Ingham Spring
Dam Removal Study

November 2004

Prepared For:
Bucks County Chapter of
Trout Unlimited

Prepared By:

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FXB File No. PA1553-03-001

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Executive Summary

Aquetong Lake is a 15-acre impoundment located within Solebury Township, Bucks County, approximately 2.5 miles west of New Hope, Pennsylvania. The lake is formed by a 500-foot long earthen dam. The lake is fed by Aquetong Spring, a significant groundwater spring also known locally as Ingham Spring. Solebury Township is considering purchasing lands from the Pennsylvania Fish and Boat Commission that contain both Aquetong Lake and Ingham Spring to create a recreation area and nature preserve for Township residents. The dam is currently in need of major rehabilitation. If the sale of the property is completed, the Township is planning to rehabilitate the dam at an estimated cost of nearly $1 million.

The Bucks County Chapter of Trout Unlimited is interested in working with Solebury Township exploring the possibility of removing, rather than rehabilitating Aquetong Lake Dam. The purpose of this study is to collect information critical to assessing the feasibility of a dam removal including quantifying environmental impacts of the dam and evaluating the current condition of the dam. This study is not intended to substitute for a comprehensive feasibility analysis of dam removal and rehabilitation options at the site, but is rather intended to provide useful information about key areas of concern that can be used by BCTU as they pursue further dialogue with the Township concerning design options.

An informal visual dam inspection was performed on June 26, 2004 to ascertain the condition of the Aquetong Lake dam. The dam crest and upstream slope appeared to be in good condition with no major problems. We observed significant tree growth on the downstream slope which can pose a threat to the dam's overall stability. The toe area of the dam appeared to be free of major problems.

Stream temperature was continuously monitored at sampling stations located immediately upstream and downstream of Aquetong Lake for an approximately two-month period during summer 2004. Results showed marked increases in average temperature, daily maximum temperature, and daily temperature variability at the downstream sampling station when compared with the upstream station. For the entire study period stream temperature at the downstream station exceeded stream temperature at the upstream station by an average of 15.29 °F ± 3.15.

Stream water grab samples were collected on July 26, 2004 from one upstream and one downstream monitoring location to determine differences in water quality. Results showed that total dissolved solids, total suspended solids, total phosphorus, and chlorophyll a were higher in the downstream sample, while nitrate/nitrite was higher in the upstream sample. Dissolved reactive phosphorus concentrations were identical in the upstream and downstream sample. Chlorophyll a concentration was more than 20 times higher in the downstream sample (5.9 mg/m^3 vs. 0.3 mg/m^3)

The results of the study show that removing Aquetong Lake dam could positively effect downstream reaches of Aquetong Creek by reducing stream temperature and improving water quality. In particular, the amelioration of thermal impacts would most likely create a year-round temperature regime that could support a high quality cold-water fishery in Aquetong Creek throughout its length. In addition to providing a substantial environmental benefit, removing rather than rehabilitating the dam would significantly reduce total project costs. Moving forward, BCTU should work with Solebury Township and other partners to more fully develop and evaluate potential dam removal design alternatives in the context of a detailed feasibility study

1.0 Introduction

Aquetong Lake is a 15-acre impoundment located in Solebury Township, Bucks County, Pennsylvania. The impoundment is formed by a 500 foot-long earthen embankment dam across Aquetong Creek. Below the dam, Aquetong Creek flows approximately 2.5 miles before discharging into the Delaware River at New Hope, Pennsylvania. The source of Aquetong Creek and Aquetong Lake is Aquetong Springs, a locally-famous artesian spring that flows at an estimated 2,000 gallons per minute. The springs, which is also commonly known as Ingham Spring after a family that owned the site for over a century, is thought to have been a place of significance for local Indian tribes and has long been recognized as a place of unparalleled natural beauty by local residents.

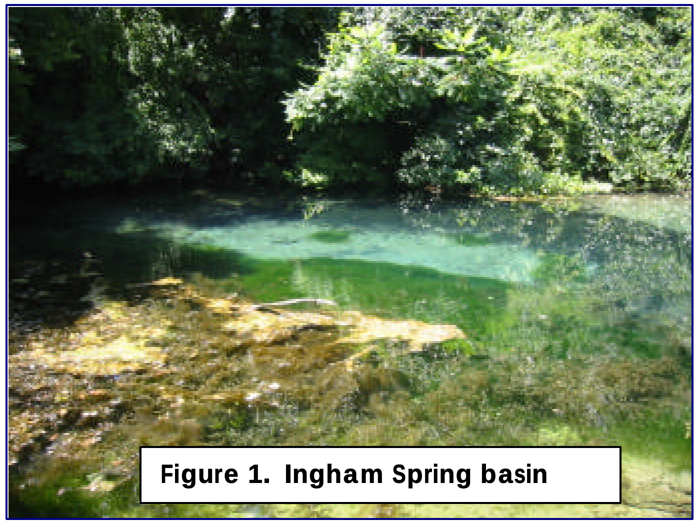

Figure 1. Ingham Spring basin

The Springs wells up from fissures in the underlying red shale and limestone bedrock into a surface basin, shown in Figure 1, which is approximately 12 feet deep and measures 40 feet long by 75 feet wide. The spring water exits the eastern side of the basin, flowing over a waterfall, which shown in Figure 2. A small stream channel flows from the base of the waterfall approximately 250 feet to the inlet of Aquetong Lake.

Figure 2. Ingham Spring

Site History

A number of mills (nine, according to one source) were established along Aquetong Creek during the 1700s. (Lapp, 1926). The New Centennial Atlas (Scott, 1876) shows five impoundments along the course of Aquetong Creek, including a paper mill which was located near the present day lake (1860 plat map). By 1871, a trout hatchery had been established on the site (1871 Intelligencer article). Remains of the hatchery pens can still be seen immediately downstream of the collection pool and waterfall. In the late 1800s, Deer Park, a regionally-popular amusement park was established on the site. In 1921, the park facilities had been abandoned and the property was sold and converted to a religious camp (1921 Intelligencer article). In the 1930s, Deer Park was reopened. In 1969, the County considered acquiring 25 acres, including Aquetong Lake and Ingham Spring to create a park. However, the purchase never occurred. The Pennsylvania Fish and Boat Commission purchased the property in 1990s and currently owns both Ingham Spring and Aquetong Lake.

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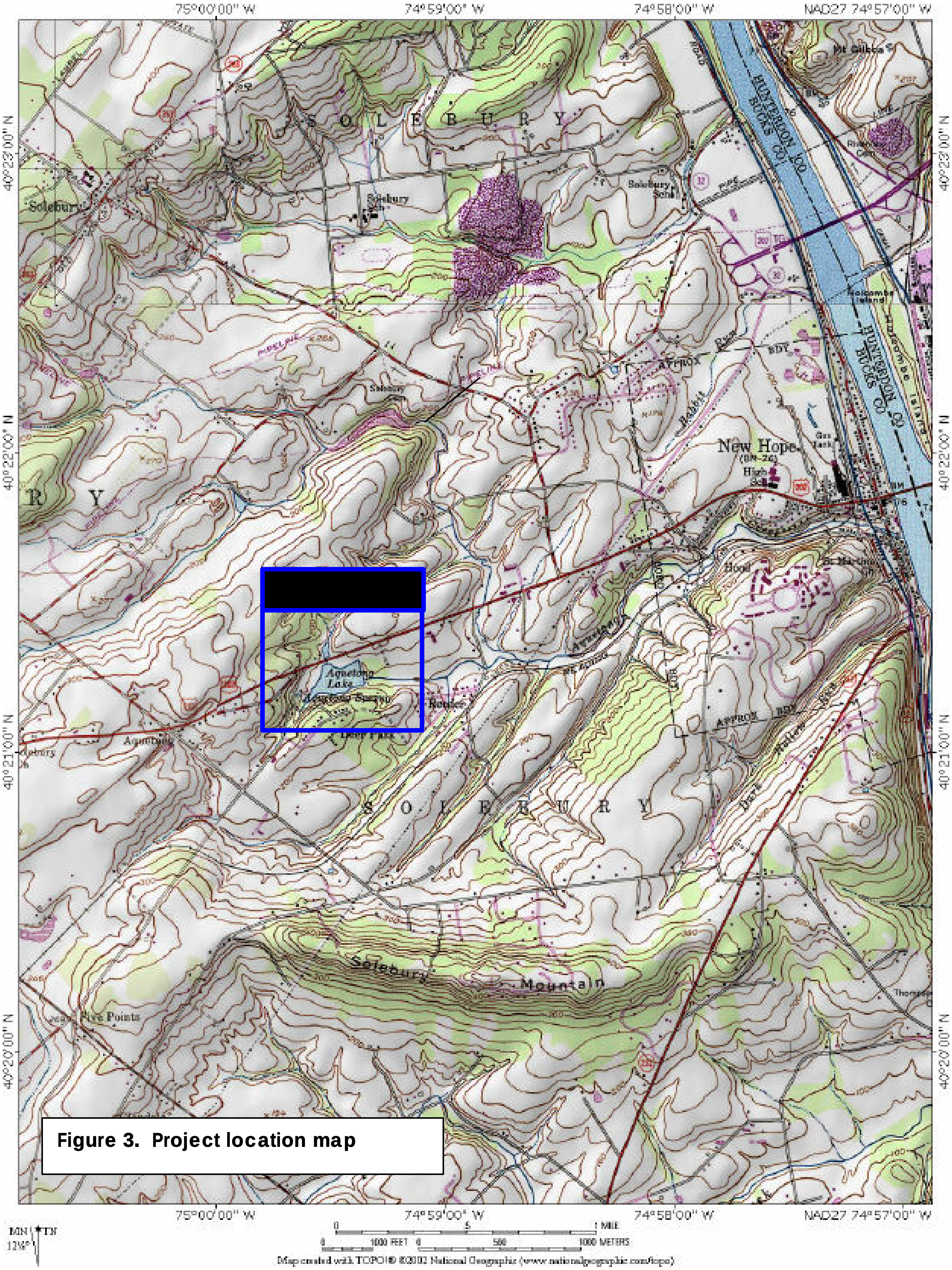


Figure 3. Project location map

In 1998, the Pennsylvania Fish and Boat Commission partially breached the dam to make repairs to the spillway. The partial breach has not been repaired, and the lake today is several acres smaller and several feet shallower than its historical size.

Figure 4. View of Aquetong Lake

Within the last decade, Solebury Township has become increasingly interested in acquiring the site to preserve the area's natural and scenic qualities. In 2003, Solebury Township announced plans to acquire a 50-acre tract that includes Aquetong Lake and Ingham Spring. The Township applied for funds from the Bucks County Natural Area for this purpose. However, talks between the Township and the PAFBC have since broken down over a number of issues.

Study Objectives

Figure 5. Looking south across Aquetong Lake

Currently, Solebury Township plans for the Ingham Spring and Aquetong Lake site include repairing the existing dam, which will cost an estimated $905,000 according to figures released by the Township. The Bucks County Chapter of Trout Unlimited (BCTU) has approached Solebury Township about the possibility of instead removing the dam and restoring the free-flowing nature of the stream. Among other benefits, BCTU feels that this approach offers a suite of benefits to the Township which make it an attractive option worthy of serious consideration. First, a dam removal would be far less expensive than the proposed dam repair. Secondly, the removal would restore Aquetong Creek to a free flowing stream for the first time in 300 years, and would create the potential for establishing an exceptional-value, cold-water fishery throughout Aquetong Creek. This would not only benefit fisherman and stream enthusiasts, but would create a high quality resource that could qualify for special protection through PA-DEP. Other potential benefits of a dam removal would include the elimination of liability issues associated with a potential dam failure, enhanced downstream water quality, and natural landscape beauty.

Figure 6. Remnants of the former fish hatchery at Ingham Spring

This study was funded by BCTU in an effort to more fully understand the costs and benefits associated with a dam removal project at Aquetong Lake. In particular, BCTU was interested in better understanding the impact of the existing dam and impoundment on stream temperature and on stream chemistry. Visual evidence collected by chapter members suggest that the impoundment is warming stream water and is a source of nutrients, algae, and sediments, which are subsequently transported to downstream areas including the Delaware River. BTCU was also interested in evaluating the current condition of the dam structure in more detail.

2.0 Dam Inspection

F. X. Browne, Inc. conducted an informal, visual inspection of the Aquetong Lake Dam on June 26, 2004. Conditions were sunny. Air temperature was approximately 80° F. Light rain had occurred within 48 hours of the inspection. The inspection was conducted by Shandor J. Szalay, Senior Project Scientist with F. X. Browne, Inc.

Description

The Aquetong Lake dam is an earthen embankment dam measuring 550 feet long. The dam does not have structural abutments, outlet structures, or an external drainage system. The dam is partially breached along the northern terminus. The breach is approximately 45 feet wide and appears stable. The height of the dam increases from north to south. At the northern end of the dam, the dam height is approximately 8.5 feet, while the height of the dam at the southern terminus is approximately 28 feet. The slope of the downslope embankment is approximately 1.5(H):1(V), while the slope of the upslope embankment is approximately 3(H): 1(V). The width of the dam breast varies between 10 and 13 feet.

Condition

Crest. The dam crest appears to be in good condition and is free of major problems. The vertical alignment of the crest is flat, while the horizontal alignment was observed to have a slight bend. No surface cracks or settlement were observed along the crest.

Upstream slope. The upstream slope appears to be in good condition. Most of the upstream slope is covered with unmowed herbaceous vegetation. There are no significant trees growing on the upstream slope. No sloughing, subsidences or depressions were observed along the upstream slope. Occasional areas of loosely placed rip-rap slope protection were observed along the upstream slope. No surface cracks, toe movement, or other unusual conditions were observed along the upstream slope. No animal burrows were observed.

Downstream slope. The downstream slope is characterized by significant tree growth, which can cause serious problems for dam stability. Forty-seven >6 in. caliper trees were observed on the downstream slope. Many of the trees are mature specimens of over 18 in. caliper. No sloughing, subsidence, or depressions were observed on the downstream slope. No surface cracks or movement at the toe were observed. No seepage was observed. No animal burrows were observed.

Toe area. No erosion, depressions, sinkholes, signs of movement, or unusual conditions were observed at the toe area. The area immediately downstream of the toe area along the southern portion of the dam is a wetland-like area that may indicate seepage along the toe. However, no direct evidence of seepage along the toe was observed. The wetland area is located directly adjacent to the downstream stream channel and may experience periodic flooding. Therefore, we cannot confidently conclude that the wetland indicates seepage along the bank toe.

Figure 7. Unmowed herbaceous vegetation growing on the upstream slope

Figure 8. Mature trees growing on the downstream slope

Figure 9. Rip-rap slope protection along the upstream slope

Figure 10. Looking south along dam crest

Figure 11. Looking north at partial breach section

Figure 12. Looking north at partial breach section

3.0 Temperature Monitoring

Methods. Continuous stream temperature monitoring was conducted at monitoring stations located immediately upstream and downstream of Aquetong Lake. Upstream and downstream stations were located in stream sections with similar water depth (approximately 1 foot) and that received direct sunlight throughout the day. HOBO® Water Temp Pro automated temperature sensors were installed at the upstream and downstream monitoring stations. Temperature data collection at both stations began at 14:00:00 hours on July 26, 2004 and ended at 14:15:00 hours on September 17, 2004. Stream temperature was recorded every fifteen minutes throughout the study period.

Results. Summary statistics for the temperature monitoring program data are presented in Table 1. Average and maximum stream temperatures were markedly elevated at the downstream station. As shown in Figure 14., which displays average daily temperature throughout the study period for both stations and Figure 15, which displays average daily maximum temperature throughout the study period for both stations, pronounced differences in temperature between the upstream and downstream stations were evident at all periods through the day and throughout the course of the entire study. Average stream temperature at the upstream station was 53.13 °F ± 0.33. Average stream temperature at the downstream station was 67.72 °F ± 3.26. The average difference between temperature readings at upstream and downstream stations was 15.29 °F ± 3.15. Average daily maximum stream temperature at the upstream sampling station during the study period was 53.88 °F ± 0.52, compared with 72.50 °F ± 3.32 for the downstream station.

Table 1. Comparison of Summary Statistics Average Stream Temperature and Average Maximum Daily Stream Temperature Upstream and Downstream of Aquetong Lake

	Stream Temperature (°F)		Maximum Daily Temperature (°F)	
	Upstream	Downstream	Upstream	Downstream
Average	53.13	68.42	53.88	72.50
Standard Deviation	0.33	3.26	0.52	3.32
Minimum	52.64	61.63	53.30	65.06
Maximum	56.56	79.17	56.56	79.17
Coefficient of Variation	0.20	15.54	0.50	15.24

Discussion. Stream temperature data collected during the study clearly indicate that stream temperatures below Aquetong Lake are much higher than above Aquetong Lake. The difference in average stream temperature between the upstream and downstream station averaged more than 15 °F for the entire study period. Thermal stress associated with impoundments, stormwater runoff, and depleted groundwater resources have converted many of Pennsylvania's cold water fisheries into warm water fisheries. Particularly in and around urban areas, where thermal stress, habitat alteration, and other impacts have resulted in extensive loss of cold water fisheries, cold water stream ecosystems are rarely found.

Sustainable cold water fisheries in Pennsylvania are characterized primarily by the presence of wild trout. Although wild trout require a host of physical, chemical, and biological resources and conditions throughout their life cycle, year-round cool stream temperatures is a fundamental requirement for trout and is a prerequisite for sustaining wild trout populations. In Pennsylvania, streams that maintain water cool enough to support year-round trout populations are generally found in areas of limestone and dolomite geology where stream temperatures are moderated by the continual input of groundwater from high yielding aquifers. Dams that dramatically increase stream temperature can have devastating consequences for the growth and survival of wild trout. For example, brown trout growth rates are already significantly curtailed by the metabolic consequences of increasing stream temperature above 59 °F (Allen, 1995). Above 68 °F, trout cannot generally maintain year-round populations because their growth, feeding, and reproductive rates are insufficient to maintain significant population species (Allen, 1995). When temperatures exceed 77 °F, thermal stress is so great that adult trout cannot survive for periods of days or weeks (Allen, 1995).

Our data suggests that the Aquetong Lake changes the downstream thermal regime of Aquetong Creek from a regime that could most likely support a naturally-reproducing trout population to a regime where temperatures reach levels that can produce acute morality for adult trout. Given the relatively short length of the creek and the lack of other significant thermal stresses, it is likely that the removal of the Aquetong Lake Dam would most likely result in a thermal regime that could support the natural reproduction of wild trout. Based on a visual review of downstream habitat conditions, stream habitat seems sufficient to support trout development, feeding, and reproduction. Pool and riffle habitats are well developed, the stream channel is well-shaded, banks are generally well-vegetated and stable, and large woody debris is plentiful within the stream channel. Wild trout have been documented in the reaches above Aquetong Lake. For instance, wild trout can be seen in the large pool into which Ingham Spring flows. These populations could provide an ample colonization source for downstream populations if the Aquetong Dam were removed.

Figure 13. Close up view of deployed HOBO® Water Temp Pro automated temperature sensor.

Figure 14. Average and Maximum Daily Temperatures Upstream and Downstream of Aquetong Lake Dam, July-September 2004

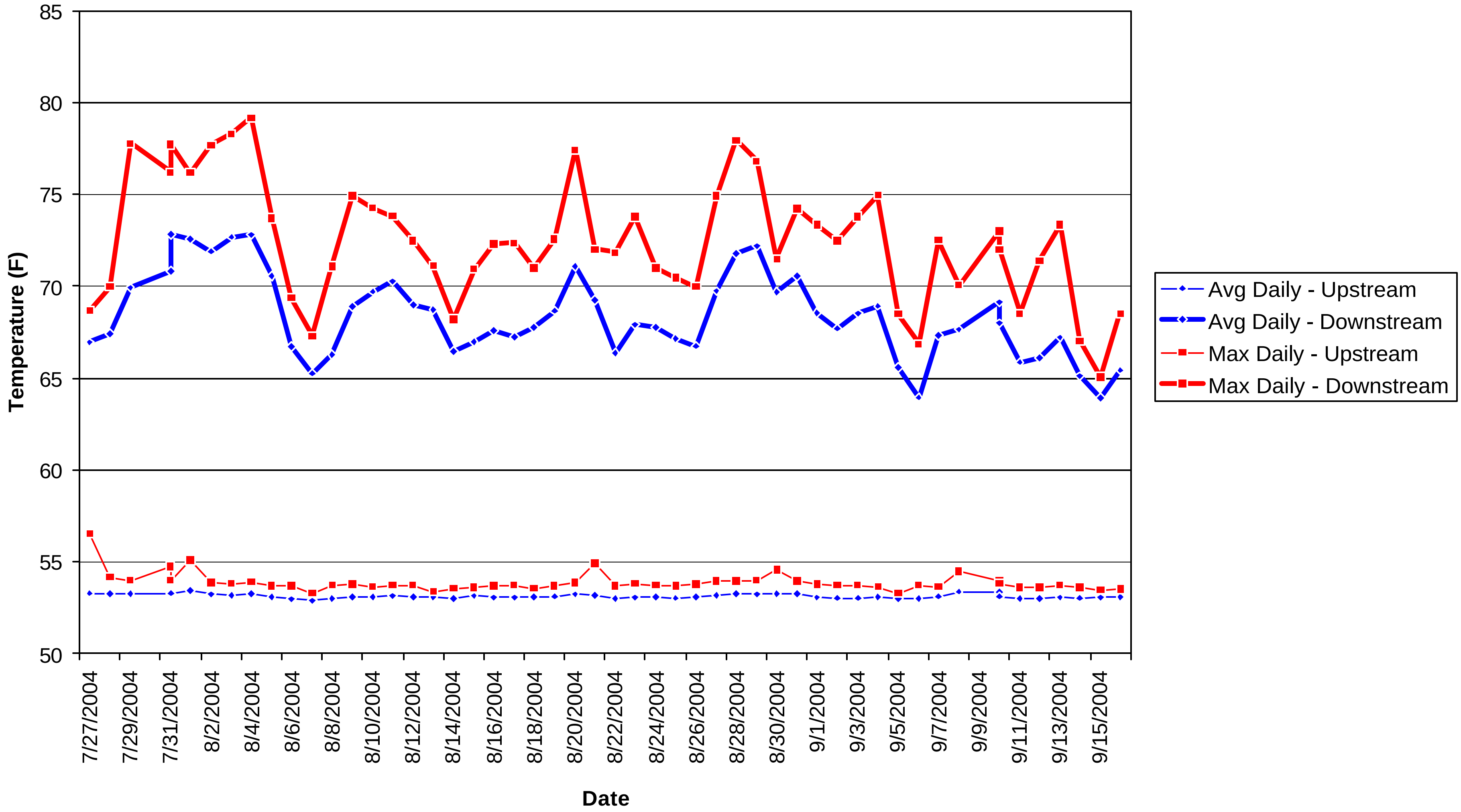
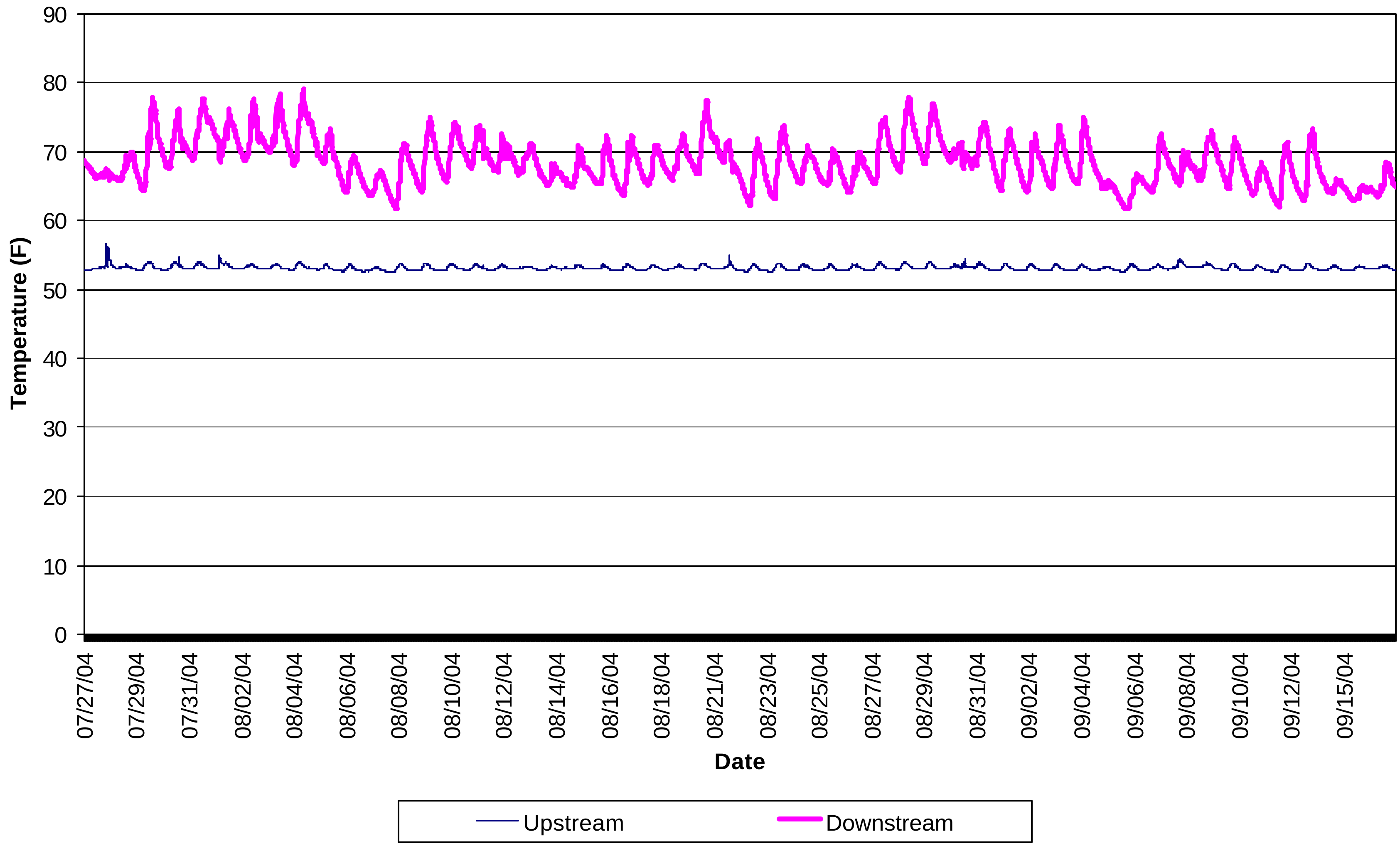


Figure 14. Stream Temperature Upstream and Downstream of Aquetong Lake Dam, July - September, 2004



4.0 Water Quality Monitoring

Methods. Stream water grab samples were collected from one upstream and one downstream sampling location to determine differences in stream chemistry. Samples were collected during mid-afternoon on July 26, 2004. Samples were analyzed for the following parameters according to standard analytical methods by F. X. Browne, Inc. Laboratory in Marshalls Creek, PA:

- Dissolved reactive phosphorus
- Total dissolved solids
- Total phosphorus
- Chlorophyll a
- Nitrate/Nitrite
- Total Suspended Solids

Results. Results of the water quality monitoring are presented in Table 2. Total dissolved solids, total phosphorus, total suspended solids, and chlorophyll a were higher in the downstream sample. In particular, chlorophyll a concentration, a measure of algal biomass, was nearly 20 fold higher in the downstream sample. Dissolved reactive phosphorus concentration was identical in the downstream and upstream sample, while nitrate/nitrite concentration was higher in the upstream sample.

Table 2. Results of Water Chemistry Sampling Upstream and Downstream of Aquetong Lake Dam

Station	Dissolved Reactive Phosphorus (mg/l)	Total Dissolved Solids (mg/l)	Total phosphorus (mg/l)	Chlorophyll a; Pheophytin a (mg/m^3)	Nitrate/nitrite (mg/l)	Total Suspended Solids (mg/l)
#1 Downstream	0.002	248	0.019	5.9; <0.1	2.8	2.5
#2 Upstream	0.002	246	0.016	0.3; <0.1	3.6	1.5

Discussion. Our sampling results support the hypothesis that water flowing out of Aquetong Lake may contain more suspended particles, algae and plant material, and phosphorus than water flowing into Aquetong Lake during dry weather conditions. Not surprisingly, levels of chlorophyll a, which is a measure of the amount of algae present in the water, was dramatically higher in the downstream sample. This result indicates that significant quantities of algal material are produced within the lake and subsequently released to downstream waters. The increase in chlorophyll a downstream may have consequences for downstream ecosystem health. For example, increased algae may produce a shift in the macroinvertebrate community that favors organisms that filter algae rather than other feeding strategies. More importantly, increased algal biomass may increase decomposition rates, which could result in higher oxygen consumption in streamwater and may contribute to depressed oxygen levels in downstream waters.

Levels of suspended solids were higher in the downstream sample, although the levels of increase were modest. Levels of dissolved solids were slightly higher in the downstream sample. These results indicate that, during dry weather conditions, the physical, biological, and chemical processes occurring within Aquetong Lake do not likely produce significant effects on the total amount of materials present in stream water. Levels of nutrients showed little to modest changes from upstream to downstream. Total phosphorus concentration in the upstream sample was 18% lower than the downstream sample. Nitrate/Nitrite concentration showed the opposite trend; concentration in the downstream sample was 22% lower than in the upstream sample. Dissolved reactive phosphorus concentrations were unchanged. These results indicate that Aquetong Lake most likely does not dramatically alter nutrient concentrations of stream water entering and exiting the lake.

5.0 Conclusions

Pronounced differences in stream temperature and dry weather chlorophyll a concentration between sampling points located upstream and downstream of Aquetong Lake indicate that the lake may be contributing to significant ecological impairment of downstream reaches. The effect of the dam on stream temperature is so pronounced that it may be producing a fundamental change in the community structure of the downstream fishery from a cold water to a warm water fishery. The temperature of the upstream water suggests that removal of the Aquetong Lake Dam would likely dramatically reduce stream temperature throughout the entire length of Aquetong Creek and could allow for the establishment of nearly two miles of high quality cold water fisheries within Solebury Township.

The restored, free-flowing stream channel in conjunction with the Ingham Spring site could form the nucleus of a uniquely beautiful natural area within Solebury Township. The restored creek would provide exceptional recreational, educational, and interpretive opportunities for local residents and could qualify for special protection status under Pennsylvania's Chapter 93 water quality designation system. Special protection waters are those waters within Pennsylvania which are given the status HQ (high quality) or EV (exceptional value) by PA-DEP. Proposed development and infrastructure projects occurring in special regulation watersheds are subject to PA-DEP's anti-degradation requirements, which require more stringent design and construction standards. Special protection waters status is also helpful in leveraging state and federal funding for open space protection, watershed management, and stream protection projects.

The visual dam inspection conducted as part of this project indicates that the integrity of the Aquetong Lake dam is severely compromised by the extensive growth of large trees along the downstream embankment. While reconstruction of the dam would likely cost close to $1 million, the removal of the dam would likely be far less expensive and would offer the significant benefits associated with restoration of a high quality cold water fishery throughout Aquetong Creek. The results of our study suggest that a dam removal option may represent a low cost, high benefit option for the Ingham Spring Site when compared with the dam rehabilitation option currently being considered by the Township. We recommend that BCTU work with Solebury Township and the PA Fish and Boat Commission to more comprehensively evaluate the feasibility of a dam removal at the Ingham Spring site.

6.0 References

Allan, J. D. 1995. Stream Ecology: Structure and function of running waters. Chapman & Hall, London. 388 p.

Lapp, Walter, S. 1926. A report on Ingham Spring, Bucks County, Pennsylvania. M.S. Thesis. University of Pennsylvania.

Appendix A

Temperature Data

Appendix B

Water Quality Monitoring Data