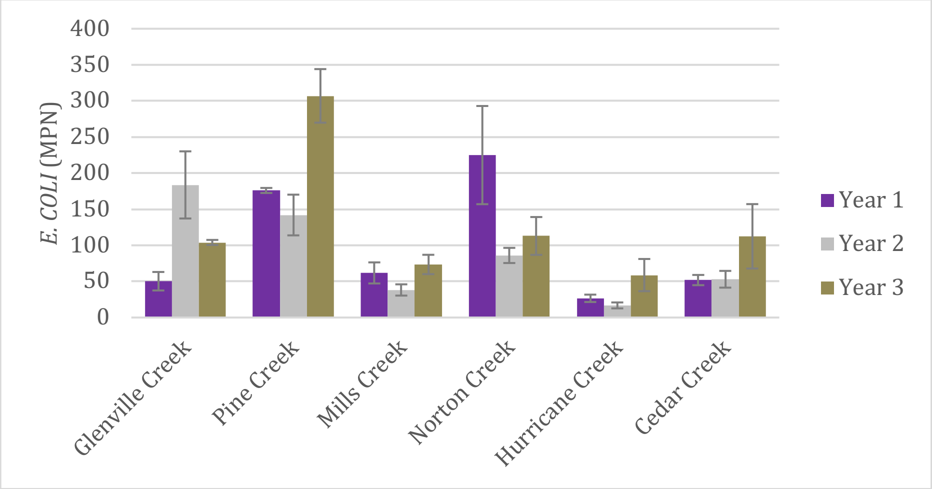


Figure 37. Mean E. coli concentration at each monitoring site by year



Conclusions

Chemical and microbial analysis of samples collected at Lake Glenville area sites was intended to characterize the water quality relative to ambient water quality standards. Such information can be useful to help identify problems and evaluate solutions relating to water quality. Characterizing the water quality of any area is a complex undertaking and data interpretation can be influenced by several factors.

Based on the visual and statistical comparisons of spatial and temporal trends of stream data collected from June 2019 – December 2019, water quality of the six monitored streams is acceptable and within established ambient water quality standards. Orthophosphate concentrations decreased from Year 2 to Year 3 of monitoring suggesting the successful implementation and maintenance of BMPs. Nitrate concentrations increased from Year 2 to Year 3 but remain below those concentrations observed in Year 1 of this study and well below the ambient water quality standard.

Based on the results in this study, none of the monitored streams discharging into Lake Glenville have exhibited pollutant levels that would significantly affect lake water quality. The influence of runoff and soil erosion on stream water quality may continue to be investigated but results of this study do not allow for the direct attribution of *E. coli* or nutrients to specific land use practices. It is probable that any decline in lake water quality is related to activities directly in and around the lake rather than to pollution inputs from the monitored streams.

Recommendations

1. Continued monitoring of the six streams feeding into Lake Glenville will provide additional insight into spatial and temporal water quality dynamics and help identify the nature and extent of impairment.

2. Continued implementing and maintaining Best Management Practices (BMPs) in the form of riparian vegetation along these streams can help minimize the impact of nutrients on water quality.

3. It does not appear that these streams are negatively impacting the water quality of Lake Glenville. Continued Sonde monitoring of Lake Glenville by Friends of Lake Glenville can help identify the nature and extent of changes in lake water quality.

4. Lake Glenville water quality can best be maintained through the actions of those in closest proximity to the lake, including preventing the introduction of leaf litter, fertilizers, and pet wastes from private residences, practicing safe waste disposal practices while on the lake, and maintaining riparian vegetation along the lakeshore.

Appendix A: Sample Collection and Analysis

Quarterly sampling events occurred on 6/19/19, 9/24/19, and 12/5/19 between 7am-9am. Water samples were collected in triplicate in 2L Nalgene™ bottles. Samples for *E. coli* analysis were collected in sterile Whirl-pak™ bags. Samples were transported on ice to the Environmental Health laboratory. Laboratory analysis of collected samples occurred within 6 hours of arrival for the parameters identified in Table A1.

Table A1. Water quality parameters and analytical methodology

Parameter	**Analysis Method/Instrumentation**
pH	Oakton pH6+ meter
Conductivity	Oakton Cond6+ meter
Alkalinity	HACH method 8203: Phenolphthalein and Total Alkalinity
Turbidity	HACH 2100Q Portable Turbidimeter
Total Suspended Solids	APHA method 2540
Orthophosphates (PO_4^{3-})	HACH method 8048/USEPA and Standard Method 4500-P-E
Nitrates	HACH method 8039
Ammonia	HACH method 8155 adapted from Clin. Chim. Acta. 14:403 (1966)
E. coli	Coliert® method (2017)

Appendix B: Data Summary

Sample #:	the number of samples collected for each parameter
Low:	minimum value of any sample(s)
Mean:	average value for each site during study period
High:	maximum value of any sample(s)

pH: June 2019 – December 2019

Site	Sample #	Low	Mean	High
H-1	9	7.0	7.4	7.7
N-1	9	7.0	7.4	7.6
M-1	9	7.0	7.2	7.7
P-1	9	7.1	7.5	7.9
C-1	9	7.0	7.2	7.4
G-1	9	7.1	7.4	8.2

Alkalinity: June 2019 – December 2019

Site	Sample #	Low	Mean	High
H-1	9	3.0	5.0	8.0
N-1	9	3.0	5.9	8.0
M-1	9	5.0	7.2	9.0
P-1	9	6.0	7.7	9.0
C-1	9	2.0	3.7	6.0
G-1	9	4.0	6.6	8.0

Turbidity: June 2019 – December 2019

Site	Sample #	Low	Mean	High
H-1	9	0.8	2.2	4.7
N-1	9	1.2	3.5	7.6
M-1	9	1.3	2.9	5.1
P-1	9	3.0	5.9	7.9
C-1	9	0.9	2.2	3.6
G-1	9	1.8	3.8	5.5

Total Suspended Solids: June 2019 – December 2019

Site	Sample #	Low	Mean	High
H-1	9	0.0010	0.0031	0.0060
N-1	9	0.0020	0.0091	0.0210
M-1	9	0.0020	0.0192	0.1020
P-1	9	0.0020	0.0296	0.1270
C-1	9	0.0010	0.0040	0.0060
G-1	9	0.0030	0.0322	0.0880

Conductivity: June 2019 – December 2019

Site	Sample #	Low	Mean	High
H-1	9	19.8	58.2	120.7
N-1	9	17.5	28.4	36.7
M-1	9	18.9	51.5	105.4
P-1	9	17.0	45.7	84.1
C-1	9	18.3	33.5	61.7
G-1	9	19.6	58.2	108.4

Orthophosphate: June 2019 – December 2019

Site	Sample #	Low	Mean	High
H-1	9	0.01	0.10	0.19
N-1	9	0.04	0.13	0.25
M-1	9	0.07	0.12	0.24
P-1	9	0.06	0.18	0.38
C-1	9	0.03	0.10	0.21
G-1	9	0.06	0.22	0.39

Ammonia: June 2019 – December 2019

Site	Sample #	Low	Mean	High
H-1	9	0.01	0.11	0.19
N-1	9	0.01	0.10	0.21
M-1	9	0.20	0.11	0.19
P-1	9	0.01	0.09	0.20
C-1	9	0.02	0.11	0.22
G-1	9	0.01	0.09	0.16

Nitrate: June 2019 – December 2019

Site	Sample #	Low	Mean	High
H-1	9	0.03	0.06	0.09
N-1	9	0.05	0.08	1.7
M-1	9	0.02	0.06	0.08
P-1	9	0.04	0.08	1.4
C-1	9	0.02	0.05	0.80
G-1	9	0.04	0.06	0.08

Appendix C: Mean concentrations of each analyzed parameter by stream and season

Figure C1. Mean *E. coli* concentration by stream and season

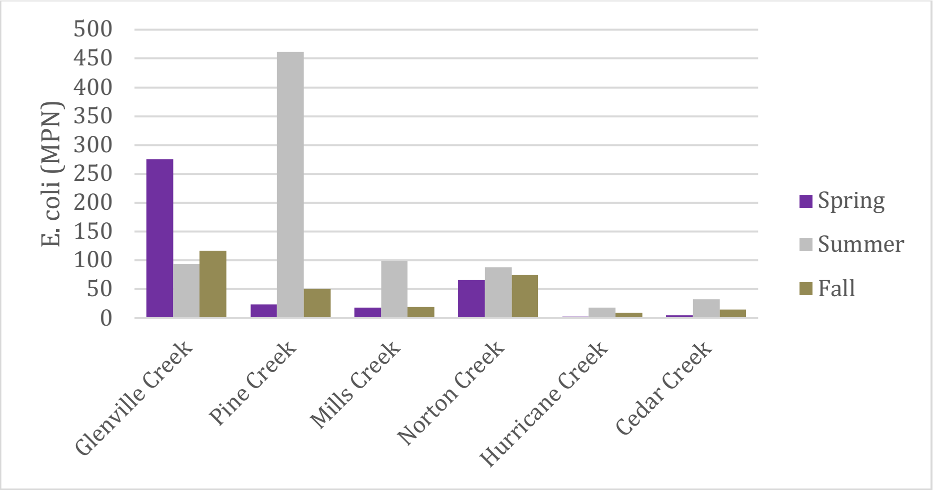


Figure C2. Mean pH by stream and season

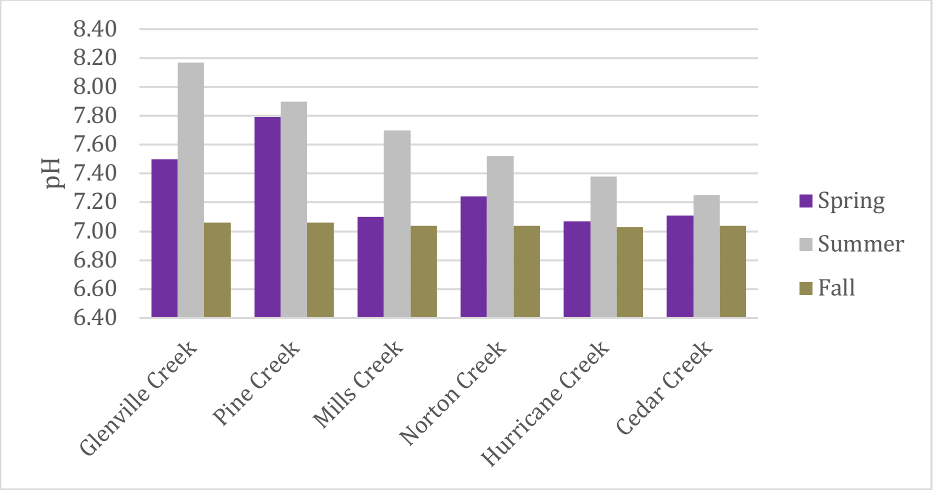


Figure C3. Mean alkalinity concentrations by stream and season

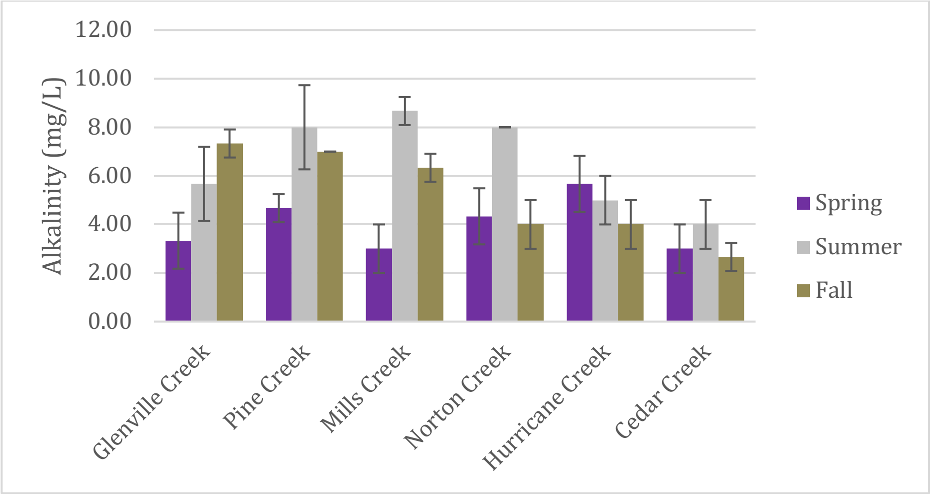


Figure C4. Mean turbidity levels by stream and season

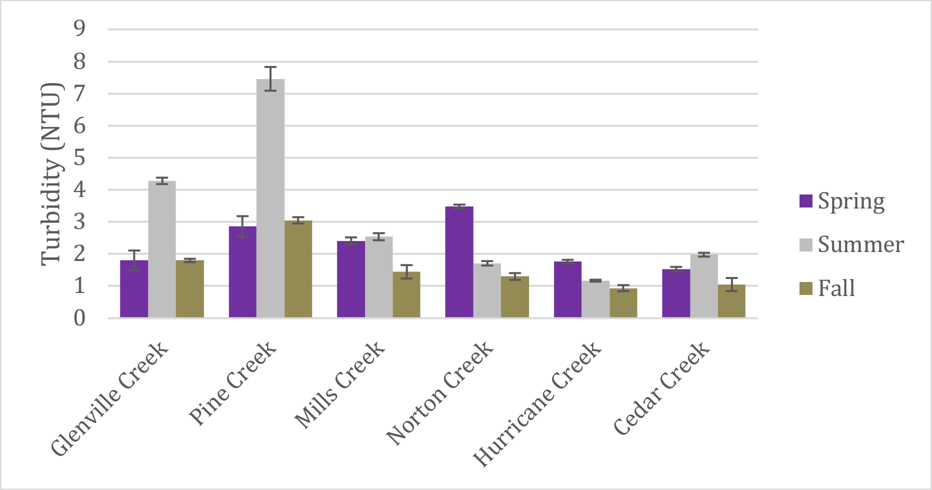


Figure C5. Mean total suspended solids concentrations by stream and season

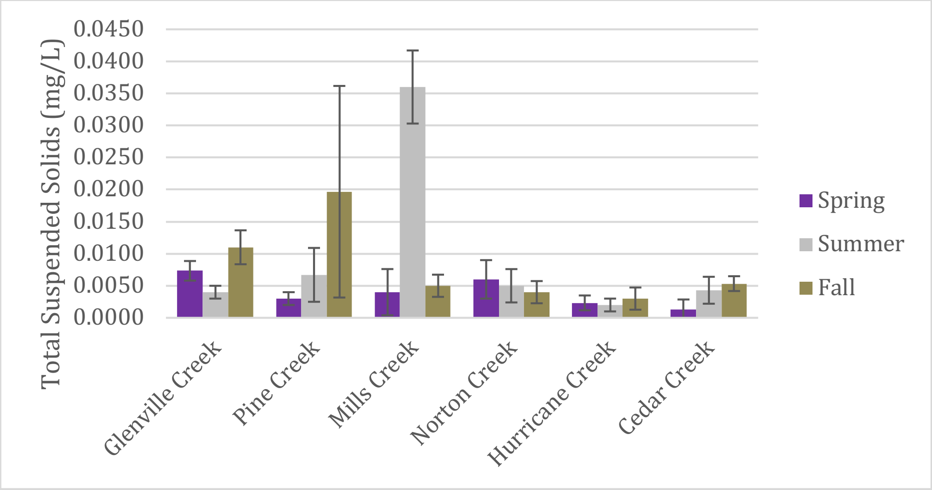


Figure C6. Mean conductivity levels by stream and season

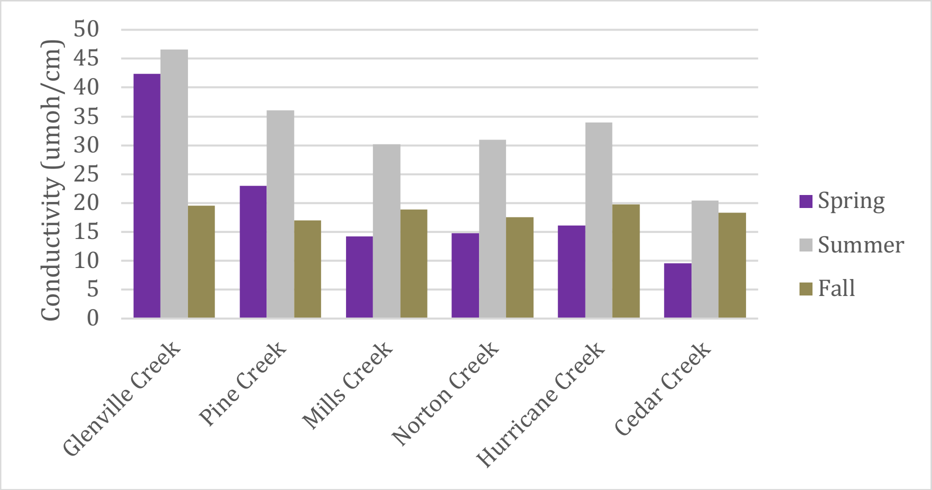


Figure C7. Mean orthophosphate concentrations by stream and season

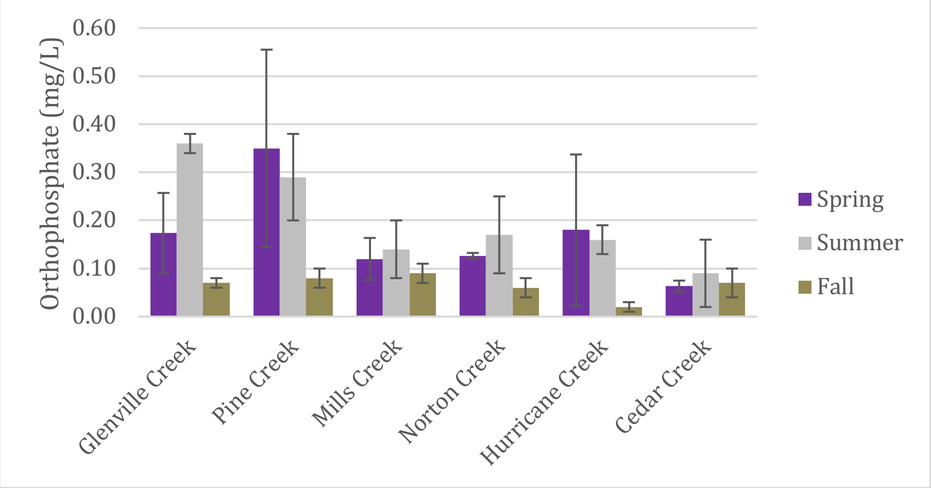


Figure C8. Mean ammonia concentrations by stream and season

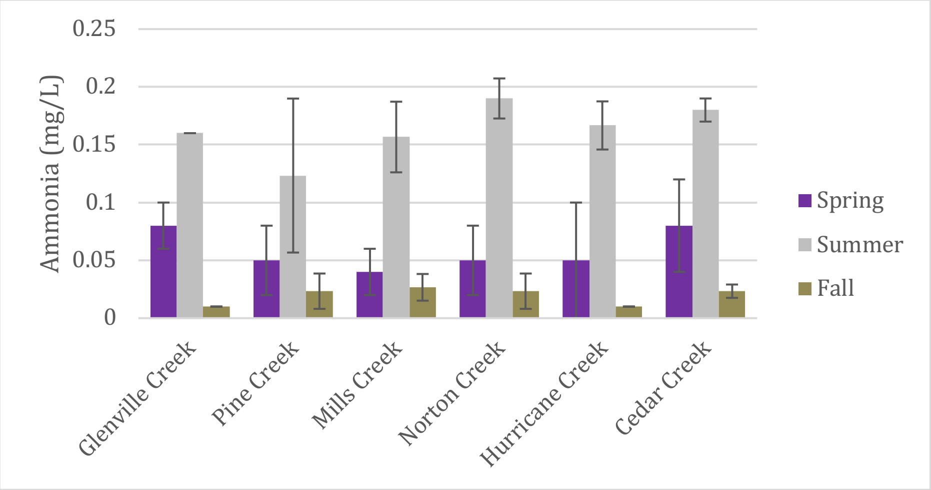


Figure C9. Mean nitrate concentrations by stream and season