Susquehanna River Basin Commission

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Middle Susquehanna Subbasin Year-2 Survey

Introduction

The Susquehanna River Basin Commission (SRBC) performed a water quality survey in the Lackawanna River Watershed from April 2009–April 2010 for the Year-2 small watershed study in the Middle Susquehanna Subbasin (Figure 1). Year-1 and Year-2 surveys are part of SRBC's Subbasin Survey Program, which is funded by the United States Environmental Protection Agency (USEPA). This program consists of two-year assessments in each of the six major subbasins in 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. 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 Middle Susquehanna Year-1 study from June-August 2008 (Buda, 2009). 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 http://www.srbc.net/programs/subbasinsurveys.htm, and technical reports are available in hard copy or online at www.srbc.net/pubinfo/techdocs/Publications/techreports.htm.

The Lackawanna River Watershed was chosen for a small watershed study in the Middle Susquehanna Subbasin because of local support from the Lackawanna River Corridor Association (LRCA), as well as interest by local and state government agencies. In 2001, LRCA developed a Rivers Conservation Plan (RCP) for the Lackawanna River Watershed. This plan examines the conditions of the watershed related to ecological health of land and water resources, as well as issues related to open space, recreation, aesthetics, and public infrastructure. To date, abandoned mine drainage (AMD) is the issue that has received the most attention and funding, but the RCP also pointed out that stormwater and combined sewer overflows (CSOs) are important concerns throughout the watershed that should be considered and addressed. SRBC agreed and chose to focus this Year-2 project on the impacts of stormwater runoff and CSOs on the water quality in the Lackawanna River Watershed and its tributaries.

An additional motivation in pursuing this project on stormwater was SRBC's involvement in and experiences from a large-scale stormwater retrofitting and management project in the Harrisburg, Pa., area. As part of that three-year stormwater initiative, SRBC built in the idea of transferability to other areas of the state. The baseline data collection work in the Lackawanna River Watershed will be important as local municipalities continue to deal with the many issues associated with controlling stormwater in urban areas.

The Lackawanna River Watershed

The Lackawanna River Watershed encompasses about 350 square miles in the northeastern portion of the Susquehanna River Basin (Figure 1). The Lackawanna River flows nearly 60 miles in four counties of northeastern Pennsylvania to its confluence with the Susquehanna River. It originates in a series of glacial ponds and a wetland bog complex along the border of Susquehanna and Wayne counties (LRCA, 2001). The east and west branches of the Lackawanna River flow into the reservoir at Stillwater Dam, the outflow of which begins the mainstem Lackawanna. The river then flows 40 miles in a northeast to southwest direction through Forest City, Carbondale, Scranton, and down to its mouth at Pittston, Pa. The lower 20 miles of river and 200 square miles of drainage area are located in the greater Scranton region and are highly urbanized (Figure 2). There are more than 60 tributaries to the Lackawanna that rise from the surrounding mountains and flow through gaps to join the mainstem (LRCA, 2001).

Small Watershed Study: Lackawanna River

An Assessment of Water Quality in Base Flow and Stormflow Conditions

April 2009 - April 2010

Report by Luanne Steffy, Aquatic Biologist

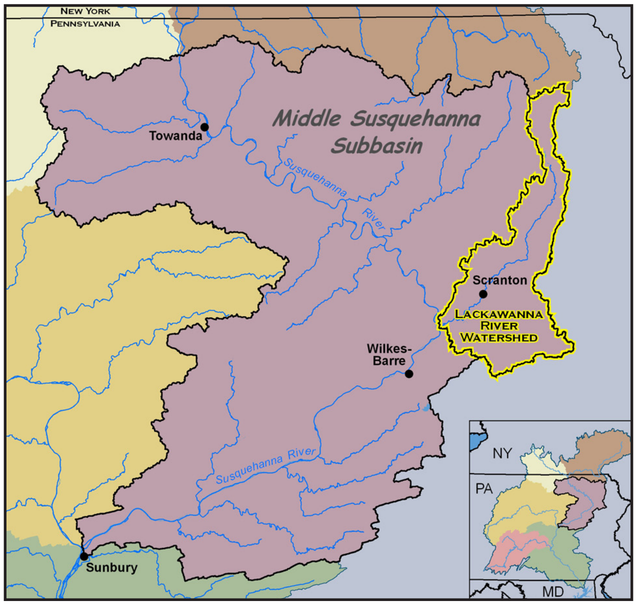

Figure 1. Location of Lackawanna River Watershed within the Middle Susquehanna Subbasin

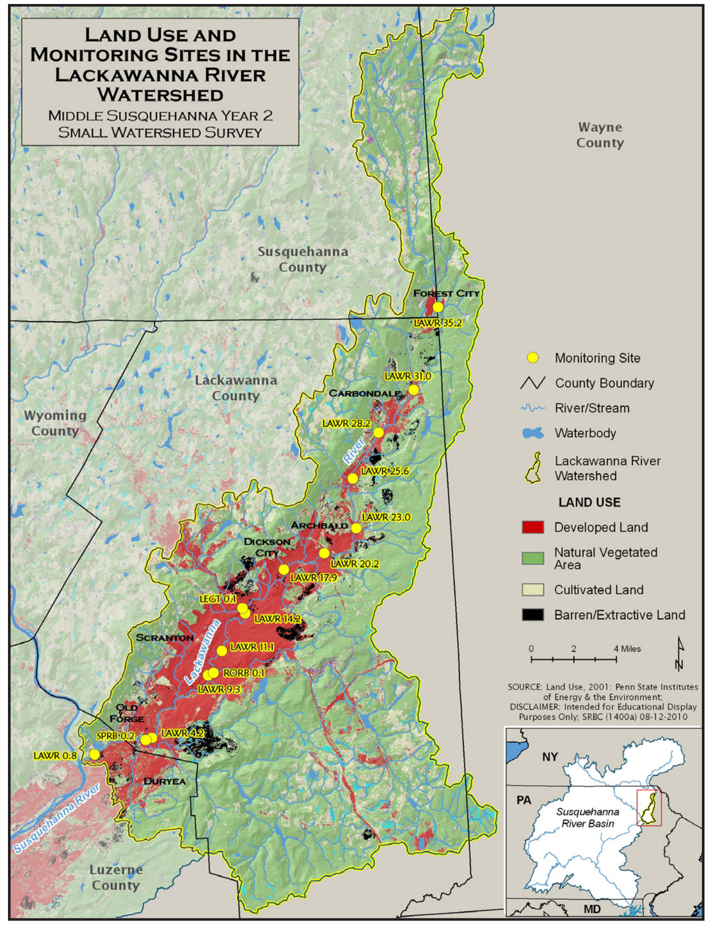

Figure 2. Sampling Site Locations and Land Use for the Lackawanna River Watershed

Overall, the land use of the Lackawanna River Watershed is 17 percent urbanized, with almost all of that urban development surrounding the river corridor through the greater Scranton area (Figure 2). Forested land makes up about 63 percent of the watershed, while agriculture constitutes the only other large land use category, with 14 percent. The remaining area is a mixture of wetlands, quarries, and industrial land uses. The Lackawanna River Watershed has numerous water quality issues, including AMD, urban stormwater runoff, and CSOs.

Table 1. Sampling Site Descriptions

Station ID	County	Latitude	Longitude	Site Description
LAWR 0.8	Luzerne	41.346149	-75.780512	Mouth of Lackawanna River at Coxton Rd. bridge near Duryea
LAWR 4.2	Lackawanna	41.356988	-75.728306	Lackawanna River at 3rd St. bridge in Old Forge
LAWR 9.3	Lackawanna	41.399321	-75.676498	Lackawanna River downstream of Roaring Brook at Elm St. bridge
LAWR 11.1	Lackawanna	41.415838	-75.663501	Lackawanna River above downtown Scranton at Olive St.
LAWR 14.2	Lackawanna	41.441191	-75.642104	Lackawanna River at Parker St. bridge
LAWR 17.9	Lackawanna	41.470717	-75.606289	Lackawanna River at West Lackawanna St. bridge in Olyphant
LAWR 20.2	Lackawanna	41.481461	-75.569132	Lackawanna River at Bridge St. near Jessup
LAWR 23.0	Lackawanna	41.498378	-75.539884	Lackawanna River in Archbald at Gilmartin St. bridge
LAWR 25.6	Lackawanna	41.532299	-75.542018	Lackawanna River near Mayfield at Poplar St.
LAWR 28.2	Lackawanna	41.563387	-75.517977	Lackawanna River downstream of Carbondale at Pike St.
LAWR 31.0	Lackawanna	41.592147	-75.485436	Lackawanna River upstream of Carbondale at Morse St. bridge
LAWR 35.2	Wayne	41.648456	-75.461715	Lackawanna River upstream SR247 bridge near Forest City
RORB 0.1	Lackawanna	41.400881	-75.671582	Mouth of Roaring Brook at South Washington St. bridge
LEGT 0.1	Lackawanna	41.444809	-75.644511	Mouth of Leggetts Creek at Wells St.
SPRB 0.2	Lackawanna	41.355670	-75.734171	Mouth of Spring Brook at Main St. in Moosic

In addition to twelve mainstem Lackawanna River sites, three tributaries (Leggetts Creek, Roaring Brook, and Spring Brook) were sampled as part of this project. (The number after the river abbreviation denotes the river mile from the mouth where the station was located — i.e., LAWR 23.0 is 23 miles upstream from the mouth of the Lackawanna River.)

The sampling sites listed in Table 1 were selected so SRBC staff could collect water quality samples during two storms and one baseline period throughout the urbanized portion of the Lackawanna River Watershed. The data from this assessment will provide valuable water quality information to SRBC and other interested parties, including LRCA, Lackawanna Heritage Valley Authority (LHVA), Pennsylvania Department of Environmental Protection (PADEP), and Lackawanna County Conservation District (LCCD).

Combined Sewer Overflows

Combined sewer systems were designed to collect rainwater runoff, domestic sewage, and industrial waste in the same pipe. During periods of rainfall, the wastewater volume in a combined system can exceed the capacity of the system or the treatment plant. When this capacity is exceeded, the excess wastewater flows directly into nearby streams and rivers. This typically occurs during heavy or extended rain events but can happen as a result of very little rain. These overflows can contain not only stormwater but also untreated human sewage, industrial waste, toxic materials, and other debris. This small watershed study focuses on stormwater and the impacts of CSOs on water quality during high flow events.

As of June 2010, more than 130 CSOs are still active and can discharge into the Lackawanna River and its tributaries between Carbondale and Old Forge, Pa., during rain events. In addition, surface stormwater flows over land, across un-vegetated mine spoil piles and contributes to excessive particulate sedimentation and further degraded water quality (LRCA, 2001).

Combined sewer overflow systems have been a priority of federal and state water quality regulators for the past 20 years. In 1994, USEPA published a national framework for the control of CSOs, which, in 2000, was incorporated into the Wet Weather Water Quality Act. In 2008, PADEP Bureau of Water Standards and Facility Regulation published the Pennsylvania Combined Sewer Overflow Policy.

CSOs continue to be a concern in many older cities, including the greater Scranton area, because of the considerable resources and time needed to completely rework an area's wastewater infrastructure. However, a substantial amount of money has been invested already in the Lackawanna River Watershed to fix the problems related to CSOs. For example, over the past ten years, the Lackawanna River Basin Sewer Authority (LRBSA) has completed numerous projects at the Throop wastewater treatment plant in Dickson City. These improvements include automatic mechanical screening to remove solids and debris, additional chlorine disinfection to reduce fecal coliform, eliminating one CSO discharge by rerouting the flow back to the treatment plant, and installing a remote monitoring system to alert facilities of possible overflows. Other improvements within the LRBSA include standby emergency generators to maintain operation in the event of power loss, a wet weather treatment system, updated interceptors, and manhole improvements. Additionally, for local citizens concerned about stormwater, LRCA has information about rain gardens, downspout disconnection, and rain barrels on its web site (www.lrca.org).

Methods

Between July 2009 and March 2010, SRBC staff collected base flow and stormflow water quality samples at 15 locations within the Lackawanna River Watershed. Macroinvertebrate samples also were collected at four locations in July 2009. Table 1 contains a list of station names, sampling location descriptions, drainage areas, and latitude and longitude coordinates for each of these sites. Given the number of CSOs in the watershed (more than 130), it is not feasible to sample at all of them during

Table 2. Water Quality Standards and Levels of Concern and References

Parameter	Limit	Reference
Temperature	> 25 degrees	a,e
Dissolved Oxygen	< 4 mg/l	a,f
Conductivity	> 800 µmhos/cm	c
pH	< 5	b,e
Total Suspended Solids	> 15 mg/l	g
Total Dissolved Solids	>500 mg/l	a,h,i
Total Organic Carbon	> 10 mg/l	j
Total Nitrogen	> 1.0 mg/l	h
Total Phosphorus	> 0.1 mg/l	d, k
Total Copper	> 200 ug/l	i
Total Iron	>1.5 mg/l	a
Total Lead	>65 ug/l	n
Total Zinc	>120 ug/l	n
Total Aluminum	0.75 mg/l	a.
Total Cadmium	>5 ug/l	i
Total Chromium	>100 ug/l	n

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. http://www.uky.edu/WaterResources/Watershed/KRB_AR/krww_parameters.htm
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.dec.state.ny.us/website/regs/part703.html
j. Hem (1970) – http://water.usgs.gov/pubs/wsp/wsp2254/
k. http://water.usgs.gov/nawqa/circ-1136/h6.html#NIT
l. http://www.epa.gov/waterscience/criteria/wqcriteria.html
m. EPA (2002), EPA 822-R-02-038
n. http://www.mde.state.md.us/Programs/WaterPrograms/TMDL/wqstandards/index.asp

a storm event. Sampling sites were selected so SRBC staff could collect water quality data upstream and downstream of major urban areas and bracket as many clusters of CSOs as possible. The farthest upstream site was chosen to be a reference site, as it was located in a mainly forested area and north of the greater Scranton metro area.

Base flow samples were collected instream, when possible, for field and laboratory water quality parameters and stream discharge. Water was collected using a hand-held, depth integrated sampler at six verticals across the stream channel. At locations where stream entry was not possible, a depth-integrated bridge sampler was used. The water was composited into a churn splitter and mixed thoroughly before filling sample bottles for laboratory analysis. Table 2 lists the parameters analyzed in this study, which included nutrients, metals, and other pollutants. The remaining water was used to measure field chemistry parameters: water temperature, pH, dissolved oxygen, conductivity, and turbidity. Stream discharge was measured using a FlowTracker according to U.S. Geological Survey (USGS) methods (Buchanan and Somers, 1969).

These water quality parameters were chosen to incorporate the constituents expected to be found in stormwater runoff and CSO discharges. These included nutrients, indicators of organic pollution, and metals. Also listed are the references for the water quality standards and levels of concern that were used for analysis.

Macroinvertebrates were surveyed to provide a biological assessment of the aquatic habitat conditions in the watershed. Macroinvertebrates were collected at a subset of the sites using a modified version of Rapid Bioassessment Protocol (RBP) III (Barbour and others, 1999). Two kicks were done using a one-meter kick screen net in the best available riffle habitat. All material collected was composited into one sample and preserved in the field with 90 percent ethanol for later lab processing and identification. Since only four macroinvertebrate samples were collected, results were compared to reference sites of a similar drainage size as determined by the Middle Susquehanna Subbasin Survey, which was completed in 2008 (Buda, 2009). Table 3 gives an explanation of the metrics used to evaluate the macroinvertebrate data. An assessment of physical habitat also was completed for all sampling locations where macroinvertebrates were collected.

SRBC Aquatic Biologist collecting a water sample.

Table 3. Explanation of Macroinvertebrate Metrics

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.

PERCENT EPHEMEROPTERA: Percentage of number of Ephemeroptera in the sample divided by 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.

EPHEMEROPTERA, PLECOPTERA, TRICHOPTERA INDEX (EPT INDEX): Total number of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) taxa present in a sample. Number decreases with increasing stress.

PERCENT CHIRONOMIDAE: Percentage of number of Chironomidae individuals out of total number of macroinvertebrates in the sample. Percentage increases with increasing stress.

SHANNON-WIENER DIVERSITY INDEX: A measure of the taxonomic diversity of the community. Index value decreases with increasing stress.

Storm samples were collected during December 2009 and March 2010. When possible, staff collected two samples at each site during the duration of the rain event with the goal of obtaining one sample on the rise and one sample as close to peak flow as possible. Samples were collected from bridges during storm events, and the water was processed in the same manner as described above for the base flow samples. Instantaneous flow data from three USGS gages on the Lackawanna River were used to determine flows and estimate when samples should be taken at each sampling location.

In addition to base flow and storm sampling, staff also deployed YSI water quality sondes on numerous occasions to gather continuous water chemistry data over a one- or two-week period that included a rain event. These instruments are designed to be deployed in the river on a long-term (weeks to months) basis and collect data at set intervals over that time frame. These sondes were calibrated in the laboratory prior to deployment and were set to collect data every 15 minutes for pH, dissolved oxygen, conductance, temperature, and turbidity.

Results

Base Flows

Base flow samples were collected in baseline conditions after there had been no significant rainfall for more than 10 consecutive days. Thirteen samples were taken on July 28-29, 2009, and the remaining three samples were collected on September 10, 2009, under very similar flow conditions. Only 8 percent of the parameters tested for all the sites exceeded water quality standards or levels of concern. During base flow, total phosphorus and total nitrogen were the two parameters that most consistently were above levels of concern for aquatic life. According to a USGS report (USGS, 1999), total phosphorus concentrations above 0.1 mg/l and total nitrogen above 1.0 mg/l are considered to be above natural background levels and are likely anthropogenically affected. This nitrogen and phosphorus can come from numerous sources, including effluent from wastewater treatment plants. Excess nutrients are harmful to streams, as high levels can lead to eutrophication. This abundant growth of algae and aquatic plants that may develop in nutrient-rich waters is often unsightly and decreases the value of waterbodies for recreation, fishing, and aesthetic enjoyment. Decomposing vegetation consumes large quantities of oxygen, which can lead to fish kills, foul odors and tastes, and increased water-treatment costs. Eight sites in the Lackawanna showed a concentration of total phosphorus above 0.1 mg/l and six of these sites (plus one additional site) also had total nitrogen concentrations above 1.0 mg/l during the baseline conditions.

Total aluminum was below the water quality standard (0.75 mg/l) at all sites during base flow, and iron was only above the water quality standard (1.5 mg/l) at the mouth of the Lackawanna River, which is expected since this site is downstream of the Old Forge borehole discharge. Total organic carbon (TOC), total dissolved solids (TDS), total suspended solids (TSS), zinc, and lead were all either under levels of concern or not detected at all. All sample results for copper, chromium, cadmium, and oil and grease came back below detection limits for the base flow sampling. Water temperature at all sampling locations was below 25°C, and dissolved oxygen levels varied from 5.7-9.7 mg/l. Turbidity was low at all sites, conductivity ranged from 180-760 mS/cm, and pH ranged from 6.1-7.6.

During base flow, total phosphorus and total nitrogen were the two parameters that most consistently were above levels of concern for aquatic life.

For storm samples, iron, aluminum, nitrogen, phosphorus, and TSS were parameters of concern.

Stormflows

Two separate storms, one in December 2009 and one in March 2010, were sampled for this project. The December storm was a smaller rain event with about a half inch of rain in most areas, but less in others. Due to the short duration and smaller magnitude of this rain event, only half of the sites were sampled. In addition, staff deployed a YSI sonde downstream of Scranton at LAWR 7.0 to record continuous data during the storm. The second storm (March 2010) produced a longer and heavier rain event, with much of the watershed receiving an inch of rain or more in a 10-12 hour period. The March storm was representative of a high flow event for the Lackawanna River Watershed. Using statistics from the USGS gage at Old Forge, the average daily flow for March 23, 2010 (1840 cfs), would be equal to annual P4 flow and the peak flow from the storm (2890 cfs) would be equal to annual P1 flow. This means that based on probabilities from the past 72 years, flows are below these values 96 and 99 percent of the time, respectively. In addition, during the past ten years, only 3 percent of the days (125 days) have had higher average daily flow than during this storm event. For this storm, all sites were sampled, and most were sampled twice, with at least one sample collected on the rise of the hydrograph.

In the storm samples, 15 percent of the parameters for all sites exceeded water quality standards or levels of concern. These included iron, aluminum, nitrogen, phosphorus, and TSS. Total phosphorus typically increases during storms because phosphorus is linked to soil erosion and adheres to sediment particles. As erosion increases during high flows, more phosphorus is introduced into the system. During storms, nitrogen and TSS increased primarily due to the introduction of human sewage from CSOs. Iron and aluminum may be increased through CSO discharges, especially if they include industrial waste or overland runoff through old mining areas where exposed mine spoils lay bare and un-vegetated.

During storms, all sample results for chromium, cadmium, and oil and grease came back below detection limits for the stormflow sampling. There were two very low detections of copper during stormflow. The non-detection of oil and grease was likely the result of the timing of the sampling, which focused more on capturing the rise and peak of the storm, rather than the initial run-off that would contain a majority of the oil and grease from parking lots and roads. While no heavy metals were found in concentrations which were greater than water quality standards, zinc, copper, and lead were detected more frequently and in higher concentrations during stormflow than in base flow. There was a wide range in field chemistry from the storm samples as well, with conductivity values ranging from 60-500 mS/cm and turbidity from 3.3 – 105 NTU.

LEGGETTS CREEK

Total nitrogen concentrations during base flow are four to five times higher in Leggetts Creek than anywhere else in the Lackawanna River Watershed.

Leggetts Creek Watershed is relatively small – slightly more than 18 square miles – but it has some of the highest nutrient concentrations in the Lackawanna River Watershed. Land use is 25 percent urban and suburban development (mostly adjacent to the stream corridor), 22 percent agriculture, and 45 percent forested. The sampling site is a few miles downstream of a wastewater treatment plant outfall, which could be a possible source of high nutrient concentrations. Total nitrogen concentrations during base flow are four to five times higher in Leggetts Creek than anywhere else in the Lackawanna River Watershed. In July 2009, total phosphorus was 0.87 mg/l (eight times greater than background levels) and total nitrogen was 5.2 mg/l (five times greater than background levels). Previous SRBC data confirm the same findings of very elevated nitrogen concentrations at this site during the summer months (Buda, 2009). Leggetts Creek also had the highest TDS concentrations, even greater than the site downstream of the Old Forge borehole, and conductance values were far higher than any other sampling location in the watershed. During storm events, water quality in Leggetts Creek exceeds even more standards. Total aluminum, total nitrogen, total phosphorus, and TSS concentrations were above water quality standards or levels of concern during both storms, and total iron was above water quality standards during the March 2010 storm. In addition, lead, TOC, zinc, and TDS concentrations were greater during stormflows but did not exceed standards. Suspended sediment concentration was also highest in Leggetts Creek.

ROARING BROOK

During base flow, Roaring Brook showed relatively high concentrations of iron — second only to the AMD-impacted site at the mouth of the Lackawanna River.

Roaring Brook drains an area more than 58 square miles and empties into the mainstem Lackawanna River in the city of Scranton through a concrete channel. The Roaring Brook Watershed is 12 percent urban and suburban development, with a majority of development located near the mouth in Scranton, 16 percent agriculture, and 64 percent forested. During base flow, Roaring Brook showed relatively high concentrations of iron – second only to the AMD-impacted site at the mouth of the Lackawanna River. Roaring Brook also was the only site that had aluminum values above the detection limit during base flow sampling. The lead concentration was 13 times higher in Roaring Brook than anywhere else in the watershed during base flow, although concentrations did not exceed water quality standards (65 µg/l). TSS levels in Roaring Brook were slightly above the water quality standard during base flow sampling. During stormflows, both nitrogen and phosphorus were above water quality levels of concern, as was TSS. Iron exceeded water quality standards during the larger storm in March 2010.

SPRING BROOK

Spring Brook was the only tributary that did not have any parameters that exceeded water quality standards or levels of concern during base flow or stormflow events.

Spring Brook was the only tributary that did not have any parameters that exceeded water quality standards or levels of concern during base flow or stormflow events. Spring Brook Watershed is mostly forested, and, of its more than 70-square-mile drainage area, less than 5 percent is comprised of urban land use. As a result, despite the fact that the lower reaches of Spring Brook are confined in a concrete channel between Old Forge and Duryea, the water quality is relatively good.

LAWR 35.2 (NORTH OF FOREST CITY)

The most upstream site on the Lackawanna River was north of Forest City and was chosen as a control or reference site, as it is located in a primarily forested area above the greater Scranton metro area and above CSO influences. During base flow conditions, this site had no parameters that exceeded water quality standards or levels of concern. Macroinvertebrates were sampled here during base flow conditions, and the results showed a slightly impaired biological community due to a high percentage of one genus from the Philopotamidae family of caddisflies. Taxa richness, species diversity, Hilsenhoff score, percentage of EPT taxa, and percent Chironomidae all compare closely to the best sites of this size in the entire Middle Susquehanna Subbasin. During stormflows, the water quality at this site did not differ greatly from base flow as all parameters remained below water quality standards and level of concern. These results demonstrate the benefits that the stream receives from forested riparian buffers, a less impervious drainage area, and no CSO inputs.

Chosen as control or reference site — primarily forested area.

No parameters above standards — these results demonstrate the benefits that the stream receives from forested riparian buffers, a less impervious drainage area, and no CSO inputs.

LAWR 31.0 (MORSE STREET BRIDGE)

The next site was located at the Morse Street bridge upstream of Carbondale. During base flow, water quality at this site was quite good with no parameters exceeding limits. The substantial riparian buffer along the right bank is beneficial to maintaining good water quality even in an otherwise residential and industrial area. Even in stormflows, there were few water quality exceedances and minimal increases in sediment and turbidity. Total phosphorus and TSS were slightly over levels of concern during the December storm, but all other parameters were well within limits during both high flow events.

LAWR 28.2 (PIKE STREET, CARBONDALE)

This site was located downstream of Carbondale at Pike Street and was chosen to capture any water quality impacts coming from Carbondale. Compared to the upstream site (LAWR 31.0), base flow conditions were very similar with the exception of total phosphorus, which was 10 times higher at LAWR 28.2 than upstream at LAWR 31.0. Exact reasons for this are unknown, but phosphorus is a common constituent of fertilizers, organic wastes in sewage, and industrial effluent and could be entering the Lackawanna River Watershed by numerous means in this reach. During stormflows, concentrations of most parameters, including total aluminum, total iron, total nitrogen, total phosphorus, TOC, and TSS were all higher than at the upstream sampling location, although only TSS was above water quality standards. The drainage area between these two sites is comprised of, almost exclusively, the high density development of Carbondale. Macroinvertebrates also were sampled at LAWR 28.2 during base flow. Biological conditions at this site were rated as slightly impaired with a high percentage of mayflies and high taxa richness (18) for an urbanized stream. However, there was a fairly high percentage of Chironomidae, which brought the overall score down to slightly impaired.

LAWR 25.6 (POPLAR STREET, MAYFIELD)

The next downstream site on the Lackawanna River was in Mayfield at Poplar Street. As a flood control prevention measure, the river in this reach is confined to a concrete channel. Water quality during baseline conditions was largely unremarkable, with nutrient and metals concentrations far below standards or levels of concern. The elevated phosphorus concentrations seen upstream were not seen at this sampling location during base flow. However, during high flow events, this site marked the first of the sites to have aluminum and iron concentrations above water quality standards. These exceedances occurred only during the larger storm and close to the peak of the flow.

Nutrient and metals concentrations were far below standards or levels of concern for baseline samples. During high flow events, this site marked the first of the sites to have aluminum and iron concentrations above water quality standards.

Concentrations of nitrogen and phosphorus were two and three times higher than base flow but still not over the levels of concern. TSS concentrations exceeded levels of concern during both storms.

LAWR 23.0 – LAWR 17.9 (Archbald, Jessup, Olyphant)

The next three downstream sites had very similar water quality conditions during base flow and stormflow conditions. These sites were located at Gilmartin Street in Archbald, at Bridge Street in Jessup, and at Lackawanna Avenue in Olyphant, respectively. In base flow conditions at all three sites, no parameters exceeded water quality standards or levels of concern. However, as was the case upstream at LAWR 25.6, aluminum, iron, and TSS concentrations exceeded water quality standards during the March storm. Lead was only detected in the stormflow samples. Nitrogen and phosphorus were found at higher concentrations but did not exceed background levels during storm conditions.

LAWR 14.2 (Parker Street, N. Scranton)

During storms, suspended sediment concentration was one of the highest on the mainstem Lackawanna River.

The next site was located downstream of Leggetts Creek at Parker Street in north Scranton. Starting with samples collected here and continuing at the remaining five downstream sites, nutrient concentrations were notably and consistently higher during base flow than anywhere upstream. The influence of Leggetts Creek is seen strongly in the water quality data at this site during baseline conditions. During base flow, the upstream concentration of nitrogen is 0.3 mg/l; at this site, it is 2.4 mg/l. The largest contributor of flow between these two points is Leggetts Creek. During stormflow, these same increasing trends are evident for nitrogen and phosphorus levels in addition to the metals. The cumulative water quality impacts of the densely populated and heavily urbanized city of Scranton, along with the influence of many discharging CSOs, make the influence of Leggetts Creek less obvious during stormflows. During storms, aluminum, iron, nitrogen, phosphorus, and TSS exceeded water quality standards and limits. In addition, the suspended sediment concentration was one of the highest on the mainstem Lackawanna River, and Leggetts Creek had the highest concentration of suspended sediment in the whole watershed.

LAWR 11.1 (Olive Street, Scranton)

The Lackawanna River sampling site at Olive Street in the middle of Scranton was located three miles further downstream. Nitrogen and phosphorus both exceeded naturally occurring background levels at 2.07 mg/l and 0.25 mg/l, respectively, during base flow sampling. The macroinvertebrate community was noticeably degraded from the two upstream sites but still was considered only slightly impaired. The increased urbanization was reflected in fewer total taxa (10), fewer EPT taxa, and a higher Hilsenhoff score, meaning the genera found were more tolerant of organic pollution. However, the sample consisted of more than 18 percent Ephemeroptera (mayflies), which boosted the overall metric score. In the high flow events, total aluminum and iron were above water quality standards, including an iron concentration ten times greater than during base flow conditions. Total aluminum concentrations increased from undetected during base flow conditions to exceeding water quality standards during storms.

LAWR 9.3 (Elm Street Bridge)

This site was downstream of Scranton at the Elm Street bridge. Base flow nutrient concentrations were very similar to the site upstream, with both nitrogen (2.1 mg/l) and phosphorus (0.23 mg/l) above water quality background levels of concern. The remaining parameters were all within acceptable ranges. Storm sample results showed similar trends to the upstream site as well. Iron concentrations increased more than ten times from base flow to stormflow situations. However, neither nitrogen nor phosphorus concentrations exceeded background levels during high flows.

LAWR 7.0 (Taylor)

Due to a limited number of river access points in the city of Scranton, an additional location was sampled during base flow for water quality and macroinvertebrates. This site could not be sampled during storms because there was no bridge crossing, but staff collected biological and water quality data during baseline conditions directly downstream of Scranton in Taylor. During base flow, nitrogen was higher at this site than any site along the mainstem Lackawanna River at 4.7 mg/l, and total phosphorus also was elevated at 0.6 mg/l. All other water quality parameters were within acceptable ranges. The biological community at LAWR 7.0 was ranked as moderately impaired. The dominant taxon was Chironomidae, which encompassed more than 30 percent of the sample; only ten taxa were found, including only five EPT taxa. This biological condition was expected as the site was downstream of a majority of the greater Scranton area and all the perturbations that come from urban areas. A YSI datalogger was also deployed during two rain events at this site to take continuous field chemistry data readings.

LAWR 4.2 (3rd Street, Old Forge)

This was the last downstream site (located at 3rd Street in Old Forge, Pa.) on the mainstem Lackawanna River that is not impacted by discharge from the Old Forge borehole. Baseline conditions were similar to the four upstream stations, with nitrogen and phosphorus concentrations exceeding background levels and all other parameters within acceptable ranges. In high flow events, aluminum, iron, nitrogen, phosphorus, and TSS all exceeded water quality standards or levels of concern. Similarly to LAWR 11.1, aluminum increased from undetected at low flows to being over the water quality standard, and iron concentration increased ten times from base flow to stormflow.

Lawr 0.8 (Mouth of Lackawanna River)

The influence of CSOs and urban development on the site at the mouth are difficult to distinguish because of the considerable influence of AMD from the Old Forge borehole. Iron is the primary pollutant, and under normal circumstances, the river here is discolored by iron precipitate (yellow boy) and devoid of almost all aquatic life (Buda, 2009). Water quality during base flow includes an iron concentration of 6.1 mg/l; the water quality standard is 1.5 mg/l. In addition, nitrogen and phosphorus were both slightly above natural background levels at 1.8 mg/l and 0.13 mg/l, respectively. During stormflows, aluminum once again increases from below the detection limit to exceeding water quality standards. With the higher flows during storm events to dilute the influence of the borehole AMD discharge, iron concentrations are lower in storms (2.3 mg/l) but are still above the standard. TSS also exceeds water quality level of concern during stormflows at LAWR 0.8.

Iron is the primary pollutant, and under normal circumstances, the river here is discolored by iron precipitate (yellow boy) and devoid of almost all aquatic life.

Influence of abandoned mine drainage from Old Forge borehole.

Review of reported CSO Data

Sewer authorities within the Lackawanna River Watershed are responsible for the operation, maintenance, and monitoring of CSO outfalls. Each sewer authority is required to submit monthly reports to PADEP documenting the operation of each outfall for which they are responsible. All reports include information about which days had overflows at which outfalls and how much rain was recorded for that day. In addition, some also include data on overflow duration and volume from specific locations. After reviewing these reports for all three sewer authorities from April 2009–April 2010, there are some interesting trends that emerge for the year as a whole, as well as for the two storms that were sampled. Reported overflow durations ranged from less than one hour to 40 hours. During very large storms, generally greater than one and one half inches, it was not uncommon to have CSOs flowing into the next day or even the second day after the rain stopped. Surprisingly, even during these large storms, not all CSOs actually discharge any water. In fact, there were numerous individual outfalls that did not overflow at all during the entire year.

However, there are also numerous outfalls that begin discharging with very little rain. During the study year, CSOs started discharging with less than a quarter of an inch of rain 40 percent of the time, and discharged with less than one half inch of rain 60 percent of the time.

During the December 2009 storm that was sampled, more than one million gallons of water was documented as being discharged from CSOs over a four-hour time period. During the March 2010 storm, more than seven million gallons of water were reported as discharged through CSOs over a 12-hour time period. These volumes do not include discharges from all CSOs, as those data are not available for all outfalls, so the cumulative volume from all CSOs is likely to be much higher.

Stormwater and CSOs are intricate issues that can be complicated to manage and difficult to correct. From this one-year study, it is easy to see the impacts of stormwater on the water quality of a watershed. Stormflows greatly increase pollutant loading, sometimes by more than 100 times the rate of base flow. The elevated nutrient and metal loadings during storms are a detriment to water quality and aquatic life. Although high flow events typically have short durations, they can cause considerable and ongoing damage to aquatic habitats. In the Lackawanna River Watershed, high storm flows, exacerbated by urban runoff and CSOs, have caused severe erosion of banks, scoured streambeds, and increased sedimentation.

Loading rates

Loading rates are calculated to determine the amount of pollutant coming from a specific sampling location based on the concentration of a given parameter and the flow discharge at that site. During storm events, loads are higher than during base flow conditions almost regardless of concentrations because of the large disparity in flows. For example, if nitrogen is 1.5 mg/l during base flow and the flow is 10 cfs, the loading is much less (80.8 lbs/day) than at the same site during a storm, which may have nitrogen concentration of 1.5 mg/l but at a flow of 400 cfs (3,234 lbs/day). Loading rates were calculated for each site for four major parameters of concern in the watershed: total aluminum, total iron, total nitrogen, and total phosphorus. During base flow sampling, discharge measurements were taken instream where there were no USGS gages. For stormflows, USGS gage flows were used to estimate flows based on drainage area for those sites that did not have gages. No loadings were calculated for tributaries since all three sites were sampled at locations where stream access was impossible during storm events and no instream flows could be measured.

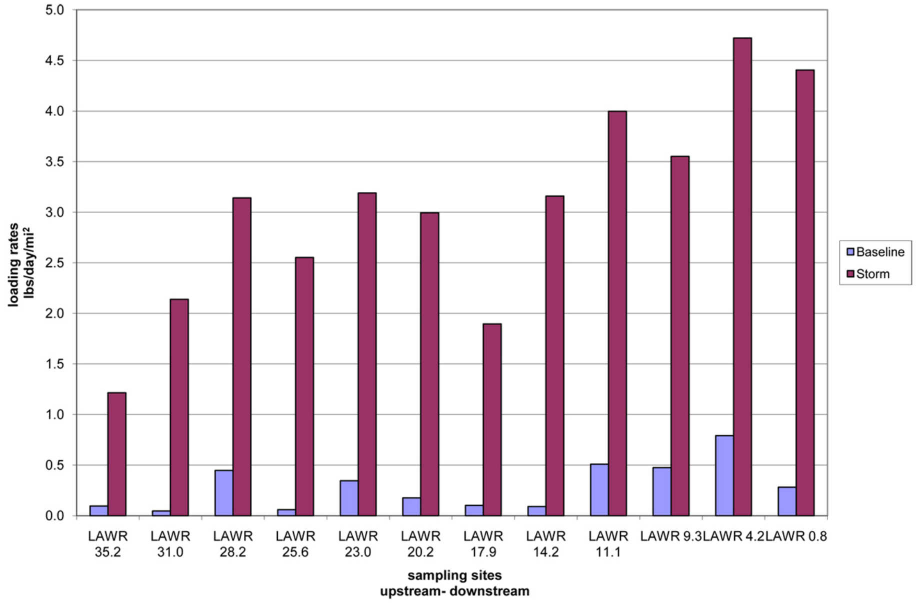

Figure 3. Total Phosphorus Loadings

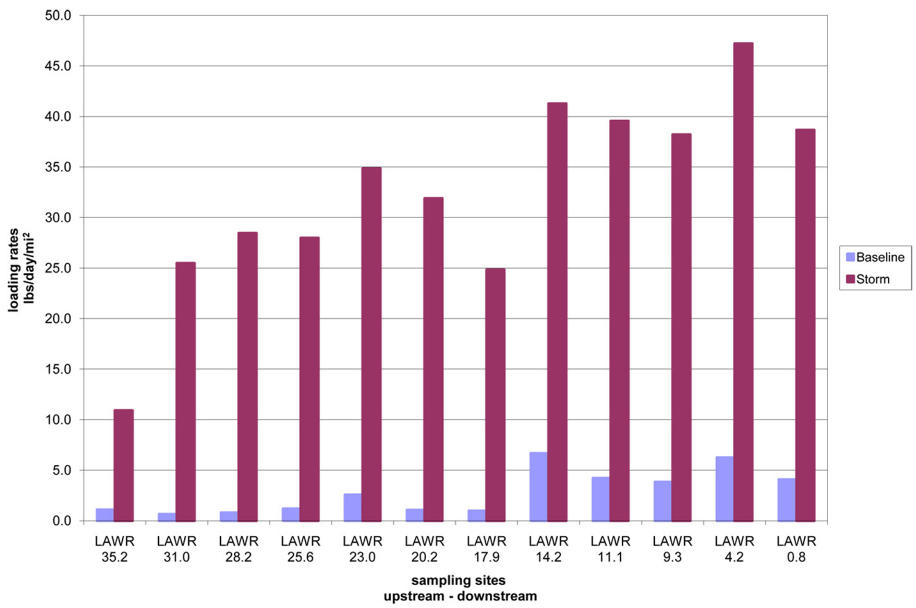

Figure 4. Total Nitrogen Loadings

During base flow, some parameters (primarily total aluminum) were reported by the lab to be below the detection limit. In situations where this occurred, the detection limit was used in the calculation to provide an estimate of loading rate for that parameter even though it likely resulted in high estimates for loadings during base flow. Loading rates are represented as pounds of the pollutant per day per square mile (lbs/day/mi_2) of drainage area at a specific site. This way, loading rates can be compared across sites, regardless of drainage size. These loading calculations only take into account one base flow sample and a maximum of three storm samples, so the results are admittedly based on a small sample size but still show the increased loading of pollutants during high flows in the Lackawanna River Watershed. This is not uncommon for urban areas but underscores the importance of stormwater management solutions, including CSO retrofitting.

Loading rates were calculated for each site for four major parameters of concern in the watershed: total aluminum, total iron, total nitrogen, and total phosphorus.

Along the mainstem Lackawanna River, the loading rates greatly increased during storms. As expected, the reference site (LAWR 35.2) showed the least amount of increase in loading rates for aluminum, iron, nitrogen, and phosphorus. This is expected because the site is located upstream of the urban development and CSOs and is located in a largely forested area. Figures 3-6 depict loading rates for these four parameters at each sampling site along the mainstem Lackawanna River for both base flow and stormflow. For phosphorus, loading rates were under 1.0 lbs/day/mi_2 for all sites during base flow. However, during stormflows, many of these loading rates increased by a factor of three to four. It also appears that there

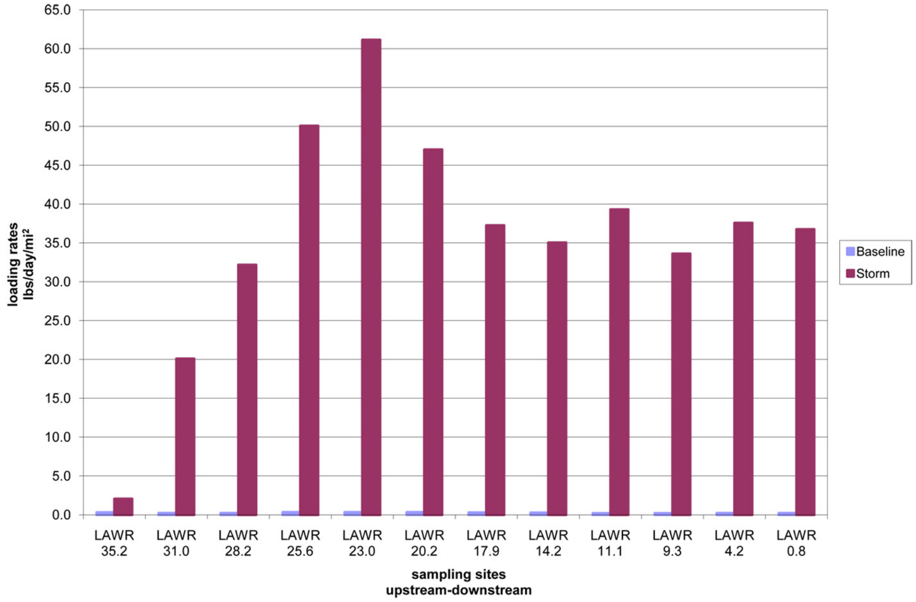

Figure 5. Total Aluminum Loadings

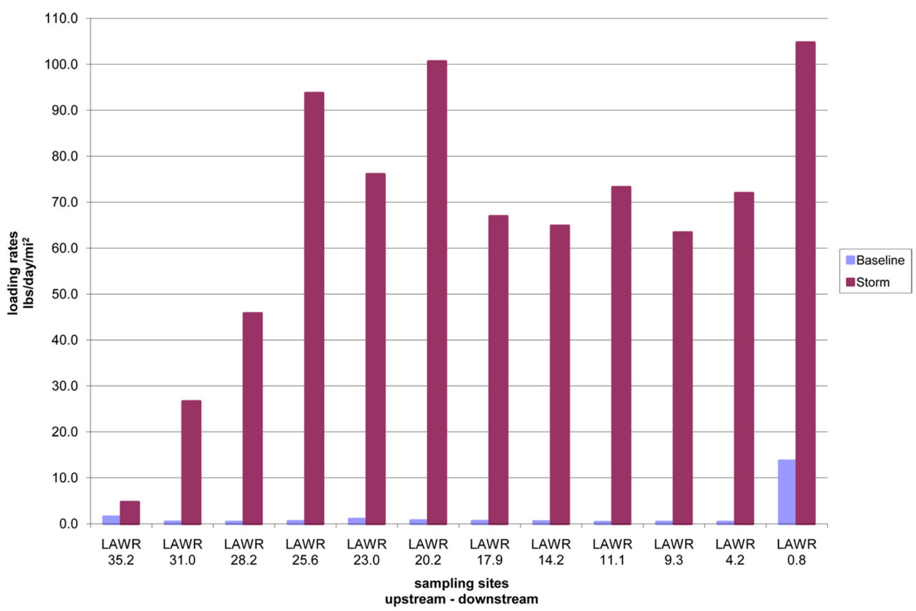

Figure 6. Total Iron Loadings

is more phosphorus addition per square mile in the lower end of the watershed, from the confluence of Leggetts Creek and downstream.

For nitrogen, a similar but larger trend prevails, with loading rates seven and eight times greater during stormflows and the higher loading rates per square mile occurring in the lower section of the watershed. Aluminum, however, had a very different pattern. Loading rates during base flow were very low with concentration values at most sites below the detection limit. During storms, the upper portion of the watershed, including those sites from Carbondale to Olyphant, had the highest increase in aluminum loading; in some cases, aluminum values were up to 60 times greater than in base flow conditions. Iron loadings were low as well during base flow, with the obvious exception of the lowest site (LAWR 0.8), which is downstream of the Old Forge borehole. Iron had a similar pattern as aluminum, with the same sites showing up to 100 times greater loading during stormflows.

YSI Continuous Data

Dataloggers were deployed for two weeks in April 2009 in Roaring Brook at Ash Street and in the Lackawanna River (LAWR 7.0) near Taylor to gather background information. This instrumentation collected a data reading every fifteen minutes for pH, temperature, dissolved oxygen, conductivity, and turbidity. During that time, a small storm event occurred and those data were useful in documenting continuous and instantaneous changes in field chemistry parameters. For the most part, results were expected at both these sites. At LAWR 7.0, dissolved oxygen concentrations followed a typical diurnal pattern, although during and directly following the rain event, the dissolved oxygen concentration was about 2 mg/l lower than during normal flows. This may be a result of the influx of organic wastes from CSOs and other stormwater conduits or a function of the higher water temperatures. Conductivity and pH were fairly constant throughout the two-week period, with both showing a slight decrease during the storm event. Temperature increased by 4 degrees Celsius (ºC) during the storm event, with the temperature staying between 11-13ºC during the storm. The average temperature for the rest of the two weeks was 7.5ºC. Turbidity was less than 10 NTU for a majority of the two-week period, but peaked at more than 1000 NTU during the storm event.

In Roaring Brook, results were similar. Dissolved oxygen showed less of a diurnal pattern but during the storm, there was an almost 2 mg/l drop in oxygen levels. Conductivity peaked during the storm and then went back to pre-storm levels, while pH remained between 7 and 7.5 during the entire two-week period. Water temperature during the storm was between 9-11ºC but averaged just 7ºC for the other non-storm days. Turbidity spiked during the storm, but Roaring Brook was much less turbid than the Lackawanna, as the highest turbidity measurement was recorded at just 27 NTU.

(continued on page 12)

Dataloggers also were deployed at LAWR 7.0 prior to the December 2009 storm sampling. Data were logged every fifteen minutes from December 2-4, 2009. Water temperatures rose three degrees during the duration of the storm and turbidity increased more than a thousand fold. Using the USGS gage about three miles downstream as a guide, turbidity peaked just after the peak of the flow passed. Dissolved oxygen decreased by more than 2 mg/l during the peak of the stormflow. Conductivity peaked early in the storm but declined as flow increased, and pH remained constant throughout.

Additional SRBC Involvement in the Lackawanna River Watershed

Besides the Subbasin Survey program, SRBC also is involved in numerous other projects that include areas of the Lackawanna River Watershed. As part of SRBC's Remote Water Quality Monitoring Network (RWQMN), a continuous monitoring station was installed in the headwaters of the Lackawanna River near Forest City in 2010. The RWQMN was formed in response to the rise of Marcellus Shale natural gas drilling in the Susquehanna River Basin with the intention of developing baseline data and providing early and quick detection of any water quality threats stemming from the natural gas industry and other activities with the potential to cause adverse impacts to water quality. All remote stations record continuous data for pH, dissolved oxygen, conductance, temperature, and turbidity and upload the data directly to a web page. This web page can be accessed by clicking a link on SRBC's web site (www.srbc.net).

SRBC staff is also, under contract with PADEP, collecting water quality samples at select water supply intake locations throughout the Susquehanna basin to assist with determining if waterbodies are meeting the public water supply designated use. Within the Lackawanna River Watershed, eight samples are being collected from November 2009 through October 2010, just upstream of PA American's drinking water intake on the Lackawanna River near Forest City. The target parameters included color, nitrogen, chloride, sulfate, fluoride, arsenic, iron, and manganese.

One of the other prominent issues often associated with the Lackawanna River Watershed is AMD from past mining of the Anthracite Coal Region. Currently, SRBC staff is involved in numerous projects involving AMD monitoring and remediation. SRBC is working on the Anthracite AMD Remediation Strategy, which will allow staff to compile all water quality data from the past 20 years into one database and use it to prioritize AMD treatment projects. Of the top ten highest discharges, three are in the Lackawanna River Watershed. Moving forward, SRBC is coordinating with local agencies and groups, including the LRCA, to address these issues and begin restoration and remediation work.

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