Susquehanna River Basin Commission

West Branch Susquehanna Subbasin Year-2 Survey

Publication 275
September 2011

INTRODUCTION

The Susquehanna River Basin Commission (SRBC) completed a water quality and biological monitoring study in two small watersheds, Drury Run and Birch Island Run, from April 2010 through February 2011 as part of the West Branch Susquehanna Subbasin Survey Year-2 Study (Figure 1). Drury Run and Birch Island Run, which are located in Clinton County, Pennsylvania, are direct tributaries to the West Branch Susquehanna River. The Subbasin Survey Program is one of SRBC's longest standing monitoring programs, ongoing since the mid-1980s, and is funded by the United States Environmental Protection Agency (USEPA). This program consists of two-year assessments in each of the six major subbasins of the Susquehanna River Basin on a rotating basis. The Year-1 studies are broad-brush, one-time sampling efforts of about 100 stream sites to assess water quality, macroinvertebrate communities, and physical habitat throughout the entire subbasin. The Year-2 studies focus on a particular region or small watershed within the major subbasin, and typically seek to address one specific issue. SRBC conducted the West Branch Susquehanna Year-1 study from June-August 2009 (Buda, 2010). The Year-2 sampling plan is tailored for the individual needs or concerns of a chosen watershed, and sampled accordingly, so a more detailed evaluation can be made. More information on SRBC's Subbasin Survey Program is available at *www.srbc.net/programs/monitoring.htm*, and technical reports are available in hard copy or online at *www.srbc.net/pubinfo/techdocs/Publications/techreports.htm*.

The West Branch Susquehanna River Subbasin is the largest subbasin within the Susquehanna River Basin, draining nearly 7,000 square miles. In addition to its 1,249 miles of Exceptional Value streams and scenic forestlands, it also contains the unfortunate legacy of past unregulated mining. More than 1,200 miles of waterways in the West Branch are impaired by abandoned mine drainage (AMD).

(continued on page 2)

Summary Report

An Assessment of the Abandoned Mine Drainage Impacts in Drury Run and Birch Island Run, Clinton County, PA

Report by Luanne Steffy, Aquatic Ecologist
and Thomas Clark, Mine Drainage Program Coordinator

Additional data available on the Internet at www.srbc.net/pubinfo/techdocs/Publication_275/techreport_275.htm

Drury Run and Birch Island Run were chosen for small watershed studies primarily because they were both targeted in SRBC's West Branch Susquehanna Subbasin Remediation Strategy (2008) as watersheds that "needed more data" before any restoration efforts could begin. Both watersheds have sections of stream listed as impaired for aquatic life by AMD as well as sections that are nonimpaired. SRBC staff coordinated with Trout Unlimited (TU), Pennsylvania Department of Environmental Protection (PADEP) Moshannon District Mining Office, Western Pennsylvania Conservancy, and Clinton County Conservation District in the sampling design and set up for this project. During initial coordination with TU, which has been leading the West Branch Restoration Initiative since 2004, SRBC learned that Birch Island Run and Drury Run are two of the last AMD-impacted tributaries to the mainstem West Branch Susquehanna that will require restoration. The data collected for the project and outlined in this report will be essential in the process of determining the most effective ways to restore these two watersheds. Using the Office of Surface Mining's AMDTReat Software package, decisions can be made regarding what types of treatment, sizes, and exact specifications are needed to abate the influence of AMD on the receiving waters based on data collected during this study. More information on the West Branch Susquehanna Subbasin Remediation Strategy and more details on the coal geology and mining history of the West Branch are available at *www.srbc.net/pubinfo/techdocs/publication_254/techreport254.htm*.

Drury Run originates in the Tamarack Swamp, which is a perennial home to rare and endangered plant and insect species and has been designated as an Important Area for many bird species by Audubon Pennsylvania.

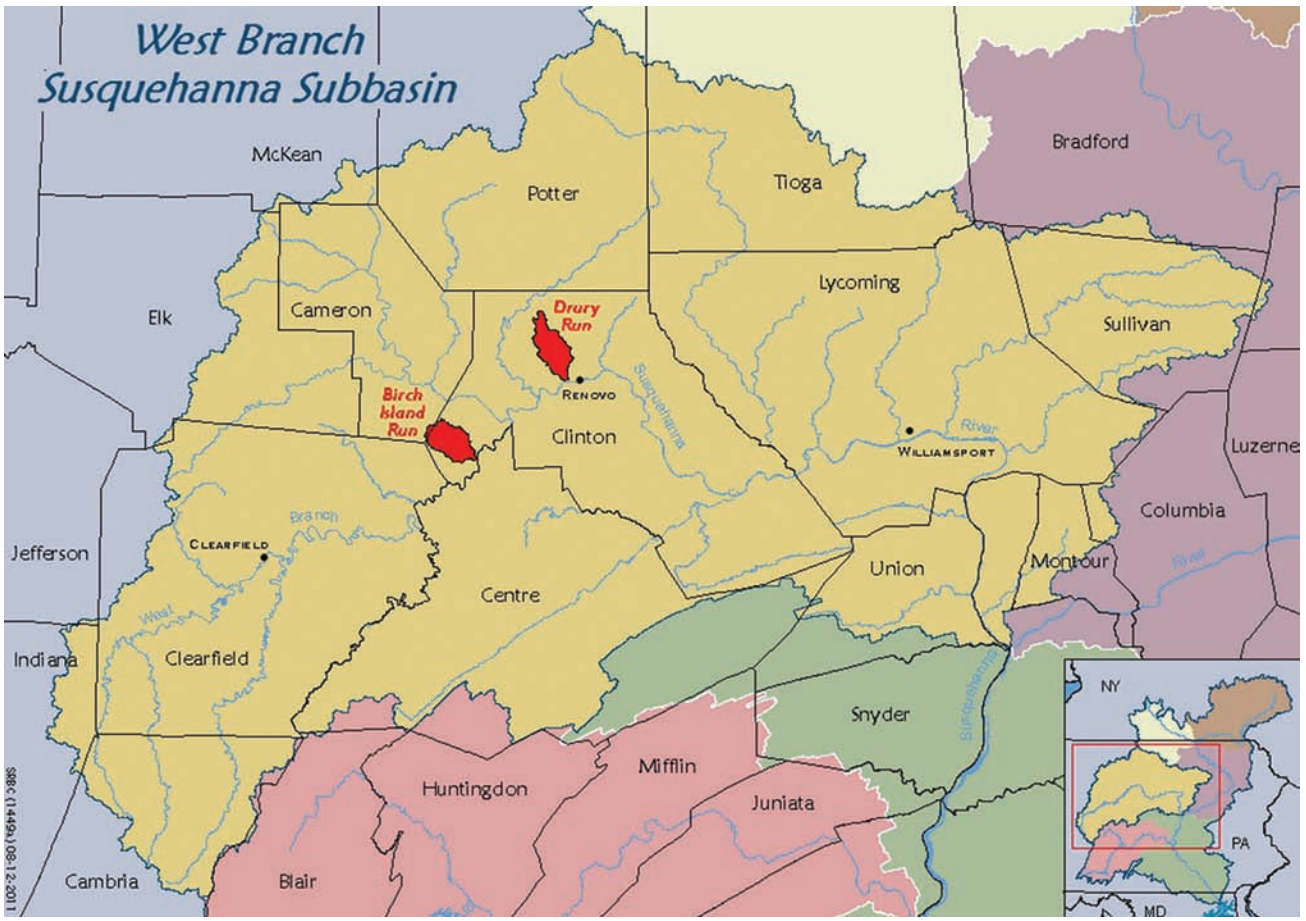


Figure 1. Location of the Birch Island Run and Drury Run Watersheds in the West Branch Susquehanna Subbasin

Watershed Descriptions

Drury Run is an 18-square-mile watershed that enters the West Branch Susquehanna River just west of Renovo, Pennsylvania. More than 90 percent of the watershed is forested and a large portion is within the boundaries of Sproul State Forest. Drury Run originates in the Tamarack Swamp, a 9,400-acre unique natural bog dominated by boreal conifers such as balsam fir, black spruce, and tamarack. It is a perennial home to rare and endangered plant and insect species, and has been designated as an Important Area for many bird species by Audubon Pennsylvania (Western PA Conservancy, *www.paconserve.org/84/tamarack-swamp*). The outflow of the Tamarack Swamp is the origin of Drury Run, and the first mile of stream exhibits the typical brown staining of natural tannins common to most bog outflows.

Drury Run, from its source to the first main tributary of Sandy Run, is designated as an Exceptional Value stream and is listed as attaining for aquatic life. The small stream segment from Sandy Run to Woodley Draft is designated as High Quality Cold Water Fishery and is attaining for aquatic life. Drury Run, from Woodley Draft to the mouth, is designated as a Cold Water Fishery but is listed as impaired for aquatic life by AMD sources (Figure 2). Nineteen sites were sampled quarterly in Drury Run Watershed. Appendix A lists more information about these sampling locations.

The AMD impairment in Drury Run is primarily located on the tributaries entering the stream in the lower 3.5 miles. Sandy Run is the most upstream named tributary, and in its headwaters, there is an AMD discharge point (Discharge No. 5) from an old deep mining operation. The entire Sandy Run subwatershed is listed as impaired by AMD. The next two tributaries downstream, Woodley Draft and Whiskey Run, are much smaller but have even worse water quality conditions. Woodley Draft, coming in from the east, is listed as impaired for aquatic life by AMD. Whiskey Run, coming in from the west, is not shown on some stream maps, but it is a perennial stream and its waters are very much impacted by AMD. However, the most impaired tributary in the Drury Run Watershed is Stony Run, which includes four smaller feeder streams that all

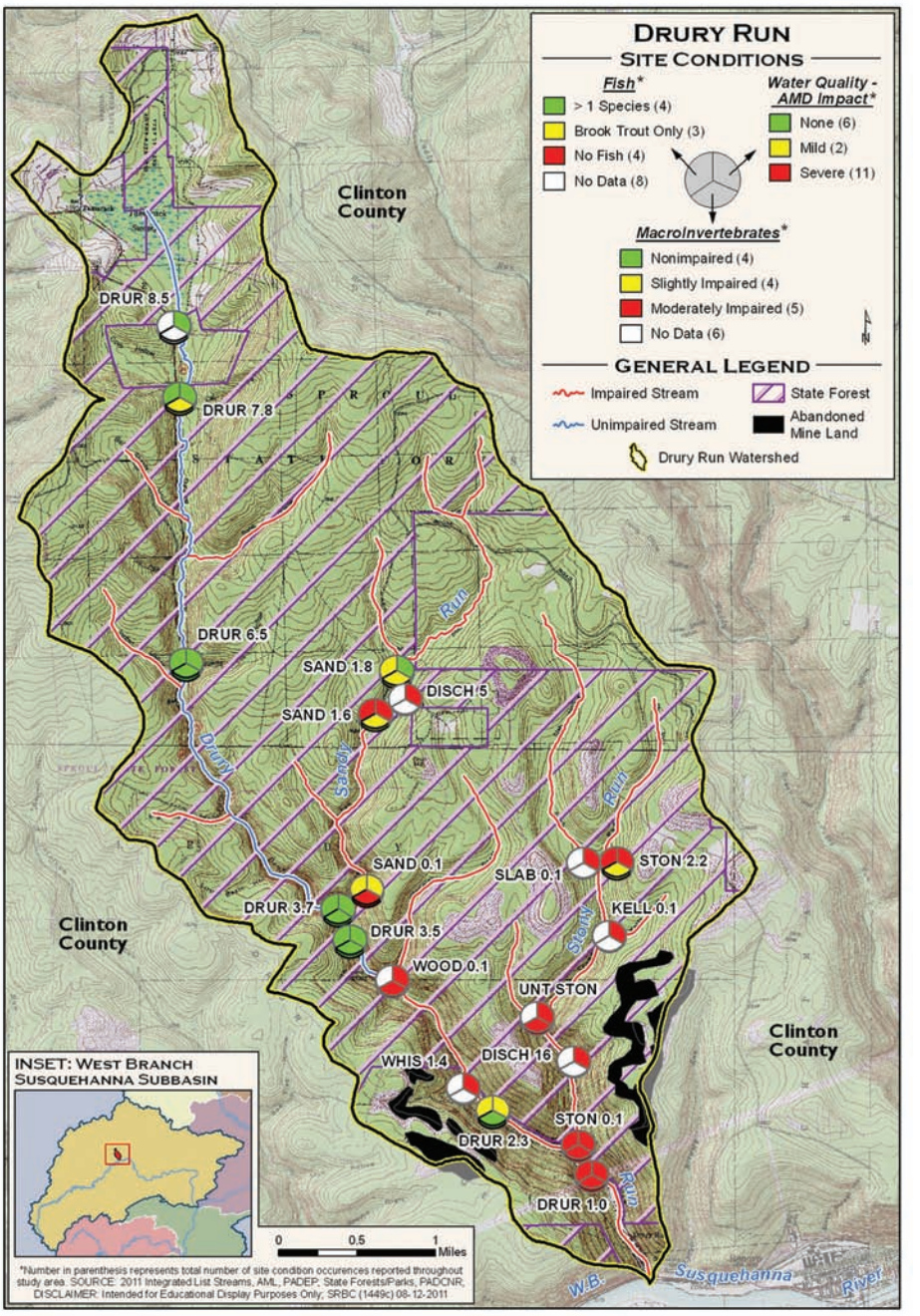


Figure 2. Map of Drury Run Watershed Showing AMD Lands, State Forest Boundaries, and Site Conditions at Sampling Locations

Sandy Run, an upstream tributary of Drury Run, is impaired by AMD, such as this discharge point (Discharge No. 5) in its headwaters.

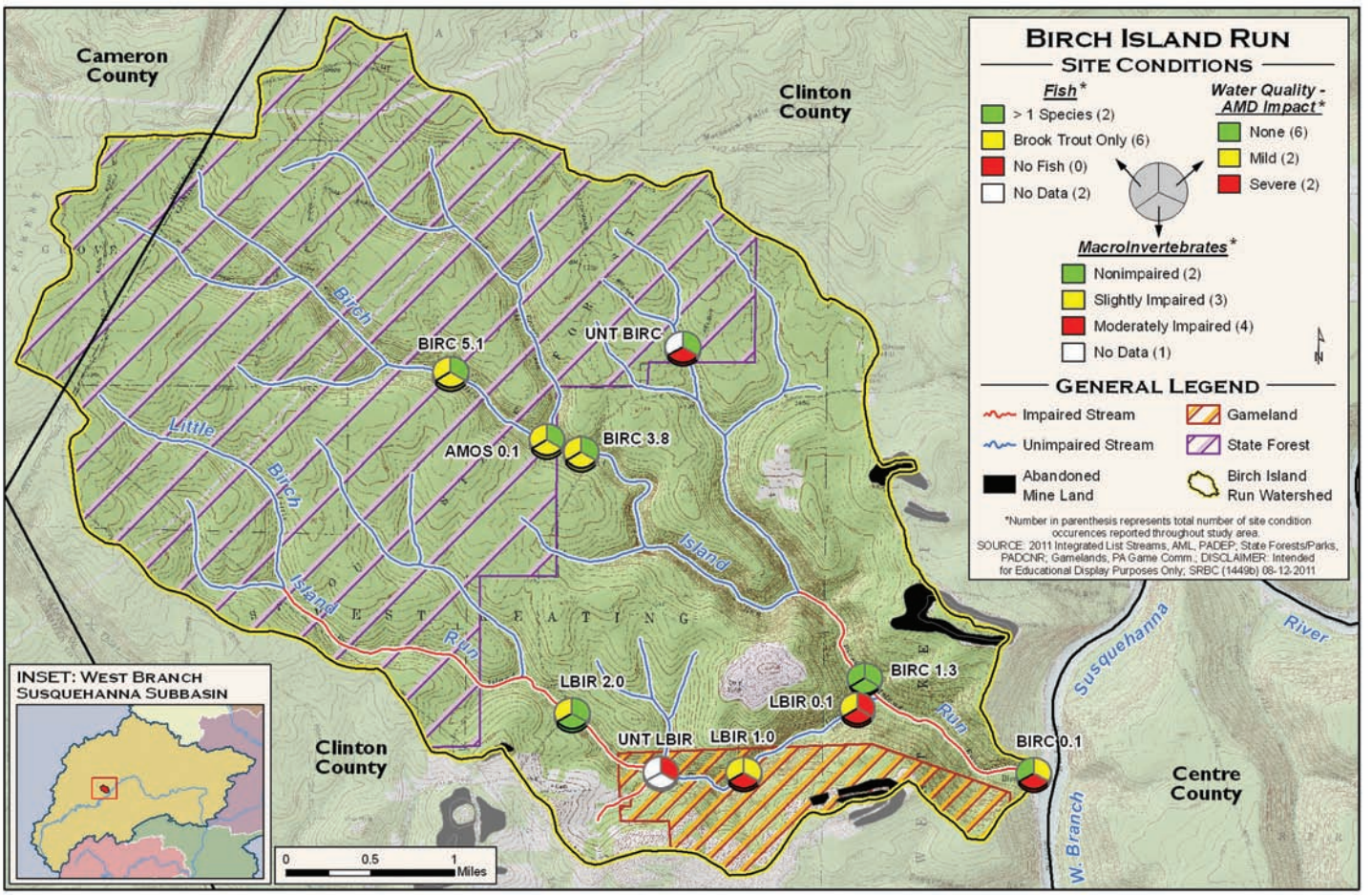


Figure 3. Map of Birch Island Run Watershed Showing AMD Lands, State Forest Boundaries, and Site Conditions at Sampling Locations

bear major impacts from past mining operations. Stony Run and its tributaries are all listed as impaired by AMD for aquatic life. As a result, from the point where Stony Run joins Drury Run, the biological and water quality conditions of Drury Run itself are markedly more degraded. The AMD impairment in Drury Run is most prominent during times of lower flow, as the most severely polluted water is groundwater, which becomes diluted with surface water during high flows.

Birch Island Run is similar in size, at 17 square miles, and similar in land use, at 95 percent forested, to Drury Run. About half of the watershed is within Sproul State Forest, and it empties directly into the West Branch Susquehanna about 20 miles upstream of Drury Run in West Keating Township. The whole watershed is designated as High Quality Cold Water Fishery. Amos Branch, a tributary to Birch Island Run, is listed as a Class A brook trout fishery. The lower two miles of Birch Island Run and the lower 1.5 miles of Little Birch Island Run are listed as impaired for aquatic life because of AMD. According to the data collected in this study, only the last mile of Birch Island Run is impaired by AMD but two miles are currently listed. Ten sites were sampled quarterly in Birch Island Run Watershed (Figure 3). Appendix A contains more information about these sampling locations.

"The lower two miles of Birch Island Run and the lower 1.5 miles of Little Birch Island Run are listed as impaired for aquatic life because of AMD."

There are two areas of AMD pollution impacting the Birch Island Run Watershed. Both of these sources are located along Little Birch Island Run and impair the final 1.5 miles of Little Birch Island and the last 1.2 miles of Birch Island before it empties into the West Branch Susquehanna River. The first source is an unnamed tributary that enters Little Birch Island from the east that is influenced by numerous seeps throughout its length from old surface mine operations that were poorly reclaimed. This tributary is net acidic and has manganese and aluminum concentrations that exceed water quality standards. A larger source of AMD enters Little Birch Island Run via the Little Bougher Run abandoned mine land (AML) site downstream of the unnamed tributary. One unnamed tributary is perennial as are other numerous small seeps, while others only flow after rain events or during periods of snow melt. The water quality in Little Birch Island Run and Birch Island Run downstream of its confluence is better in times of low flow and noticeably worse in higher flows when these AMD outflows are contributing water.

Methods

Sampling was conducted seasonally in both watersheds from spring 2010 through winter 2011. In addition to water quality sampling and flow measurements during all four sampling periods, macroinvertebrate sampling was completed during the spring and fish collection was done during the summer sampling period.

Water samples were collected while wading across the stream channel using a depth-integrated hand sampler. Field chemistry parameters (temperature, pH, conductivity, and dissolved oxygen) were measured instream using a YSI 6820 multi-parameter meter. Turbidity was measured using a Hach 2100P portable turbidometer. Flow measurements were taken using a FlowTracker and standard USGS methods when applicable. The bucket and stopwatch method was utilized for discharge points and high gradient, plunge pool tributaries where taking a traditional flow measurement was impossible. Macroinvertebrates were collected by compositing six D-frame kicks from riffles over the 100-meter sampling reach. Samples were preserved in 95-percent ethanol and taken back to the SRBC laboratory for subsampling and enumeration. Fish were collected using backpack electroshocking. All fish caught in the 100-meter reach were captured, identified to species, and returned to the stream. Game fish species were also weighed and measured.

Water quality data results were compared to water quality standards and levels of concern (Table 1). Sites were ranked for water quality as either severely, mildly, or non-impacted from AMD based on the water quality data analysis. Macroinvertebrate data analysis can be more complex in AMD-impacted communities because classically used metrics do not account for acidity or metal tolerances. For example, the Hilsenhoff Biotic Index (HBI) ranks macroinvertebrate taxa based on only their sensitivity to organic pollution. As a result, a sample taken in a heavily AMD-impacted

Field chemistry parameters (temperature, pH, conductivity, and dissolved oxygen) were measured instream using a YSI 6820 multi-parameter meter.

SRBC staff collecting fish in the headwaters of Drury Run using backpack electroshocking.

Table 1. Water Quality Standards and Levels of Concern for Aquatic Life

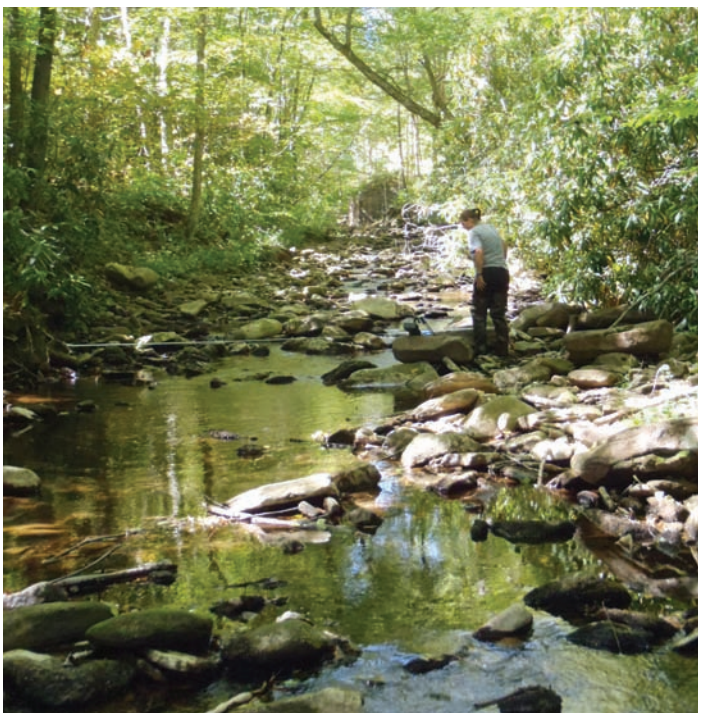
Parameter	Limit	Reference Code
Temperature	> 25 degrees	a,e
Dissolved Oxygen	< 4 mg/l	a,f
Conductivity	> 800 µmhos/cm	c
pH	< 6	a,b,e
Total Dissolved Solids	>500 mg/l	a,h
Total Aluminum	>0.75 mg/l	a
Total Iron	>1.5 mg/l	a
Total Manganese	>1.0 mg/l	a
Alkalinity	< 20 mg/l	a,f
Total Sulfate (drinking water)	> 250 mg/l	a
Hot Acidity	>0	d
Total Chloride	> 250 mg/l	a

Reference Code & References

a. http://www.pacode.com/secure/data/025/chapter93/s93.7.html
b. Gagen and Sharpe (1987) and Baker and Schofield (1982)
c. http://www.uky.edu/WaterResources/Watershed/KRB_AR/wq_standards.htm
d. Cravotta and Kirby (2004)
e. http://www.hach.com/h2ou/h2wtrqual.htm
f. http://sites.state.pa.us/PA_Exec/Fish_Boat/education/catalog/pondstream.pdf
g. http://www.epa.gov/waterscience/criteria/sediment/appendix3.pdf
h. http://water.usgs.gov/pubs/circ/circ1225/images/table.html
i. http://www.epa.gov/waterscience/criteria/wqcriteria.html

SRBC staff collects a water sample and takes a flow measurement in Drury Run during January 2010.

stream can be highly impaired and still have an excellent HBI score because the biological community is dominated by a couple of taxa that typically are intolerant to organic pollution yet acid tolerant. To better evaluate and account for impacts of AMD in the biological analysis, numerous other metrics were calculated in addition to the ones routinely used by SRBC. These included evenness, percent of taxa in each functional feeding group (i.e., scrapers, predators), similarity to reference, and community loss index (Table 2). Because the fish communities in both Drury Run and Birch Island Run were very simple and heavily dominated by brook trout, only richness and abundance measurements were used. Figures 2 and 3 depict a summary of water quality, macroinvertebrate, and fish conditions at each sampling location in Drury Run and Birch Island Run, respectively.



SRBC staff takes a flow measurement in Sandy Run.

Table 2. Explanation of Macroinvertebrate Analysis Tools

Taxonomic Richness: Total number of taxa in the sample. Number decreases with increasing stress.
Hilsenhoff Biotic Index: A measure of organic pollution tolerance. Index value increases with increasing stress.
EPT Index: Total number of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) taxa present in a sample. Number decreases with increasing stress.
Shannon-Wiener Diversity Index: A measure of the taxonomic diversity of the community. Index value decreases with increasing stress.
Percent Ephemeroptera: Percentage of number of Ephemeroptera (mayflies) in the sample divided by the total number of individuals in the sample. Percentage decreases with increasing stress.
Percent Chironomidae: Percentage of number of Chironomidae individuals out of the total number of macroinvertebrates in the sample. Percentage decreases with increasing stress.
Percent Contribution of Dominant Taxa: Percentage of the taxon with the largest number of individuals out of the total number of macroinvertebrates in the sample. Percentage increases with increasing stress.
Evenness: Measure of the relative abundance of the different species making up the richness of a population.
Percent Functional Feeding Groups: Percent of taxa that make up each functional feeding group, such as scrapers, grazers, shredders, and predators.
Jaccard Coefficient of Community Similarity: Estimates the degree of similarity between samples based on presence or absence of taxa.
Community Loss Index: Estimates the loss of taxa between comparison samples and reference samples.

All fish caught in the 100-meter reach were captured, identified to species, and returned to the stream. Game fish species were also weighed and measured.

Results/Discussion

AMD is composed of a complex set of elements that interact and affect aquatic life in various ways, but those overall effects are difficult to attribute to its separate, individual components (Earle and Callaghan, 1998). Toxicity is dependent upon many factors including discharge, pH, total acidity, and concentrations of dissolved metals. The overall effect of AMD is also dependent on the alkalinity or buffering capacity of the receiving streams. Unfortunately, the natural buffering capacity of Drury Run and Birch Island Run is quite low, which amplifies the impact of the AMD on the health of both streams.

In streams impacted by AMD, there are several common chemical signatures that indicate AMD pollution is present. Typically, one or more of the metals aluminum, manganese, or iron are found in concentrations far above water quality standards, pH is less than 5, alkalinity is near zero, hot acidity is greater than zero, and sulfate concentrations are greater than 20 mg/l. Some streams, like Birch Island Run, can have a naturally low pH and low alkalinity, and can sometimes be inaccurately assessed as being AMD-impacted.

Water Quality

Drury Run

The Drury Run Watershed originates out of the Tamarack Swamp in Leidy Township, Clinton County. The water quality at the outflow of Tamarack Swamp (DRUR 8.5) was typical for this type of environment, with elevated iron concentrations, a slightly acidic pH (6.1), elevated dissolved organic carbon, and little alkalinity. The acidity measured at this site was likely a product of tannic acids, not AMD, as the water was obviously colored by the presence of tannins in the upper reaches of Drury Run. As additional evidence, the AMD in the rest of the watershed was marked by high aluminum and manganese concentrations, neither of which was detected coming out of the swamp. One mile downstream on Drury Run (DRUR 7.8), water quality was slightly better as the effects of the swamp/bog are lessened. Iron was only above water quality standards during the June sampling event and pH ranged from 6.4 - 6.8.

The next downstream site showed no water quality impairment except for low buffering capacity, but it was net alkaline. Aluminum, iron, and manganese at DRUR 6.5 were below water quality standards year-round, sulfate concentrations were below 20 mg/l, and pH averaged 6.6. However, alkalinity was below the water quality standard of 20 mg/l throughout the sampling period. This was likely a natural condition in Drury Run and other similar nonimpaired streams in this region. The low buffering capacity alone in Drury Run would not be a problem if there were no AMD impairments entering the stream.

The sampling site DRUR 3.7 was directly above the confluence of Sandy Run into Drury Run. This site had the best water quality of any site in the Drury Run Watershed, even though alkalinity remained quite low. No metals exceeded water quality standards, there was no net acidity, and pH was almost neutral with an average of 6.7. Sulfate concentrations at each of the four sites above the confluence of Sandy Run were below 20 mg/l, indicating there was no impairment from AMD. This site is unique in that it is far enough below the Tamarack Swamp that any of those bog-related water quality effects are diluted out, and it is just above all AMD influences so it represents the best water quality in the watershed.

The tributary Sandy Run has one significant AMD discharge in its headwaters that degrades the conditions of Sandy Run itself and also impacts Drury Run. This discharge comes from the remnants of an abandoned deep mine (Discharge No. 5) and, although it is relatively small, does have tangible impacts on water quality and biota. Water samples were taken above and below the discharge as well as from the discharge itself. Another sample was taken at the mouth of Sandy Run to document how the discharge affects the entire tributary. Above Discharge No. 5, water quality met water quality standards for pH and metals, but had little natural buffering capacity with an alkalinity averaging 4 mg/l.

The slight acidity at Tamarack Swamp is likely a product of naturally occurring tannic acids.

Discharge No. 5 flowed year-round even under very low flow conditions in the fall. The maximum flow rate was 85 gallons per minute (gpm) in April. The water coming from Discharge No. 5 was quite polluted, with aluminum concentrations five times greater than the water quality standard, manganese concentrations seven times greater than water quality standards, and sulfate concentrations that averaged 200 mg/l over the four sampling events. Alkalinity was zero and pH was consistently around 4.0.

Although relatively small, AMD Discharge No. 5 has tangible impacts on water quality and biota.

Downstream of Discharge No. 5, Sandy Run became net acidic with zero alkalinity and pH dropped down to the 5.1 - 5.3 range. Aluminum was the only metal that remained above water quality standards downstream of the discharge but sulfate concentrations also reflected the AMD influence at greater than 25 mg/l. Table 3 shows a comparison of average concentrations of key AMD parameters within Drury Run.

The mouth of Sandy Run is about 1.5 miles downstream of where Discharge No. 5 enters the creek. At the mouth, visual evidence of aluminum precipitating out of the water column was noticeable with the presence of white-colored substrate. Because of the higher pH values at the mouth of Sandy Run, much of the aluminum that was in the water column upstream precipitated out downstream. Sandy Run had enough buffering capacity that at the mouth, the pH was close to water quality standards. The stream was slightly less acidic with an alkalinity of about 1 mg/l and a hot acidity of 5 mg/l.

Once Sandy Run joins Drury Run, there was an obvious mixing zone where the water from Sandy Run hovered along the left bank and white aluminum precipitate was evident on the substrate. The next sample site on Drury Run (DRUR 3.5) was downstream of this mixing zone and the water from Sandy Run was fully diluted with the non-impacted water from Drury Run. Water quality showed some degradation at this site, which is expected given Sandy Run's AMD influence. Drury Run below Sandy Run was net acidic with low buffering capacity. Sulfate concentrations were double what they were upstream but pH remained above the water quality standard in the range of 6.5 - 6.7.

Woodley Draft is a small tributary that flows through a steep gorge and joins Drury Run from the east, downstream of a small reservoir. This reservoir was created in the 1880s to provide water for railroad stops in the borough of Renovo and was later used as a back-up drinking water supply for the borough until the mid-1980s. Currently, the six-acre area is owned by Renovo as an in-holding within Sproul State Forest but is not being used for any specific purpose (D. D'Amore, personal communication, 2011).

The water quality in Woodley Draft indicated AMD influence, as alkalinity was zero and aluminum and manganese concentrations were greater than water quality standards during all sampling events. The pH of this water ranged from 4.3 - 4.5 and sulfate

Table 3. Average Concentrations of Key AMD Parameters in Drury Run

	Alkalinity mg/l	Hot Acidity mg/l	pH	Aluminum (diss/total) mg/l	Manganese mg/l	Sulfate mg/l
Drury – above all AMD	7.4	-2.3	6.7	PBQ/PBQ	0.0185	5.8
Sandy (mouth)	1.3	5.1	6.1	PBQ/0.217	0.1370	22
Woodley (mouth)	0	19	4.4	2.282/2.477	1.797	106
Whiskey (mouth)	0	45	4.1	4.884/5.039	4.295	186
Stony (mouth)	0	40	4.2	5.528/5.649	4.975	271
Discharge 5 (Sandy)	0	37	4.1	3.960/4.273	7.232	203
Discharge 16 (Stony)	0	36	4.3	4.813/4.849	2.872	175
Drury (mouth)	0.85	15.55	5.3	1.267/1.335	0.871	67

concentrations averaged 105 mg/l. Much of the aluminum was found in the dissolved form because of the low pH levels. However, because the flow was relatively small (270 gpm in high spring flows), Woodley Draft does not account for a large percentage of the AMD loading in Drury Run and should not be the first priority for treatment.

Whiskey Run is another small AMD-influenced tributary to Drury Run that comes in just downstream of Woodley Draft but entering from the west. This small tributary consists almost entirely of AMD as it exits the toe of Drury Ridge South Abandoned Mine Land (AML) site (PA0861). The water quality in this small tributary was worse than Woodley Draft, with pH ranging from 4.0 - 4.2, sulfate concentrations averaging 186 mg/l, and a hot acidity of 45 mg/l (Table 3). Whiskey Run is in a high gradient, steep channel with limited or no access to its headwaters so passive treatment would be quite difficult.

Whiskey Run is a small AMD-influenced tributary to Drury Run. Its steep channel would make passive treatment difficult.

Below both Woodley Draft and Whiskey Run, Drury Run showed some decline in water quality but the pH hovered around 6.0. A small amount of alkalinity remained due to the ratio of Drury Run flows compared to the inputs of Woodley Draft and Whiskey Run.

Stony Run is the last and largest tributary to Drury Run and is the cause of a majority of the AMD to the watershed. The water quality in Stony Run and its tributaries was severely degraded from the headwaters all the way to the mouth. STON 2.2 was net acidic with zero alkalinity. The concentrations of aluminum and manganese ranged from 3-5 times greater than the water quality standards, pH was 4.5, and sulfate concentrations averaged 140 mg/l. Three of the four tributary inputs to Stony Run (Slab Run, Kelly Run, and Discharge No. 16) had similar poor water quality with pH values of 4.1 - 4.5, metal concentrations up to 17 times the water quality standard for aluminum, and more than nine times the water quality standard for manganese. However, the unnamed tributary to Stony Run had considerably worse water quality than any of the other three tributaries. The AMD influence into Stony Run is mainly from groundwater, so pollutants are at their highest when flows are low in the late summer and fall. During September 2010, the unnamed tributary to Stony Run had the highest concentrations of aluminum (33.40 mg/l), manganese (45.0 mg/l), sulfate (1,361 mg/l), hot acidity (248 mg/l), total dissolved solids (1,902 mg/l), and the lowest pH (3.6) seen anywhere in Drury Run Watershed.

The mouth of Stony Run remains highly impacted by AMD as it accumulates all the upstream influences. The water quality at STON 0.1 was characterized by aluminum concentrations averaging 5.6 mg/l, a pH of 4.2, an average manganese concentration of nearly 5.0 mg/l, and a sulfate concentration of 270 mg/l. With this magnitude of pollution coming into Drury Run, which has already assimilated all the influences of Sandy Run, Woodley Draft, and Whiskey Run, it is easy to imagine why downstream of Stony Run, the cumulative effects are markedly apparent in Drury Run. The mainstem of Drury Run, downstream of Stony Run (DRUR 1.0), is able to assimilate and dilute some of the additional AMD from Stony Run but not all: aluminum concentrations remained double water quality standards, alkalinity was less than 1 mg/l, and the stream was net acidic.

The AMD loading in Drury Run is significant and can be easily attributed to its individual tributaries. The total AMD loading calculations shown below are based on the concentrations of pollutants and the flow of the stream or discharge. Overall, the AMD loading in Drury Run is primarily from Stony Run, which contributes 69 percent of the total loading. See Table 4 for a summary of the loading contributions of each of the four major AMD sources in Drury Run Watershed: Sandy Run, Woodley Draft, Whiskey Run, and Stony Run.

Table 4. Percent Contributions for Each AMD Tributary Source in Drury Run and Total AMD Loading

Tributary	Acidity Loading	Mn Loading	Al Loading	Total AMD Loading
Sandy Run	11	3	4	10
Woodley Draft	5	2	6	5
Whiskey Run	17	11	15	16
Stony Run	67	84	75	69
total lbs/day	**550**	**50**	**58**	**658**

Birch Island Run

The water quality data for the mainstem of Birch Island Run and its tributaries above the Little Birch Island Run confluence seem to indicate little or no influence of AMD but rather, a naturally low pH system with a naturally low buffering capacity. At the two upstream sites on Birch Island Run, pH was between 5.4 and 6.0, and alkalinity was less than 1 mg/l. Metals were below detection limits or else present at very low concentrations, and sulfate concentrations were less than 20 mg/l during every sampling event. Amos Branch and an unnamed tributary to Birch Island Run were also sampled. Both are above the confluence of Little Birch Island Run and both are characterized by low metal concentrations, sulfate concentrations less than 20 mg/l, pH between 5.7 and 6.2, and very low alkalinity.

A small unnamed tributary to Little Birch Island Run had double the water quality standard for total and dissolved aluminum and manganese concentrations, making Little Birch Run the only tributary to Birch Island Run with an identifiable source of AMD impairment.

Little Birch Island Run is the only tributary to Birch Island Run that has an identifiable source of AMD impairment. The upstream site on Little Birch Island Run (LBIR 2.0) is above the influence of AMD, and the water chemistry was similar to the rest of Birch Island Run, with a pH averaging 6.0, low sulfate concentration, low metals, and low alkalinity. About a half-mile downstream, a small unnamed, heavily impaired tributary enters Little Birch Island from the west. Total and dissolved aluminum and manganese concentrations were each more than double the water quality standard. Sulfate concentration averaged 255 mg/l for the year, pH ranged from 3.9 - 4.2, and alkalinity was zero. Downstream of this unnamed tributary, Little Birch Island Run is able to assimilate some of the AMD influences but there are obvious impacts compared to the upstream site. Downstream, numerous impaired seeps and small rivulets enter Little Birch Island between the LBIR 1.0 site and the mouth and only flow after wet weather events. The mining in Birch Island Run Watershed was primarily surface mining and as a result, conditions in Little Birch Island decline during wet weather events, as abandoned mine lands are saturated and overflow down slope into the waterway. Water quality conditions at the mouth of Little Birch Island were indicative of AMD impairment with sulfate concentrations averaging greater than 40 mg/l, no alkalinity, and a pH as low as 4.8.

The mouth of Birch Island Run is the only site along the mainstem that is impaired by AMD. Because of the low buffering capacity of Birch Island Run, the impacts from Little Birch Island can not be fully assimilated into Birch Island despite some dilution. Sulfate concentrations at the mouth averaged 25 mg/l, which is more than double any of the concentrations seen upstream on Birch Island. Overall, metals were below water quality standards but were considerably higher in the wettest sampling month of October, and pH values ranged from 5.6 - 5.9.

Little Birch Island Run

Macroinvertebrate Results

Macroinvertebrate communities are an excellent indicator of water quality conditions because they have limited mobility, relatively long residence times, and show varying degrees of sensitivity to pollutants. AMD can cause a reduction in diversity, abundance, and changes in community structure, both taxonomically and functionally (Simpson et al., 1985). Mayflies (Ephemeroptera) are one of the most sensitive groups of aquatic insects to low pH and AMD pollution. Mayflies that normally live in neutral waters experience a greater loss of sodium in their blood when exposed to low pH than do the acid-tolerant stoneflies *Leuctra* and *Amphinemura*, whose sodium uptake is only slightly reduced by low pH (Earle and Callaghan, 1998; Kimmel, 1999). Low pH also tends to eliminate scraper and grazer taxa that feed on algae, leaving AMD macroinvertebrate communities dominated by collectors, shredders, and predators. Therefore, the fauna of AMD-impaired streams are typically characterized by few or no mayfly genera, few scrapers, low taxa richness, and a dominance of *Leuctra* and *Amphinemura*. A community loss index was calculated for each site to estimate the loss of taxa at sites with AMD impairment (Figures 4 and 5). The higher the community loss index, the more taxa were absent compared to the reference site.

Figure 4. Community Loss Index Results for Drury Run Watershed (The higher the value, the more taxa were absent from the site compared to the reference site.)

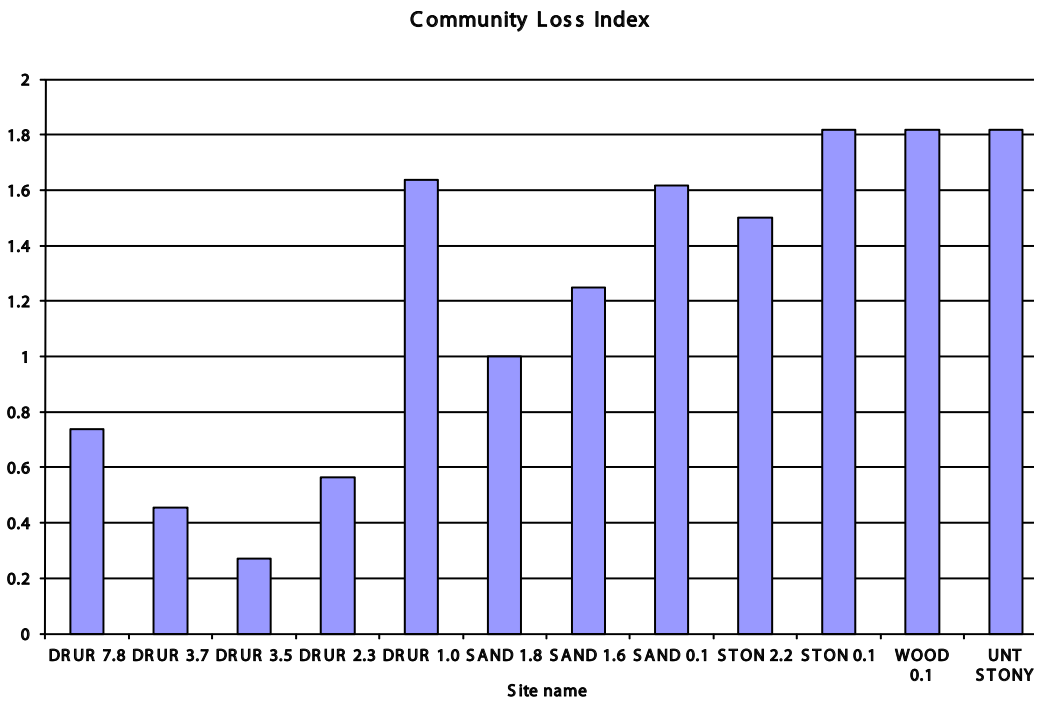
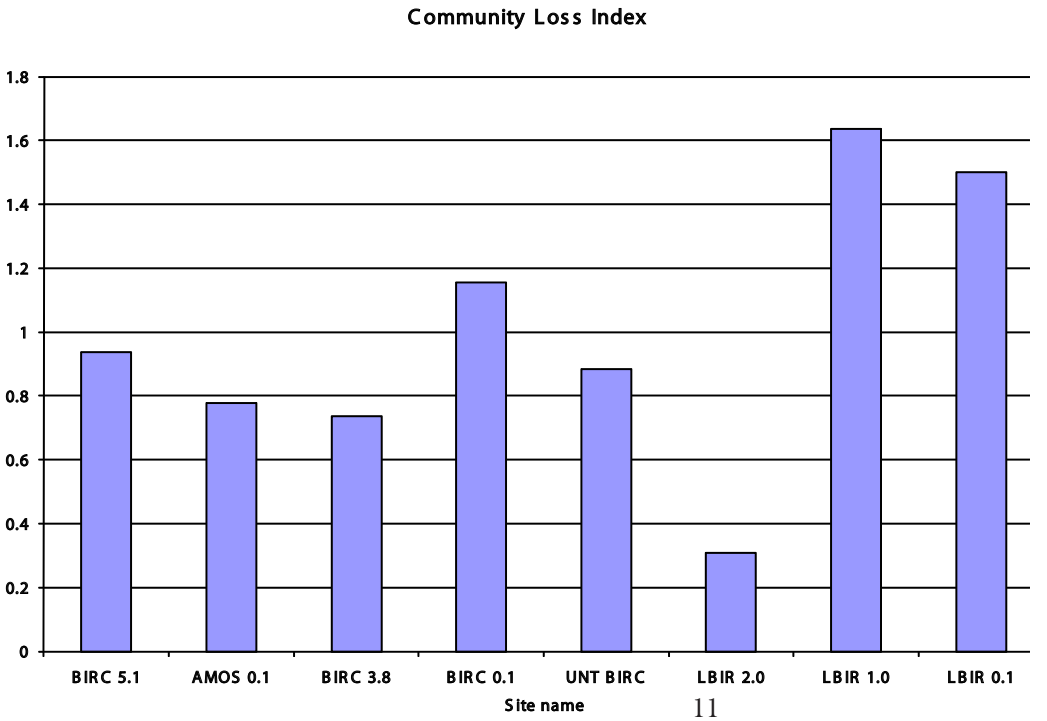


Figure 5. Community Loss Index Results for Birch Island Run Watershed (The higher the value, the more taxa were absent from the site compared to the reference site.)



Insects of the order Ephemeroptera are commonly known as Upwinged Flies or Mayflies. Mayflies are one of the most sensitive orders to AMD conditions.

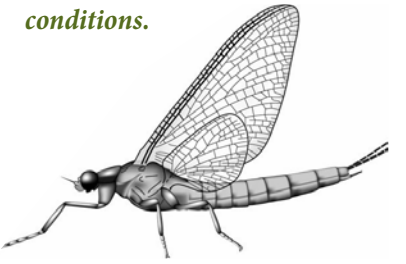


Image Credit: R.W. Holzenthal

Drury Run

In Drury Run, there were a wide variety of biological conditions. Because Drury Run originates in the Tamarack Swamp, the most upstream sampling location contained some obvious remnants of that environment such as tannins in the water, high iron concentrations, and sandy substrate despite the presence of a defined channel. The macroinvertebrate community at this location (DRUR 7.8) was slightly impaired, but the driving factor was likely habitat conditions as there was no evidence of acidic conditions or other AMD impairment. The next two downstream sites on Drury Run had nonimpaired biological communities, with one of the sites (DRUR 6.5) scoring as 85 percent of the best sites of similar drainage area in the entire West Branch Susquehanna Subbasin (Buda, 2010). Both of these sites had more than 40 percent mayfly taxa, high EPT, high species diversity, high evenness, and high taxa richness. Both of these sites were located above the AMD-impacted tributaries.

Downstream of Sandy Run, the first AMD-impacted tributary to enter Drury Run, the macroinvertebrate community continues to rank in the nonimpaired category but there are marked changes, specifically the sharp decline in percentage of mayfly taxa. Below Sandy Run, the biological community was less diverse, had a lower evenness that was dominated by acid tolerant stoneflies *Leuctra* and *Amphinemura* and was comprised of only 10 percent mayflies.

"...the greatest community loss occurred in the AMD-impacted tributaries and at the mouth of Drury Run (DRUR 1.0), downstream of all the AMD influence."

Farther down on Drury Run (DRUR 2.3), downstream of two other AMD inputs, Woodley Draft and Whiskey Run, macroinvertebrate communities were still ranked as nonimpaired. However, the evidence of AMD impacts are more obvious as mayfly taxa made up only 2 percent of the community, which was once again dominated by *Leuctra* and *Amphinemura*. Finally, at the mouth of Drury Run, downstream of all polluted tributaries, the cumulative effect of the impaired water quality was very evident. At this location, only 11 taxa were collected and there were fewer than 200 individuals in the whole sample. Species diversity was very low and mayflies made up less than 1 percent of the sample.

As expected, the sampled tributaries of Drury Run, which are all known to have some level of AMD impairment, had poor macroinvertebrate communities in general. The upstream sampling site on Sandy Run, above the AMD discharge, had the best macroinvertebrate community of all the tributary sites, and it was the only tributary site to have any mayfly taxa at all. The remaining six tributary sites all were devoid of mayfly populations, were dominated by *Leuctra* and *Amphinemura*, and had taxa richness ranging from 11-16. This was not unexpected based on the quality of the water. Stony Run is the most heavily impacted tributary, and its macroinvertebrate communities reflected that as tributaries had pH ranging from 4-5. Figure 4 shows the community loss index value for each stream sampling location compared to DRUR 6.5, which had the best macroinvertebrate community scores in the watershed. It is easy to see that the greatest community loss occurred in the AMD-impacted tributaries and at the mouth of Drury Run (DRUR 1.0), downstream of all the AMD influence.

Birch Island Run

The upper reaches of Birch Island Run are naturally acidic, with pH values in the 5.5 - 6.0 range. No other water quality parameter indicates any AMD impacts, but the macroinvertebrate community shows some similar characteristics because of the acidic nature of the water. BIRC 5.1, AMOS 0.1, and BIRC 3.8 all ranked as slightly impaired with a community composition that included very few mayfly taxa, a low similarity to reference conditions, and low species diversity. At BIRC 1.0, which is directly above the confluence with Little Birch Island Run, macroinvertebrate conditions were also ranked as slightly impaired; however, at this site, 20 percent of the sample were mayflies. There was a high level of evenness and increased taxa richness. Overall, this site compared favorably (75 percent) to the best sites of similar drainage size in the entire West Branch Susquehanna River Watershed (Buda, 2010). However, the conditions one mile downstream at the mouth of Birch Island Run were far different after the addition of AMD-impacted waters from Little Birch Island Run. BIRC 0.1 was rated as moderately impaired with lower taxonomic richness than the headwaters: no mayfly genera, low diversity, and 80 percent of the sample was comprised of acid-tolerant stoneflies.

Little Birch Island Run itself has a similar pattern of a nonimpaired macroinvertebrate community quickly shifting to an impaired community as polluted waters make their way into the stream. LBIR 2.0 was nonimpaired and, despite its low number of mayflies, this site had the highest taxa richness of the whole watershed, high EPT, and high species diversity. One mile downstream and below one AMD outflow, only half the number of taxa were found, the community was again dominated by acid tolerant stoneflies, and no mayflies at all were collected. At the mouth of Little Birch Island, one more mile downstream and incorporating further AMD issues, the macroinvertebrate community had the lowest taxa richness in the whole watershed, no mayfly taxa, the lowest EPT score, and was dominated by two taxa. Both LBIR 1.0 and LBIR 0.1 scored as moderately impaired. Figure 5 shows the Community Loss Index values for Birch Island Run. The higher the value, the more taxa were absent when compared to BIRC 1.0, which was used as the reference site for the Birch Island Run Watershed.

Fish

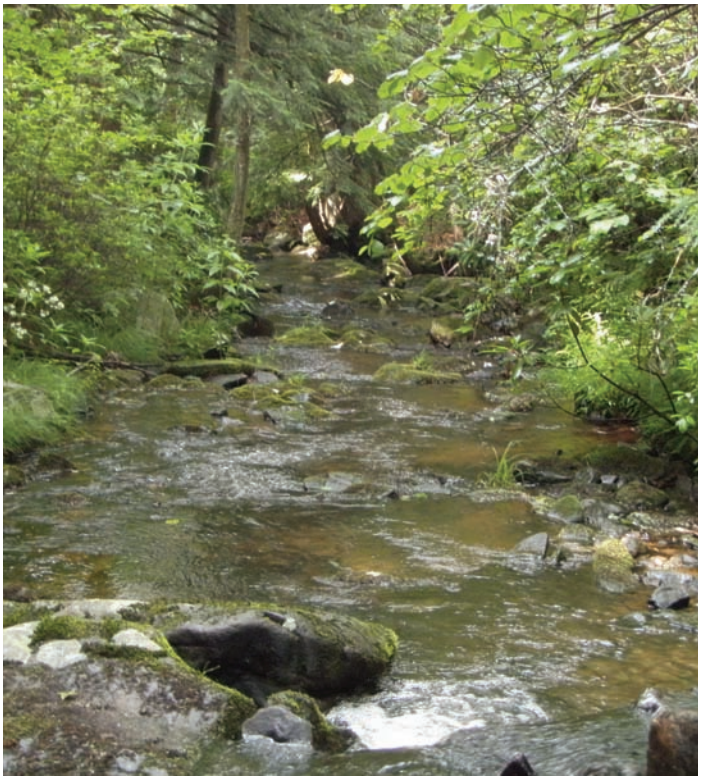
Fish sampling was conducted in both Drury Run and Birch Island Run in June 2010. Sampling results reflected water quality and were indicative of natural conditions as well as AMD-impacted ones. Cooper and Wagner (1973) studied the distribution of fish in Pennsylvania streams affected by AMD and found that fish species were severely impacted at pH 4.5 - 5.5. They found that a pH of 4.5 and total acidity of 15 mg/L accounted for a complete loss of fish in 90 percent of streams studied. While some fish species, such as brook trout, *Salvelinus fontinalis*, are very tolerant of low pH, the addition of metals decreases that tolerance (Earle and Callaghan, 1998).

Drury Run

In the upper nonimpaired reaches of Drury Run, fish communities were most diverse and can be considered typical for small headwater streams in this region. At the most upstream site, three species were collected: creek chub *(Semolitus atromaculatus*), eastern blacknose dace (*Rhinichthys atratulus*), and brook trout. Directly upstream and downstream of Sandy Run, four species were collected: sculpin (*Cottus spp.*), brook trout, brown trout (*Salmo trutta)*, and eastern blacknose dace. However, fewer numbers of these species were collected below the input of Sandy Run. Downstream of Woodley Draft and Whiskey Run, only brook trout were collected, and downstream of Stony Run, no fish were present due to the severely degraded water quality conditions.

On Sandy Run above the AMD discharge, the water quality was suitable to support brook trout despite a low pH and low buffering capacity. However, in the reach below the discharge, no fish were collected. The poor water quality coming from the discharge isolates the brook trout population above it. At the mouth of Sandy Run, four brook trout were captured, but they likely came up from Drury Run and only use Sandy Run when conditions are favorable. Stony Run supports no fish at all.

While some fish species, such as brook trout (pictured above), are very tolerant of low pH, the addition of metals decreases that tolerance (Earle and Callaghan, 1998).



The natural buffering capacity of Drury Run (above) and Birch Island Run is quite low, which amplifies the impact of the AMD on the health of both streams.

Brook trout was the dominant species in the Drury Run Watershed, and they ranged in size from 2 inches to 7 inches in length. Of the five brown trout that were collected, two were more than 9 inches long.

Birch Island Run

The fish community in the Birch Island Run Watershed was made up by almost entirely brook trout, except for the eight sculpins collected on the lower mainstem of Birch Island Run. One smallmouth bass was caught at the mouth of Birch Island Run but was likely a non-resident that used Birch Island Run marginally as a source of food. The upper sites on Birch Island Run had naturally low pH, which excluded the viability of most fish species other than brook trout. However, at BIRC 1.0, directly above the confluence with Little Birch Island, the pH was high enough and the alkalinity had improved enough to also support a population of sculpins. Little Birch Island only supports brook trout and the numbers were fairly high despite the poor water quality, as brook trout can tolerate low pH, low alkalinity, and high metal concentrations. More than 120 brook trout were collected at the eight stream locations sampled in the Birch Island Run Watershed and ranged from two to eleven inches in length.

Improving water quality conditions in Birch Island Run and Drury Run would certainly improve the brook trout fishery and would allow more connectivity with the West Branch Susquehanna River.

Restoration Priorities and Recommendations

Drury Run

In the Drury Run Watershed, Sandy Run and Stony Run are recommended as priority restoration projects. Stony Run contributes a majority of the total AMD loading but because its impacts are coming mainly from diffuse groundwater sources and not a surface discharge, it would be more difficult to treat. Sandy Run contributes only 10 percent of the watershed AMD loading; however, Discharge No. 5 is the first discharge in the watershed and a large section of Sandy Run and Drury Run could be restored upon its treatment.

The discharge on Sandy Run (Discharge No. 5) can be characterized as a low-moderate flow, acidic discharge that contains slightly elevated concentrations of aluminum and manganese. Sandy Run itself contains almost no buffering capacity, so the input from Discharge No. 5 has immediate detrimental effects on the water quality and biology of Sandy Run. The recommended treatment for Sandy Run would include an oxic limestone drain (OLD) followed by a small settling pond or wetland. The cost associated with this treatment would be approximately $150,000 for capital costs and up to $7,000 per year in operation and maintenance costs. The implementation of this system could potentially restore nearly 2 miles of Sandy Run and 0.5 miles of the mainstem of Drury Run. In addition, it would significantly improve the assimilation capacity of Drury Run to handle the AMD inputs of Woodley Draft and Whiskey Run. Not only would water quality be improved, but the brook trout population that is currently isolated above Discharge No. 5 could be reconnected to Drury Run, and brook trout could be restored to the entirety of Sandy Run.

AMD water flows into the oxic limestone drain (OLD) and dissolves limestone, which increases the alkalinity and pH of the water.

Stony Run presents different challenges. There are limited surface AMD discharges within the Stony Run Watershed. Past mining practices in the area have polluted the groundwater, and that heavily impacted groundwater is the dominant source of impairment to Stony Run. Treatment of the surface stream water is the only viable method to treat Stony Run for improving water quality conditions prior to entering Drury Run. A lime dosing silo on Stony Run could neutralize acidic conditions enough to allow for attainment of water quality standards in the mainstem of Drury Run. Capital costs for the lime dosing silo are estimated at $125,000, in addition to an annual cost of $9,000 for hydrated lime product to refill the silo each year. This will not restore Stony Run, but it should considerably improve conditions in Stony Run and restore the final mile of Drury Run.

Upon completion of any restoration activities, water quality monitoring would be recommended to assess the conditions of Drury Run from the confluence of Sandy Run to the mouth. If water quality standards are not met and biological communities still show impacts, then two additional restoration opportunities would be recommended. Woodley Draft and Whiskey Run could be treated with similar lime dosing silos as described for Stony Run, at a slightly lower costs based on the lower AMD loading produced by these smaller tributaries. Passive treatment could be a potential option in the headwaters of Whiskey Run; however, difficult access and steep topography limit the possibilities.

In all, the four recommended restoration activities could result in the restoration of 11.2 stream miles in the Drury Run Watershed, and the removal of those miles from the Integrated List of Impaired Waters. In addition, water quality conditions for an additional 8.9 miles of stream would be improved. The total capital costs are estimated at $520,000, with annual costs of just under $20,000.

Birch Island Run

Treatment of the AMD in Little Birch Island is a difficult problem since there is not one primary source, but many small sources. The recommended option is to add alkalinity into Little Birch Island Run so it can assimilate the AMD loading that is coming from these many sources. As a result, a lime dosing silo either on or above the unnamed tributary to Little Birch Island Run would meet this need. It would improve the water quality conditions for the last mile of Birch Island Run mainstem, and improve the connectivity of biological communities from the West Branch Susquehanna River and Birch Island Run. However, it would not restore Little Birch Island Run to water quality standards. But before this can happen, more data need to be collected to better characterize the acidity loading from these AMD sources. Previous sampling results from PADEP show a much higher acidity loading than more recent SRBC data. Accurate loadings are necessary before any treatment can begin, as costs for treatment are based on loading. The current discrepancy between PADEP and SRBC data, which could be due to seasonal variations or differences in stream flow, needs to be further assessed to avoid a miscalculation of the cost of treatment options.

Additionally, of the five AML features in the Little Bougher Run AML site, three remain un-reclaimed due to their designation as Priority III – Dry Strip Mines. These strip mines could be hydrologically connected to the seeps that are impacting Little Birch Island Run downslope. A recommended course of action would include coordinating with the PADEP– Moshannon District Mining Office on possible reclamation of these three Priority III features.

Conclusions

Except for the lingering water quality effects from old mining operations, Drury Run and Birch Island Run are two relatively undisturbed and pristine forested watersheds within the West Branch Susquehanna Subbasin. By focusing on the remediation of the few problem areas in each of these watersheds, clean water and healthy aquatic ecosystems can be restored throughout these streams. Not only will restoration efforts contribute to the overall restoration of the West Branch Susquehanna River but they will also improve the local brook trout fishery in both Drury Run and Birch Island Run. SRBC staff is currently pursuing funding opportunities to begin some of the proposed restoration work and are looking to partner with other organizations in this effort.

Appendix A

Station ID	County	USGS Quad	Latitude	Longitude	Site Description
BIRC000.1-4177	Clinton	Snowshoe NW	41.19650	-77.97560	Mouth of Birch Island Run
BIRC001.3-4177	Clinton	Snowshoe NW	41.20328	-77.99425	Birch Island Run above Little Birch Island Run
BIRC003.8-4178	Clinton	Pottersdale	41.22356	-78.02728	Birch Island Run downstream of Amos Branch
BITR000.1-4178	Clinton	Pottersdale	41.23267	-78.01613	Mouth of unnamed tributary to Birch Island Run
BIRC005.1-4178	Clinton	Pottersdale	41.23028	-78.04252	Birch Island Run above Amos Branch
AMOS000.1-4178	Clinton	Pottersdale	41.22457	-78.03047	Mouth of Amos Branch
LBIR000.1-4177	Clinton	Snowshoe NW	41.20212	-78.99516	Mouth of Little Birch Island Run
LBTR000.1-4178	Clinton	Pottersdale	41.19620	-78.01803	Mouth of unnamed tributary to Little Birch Island Run
LBIR001.0-4178	Clinton	Pottersdale	41.19628	-78.00862	Little Birch Island Run downstream of unnamed tributary
LBIR002.0-4178	Clinton	Pottersdale	41.20118	78.02824	Little Birch Island Run upstream of unnamed tributary
DRUR008.5-4177	Clinton	Tamarack	41.41394	-77.83613	At the outflow of Tamarack Swamp
DRUR007.8-4177	Clinton	Tamarack	41.40734	-77.83538	Headwaters of Drury Run along Rt. 144
DRUR006.5-4177	Clinton	Tamarack	41.38274	-77.83426	Drury Run along Rt. 144
DRUR003.7-4177	Clinton	Renovo	41.35948	-77.81413	Drury Run directly upstream of Sandy Run
DRUR003.5-4177	Clinton	Renovo	41.35948	-77.81431	Drury Run downstream of Sandy Run
DRUR002.3-4177	Clinton	Renovo	41.34159	-77.79605	Drury Run downstream of Woodley Draft and Whiskey Run
DRUR001.0-4177	Clinton	Renovo	41.33629	-77.78462	Drury Run near mouth
SAND000.1-4177	Clinton	Renovo	41.36005	-77.81345	Mouth of Sandy Run
STON000.1-4177	Clinton	Renovo	41.33852	-77.78555	Mouth of Stony Run
SAND001.8-41.77	Clinton	Tamarack	41.38052	-77.80850	Sandy Run upstream of Discharge 5
SANDD01.0-4177	Clinton	Tamarack	41.37969	-77.80870	Discharge 5
SAND001.6-4177	Clinton	Tamarack	41.37908	-77.80936	Sandy Run downstream of Discharge 5
WOOD000.1-4177	Clinton	Renovo	41.35355	-77.80856	Mouth of Woodley Draft
WHIS000.1-4177	Clinton	Renovo	41.34360	-77.79971	Mouth of Whiskey Run
STON002.2-4177	Clinton	Renovo	41.36443	-77.78256	Stony Run upstream of Slab Hollow
SLAB000.1-4177	Clinton	Renovo	41.36442	-77.78345	Mouth of Slab Hollow
KELL000.1-4177	Clinton	Renovo	41.35784	-77.78199	Mouth of Kelly Hollow
STTR000.1-4177	Clinton	Renovo	41.35026	-77.79074	Mouth of western unnamed tributary to Stony Run
STOND01.0-4177	Clinton	Renovo	41.34621	-77.78619	Discharge 16

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