# Taylor Run: A Stream Worth Protecting and Preserving

Why Nutrient Reduction Estimates for Some "Stream Restoration" Projects May Be Greatly Overstated

**Final Report of the Taylor Run Monitoring Project, Contract 17052**
**March 31, 2022**

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## Table of Contents


Executive Summary ..... 1

Introduction ..... 2

History and Reason for Project ..... 2

Goals of the Project ..... 2

Background & Methodology ..... 3

Monitoring Methodology ..... 4

Macro-Invertebrate Surveys ..... 5

Summary of the Data ..... 6

Total Nitrogen (TN) ..... 7

DEQ-Measured Total Nitrogen ..... 8

Kjeldahl Nitrogen ..... 9

Nitrate and Nitrite ..... 10

Total Phosphorous (TP) ..... 11

DEQ-Measured Total Phosphorous ..... 12

Total Suspended Sediment ..... 13

Dissolved Oxygen ..... 14

Acidity (pH) ..... 15

Conductivity ..... 16

Turbidity ..... 17

Stream Flow ..... 18

Aquatic Life ..... 20

Discussion ..... 22

Total Nitrogen ..... 22

Total Phosphorous ..... 22

Total Suspended Sediment ..... 22

Aquatic Life ..... 23

Stream Bank Sampling ..... 23

Basing Stream Restoration Projects on Sound Measurement Science ..... 24

Best Management Practices Upstream ..... 24

Alternatives to Stream Restorations ..... 25

Are Stream Restorations a Good Use of Scarce Taxpayer Dollars? ..... 25

Conclusions ..... 26

**Remaining questions** ..... 27

**Follow-up Steps Taken** ..... 28

**Appendices** ..... 29

- A – Acknowledgements ..... 29
- B -- Contact Information for the Authors ..... 29
- C – Possible Sources of Error ..... 30
- D – Data Tables ..... 32

# Executive Summary


The North Ridge Citizens' Association's water quality monitoring project conducted by resident volunteers showed that Taylor Run does not contribute a significant amount of nutrient pollution to the Chesapeake Bay. Taylor Run is not the problem. Nutrient and sediment pollution that arrives in the stream from the upstream watershed and stormwater sewer system is the problem.

The North Ridge Team monitored Taylor Run at two principal sites – one at each end of the 1,900-foot segment that was to be "restored." The monitoring project found that only a small amount of Total Nitrogen (TN) is generated in the proposed "stream restoration" project area. About 75 percent of the TN arrives in the stream from the upstream stormwater sewer system. Almost all the Total Phosphorous (TP) and Total Suspended Sediment (TSS) was found to originate in the stormwater sewer system and the upstream watershed, not in the stream restoration project area. The Virginia Department of Environmental Quality (DEQ) monitored Taylor Run in Alexandria's Angel Park approximately 0.6 miles downstream from the NRCA's downstream site. Their findings for average TN and TP concentrations at the DEQ monitoring site were lower than the NRCA's downstream site. This indicates Taylor Run contributes little nutrient pollution to the Chesapeake Bay.

During periods without rain, Taylor Run stream flow is about 157 liters per minute. During heavy rain events, stream flow is much higher and faster. This is typical of urban streams fed by stormwater drainage from large impermeable surfaces. Flow was not measured during high-water events, but it was visually observed, sampled, and photographed. Sampling during high and low events showed that TP and TSS concentrations increase sharply during high water events. Large episodic rainfall events appear to bring TP to the stream from the upstream watershed. Large episodic rainfall events appear to bring TSS to the stream from the upstream watershed and from hiking trails in Chinquapin Park.

This report provides information on why it is important to:

- Not rely solely on pollution reduction estimates from the Bank Erosion Hazard Index (BEHI) method of calculating nutrient reductions.
- Do stream bank soil sampling to better approximate nutrient reductions.
- Do low-cost water quality monitoring to estimate real nutrient reductions.
- Base nutrient reductions on good measurements and sound science.
- Consider installing stormwater Best Management Practices (BMPs) upstream to slow down, filter and sequester stormwater before it reaches a surface water body.
- Consider alternative methods of achieving Chesapeake Bay Program nutrient reduction credits that avoid the invasive and destructive "stream restoration" process.

Finally, this report asks the question: "Are 'stream restorations' a good use of scarce taxpayer dollars?"

# Introduction

## History and Reason for Project

In 2019, the City of Alexandria proposed to conduct a "stream restoration" project on Taylor Run as part of its Chesapeake Bay TMDL 40% Plan. The stated purpose of this project was to reduce the flow of nutrients into the Potomac River and the Chesapeake Bay. The City claimed that the project was needed to help meet its nitrogen, phosphorus and sediment reductions as required under the Chesapeake Bay Program.

Several citizens' groups questioned whether the proposed plan was appropriate for meeting the City's pollution reduction targets, and whether "stream restoration" was the right approach. Further investigation brought to light that the proposed project would dramatically alter Taylor Run by excavating an area 1,900 by 75 feet; cutting down more than 250 trees (including Alexandria's champion maple); raising the stream bed by 3 to 7 feet; destroying existing plant and animal communities; and threatening a unique wetland containing many Alexandria-rare species.

Led by Russ Bailey and Bill Gillespie, a group of citizens proposed to gather scientific data to better determine existing conditions in Taylor Run. With administrative support from the North Ridge Citizens' Association (NRCA), and a grant from the Virginia Department of Environmental Quality (VADEQ), this team of volunteers agreed to donate their time to gathering the needed data to better understand the nutrient and sediment flows from Taylor Run into the Potomac and the Bay.

Nine (9) volunteers were trained and certified in water quality monitoring by the RiverTrends Program of the Alliance for the Chesapeake Bay. Between them, they contributed over 600 hours to this project between February and December of 2021. (Appendix A).

## Goals of the Project

- Assess the water quality of Taylor Run, an urban stream in Alexandria, VA.
- Determine whether the first 1,900 feet of Taylor Run contributes significant amounts of Total Nitrogen (TN), Total Phosphorus (TP), and Total Suspended Sediment (TSS) pollution to the Chesapeake Bay or whether these pollutants originate primarily in the stormwater collection system upstream.
- Provide accurate water quality measurements to determine whether a $4.5 million stream restoration project should be done or whether other stormwater projects should be considered.
- Measure the existing ecological state of Taylor Run so that functional ecological uplift (ecological improvement) can be quantified if a stream restoration project is performed.
- Educate the local community on water quality monitoring and the effects of human activities on water quality.

## Background & Methodology

In preparation for this project, team leaders:

- Applied for $5,000 grant from the Virginia DEQ to cover lab analysis costs;
- Enlisted NRCA to host the project and manage the funds;
- Contracted with Analytics LLC, a state-certified laboratory near Richmond to analyze samples for Total Nitrogen, Total Phosphorus, and Total Suspended Sediment;
- Enlisted the help of The Alliance for the Chesapeake Bay which provided free equipment and training for on-site physical and chemical testing of stream waters (the volunteers each took the Alliance's training and exam and were certified as River Trends water monitors); and
- Purchased (with private funds) additional equipment needed for the project – including a dedicated dipping pole, plus rulers and stakes for tracking stream levels.

As one of the conditions of the grant, DEQ required a detailed Quality Assurance Project Plan (QAPP). The team prepared and submitted a Quality Assurance Project Plan to DEQ in July 2021.

The team selected two principal monitoring sites on Taylor Run - one near the upstream end of the stream segment to be "restored" and the other at the downstream end. Aluminum rulers were installed on stakes at these two sites so that stream height could be measured on a daily basis:

- The Upstream Sampling Site, TayRun 1.8 is located at 38° 49' 24.2"N, 77° 04' 56.1"W. The second pool below the culvert that empties into Taylor Run at the north end of the stream. This pool avoids the turbulence of the first splash pool but has enough water to allow for quality sampling and height measurements. During periods of lowest flow, we were able to measure stream flow directly from the culvert using a bucket and safety scaffold with a custom support bracket.

- The Downstream Sampling Site, TayRun 1.5 is located at 38° 49' 8" N, 77° 4' 46" W. It is a short distance upstream of the two culverts that mark the end of the 1,900-foot stream restoration project area and just downstream of the drainage from the First Baptist Church of Alexandria parking lot. This location had enough water at all flow levels to allow for sampling and height measurements. We used this same location to measure stream flow during high, medium, and low flow events.

- Two additional locations were selected to measure stream flow:
    - TayRun 1.7 (38° 49' 18"N, 77° 4' 50" W) because of its hard clay bottom and shape.
    - TayRun 1.6 (38° 49' 24.2"N, 77° 4' 56.1" W) because all the stream flow was concentrated into a narrow channel during low flow periods.

Two 48" rulers were installed on vertical stakes at TayRun 1.5 and 1.8 to measure change in stream height.

**Monitoring Methodology**

Team members covered different days of the week to report stream height daily at 10:30 am at TayRun 1.5 and 1.8. This data was entered into the Project Spreadsheet maintained by Bill Gillespie.

Chuck Kent and Rita drawing sample at TayRun 1.5 (Downstream)

Russ Bailey, Rita Leffers, Bill Gillespie, Trisha Gruesen, John Fehrenbach, John Winstead and Don Bobby sampling at TayRun 1.8 (Upstream)

Volunteers took water samples a the NRCA upstream and downstream monitoring sites on 19 days in 2021. Scheduled samples were taken on the second and fourth Tuesdays of each month from March through November. Three additional days were added to the sampling schedule to capture concentrations during high water events on June 10, August 16, and October 29, 2021. On the second and fourth Tuesday of each month, the team did a full sampling run at each location, including:

- Grab Samples which were placed on ice In a cooler for transport to the lab.
  - 1,000 ml sample for Total Suspended Sediment (TSS)
  - 250 ml sample (preserved with $H_2SO_4$) for Total Nitrogen (TN)
  - 250 ml sample (preserved with $H_2SO_4$) for Total Phosphorus (TP)
- Water Chemistry
  - Dissolved Oxygen, using a LaMott DO Kit – 2 sample bottles were collected at each site
  - Conductivity, using Oakton PCTSTestr 5 Multiprobe meter
  - pH, using an Oakton PCTSTestr 5 Multiprobe meter
  - Turbidity, using a Turbidity Tube
- Conditions
  - Air and water temperature using a Hanna Digital Thermometer HI 98501)
  - Color (visual observations)
  - Stream height as measured at the vertical rulers/stream gauges

The night before each sampling run, a designated trained volunteer ran calibration tests for:

- Dissolved Oxygen, verifying the stability of the Sodium Thiosulfate 0.025N,
- Conductivity, using a standard solution 1413 µS/cm, and
- pH, using standards solutions for pH 4.0 and 7.0.

After each sampling run, one volunteer would immediately drive the iced grab samples for TSS, TN, and TP to Analytics, LLC in Ashland, VA, recording the Chain of Custody for each batch of samples. The temperature of all samples was recorded on delivery.

Within no more than 8 hours of the sampling run, a trained volunteer would perform the post-sampling calibrations for pH and conductivity, as well as the titrations for dissolved oxygen (4 bottles, two from each site).

All data were recorded on a standard RiverTrends Field Data Sheet and reported to the online data system maintained by the Alliance for the Chesapeake Bay and the Chesapeake Monitoring Cooperative.

**Measuring Stream Flow**

NRCA volunteers studied U.S. Environmental Protection Agency (EPA) and U.S. Geological Survey (USGS) guidance and recommendations on measuring stream flow. Volunteers held a conference call with John Jastram, a hydrologist who serves as the Chief of the Watershed Studies Section and the Program Development Specialist for the USGS's Virginia and West Virginia Water Science Center in Richmond, VA. It became clear NRCA volunteers would not be able to operate a fully equipped stream gauging station on Taylor Run with DEQ's limited grant funding. NRCA volunteers opted to make daily stream height measurements and measure base (low) flow. Attempts were also be made to measure some high-water events.

**Macro-Invertebrate Surveys**

The volunteer group performed three macroinvertebrate surveys or "pulls" to evaluate the presence of life in the stream; these took place on May 7, August 8, and October 28, 2021. The surveys were conducted at stream riffles near the NRCA downstream sampling site.

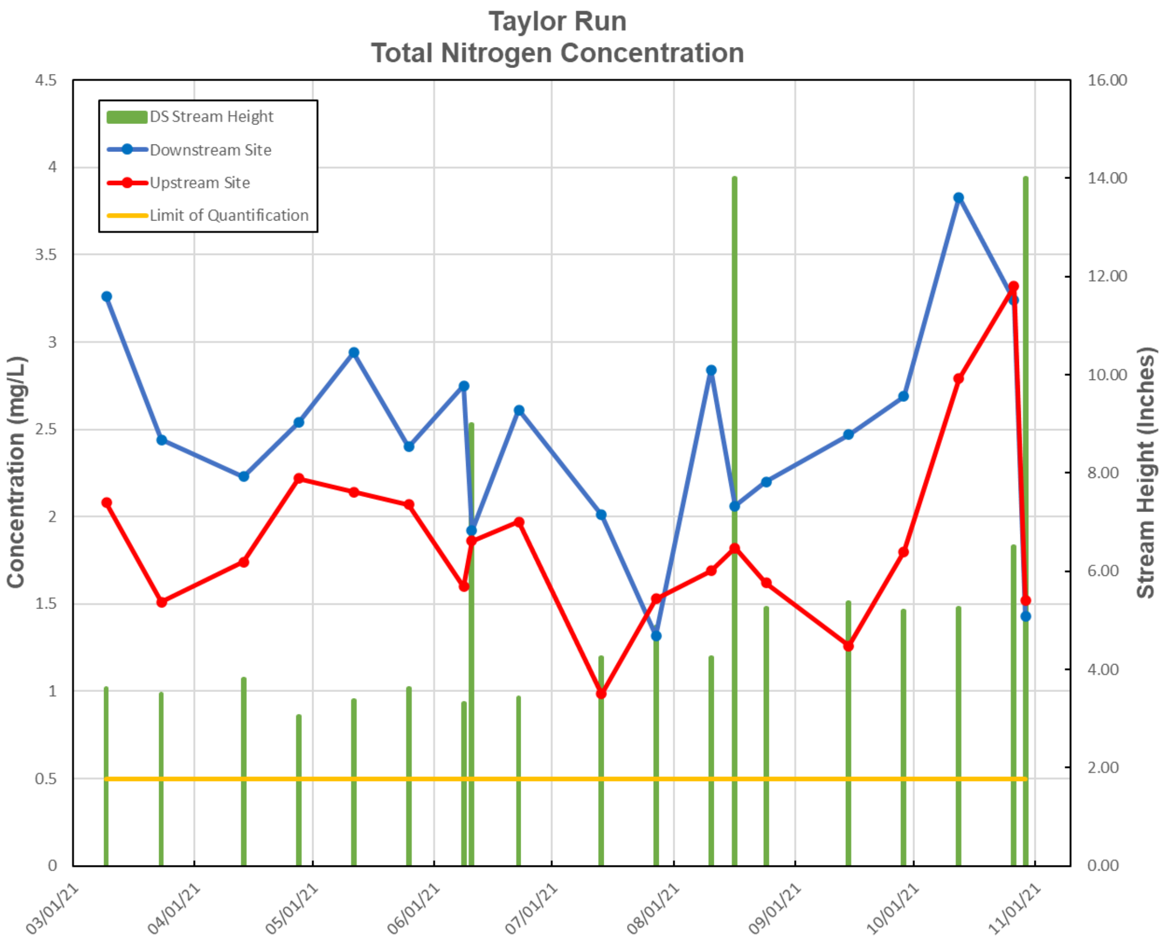
The May 7 pull was led by Emily Bialowas of The Izaak Walton League, a certified stream monitor. The August 8 and October 28 pulls were led by Trisha Gruesen, one of the volunteer water quality monitors, who took the Izaak Walton training in macroinvertebrate identification and monitoring protocols and was certified by the League to be a water monitoring leader.

Chuck Kent, Bill Gillespie, Trisha Gruesen, Amy Krafft and Russ Bailey sampling for macro-invertebrates October 28, 2021

## Summary of the Data

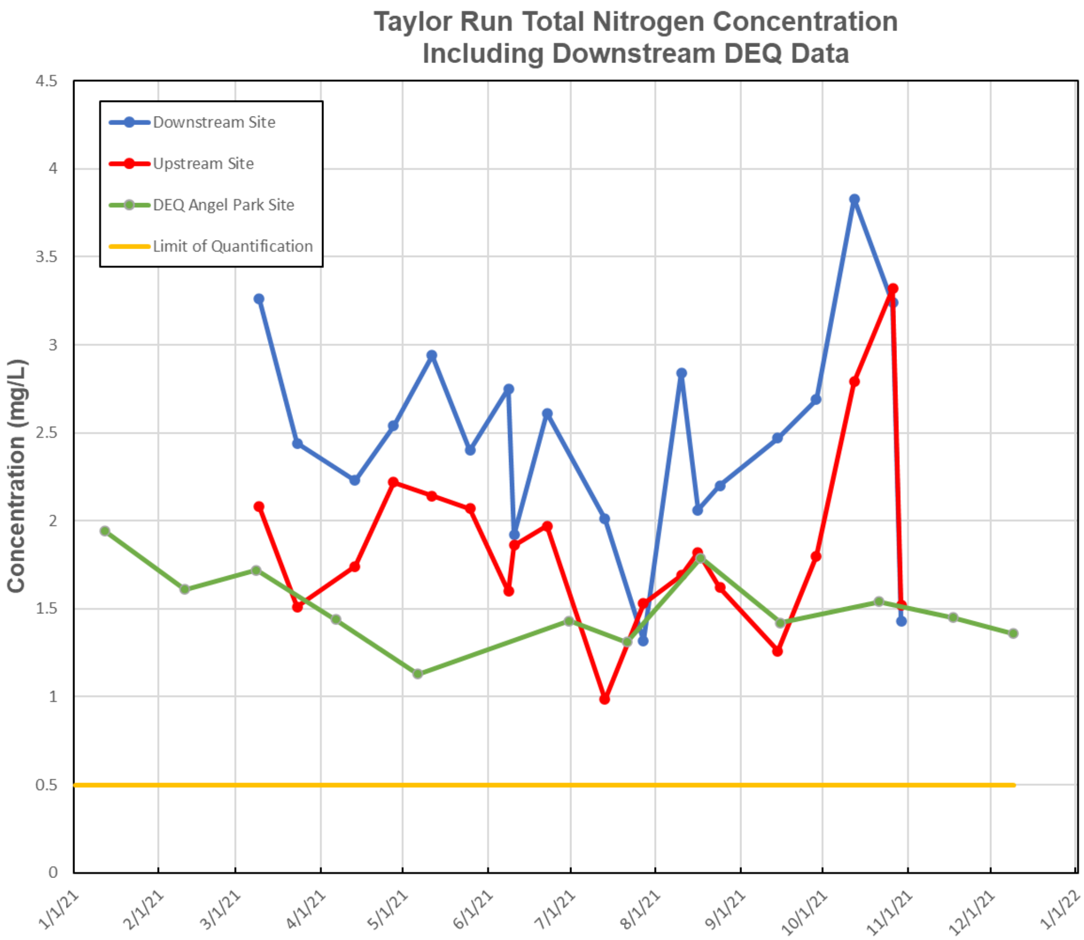
The following graphs summarize the data collected at both the upstream and downstream NRCA monitoring sites. TN, TP and TSS sampling was performed from March 2021 through October 2021. Air temperature, water temperature, pH, dissolved oxygen, conductivity, and turbidity data were collected for one year from March 2021 through February 2022. Time series plots show how concentrations and other measured parameters varied over time. The data are provided in Appendix D.

**Total Nitrogen (TN)**



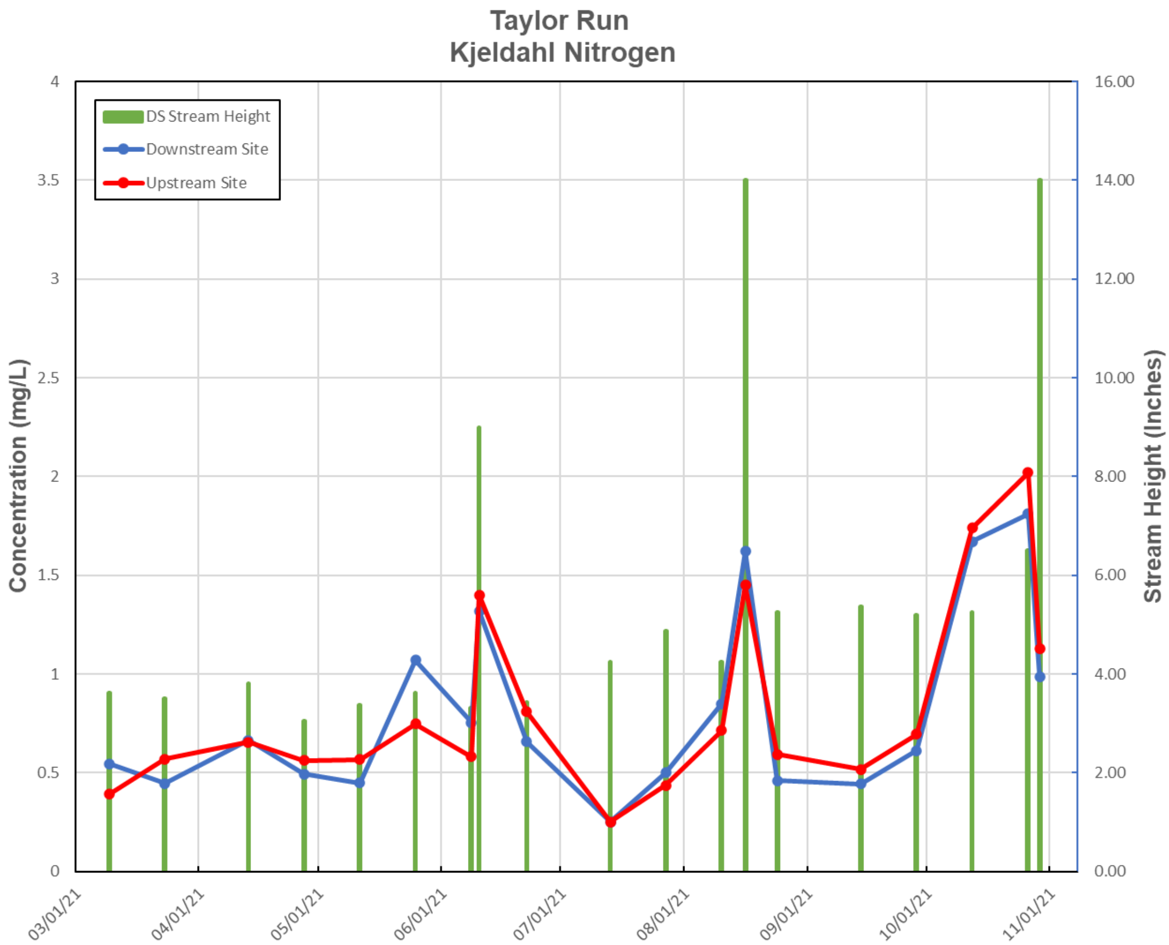

- About 75 percent of the TN arrives in the stream from the stormwater sewer system.
- At low flows, the downstream site averaged 0.72 mg/L higher TN concentrations than the upstream site.  Most of the higher nitrogen concentration observed at the downstream site was nitrate and nitrite nitrogen.
- During high water events, the two sampling sites approximately 1,900 feet apart, exhibited similar TN concentrations probably because water of similar nutrient concentration was moving quickly between the two sites.
- TN concentration at the upstream and downstream sampling sites averaged 1.87 mg/L and 2.48 mg/L, respectively.
- The average TN concentration at the Virginia DEQ monitoring site, approximately 0.6 mile downstream of the NRCA downstream sampling site, was 1.53 mg/L.
- 19 measurements of TN were made at the upstream and downstream sites during high and low water events.

**DEQ-Measured Total Nitrogen**



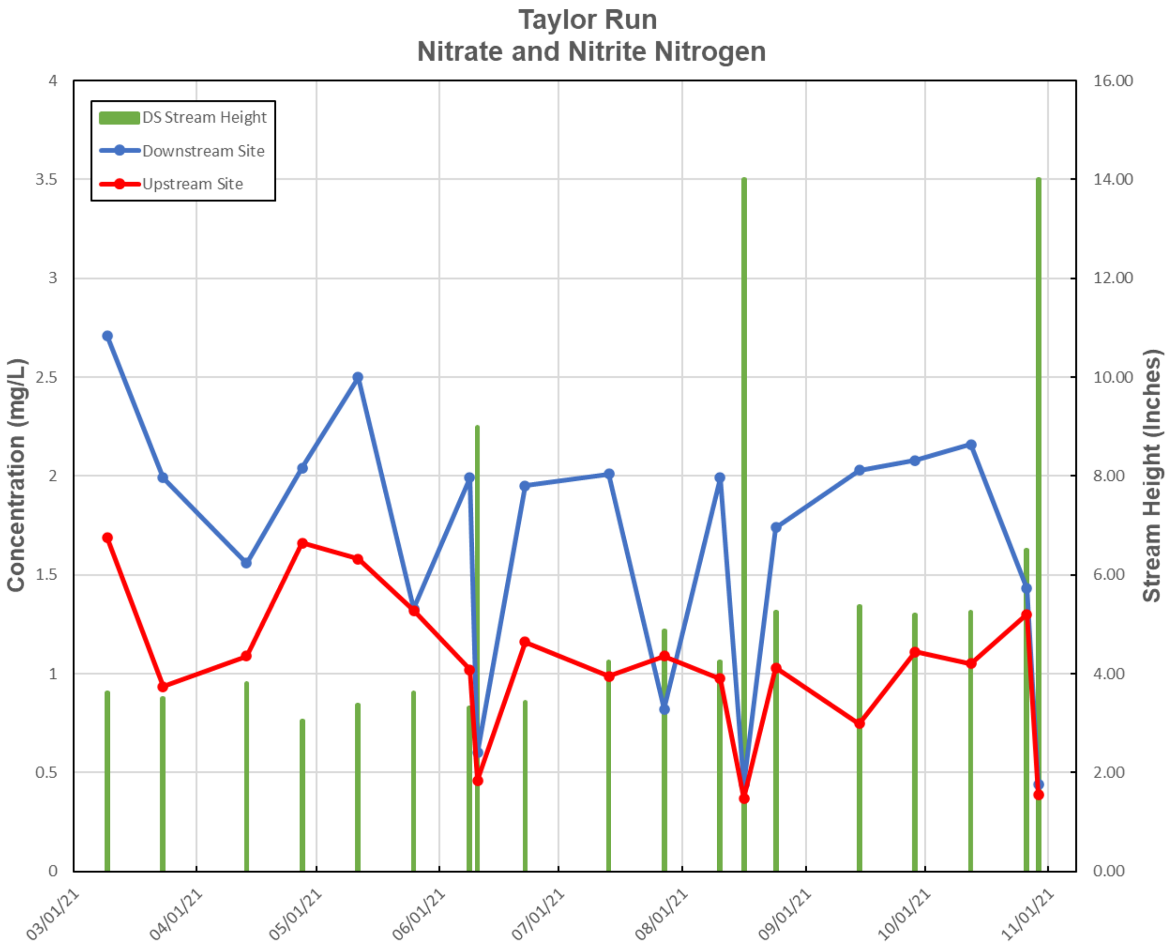

- The Virginia Department of Environmental Quality (DEQ) sampled Taylor Run monthly approximately 0.6 mile downstream of the NRCA downstream sampling site from January through December 2021.
- DEQ did not sample on the same days that NRCA volunteers sampled so direct comparisons of daily data cannot be made.
- DEQ measured concentrations were frequently lower than NRCA measurements.
- The annual average TN concentration at the Virginia DEQ monitoring site was 1.53 mg/L.
- The annual average TN concentrations at the upstream and downstream NRCA sampling sites were 1.87 mg/L and 2.48 mg/L, respectively.

## Kjeldahl Nitrogen




- The Kjeldahl method in analytical chemistry is a method used to find nitrogen contained in organic substances plus the nitrogen contained in the inorganic compounds ammonia ($NH_3$) and ammonium ($NH_4^+$).
- Kjeldahl nitrogen concentration was remarkably similar at the upstream and downstream sites.
- The average Kjeldahl nitrogen concentration at the upstream and downstream sampling sites averaged 0.83 mg/L and 0.82, respectively.
- Kjeldahl nitrogen concentration rose at both sampling sites during high water events and often fell after these events.

**Nitrate and Nitrite**




- Nitrate/nitrite nitrogen concentration was in almost all cases higher at the downstream site.
- The average nitrate/nitrite nitrogen concentration at the upstream and downstream sampling sites averaged 1.05 mg/L and 1.67, respectively.
- It is unclear why the nitrate/nitrite concentration was higher at the downstream site. The higher concentration may be due to natural biological processes; fertilizer applications at the community gardens upslope from the stream in Chinquapin Park; ground water seepage which has been observed in the stream valley; leakage from old, abandoned sewer systems for the Chinquapin Village development; pet waste; or other causes.

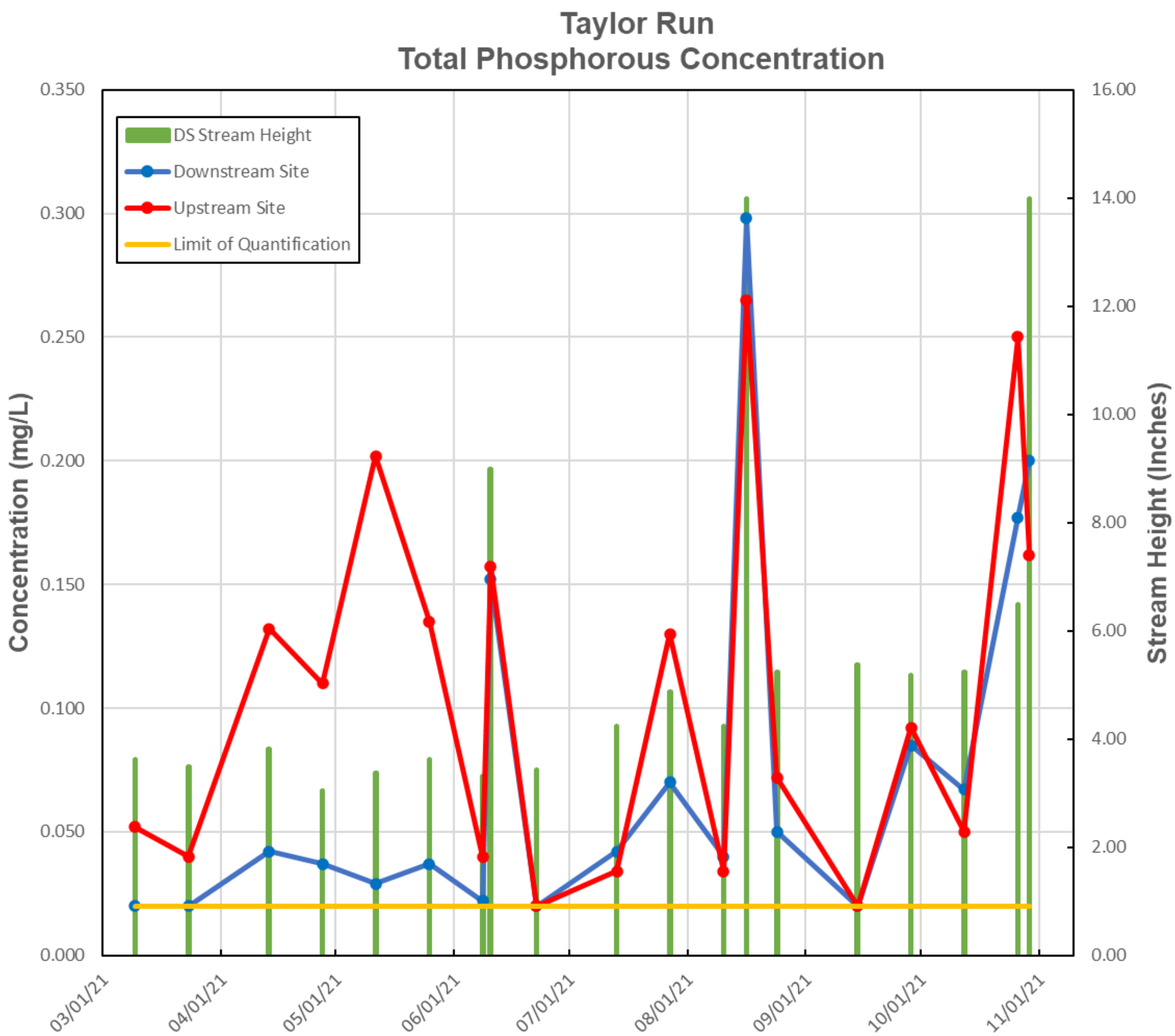
A Scientific Investigation Report prepared by the U. S. Geological Survey for Fairfax County streams provides an excellent summary of the sources of nitrogen in urban streams. The report states:

> "Common urban nonpoint nitrogen inputs include anthropogenic sources such as atmospheric deposition, fertilizer application, leaking wastewater infrastructure, septic

systems, and pet waste (Paul and Meyer, 2001; Bettez and Groffman, 2013; Hyer and others, 2016), as well as natural sources such as plant humic substances and biological fixation (Wanielista and others, 1977; Carpenter and others, 1998)."

Source: Spatial and Temporal Patterns in Streamflow, Water Chemistry, and Aquatic Macroinvertebrates of Selected Streams in Fairfax County, Virginia, 2007–18, Aaron J. Porter, James S. Webber, Jonathan W. Witt, and John D. Jastram, page 61.

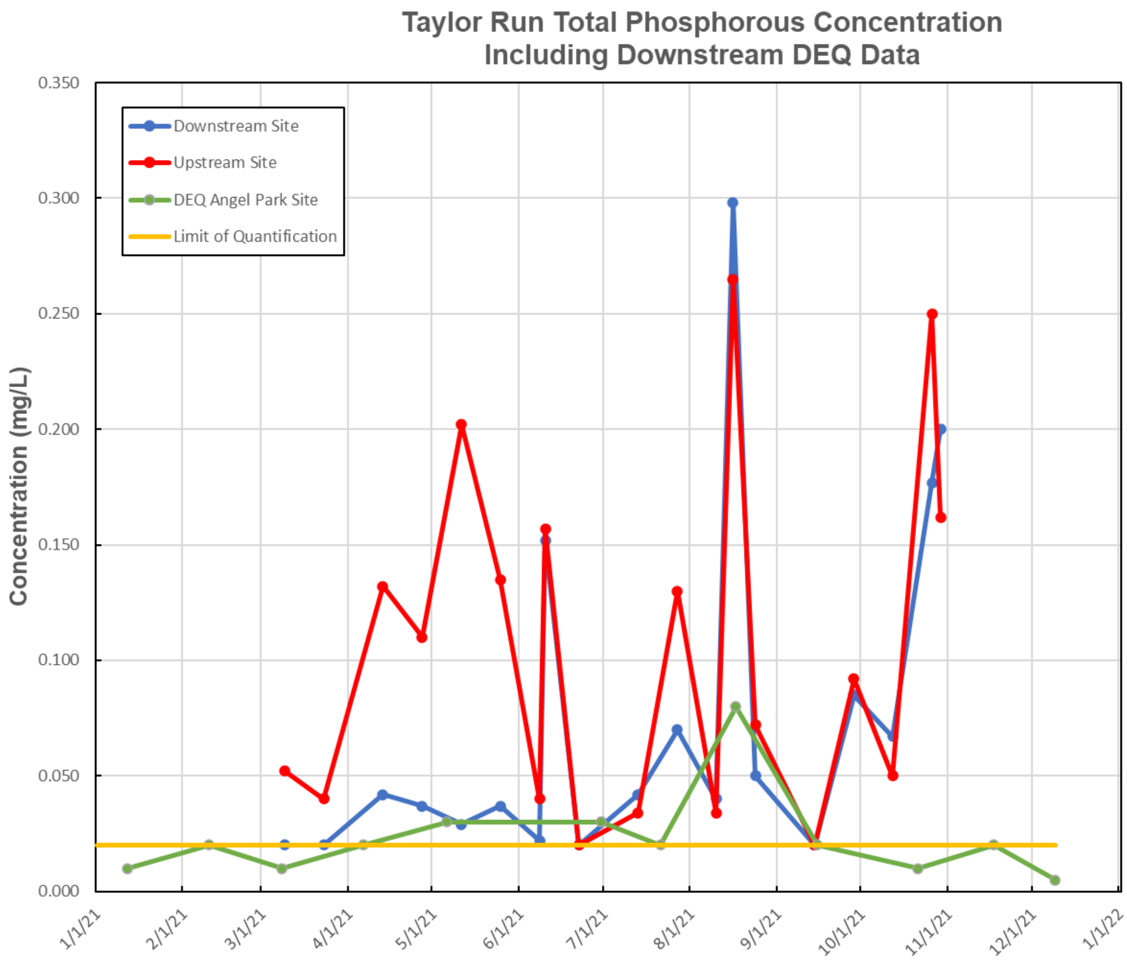
**Total Phosphorous (TP)**




- During most sampling events, TP concentrations were higher at the upstream site than the downstream site.
- At low flow, many TP measurements at the downstream site and the DEQ site further downstream were at or near the detection limit for phosphorous, 0.02 mg/L.
- The TP concentration at the upstream and downstream sampling sites averaged 0.11 mg/L and 0.08, respectively.

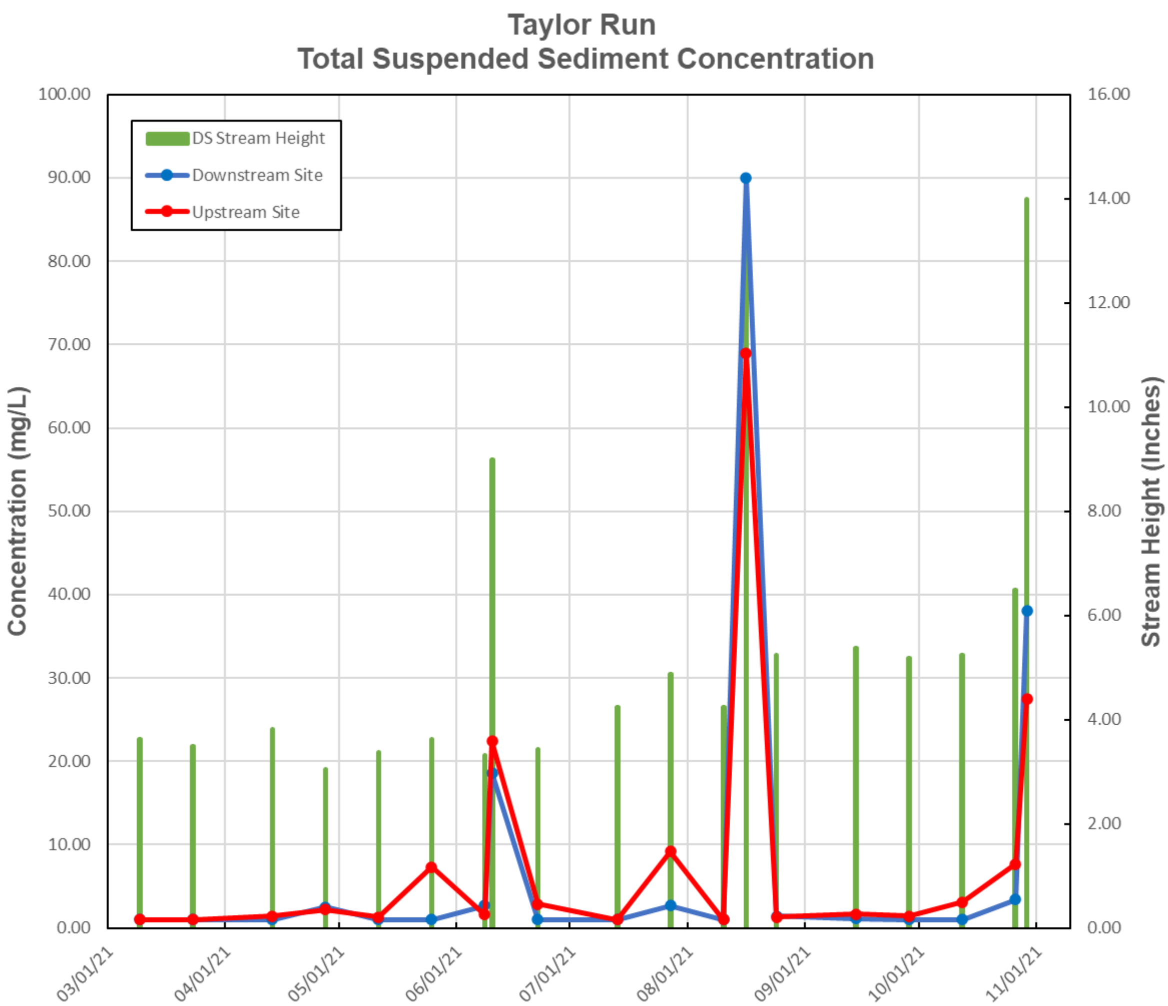
- The TP concentration at the Virginia DEQ monitoring site, approximately 0.6 mile downstream of the NRCA downstream sampling site, averaged 0.025 mg/L.

**DEQ-Measured Total Phosphorous**




- DEQ sampled Taylor Run monthly approximately 0.6 mile downstream of the NRCA downstream sampling site from January through December 2021.
- DEQ did not sample on the same days that NRCA volunteers sampled so direct comparisons of daily data cannot be made.
- DEQ measured TP concentrations were frequently lower, sometimes much lower, than NRCA measurements.
- The annual average TP concentration at the Virginia DEQ monitoring site was 0.023 mg/L. The DEQ limit of quantification/detection limit was 0.005 mg/L.
- Average TP concentrations at the upstream and downstream NRCA sampling sites were 0.11 mg/L and 0.08 mg/L, respectively. The limit of quantification/detection limit for NRCA samples was 0.02 mg/L. Two of the upstream samples and three of the downstream NRCA samples were beneath the laboratory's detection limit. In these cases, the limit of quantification is reported and shown on the graph.

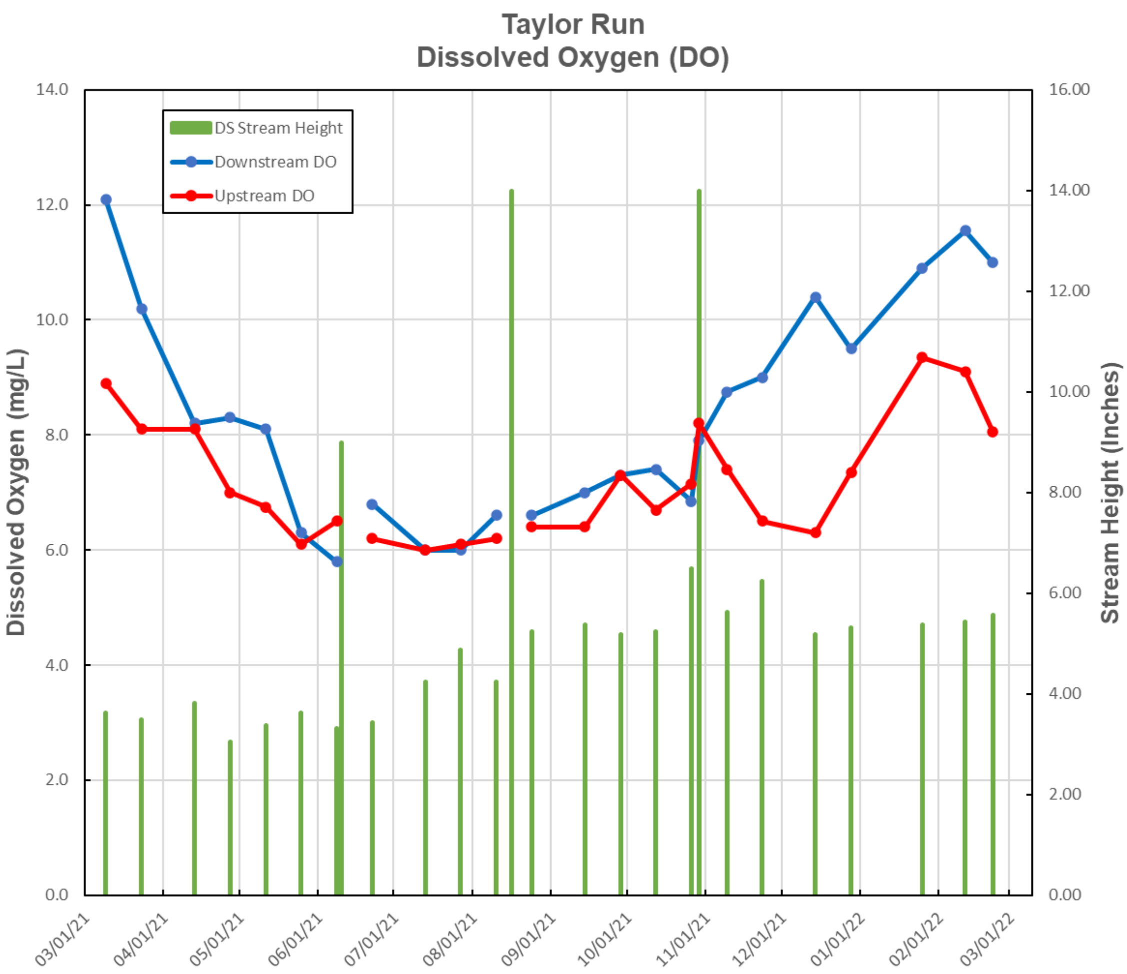
**Total Suspended Sediment**




- At low flows:
  - TSS concentrations are very low and about the same at the upstream and downstream sites.
  - TSS concentrations are so low, they are typically below the analytical laboratory's detection limit and are reported as being "less than the detection limit of 1.00 mg/L.
  - Turbidity tube measurements indicated excellent water clarity. An observer could see through more than 115 centimeters (45.3 inches) of stream water.
- At low flows, TSS concentrations averaged 2.82 mg/L and 1.49 mg/L at the upstream and downstream sites, respectively.
- During high water events, large concentrations of sediment arrived in the stream from the stormwater sewer system.
- During rain events, TSS concentrations averaged 39.63 mg/L and 48.9 mg/L at the upstream and downstream sites, respectively.

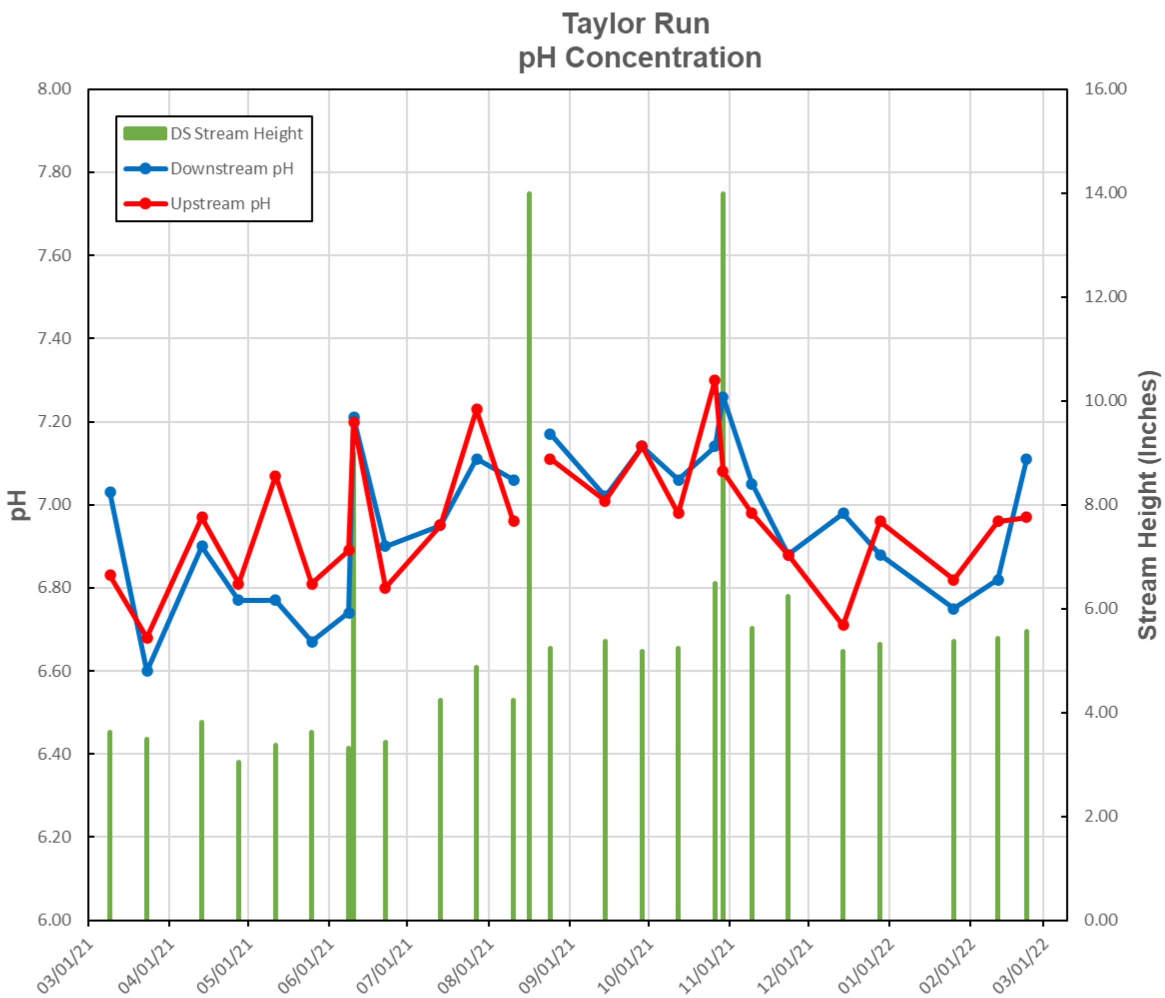
- The higher sediment concentrations observed at the downstream site during heavy rain events were likely due to sediment entering the stream from additional stormwater sewer inflows and water coursing down poorly maintained trails in Chinquapin Park.

**Dissolved Oxygen**



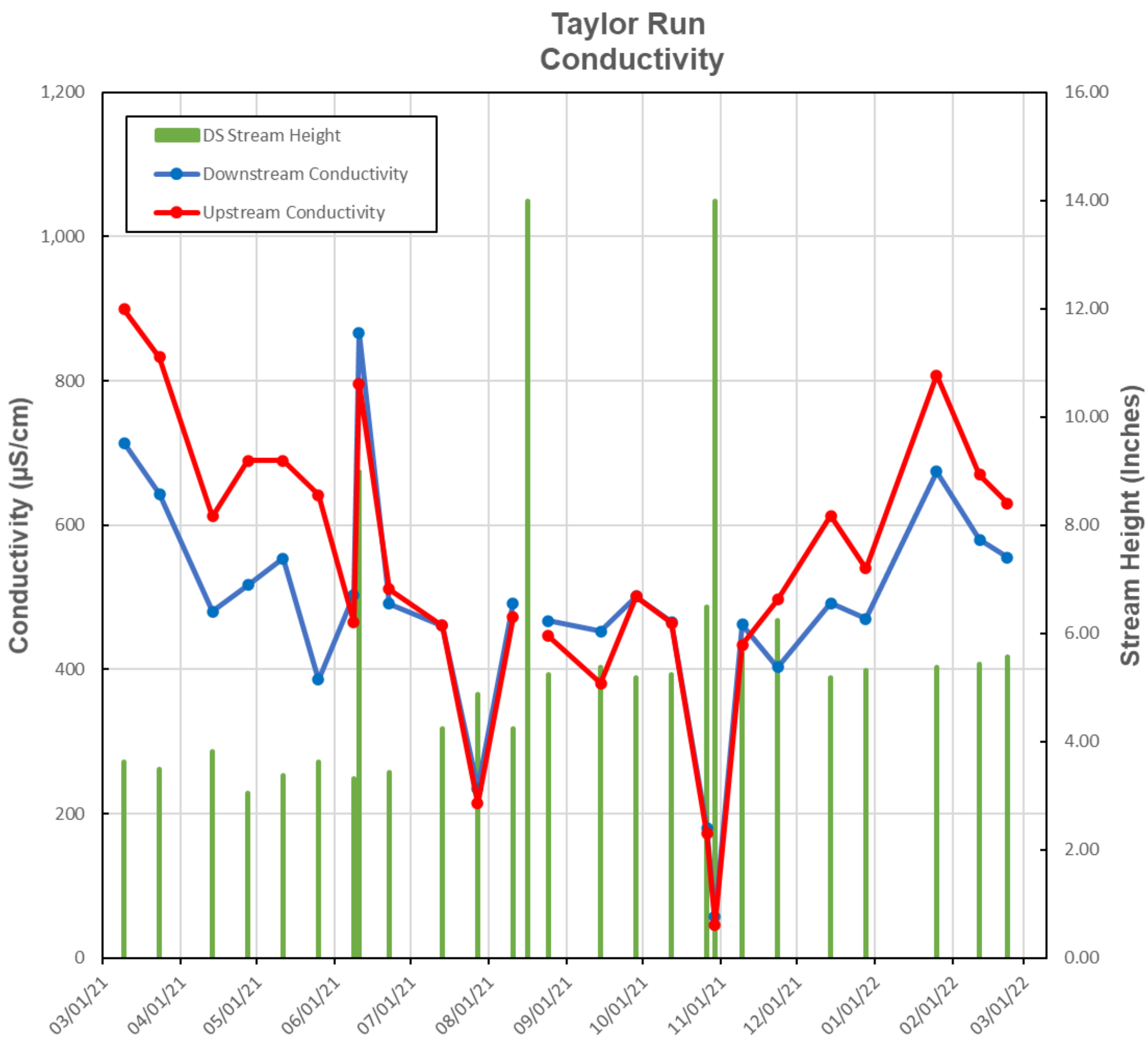

- The downstream site usually exhibited higher dissolved oxygen, likely because the stream aerates the water over the 1,900 feet of the stream from the stormwater sewer outfall to the downstream monitoring site.
- Since dissolved oxygen is correlated with water temperature, dissolved oxygen was greatest during cold winter months and lower during summer months.
- The downstream sampling site was highly correlated with temperature (R-Squared value 0.86).
- It remains unclear why dissolved oxygen was so much lower at the upstream site in November and December 2021.
- Dissolved oxygen was not measured during the first two high water events on June 10 and August 16, 2021. Dissolved oxygen was measured during the high-water event that occurred October 29, 2021.

## Acidity (pH)



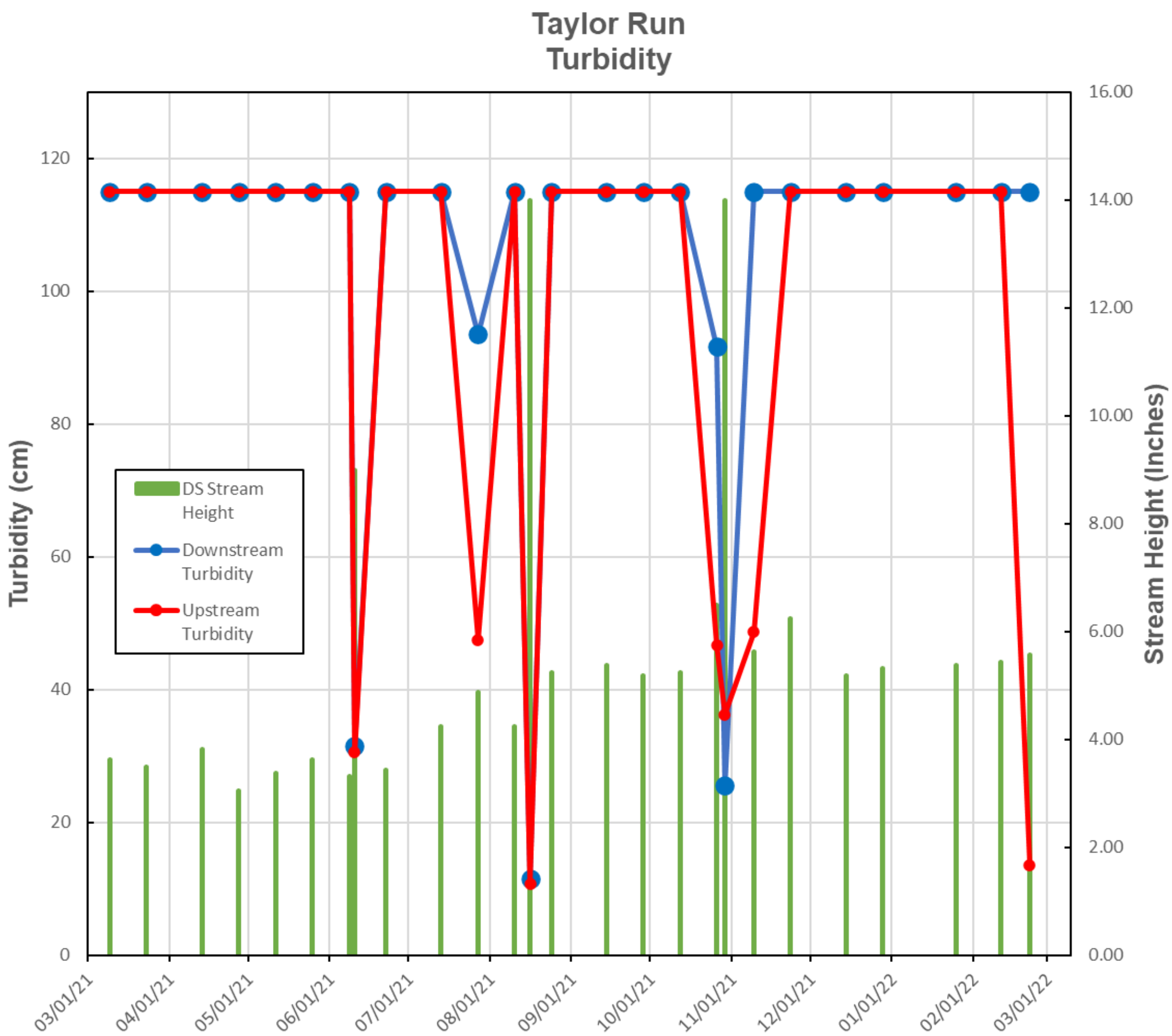

- pH appeared to peak at both sampling sites in mid-September.
- pH is elevated during rain/high-water events.

## Conductivity




- Conductivity was somewhat higher at the upstream site from late November through May.
- High-water events have a strong effect on conductivity. Sampling at the beginning of a heavy rain event like the thunderstorm on June 10, 2021, produced high conductivity measurements at both the upstream and downstream sites. Samples taken on July 27 and October 26, fourteen hours after rain event resulted in lower-than-normal conductivity measurements. The lowest conductivity measurements occurred on October 29 during a high-water event when it had been raining for some period of time.

## Turbidity




- These measurements were made using a Turbidity Tube, which creates a column of water through which the field observer views a Secchi Disk at the bottom of the tube. The maximum tube reading is 115 cm when the water is very clear. If the water is turbid, water is released through a spring valve at the bottom of the tube until the Secchi Disk can be observed. The graph above provides an inverse picture of the turbidity, as high numbers represent the clearest water, and the lower the numbers greater turbidity.
- As one would expect, in most cases, turbidity varied as TSS concentration varied.
- On most low flow days:
  - Turbidity was very low and the same at the upstream and downstream sites.
  - High turbidity tube measurements indicated excellent water clarity. An observer could see through more than 115 centimeters (45.3 inches) of stream water.
- On two low flow days, November 9 and February 22, the upstream site exhibited much higher turbidity than the downstream site. Stream monitoring volunteers observed cloudy water quality conditions at the upstream site. The cloudiness dissipated as the

water flowed downstream to the point where the downstream site registered a turbidity tube clarity of greater than 115 centimeters.

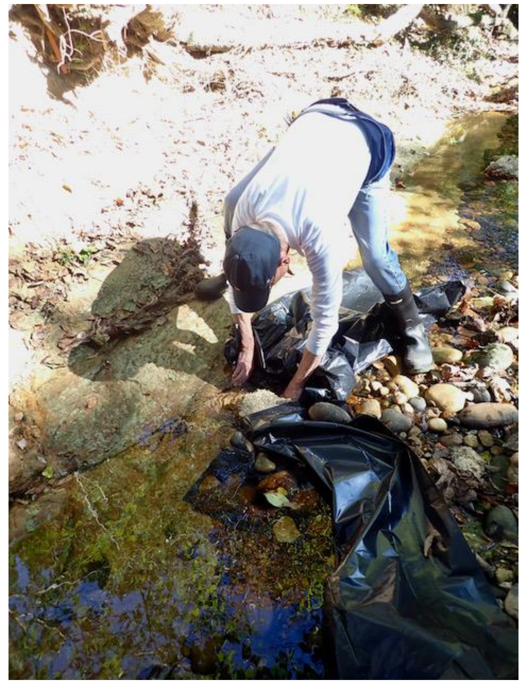
- As with TSS concentration, high-water events have a strong effect on turbidity. Sampling at the beginning of a heavy rain event, like the thunderstorm on June 10, 2021, produced turbid conditions at both the upstream and downstream sites.
- Water tested on July 27 and October 26, fourteen hours after rain event, also showed more turbid water than usual with the upstream site exhibiting much poorer water clarity. On these two days, turbidity improved significantly as water flowed to the downstream site.
- Three of the four highest turbidities occurred on high water events on June 10, August 16, and October 29, 2021.

**Stream Flow**

Stream flow on Taylor Run is low most of the year. Occasionally, during rain events, the stream flow increases dramatically. The picture on the left below shows typical low flow conditions. The picture was taken June 27, 2021, at 11:30 a.m. The picture on the right was taken on June 10, 2021, at 5:56 p.m. during a heavy rain event.

Based on rainfall data, it is estimated that the stream exhibited low flow conditions on about 80 percent of days in 2021. These were days when rainfall was zero or less than or equal to 0.01 inches as measured at Reagan National Airport. Given that high TP and TSS concentrations are associated with high-water events that bring pollutants to the stream, it is important to keep in mind that, most of the time, the stream is in a low flow state.

Bill and Chuck measuring flow at TayRun 1.8



Bill capturing flow at TayRun 1.7

Efforts were made to measure flow on low flow days. On April 10 and October 19, 2021, low flow measurements were made at the culvert outlet where the stormwater sewer system deposits water in the stream bed. A scaffolding was put in place at the outlet and two volunteers on the platform captured the entire flow in a graduated bucket. Each measurement was timed. The average flow on April 10th after six runs was 195 liters per minute. Using the same technique, the average flow on October 19 was 141 liters per minute. The October 19th measurement is likely a better estimate of low flow because rain had not occurred during the two prior days. Photographs of flow at the culvert outlet in August indicate even lower flow may occur during hot and dry meteorological conditions. Flow measurements were not made during absolute minimum flow conditions.

On October 19, 2021, a low flow measurement was also performed at a site where the stream narrows downstream from the culvert. At this site, the entire flow of the stream could be captured in a large plastic bag over a timed interval. The volume of the water "catch" was then measured in a graduated bucket. The average of eight runs was 157 liters per minute. This value compares well with the upstream flow of 141 liters per minute measured the same day. There are additional sources of water between the culvert flow measurement and the downstream flow measurement.

An attempt was made to measure a high-water event on October 29, 2021. Reagan National Airport reported receiving 1.15 inches on October 29. An aluminum stream gauge had been installed in a straight section of the stream that had fairly smooth walls and relatively smooth bottom. Volunteers had also installed two strings across the stream well above the water surface 20 feet apart. To measure velocity, ping-pong balls were dropped on the surface of the water and were timed as they passed between the upstream and downstream lines. Twelve velocity measurements were made at different locations across the cross-sections of the stream. On a following day, the cross-section of the stream was measured using the stream gage, a laser level, and measuring tapes. Calculations yielded an estimated flow of about 36,400 liters per minute.

Harold Post, a Research Associate with Virginia Tech's Occoquan Watershed Monitoring Lab (OWML) kindly loaned the NRCA volunteers a Pygmy Current Meter for making discharge (flow) measurements on Taylor Run. Low flow measurements were attempted with the meter on May 1 and December 17, 2021. In both cases, the cross-sectional area where the measurements were made was so small that "wall effects" – turbulence induced by the sides of the small cross-section – interfered with the consistent spin of the meter's bucket wheel. NRCA may make use of the OWML meter in future high and medium flow measurements.

From our flow measurements, one thing became clear - hydrology and stream flow dynamics are very important. To accurately measure annual pollutant loads in pounds per year, one needs accurate stream flow measurements coupled with accurate pollutant concentrations measurements.

**Aquatic Life**

The three macro-invertebrate surveys on Taylor Run produced useful data on the stream's health.

Water Strider

Bill, Trisha and Amy Krafft sorting macro-invertebrates

The first survey, performed on the morning of May 7, 2021 found 145 midges, 68 mayflies, 41 worms, 3 true flies and 2 lunged snails. The Save Our Streams (SOS) Multimetric Index Score was 5. A score of 5 indicates an unacceptable ecological condition. The SOS ecological ranking systems is summarized below.

- 0 – 7, unacceptable ecological condition.
- 8, ecological conditions cannot be determined at this time.
- 9 – 12, acceptable ecological condition.

The second survey was performed on the morning of August 5, 2021. The survey found 64 worms, 26 midges, 13 mayflies, 11 common netspinning caddisflies, 7 caddisflies, 5 black flies, 4 craneflies and 2 lunged snails. The SOS score was 3 indicating an even poorer ecological condition than the first survey.

The third survey, conducted on the morning of October 28, 2021, yielded 92 caddisflies, 40 worms, 24 common netspinning caddisflies, 16 midges, 8 mayflies, 4 black flies, 4 scuds, 2 true flies and 2 lunged snails. The SOS score was 7, an improvement over the two previous surveys but still a score of unacceptable ecological condition.

The following are examples of macro-invertebrates found in Taylor Run:

Mayfly Larva

Caddisfly Larva

Netspinning Caddisfly larva

Juvenile Newt

Scud

Lunged Snail

## Discussion

### Total Nitrogen

At low flows, the downstream sampling site exhibited somewhat higher TN concentrations than the upstream site. During heavy rain events, TN concentrations were similar, possibly because water was moving quickly between the sampling sites giving the water little time to change nitrogen concentration. The higher concentrations of TN at the downstream site during low flow conditions were due almost entirely to a higher nitrate/nitrite concentration at the downstream site. While higher concentrations of nitrogen were observed at the downstream site, it is important to note that about 75 percent of the nitrogen measured in the stream water arrived in the stream from the storm sewer system. This implies that a stream restoration performed in the proposed project area would not significantly reduce nitrogen concentration in the stream. Measurements made by the Virginia DEQ, about 0.6 miles downstream from the NRCA sampling sites, revealed even lower TN concentrations than the NRCA sites. This raises the question, why would one conduct a stream restoration to reduce TN concentrations when the TN concentration in Taylor Run decreases as the stream approaches Cameron Run, the Potomac River and ultimately the Chesapeake Bay.

### Total Phosphorous

Very little phosphorous was found at the NRCA downstream site or the DEQ sampling site further downstream. Some phosphorous measurements were near or below the analytical detection limit for phosphorous at these two sites. Importantly, most of the phosphorous arrived in the stream from the stormwater sewer system. Phosphorous concentrations were highest at the upstream site during April and May. During this period, TP concentrations were 3 to 7 times higher at the upstream site than the downstream site. Phosphorous concentrations rose sharply at both NRCA sites during high water events and also about 14 hours after high water events. Monthly total phosphorous measurements made over an entire year by the Virginia DEQ, downstream from the NRCA sampling sites, averaged 0.023 mg/L. All but three of the DEQ measurements were taken at low water. From March through October 2021, the upstream and downstream NRCA sites had average concentrations of 0.11 mg/L and 0.08 mg/L, respectively.

Over the stream segment monitored, Taylor Run appeared to have a beneficial effect on phosphorous concentration. At low flows, the downstream site averaged about 0.04 mg/L less phosphorous than the upstream site.

### Total Suspended Sediment

TSS concentrations were very low at both NRCA sampling sites during periods of low stream flow. At the downstream NRCA sampling site, at low flow, most of the TSS measurements were below the detection limit for sediment. At low flows, TSS concentrations averaged 2.82 mg/L and 1.49 mg/L at the upstream and downstream sites, respectively.

As expected, TSS concentrations were a function of rainfall. During high water events, large concentrations of sediment arrived in the stream from the stormwater sewer system. During rain events, TSS concentrations averaged 39.63 mg/L and 48.9 mg/L at the upstream and downstream sites, respectively. Two high sediment concentrations observed at the downstream site during heavy rain events on August 16 and October 29 were likely due to sediment entering the stream from additional stormwater sewer inflows and water running down poorly maintained hiking trails in Chinquapin Park. The DEQ did not sample for TSS at their sampling site in Angel Park.

Taylor Run has been scoured out by high-water events for approximately 70 years since urban development began in earnest in the 1950s. It appears that most of the sediment in the stream is transported there by the stormwater sewer system and poorly maintained trails in Chinquapin Park. Undoubtably, there is also sediment erosion from the streambed during the most extreme high-water events.

**Aquatic Life**

Each of the three surveys conducted indicated that Taylor Run is an impaired stream in an unacceptable ecological condition. While macroinvertebrate scores were low, significantly more life was found in the stream than predicted by Wetlands Studies and Solutions, Inc., a City of Alexandria contractor promoting the “restoration” of Taylor Run. Our findings included mayflies, netspinner caddisflies, craneflies, lunged snails, and salamanders. As the NRCA monitoring effort has shown, most of the nitrogen and phosphorous pollution in Taylor Run originates in the watershed and stormwater sewer system upstream. The NRCA did not sample for harmful pollutants typically found in urban stormwater that are harmful to aquatic life. Slowing down, filtering, and better controlling stormwater discharges would certainly reduce nitrogen and phosphorous concentrations in Taylor Run. These actions would also likely reduce other pollutants found in the stream that harm or inhibit aquatic life.

**Stream Bank Sampling**

In response to citizen requests, in July 2021, the City had a contractor sample the stream banks of Taylor Run. The soil sample results showed that nutrient reduction credits based on default engineering estimates, originally used to justify the stream restoration, were badly inflated. Based on soil sampling, the new Total Nitrogen reduction result was 20 percent of the original engineering estimate. The new Total Phosphorus reduction result was 31 percent of the original engineering estimate. Total suspended solids result was 67 percent of original estimates. Soil sampling showed that low-cost stream measurements can provide important, insightful information about the nutrient reduction potential of a proposed project.

**Basing Stream Restoration Projects on Sound Measurement Science**

In the opinion of the NRCA team, nutrient reduction credits from stream restoration projects should not be based on estimates. Credits should be based on good measurements and sound science. Both stream bank sampling and water quality monitoring offer good, practical information as to whether a stream restoration project should proceed. Happily, making measurements to inform the decision-making process for stream restoration projects is inexpensive. The City of Alexandria estimated the cost of the Taylor Run stream restoration project at about $4.5 million. Four stream bank samples cost less than $1,000, or 0.02 percent of the proposed cost of the project.

Water quality monitoring is also inexpensive compared to project costs. Water quality analyses for TN, TP and TSS cost about $89, $45, and $18 per sample, respectively. Sampling for several months at the upstream and downstream ends of a proposed project can provide important information as to whether the project will achieve real, quantifiable nutrient reduction credits.

Given the experience on Taylor Run, where default engineering estimates badly overstated reduction credits, jurisdictions and regulatory agencies should look critically at previously awarded credits earned by past stream restoration projects. These projects may not have produced the credits they originally claimed.

**Best Management Practices Upstream**

The best thing that can happen to an abused urban stream is to put Best Management Practices (BMPs) in place upstream. These BMPs can slow down, filter and capture stormwater flows. At Taylor Run, there is physical space on public land for BMPs including stormwater retention ponds, bioswales, raingardens, and smaller measures. Implementing erosion control measures within the park along park trails, along the stream banks, and in Chinquapin Park above Taylor Run would slow down and reduce nutrient pollution that finds its way into Taylor Run.



**Alternatives to Stream Restorations**

Under public pressure and with help from interested citizens and civic associations, the City of Alexandria found viable alternatives to the proposed stream restoration projects on Strawberry Run and Taylor Run. These alternatives allowed the City to meet its Chesapeake Bay TMDL Program requirements without these stream restorations. The alternatives included: credits from BMPs that will be put in place in connection with large urban development projects, credits from retrofits on city street Rights-of-Way and City-owned property, and credits from the Alexandria Renew wastewater treatment facility.

**Are Stream Restorations a Good Use of Scarce Taxpayer Dollars?**

State environmental programs are spending large amounts of taxpayer dollars on stream restoration in the Chesapeake Bay watershed. In fiscal year 2019, the Virginia Department of Environmental Quality (DEQ) awarded over $12 million in Stormwater Local Assistance Fund (SLAF) grants to local jurisdictions for stream restorations. In FY2017, the amount was also over $12 million. At the time this report was prepared, the authors requested stream restoration cost information from the Maryland Department of Environment (MDE) and the Pennsylvania Department of Environmental Protection (DEP). The Maryland and Pennsylvania had not responded at the time this report was finalized.

As noted above, the Taylor Run stream restoration proposed by the City of Alexandria initially relied on nutrient reductions based on engineering estimates that were inflated by as much as 80 percent. Few stream restorations in the Chesapeake Bay watershed have been scrutinized as closely as Taylor Run. It is likely that many stream restorations performed in the watershed, using scarce taxpayer dollars, did not achieve the nutrient reductions they claimed. This leaves the question open as to whether stream restorations truly benefit the Chesapeake Bay and whether they are a cost-effective use of taxpayer dollars.

## Conclusions

After a year of stream height and water quality measurements, it became clear that Taylor Run is a small, urban stream that has little steam flow during dry periods without rain. Occasionally, large volumes of water do arrive in the stream during rain events when rainwater is channeled into the stream from impervious surfaces and the stormwater sewer system upstream. The stream itself is not a significant source of the Chesapeake Bay nutrient and sediment pollution. On average, 75 percent of the nitrogen found in the steam is from upstream sources. Almost all the phosphorous and sediment found in the water is from upstream sources. In short, the stream is not the problem, the upstream watershed is the problem. A reconstruction of the stream, a so called "stream restoration," will not measurably improve the waters of the Chesapeake Bay.

The good news is that many things can be done to improve the water quality in Taylor Run. Those things include installing stormwater Best Management Practices (BMPs) in the watershed upstream of Taylor Run. There is physical space for BMPs like bioretention ponds, bioswales, rain gardens, and other features in Chinquapin Park and at other locations upstream of Taylor Run. Good urban nutrient management practices upstream could also reduce nitrogen and phosphorous pollution downstream.

Other efforts that would improve water quality include:

- Installation of riprap to protect stream banks from erosion,
- Trail improvements in Chinquapin Park that prevent soil and sediment runoff, and
- Installation of pervious surfaces on park roads and/or the installation of road gutters that transport stormwater runoff to bioretention ponds.

Undoubtedly, there are more actions that can be taken to slow down, filter and capture stormwater before it reaches Taylor Run. These improvements can be made without a wholesale re-engineering of Taylor Run, a beautiful natural area.

The Taylor Run water quality monitoring effort brings several EPA Chesapeake Bay Program (CBP) questions to mind. First, it should be clear that stormwater management practices implemented to improve the Bay should be planned, prioritized, and evaluated based on good scientific measurements, not estimates. Future stream restorations projects should not move forward until stream bank soil sampling and water quality monitoring demonstrate the project has significant value. To the extent possible, an audit of past stream restoration projects should be conducted to determine if those projects achieved the nutrient and sediment reductions originally claimed.

Second, project assessment tools like stream bank soil sampling and water quality monitoring are remarkably cheap compared to stream restoration project costs. The CBP and state stormwater programs should require these low-cost measurements to inform decision making and ensure the good and proper use of taxpayer dollars.

Third, EPA's Chesapeake Bay Program is supporting the expenditure of huge amounts of public funds on stream restorations. While Taylor Run is only one case, it is likely there are other examples where a stream restoration was performed and there was little or no improvement in the water quality of the Chesapeake Bay. From a programmatic perspective, if stream restorations are not achieving the reductions needed, scarce public dollars need to be redirected to projects and activities that do achieve real, quantifiable benefits for the Chesapeake Bay.

Finally, a short note on civic engagement is in order. City and county managers should recognize that residents in urban settings highly value – perhaps even cherish – the few natural or wild places that remain in their neighborhoods. It is understandable that urban residents expect, even demand, that city and county managers save, protect, and nurture these places. Residents will find it especially troubling if a proposed project, like a "stream restoration" project, billed as something that will improve the waters of the Chesapeake Bay, will make wholesale changes to or possible destroy a natural ecosystem and the project will do little, if anything, to improve water quality in the Chesapeake Bay.

## Remaining questions

There are many interesting questions that remain unanswered after the NRCA work on Taylor Run. Most of the scientific questions could be answered by an in-depth monitoring of the stream by the U.S. Geological Survey, an organization with stream monitoring expertise. A year-long or longer USGS study of Taylor Run could:

- Accurately measure annual stream flow.
- Develop a good stream stage (stream height) to discharge relationship.
- Provide good estimates of annual pollutant loads for TN, TP, and TSS.
- Correlate local rainfall with stream flow.
- Help elucidate why nitrate/nitrogen levels are higher at the downstream site than the upstream site.
- Identify other pollutants, not measured in the NRCA effort, that arrive in the stream and inhibit aquatic life.
- Provide some indication as to what pollutant occasionally gives the stream water at the upstream site a milky appearance during low flow conditions.

An important remaining question is how to improve and maintain Chinquapin Park and Taylor Run without harming the existing ecosystem. NRCA volunteers believe the following list provides some answers.

- Install well-known Best Management Practices upstream of Taylor Run to slow down, filter and capture urban runoff.
- Protect the sanitary sewer in and along Taylor Run in a minimally intrusive way.
- Protect some stream banks from erosion using thoughtful proven techniques.
- Lengthen bridges over wetland areas that cross the trail.

- Make trail improvements to keep stormwater runoff out of the stream.
- Improve park infrastructure like roads and gutters to better control and sequester stormwater.

A final regulatory question is: “Will the U.S. EPA modify the Chesapeake Bay Program so that “stream restorations” will not be allowed unless they can demonstrate through good scientific measurements that the project will produce real, quantifiable pollution reductions that benefit the Chesapeake Bay.

## Follow-up Steps Taken

The Taylor Run Water Monitoring Team has taken the following steps as of March 30, 2022:

- Presentation of findings to Alexandria Environmental Policy Commission November 15, 2021
- Presentation to the Board of North Ridge Citizens’ Association, January 10, 2022
- Correspondence with Karen Doran, the Director of the SLAF Program in VADEQ, starting in January 28, 2022 and continuing
- Discussion of findings with representatives of the Alliance for the Chesapeake Bay and the Chesapeake Monitoring Cooperative, February 17, 2022
- Presentation to officials in the Water Program of the USEPA, March 8, 2022

# Appendices

## A – Acknowledgements


- **Trained and Certified Volunteer Citizen Scientists**
    - Russ Bailey, certified Tree Steward, retired attorney, member of NRCA Board
    - Bill Gillespie, certified Tree Steward, trained chemist, retired air quality scientist
    - Chuck Kent, past President and Board member of NRCA, retired official at USEPA
    - Rita Leffers, certified Tree Steward, retired chemist
    - Don Bobby, Master Gardener, retired Department of Defense
    - Amy Krafft, PhD, Scientist, Program Officer for Influenza Therapeutics and Diagnostics Product Development, National Institutes of Health (NIH)
    - Patricia Gruesen, Arlington Master Naturalist, certified Tree Steward, MS in Wildlife Conservation, certified in macro-invertebrate survey methodology
    - John Fehrenbach, President of NRCA, attorney
    - John Winstead, member of NRCA Board, realtor
- **Technical and Financial Assistance**
    - Stuart Torbeck, Virginia Department of Environmental Quality (VADEQ)
    - Sophie Stern and Liz Chudoba, Alliance for the Chesapeake Bay - RiverTrends
    - Dwain Winters, USEPA retired – for fabrication of a custom bracket to support a 7' scaffold at the mouth of the culvert at TayRun1.5; for loaning us the scaffold; and for loaning professional surveying equipment for mapping stream profiles
    - Russell Bailey -- for funding lab analysis expenses that exceeded our $5,000 grant from the Virginia DEQ
    - Bill Gillespie and Chuck Kent for acquiring, fashioning, and installing water monitoring equipment
    - Chuck Kent, Rita Leffers, and Bill Gillespie for documentary photography of the project
    - Harold Post, Research Associate with Virginia Tech's Occoquan Watershed Monitoring Lab (OWML) for the loan of instruments for measuring water velocity
    - John Jastram and Aaron Porter, Specialists at USGS for their advice and counsel on measuring water quality in urban streams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**C – Possible Sources of Error**

NRCA volunteers took the water samples collected from Taylor Run to Analytics Corporation laboratory located in Ashland, VA. The address of the laboratory is: Analytics Corporation 10329 Stony Run Lane, Ashland, VA 23005. The lab is certified under the Virginia Environmental Laboratory Accreditation Program (VELAP), VELAP Certificate Number 11218. After samples were taken, they were placed on ice in coolers and driven to the lab. Chain-of-Custody procedures were followed for all sample deliveries.

The following table provides the Limit of Quantitation (LOQ) for each analytical method employed by the lab.

| Analytical Method | Limit of Quantitation |
|---|---|
| Total Kjeldahl Nitrogen | 0.50 mg/L |
| Nitrite-Nitrate as N | 0.05 mg/L |
| Total Nitrogen | 0.50 mg/L |
| Total Phosphorous | 0.02mg/L |
| Total Suspended Solids | 1.00 mg/L |

Andrew Teague, the Director of the Analytics Corporation lab in Ashland, VA provided the following additional information on the lab's estimation of uncertainty and probable bias. The uncertainty and probable bias information is from recovery data for batch quality control samples in 2021.

| Analyte | Reference Method for Testing | No. of Points | Date Interval | Average Recovery (%) | Standard Deviation of Recovery (%) | Relative Standard Deviation | Expanded Uncertainty Factor (k=2) | Probable Bias Factor |
|---|---|---|---|---|---|---|---|---|
| Nitrate-Nitrite | SM 4500NO3-F-2011 | 68 | 1/1/2020 - 12/31/2021 | 101 | 7.4 | 0.073 | 0.15 | 0.010 |
| Total Kjeldahl Nitrogen | EPA 351.2 | 40 | 1/1/2020 - 12/31/2021 | 102 | 5.4 | 0.053 | 0.11 | 0.020 |
| Total Suspended Solids | SM 2540-D | 38 | 1/1/2020 - 12/31/2021 | 96.4 | 8.6 | 0.089 | 0.18 | -0.036 |
| Total Phosphorus | SM 4500-P-E | 53 | 1/1/2020 - 12/31/2021 | 105 | 5.0 | 0.048 | 0.095 | 0.050 |

Measured concentration times the Expanded Uncertainty Factor yields the ± concentration for establishing a 95% certainty interval around the reported concentration. Measured concentration times the Probable Bias Factor yields the probable concentration bias in the reported concentration.

The RiverTrends program of the Alliance for the Chesapeake Bay provided NRCA with the equipment needed for measuring air and water temperature, dissolved oxygen, conductivity, pH, and turbidity.   The table below provides the measurement range, accuracy and precision information for the instruments used to make RiverTrends measurements.

| Matrix | Method/Instrument | Parameter | Measurement Range | Accuracy | Precision |
|---|---|---|---|---|---|
| Air | Hanna Thermometer HI 98501 | Temperature | -50 to 150º C | ±0.2ºC | ±0.1ºC |
| Water | Hanna Thermometer HI 98501 | Temperature | -50 to 150º C | ±0.2ºC | 0.1ºC |
| Water | Transparency Tube | Clarity | 0 – 115 cm | ±0.5 cm | ±0.5 cm |
| Water | Oakton PCTSTestr 5 Multiprobe | pH | pH -2.00-16 | ±0.01 pH | ±0.20 pH |
| Water | Oakton PCTSTestr 5 Multiprobe | Conductivity | 0 to 2,000 µS/cm | ±1 µS/cm | ±10% of reading |
| Water | LaMotte DO Kit | Dissolved Oxygen | 0-20 mg/l | ±0.2 mg/l | ±0.5 mg/l |

For a full discussion of measurement error and quality assurance, see the Quality Assurance Project Plan (QAPP) submitted to the Virginia Department of Environmental Quality on July 25, 2021.

## D – Data Tables

### D.1 – Upstream Data, TayRun 1.8

| Date | Stream Height (Inches) | Stream Height (Meters) | Rainfall 24hr (mm) | Rainfall 48hr (mm) | Rainfall 7 days (mm) | Dissolved Oxygen | pH | Conductivity | Turbidity | Kjeldahl N (mg/L) | Nitrite-Nitrate N (mg/L) | TN (mg/L) | TP (mg/L) | TSS (mg/L) | Air Temp (C) | Water Temp (C) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3/9/21 | 4.375 | 0.111 | 0.0 | 0.0 | 0.0 | 8.9 | 6.83 | 899 | >115 | 0.390 | 1.69 | 2.08 | 0.052 | <1.00 | 16.8 | 9.1 |
| 3/23/21 | 4.125 | 0.105 | 0.0 | 0.0 | 9.4 | 8.1 | 6.68 | 833 | >115 | 0.570 | 0.935 | 1.51 | 0.04 | 1.00 | 12.2 | 10.5 |
| 4/13/21 | 4.500 | 0.114 | 0.3 | 3.6 | 19.1 | 8.1 | 6.97 | 612 | >115 | 0.654 | 1.09 | 1.74 | 0.132 | 1.40 | 13.1 | 14.1 |
| 4/27/21 | 4.000 | 0.102 | 0.0 | 21.8 | 22.1 | 7.0 | 6.81 | 689 | >115 | 0.562 | 1.66 | 2.22 | 0.11 | 2.20 | 18.3 | 15.2 |
| 5/11/21 | 3.875 | 0.098 | 0.0 | 0.3 | 17.3 | 6.8 | 7.07 | 689 | >115 | 0.566 | 1.58 | 2.14 | 0.202 | 1.30 | 15.6 | 13.8 |
| 5/25/21 | 4.400 | 0.112 | 5.6 | 3.0 | 3.0 | 6.1 | 6.81 | 642 | >115 | 0.748 | 1.32 | 2.07 | 0.135 | 7.30 | 17.6 | 18.1 |
| 6/8/21 | 4.000 | 0.102 | 0.0 | 0.0 | 3.8 | 6.5 | 6.89 | 465 | >115 | 0.582 | 1.02 | 1.60 | 0.04 | 1.60 | 20.2 | 18.0 |
| 6/10/21 | 14.500 | 0.368 | 12.7 | 12.7 | 14.2 |  | 7.20 | 796 | 30.5 | 1.400 | 0.461 | 1.86 | 0.157 | 22.40 | 23.1 | 25.1 |
| 6/22/21 | 4.250 | 0.108 | 1.3 | 4.3 | 50.8 | 6.2 | 6.80 | 511 | >115 | 0.810 | 1.16 | 1.97 | <0.02 | 2.90 | 21.2 | 19.8 |
| 7/13/21 | 3.750 | 0.095 | 0.0 | 0.0 | 3.3 | 6.0 | 6.95 | 461 | >115 | <0.25 | 0.986 | <0.986 | 0.034 | 1.00 | 29.1 | 21.4 |
| 7/27/21 | 5.313 | 0.135 | 9.4 | 9.4 | 21.6 | 6.1 | 7.23 | 214 | 47.5 | 0.437 | 1.09 | 1.53 | 0.13 | 9.20 | 24.8 | 23.9 |
| 8/10/21 | 3.500 | 0.089 | 0.0 | 0.0 | 6.1 | 6.2 | 6.96 | 472 | >115 | 0.713 | 0.975 | 1.69 | 0.034 | 1.00 | 24.6 | 21.4 |
| 8/16/21 | 21.500 | 0.546 | 6.1 | 66.5 | 86.4 |  |  |  | 10.75 | 1.450 | 0.369 | 1.82 | 0.265 | 69.00 |  |  |
| 8/24/21 | 4.563 | 0.116 | 0.5 | 0.5 | 88.4 | 6.4 | 7.11 | 446 | >115 | 0.592 | 1.03 | 1.62 | 0.072 | 1.30 | 26.7 | 23.5 |
| 9/14/21 | 4.562 | 0.116 | 0.0 | 0.0 | 6.4 | 6.4 | 7.01 | 381 | >115 | 0.516 | 0.747 | 1.26 | <0.02 | 1.70 | 23.7 | 22.5 |
| 9/28/21 | 4.438 | 0.113 | 0.0 | 0.0 | 41.7 | 7.3 | 7.14 | 501 | >115 | 0.694 | 1.11 | 1.80 | 0.092 | 1.40 | 19.1 | 17.8 |
| 10/12/21 | 4.688 | 0.119 | 1.5 | 1.0 | 1.5 | 6.7 | 6.98 | 464 | >115 | 1.740 | 1.05 | 2.79 | 0.05 | 3.10 | 18.7 | 20.0 |
| 10/26/21 | 6.625 | 0.168 | 2.8 | 39.4 | 39.4 | 7.2 | 7.3 | 172.5 | 46.7 | 2.020 | 1.3 | 3.32 | 0.25 | 7.70 | 16.4 | 18.5 |
| 10/29/21 | 22.000 | 0.559 | 29.2 | 0.0 | 42.2 | 8.2 | 7.08 | 46 | 36.25 | 1.13 | 0.386 | 1.52 | 0.162 | 27.5 | 15.7 | 16.7 |
| 11/9/21 | 5.125 | 0.130 | 0.0 | 0.0 | 2.5 | 7.4 | 6.98 | 434 | 48.7 |  |  |  |  |  | 14 | 15.0 |
| 11/23/21 | 5.000 | 0.127 | 0.0 | 1.8 | 3.3 | 6.5 | 6.88 | 497 | >115 |  |  |  |  |  | 4.2 | 11.5 |
| 12/14/21 | 3.938 | 0.100 | 0.0 | 0.0 | 4.3 | 6.3 | 6.71 | 613 | >115 |  |  |  |  |  | 9.3 | 9.6 |
| 12/28/21 | 3.750 | 0.095 | 0.0 | 0.0 | 4.1 | 7.4 | 6.96 | 540 | >115 |  |  |  |  |  | 11 | 10.8 |
| 1/25/22 | 4.375 | 0.111 | 0.0 | 0.0 | 7.9 | 9.4 | 6.82 | 808 | >115 |  |  |  |  |  | 5.7 | 8 |
| 2/11/22 | 4.375 | 0.111 | 0.0 | 0.0 | 29.2 | 9.1 | 6.96 | 670 | >115 |  |  |  |  |  | 9.1 | 8.2 |
| 2/22/22 | 4.250 | 0.108 | 1.8 | 0.0 | 0.3 | 8.1 | 6.97 | 630 | 13.5 |  |  |  |  |  | 13.8 | 9.5 |

## D.2 – Downstream Data, TayRun 1.5

| Date | Stream Height (Inches) | Stream Height (Meters) | Rainfall 24hr (mm) | Rainfall 48hr (mm) | Rainfall 7 days (mm) | Dissolved Oxygen | pH | Conductivity | Turbidity | Kjeldahl N (mg/L) | Nitrite-Nitrate N (mg/L) | TN (mg/L) | TP (mg/L) | TSS (mg/L) | Air Temp (C) | Water Temp (C) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 03/09/21 | 3.625 | 0.092 | 0.0 | 0.0 | 0.0 | 12.1 | 7.03 | 714 | >115 | 0.546 | 2.71 | 3.26 | <0.02 | <1.00 | 13.0 | 6.0 |
| 03/23/21 | 3.500 | 0.089 | 0.0 | 0.0 | 9.4 | 10.2 | 6.60 | 643 | >115 | 0.446 | 1.99 | 2.44 | 0.020 | <1.00 | 13.1 | 9.0 |
| 04/13/21 | 3.813 | 0.097 | 0.3 | 3.6 | 19.1 | 8.2 | 6.90 | 480 | >115 | 0.665 | 1.56 | 2.23 | 0.042 | <1.00 | 13.3 | 12.9 |
| 04/27/21 | 3.060 | 0.078 | 0.0 | 21.8 | 22.1 | 8.3 | 6.77 | 517 | >115 | 0.494 | 2.04 | 2.54 | 0.037 | 2.50 | 16.1 | 11.9 |
| 05/11/21 | 3.375 | 0.086 | 0.0 | 0.3 | 17.3 | 8.1 | 6.77 | 554 | >115 | 0.447 | 2.5 | 2.94 | 0.029 | <1.00 | 14.3 | 12.9 |
| 05/25/21 | 3.622 | 0.092 | 5.6 | 3.0 | 3.0 | 6.3 | 6.67 | 386 | >115 | 1.07 | 1.33 | 2.4 | 0.037 | <1.00 | 16.4 | 16.4 |
| 06/08/21 | 3.313 | 0.084 | 0.0 | 0.0 | 3.8 | 5.8 | 6.74 | 503 | >115 | 0.755 | 1.99 | 2.75 | 0.022 | 2.70 | 24.4 | 21.5 |
| 06/10/21 | 9.000 | 0.229 | 12.7 | 12.7 | 14.2 | | 7.21 | 867 | 31.5 | 1.32 | 0.599 | 1.92 | 0.152 | 18.60 | 22.9 | 24.8 |
| 06/22/21 | 3.438 | 0.087 | 1.3 | 4.3 | 50.8 | 6.8 | 6.90 | 491 | >115 | 0.657 | 1.95 | 2.61 | <0.02 | <1.00 | 21 | 21.2 |
| 07/13/21 | 4.250 | 0.108 | 0.0 | 0.0 | 3.3 | 6.0 | 6.95 | 461 | >115 | <0.25 | 2.01 | <2.01 | 0.042 | <1.00 | 27.1 | 23.6 |
| 07/27/21 | 4.875 | 0.124 | 9.4 | 9.4 | 21.6 | 6.0 | 7.11 | 235 | 93.5 | 0.5 | 0.82 | 1.32 | 0.070 | 2.70 | 23.5 | 23.1 |
| 08/10/21 | 4.250 | 0.108 | 0.0 | 0.0 | 6.1 | 6.6 | 7.06 | 492 | >115 | 0.85 | 1.99 | 2.84 | 0.040 | <1.00 | 24.6 | 22.7 |
| 08/16/21 | 14.000 | 0.356 | 6.1 | 66.5 | 86.4 | | | | 11.5 | 1.62 | 0.439 | 2.06 | 0.298 | 90 | | |
| 08/24/21 | 5.250 | 0.133 | 0.5 | 0.5 | 88.4 | 6.6 | 7.17 | 467 | >115 | 0.461 | 1.74 | 2.20 | 0.050 | 1.40 | 25.6 | 23.3 |
| 09/14/21 | 5.375 | 0.137 | 0.0 | 0.0 | 6.4 | 7.0 | 7.02 | 453 | >115 | 0.443 | 2.03 | 2.47 | <0.02 | 1.1 | 22.9 | 21.3 |
| 09/28/21 | 5.188 | 0.132 | 0.0 | 0.0 | 41.7 | 7.3 | 7.14 | 501 | >115 | 0.612 | 2.08 | 2.69 | 0.085 | <1.00 | 19.1 | 17.8 |
| 10/12/21 | 5.250 | 0.133 | 1.5 | 1.0 | 1.5 | 7.4 | 7.06 | 466 | >115 | 1.67 | 2.16 | 3.83 | 0.067 | <1.00 | 17.9 | 18.3 |
| 10/26/21 | 6.500 | 0.165 | 2.8 | 39.4 | 39.4 | 6.9 | 7.14 | 180.5 | 91.6 | 1.81 | 1.43 | 3.24 | 0.177 | 3.40 | 15.6 | 17.5 |
| 10/29/21 | 14.000 | 0.356 | 29.2 | 0.0 | 42.2 | 7.9 | 7.26 | 57 | 25.5 | 0.988 | 0.44 | 1.43 | 0.200 | 38.1 | 16.6 | 16.7 |
| 11/9/21 | 5.625 | 0.143 | 0.0 | 0.0 | 2.5 | 8.8 | 7.05 | 462 | >115 | | | | | | 11.7 | 10.4 |
| 11/23/21 | 6.250 | 0.159 | 0.0 | 1.8 | 3.3 | 9.0 | 6.88 | 403 | >115 | | | | | | 3.8 | 6.3 |
| 12/14/21 | 5.188 | 0.132 | 0.0 | 0.0 | 4.3 | 10.4 | 6.98 | 492 | >115 | | | | | | 4.4 | 4.9 |
| 12/28/21 | 5.313 | 0.135 | 0.0 | 0.0 | 4.1 | 9.5 | 6.88 | 470 | >115 | | | | | | 7.2 | 6.8 |
| 1/25/22 | 5.375 | 0.137 | 0.0 | 0.0 | 7.9 | 10.9 | 6.75 | 674 | >115 | | | | | | 3.7 | 3.6 |
| 2/11/22 | 5.438 | 0.138 | 0.0 | 0.0 | 29.2 | 11.6 | 6.82 | 580 | >115 | | | | | | 6.5 | 4.8 |
| 2/22/22 | 5.563 | 0.141 | 1.8 | 0.0 | 0.3 | 11.0 | 7.11 | 555 | >115 | | | | | | 13.7 | 7.3 |

**D.3 -- Virginia Department of Environmental Quality Data**

| Site ID | Date | Depth | Temperature (C) | Field pH | Dissolved Oxygen | E. coli | TN (mg/L) | TP (mg/L) |
|---|---|---|---|---|---|---|---|---|
| 1ATAY000.83 | 1/12/2021 | 0.3 | 5.33 | 7.48 | 13.33 | 410 | 1.94 | 0.01 |
| 1ATAY000.83 | 2/10/2021 | 0.3 | 6.35 | 7.67 | 13.15 | 85 | 1.61 | 0.02 |
| 1ATAY000.83 | 3/8/2021 | 0.3 | 7.89 | 7.71 | 13.19 | 20 | 1.72 | 0.01 |
| 1ATAY000.83 | 4/6/2021 | 0.3 | 15.85 | 7.63 | 11.91 | 63 | 1.44 | 0.02 |
| 1ATAY000.83 | 5/6/2021 | 0.3 | 16.5 | 7.6 | 9.25 | 359 | 1.13 | 0.03 |
| 1ATAY000.83 | 6/30/2021 | 0.3 | 25.71 | 7.37 | 7.8 | 1,396 | 1.43 | 0.03 |
| 1ATAY000.83 | 7/21/2021 | 0.3 | 24.95 | 7.68 | 8.79 | 813 | 1.31 | 0.02 |
| 1ATAY000.83 | 8/17/2021 | 0.3 | 24.27 | 7.47 | 8.25 | 906 | 1.79 | 0.08 |
| 1ATAY000.83 | 9/15/2021 | 0.3 | 23.42 | 7.58 | 8.46 | 336 | 1.42 | 0.02 |
| 1ATAY000.83 | 10/21/2021 | 0.3 | 16.32 | 7.32 | 9.33 | 97 | 1.54 | 0.01 |
| 1ATAY000.83 | 11/17/2021 | 0.3 | 10.41 | 7.6 | 10.48 | 134 | 1.45 | 0.02 |
| 1ATAY000.83 | 12/9/2021 | 0.3 | 5.82 | 7.48 | 12.17 | 74 | 1.36 | 0.005 |

Note: The comment field for the December 9, 2021, Total Phosphorous (TP) measurement stated: "Material analyzed for, but not detected.  Value stored is the limit of detection for the process in use."