Remote Water Quality Monitoring Network

Data Report of Baseline Conditions for 2010/2011

A SUMMARY

Susquehanna River Basin Commission

Publication No. 280 *Modified April 5, 2012*

Purpose of this Report Is:

To release data characterizing baseline water quality conditions to determine the existing conditions within select watersheds – not to draw conclusions on water quality impacts – for the watersheds containing the first 37 monitoring stations installed by SRBC. As with any science-based project where baseline conditions need to be set first, SRBC is continuing to collect and analyze data at all 51 stations before it can determine if any observed water quality conditions are departures from baseline conditions.

To inform the public about the future direction of data collection and analysis efforts, and where more detailed studies will be conducted at targeted stations based on the baseline data results and other water quality observations.

Abstract

Approximately 85 percent of the Susquehanna River Basin is underlain by shales containing natural gas, including the Marcellus shale formation. Extracting gas from these formations became economically feasible through hydraulic fracturing – the process of using large volumes of water to fracture shales and release trapped gas.

With the onset of hydraulic fracturing activities in the Susquehanna River Basin, the Susquehanna River Basin Commission (SRBC) initiated additional water quality monitoring activities to generate data that can help determine if natural gas drilling activities are or are not changing water quality conditions. Most notably, SRBC established the Remote Water Quality Monitoring Network (RWQMN) for real-time, continuous monitoring.

At the time of this report, SRBC's RWQMN consists of 51 monitoring stations installed in select watersheds within the region of the basin experiencing unconventional shale gas development. The stations are located in a variety of areas including state forests, state gamelands, private property, and municipal property.

Each station is equipped with a data sonde, data platform, and a solar panel or power source to continuously monitor the following parameters: pH, temperature, conductance, dissolved oxygen, and turbidity. The data are collected at five-minute intervals and uploaded to SRBC's public web site *(mdw.srbc.net/remotewaterquality/)* at predetermined intervals via cell or satellite transmission.

Since initiating the RWQMN project in January 2010, SRBC has been collecting baseline water quality conditions in smaller watersheds within the headwaters' region of the basin, where data have typically been scarce to non-existent. This will help characterize the basin's water resources and evaluate any impact on water quality from natural gas development over the next 5-10 years.

The focus of this report is on the data collected at the initial 37 remote water quality stations installed from January to December 2010. These are the stations for which SRBC had at least six months of data collected and assessed in preparation for this first RWQMN summary data report.

After analyzing attributes of each station, SRBC decided to group them by ecoregions for data analysis. SRBC concentrated its analysis on the continuous data for pH, specific conductance, and turbidity, as well as on water samples analyzed in a lab for other chemical parameters. Stations that had field chemistry atypical of their ecoregion were identified for future analysis. SRBC anticipates continuing data collection at all stations and periodically issuing subsequent data reports.

This publication is a summary of the full report, which is available on SRBC's web site at mdw.srbc.net/remotewaterquality/.

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Introduction

With the majority of the Susquehanna River Basin (85 percent) underlain with natural gas shales and hydraulic fracturing increasing since 2008, SRBC initiated measures to manage water resources and encourage sustainable use and development, and established a real-time, continuous water quality monitoring network called the Remote Water Quality Monitoring Network (RWQMN).

This report is focused on the initial 37 stations (Figure 1) installed and for which there has been enough time to collect and assess a sufficient amount of data. Funding for the intial stations was provided by SRBC's general operating fund and a contribution from East Resources, Inc.

The network currently stands at 51 stations (Appendix A), which includes the stations funded by East Resources, Inc. as well as those funded by the Pennsylvania Department of Conservation and Natural Resources (PADCNR), New York State Energy Research and Development Authority, and Headwaters Resource & Conservation Development Council Sinnemahoning Stakeholders Committee.

Specific criteria were identified for all stations selected within the shale gas region. The following criteria were considered when locating stations:

- Watershed size between 30-60 square miles;
- Gas pad density and other gas related infrastructure (on the ground or proposed);
- Non-impaired or minimally impaired waterbodies;
- Presence of wastewater discharges;
- Presence of drinking water intakes;
- Land use;
- Channel morphology that would allow the data sonde to be in moving water during all flow regimes;
- Availability of sunlight to power the battery; and,
- Local interest.

Stations were located on both private and public lands having met all or the majority of the identified criteria.

The initial 18 months of sampling in these watersheds have allowed SRBC to build a substantial baseline dataset

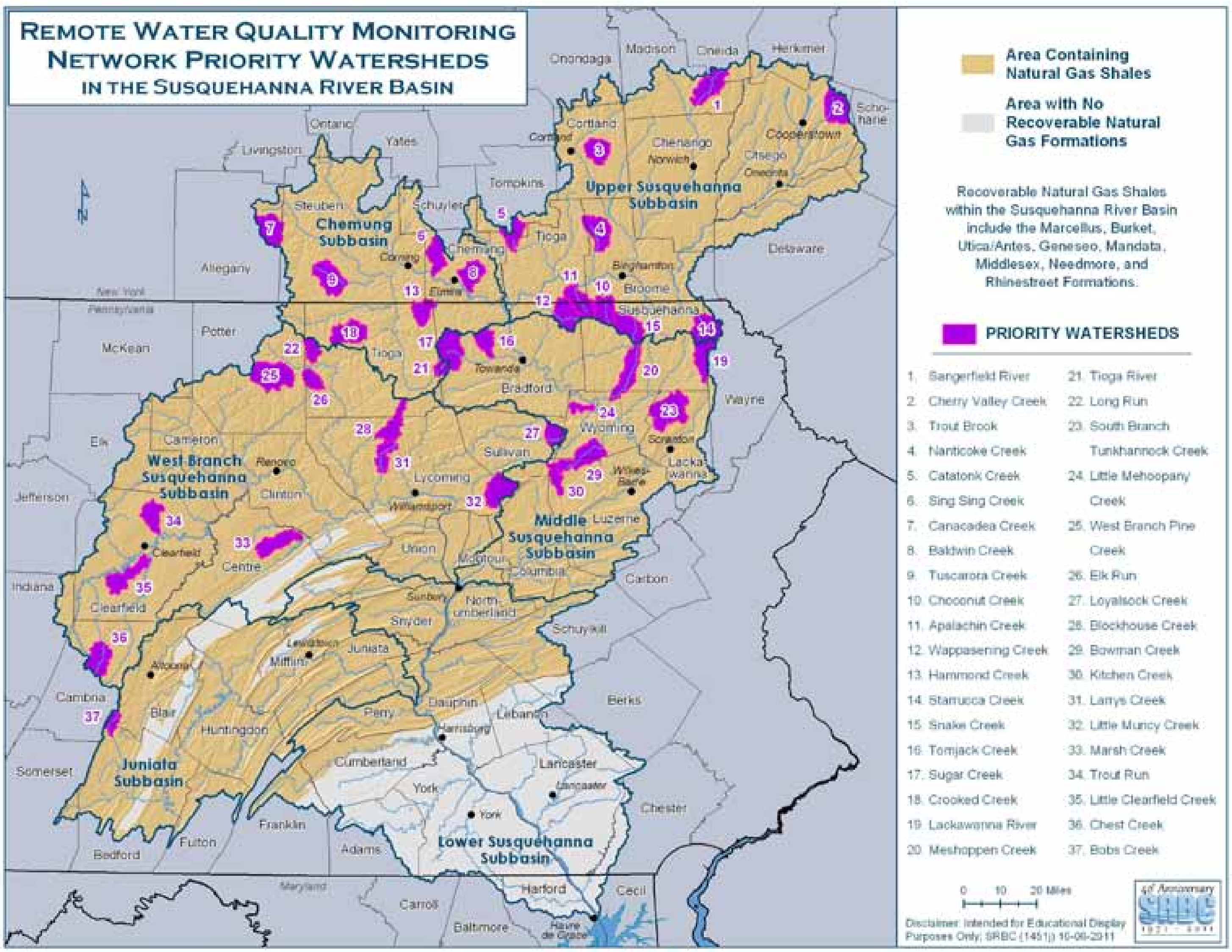


Figure 1. Map of the Initial 37 RWQMN Stations

in smaller streams and headwater areas previously lacking these types of data. The period of data collection for the 37 sites ranges from six to 18 months (Appendix B). Baseline data on these streams will assist SRBC and other agencies to detect if activities in the watershed are having an adverse effect on the water quality.

SRBC staff installs data sonde at a station along Loyalsock Creek, Sullivan County, Pa.

Equipment and Parameters

Each RWQMN station is comprised of the same equipment: data sonde, data platform, and solar panel or other power source.

The data sonde is a multi-parameter water quality sonde (see photo lower right) with an optical dissolved oxygen probe, an optical turbidity probe, a pH probe, and a conductance and temperature probe. The data sonde also includes a non-vented relative depth sensor. The entire unit is placed in protective housing in free-flowing water at each site.

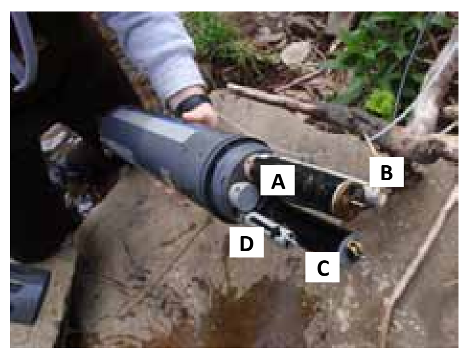
The data platform stores the water quality observations and transmits the data by either cellular or satellite signal, depending on the type of communications needed at the station location. The data platform is powered by a rechargeable 12V battery connected to a solar panel or other power source.

The continuously-monitored water quality parameters at each station include temperature, pH, conductance, dissolved oxygen, and turbidity.

pH is the measure of the stream water acidity or alkalinity. In Pennsylvania, the water quality standard range for pH is 6.0 to 9.0 and the New York water quality standard range is 6.5 to 8.5. Conductance is the ability of water to conduct electricity; streams with high levels of dissolved solids and chlorides will have elevated conductance measurements. Dissolved oxygen is the amount of oxygen available to aquatic life in a stream; aquatic life needs are generally above 4-5 milligrams/liter (mg/l) range. Oxygen levels are impacted by temperature and organic material. Turbidity is the measure of water clarity and typically increases with higher flows or other instream disturbance, as sediment and other particulate matter mobilize.

The data sonde collects the water quality parameters as frequently as every five minutes with data transmission times varying based on the type of communication. Data from stations with cellular data transmission are uploaded every two hours, while data from stations utilizing satellite data communication are uploaded every four hours. Data transmitted via satellite telemetry are an average of the data collected at five-minute intervals over the four-hour time period.

The data are uploaded to a public web site maintained by SRBC. The web site allows users to view, download, graph, and determine basic statistics from the raw data. General project information and maps are also found on the user-friendly web site at *mdw.srbc.net/remotewaterquality/.*



Each station is equipped with a data sonde (above) that measures dissolved oxygen, turbidity, pH, conductance and temperature. The data sonde also includes a non-vented relative depth sensor.

A – Dissolved Oxygen
B – pH
C – Turbidity
D – Conductance/Temperature

Results

The 37 RWQMN stations are distributed over three Level III ecoregions: North Central Appalachian, Northern Appalachian Plateau and Uplands, and Central Appalachian Ridges and Valleys (Table 1).

The majority of the shale gas region of the Susquehanna River Basin is located in the Northern Appalachian Plateau and Uplands and the North Central Appalachian ecoregions (Figure 2) (Woods and others, 1996).

North Central Appalachian Ecoregion

Ten stations fall within the North Central Appalachian ecoregion (Figure 2). This ecoregion is a forested, sedimentary upland that has high hills and low mountains. It is divided into an unglaciated western region and a glaciated eastern region. Seven of the 10 RWQMN sites are located in the Glaciated Allegheny High Plateau subecoregion and the remaining three are located in the Unglaciated Allegheny High Plateau subecoregion. A significant portion of Pennsylvania's oil and gas production is located in this region (Woods and other, 1996).

The stations located in this ecoregion are designated as cold water fishes (CWF), high-quality cold water fishes (HQ-CWF), or exceptional value waters (EV), with the exception of the Tioga River, which is designated as warm water fishes (WWF). Bowman Creek, West Branch Pine Creek, Long Run, Elk Run, and Blockhouse Creek are meeting their designated uses. Larrys Creek and Trout Run have short stream segments impaired by abandoned mine drainage (AMD) and Loyalsock Creek, Tioga River, and Kitchen Creek contain segments of acid deposition impairment.

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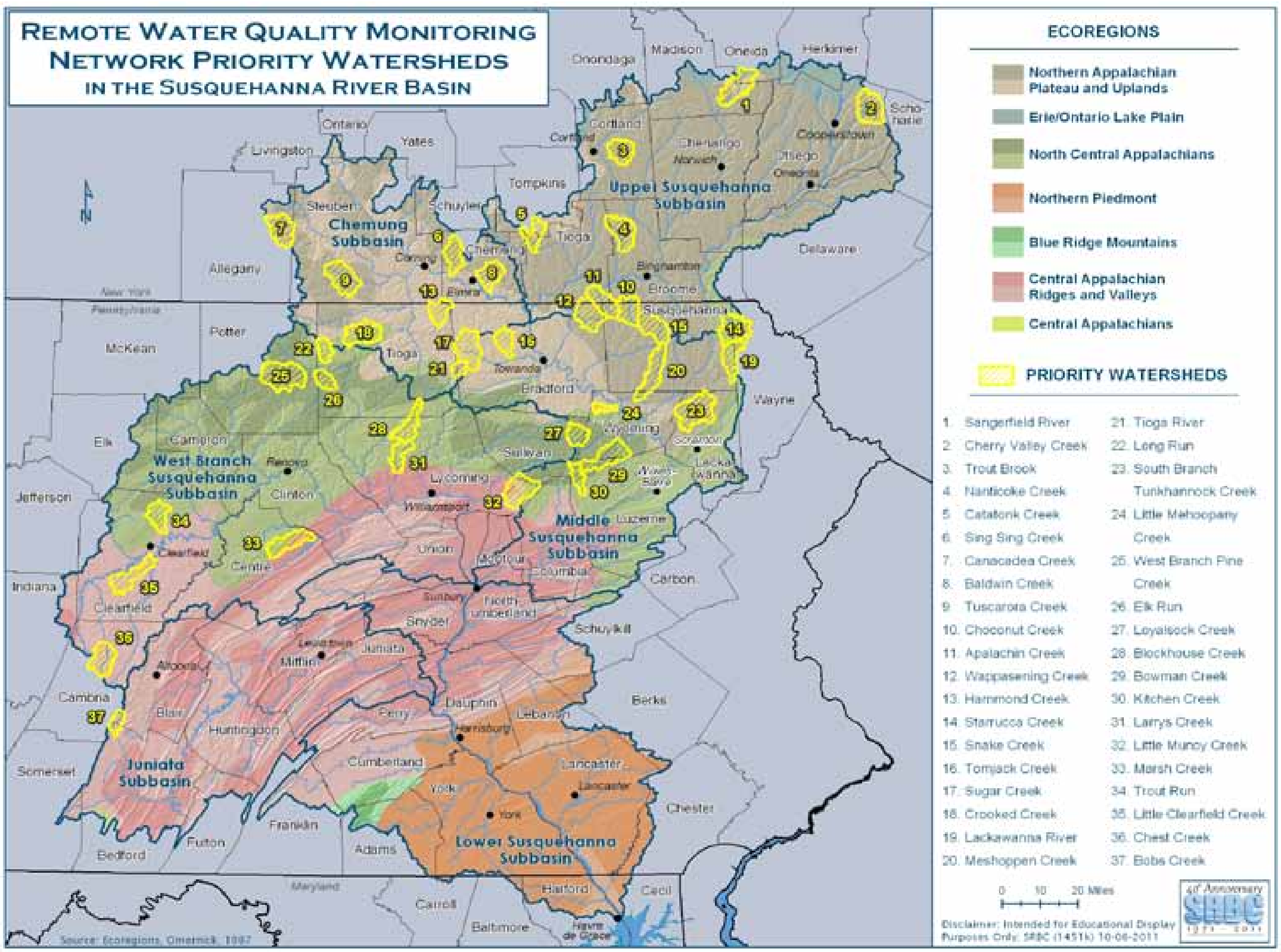


Figure 2. Map of the Initial 37 RWQMN Stations Shown with the Level III Ecoregions

Table 1. RWQMN Station List with Basic Watershed Characteristics

Watershed Name	Map ID	Dominant Landuse(s)	Watershed Size (mi²)	Dominant Bedrock Geology	Impaired Stream Miles[2]	% Impaired Stream Miles[2]	Gas Well Pad Approvals*[1]	Gas Wells*[1]
Northern Appalachian Plateau and Uplands								
Apalachin Creek	11	Forest (70%) Agriculture (26%)	43	Shale	0	0%	0	0
Baldwin Creek	8	Forest (73%) Agriculture (21%)	35	Shale	0	0%	0	0
Canacadea Creek	7	Forest (70%) Agriculture (23%)	47	Shale	0	0%	0	0
Catatonk Creek	5	Forest (70%) Agriculture (16%)	30	Shale	0	0%	0	0
Cherry Valley Creek	2	Forest (67%) Agriculture (23%)	51	Shale	0	0%	1	0
Choconut Creek	10	Forest (73%) Agriculture (23%)	38	Shale	0	0%	0	0
Crooked Creek	18	Agriculture (53%) Forest (44%)	47	Shale	0	0%	18	21
Hammond Creek	13	Agriculture (51%) Forest (46%)	29	Shale	0	0%	11	19
Lackawanna River	19	Forest (68%) Agriculture (23%)	38	Sandstone	4.3	6%	1	0
Little Mehoopany Creek	24	Forest (68%) Agriculture (26%)	11	Sandstone	0	0%	4	2
Meshoppen Creek	20	Forest (48%) Agriculture (48%)	52	Sandstone	0	0%	56	58
Nanticoke Creek	4	Forest (62%) Agriculture (34%)	48	Shale	0	0%	0	0
Sangerfield River	1	Forest (35%) Agriculture (32%)	52	Shale	0	0%	0	0
Sing Sing Creek	6	Forest (60%) Agriculture (21%)	35	Shale	0	0%	0	0
Snake Creek	15	Forest (68%) Agriculture (28%)	45	Sandstone	0	0%	13	19
South Branch Tunkhannock Creek	23	Forest (55%) Agriculture (32%)	70	Sandstone	2.1	2%	3	0
Starrucca Creek	14	Forest (74%) Agriculture (18%)	52	Sandstone	0	0%	7	0
Sugar Creek	17	Agriculture (51%) Forest (48%)	56	Sandstone	10.8	13%	44	99
Tomjack Creek	16	Agriculture (55%) Forest (42%)	27	Shale	0	0%	25	15
Trout Brook	3	Forest (64%) Agriculture (31%)	36	Shale	0	0%	0	0
Tuscarora Creek	9	Agriculture (52%) Forest (42%)	53	Shale	0	0%	0	0
Wappasening Creek	12	Forest (64%) Agriculture (33%)	47	Shale	1.8	2%	23	6

* As tracked by SRBC

[1] Multiple wells can be located on one pad. Data last updated February 2012

[2] PA and NY State 2011 Integrated List and 2011 Priority Waterbodies List

(table continued on next page)

Table 1. RWQMN Station List with Basic Watershed Characteristics *(continued)*

Watershed Name	Map ID	Dominant Landuse(s)	Watershed Size (mi²)	Dominant Bedrock Geology	Impaired Stream Miles[2]	% Impaired Stream Miles[2]	Gas Well Pad Approvals*[1]	Gas Wells*[1]
Northern Central Appalachian								
Blockhouse Creek	28	Forest (75%) Agriculture (21%)	38	Sandstone	0	0%	6	0
Bowman Creek	29	Forest (90%)	54	Sandstone	0	0%	3	0
Elk Run	26	Forest (82%) Agriculture (11%)	21	Sandstone	0	0%	21	13
Kitchen Creek	30	Forest (88%)	20	Sandstone	1.8	5%	0	0
Larrys Creek	31	Forest (76%) Agriculture (22%)	29	Sandstone	1.9	4%	15	4
Long Run	22	Forest (81%) Agriculture (14%)	21	Sandstone	0	0%	0	0
Loyalsock Creek	27	Forest (86%) Grassland (9%)	27	Sandstone	55.0	100%	0	0
Tioga River	21	Forest (85%) Grassland (9%)	13	Sandstone	4.2	18%	5	11
Trout Run	24	Forest (91%) Grassland (8%)	33	Sandstone	1.5	3%	24	4
West Branch Pine Creek	25	Forest (86%) Grassland (13%)	70	Sandstone	0	0%	1	0
Central Appalachian Ridges and Valleys								
Bobs Creek	37	Forest (92%)	17	Sandstone	0	0%	1	3
Chest Creek	36	Forest (60%) Agriculture (35%)	44	Shale	29.6	24%	0	0
Little Clearfield Creek	35	Forest (74%) Agriculture (22%)	44	Sandstone	0	0%	2	1
Little Muncy Creek	32	Forest (57%) Agriculture (39%)	51	Sandstone	1.8	2%	28	16
Marsh Creek	33	Forest (88%) Agriculture (11%)	44	Sandstone	17.1	20%	1	0

* As tracked by SRBC

[1] Multiple wells can be located on one pad. Data last updated February 2012
[2] PA and NY State 2011 Integrated List and 2011 Priority Waterbodies List

Within the North Central Appalachian ecoregion there are five stations that present similar characteristics and water quality results: Loyalsock Creek, Tioga River, Bowman Creek, Kitchen Creek, and Trout Run. Watershed characteristics considered include subecoregion, land use, geology, and drainage size. Of these five watersheds, Trout Run is the only one located in the Unglaciated Allegheny High Plateau subecoregion. Land use in the watersheds is at minimum 85 percent forested and less than 10 percent agricultural land. The underlying geology of the stations is sandstone and the drainage size varies for these watersheds (14 to 54 square miles).

Overall, the RWQMN stations exhibiting the lowest conductance, pH, and turbidity values are located in the North Central Appalachian ecoregion. All of these streams can be characterized as naturally acidic systems with low buffering capacities.

Overall, the RWQMN stations exhibiting the lowest conductance, pH, and turbidity values are located in the North Central Appalachian ecoregion. All of these streams can be characterized as naturally acidic systems with low buffering capacities. The median pH ranged from 5.78 to 6.86. The low buffering capacities, as evidenced by very low alkalinity, allow for even small introductions of acidic solutions to dramatically drop the pH causing adverse effects to aquatic organisms.

Low concentrations of chloride, sulfate and dissolved solids in the water column were recorded at these stations from grab samples. Low conductance values, ranging from 35 to 60 µS/cm in these watersheds, are consistent with these findings. Chloride, sulfate, and dissolved solids concentrations have a tendency to increase with human activities in a watershed. Conductance may slightly increase during low flow periods; however, these systems consistently yield low values.

Turbidity and dissolved oxygen in streams often reflect land use in the watershed. Watersheds that drain predominantly forested land and contain very little agriculture typically have low turbidity and high dissolved oxygen. The forested land use provides canopy cover to maintain cooler water temperatures and root systems to help control erosion. The median turbidity value for these watersheds is less than 2.0 NTU and dissolved oxygen concentrations range from 10.9 to 12.7 mg/l.

Of the remaining five stations in the North Central Appalachian ecoregion, four stations display comparable water chemistry results. Larrys Creek, West Branch Pine Creek, Long Run, and Elk Run share the same sandstone geology, but are divided between the Glaciated Allegheny High Plateau subecoregion (Long Run and Elk Run) and the Unglaciated Allegheny High Plateau subecoregion (Larrys Creek and West Branch Pine Creek). Agriculture is more common in these watersheds, covering up to 22 percent of the watershed; forested land use is less and ranges from 76 to 82 percent coverage.

There is only a small difference in the water chemistry exhibited in this group of stations compared to the first grouping. These systems also have limited buffering capacities, but have more neutral water chemistry (median pH range from 7.00 to 7.21). Conductance is fairly low in these streams ranging from 48 to 81 µS/cm. The median turbidity and dissolved oxygen range from 1.4 to 9.4 NTU and 9.8 to 12.2 mg/l, respectively.

SRBC staff conducts Aquatic Resource Survey along Meshoppen Creek in Wyoming County, Pa. Monitoring found elevated pH values at this station; report recommends further investigation.

The Blockhouse Creek station is the outlier in this ecoregion, and does not share the water quality characteristics of the other nine stations in the ecoregion. The watershed characteristics are consistent with the other watersheds in the ecoregion–sandstone geology, Glaciated Allegheny High Plateau subecoregion, and dominant forested land use. There is a small portion of the drainage area that lies in the Northern Appalachian Plateau and Uplands ecoregion that may influence the water chemistry. In addition, about one-fifth of the watershed is agriculture, and a major transportation corridor (State Route 15) bisects the headwaters.

Continuous monitoring results display a median pH value of almost 8, indicating a basic stream system. Grab sample alkalinity values are almost double the highest value (40 mg/l and 27 mg/l, respectively) in the other nine watersheds. Conductance for Blockhouse Creek averages 140 µS/cm, much higher than other monitored streams in the North Central Appalachian ecoregion. The average dissolved oxygen is 9.5 mg/l, but the median turbidity is only 0.5 NTU.

Northern Appalachian Plateau and Uplands Ecoregion

The Northern Appalachian Plateau and Uplands ecoregion, which spans a large portion of the Susquehanna River Basin, has experienced a significant amount of natural gas development activities. Twenty-two of the 37 stations discussed in this report are located in this ecoregion. This region is characterized by open valleys and low mountains that are able to support woodlands and agriculture. It is typically less forested than the bordering Glaciated Allegheny High Plateau subecoregion (Woods and others, 1999). The 22 stations in this ecoregion are split between the Northeastern Uplands and Glaciated Low Plateau subecoregions. Seven stations are located within the Northeastern Uplands subecoregion and the remaining 15 stations are located in the Glaciated Low Plateau subecoregion.

The Northeastern Uplands subecoregion typically is higher in elevation and more forested than the Glaciated Low Plateau. The seven stations located in the Northeastern Uplands subecoregion include the Lackawanna River, Starrucca Creek, Snake Creek, Choconut Creek, Wappasening Creek, Apalachin Creek, and Meshoppen Creek (approximately 50 percent of this watershed is in the Glaciated Low Plateau). These watersheds have designated uses of EV, HQ-CWF, CWF, or Class C, with the exception of Choconut Creek, which is designated as WWF in Pennsylvania.

Overall, these stations have lower pH and conductance values when compared to the stations in the Glaciated Low Plateau. Conductance values range from 77 to 135 µS/cm indicating low levels of dissolved solids in the waterbodies. Lab water quality samples collected at the stations support the continuous data. Five of the seven stations exhibit neutral water chemistry with median pH values ranging from 6.97 to 7.22; however, Meshoppen and Starrucca Creeks do not follow this pattern with median pH values exceeding 7.6. These two systems will require further investigation to determine the reason for the atypical pH values.

The remaining 15 stations in the Northern Appalachian Plateau and Uplands are located in the Glaciated Low Plateau subecoregion. This includes stations Little Mehoopany Creek, Nanticoke Creek, Trout Brook, Baldwin Creek, Tomjack Creek, Crooked Creek, Cherry Valley Creek, Hammond Creek, Tuscarora Creek, Sangerfield River, South Branch Tunkhannock Creek, Sugar Creek, Catatonk Creek, Sing Sing Creek, and Canacadea Creek. The six streams in Pennsylvania are designated as CWF or trout stocked fishes (TSF) with the exception of Crooked Creek, which is designated as WWF. The nine streams in New York are classified as Class C, Class C(t) or Class C(ts), which represent higher quality waters. Baldwin Creek has a small stream segment designated as Class B.

Surficial glacial till geology consists of unconsolidated material deposited on bedrock by a continental glacier and can measure up to 50 meters in thickness. Most of New York's bedrock geology is covered by glacial till deposits (Rogers and others, 1999). Streams in this portion of the Susquehanna River Basin can generally be characterized as having highly mobile, unconsolidated substrate material. Based on the leachability of glacial till geology,

Station along Little Mehoopany Creek, Wyoming County, Pa.

sulfate, chloride, total dissolved solids, and conductance concentrations as well as turbidity are typically found at higher ranges within these types of settings (Missouri Department of Natural Resources, 2006).

The stations in this ecoregion have slightly basic water chemistry with median pH values ranging from 7.12 to 8.04. Overall, conductance is higher in this subecoregion, ranging from 108 to 379 µS/cm, indicating higher levels of dissolved solids in the water column. Little Mehoopany Creek and Nanticoke Creek are the only two watersheds in the subecoregion with conductance below 150 µS/cm.

Median turbidity values for 16 stations located in the ecoregion range from 2 to 10 NTU; three stations have median turbidity below 2 NTU and three stations have median turbidity above 10 NTU. Dissolved oxygen concentrations (greater than 9 mg/l) are well above the levels needed to sustain aquatic life. Turbidity at several stations (Apalachin Creek, Canacadea Creek, and Sugar Creek) was studied further with results found in the Turbidity and Specific Conductance section of this report.

Central Appalachian Ridges and Valleys Ecoregion

With only a small portion of this ecoregion underlain by Marcellus shale, the Central Appalachian Ridges and Valleys ecoregion, an area of parallel ridges and valleys, is experiencing very little natural gas development activities.

Given this fact, SRBC located only five continuous monitoring stations in this region. These stations include Bobs Creek, Chest Creek, Little Clearfield Creek, Marsh Creek, and Little Muncy Creek. Portions of Marsh Creek and Little Muncy Creek Watersheds lie in the North Central Appalachian ecoregion. These watersheds are underlain with sandstone geology, with the exception of Chest Creek's shale geology.

Neutral water chemistry characterizes these watersheds with median pH values ranging from 7.11 to 7.49. Average specific conductance concentrations vary in the watersheds ranging from 77 to 384 µS/cm. Chest Creek and Little Clearfield Creek both lie in areas that have been mined and which contain more than 20 percent agriculture land use in their contributing areas. These two watersheds show some of the highest conductance concentrations of the RWQMN stations, but the concentrations are relatively low when compared to impaired AMD streams in the region. Little Clearfield and Chest Creeks are located in the Uplands and Valleys of Mixed Land Use subecoregion and are primarily designated as HQ-CWF streams.

Bobs Creek, located in the Northern Sandstone Ridge subecoregion, has greater than 90 percent forested lands, has no stream impairments and is designated as a HQ-CWF. It also has the lowest conductance concentration and most neutral water quality of the stations in the Central Appalachian Ridges and Valleys ecoregion. The average specific conductance concentration is 77 µS/cm and the median pH value of 7.11.

Little Muncy Creek and Marsh Creek are both located in the Northern Dissected Ridges and Knobs subecoregion and are designated as CWF. The Little Muncy Creek and Marsh Creek Watersheds contain about 40 percent and 10 percent agricultural land use, respectively (Table 1). Median turbidity is less than 3 NTU, but the large standard deviations surrounding the mean values indicate more variability over a range of conditions.

Turbidity and Specific Conductance

Variability of Select Field Parameters by Ecoregion

Due to the nature of natural gas development and concerns over potential water quality impacts, turbidity and specific conductance were selected as surrogate indicator parameters. A box plot depicts the median value of the dataset, inter-quartile ranges, as well as the range of outliers. For these data analyses, the top and bottom five percent of data values were eliminated to remove extreme data values. The following box plots provide a graphical representation of the distinct differences in baseline specific conductance and turbidity data across ecoregions.

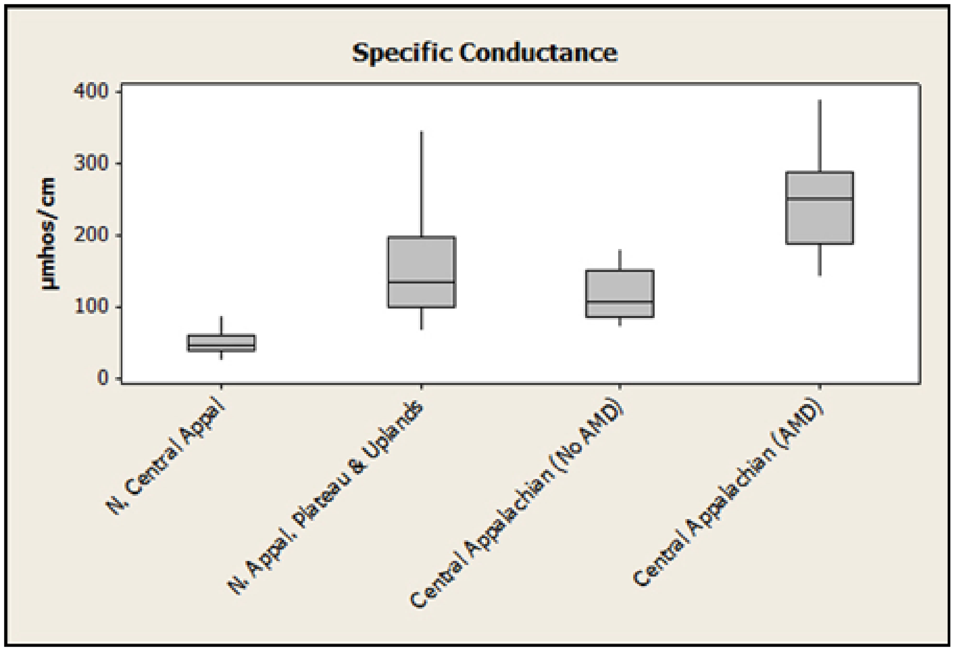


Figure 3. Box Plot for Specific Conductance by Ecoregion

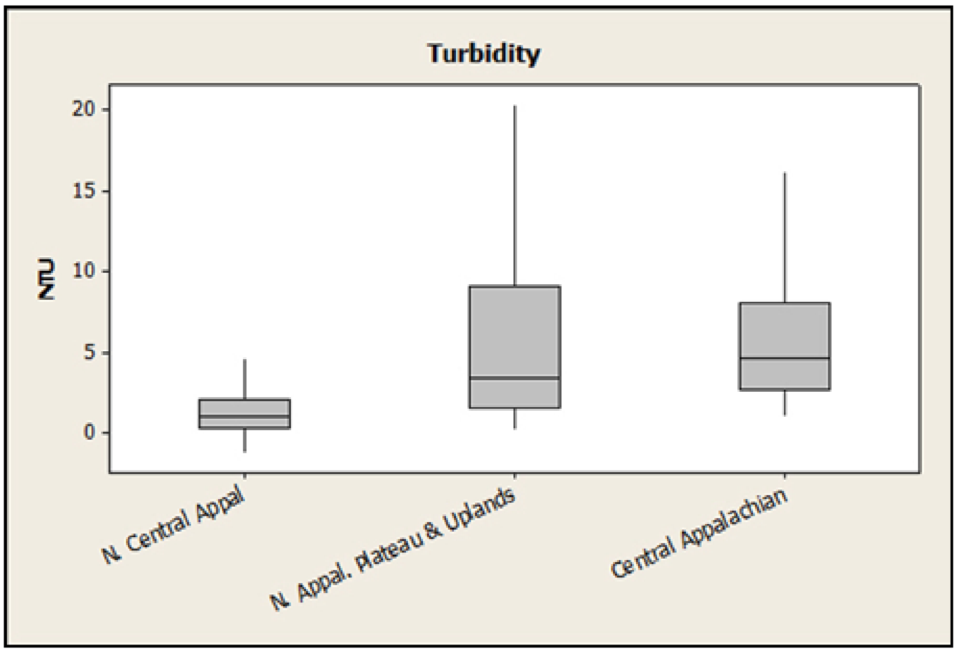


Figure 4. Box Plot for Turbidity by Ecoregion

The box plot for specific conductance is divided into four box-and-whisker plots, one for each ecoregion with the Central Appalachian Ridges and Valleys ecoregion being divided into two plots because of AMD impacted stations (Figure 3). AMD typically impacts the specific conductance of water chemistry. The box plot indicates a significant difference in specific conductance between ecoregions.

The North Central Appalachian ecoregion is tightly grouped indicating low variability of specific conductance. The Northern Appalachian Plateau and Uplands ecoregion contains the largest number of stations and shows a greater variability. The majority of stations have a glacial till surficial geology; however, several stations do not share this geology. Glacial till geology can contribute to higher specific conductance, explaining the larger variability and higher upper range in specific conductance in the ecoregion.

The Central Appalachian Ridges and Valleys ecoregion only contains five monitoring stations, and two of these stations are impacted by AMD. With few stations, a greater variability is typical in a box plot and this is portrayed in the two Central Appalachian box-and-whisker plots. Chest and Little Clearfield Creeks are represented in the AMD impacted plot and show a greater variability than the streams not impacted by AMD.

Turbidity for each station was grouped by ecoregion and visually presented in a box plot (Figure 4). None of the ecoregions show a significant difference in turbidity as the inter-quartile ranges overlap each other. Observed data in the North Central Appalachian ecoregion show low variability in turbidity as it did with specific conductance, indicating similar and consistent water chemistry within the monitored watersheds in this ecoregion.

SRBC staff verifies that the station along Loyalsock Creek is working.

The variability seen in the turbidity in the Northern Appalachian Plateau and Uplands stations could be linked with the glacial till geology and the land use in the ecoregion. Streams located in areas of glacial till geology typically will have higher turbidity (Cornell Cooperative Extension – Ulster County, 2007).

The Central Appalachian ecoregion displays less variability than the Northern Appalachian Plateau and Uplands ecoregion, but still indicates inconsistency in baseline turbidity values between the stations in the ecoregion. Many factors may contribute to this variability, including sample size (5), difference in land uses, and AMD impacts.

Correlating Precipitation with Field Parameters at Select Stations

Several stations exhibiting large standard deviations in turbidity and specific conductance were identified for closer analysis (Tables 2 and 3). Two correlation analyses were performed for each station to determine any correlative relationship between precipitation and these two parameters. Both analyses, Kendall's tau coefficient and Pearson's correlation coefficient, measure dependence of two variables on each other. Perfect correlation between the variables in either analysis would result in a coefficient of 1 or -1; a coefficient of 1 represents a positive correlation and a coefficient of -1 represents a negative correlation. Kendall's tau coefficient is a non-parametric test that analyzes for the statistical dependence of the variables. Pearson's correlation coefficient is a measure of linear dependence of two variables.

None of the preliminary statistics from the identified stations show a significant correlation between precipitation and either of the field chemistry parameters (Tables 2 and 3). The variables were correlated directly by date and time and also with a one-day lag period (precipitation 24 hours prior was compared with parameter concentration). As the project moves forward, a continued effort will be made to incorporate the influence of precipitation on water chemistry, especially in light of the various seasonal influences.

Table 2. Selected Sites for Closer Analysis between Turbidity and Precipitation

Site	Median	Standard Deviation	Kendall's tau	Pearson's rho
Canacadea Creek	5.15	199.47	-0.02	-0.16
Long Run	9.40	186.39	-0.20	-.022
Marsh Creek	2.70	123.38	0.25	0.36
Apalachin Creek	5.27	123.12	0.23	0.14
Bobs Creek	2.70	108.05	0.19	0.03
Sugar Creek	5.60	82.37	0.31	0.36
Larrys Creek	1.46	9.60	0.14	0.37
Loyalsock Creek	0.38	9.20	0.20	0.49

Table 3. Selected Site for Closer Analysis between Specific Conductance and Precipitation

Site	Mean	Standard Deviation	Kendall's tau	Pearson's rho
Canacadea Creek	379	137	-0.01	-0.09
Sugar Creek	285	135	-0.02	-0.07
South Branch Tunkhannock Creek	263	81	-0.07	-0.01
Hammond Creek	179	9	-0.09	-0.07

Water Chemistry – Lab Samples

In addition to the five continuously recorded water chemistry parameters at the RWQMN stations, SRBC staff collects water samples, which are analyzed at a certified lab, four or six times a year. These additional parameters and the frequency at which they are measured are noted in Table 4. Each RWQMN station has been analyzed for the additional parameters at least once and a subset of 15 stations have been monitored for the parameters on a regular schedule. These stations include Apalachin Creek, Bobs Creek, Bowman Creek, Cherry Valley Creek, Elk Run, Little Clearfield Creek, Little Muncy Creek, Meshoppen Creek, Sing Sing Creek, South Branch Tunkhannock Creek, Starrucca Creek, Sugar Creek, Trout Brook, Trout Run, and West Branch Pine Creek. Beginning in October 2011, routine sampling was initiated at all 51 stations on an eight-to-nine-week schedule for the additional parameters.

A further evaluation of water chemistry at each RWQMN site was done using the supplementary lab chemistry data collected at each site. The major anion and cation structure in percentages for each station was compared using a Piper Diagram. A Piper Diagram is useful for showing the characteristics of multiple stations on one diagram. The cations are plotted on the left triangle, while the anions are plotted on the right triangle. The points on the two triangles are projected upward into the diamond where they will intersect to visually show the difference in ion chemistry between the stations (University of Idaho, 2001).

The cation and anion data collected at each RWQMN site were plotted on a Piper Diagram and visually grouped by ecoregion (Figure 5). The

Table 4. Water Chemistry Parameters Analyzed at the Lab

Six Times/Year	Four Times/Year
Acidity, Hot	Alkalinity, Bicarbonate
Alkalinity	Alkalinity, Carbonate
Barium	Bromide
Chloride	Calcium
pH	Carbon Dioxide
Specific Conductance	Gross Alpha
Sulfate	Gross Beta
Total Dissolved Solids	Lithium
Total Organic Carbon	Magnesium
	Nitrate
	Potassium
	Sodium
	Strontium

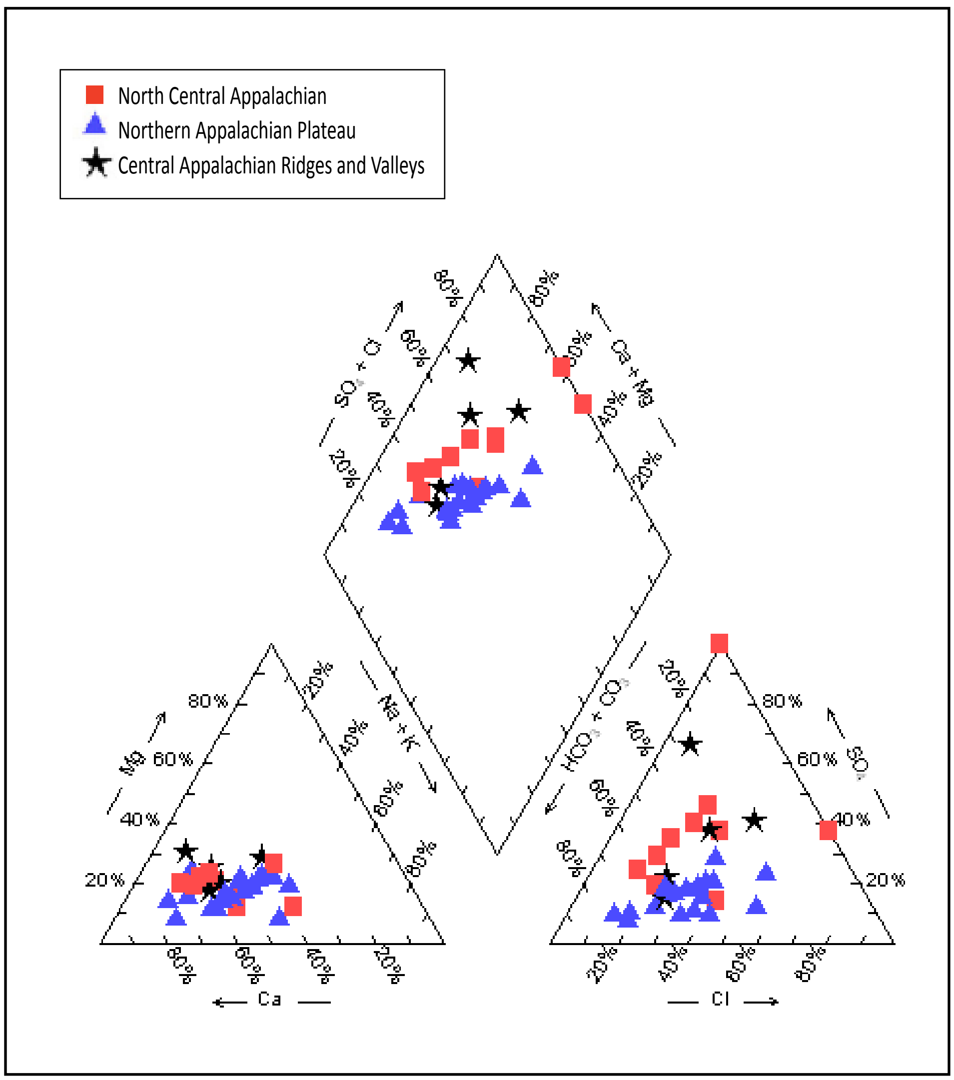


Figure 5. RWQMN Piper Diagram

North Central Appalachian ecoregion showed the most diversity within its stations. Trout Run and Kitchen Creek, represented by the two red squares on the right side of the diamond, indicate water chemistry conditions different from the other seven stations located in the North Central Appalachians.

The stations in the Northern Appalachian Plateau and Uplands ecoregion exhibit similar water chemistry, as indicated by the blue triangles. Looking at the Central Appalachian Ridges and Valleys ecoregion, there are two groupings of stations. Chest Creek, Little Clearfield Creek, and Bobs Creek are grouped together towards the top of the diamond and Little Muncy Creek and Marsh Creek are grouped near the middle of the diamond. Bobs Creek is an outlier in this ecoregion, exhibiting cation and anion percentages closer to the two streams impacted by AMD.

Little Muncy Creek, Central Appalachian Ridges and Valleys ecoregion.

Conclusions

The first 18 months of the RWQMN project have provided an abundance of baseline water quality data for headwater streams in the northern tier of Pennsylvania and New York portions of the Susquehanna River Basin. However, to accurately determine if changes in the water chemistry are the result of natural gas development activities, and not normal and/or seasonal variation, additional continuous data are needed. To achieve this, SRBC plans to continue collecting continuous monitoring data from the 51 established stations over the next several years.

While the need to maintain a continuous water quality monitoring network for all the RWQMN stations is clear, several stations exhibited water chemistry characteristics, while within water quality standards, warranting further investigation. These anomalies may have been demonstrated in the continuous monitoring data, the anion and cation structure, or in both sets of data (Table 5).

In addition to maintaining the continuous monitoring of these stations, SRBC will begin more detailed data collection in these watersheds. Some of the data collection efforts planned will involve automated water collection for lab analysis triggered by turbidity, pH, and/or conductance. Also, more targeted sampling will be conducted upstream of the RWQMN stations based on data collected during the first 18 months of the project. Stream morphology, which can be a potential influence on water chemistry, is another characteristic that SRBC will study in these targeted watersheds.

Also, to begin establishing biological baseline conditions in these watersheds, macroinvertebrates were collected in fall 2011 at each of the RWQMN sites. Macroinvertebrates will be collected at the stations during the same season each year to limit the influence of seasonal variation. Fish will be collected at several of the RWQMN sites in conjunction with several other SRBC projects during spring/summer 2012. Macroinvertebrate and/or fish data at each station will allow for comparison or documentation of any degradation of biota to the extent it can be linked to changes in the water quality.

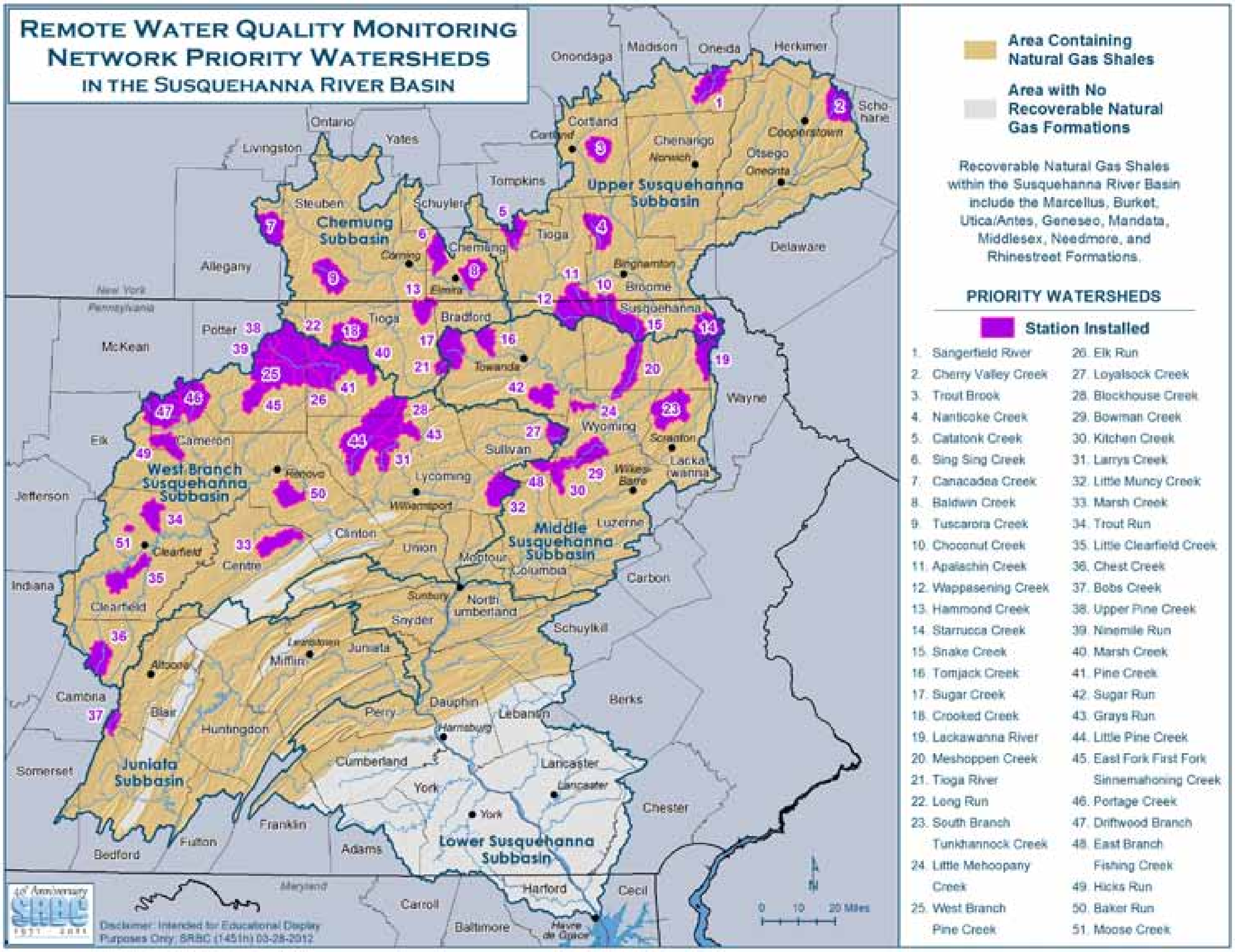
Future RWQMN data reports will continue to describe baseline water chemistry and biological data collected at all stations, but will also include detailed information on the targeted watersheds and the results of SRBC's analysis following pollution events where the data can be directly attributed to specific events.

Table 5. Watersheds Requiring Further Study

Watershed	Reason for Further Study
Blockhouse Creek	Water chemistry results differ from other watersheds in the same ecoregion
Kitchen Creek	Cation and anion percentages are different from other watersheds in the same ecoregion
Trout Run	Cation and anion percentages are different from other watersheds in the same ecoregion; observed specific conductance spikes not attributable to known causes
Meshoppen Creek	Elevated pH levels compared to other watersheds in the same ecoregion
Starrucca Creek	Elevated pH levels compared to other watersheds in the same ecoregion
Bobs Creek	Observed specific conductance spikes not attributable to known causes; cation and anion percentages correlate closer with AMD impaired watersheds than non-impaired

APPENDIX A

RWQMN Watersheds – 51 Stations



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APPENDIX B

Data Collection Timeframe

Stream Name	Map ID	Station	Period of Data Collection
Apalachin Creek	11	Apalachin Creek near Apalachin, NY	12/14/2010 – 7/5/2011
Baldwin Creek	8	Baldwin Creek near Lowman, NY	12/7/2010 – 6/20/2011
Blockhouse Creek	28	Blockhouse Creek near English Center, PA	6/4/2010 – 5/23/2011
Bobs Creek	37	Bobs Creek near Pavia, PA	3/30/2010 – 7/27/2011
Bowman Creek	29	Bowman Creek near Noxen, PA	4/1/2010 – 7/11/2011
Canacadea Creek	7	Canacadea Creek near Almond, NY	12/17/2010 – 7/5/2011
Catatonk Creek	5	Upper Catatonk Creek near Spencer, NY	12/16/2010 – 6/20/2011
Cherry Valley Creek	2	Cherry Valley Creek near Middlefield, NY	12/2/2010 – 6/28/2011
Chest Creek	36	Chest Creek near Patton, PA	9/21/2010 – 7/18/2011
Choconut Creek	10	Choconut Creek near Vestal Center, NY	1/27/2010 – 6/27/2011
Crooked Creek	18	Upper Crooked Creek near Keeneyville, PA	6/16/2010 – 7/5/2011
Elk Run	26	Elk Run near Watrous, PA	6/23/2010 – 6/6/2011
Hammond Creek	13	Hammond Creek near Millerton, PA	1/27/2010 – 6/20/2011
Kitchen Creek	30	Kitchen Creek near Huntington Mills, PA	10/30/2010 – 6/1/2011
Lackawanna River	19	Lackawanna River near Forest City, PA	7/14/2010 – 5/26/2011
Larrys Creek	31	Larrys Creek near Salladasburg, PA	3/30/2010 – 5/23/2011
Little Clearfield Creek	35	Little Clearfield Creek near Dimeling, PA	4/28/2010 – 7/18/2011
Little Mehoopany Creek	24	Little Mehoopany Creek near North Mehoopany, PA	9/8/2010 – 7/6/2011
Little Muncy Creek	32	Little Muncy Creek near Moreland, PA	8/6/2010 – 5/25/2011
Long Run	22	Long Run near Gaines, PA	12/17/2010 – 6/6/2011
Loyalsock Creek	27	Loyalsock Creek near Ringdale, PA	6/3/2010 – 7/6/2011
Marsh Creek	33	Marsh Creek near Blanchard, PA	6/30/2010 – 6/7/2011
Meshoppen Creek	20	Meshoppen Creek near Kaiserville, PA	1/27/2010 – 6/1/2011
Nanticoke Creek	4	Nanticoke Creek near Maine, NY	12/16/2011 – 6/8/2011
Sangerfield River	1	Sangerfield River near Poolville, NY	12/2/2010 – 6/28/2011
Sing Sing Creek	6	Sing Sing Creek near Big Flats, NY	12/1/2010 – 6/6/2011
Snake Creek	15	Snake Creek near Lawsville Center, PA	6/2/2010 – 7/6/2011
South Branch Tunkhannock Creek	23	South Branch Tunkhannock Creek near La Plume, PA	7/2/2010 – 5/16/2011
Starrucca Creek	14	Starrucca Creek near Stevens Point, PA	7/1/2010- 7/11/2011
Sugar Creek	17	Sugar Creek near Troy, PA	4/27/2010 – 6/1/2011
Tioga River	21	Tioga River near Fall Brook, PA	6/23/2010 – 6/20/2011
Tomjack Creek	16	Tomjack Creek near Burlington, PA	4/17/2010 – 7/5/2011
Trout Brook	3	Trout Brook near McGraw, NY	12/16/2010 – 6/28/2011
Trout Run	24	Trout Run near Shawville, PA	4/28/2010 – 6/7/2011
Tuscarora Creek	9	Upper Tuscarora Creek near Woodhull, NY	12/16/2010 – 6/6/2011
Wappasening Creek	12	Wappasening Creek near Windham Center, PA	6/2/2010 – 7/5/2011
West Branch Pine Creek	25	West Branch Pine Creek near Galeton, PA	6/3/2010 – 7/18/2011

APPENDIX C

Continuous Water Chemistry Statistics

Site	Map ID	Number of observations (=>)	Median SpCond µS/cm	Mean SpCond µS/cm	StDev SpCond µS/cm	Median DO mg/l	Mean DO mg/l	StDev DO mg/l	Median pH	Median Turb NTU	Mean Turb NTU	StDev Turb NTU
Apalachin Creek	11	48,418	0.155	0.156	0.022	13.14	12.02	2.35	7.22	5.27	34.13	123.12
Baldwin Creek	8	53,461	0.156	0.158	0.043	14.02	12.84	2.22	7.26	5.73	20.33	58.91
Blockhouse Creek	28	21,834	0.148	0.14	0.031	9.32	9.52	1.11	7.92	0.50	6.03	72.86
Bobs Creek	37	2,767	0.077	0.077	0.013	10.34	10.97	1.83	7.11	2.70	24.62	108.05
Bowman Creek	29	105,247	0.045	0.05	0.014	11.14	11.17	1.69	6.86	1.81	4.23	24.47
Canacadea Creek	7	53,427	0.373	0.379	0.137	12.90	12.30	2.20	8.04	5.15	63.12	199.47
Catatonk Creek	5	53,019	0.277	0.288	0.107	11.20	10.74	1.64	7.74	3.43	11.03	31.69
Cherry Valley Creek	2	1,034	0.184	0.192	0.041	12.64	11.87	1.65	7.63	7.58	14.85	32.12
Chest Creek	36	76,238	0.251	0.245	0.072	11.06	10.91	1.71	7.23	6.40	12.77	32.42
Choconut Creek	10	136,439	0.084	0.09	0.026	11.39	11.41	2.56	7.10	5.59	12.10	41.58
Crooked Creek	18	1,745	0.198	0.184	0.063	11.25	11.16	2.52	7.74	0.55	6.15	23.98
Elk Run	26	1,943	0.073	0.081	0.023	11.61	11.68	2.09	7.00	4.51	16.58	65.86
Hammond Creek	13	126,356	0.178	0.197	0.09	12.21	11.36	3.07	7.66	2.40	14.56	67.79
Kitchen Creek	30	1,264	0.059	0.06	0.012	13.09	12.78	1.41	6.75	1.61	1.65	10.31
Lackawanna River	19	82,777	0.075	0.077	0.019	12.05	11.34	2.38	6.97	2.54	24.02	80.60
Larrys Creek	31	8,765	0.055	0.06	0.005	11.97	11.34	1.58	7.21	1.46	2.95	9.60
Little Clearfield Creek	35	3,134	0.081	0.384	0.192	9.79	9.42	0.97	7.49	2.50	15.12	31.26
Little Mehoopany Creek	24	86,411	0.108	0.108	0.034	12.19	12.26	2.05	7.47	2.16	6.41	23.05
Little Muncy Creek	32	1,475	0.094	0.101	0.022	12.37	11.84	1.86	7.13	2.90	10.08	43.37
Long Run	22	12,212	0.066	0.077	0.01	10.41	12.24	0.77	6.95	9.40	34.82	186.39
Loyalsock Creek	27	114,423	0.03	0.035	0.016	10.49	10.91	2.25	6.33	0.38	1.31	9.20
Marsh Creek	33	90,156	0.107	0.118	0.038	12.23	11.60	2.87	7.38	2.70	33.02	123.38
Meshoppen Creek	20	126,513	0.124	0.122	0.025	11.11	11.15	2.51	7.62	3.00	9.67	35.72
Nanticoke Creek	4	41,585	0.127	0.125	0.036	13.59	13.23	1.27	7.18	15.00	92.74	174.78
Sangerfield River	1	54,502	0.257	0.25	0.057	12.35	11.82	1.74	7.91	7.48	16.09	66.32
Sing Sing Creek	6	43,831	0.348	0.377	0.141	12.03	11.68	1.87	7.63	20.27	47.91	127.68
Snake Creek	15	99,477	0.088	0.09	0.021	10.32	10.72	2.42	7.02	2.33	8.54	36.18
South Branch Tunkhannock Creek	23	57,400	0.255	0.263	0.081	10.93	11.62	2.19	7.74	1.60	9.22	49.56
Starrucca Creek	14	66,341	0.085	0.083	0.018	10.33	11.18	2.22	7.60	0.60	4.50	25.47
Sugar Creek	17	59,485	0.21	0.285	0.135	10.85	10.31	2.87	7.61	5.60	19.08	82.37
Tioga River	21	1,741	0.042	0.043	0.012	11.72	11.44	1.86	6.76	0.97	23.36	129.88
Tomjack Creek	16	59,693	0.184	0.181	0.05	9.17	9.08	1.84	7.86	2.26	11.75	61.43
Trout Brook	3	55,768	0.157	0.157	0.054	13.09	12.26	1.72	7.81	2.70	12.36	43.01
Trout Run	24	103,282	0.048	0.051	0.012	10.85	11.23	1.73	5.76	0.27	1.17	10.79
Tuscarora Creek	9	42,743	0.192	0.198	0.042	13.52	12.86	1.66	7.90	17.12	38.09	96.54
Wappasening Creek	12	93,671	0.099	0.103	0.026	10.59	10.29	3.15	7.06	2.40	16.45	66.56
West Branch Pine Creek	25	72,979	0.044	0.048	0.009	9.62	9.59	1.48	7.16	1.60	9.56	36.87

Lick Run, Clinton County, Pa

Acknowledgments

The Susquehanna River Basin Commission (SRBC) wishes to thank the more than 35 state, county, and local government agencies and private landowners who partnered with SRBC on the installation of the RWQMN stations. These partnerships made it possible for SRBC to locate and install each monitoring station.

SRBC also thanks the partners who provided the invaluable funding necessary to launch the successful real-time water quality monitoring network. The RWQMN is funded by private and public sector contributions and by SRBC, which covers the network's ongoing maintenance expenses. To date, the funding partners are:

- East Resources, Inc.
- New York State Energy Research and Development Authority
- Pennsylvania Department of Conservation and Natural Resources
- Headwaters Resource Conservation & Development Council Sinnemahoning Stakeholders Committee

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