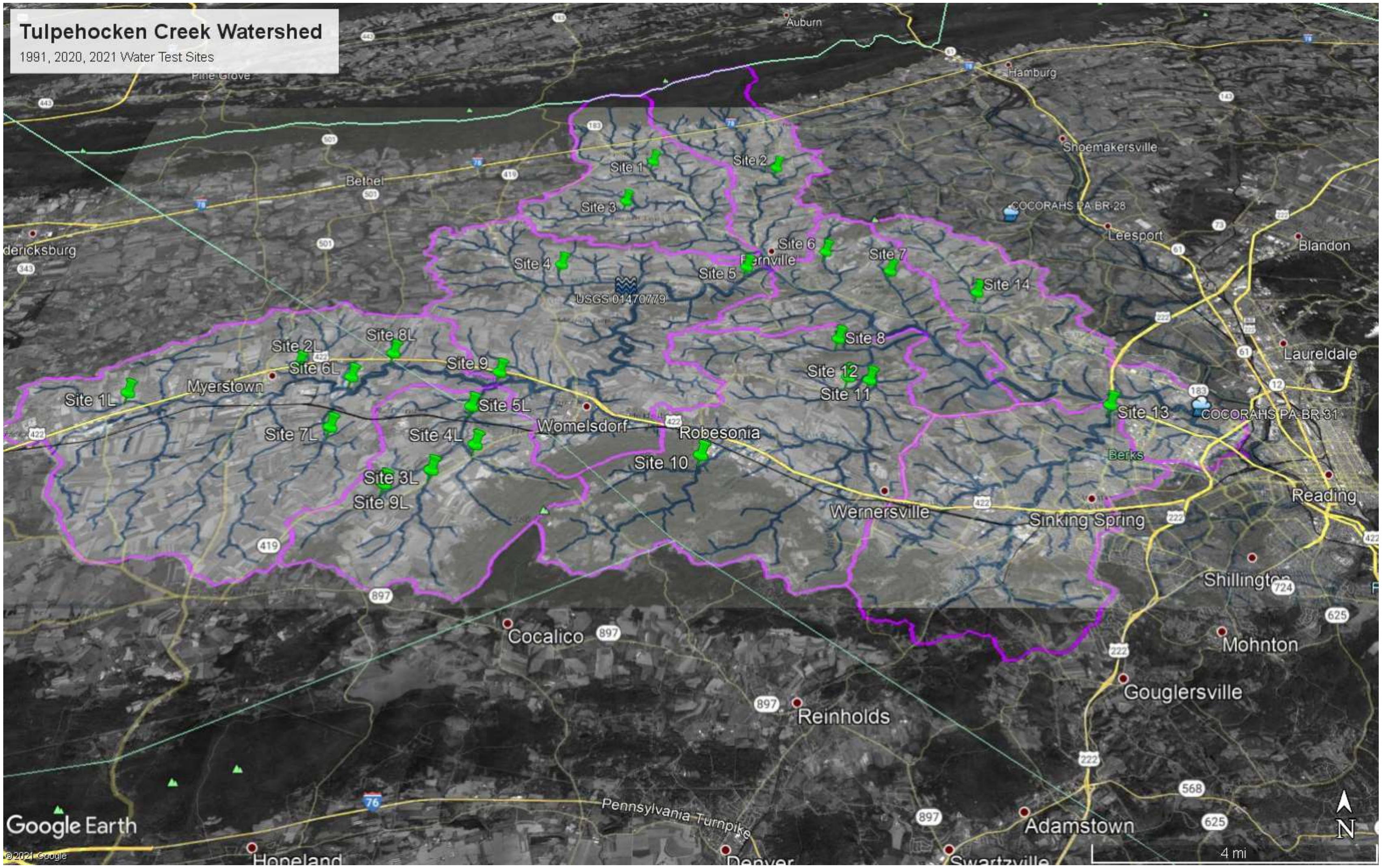
Tulpehocken Creek Watershed
Water Testing Results 2021



Executive Summary

Phosphates - Most of the 2021 measurements were similar to the 2020 measurements. The results all were in the “Excellent” category in accordance with Izaak Walton’s “Water Quality Summation for Chemical Tests”. Site 3L should be investigated in more detail as that site had readings of 0.44 mg/L in 2020 and 2021. See Graph/Table 1.

pH - Many of the 2021 measurements were similar to the 2020 measurements. A majority of the results all were in the “Good” category in accordance with Izaak Walton’s “Water Quality Summation for Chemical Tests”. Sites 12, 14, 5 and 6L may merit further investigation. See Graph/Table 2.

% Saturated Oxygen – A majority of the 2021 measurements were similar to the 2020 measurements. Site 9 requires more testing. See Graph/Table 3.

Nitrates – Twenty-one of the twenty-two tests done in 2021 had higher Nitrate concentrations as compared to the 2020 test results. The average reading was over 2 times that measured in 2020, with an average of 2.6 mg/L in 2020 versus 6.1 mg/L in 2021. Site 2 was the only site with a reading lower than 2020. A majority of the 2021 results were in the “Fair” or “Poor” category in accordance with Izaak Walton’s “Water Quality Summation for Chemical Tests”. See Graph/Table 4.

We also found three Sites in southeastern Pennsylvania where nitrates are continuously monitored. There appears to be an increase in nitrate concentration at those sites when comparing the same time periods that our testing was done. See Graphs 8, 9, and 10.

We could not arrive at a single explanation for the increase in nitrate concentration from 2020 to 2021. However, differences in 2020 versus 2021 rainfall patterns, and the impacts on stream flowrates and the effect on groundwater contributions to stream flow, may offer partial explanations. Other potential considerations for the change are listed in Table 5.

Also, discrete chemical testing only provides an extremely limited view of the nutrient concentration of a stream. Projections based on limited sampling will have questionable accuracy. Continuous monitoring is the only sure way of getting an accurate picture of the quantity of nitrates being carried by the stream. See Graph 7.

Background Information

During the Summer of 2020, the Tulpehocken Creek Watershed Association (TCWA) conducted twenty-two water quality sampling tests within the Tulpehocken Creek Watershed (TCW). The purpose of the 2020 testing was to replicate the testing performed by the United States Department of Agriculture (USDA) in July of 1991. The basis for their testing, as well as the methodology used in their sampling, is described in the USDA document titled “Agricultural Nonpoint Source Evaluation for the Tulpehocken Creek Watershed”, which was published in April 1992. That document is attached to this Report. (USDA, 1992)

The USDA evaluation included detailed test results taken at 23 different sites throughout the TCW during 1991. In addition, the report also included reference data from earlier water monitoring performed by the Berks County Conservation District (BCCD) in 1990. USDA data included levels of Dissolved Oxygen, Nitrates, Phosphates, pH, as well as air and water temperatures. BCCD data included nitrate and phosphate concentrations for several sampling points within the TCW.

The Executive Summary of the USDA Report stated, “A 5-year implementation program with financial aid and technical assistance would reduce the nutrient pollution of the streams by about 32 percent”. (USDA, 1992) The Report also said, “a program will be necessary to monitor the success of the remediation program”. TCWA did find evidence that monies were spent to implement the nutrient pollution reduction program (Archives, 1998), however, we did not find any published test data to confirm the estimated improvements projected in the 1992 Report. The 22 water quality sampling tests performed by TCWA within the Tulpehocken Creek Watershed in 2020 was an effort to partially fill this information gap. . USDA Site 11 was not tested by TCWA in 2020.

The Summary in the “Tulpehocken Creek Watershed Water Testing Results Report” from last year (2020) stated, “Although the data is rather limited, typically one test by TCWA at each Site versus three tests by USDA and two tests by BCCD, we did a comparison of the data by taking gross averages. From our test data, it appears that, in general, looking at the averages for the entire TCW sampling points, the nutrient reduction goal was achieved.” The TCWA 2020 document is also attached to this Report (TCWA, 2020)

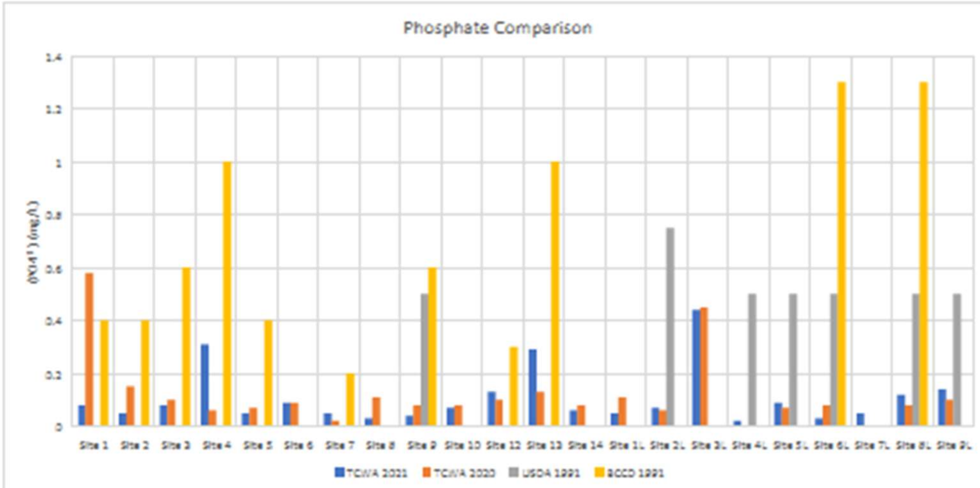
The summary of the 2020 Report also read, “However, it is important to look at the results for the individual locations and to tease out any data that may not be representative, any areas that may be problematic, or areas that may have potential for an up grading of their current DEP rating. Working in conjunction with BCCD, and PADEP, this will most likely be the direction for future testing by TCWA.”

2021 Testing and Results

After discussions, TCWA decided that rather than focusing on individual locations for 2021, it would be a worthwhile exercise to repeat evaluating all 22 Sites identified in the TCWA 2020 Report to substantiate our findings and conclusions. During July and August 2021, we again tested Sites 1 through 9L. See Map on page 1 of this Report for locations.

<u>Phosphates</u>

As noted in the 2020 Report, based on these snapshots in time, it appears that over the past 30 years there has been significant reduction in the concentration of phosphates found in a majority of the TCW streams that were sampled. For most of the Sites tested, the 2021 findings were similar to the 2020 numbers, both much lower than the 1991 values. However, Site 3L should be investigated in more detail as these numbers for both 2020 and 2021 are high.

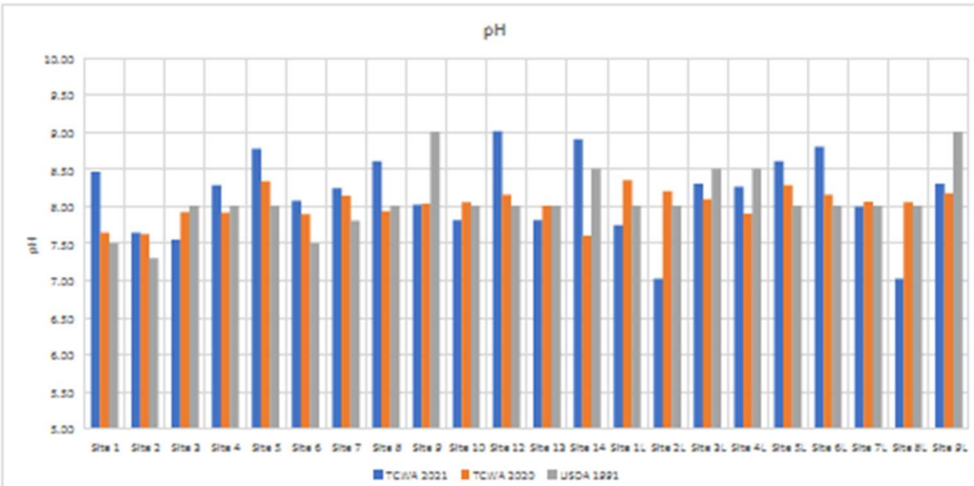


Phosphate (PO_4^{3-}) (mg/L)				
	TCWA 2021	TCWA 2020	USDA 1991	BCCD 1991
Site 1	0.08	0.58		0.40
Site 2	0.05	0.15		0.40
Site 3	0.08	0.10		0.60
Site 4	0.31	0.06		1.00
Site 5	0.05	0.07		0.40
Site 6	0.09	0.09		
Site 7	0.05	0.02		0.20
Site 8	0.03	0.11		
Site 9	0.04	0.08	0.50	0.60
Site 10	0.07	0.08		
Site 12	0.13	0.10		0.30
Site 13	0.29	0.13		1.00
Site 14	0.06	0.08		
Site 1L	0.05	0.11		
Site 2L	0.07	0.06	0.75	
Site 3L	0.44	0.45		
Site 4L	0.02	0.00	0.50	
Site 5L	0.09	0.07	0.50	
Site 6L	0.03	0.08	0.50	1.30
Site 7L	0.05	0.00		
Site 8L	0.12	0.08	0.50	1.30
Site 9L	0.14	0.10	0.50	
Average	0.11	0.12	0.54	0.68

Graph/Table 1 – Phosphate Comparison 2020 versus 2021

pH

Looking at the pH readings from 2021 versus the 2020 measurements, there is no notable change for the average value, which in turn was similar to the 1991 average value.   However, looking at the graph below, there are a few sites where the values varied significantly from 2020 to 2021. The Isaak Walton League “Water Quality Summation for Chemical Tests” (League, 2020) lists pH units in the range of 6.5 to 8.5 to be “Good”, with 7.0 to 7.5 as being “Excellent”. Sites 12, 14, 5 and 6L may merit additional investigation.



pH			
	TCWA 2021	TCWA 2020	USDA 1991
Site 1	8.46	7.64	7.50
Site 2	7.64	7.62	7.30
Site 3	7.55	7.92	8.00
Site 4	8.28	7.91	8.00
Site 5	8.77	8.33	8.00
Site 6	8.07	7.89	7.50
Site 7	8.24	8.14	7.80
Site 8	8.60	7.93	8.00
Site 9	8.02	8.03	9.00
Site 10	7.81	8.05	8.00
Site 12	9.01	8.15	8.00
Site 13	7.81	8.00	8.00
Site 14	8.90	7.60	8.50
Site 1L	7.74	8.35	8.00
Site 2L	7.02	8.20	8.00
Site 3L	8.30	8.09	8.50
Site 4L	8.26	7.90	8.50
Site 5L	8.60	8.28	8.00
Site 6L	8.80	8.15	8.00
Site 7L	7.99	8.06	8.00
Site 8L	7.02	8.05	8.00
Site 9L	8.30	8.17	9.00
Average	8.15	8.02	8.07

Graph/Table 2 – pH Comparison 2020 versus 2021

Dissolved Oxygen - % Saturated Oxygen

The average value for the TCWA measured Dissolved Oxygen (DO) Saturation levels in both 2020 and 2021 were similar, 76% versus 80% respectively, while the average for the USDA measurements was 106% in 1991. Dissolved oxygen readings of greater than 100% air saturation can occur in environmental water because of the production of pure oxygen by photosynthetically active organisms and/or because of non-ideal equilibration of dissolved oxygen between the water and the air above it.

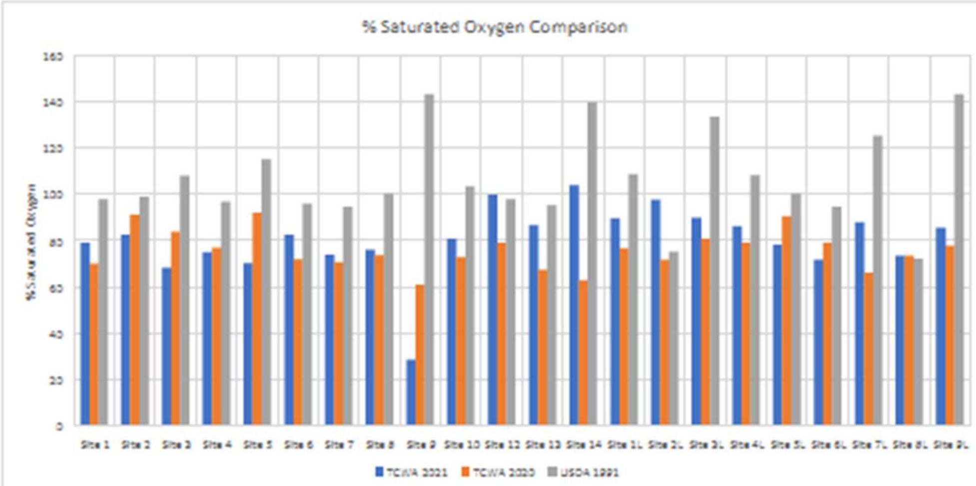
Looking at Graph 3 on the next page, there are some anomalies, but for most of the Sites, the trend for 2020 and 2021 is much lower than the 1991 values.

Fortunately, even at the measured lower levels, our DO results are still in the “Good” zone (70 to 140%) based on the Izaak Walton Water Quality Summation for Chemical Tests (League, 2020) used in our evaluation.

Excess nitrate and phosphate in the stream water are a source of nutrients for aquatic plants and algae. In many cases, the amount of nitrate and phosphate in the water is what limits how much plants and algae can grow. If there is an excess level of these nutrients, plants and algae will grow excessively. An excess in the growth of plants and algae create an unstable amount of dissolved oxygen. During the day, there will be high levels of dissolved oxygen, and at night the levels of oxygen can decrease dramatically. (Metre, 2016)

The average 1991 nitrate measurements (6.3 mg/L) and phosphate levels (0.54 mg/L) were much higher than 2020 numbers (2.6 mg/L nitrate and 0.12 mg/L phosphate), and higher than the 2021 phosphate readings (0.11 mg/L). Assuming the testing was done during the day, the higher levels of dissolved oxygen may have been attributed to the higher nutrient concentrations.

In addition to the above observations, Site 9 should be retested, as that value is well into the “Poor” category, to determine if it is an ongoing situation.



% Saturated Oxygen			
	TCWA 2021	TCWA 2020	USDA 1991
Site 1	79	70	98
Site 2	83	91	99
Site 3	68	84	108
Site 4	75	77	96
Site 5	70	92	115
Site 6	82	72	96
Site 7	74	70	94
Site 8	76	74	100
Site 9	28	61	143
Site 10	81	73	103
Site 12	99	79	98
Site 13	87	67	95
Site 14	104	63	140
Site 1L	89	77	108
Site 2L	97	72	75
Site 3L	90	81	133
Site 4L	86	79	108
Site 5L	78	90	100
Site 6L	72	79	94
Site 7L	88	66	125
Site 8L	73	73	72
Site 9L	85	78	143
Average	80	76	106

Graph/Table 3 – % Saturated Oxygen Comparison 2020 versus 2021

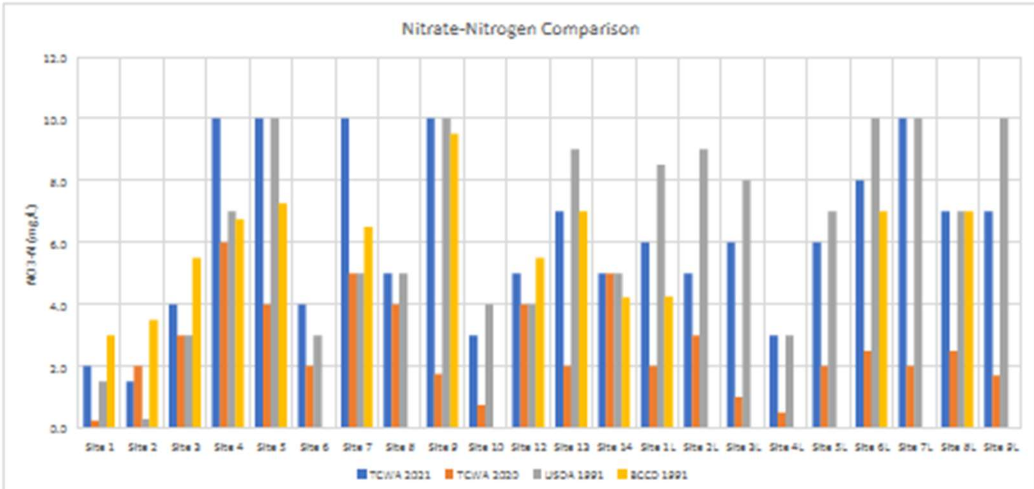
Nitrates

The test results from 2020 led us to the conclusion that over the last 30 years there has been significant decrease in the concentration of nitrates found in the TCW streams that were sampled. This was based on the average of the levels that TCWA measured in 2020, at 2.6 mg/L (NO_3-N), as compared to the average of 6.3 mg/L for the USDA tests. Also, the BCCD had a NO_3-N equivalent average of 5.9 mg/L, which was in line with the USDA average. Both averages were more than two times higher than the concentration that was measured by TCWA in 2020.

Looking at Graph 4 on the next page and comparing the USDA 1991 values to the TCWA 2020 values, the difference between almost all the Sites, not just the average, is obvious.

However, if we look at the TCWA 2021 values, many are the same as what was measured in 1991 rather than 2020. The average value for the 2021 measurements is 6.1 mg/l, almost equal to the USDA 1991 average of 6.3 mg/L and exceeding the BCCD 1991 average of 5.9 mg/l.

Unlike the previous three water quality indicators, where the 2021 results corroborated the 2020 test results, the Nitrate results from 2021 bring into question our conclusion from 2020 results.



Nitrate-Nitrogen (NO_3-N) (mg/L)				
	TCWA 2021	TCWA 2020	USDA 1991	BCCD 1991
Site 1	2.0	0.3	1.5	3.0
Site 2	1.5	2.0	0.3	3.5
Site 3	4.0	3.0	3.0	5.5
Site 4	10.0	6.0	7.0	6.8
Site 5	10.0	4.0	10.0	7.3
Site 6	4.0	2.0	3.0	
Site 7	10.0	5.0	5.0	6.5
Site 8	5.0	4.0	5.0	
Site 9	10.0	1.8	10.0	9.5
Site 10	3.0	0.8	4.0	
Site 12	5.0	4.0	4.0	5.5
Site 13	7.0	2.0	9.0	7.0
Site 14	5.0	5.0	5.0	4.2
Site 1L	6.0	2.0	8.5	4.3
Site 2L	5.0	3.0	9.0	
Site 3L	6.0	1.0	8.0	
Site 4L	3.0	0.5	3.0	
Site 5L	6.0	2.0	7.0	
Site 6L	8.0	2.5	10.0	7.0
Site 7L	10.0	2.0	10.0	
Site 8L	7.0	2.5	7.0	7.0
Site 9L	7.0	1.7	10.0	
Average	6.1	2.6	6.3	5.9

Nitrate-Nitrogen 2021 Compared to 2020			
	TCWA 2021	TCWA 2020	Nitrates 2021/2020
Site 1	2.0	0.3	800%
Site 2	1.5	2.0	75%
Site 3	4.0	3.0	133%
Site 4	10.0	6.0	167%
Site 5	10.0	4.0	250%
Site 6	4.0	2.0	200%
Site 7	10.0	5.0	200%
Site 8	5.0	4.0	125%
Site 9	10.0	1.8	571%
Site 10	3.0	0.8	400%
Site 12	5.0	4.0	125%
Site 13	7.0	2.0	350%
Site 14	5.0	5.0	100%
Site 1L	6.0	2.0	300%
Site 2L	5.0	3.0	167%
Site 3L	6.0	1.0	600%
Site 4L	3.0	0.5	600%
Site 5L	6.0	2.0	300%
Site 6L	8.0	2.5	320%
Site 7L	10.0	2.0	500%
Site 8L	7.0	2.5	280%
Site 9L	7.0	1.7	412%

Graph/Table 4 – Nitrate-Nitrogen Comparison 2020 versus 2021

Looking for a reason for the inconsistency, the first area to consider is whether the testing, rather than the results, is questionable.

The tests were conducted by three separate groups, each with their own test kit. Each of the groups recorded at least one Site with a nitrate measurement of 10 mg/L. In 2020, the highest nitrate measurement at any of the Sites was only 6 mg/L. So, it's not likely the kits were at fault since all three had a least one very high measurement. Also, the people conducting the tests were the same group that did the testing in 2020.

We also tested at least one Site with two kits to confirm consistency between the test kits. The results all matched except for the Nitrate. One kit had a low reading of less than 1.0 and the other kit reading was 6.0 mg/L. It turned out that the lower reading kit had expired reagent. When a retest was done with new reagent, the number was also 6.0 mg/L.

All the other chemicals in the three kits had not yet reached the expiration date.

The next potential testing error to consider is the matching of the sample color to the LaMotte Octa-Slide 2 Viewer. The shades of the color on the slide gradient from 6.0 to 10.0 are not much different, so there is a bit of subjectiveness to color matching the sample with the Octa-Slide color. However, comparing the photos shown below, both from Site 1L, it is obvious that the 2020 sample on the left, is much lighter than the 2021 sample on the right. The 2020 value was recorded as 2.0 mg/L, while the 2021 was recorded as 6.0 mg/L.

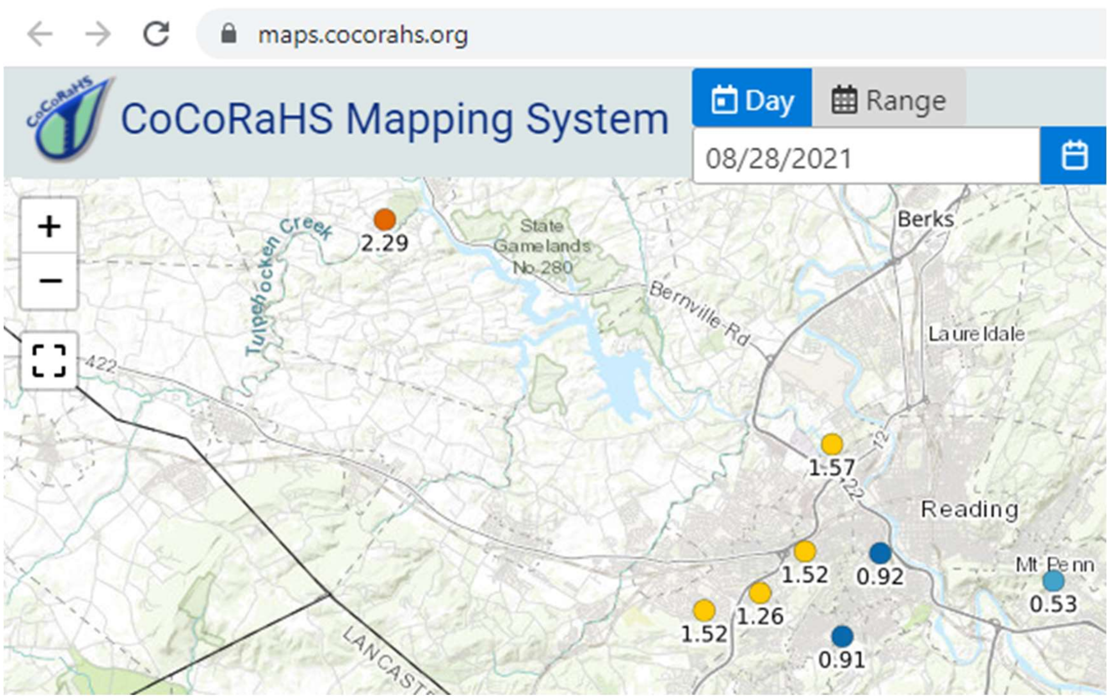
Photo 1 – Comparison of Nitrate LaMotte Test Kit Color Results - 2020 vs 2021

It appears that faulty test equipment or inaccurate test results are unlikely to be the cause of the differences we observed in the measurements from 2020 to 2021.

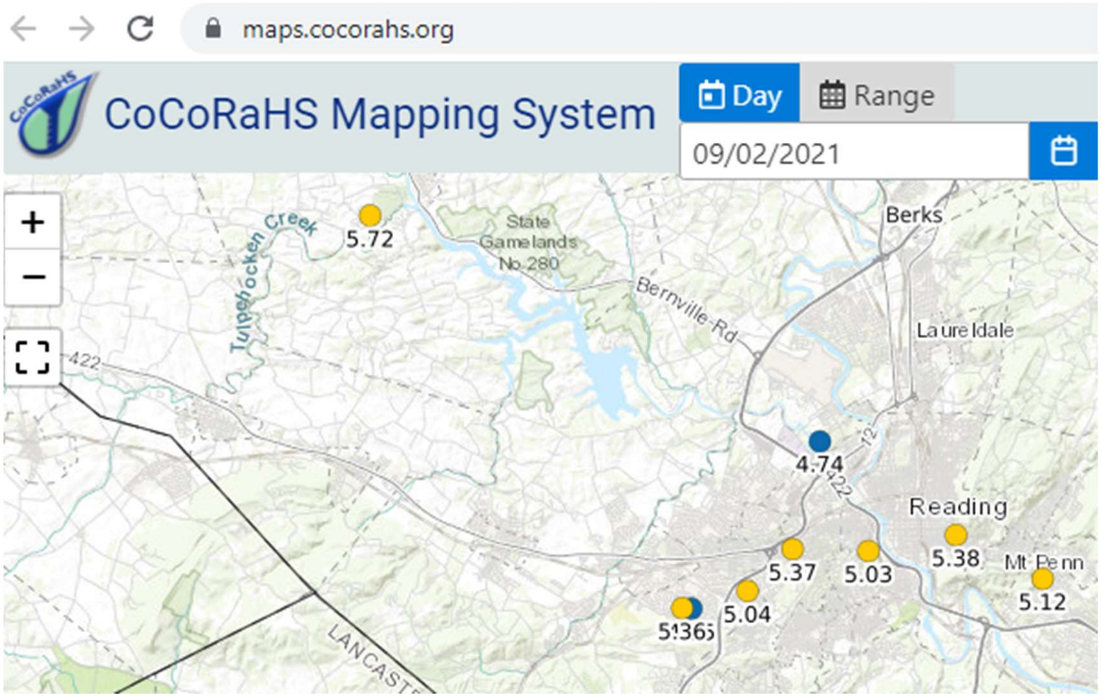
There are many variables that affect the concentration of Nitrates in stream water. Specific factors that appear to influence ground-water nitrate concentrations along the flow paths or in the streams include soil drainage, presence or absence of riparian buffers, evapotranspiration, fertilizer use, ground-water recharge rates and residence times, aquifer properties, subsurface tile drainage, sources and amounts of organic matter, how the surface water bodies continuously interact with the subsurface and rainfall. (Spruill, 2008). Many of these factors have not changed substantially from 2020 to 2021 at most of the Sites, so are unlikely to be the cause for the differences in our measurements.

However, factors that could impact the nitrate test results and that may have been different between 2020 and 2021 are: how the surface water bodies continuously interact with the subsurface; rainfall; and ground water recharge rates. During our testing in 2020 we did see the impact of heavy rainfall on our test measurements. On 8/6/2020, we recorded initial measurements of 10 mg/L at Sites 2L and 5L. Since this was significantly higher than all the tests TCWA had done in the previous years, another test was done later that day on a stream that we had nitrate history and never had measurements of 10 mg/L. That stream also measured 10 mg/L. We later checked rainfall data and found that there was 3 inches of rain the day before the test. We repeated the tests on 8/10/2020, after 3 days of very little rainfall, and the measurements dropped to 3 mg/L at Site 2L and 2 mg/L at Site 5L. We repeated the test in October at Site 2L. The reading was 3 mg/L again.

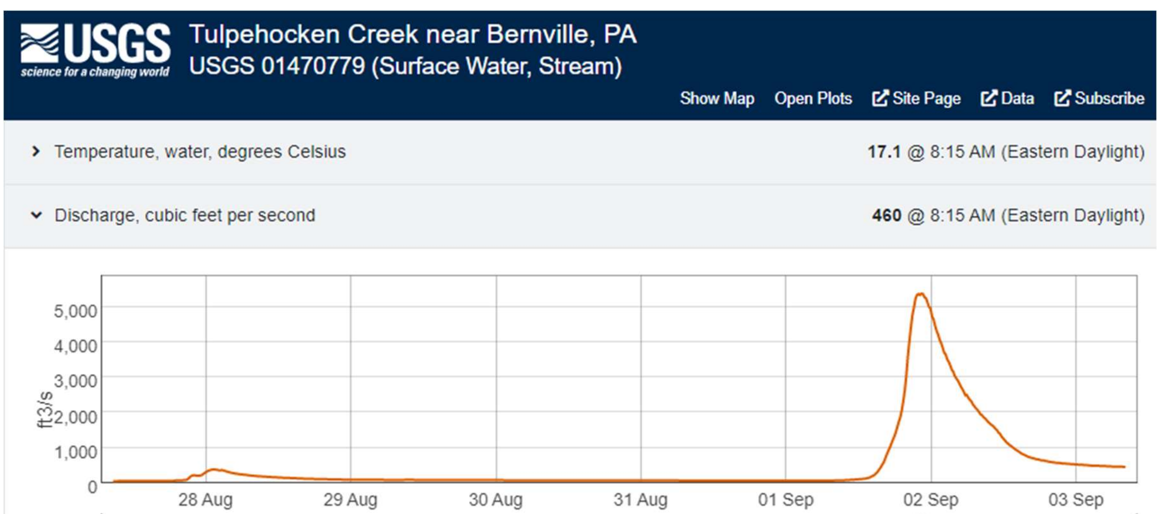
In an attempt to limit the influence of rainfall on the 2021 tests we set a criterion of not testing within three days of a daily rainfall exceeding 0.5 inches. Based on stream flow responses to rainfall from USGS data for the Tulpehocken Creek, it appears that the effect of heavy rainfall on the stream flow subsides within a few hours after the rain event. See Graph 5 for Tulpehocken Creek above Blue Marsh flow rate response to 2.3-inch rain on 8/28/2021 and a 5.7-inch rain on 9/2/2021storm, as shown in Map 1 and 2 below (COCORAHS, 2021). These dates were after our testing was complete.



Map 1 - Rainfall in Tulpehocken Creek Watershed – 8/28/2021



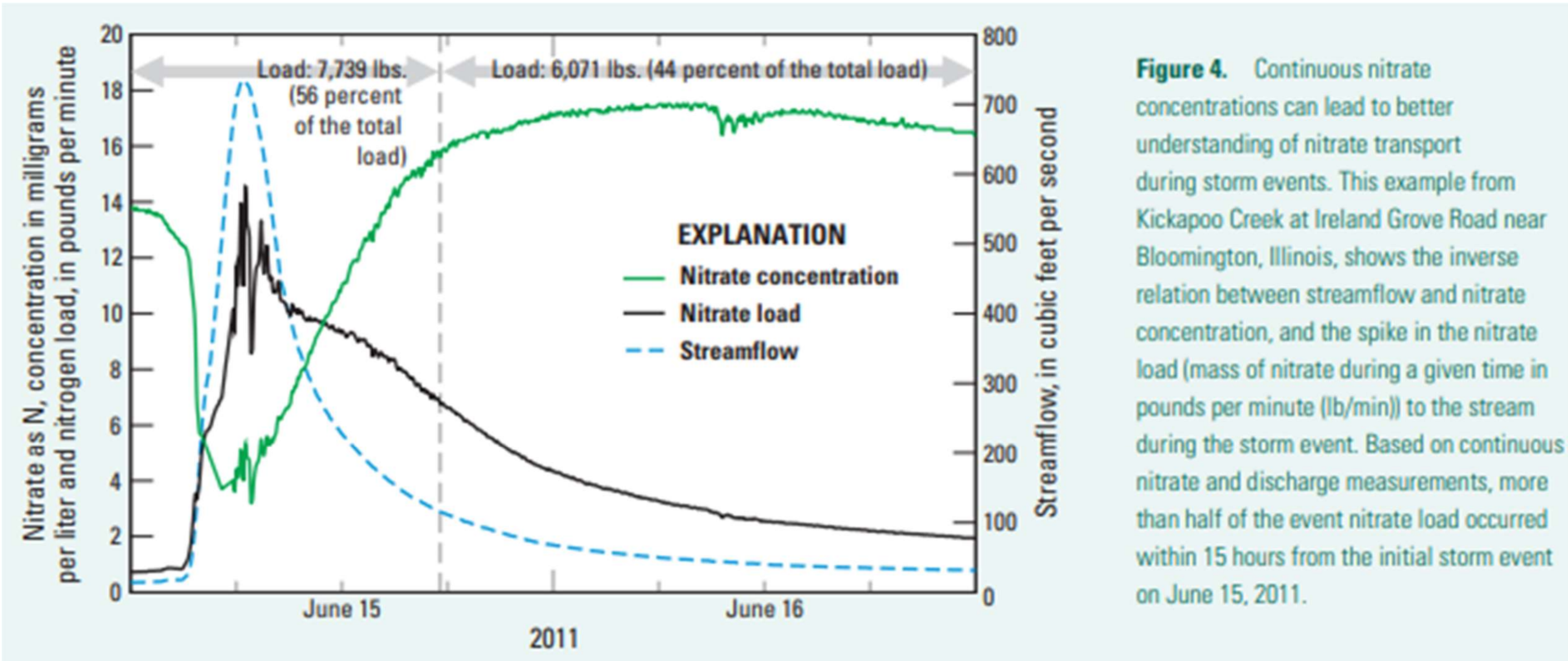
Map 2 - Rainfall in Tulpehocken Creek Watershed – 8/28/2021



Graph 5 - Tulpehocken Creek Response to Significant Rainfall - 2021

It is interesting to note the different reaction of the stream from the 2.29-inch rainfall on 8/28/2021 as compared to the reaction to the 5.72-inch rainfall on 9/02/2021. Far from being a linear relationship! Also, rainfall intensity may have varied between these storms.

Studies have shown that nitrate concentration in streams is affected by streamflow and, although initially depressed, elevated nitrate concentrations may last for a few days after an increase in streamflow. See Graph 6 below illustrating the longevity of nitrate concentration increase due to bump up in streamflow. Of course, different sized streams and different shaped watersheds will impact this relationship. (USGS, 2013)



Graph 6 - Nitrate Concentration versus Streamflow

Also, information from this document illustrates the potential for discrete chemical testing not accurately reflecting the nitrate concentration. Note the 12.8 mg/L on May 7 is significantly higher (64%) than the discrete test results on May 1 (7.82 mg/L) and the discrete test on May 22 (7.52 mg/L). (USGS, 2013)

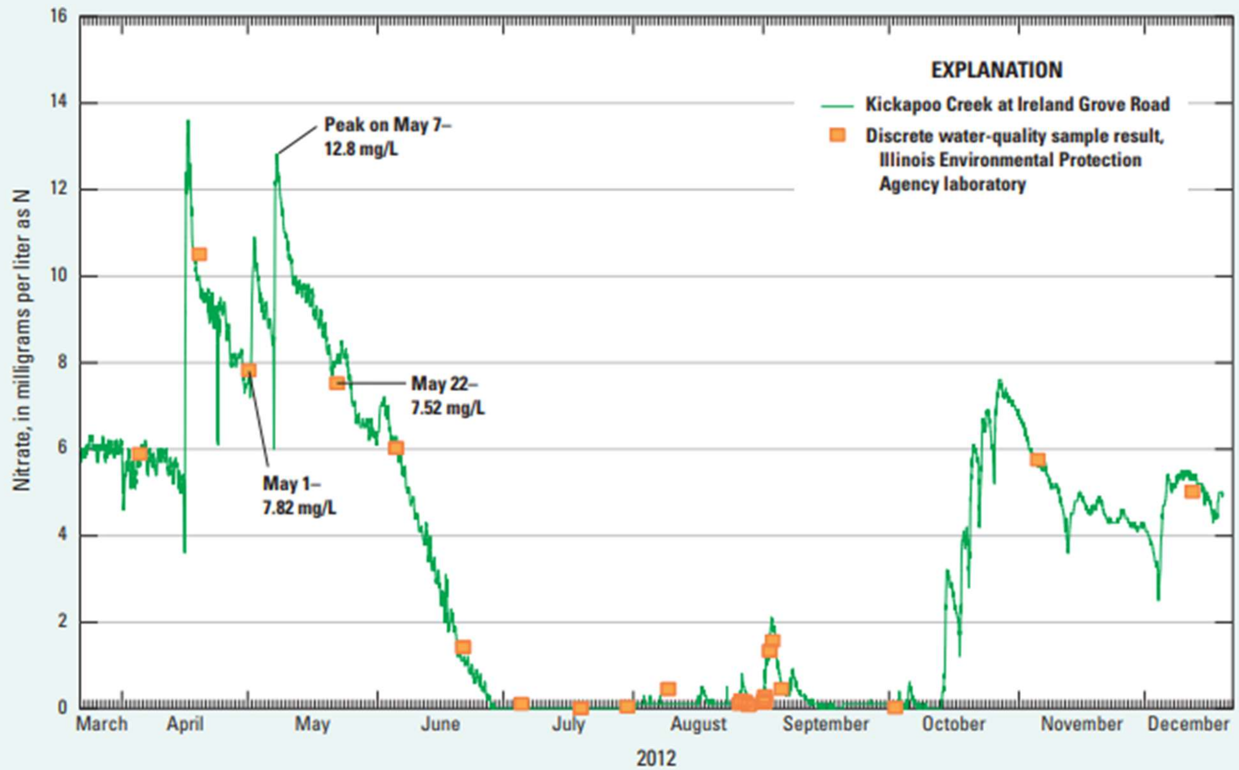
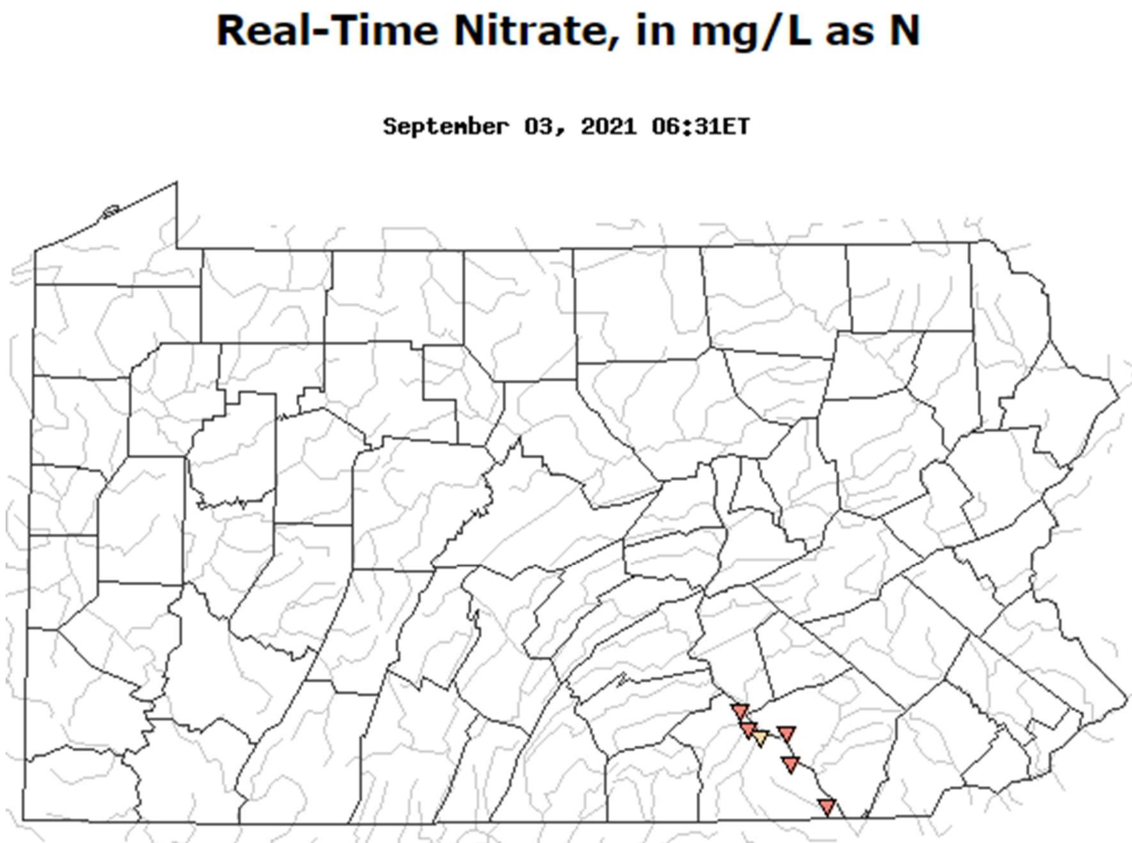


Figure 3. Continuous nitrate monitoring captures spikes in nitrate concentration that would not be evident by periodic laboratory samples. The graph of continuous nitrate concentration from Kickapoo Creek at Ireland Grove Road near Bloomington, Illinois, shows the relation between discrete water-quality samples and continuous data. The continuous data pick up peaks in nitrate concentrations that are not evident in the discrete samples. The peak of 12.8 milligrams per liter (mg/L) as N between a discrete sample collected on May 1, 2012 (7.82 mg/L), and May 22, 2012 (7.52 mg/L), would have been missed without the continuous data collection. When nitrate is a concern in drinking water or the accurate calculation of load is needed, the identification of the peak concentration is important for managing the water quality.

Graph 7 - Discrete Chemical Testing Results versus Continuous Monitoring Results

Based on the above, it appears that the only method to accurately measure nitrate carried in the streams would be by continuously monitoring nitrate concentration and continuously monitoring stream flow and using these two values to calculate the nitrate load.

Information from the USGS website indicates that continuous nitrate monitors are being installed in Pennsylvania. The triangular symbols on the map below show locations of where real-time continuous monitoring of nitrates is currently occurring. (USGS, Water Quality Watch -- Continuous Real-Time Water Quality of Surface Water in the United States, 2021)

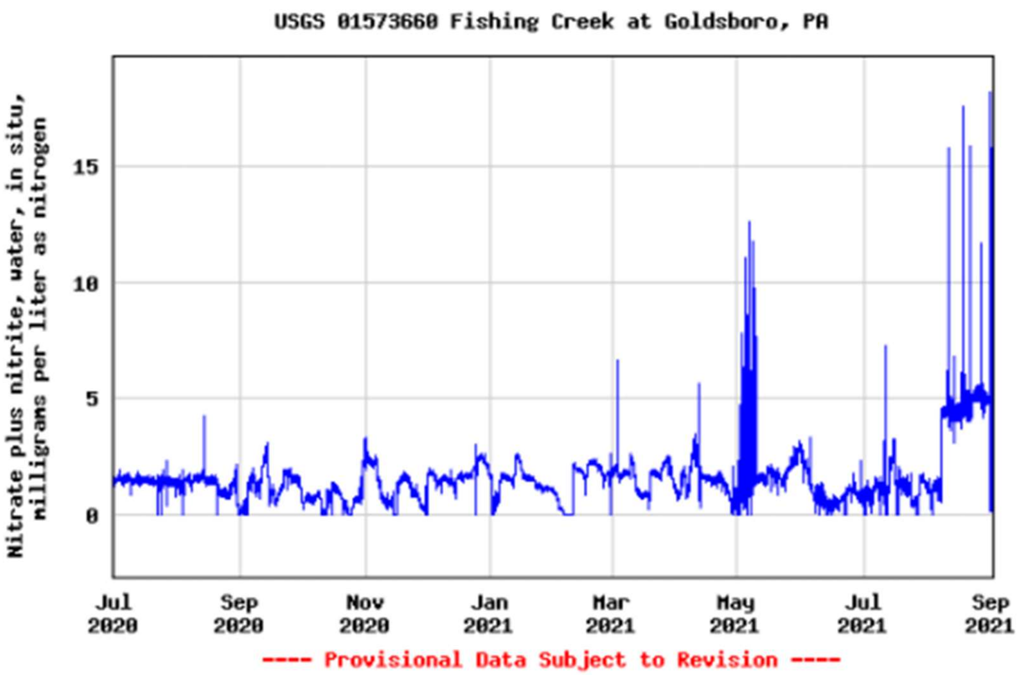


Map 3 – Locations of Continuous Monitoring in Southeast Pennsylvania

Looking at three of these locations, which have data from 2020 as well as 2021, shows an interesting trend in nitrate concentrations, with levels for July and August 2021 being more erratic and higher than levels for July and August 2020.

Nitrate plus nitrite, water, in situ, milligrams per liter as nitrogen

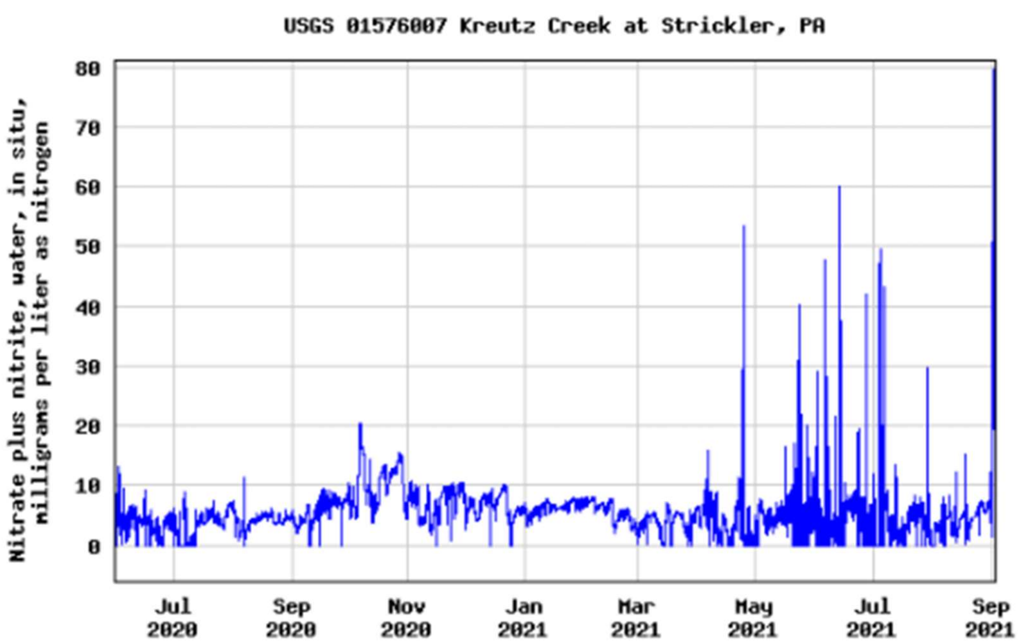
Most recent instantaneous value: 6.10 09-02-2021 21:00 EDT



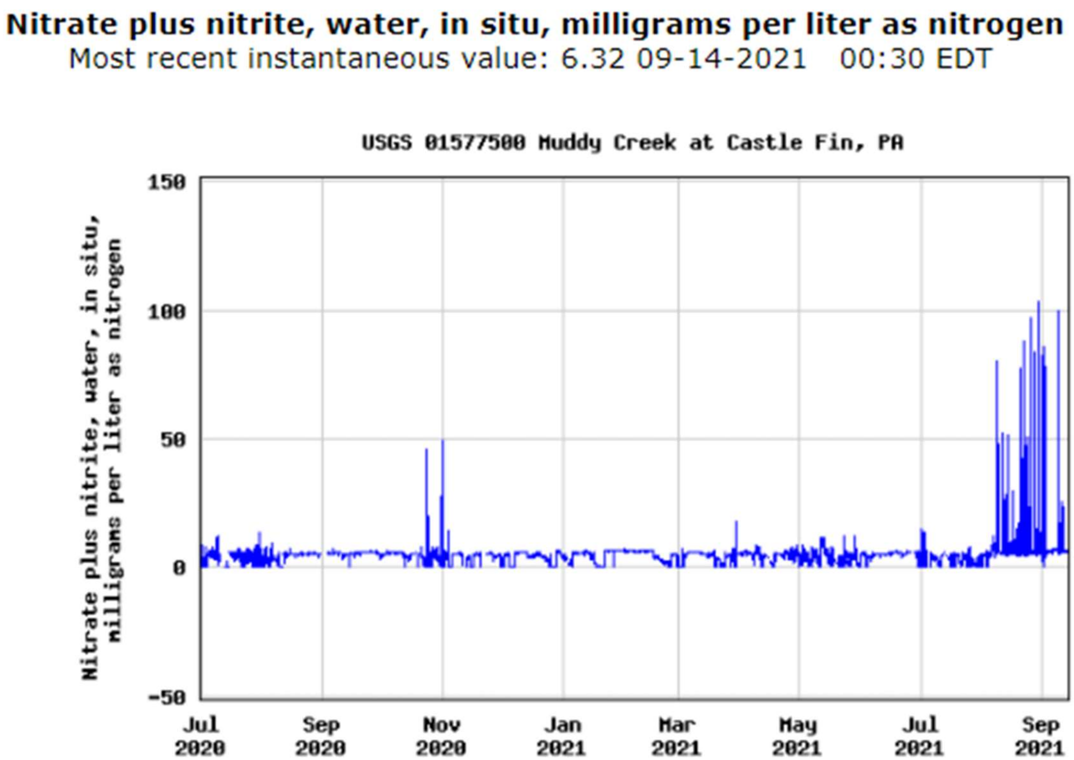
Graph 8 – Continuous Nitrate Monitoring Fishing Creek - 2020 to 2021

Nitrate plus nitrite, water, in situ, milligrams per liter as nitrogen

Most recent instantaneous value: 28.5 09-03-2021 06:15 EDT



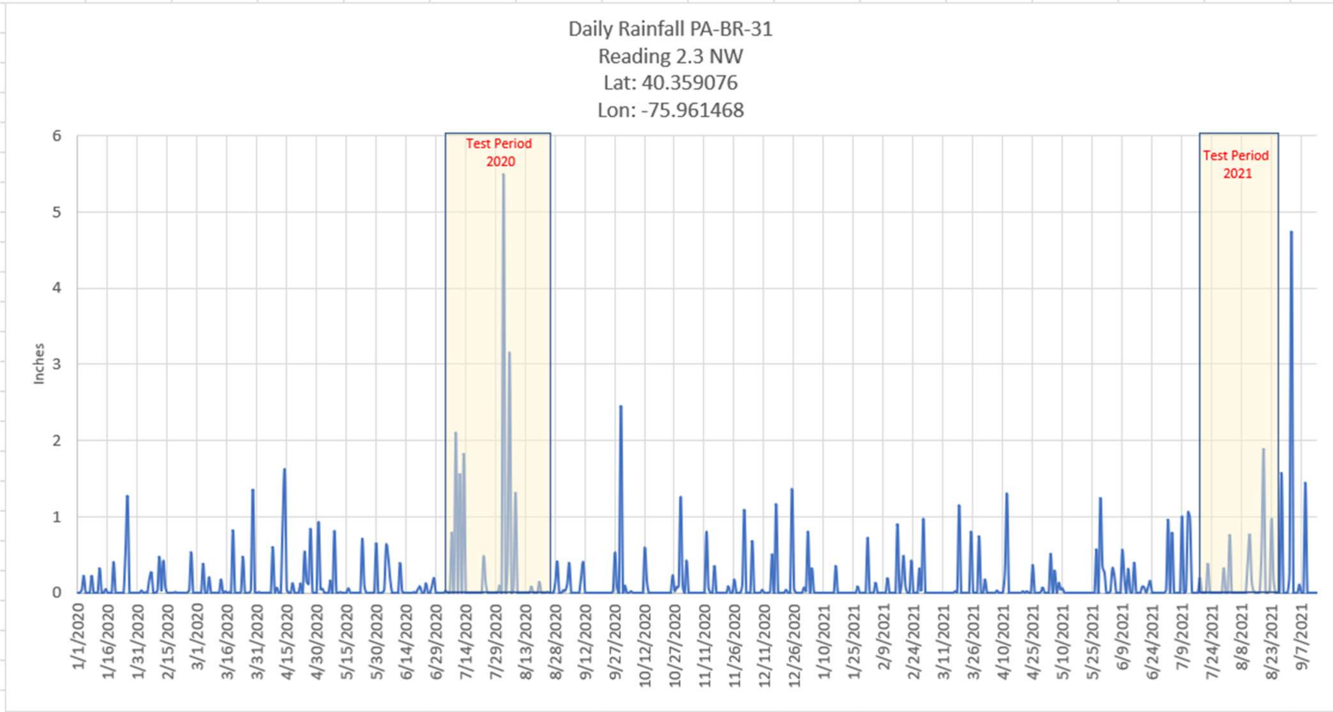
Graph 9 – Continuous Nitrate Monitoring Kreutz Creek - 2020 to 2021



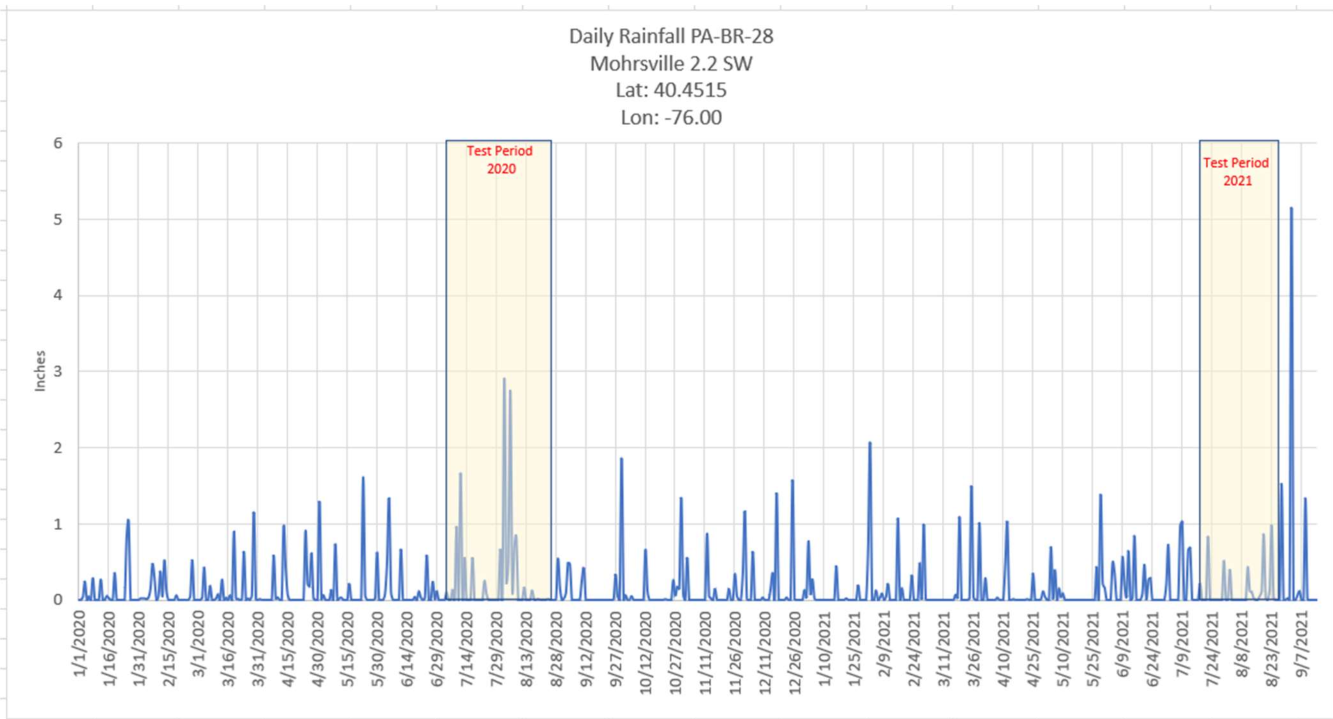
Graph 10 – Continuous Nitrate Monitoring Muddy Creek - 2020 to 2021

Looking for clues as to the cause for this interesting increase in nitrogen in multiple locations, the one factor which merits consideration is rainfall. However, if we look at the rainfall in two locations within the TCW (Reading and Mohrsville) (COCORAHS, 2021), Graph 11 and 12, there seems to have been more rainfall around the time the 2020 tests were done as compared to 2021. The "Nitrate Concentration versus Streamflow", Graph 6, implies that the nitrate concentration is initially depressed during rainfall (assuming streamflow reacts fairly quickly in most of these Sites) but then rises above the pre-storm level and stays elevated for a day or two. This does not explain why the 2021 nitrate readings were higher than 2020 as we would expect that more rain during the 2020 test period would result in more nitrates carried into the stream.

Looking at Graphs 11 and 12, "Test Dates Compared to Daily Rainfall", for two of the rain-gage stations within the TCW, we see that on both graphs significant rainfall events occurred during the 2020 test period. The 2021 test period was conducted during a period of less rainfall as recorded at both rain gage stations. This should have resulted in higher nitrate concentrations in 2020 if the stream behaved as shown in Graph 6, "Nitrate Concentration versus Streamflow". The 2021 tests were typically done at least two days after a rainfall of 0.5 inches or more, in an attempt to limit the influence of rain on the test results. So direct rainfall does not appear to explain the increase in the nitrate levels in 2021 compared to 2020.

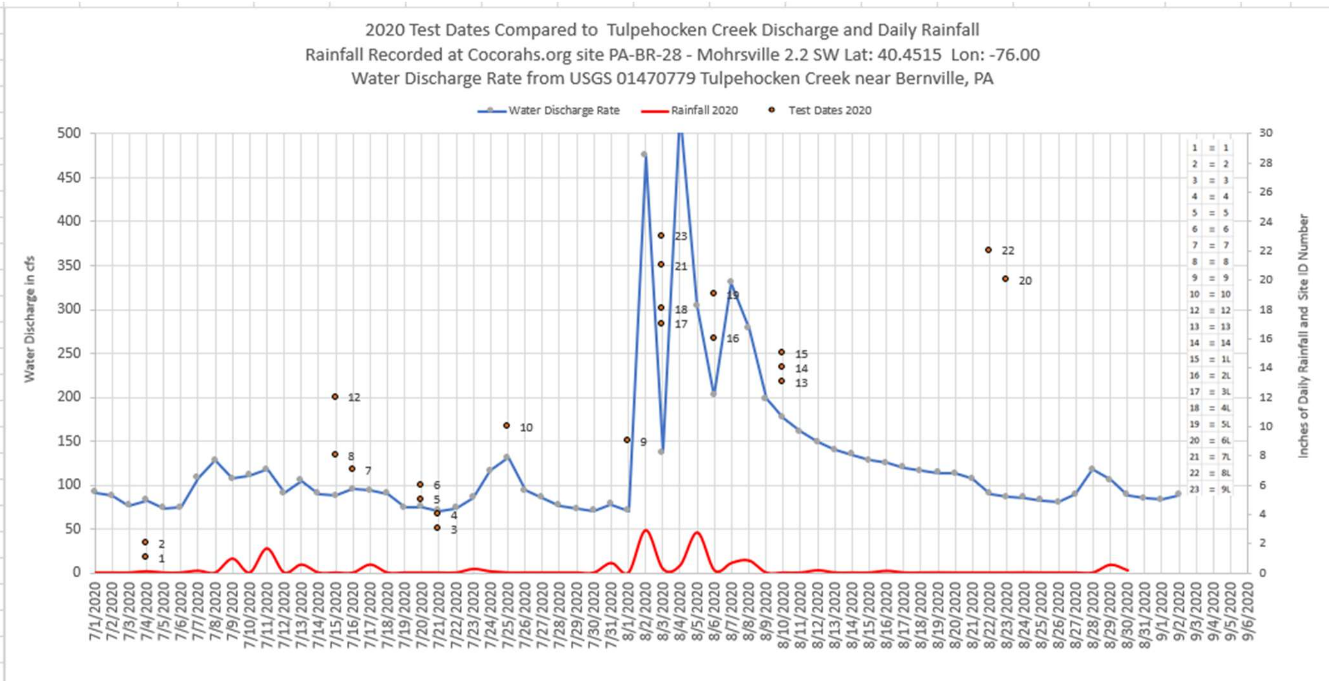


Graph 11 – Test Period Compared to Daily Rainfall as Reported by Reading Airport - 2020 to 2021

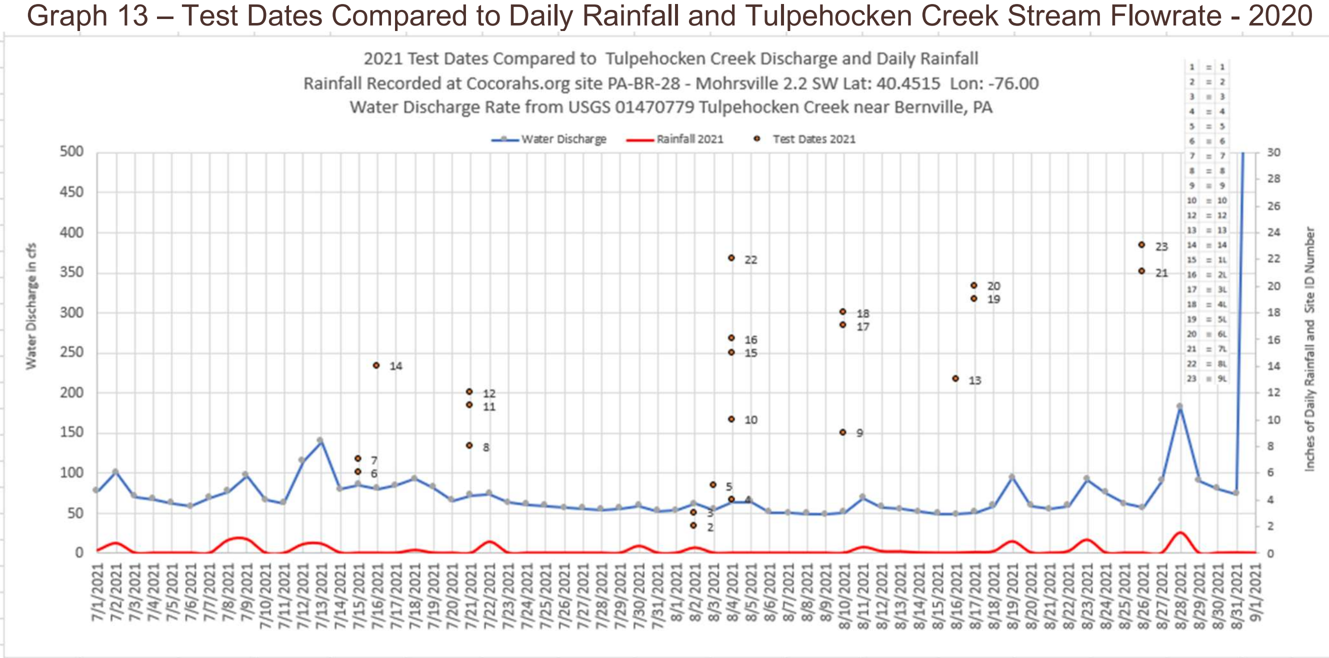


Graph 12 –
Test Period Compared to Daily Rainfall as Reported by COCORAHS in Mohrsville - 2020 to 2021

Looking at Graph 13 and 14 below provides more detail showing the day the tests were done at the numbered Sites compared to the daily rainfall and water discharge rate occurring around the test date. Although the Tulpehocken Creek near Bernville is not representative of all the streams where we tested, it does provide a possible explanation for the differences in some of the test results. The higher volume of water in 2020 could be a partial explanation of the lower readings as the nitrate concentration may have been diluted by the increased water flow which was occurring during many of the 2020 tests.



Graph 13 – Test Dates Compared to Daily Rainfall and Tulpehocken Creek Stream Flowrate - 2020

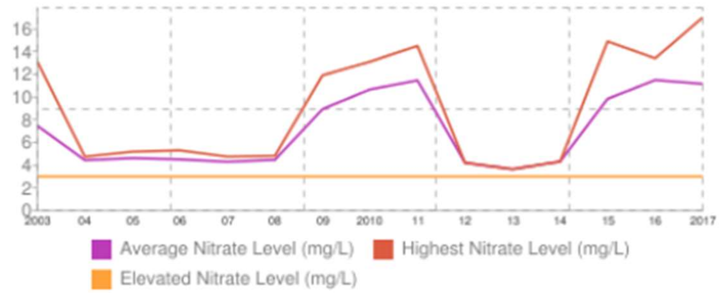


Graph 14 – Test Dates Compared to Daily Rainfall and Tulpehocken Creek Stream Flowrate - 2021

The other factors which affect the concentration of nitrates in stream water to be considered for explaining the rise in nitrates from 2020 to 2021 and the likelihood of their impact are listed in the table below:

Soil drainage	Not likely to change much in one year.
Presence or absence of riparian buffers	Not likely to change much in one year.
Evapotranspiration	Not likely to change much in one year.
Aquifer properties	Not likely to change much in one year.
Subsurface tile drainage	Not likely to change much in one year.
Surface water bodies continuously interact with the subsurface and rainfall	Some studies have shown that multiyear precipitation patterns can affect nitrate loading to streams. (Metre, 2016))
Sources and amounts of organic matter	May explain some of the increase.
Fertilizer and manure application	May explain some of the increase.
Rainfall and resulting stream flow variation	May explain some of the increase. Addressed above.
Ground-water recharge rates and residence times	Groundwater can move at varying rates, sometimes taking years to travel. This may influence the stream concentrations as nitrate in groundwater has been increasing and may contribute more to the flow when the discharge rate is low. (USGS, Water Quality Watch -- Continuous Real-Time Water Quality of Surface Water in the United States, 2021)
Discrete testing versus Continuous Monitoring	Discrete tests at varying times may not capture maximum or minimum concentrations.

Table 5 – Factors That Can Affect the Concentration of Nitrates in Stream Water



Water Testing	Total tests	3 mg/L	5 mg/L	10 mg/L
Total tests	65	65	33	31

DETAILS

Community water system: MYERSTOWN WATER AUTH

Water source: Groundwater

Population served: 9,500

Urban area: No

Graph 15 – Nitrate Levels in Groundwater – Myerstown Area – 2003 to 2017 (10)

The “Nitrate Trends in Pennsylvania Drinking Water Report” (EWG, 2020), which is the source for Graph 15, also stated, “Nitrate contamination got worse in 41 percent of these systems over that time frame and nitrate test averages increased by 37 percent on average across the 266 systems with worsening contamination.”

The Graph 15 shows groundwater nitrate levels rising in recent years with concentrations higher than typically seen in streams. If a significant amount of the water source for the streams is coming from the groundwater, this may explain the higher numbers seen in the streams.

USGS study (USGS, Nitrate Loads and Concentrations in Surface-Water Base Flow and Shallow Groundwater for Selected Basins in the United States, Water Years 1990–2006) states, “The site on Tulpehocken Creek, located in an agricultural area of eastern Pennsylvania (the northern most of the indicated Valley and Ridge sites, part of the Delaware River Basin), has 78 percent of the nitrate load contributed by base flow, as well as, a high base-flow index of 0.73. Nitrate concentrations are relatively high and invariant at low and moderate flows and decrease during high-flow conditions (fig. 7)”

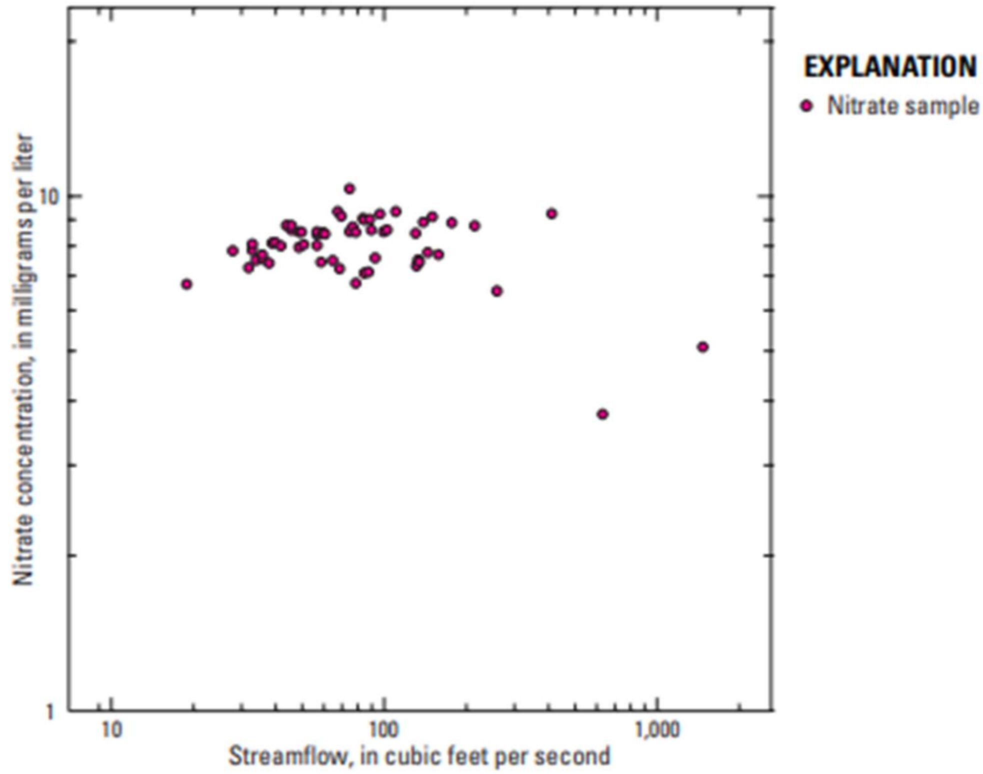


Figure 7. Relation of nitrate concentration and streamflow for Tulpehocken Creek near Bernville, Pennsylvania, where 78 percent of the nitrate load is contributed by base flow, water years 1999–2001.

“Nitrate concentrations are elevated in both base flow and shallow groundwater in the vicinity of Tulpehocken Creek. This site is located in an agricultural area of eastern Pennsylvania with highly permeable underlying rocks (Fischer and others, 2004). Manure from livestock operations commonly is applied to farm fields in this area. Lindsey and others (1998) describe the rapid infiltration of nitrate from fertilizer and manure in other agricultural areas of Pennsylvania with similar shallow and highly permeable bedrock. The correspondence between groundwater and base-flow nitrate concentrations indicates a fairly rapid and unattenuated transport of nitrate in groundwater to this stream.”

Although the study states 78% of the nitrate load was found to come from the base flow, it also mentions “Nitrate concentrations are relatively high and invariant at low and moderate flows and decrease during high-flow conditions”, which implies that the higher nitrate concentration in 2021 may be attributable to low flow occurring during the test period. Also, with the lower flow, the groundwater effect may be more significant and also help to explain the difference in the nitrate concentration from 2020 to 2021.

Lessons Learned

Discrete chemical testing only provides a very limited view of the nutrient concentration of a stream.

Projections based on limited sampling will have questionable accuracy. Continuous monitoring of nutrients and stream flow is the only sure way of getting an accurate picture of the quantity of nutrients being carried by the stream.

Rainfall has a significant effect on stream chemistry and should be documented and included with chemical testing data.

Stream discharge rates may also have a significant impact on water chemistry and its response to rainfall is complex, as can be seen from the graphs in this report.

Groundwater also impacts stream chemistry and may be a factor in prolonging elevated nutrient levels after a heavy rain or during times of low stream discharge rates.

Long periods of drought followed by heavy rain may impact the longevity of elevated nutrient levels. (Metre, 2016)

Learn more about the TCWA by visiting our website at

https://berksnature.org/tulpehockencreekwatershedassociation/?fbclid=IwAR3us3vI0a_UZqFkkbfhBhGDCPT5apxYZASh_cuAPabF-9UMwl6TPKVEW00

TABLE 1 – Location Descriptions from 1992 USDA Study which was the basis for locations used in the 2020 and 2021 water testing.

Berks County

SITE NO.	STREAM (LOCATION)	SUBWATERSHED NUMBER[1]
1	Little Northkill Creek (Spring Road off Rte. 183)	8
2	Northkill Creek (North Boundary Road)	1
3	Tributary - Little Northkill Creek (Road - across from Tulpehocken High School driveway)	8
4	Mill Creek (Berks County) (Parkside Inn Road towards Host Church)	9/10
5	Tulpehocken Creek (Christmas Village Road by Bridge)	10
6	Tributary - Blue Marsh Lake (Garfield Road, east of TWSP. Bldg. (Powder Mill Creek Road)	11
7	Licking Creek (Power Mill Road, SGL 280) (Synder School Road)	11
8	Tributary - Blue Marsh Lake (Peacock Road, SGL 280)	10
9	Mill Creek (Berks/Lebanon Counties) (Sheridan Road north of County Line)	21
10	Furnace Creek (Church Street south of Robesonia)	22
11	Tributary - Blue Marsh Lake (Milestone Road just off Brownsville Road)	12
12	Spring Creek (Brownsville Road by Bridge West of town)	12
13	Cacoosing Creek (Pendergeast Road by Road to Nowhere Intersection)	13
14	Plum Creek (Fisher Mill Road 1/10 mile off Plum Creek Road)	2

TABLE 1 – Location Descriptions from 1992 USDA Study (continued)

Lebanon County

1L	Tulpehocken Creek (North of Rte. 422 on Halfway Drive; Lebanon)	20
2L	Owl Creek (E. Main Street bridge; Myerstown)	20
3L	Tributary - Mill Creek (Lebanon County) (Rte. 419 at bridge; Millbach)	21
4L	Tributary - Mill Creek (Lebanon County) (Rte. 419 bridge; Fort Zeller's, Newmanstown)	21
5L	Mill Creek (Berks/Lebanon Counties) (Furnace Road, Sheridan 500 ft. west of Lebanon/Berks County line)	21
6L	Tributary - Tulpehocken Creek (1.5 mile south of Tulpehocken and Flanagan Roads)	24
7L	Tributary - Tulpehocken Creek (Elco Road bridge, east of ELCO High School)u	24
8L	Tulpehocken Creek (Reilley Road bridge; Millardsville)	20/24
9L	Mill Creek (Lebanon County) (Krumstown Road bridge; Millbach Springs)	21

TABLE 2 – TCW TEST RESULTS COMPARISON

Site #	Testing Organization	Site Name	Date	Air Temp C	Chloride (mg/L)	Dissolved oxygen (mg/L)	% Saturated Oxygen	Nitrate-Nitrogen NO_3-N (mg/L)	Nitrate NO_3^- (mg/L)	Phosphate PO_4^3 (mg/L)	Phosphorus PO_4-P (mg/L)	pH	Water Temp (C)	Conductivity (µs)	Water Transparency (cm)
1	TCWA 2020 Site 1	Little Northkill Creek by 183	7/4/2020	18.7		6.4	69.9	0.3	1.1	0.58	0.19	7.64	19.7	130	106
	TCWA 2021 Site 1	Little Northkill Creek by 183	8/2/2021	21.2		6.8	78.8	2.0	8.8	0.08	0.03	8.46	22.7	175	104
	USDA 1, SW8	Little Northkill Creek by 183	7/9/1991	30.0	-	8.4	97.5	1.5	6.6	< 0.50	< 0.17	7.5	22.8	-	-
	BCCD 12, SW8	Little Northkill Creek by 183	7/12/1990	-	-	-	-	-	13.2	0.40	0.13	-	-	-	-
2	TCWA 2020 Site 2	Northkill Creek by Boundary Rd	7/4/2020	25.6	20	8	91.1	2.0	8.8	0.15	0.05	7.62	21.8	110	80
	TCWA 2021 Site 2	Northkill Creek by Boundary Rd	8/2/2021	24.1		7.8	82.5	1.5	6.6	0.05	0.02	7.64	18.1	125	108
	USDA 2, SW1	Northkill Creek by Boundary Rd	7/9/1991	27.8	-	9.4	98.6	0.3	1.3	< 0.50	< 0.17	7.3	17.7	-	-
3	TCWA 2020 Site 3	UT to Little Northkill Creek Bricker near Tulpy HS	7/21/2020	32.2	28	7	83.8	3.0	13.2	0.10	0.03	7.92	24.4	185	-
	TCWA 2021 Site 3	UT to Little Northkill Creek Bricker near Tulpy HS	8/2/2021	22.0		6.2	68.2	4.0	17.6	0.08	0.03	7.55	20.0	175	80
	USDA 3, SW 8	UT to Little Northkill Creek Bricker near Tulpy HS	7/9/1991	28.9	-	8.8	107.6	3.0	13.2	< 0.50	< 0.17	8	25.6	-	-
4	TCWA 2020 Site 4	UT to Mill Creek near Host Church	7/21/2020	33.5	36	7	76.8	6.0	26.4	0.06	0.02	7.91	19.9	395	-
	TCWA 2021 Site 4	UT to Mill Creek near Host Church	8/4/2021	19.7		7.2	74.9	10.0	44.0	0.31	0.10	8.28	17.3	405	
	USDA 4, SW 9	UT to Mill Creek near Host Church	7/9/1991	28.9	-	8.4	96.5	7.0	30.8	< 0.50	< 0.17	8	22.2	-	-
	BCCD 7, SW 9	UT to Mill Creek Summer Mt Rd	7/12/1990	-	-	-	-	-	29.7	1.00	0.33	-	-	-	-
5	TCWA 2020 Site 5	Tulpehocken Creek By Heidelberg Country Club	7/20/2020	32	35	7.5	91.8	4.0	17.6	0.07	0.02	8.33	25.6	435	85
	TCWA 2021 Site 5	Tulpehocken Creek By Heidelberg Country Club	8/3/2021	19.2		6.6	70.1	10.0	44.0	0.05	0.02	8.77	18.3	455	112
	USDA 5, SW10	Tulpehocken Creek By Heidelberg Country Club	7/9/1991	30.6	-	10	114.8	10.0	44.0	< 0.50	< 0.17	8	22.2	-	-
	BCCD 8, SW10	Tulpehocken Creek By Blue Marsh Lake	7/12/1990	-	-	-	-	-	31.9	0.40	0.13	-	-	-	-
6	TCWA 2020 Site 6	Power Mill Creek Rd	7/20/2020	36	20	5.8	71.8	2.0	8.8	0.09	0.03	7.89	26.2	140	-
	TCWA 2021 Site 6	Power Mill Creek Rd	7/15/2021	30.2	20	7	82.4	4.0	17.6	0.09	0.03	8.07	23.5	200	30
	USDA 6, SW11	Power Mill Creek Rd	7/9/1991	26.7	-	8.6	95.6	3.0	13.2	< 0.50	< 0.17	7.5	20.6	-	-
7	TCWA 2020 Site 7	Licking Creek	7/16/2020	28.3	20	6.5	70.5	5.0	22.0	0.02	0.01	8.14	19.3	280	65
	TCWA 2021 Site 7	Licking Creek	7/15/2021	30.2	20	6.6	73.9	10.0	44.0	0.05	0.02	8.24	20.9	395	90
	USDA 7, SW11	Licking Creek	7/9/1991	32.2	-	8.4	94.4	5.0	22.0	< 0.50	< 0.17	7.8	21.1	-	-
	BCCD 15,SW11	Licking Creek	7/12/1990	-	-	-	-	-	28.6	0.20	0.07	-	-	-	-
8	TCWA 2020 Site 8	Tributary to Blue Marsh at Peacock Rd	7/15/2020	32	36	6.4	73.6	4.0	17.6	0.11	0.04	7.93	22.3	230	30
	TCWA 2021 Site 8	Tributary to Blue Marsh at Peacock Rd	7/21/2021	26.9	20	7	76.0	5.0	22.0	0.03	0.01	8.6	19.4	365	85
	USDA 8, SW10	Tributary to Blue Marsh at Peacock Rd	7/9/1991	22.8	-	9.4	99.9	5.0	22.0	< 0.50	< 0.17	8	18.3	-	-
9	TCWA 2020 Site 9	Tulpehocken Creek at Stouchsburg Bridge	8/1/2020	21.8	30	5.7	60.8	1.8	7.7	0.08	0.03	8.03	18.5	580	98
	TCWA 2021 Site 9	Tulpehocken Creek at Stouchsburg Bridge	8/10/2021	23.5	-	2.6	28.5	10.0	-	0.04	0.01	8.02	19.8	620	112
	USDA 9, SW 21	Tulpehocken Creek at Stouchsburg Bridge	7/9/1991	26.7	-	11.8	142.8	10.0	44.0	0.50	0.16	9	25.0	-	-
	BCCD 5, SW 21	Tulpehocken Creek at Stouchsburg Bridge	7/12/1990	-	-	-	-	-	41.8	0.60	0.20	-	-	-	-
10	TCWA 2020 Site 10	Furnace Creek by Church Street	7/25/2020	23.3	31	6.6	72.7	0.8	3.3	0.08	0.03	8.05	20.1	130	100
	TCWA 2021 Site 10	Furnace Creek by Church Street	8/4/2021	17.1	-	7.9	80.7	3.0		0.07	0.02	7.81	16.4	210	112
	USDA 10, SW22	Furnace Creek by Church Street	7/9/1991	28.3	-	9.6	103.2	4.0	17.6	< 0.50	< 0.17	8	18.9	-	-
12	TCWA 2020 Site 12	Spring Creek	7/15/2020	29.6	50	6.8	78.8	4.0	17.6	0.10	0.03	8.15	22.7	315	70
	TCWA 2021 Site 12	Spring Creek	7/21/2021	26.6	50	8.8	99.5	5.0	22.0	0.13	0.04	9.01	21.4	490	105
	USDA 12, SW12	Spring Creek	7/9/1991	23.3	-	9.4	97.7	4.0	17.6	< 0.50	< 0.17	8	17.2	-	-
	BCCD 25, SW12	Spring Creek	7/12/1990	-	-	-	-	-	24.2	0.30	0.10	-	-	-	-
13	TCWA 2020 Site 13	Cacoosing Creek at Pendergeast	8/10/2020	30	-	6.2	67.2	2.0	8.8	0.13	0.04	8	19.3	485	112
	TCWA 2021 Site 13	Cacoosing Creek at Pendergeast	8/16/2021	24.1	-	8.2	86.6	7.0	30.8	0.29	0.09	7.81	18.0	460	112
	USDA 13, SW13	Cacoosing Creek at Pendergeast	7/9/1991	23.0	-	9.8	95.1	9.0	39.6	< 0.50	< 0.17	8	14.0	-	-
	BCCD 19, SW13	Cacoosing Creek at Confluence	7/12/1990	-	-	-	-	-	30.8	1.00	0.33	-	-	-	-
14	TCWA 2020 Site 14	Plum Creek at Fisher Mill Road	8/10/2020	33.5	-	5.4	62.7	5.0	22.0	0.08	0.03	7.6	22.8	165	67
	TCWA 2021 Site 14	Plum Creek at Fisher Mill Road	7/16/2021	30.7	24	9	103.7	5.0	22.0	0.06	0.02	8.9	22.4	295	80
	USDA 14, SW2	Plum Creek at Fisher Mill Road	7/9/1991	28.0	-	12.2	139.5	5.0	22.0	< 0.50	< 0.17	8.5	22.0	-	-
	BCCD 16, SW2	Plum Creek at North Garfield Road	7/12/1990	-	-	-	-	-	18.6	-	-	-	-	-	-

TABLE 2 – TEST RESULTS COMPARISON (Continued)

Site #	Testing Organization	Site Name	Date	Air Temp C	Chloride (mg/L)	Dissolved oxygen (mg/L)	% Saturated Oxygen	Nitrate-Nitrogen NO_3-N (mg/L)	Nitrate NO_3^- (mg/L)	Phosphate PO_4^{3} (mg/L)	Phosphorus PO_4-P (mg/L)	pH	Water Temp (C)	Conductivity (µs)	Water Transparency (cm)
1L	TCWA 2020 Site 1L	Tulpehocken Creek at Halfway Drive	8/10/2020	31.3	40	7	76.5	2.0	8.8	0.11	0.04	8.35	19.7	570	-
	TCWA 2021 Site 1L	Tulpehocken Creek at Halfway Drive	8/4/2021	25.0	36	8.4	89.4	6.0	26.4	0.05	0.02	7.74	18.4	490	100
	USDA 1L, SW 20	Tulpehocken Creek at Halfway Drive	7/3/1991	21.7	-	10.3	108.3	8.5	37.4	< 0.50	< 0.17	8	17.8	-	-
	BCCD 1, SW 20	Tulpehocken Creek at Weavertown Rd	7/12/1990	-	-	-	-	-	18.7	-	-	-	-	-	-
2L	TCWA 2020 Site 2L	Owl Creek by East Main Street Bridge	8/6/2020	15.7	-	6.2	60.7	10.0	44.0	0.17	0.06	7.82	14.4	350	80
	TCWA 2020 Site 2L	Owl Creek by East Main Street Bridge	8/10/2020	31.2	-	-	-	3.0	13.2	0.06	0.02	8.2	22.5	635	-
	TCWA 2021 Site 2L	Owl Creek by East Main Street Bridge	8/4/2021	25.4	32	9	97.4	5.0	22.0	0.07	0.02	7.02	19.2	455	90
	USDA 2L, SW 20	Owl Creek by East Main Street Bridge	7/3/1991	22.2	-	6.4	75.0	9.0	39.6	0.75	0.24	8	23.3	670	40
3L	TCWA 2020 Site 3L	Trib to Mill Creek at 419 Bridge Millbach	8/3/2020	29.5	26	7	80.7	1.0	4.4	0.45	0.15	8.09	22.4	410	-
	TCWA 2021 Site 3L	Trib to Mill Creek at 419 Bridge Millbach	8/10/2021	33.0	60	7.2	89.7	6.0	26.4	0.44	0.14	8.3	26.6	430	50
	USDA 3L, SW 21	Trib to Mill Creek at 419 Bridge Millbach	7/9/1991	27.8	-	11	133.1	8.0	35.2	< 0.50	< 0.17	8.5	25.0	-	-
4L	TCWA 2020 Site 4L	Trib to Mill Creek at 419 Bridge Ft Zellers Rd	8/3/2020	29.8	24	7.5	79.0	0.5	2.2	0.00	0.00	7.9	17.9	300	-
	TCWA 2021 Site 4L	Trib to Mill Creek at 419 Bridge Ft Zellers Rd	8/10/2021	31.2	36	7.8	86.1	3.0	13.2	0.02	0.01	8.26	20.2	270	90
	USDA 4L, SW 21	Trib to Mill Creek at 419 Bridge Ft Zellers Rd	7/9/1991	29.4	-	9.4	108.0	3.0	13.2	0.50	0.16	8.5	22.2	-	-
5L	TCWA 2020 Site 5L	Mill Creek by Furnace Road	8/6/2020	17.4	-	8	75.6	10.0	44.0	0.21	0.07	7.81	12.8	355	84
	TCWA 2020 Site 5L	Mill Creek by Furnace Road	8/10/2020	31.8	-	-	-	2.0	8.8	0.07	0.02	8.28	21.4	590	-
	TCWA 2021 Site 5L	Mill Creek by Furnace Road	8/17/2021	25.2		7.2	78.2	6.0	6.0	0.09	0.03	8.6	19.4	410	115
	USDA 5L, SW 21	Mill Creek by Furnace Road	7/9/1991	25.0	-	9.2	99.9	7.0	30.8	0.50	0.16	8	19.4	-	-
6L	TCWA 2020 Site 6L	Tulpehocken Creek near Flanagan Road	8/23/2020	22.1	36	7.6	78.9	2.5	11.0	0.08	0.03	8.15	17.2	790	105
	TCWA 2021 Site 6L	Tulpehocken Creek near Flanagan Road	8/17/2021	25.5		6.6	71.6	8.0	35.2	0.03	0.01	8.8	19.3	560	
	USDA 6L, SW 24	Tulpehocken Creek near Flanagan Road	7/3/1991	24.4	-	9	94.4	10.0	44.0	0.50	0.16	8	17.7	-	-
7L	TCWA 2020 Site 7L	Trib to Tulpehocken at Elco Rd Bridge	8/3/2020	34	40	6	66.0	2.0	8.8	0.00	0.00	8.06	20	290	-
	TCWA 2021 Site 7L	Trib to Tulpehocken at Elco Rd Bridge	8/26/2021	35.0	44	7.6	87.7	10.0	44.0	0.05	0.02	7.99	22.5	570	-
	USDA 7L, SW 24	Trib to Tulpehocken at Elco Rd Bridge	7/9/1991	25.6	-	11.5	125.0	10.0	44.0	< 0.50	< 0.17	8	19.4	-	-
8L	TCWA 2020 Site 8L	Tulpehocken Creek near Reilly Road Bridge	8/22/2020	25.1	32	7.16	73.3	2.5	11.0	0.08	0.03	8.05	16.5	745	78
	TCWA 2021 Site 8L	Tulpehocken Creek near Reilly Road Bridge	8/4/2021	23.3	40	6.8	73.3	7.0	30.8	0.12	0.04	7.02	19.0	550	100
	USDA 8L, SW 24/20	Tulpehocken Creek near Reilly Road Bridge	7/3/1991	22.2	-	6.5	72.2	7.0	30.8	0.50	0.16	8	20.5	-	-
9L	TCWA 2020 Site 9L	Mill Creek Krumstown Rd Bridge	8/3/2020	34	35	7	77.6	1.7	7.5	0.10	0.03	8.17	20.4	490	-
	TCWA 2021 Site 9L	Mill Creek Krumstown Rd Bridge	8/26/2021	37.0	40	7.4	85.4	7.0	30.8	0.14	0.05	8.3	22.5	540	15
	USDA 9L, SW 21	Mill Creek Krumstown Rd Bridge	7/9/1991	26.7	-	11.8	142.8	10.0	44.0	0.50	0.16	9	25.0	-	-

WATER QUALITY SUMMATION for Chemical Tests

	Excellent	Good	Fair	Poor
Dissolved Oxygen (% Saturation)	80-120	70-80 120-140	50-70 >140	<50
pH (units)	7.0-7.5	6.5-7.0 7.5-8.5	5.5-6.5 8.5-9.0	<5.5 >9.0
Chloride (Cl) (mg/L)	0-20	20-50	50-250	>250
Reactive Phosphate (PO_4X^3) (mg/L)	0-0.2	0.2-0.5	0.5-2.0	>2.0
Nitrate (NO_3) (mg/L)	0-3	3-5	5-10	>10
Transparency (cm)	>65.0	65.0-35.0	35.0-15.5	<15.5

Excellent
Good
Fair
Poor

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