



AQUETONG CREEK ECOLOGICALLY BASED WATER QUALITY MONITORING- 2024

SOLEBURY TOWNSHIP, BUCKS COUNTY, PA

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INTRODUCTION

The Aquetong Creek restoration site is located in Solebury Township, Bucks County, PA, at the location of the former Aquetong Lake. Aquetong Lake was a 15-acre impoundment formed in 1870 by the construction of an earthen dam on Aquetong Creek. The main source of Aquetong Creek is Ingham Spring, an artesian spring formed at the contact of two geologic formations that flows at a rate of approximately 2,000 gallons per minute (GPM) (F.X. Browne, Inc., 2004). Aquetong Creek flows approximately 2.5 miles from Ingham Spring to its mouth at the Delaware River in New Hope, PA.

A 2004 study funded by Bucks County Trout Unlimited found that the impoundment was affecting downstream water quality, particularly water temperature (F.X. Browne, Inc., 2004). In 2015, the dam was breached with the goal of reducing thermal impacts on the creek and supporting a high-quality cold-water fishery in Aquetong Creek, while also avoiding the need for continued dam maintenance. With the dam breached and the lake drained, a meandering channel formed through the exposed former lakebed, connecting the upper and lower reaches of Aquetong Creek. Additionally, a small tributary flowing from the north under Route 202 now joins Aquetong Creek in the approximate center of the formerly impounded area.

In 2017 and 2018, Princeton Hydro conducted several monitoring events focusing on the downstream area closer to the dam breach, as well as upstream to the Ingham Spring and also within the northern tributary passing under Route 202. This monitoring concluded that conditions within the former lakebed were partially conducive to maintaining a brook trout (*Salvelinus fontinalis*) population as it pertains to temperature, dissolved oxygen, and available forage. However, the physical habitat still needed additional restoration to further increase the stability of streambanks and create more refuge habitat for trout. Another survey was conducted in 2019 focusing on the areas downstream of the breach to assess impacts of the removal of several ash trees within the park, and further surveys focusing on the original study area were conducted in the fall of 2020 and the growing seasons of 2021-2023.

In 2024, Princeton Hydro again conducted a survey of the ecological condition of the six (6) main sites within the study area. In addition, at the request of the Aquetong Watershed Association, two (2) sites outside of the initial study area previously monitored by the PADEP were also sampled. This extended survey was repeated in 2024. The overall goal of the 2024 study was to continue to assess current water quality conditions, fish, and benthic invertebrate communities within the project site. Comparisons were also made between the 2024 data and data collected in previous years (where they apply) in order to assess any longitudinal changes occurring in the stream over time.

METHODS

As in previous years, six (6) points within the old lakebed and in areas downstream were sampled for water quality three (3) times in 2024 (Figure 1). A survey of the stream's macroinvertebrate and fisheries communities at each site was conducted on October 29th, 30th and November 1st. The downstream-most of these points is located near the eastern property line, while an additional site (ST1) is located approximately 450' downstream of the dam breach. ST2 is sited at the dam breach. ST2, ST3, and ST5 are all located along the mainstem of the Aquetong, while ST4 is located on a small tributary that enters the mainstem from the direction of Rt. 202. As in 2022 and 2023, two (2) additional sites outside of the Aquetong Park were also sampled in 2024. These are located near sites that have been previously sampled by the Pennsylvania Department of Environmental Protection (PADEP). One of these sites is located approximately 0.5 miles downstream of the dam breach and approximately 225 m downstream of Reeder Road (AW1). The other site is located along a northern branch of the Aquetong Creek at a reach that runs parallel to Creekside Drive (AW2). A map of locations is provided in Figure 1.



IN-SITU AND STREAMFLOW DATA COLLECTION

At each location, Princeton Hydro scientists collected *in-situ* water quality data using an *In-situ* Aquatroll 500 calibrated multimeter water quality probe. This probe measured the following analytes:

- Temperature (°C)
- Dissolved Oxygen (concentration as mg/L and percent saturation as %)
- Specific Conductivity ($\mu\text{S}/\text{cm}$)
- pH (standard units)

Additionally, water velocity data was collected at several points along a cross-section at each station using a Marsh-McBirney, Inc. Flo-Mate™ Model 2000 Portable digital flowmeter and a wading rod. Total streamflow was calculated using water velocity, depth, and distance along the cross section collected at each point.

DISCRETE WATER QUALITY DATA COLLECTION

On each water quality sampling date, whole water samples were collected at each station and analyzed for the following:

- Total Phosphorus
- Total Nitrogen
- Total Suspended Solids

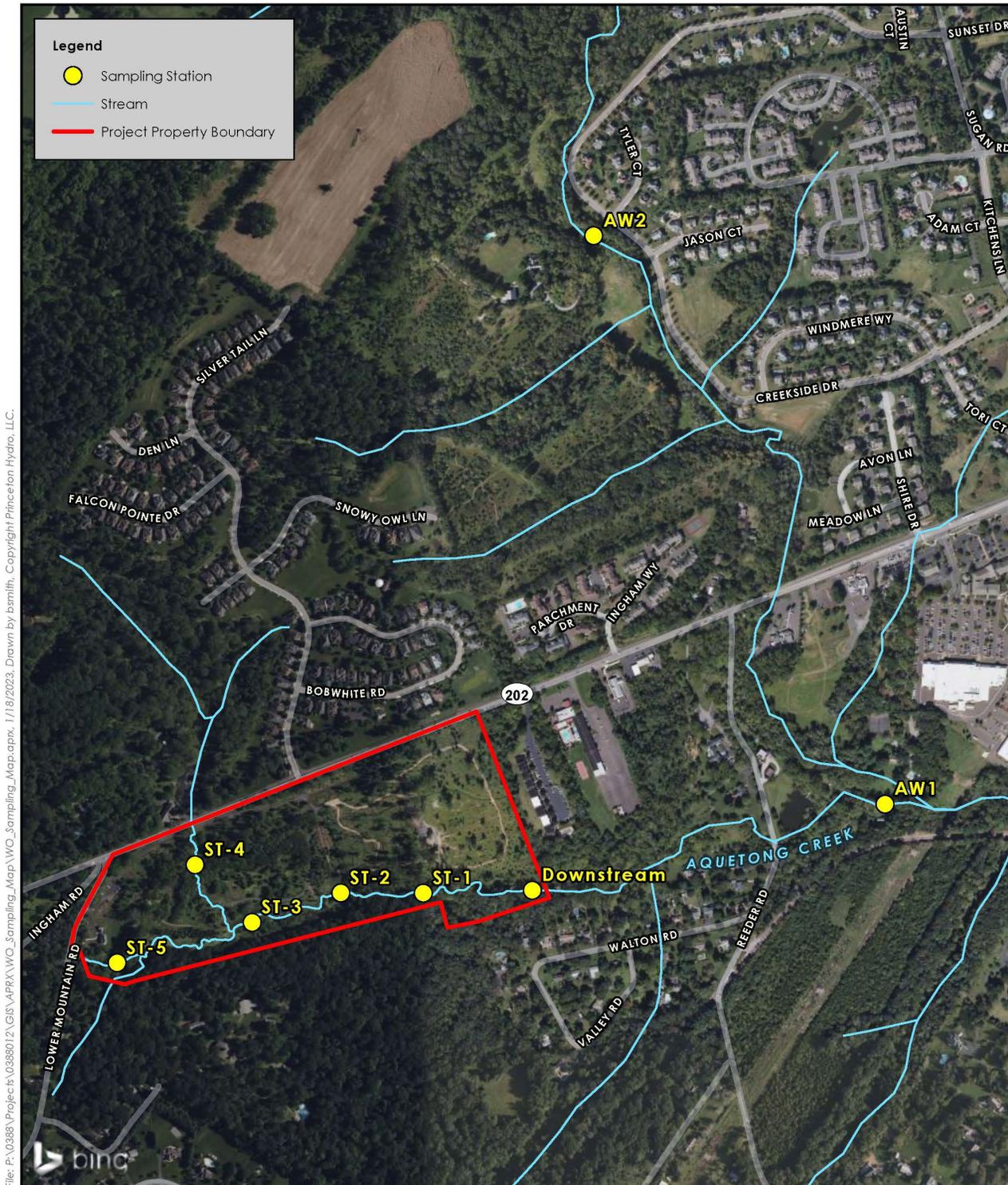
Following each sampling event, samples were delivered to Environmental Compliance Monitoring (ECM), a certified laboratory, for analysis.

FISHERIES SURVEY

A survey of the fish communities at each site was conducted in late October and early November 2024 using the backpack electrofishing method. During each sampling event, seine nets were placed in the upstream and downstream ends of the reach to prevent fish from moving into and out of the area to be sampled. The length of each reach was sampled multiple times, beginning at the downstream end of the reach. Captured fish were kept in a temporary holding vessel. After each electrofishing pass the fish were either immediately processed and released outside the sampling area or pooled for the three runs and subsequently processed and released to avoid recapture in the surveyed segment. All captured fish were identified to species, measured for total length, and returned to the stream immediately following measurement. Additionally, all brook trout were weighed using a small digital scale to obtain their approximate mass. The resulting data was analyzed for composition, catch per unit effort, Shannon's diversity, and evenness.

BENTHIC MACROINVERTEBRATE SAMPLING

During the October/November sampling event, the benthic macroinvertebrate community was sampled at each station using a D-net. Ten kicks or jabs were collected per station in various microhabitat types (e.g. riffles, coarse woody debris, aquatic vegetation) and compiled into a single sample. This sample was preserved with alcohol and analyzed in Princeton Hydro's in-house laboratory. A subsample of at least 50 organisms was picked from each sample, and each organism was identified to lowest practical taxon (typically family). The resulting data was used to calculate metrics such as %EPT, richness, diversity, and the family-level biotic index.



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NOTES:
 1. Stream sampling locations are approximate.
 2. Property boundary is approximate.
 3. Streams obtained from the Pennsylvania Spatial Data Access (PASDA) website: <http://www.pasda.psu.edu/>
 4. Aerial imagery obtained through ArcGIS Online Bing Maps (C) 2021 Microsoft Corporation and its data suppliers.

Map Projection: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet

FIGURE 1: ECOLOGICAL SURVEY SAMPLING STATIONS
 AQUETONG CREEK RESTORATION PROJECT
 AQUETONG SPRING PARK
 SOLEBURY TOWNSHIP
 BUCKS COUNTY, PENNSYLVANIA





RESULTS

GENERAL OBSERVATIONS

Significant physical changes to the Aquetong Creek's morphology were generally not observed in 2024. Usually, such changes occur following an extreme weather event, such as a hurricane, that increases flows to such a high velocity that they erode banks, changing the morphology of the stream channel. This can also occur when large woody debris (larger trees) falls into the stream and create changes to physical flow. Areas within the park boundaries remained relatively consistent in regard to channel morphology with observations made in 2023. As noted in past years, areas of fine sediment deposits are still present, such as in the inside of bends where water velocity slows. A point of note made by Princeton Hydro staff in 2024, however, is the gradual evolution of the area downstream of ST5, which has featured a considerable drop in grade (over 3') in the past several years. Due to the high flows that cascade from this height, the pool beneath this drop has become remarkably deep. As noted in past years, this drop likely serves as a barrier to upstream movement for Brook Trout and other fish.

Also of particular note was the period of dry weather in Solebury during the late summer/early fall period of 2024. While much of the main channel of the Aquetong Creek was apparently unaffected by this due to spring flow, aside from lower measured discharges, the tributary reaches ST4 and AW2 both experienced notably lower flows than in past years. ST4, while still visibly featuring flow, featured velocities low enough that measurements using a flow meter could not be taken effectively and accurately. AW2 also featured visibly lower flows, and was observed during the fall 2024 event to feature a buildup of leaves and other organic debris, as well as growths of benthic algae in a pool at the bottom of the reach that were observed to be more dense than they were in previous years. These conditions reduced visibility and notably impacted fish sampling. The fish and aquatic macroinvertebrate populations in this reach were also likely impacted by this overall decrease in discharge, as will be further explained below.

IN-SITU AND FLOW DATA

Aquetong Creek has continued to exhibit stable, cold temperatures over the three monitoring events in the mainstem stations. Consistent with previous years, average temperatures varied by less than 1.0 °C. ST-4, a tributary to the creek, is a notable exception to the consistent temperatures of the main stem. Temperatures at ST-4 ranged from 26.58 °C in July to 15.45 °C during the 2024 fall events. The higher temperatures are largely attributable to the upstream impoundment, north of RT. 202, which feeds the tributary. The two newer sampling stations (AW-1 and AW-2) also typically feature temperatures that differed from the initial study area. AW-1 saw temperatures ranging from 12.09 °C in April to 17.88 °C in July, and AW-2 had a minimum temperature of 10.77 °C in the Fall and a maximum temperature of 26.81 °C in July. The increased temperatures at AW-2 are likely due to the Honey Hollow Pond impoundment that releases stagnant water into the stream.

Dissolved oxygen concentrations in the mainstem stations were similarly consistent and well within a preferable range, fluctuating between 9.72-10.93 mg/L during the 2024 season. ST-4 had a wider range in DO with concentrations between 6.76 mg/L in July and 13.88 mg/L in April. AW-1's dissolved oxygen concentrations were similar to those measured in the mainstem upstream in the Aquetong Park, ranging from 8.61-10.26 mg/L. AW2 featured a wider range of dissolved oxygen, ranging from 6.52 mg/L in July to 10.72 mg/L in April. The consistent temperatures and dissolved oxygen concentrations that stayed within the preferred range in the park's boundaries are largely due to the groundwater input from the spring in the park. This along with strong flows allow for good mixing in the stream throughout the park. These measurements are largely consistent with temperature and dissolved oxygen measurements collected in previous surveys.

The mainstem's specific conductivity (SpC) within the Aquetong park was, on average, 424.41 µS/cm in April, increasing slightly to 434.03 µS/cm in July and decreasing again to 426.36 µS/cm in October. These



concentrations are consistent with levels seen in previous years. Conductivity values are reflective of the watershed and are heavily affected by its geology. Aquetong Park's watershed and the Aquetong Spring's geology are mostly limestone, resulting in a slightly elevated baseline conductivity. As in past years, ST-4 featured slightly higher conductivity values, with a 2024 average of 459.84 $\mu\text{S}/\text{cm}$. These higher values likely reflect the denser development in that tributary's sub watershed. AW-2 had the largest range of conductivity values, from a minimum of 232.87 $\mu\text{S}/\text{cm}$ in April to a maximum of 464.82 $\mu\text{S}/\text{cm}$ in October.

Following the trend from previous years, pH values in the Aquetong Creek ran slightly basic during the 2024 monitoring season. pH values in April averaged 8.01, 8.00 in July and 8.03 in October. These alkaline values are likely due to local limestone geology and the stream's origin at Ingham Spring. To a lesser extent, higher pH values may be due to abundant plant life along the stream, as photosynthesis increases pH values. Unlike previous years, ST-4 had an average pH of 8.01, ending its trend of increased values. AW-1 and AW-2 had the highest pH values, averaging 8.17 and 8.15 respectively.

Figures displaying long-term In-situ data for Aquetong Creek are provided in Appendix (I).

Table 1: Aquetong Creek In-Situ Data 2024

Date	Station	Temperature °C	SpC $\mu\text{S}/\text{cm}$	DO mg/L	DO %	pH s.u.	Flow CFS
4/24/2024	AW1	12.09	380.2	10.06	94.0	8.15	18.58
	AW2	13.94	232.9	10.72	104.7	8.27	6.20
	Downstream	12.20	424.3	10.93	102.6	8.16	9.28
	ST1	12.39	426.0	10.88	102.7	8.18	8.81
	ST2	12.57	422.6	10.83	102.4	8.21	8.61
	ST3	12.23	425.0	10.58	99.6	8.03	8.67
	ST4	18.12	377.4	13.88	149.2	7.88	0.43
	ST5	11.44	424.1	9.72	89.7	7.81	9.22
	Spring	15.45	403.1	7.16	71.1	7.93	-
7/18/2024	AW1	17.88	410.5	8.61	91.1	8.01	7.00
	AW2	26.81	412.4	6.52		7.98	2.36
	Downstream	12.95	431.7	10.74	103.0	8.16	5.12
	ST1	12.85	432.9	10.85	103.0	8.12	5.30
	ST2	12.75	432.2	10.83	102.9	8.06	4.96
	ST3	12.03	435.9	10.66	99.7	7.96	5.05
	ST4	26.58	482.2	6.76	85.7	8.33	0.00*
	ST5	11.53	437.4	9.96	92.2	7.68	4.55
	Spring	13.21	425.6	7.51	71.6	7.57	-
10/29/2024, 10/30/2024, 11/1/2024	AW1	12.34	424.3	10.26	95.1	8.34	3.26
	AW2	10.77	464.8	9.35	84.2	8.20	0.27
	Downstream	11.53	426.6	10.85	98.5	8.16	4.00
	ST1	11.97	427.5	10.87	99.8	8.12	4.27
	ST2	12.59	426.9	10.59	99.1	7.93	3.82
	ST3	12.16	424.1	10.31	96.7	8.00	4.05
	ST4	15.45	519.9	9.33	92.6	7.81	0.00*
	ST5	11.74	426.7	9.83	90.9	7.92	3.60
	Spring	12.74	405.2	85.63	405.2	7.71	-

*ST4 featured flows in Summer and Autumn of 2024 too low to properly sample using usual methods



The mainstem of the Aquetong Creek is characterized by consistent and swift flows. Unlike previous years, the discharge of the creek fluctuated over the 2024 monitoring season. The creeks discharge was highest during the April event, and decreased for the remaining two events, which is expected with seasonal precipitation. Average discharge of the mainstem of Aquetong creek was 8.92 CFS in April, 5.00 CFS in July, and 3.95 CFS in October. The highest amount of discharge seen during the April and July event was at AW-1, at 18.58 and 7.00 CFS. ST-1 had the most discharge during the October event, at 4.27 CFS. ST-4 consistently featured the smallest discharge. During the Summer and Fall events, flows, while visible, were so low that discharge could not be measured accurately via flowmeter. Many flow readings that were obtained this way yielded negative values. This would normally occur in an eddy, such that found behind a large rock or similar feature in a stream. In ST-4, This may be due to a difference in flow at certain depths. The significantly lower flow out of that station is due to its origin of a dammed pond with a controlled discharge.

AW-1 had variable flows throughout the width of the channel but had relatively consistent water depth. AW-2 had very consistent depth across its width, but had more variation in its flow rates, both in the channel, and from one monitoring event to another. The downstream station featured notable variation in water depth between events, but had consistent, swift water velocity. ST-1 had moderate depth and velocity across the channel. ST-2 was consistently the deepest station, but did not have significantly fast water velocity. ST-4 is the most narrow and slowest flowing reach of those assessed.

COMPARISON TO WATER QUALITY CRITERIA

The collected data was also compared to the specific water quality criteria outlined in 25 Pa. Code § 93.7 where applicable. Of the various metrics described during this study, only three have directly comparable analogs in the technical regulations, including temperature, DO, and pH. The criteria and narratives provided below are applicable to Cold Water Fisheries (CWF).

Temperature: Maximum temperatures in the receiving water body resulting from heated waste sources regulated under Chapters 92a, 96 and other sources where temperature limits are necessary to protect designated and existing use.

Table 2. Maximum temperature standards for Pennsylvania streams during several critical use periods. From 25 Pa. Code § 93.7

Critical Use Period	°F
January 1-31	38
February 1-29	38
March 1-31	42
April 1-15	48
April 16-30	52
May 1-15	54
May 16-31	58
June 1-15	60
June 16-30	64
July 1-31	66
August 1-15	66
August 16-30	66
September 1-15	64
September 16-30	60
October 1-15	54
October 16-31	50
November 1-15	46
November 16-30	42
December 1-31	40



Dissolved Oxygen: For flowing waters, 7-day average 6.0 mg/L; minimum 5.0 mg/L. For naturally reproducing salmonid early life stages, 7-day average 9.0 mg/L; minimum 8.0 mg/L. Early life stage criteria applies from October 1 to May 31.

pH: From 6.0 to 9.0 inclusive.

In general, most of the sites stayed within PADEP compliance for applicable criteria. Starting with the temperature for CWF it is interesting to note that the standard has dual purposes, sustaining trout populations as well as protecting the temperature regime from heated discharges. The criteria are divided into discrete critical use periods throughout the year recognizing the expected seasonal changes in temperature.

During the April 2024 event, all stations exceeded the maximum temperature criteria for CWF, which is listed as 52°F (11.1°C) for the second two weeks of April. While most reaches did not exceed this by greater than 3°F, The temperatures at ST4 and AW2, however, did exhibit higher exceedances in temperature than the other reaches, likely due to their origins outside of the spring-fed mainstem. By 18 July, all mainstem stations featured temperatures well below the maximum temperature criteria for CWF of 66°F (18.88°C), with AW2 and ST4 again exceeding this.

The Fall events took place across two critical use periods. Most of the stations were sampled within the October 16-31 critical use period, while stations ST3 and ST5 were sampled within the November 1-15 critical use period. During this time period, all stations again exceeded the maximum temperature criteria for CWF. It should be noted that, within the mainstem stations, water temperatures are remarkably consistent throughout an average year. As such, during the colder periods of the year the water in these reaches may be warmer than the air, and will likely exceed the maximum temperature criteria for cold water fisheries. The impact this may have on Aquetong Creek brook trout populations, if any, is not well understood.

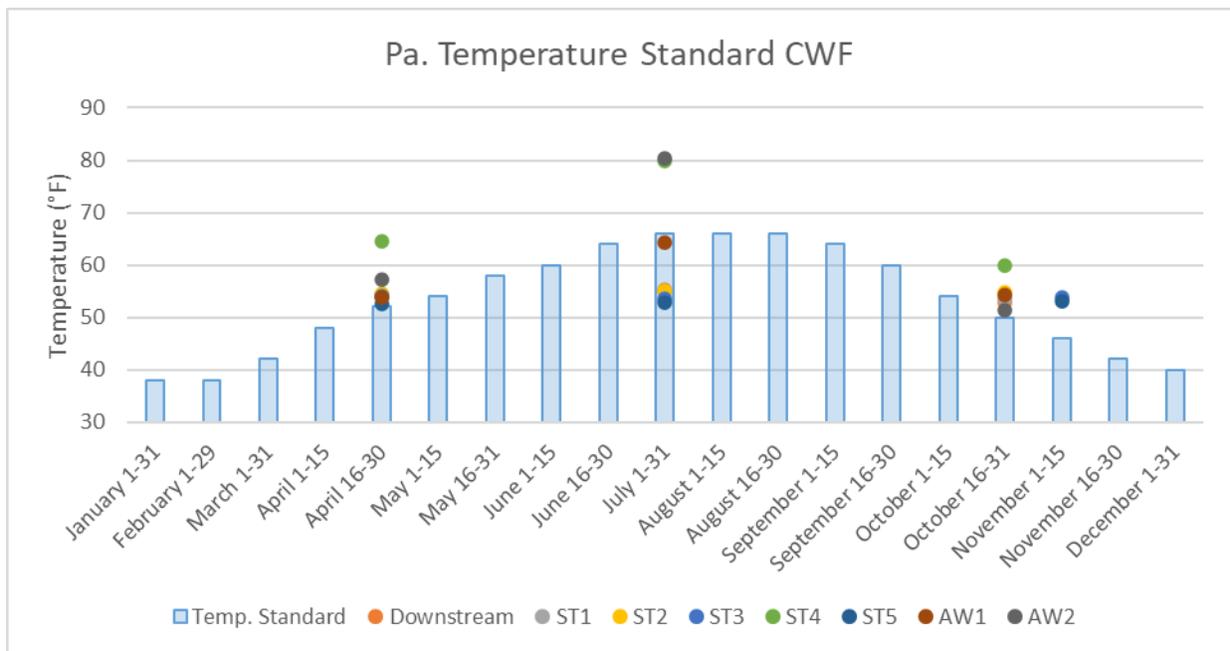


Figure 2: 2024 Water temperature data collected in Aquetong Creek compared to the Pennsylvania water temperature standard for CWF.



The DO criteria specify average and minimum values, with the objective of maintaining higher concentrations. Because young-of-year trout have been discovered onsite in past years, the criteria for early life stage (ELS) salmonids were explored in addition to the CWF criteria (Figure 3).

In May all of the sites satisfied all criteria even for ELS trout which need more oxygen than larger fish. Consistently cool stream temperatures and energetic flow help maintain high DO concentrations throughout the year. These flow patterns allow ripples to add oxygen to the stream throughout the sampled stretch. Throughout the season, all stations remained above both the 7-day and minimum criteria for adult cold-water fish. In July, however, ST4 and AW2 did not meet the 7-day or minimum criteria for earlier life-stage trout. AW1 met the minimum oxygen criteria for early life-stage trout during this event, but not the 7-day criteria. By the fall sampling event, all stations again exceeded all criteria. In most cases, failures to meet criteria were likely due to the positioning of the locations and the stream topography in those areas.

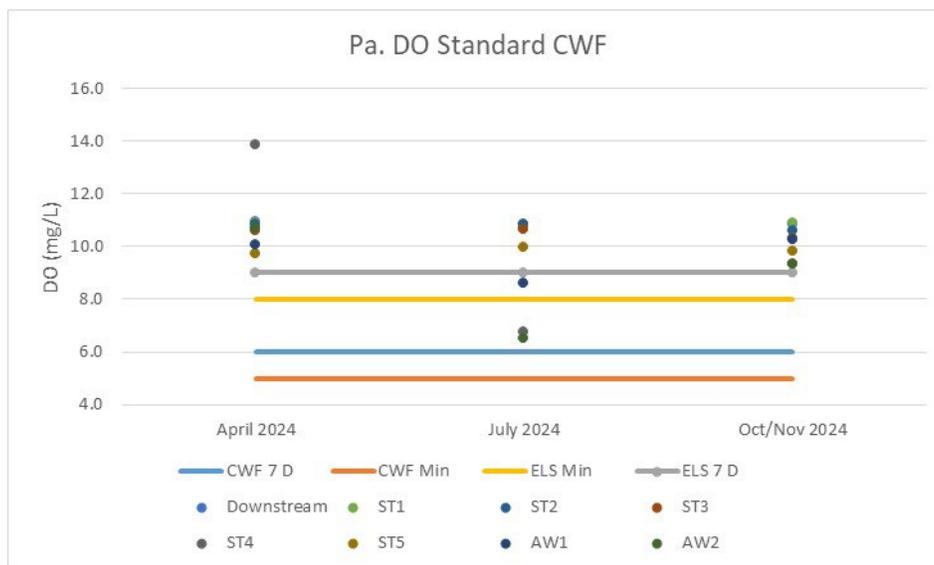


Figure 3: 2024 Dissolved oxygen data collected in Aquetong Creek compared to the Pennsylvania dissolved oxygen standards for CWF and ELS.

Lastly, pH was satisfied at all times at all stations and stayed with the limits of 6.0 to 9.0.

DISCRETE WATER QUALITY DATA COLLECTION

Nutrients such as nitrogen and phosphorus influence growth of primary producers such as plants and algae, including periphyton and often indicate other organic pollutants. Total suspended solids are a measurement of sediment or other particulates. Phosphorus, an important nutrient for plant and algae life, was typically measured in relatively low amounts in the mainstem stations within the park, although some higher concentrations were measured occasionally (Table 3).

ST-4 had the highest level of phosphorous throughout the 2024 season with concentrations of 0.04 mg/L and 0.18 mg/L in April and July (Table 3). This spike may have been caused by a small precipitation event that occurred the day previous to the sampling event, which may have caused large amounts of nutrients from the impoundment to enter the reach. Phosphorus levels dropped again moving into the fall event, not exceeding 0.03 mg/L at any station during that event. During the April event, the average level of phosphorous was 0.02 mg/L, below recommended thresholds. Increasing slightly into July, the average phosphorous level was 0.05



mg/L, still relatively low. Levels dropped again moving into the fall monitoring event, with an average of 0.02 mg/L.

Similar to previous years, levels of total nitrogen were elevated in Aquetong creek, ranging from 2.6 mg/L to 3.3 mg/L in the mainstem stations. AW2 typically featured overall lower concentrations of nitrogen, while ST4 featured a wider range, with a seasonal high of 4.1 mg/L detected in the 18 July sample. Consistently high nitrogen concentrations can be expected in the mainstem stations where groundwater dominates flow, as groundwater typically contains higher concentrations of nitrogen than surface waters.

Total suspended solids (TSS) concentrations varied between monitoring events, but only exceed the recommended threshold of 25 mg/L twice. During the April event, levels of TSS were largely below the detection limit of 2 mg/L, with the exception of ST-4, where concentrations reached 8 mg/L. Levels increased during the July event, with ST-4 and AW-2 reaching 26 mg/L and 32 mg/L respectively. Concentrations above 25 mg/L can contribute to decrease water clarity and a 'muddy' appearance. Levels remained below 5 mg/L at all other stations during the July event. The Autumn event saw slightly higher overall levels, varying between 3 mg/L and 12 mg/L. ST-5 and AW-1 had levels below the detection limit (<2 mg/L) at this time.

Table 3: Aquetong Creek Discrete Water Quality 2024

Date	Station	TN mg/L	TP mg/L	TSS mg/L
4/24/2024	Downstream	2.8	0.02	ND <2
	1	2.8	0.02	ND <2
	2	2.8	0.02	ND <2
	3	2.8	0.02	ND <2
	4	0.7	0.04	8
	5	3.3	0.01	ND <2
	AW-1	2.1	0.02	ND <2
	AW-2	1.7	0.03	ND <2
7/18/2024	Downstream	3.0	0.02	5
	1	3.1	0.02	2
	2	3.3	0.02	2
	3	3.3	0.02	2
	4	4.1	0.18	26
	5	3.1	0.02	ND <2
	AW-1	2.3	0.04	3
	AW-2	1.4	0.05	32
10/29/24, 10/30/24, 11/1/24	Downstream	2.8	0.01	5
	1	2.6	0.02	6
	2	2.8	0.01	7
	3	2.7	0.01	3
	4	0.2	0.03	12
	5	3.0	0.02	ND <2
	AW-1	2.8	0.02	ND <2
	AW-2	0.2	0.03	6

"ND" = Not detected at or above minimum detection limit



FISHERIES SURVEY

The fisheries community sampled in the fall of 2024 was marked by a significant decrease in brook trout numbers from 2023. In total, 260 fish were sampled between the eight (8) reaches of the stream, with 11 species being recorded. Stations ST-4 and AW-1 had the highest number of fish, at 79 and 129 respectively. Blacknose dace (*Rhinichthys atratulus*) were the most abundant fish collected, with a large majority of these being collected in AW-1. Pumpkinseed (*Lepomis gibbosus*) were also abundant, with 71 of 72 individuals recorded coming from ST-4. The stations with the lowest fish abundance were ST-1, ST-5 and the downstream station, each only producing a single fish.

Shannon's diversity index, a measure of the general species diversity of a system, was calculated to be 1.19 for ST-1 through ST-5. This is a slight decrease from 2023, where the diversity index was calculated as 1.32, itself a decrease from the 2022 values. ST3 had the highest diversity index of 1.37, with ST-2 also featuring a relatively high diversity index of 1.28. ST-2 and ST-3 saw the highest number of brook trout, with three (3) individuals collected at each station.

As in past years, it should be noted that a majority of the fish sampled at ST4 were caught in the plunge pool immediately below Rt. 202. In 2024, most of the fish captured were pumpkin seeds, with small numbers of Creek Chubs (*Semotilus atromaculatus*) and Largemouth bass (*Micropterus salmoides*) also caught. Most of the fish in the pool most likely have migrated from the pond on the other side of Rt. 202. This may also be a point of origin for some sunfish obtained at reaches further downstream, although this cannot be confirmed. It also suggests that this feature is a barrier to upstream migration for most if not all fish in this reach.

Lengths and masses of all captured brook trout are provided in Table 4. In 2024, 7 brook trout were sampled in the reaches of Aquetong Spring Park, a significant decrease from the 43 individuals sampled in 2023. This year's sampling contained a disproportionate number of mature fish compared to young-of-the-year, of which there was only one (1). The average length of brook trout was 216.5 mm, and had an average weight of 159.3 g. These values are significantly higher than last year, likely due to the lack of young fish. One of the fish sampled is categorized as young-of-the-year based on its length of 130 mm. Lack of young fish suggests that brook trout spawning was relatively unsuccessful during the spawning season of 2023. The two largest fish, both measuring 330 mm, were found in the ST-2 reach, suggesting that food and habitat are available to support larger, older fish.

Brook trout were weighed using a small digital scale to obtain their mass in grams. A length-to-mass regression is provided in Figure 3. Note that this regression may not be as accurate as in past years due to the low amount of brook trout sampled. In total, brook trout biomass was measured to be approximately 1,115 g or 2.46 lbs. Using the combined area of ST-1 through ST-5 and the downstream station, it correlates to approximately 21.09 lbs/acre of trout biomass. This is a slight decrease from 2023, which yielded 21.5 lbs/acre. This fulfills conditions listed by the PFBC for Class B wild brook trout streams (total wild trout biomass of over 17.8 lbs/acre). The similarity between the two years in regard to brook trout biomass per unit area is interesting, as while 2024 yielded lower amounts of fish, they were overall larger, with an average mass of 159.3 g. The brook trout population in 2023 yielded a much larger number of fish, however many of these were smaller, with an average mass of approximately 71.9 g.

It should be noted that additional brook trout observations were made outside of the electrofishing passes in the listed reaches. A single individual of 280 mm and 190 g in mass was collected in a pool between ST1 and the footbridge downstream. Additionally, though not captured, a large individual was observed in the plunge pool downstream of ST5. This individual was estimated to be approximately 280 mm in length and 223 g in mass. Lastly, digital underwater camera filming collected an observation of a single individual less than 100 mm in length in this same plunge pool several weeks prior to the fisheries survey. This is one of the few observations of an



apparently young-of-the-year (YOY) fish from 2024. It should be noted that these additional observations were not utilized in fisheries metrics.

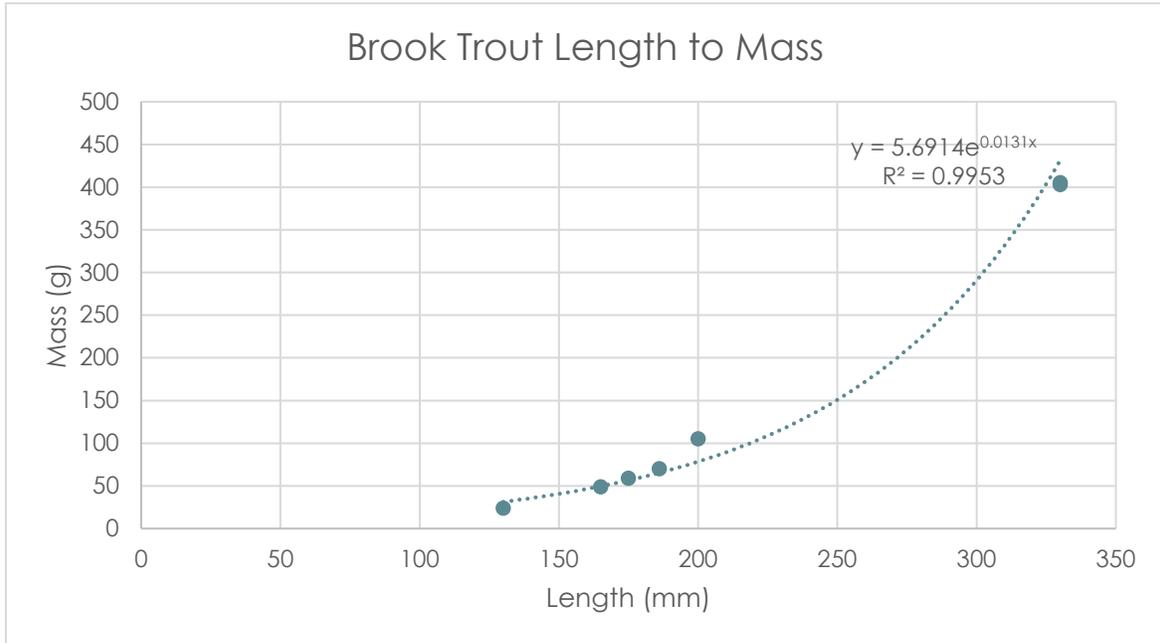


Figure 3: Length-to-mass regression for Brook Trout 2024

Table 4: Weights and Masses of brook trout sampled in 2024

Reach	Length (mm)	Mass (g)
ST2	330	403
ST2	330	405
ST2	130	24
ST3	175	59
ST3	165	49
ST3	200	105
ST5	186	70



Table 5: All Fish Sampled in Aquetong Creek 2024

Common Name	Downstream	ST-1	ST-2	ST-3	ST-4	ST-5	AW-1	AW-2	Total	Relative Abundance (fish/acre)
Black Nose Dase	1	1	7	5			80	1	95	449.55
White Sucker							20	1	21	99.37
Tessalated Darter							25	2	27	127.77
Banded Killifish								15	15	70.98
Largemouth Bass			2		3			1	6	28.39
Brook Trout			3	3		1			7	33.12
Green Sunfish				1					1	4.73
Pumpkinseed				1	71				72	340.71
Creek Chub					3				3	14.20
American Eel			6	1	2		4		13	61.52
Total Abundance	1	1	18	11	79	1	129	20	260	1230.34
Richness (# Taxa)	1	1	5	5	4	1	5	5	12	
CPUE (fish/pass)	0.5	0.5	6.00	3.67	39.5	0.33	43.00	6.67	12.38	
Shannon's Diversity	0.00	0.00	1.2763	1.367	0.437	0.00	1.01102	0.895	1.987	
Evenness	-	-	0.442	0.570	0.100	-	0.208	0.299	0.357	

BENTHIC MACROINVERTEBRATE SURVEY

Consistent with previous years, the mainstem reaches of Aquetong Creek were dominated by amphipods ("scuds" or "side swimmers"; order Amphipoda, family Gammaridae). Scuds tend to be common and dominate in limestone stream systems. ST-4 was dominated by Ostrocooda, also known as seed shrimp for their very small size. Ostrocooda is a very diverse family, can be found in essentially every aquatic habitat. Mayflies (order Ephemeroptera, family Baetidae) are more sensitive to pollution than other species and were abundant at AW-1. Non-biting midges (order Diptera, family Chironomidae) dominated AW-2. Chironomidae is a common and very diverse family that are able to withstand lesser water quality conditions, likely contributing to their large range.

Table 6: Benthic Macroinvertebrate Data 2024

Station	Density per ft ²	Taxa Richness	Dominant Taxa	Shannon's Diversity	Evenness	% EPT Taxa	Family Biotic Index
Downstream	522	13	Amphipoda, Gammaridae (Scuds)	1.49	0.60	35.17	4.11
ST-1	194.4	8	Amphipoda, Gammaridae (Scuds)	1.22	0.59	26.54	4.04
ST-2	204	9	Amphipoda, Gammaridae (Scuds)	1.22	0.56	17.06	4.35
ST-3	403.2	11	Amphipoda, Gammaridae (Scuds)	1.03	0.43	19.64	4.01
ST-4	105.6	13	Ostrocooda, All (Seed Shrimp)	2.13	0.86	0.00	5.92
ST-5	190.8	9	Amphipoda, Gammaridae (Scuds)	0.88	0.40	5.03	4.21
AW-1	218.4	13	Ephemeroptera, Baetidae (Mayflies)	1.88	0.73	68.13	3.81
AW-2	258	16	Diptera, Chironomidae (Non-biting Midges)	1.55	0.56	10.23	4.81

Table 6, and Figures 4-6 display metrics pertaining to the benthic macroinvertebrates collected at each site. Note that these are calculated from the subsample collected for each sample. Using Hilsonhoff's family-level biotic index, sites that were sampled during this survey measured in the "fairly poor", "good" and "very good" categories. Percentages of EPT taxa (Ephemeroptera - mayflies, Plecoptera - stoneflies, and Tricoptera - caddisflies), a group of relatively sensitive taxa, were also calculated in order to assess ecological function of the



stream and its ability to provide habitat to these sensitive taxa. An increase in % EPT taxa over time may suggest an overall increase in ecological function and habitat quality. ST-4 had the highest family biotic index value, at 5.92, placing it in the “fairly poor” category. Shannon’s diversity index was also calculated at 2.13, the highest of any sampling station. This suggests that while ST-4 had the highest level of diversity among the stations, the taxa present are more tolerant to organic pollutants. ST-4 also had 0.00% EPT, with no organisms from those orders being detected in the sample. This reflects the quality of the habitat there, which saw warmer temperatures, high levels of TP and elevated values of TSS. AW-2 and ST-2, with family biotic index values of 3.81 and 4.35 respectively, both fell in the “good” category. All other sites (Downstream, ST-1, ST-3, ST-5 and AW-1) all fell within the “very good” category, with family biotic index values between 3.81 and 4.21. AW-1 had the lowest family biotic index score (3.81), and had a diversity score of 1.88. This site also had the highest percentage of EPT taxa, at 68%, due to the significant number of mayflies identified in the sample. This indicates very good quality habitat, and minimal organic pollution present at that site.

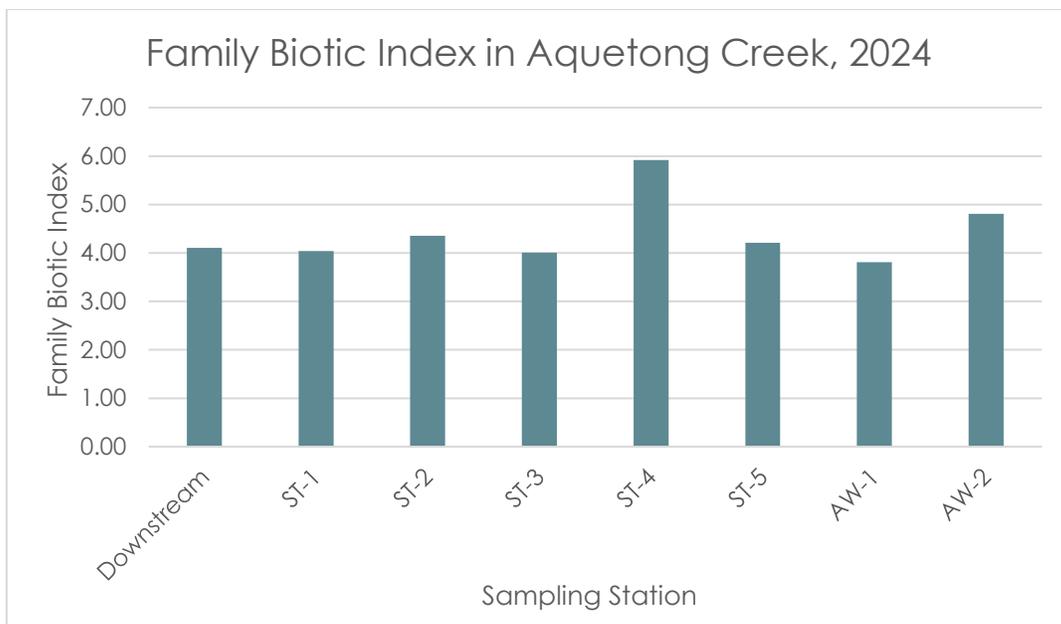


Figure 4: Hilsenhoff’s Family Biotic Indices for Aquetong Creek

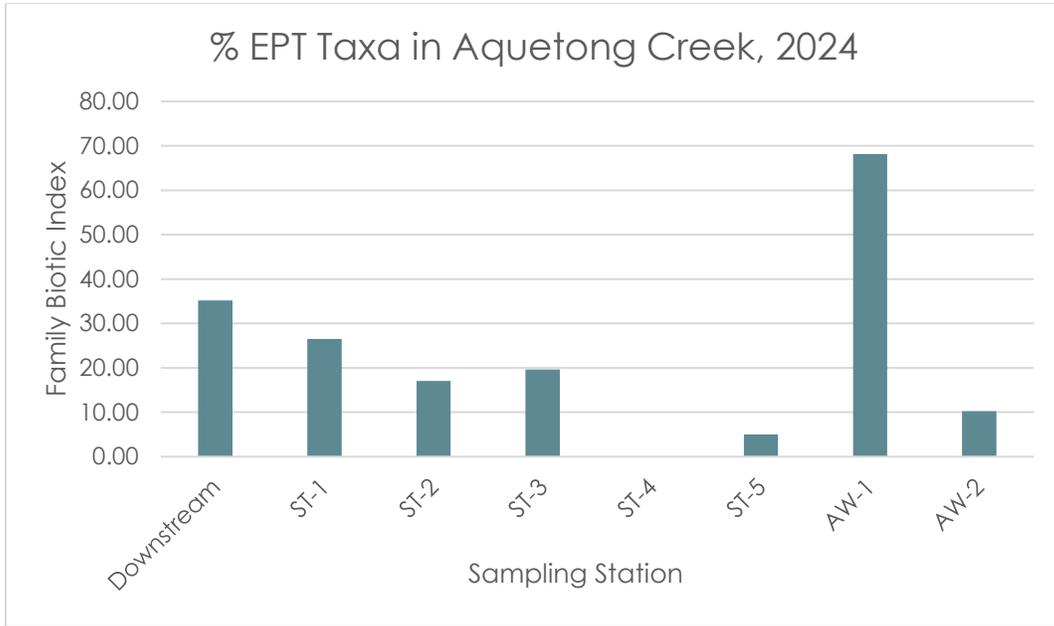


Figure 5: Percentage of samples comprising individuals from the orders Ephemeroptera, Plecoptera and Trichoptera

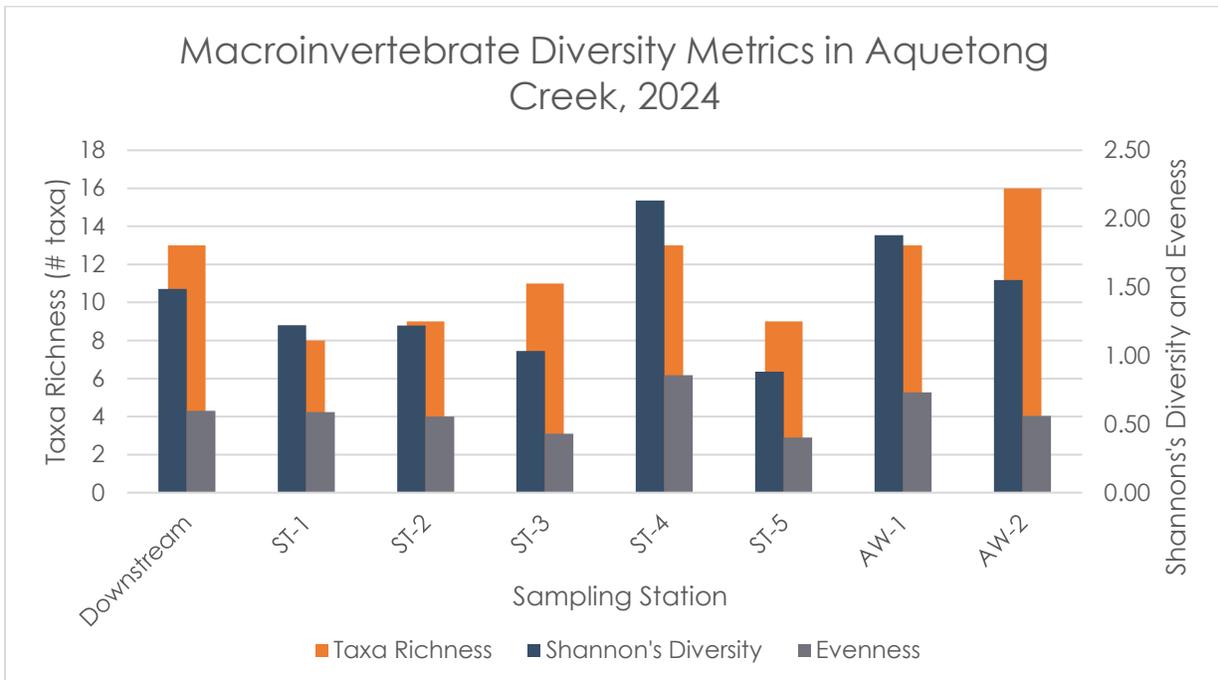


Figure 6: Aquatic Macroinvertebrate Density Metrics for Aquetong Creek



RECOMMENDATIONS

Based on the observations and measurements made during the 2024 monitoring of Aquetong Creek, Princeton Hydro proposes the following recommendations:

REDD SURVEY

Trout data from 2024 contained a lack of young-of-the-year trout, suggesting a possible lack of spawning success from the 2023 spawning season. In order to assess brook trout spawning success in the Aquetong Creek, the township may be interesting in conducting a redd survey. Such a survey would entail counting the number of trout spawning nests, referred to as redds, and identifying which areas within the park are most utilized by spawning trout. These areas may subsequently be monitored prior to the annual fish survey for the presence of young of the year fish. Such a survey would be relatively easy to conduct, requiring only a GPS, polarized sunglasses, a notebook, and 2-3 volunteers. Yearly surveys may also be performed to assess long term patterns or changes in brook trout spawning behavior in Aquetong Creek. Trout Unlimited has published a handbook outlining how redd surveys may be conducted (Lemon and Rummel).

BROOK TROUT HABITAT SUITABILITY INDEX (OPTIONAL)

One of the goals for the Aquetong Creek Park is the establishment of a viable population of naturally reproducing brook trout. In order to facilitate this, Princeton Hydro recommends a full habitat assessment of the stream in accordance with the parameters used in the brook trout habitat suitability index (HSI, Raleigh, 1982). This index features a collection of several habitat metrics and their optimal ranges for different brook trout life stages (e.g. breeding habitat, habitat for larvae and fry, etc.). Many of these metrics within the Aquetong Creek can be obtained while conducting the usual annual stream monitoring, although some of them require taking measurements during certain times of year (e.g. assessing minimum winter temperatures, as this influences larvae survival). By collecting such data on the Aquetong Creek, the exact elements in which the stream needs improvement as they relate to brook trout habitat can be further ascertained. It should be noted, however, that a favorable HSI index for a stream does not necessarily guarantee a high brook trout biomass. This would need to be accompanied with fish surveys such as those that have been conducted in the present study to assess the continued impacts of restoration efforts on the standing stock of brook trout in the stream. Princeton Hydro recommends this assessment occur in 2025 to 2026.

REMOVAL OF BARRIERS TO FISH PASSAGE

As discussed above, an area immediately downstream of station ST5 was observed in the study area with a rapid change in grade that may be impassable to upstream movement by some fish. Princeton Hydro strongly recommends that this location be addressed, as barriers to fish movement may prevent fish from returning to areas upstream after downstream movement, reducing the populations upstream. This will be particularly important in maintaining brook trout populations. The same has been noted in the riverine surveys (provided under separate cover) with regard to PADEP stream restoration permit reporting requirements.

BROOK TROUT DIET STUDY

A hypothesis for explaining the recent apparent reductions in YOY brook trout in the Aquetong Creek is predation on YOY individuals by larger individuals. Current data regarding overall brook trout diet in the Aquetong Creek is lacking; it is largely assumed that most individuals feed on the stream's aquatic invertebrate community, with the prolific amphipod population probably contributing largely to this. One method for assessing the diet of brook trout in the Aquetong Creek could be the examination of stomach contents of a subset of fish, with some focus



placed on larger individuals. The biggest concern with such a study is that, in order to examine a fish's stomach contents, the fish usually needs to be euthanized. Methods do exist for obtaining stomach contents without euthanizing a fish, however these may not be effective on trout, as they stress easily and may die in the process regardless. The loss of larger individuals as a result of this process may have negative impacts on the overall population, as these bigger fish are likely contributing greatly to the spawning process. As of now, Princeton Hydro does not recommend conducting a diet study and recommends that a redd survey be prioritized over this in regards to assessing the apparent lack of YOY individuals.

AGE ASSESSMENT OF BROOK TROUT

There is a degree of uncertainty as to the age and growth rate of some of the smaller and mid-sized brook trout collected in the Aquetong Creek, although the variation in lengths and masses strongly suggests the presence of more than one age class. For purposes of determining brook trout stream class, as mentioned above, young-of-the-year (YOY) brook trout are considered to be those under 15 cm in length. While there isn't reason at this time to suspect that brook trout in the Aquetong Creek are not exhibiting healthy growth rates, this length-based aging may cause some inaccuracies if there exist smaller individuals that are over a year old. This can be assessed by collecting scales from each brook trout sampled and assessing them under magnification. While other methods of aging fish also exist, many of them (such as the assessment of otoliths) require that fish be euthanized. Collection of scales, however, is a relatively simple process that causes minimal stress to the fish being assessed and allows for assessed fish to be released. Age data can be paired with length data to produce age-length regressions similar to the length-weight regressions performed in 2021-2024. If desired, Princeton Hydro can perform scale assessments on brook trout during future fisheries assessments under a new task.

DIGITAL CAMERA-BASED UNDERWATER OBSERVATION

While not a part of the current SOW, in 2024 and in past years, Princeton Hydro staff have utilized GoPro® brand rugged digital cameras to collect underwater observations of parts of the Aquetong Creek. As briefly mentioned above, this yielded one of the only observations of a YOY brook trout individual in 2024. While the information gathered by this method has been sparse, this can be utilized for specific purposes, such as use during a redd survey, examining features of concern from an underwater view, or potentially for observing fish in a relatively non-invasive manner. The excellent water clarity in much of the Aquetong Creek allows for good camera visibility as long as appropriate light is available. Factors impacting the quality and usefulness of this data are the battery life and digital storage space of the camera, light availability, and ability to anchor the camera to the stream bottom at a useful angle. Princeton Hydro can discuss the use of this methodology further with Solebury Township if desired.

CONTINUED GENERAL MONITORING IN 2025

Princeton Hydro recommends the continued monitoring of the Aquetong Creek in order to assess the effectiveness of previous restoration efforts and the status of the stream's brook trout population. A monitoring event for 2025 should largely follow the same methodology used in 2020-2024. This involves the continued sampling of fish and macroinvertebrates at least once a year in either the Spring or Fall seasons, to assess how changes to the stream and habitat affect these populations and, in particular, if brook trout populations are reproducing.



REFERENCES

Climate Information for Management and Operational Decisions (CLIMOD2) system. National Weather Service Cooperative Weather Station DOYLESTOWN AIRPORT (54786 WBAN). October 2022. Northeast Regional Climate Center, Cornell University. <http://climod2.nrcc.cornell.edu/>.

F.X. Browne, Inc. 2004. Ingham Spring Dam Removal Study.

Hartman, K.J., and J.P. Hakala. 2006. Relationships between Fine Sediment and Brook Trout Recruitment in Forested Headwater Streams. *Journal of Freshwater Ecology*, 21:2, pp. 215-230.

Hilsenhoff, W.L. 1988. Rapid Field Assessment of Organic Pollution with a Family-Level Biotic Index. *Journal of the North American Benthological Society*, 7:1 pp. 65-68.

Lemon, J., and S. Rummel. Redd Survey Handbook: A Handbook for Trout Unlimited Chapters, Staff and Partners. Trout Unlimited with funding from United States Forest Service CitSci Fund. https://www.tu.org/wp-content/uploads/2020/01/Redd-Survey-Handbook-v1_w_appendices.pdf

Myrick, C., and M. Kondratieff. 2004. An evaluation of a potential barrier to the upstream movement of brook trout in Rocky Mountain national Park, Colorado. United States Department of the Interior, National Park Service, Water Resources Division. Technical Report NPS/NRWRD/NRTR-2005/337.

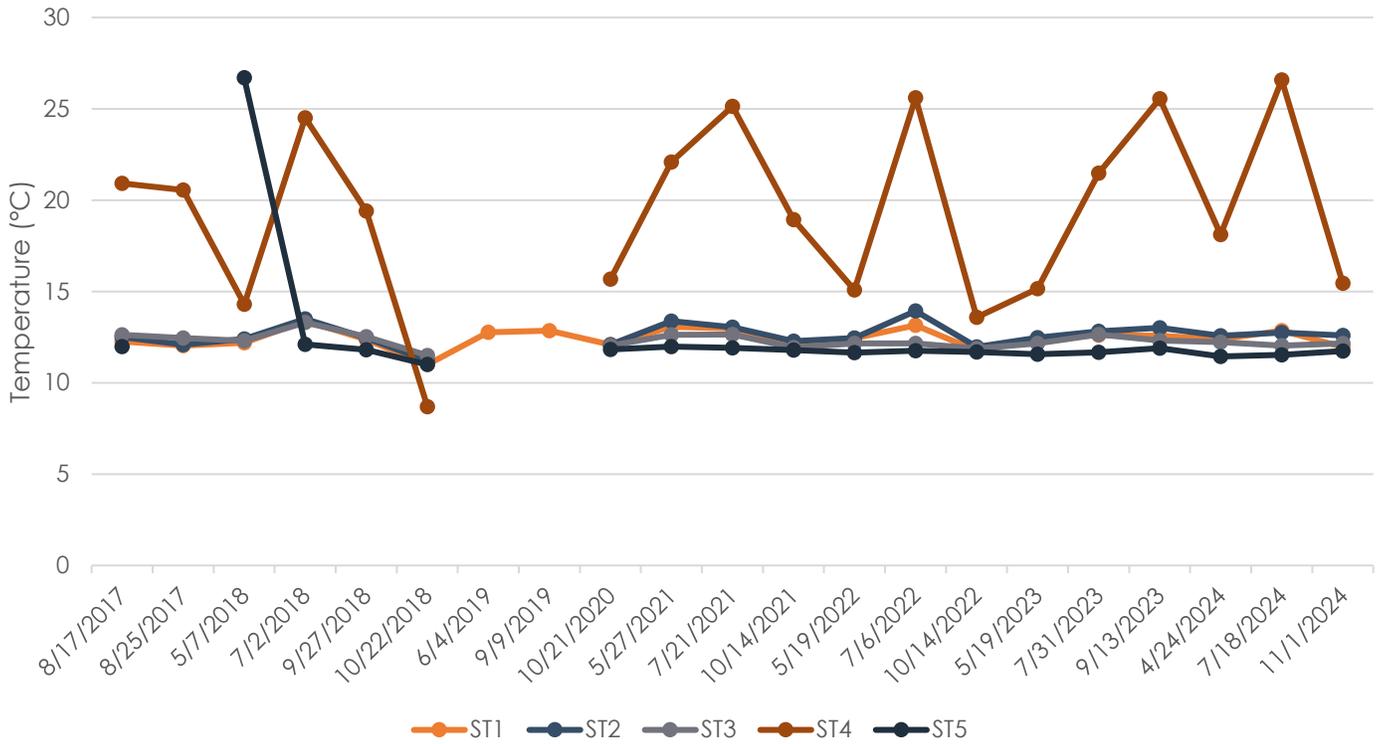
Pennsylvania Fish & Boat Commission. 2022. Operational Guidelines for the Management of Trout Fisheries in Pennsylvania Waters. Bureau of Fisheries, Division of Fisheries Management. 5th Edition.

Raleigh, R.F. 1982. Habitat suitability index models: Brook trout. U.S. Dept. Int., Fish Wildl. Serv. FWS/OBS-82/10.24. 42 pp.

APPENDIX
HISTORIC WATER QUALITY AND FISHERIES
TRENDS IN STATIONS ST1-5

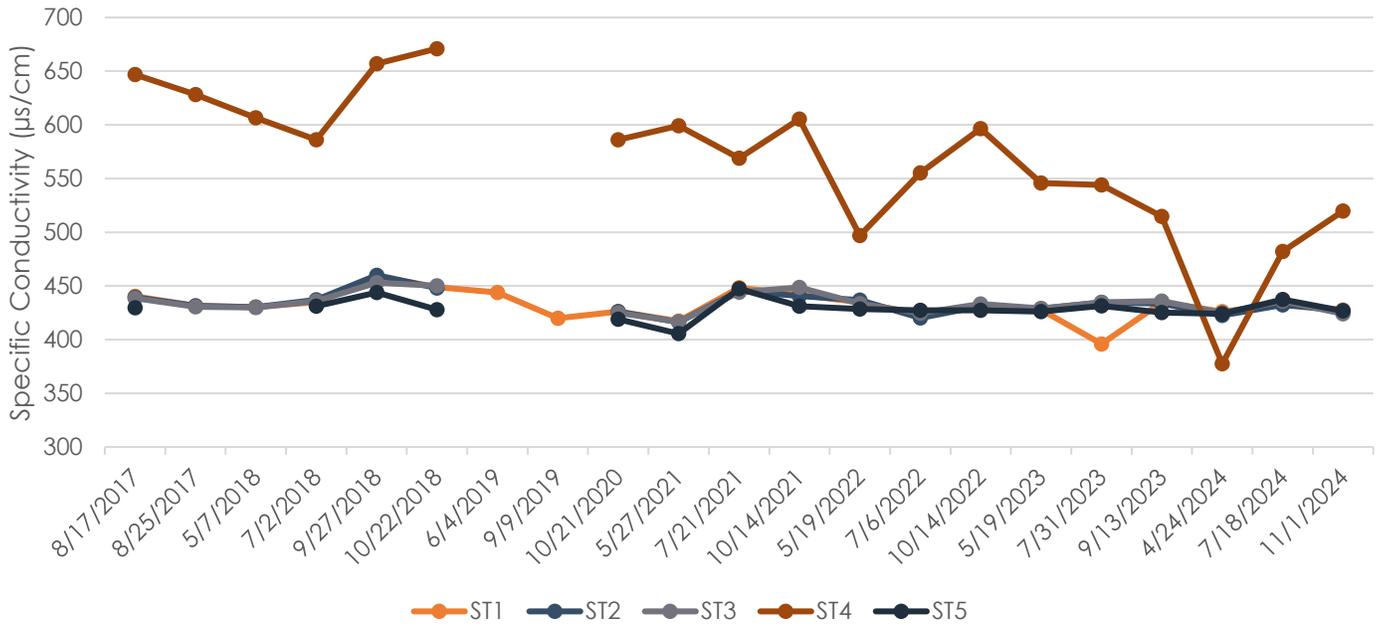


Long Term Temperature at ST1-ST5, 2017-2024

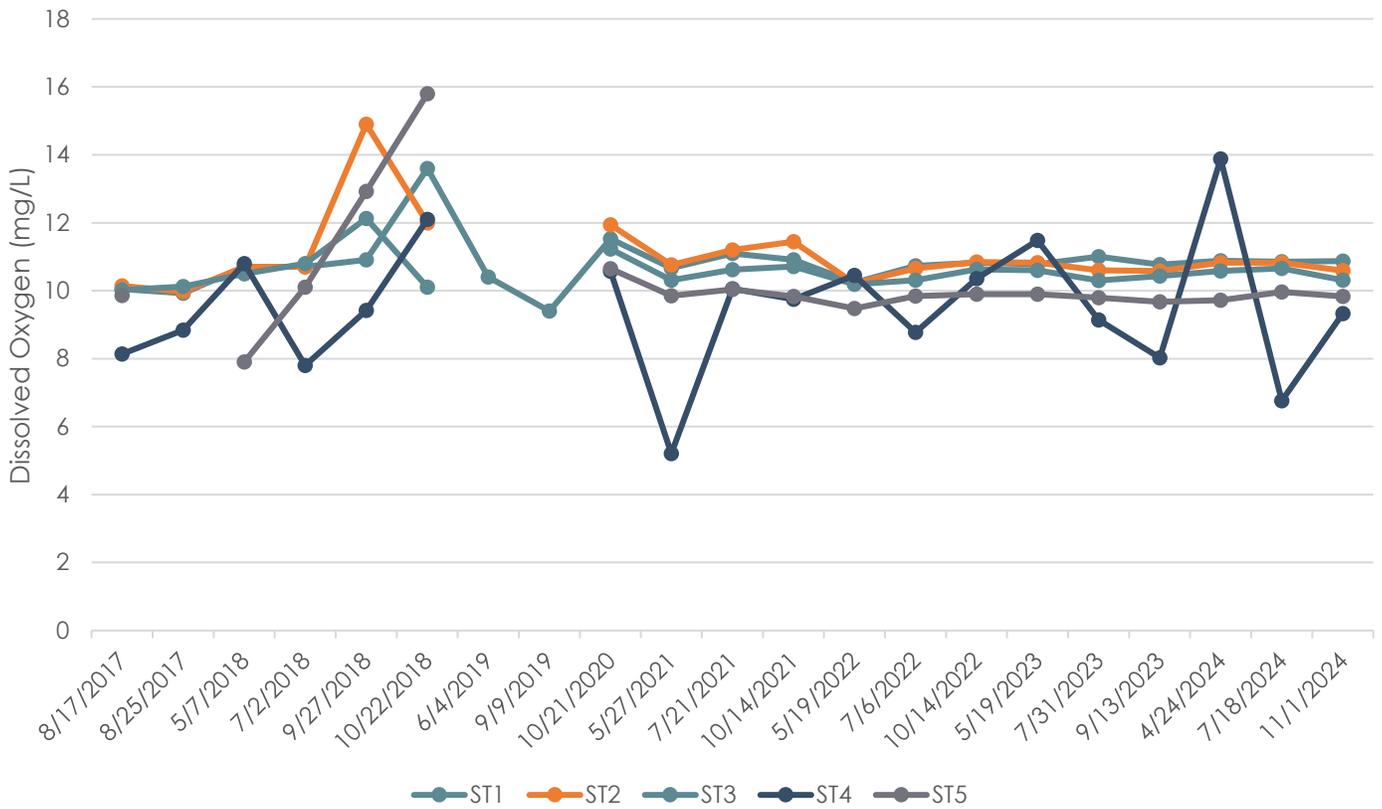




Long Term Specific Conductivity ST1-ST5, 2017-2024



Long Term DO Concentration (mg/L), ST1-ST5, 2017-2024





Long Term pH, ST1-ST5, 2017-2024

