West Branch Susquehanna River Subbasin Year 1 Survey, April through August 2015

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INTRODUCTION

One of the missions of the Susquehanna River Basin Commission (Commission) is to "protect water quality and instream uses" of streams within the Basin. To accomplish this mission, Commission scientists lead several projects and programs to better understand the interactions of biological, chemical, and physical traits of streams throughout the Basin. One such program is the Subbasin Survey Program, which involves rotating annual water quality, habitat, and macroinvertebrate assessments in each of the six major Susquehanna River subbasins (Figure 1). This program is funded in large part through the United States Environmental Protection Agency (USEPA).

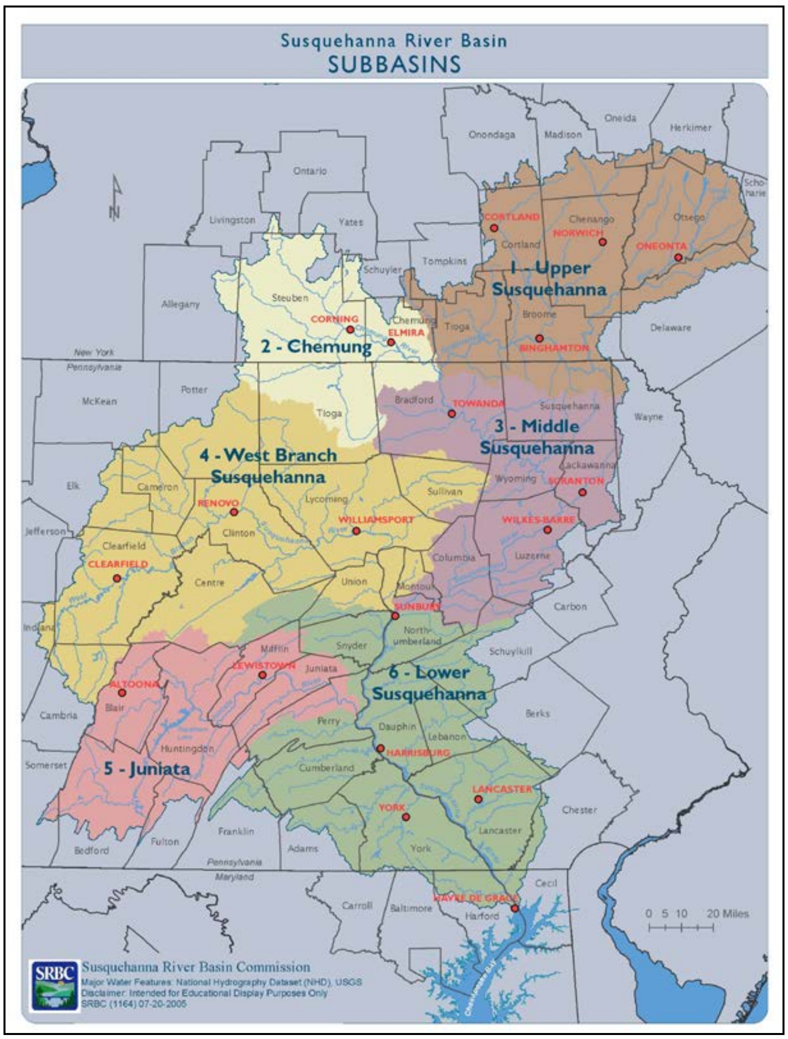

Figure 1. Counties and Population Centers in the Six Major Subbasins of the Susquehanna River Basin

From April through August 2015, the Commission assessed 71 sites in the West Branch Susquehanna River Subbasin as part of this program. The Commission conducted similar surveys in this subbasin in 1983, 1994, 2002, and 2009 (McMorran, 1985; LeFevre, 2003; and Buda, 2010). This technical summary briefly documents environmental characteristics of the West Branch subbasin, presents information on various monitoring programs currently active in the subbasin, and provides broad results from the 2015 subbasin survey.

What are characteristics of the West Branch Susquehanna Subbasin?

The West Branch Susquehanna River Subbasin is the largest of the six subbasins, draining just under 7,000 square miles of northcentral Pennsylvania. This subbasin is home to nearly 12 percent of the population in the Basin, covers large parts of 16 counties, and encompasses the cities of Clearfield, Renovo, State College, and Williamsport. Three Level III ecoregions (Omernick, 1987; Woods and others, 2003) overlap with the West Branch Susquehanna subbasin (Figure 2):

- Ecoregion 62: North Central Appalachians (NCA) (58 percent of drainage area)
- Ecoregion 67: Central Appalachian Ridges and Valleys (RV) (41 percent of drainage area)
- Ecoregion 60: Northern Appalachian Plateau and Uplands (NAPU) (1 percent of drainage area)

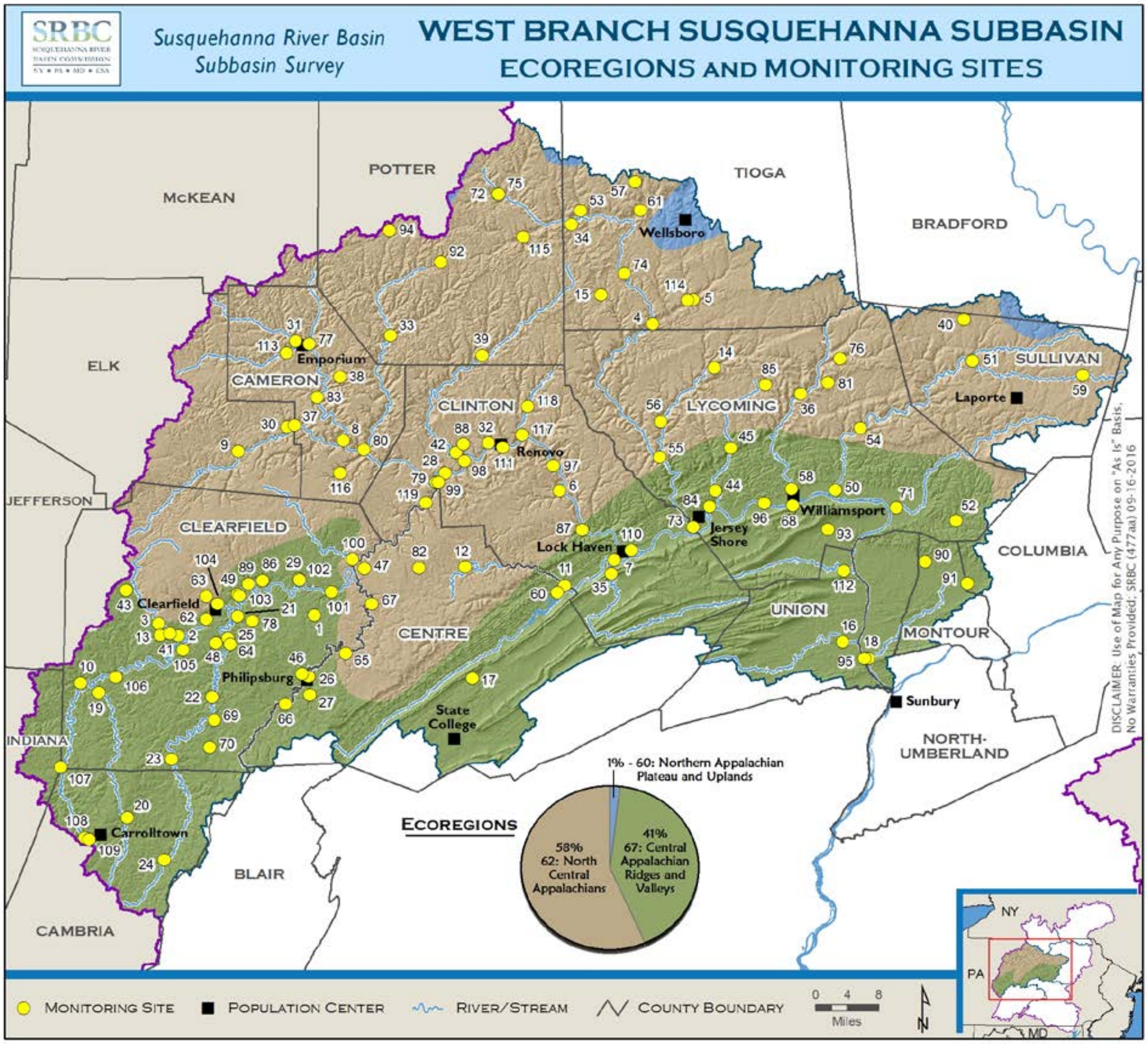

Figure 2. West Branch Susquehanna Subbasin Level III Ecoregions and Monitoring Sites

Most of the subbasin is covered by natural vegetated areas, with a large portion consisting of State Forest (Figure 3). This subbasin experienced heavy logging operations in the past. Cultivated land is most frequently found in the southeastern portion of the subbasin. Pockets of developed areas are located throughout the subbasin but are most prevalent adjacent to the cultivated areas. Extensive logging activities affected the landscape in this subbasin in the late 1800s. Heavily mined bituminous coal lands are concentrated in the southwestern portion where communities continue to deal with the remnants of the industry, such as coal slag piles, abandoned mines, and mine drainage.

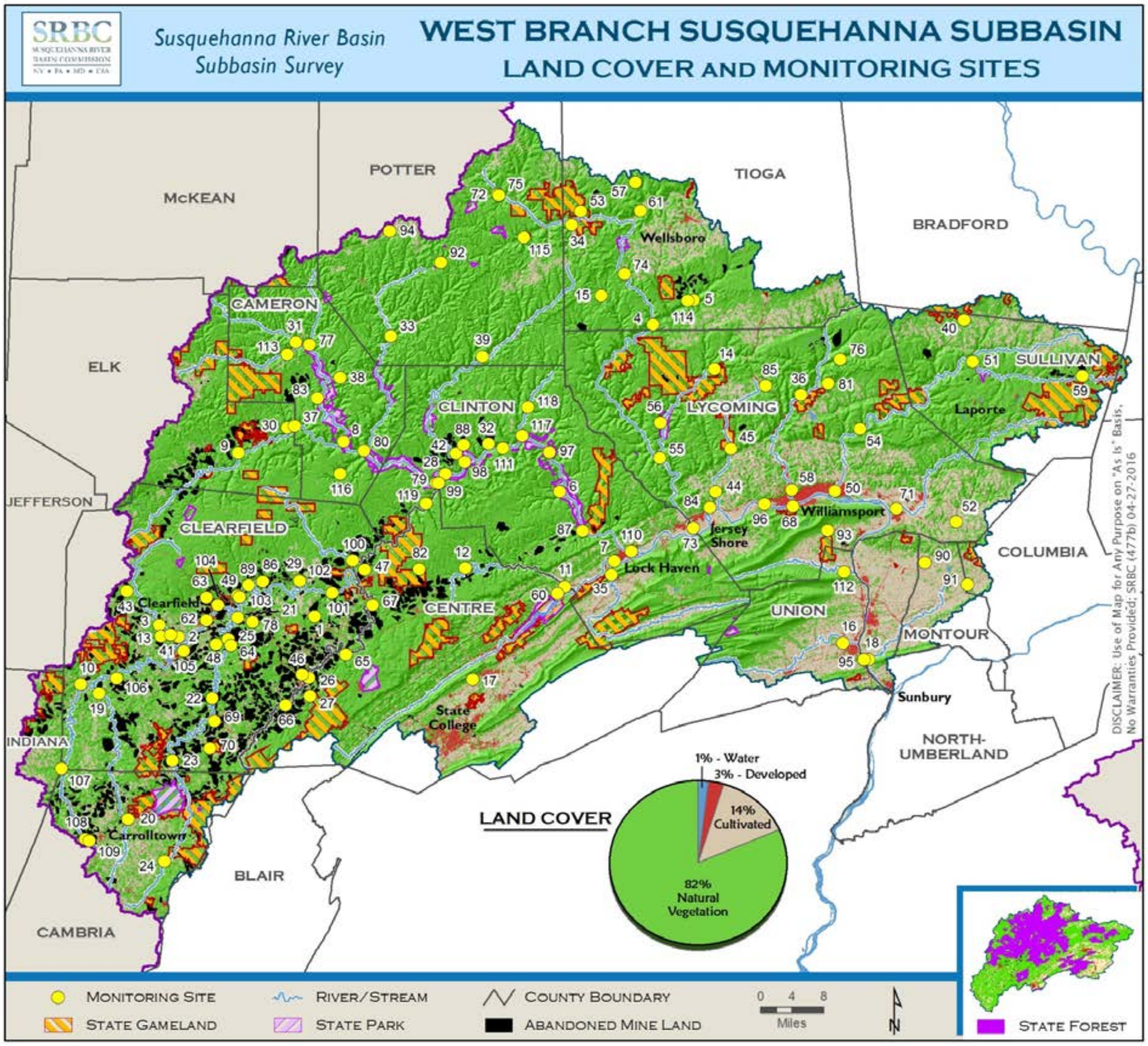

Figure 3. West Branch Susquehanna Subbasin Land Cover and Monitoring Sites

<u>What other monitoring currently occurs in this subbasin?</u>

The Pennsylvania Department of Environmental Protection (PADEP) conducts routine biological and water chemistry sampling at sites in the fixed, statewide Water Quality Network (WQN). Thirty-two WQN sites are located in the West Branch subbasin. More information and data from these sites can be accessed at dep.pa.gov/Business/Water/PointNonPointMgmt/WaterQuality/_layouts/mobile/dispform.aspx?List=920675dc-783e-4cd1-a627-5ac22dab1649&View=0cf38e9e-c455-44cb-b14f-d59f417c219e&ID=15.

The Commission currently uses many monitoring and protection projects and programs to better understand the biological, physical, and chemical traits of streams in this subbasin. More information on each of these projects and programs, which are listed below, can be found at srbc.net/programs/monitoringprotection.htm. Data collected from many of these projects can be found at the Commission's Water Quality Portal (mdw.srbc.net/waterqualityportal):

- West Branch Subbasin Year 2 Survey,
- Sediment and Nutrient Assessment Program (SNAP),
- Early Warning System Program (EWS),
- Large River Assessment Project (Large Rivers),
- Remote Water Quality Monitoring Network (RWQMN),
- Flow Monitoring Network, and
- Mine Drainage Program.

METHODS USED IN THE 2015 SUBBASIN SURVEY

How is the subbasin survey designed?

In the past, the Commission conducted subbasin surveys at sites targeted for easy access, like road crossings. However, these sites were often disturbed, so survey results were more likely to be biased towards poorer conditions. In addition, these results could not be used to generalize the condition of streams throughout the subbasin.

As a result, the Commission modified the subbasin survey design in 2014 to include sampling at sites statistically chosen at random (probabilistic sites). Once probabilistic sites are sampled in each of the six subbasins, these results will allow for an unbiased, statistically sound review of stream conditions throughout the Basin (Herlihy et al., 2000).

The revised subbasin survey design involves collection of physical, chemical, and biological data at three categories of sites within each subbasin:

- **Long-term sites**, which are a subset of sites sampled in previous subbasin surveys,
- **Probabilistic sites**, which are randomly selected through a computer program, and

- **Other sites**, which are sampled in the same timeframe by the Commission as part of other projects previously mentioned.

Through this modified subbasin survey design, the Commission retains the ability to track water quality trends at targeted streams in the subbasin, leverage the effort and results from other internal projects, and collect data for basinwide water quality generalizations. In 2015, a total of 71 subbasin sites were sampled as part of this survey, with 119 sites sampled in the subbasin as part of all Commission projects during this time period (see Appendix A).

Long-term Sites

Twenty-one of the sites sampled in previous surveys were designated as long-term sites and fill spatial gaps in the subbasin where other routine sampling sites (WQN and RWQMN) were absent. These sites are mostly located at the mouths of major tributaries and help characterize the water quality of streams entering larger systems. Water quality characteristics can be tracked through time at these sites.

Probabilistic Sites

The Commission determined that project scope and limits could support sampling of a maximum of 20 probabilistic sites within each subbasin. Through the process detailed below, 20 primary sites were randomly selected throughout the subbasin. Twenty additional oversample sites were selected for each ecoregion as replacement sampling locations if staff determined that any of the primary sites could not be sampled. The Commission plans to report on generalized water quality conditions throughout the Basin once probabilistic sites are sampled in each of the six subbasins.

USEPA recommends the use of a Generalized Random Tessellation Stratified (GRTS) design for probabilistic site selection (USEPA, 2008). The Commission used a stratified, unequal probability GRTS design based on ecoregion and placed weights on stream segments using stream order. This process used ArcGIS and R software with an associated spatial survey design and analysis (spsurvey) package (Kincaid and Olsen, 2012).

Subbasin streams were assigned to one of two stream size classes–'small' for stream orders 2 and 3 and 'large' for stream orders 4 through 6. Stream order 1 was excluded because these streams were most likely to have intermittent flow. To keep survey results restricted to wadeable streams, stream orders 7 and 8 were excluded.

Level III ecoregion was used as the strata variable, and the number of sites was distributed based on the proportion of land area in each ecoregion present. Within each ecoregion, sites were given an unequal probability of being located in each size class (small or large) based on the proportion of stream miles of each size class within the subbasin.

Other sites

In 2015, staff sampled water chemistry and macroinvertebrates at five sites in the subbasin as part of the Large Rivers project and 30 sites as part of the RWQMN project. Forty-three other sites were sampled to provide water quality data to the Commission's Mine Drainage Program. Data collected at these 78 additional sites are presented in various degrees within the results section.

<u>How were data collected and analyzed?</u>

Staff sampled all High Quality (HQ) and Exceptional Value (EV) streams and most other sites by the first week of May 2015. The winter/spring index period identified in PADEP's Index of Biotic Integrity (IBI) for Benthic Macroinvertebrate Communities in Pennsylvania's Wadeable, Freestone, Riffle-Run Streams (PADEP, 2013) runs from November through May.

Ten long-term and probabilistic sites as well as Large River sites could not be sampled until August and September 2015 because flows in the spring were too high. The EWS sonde on the West Branch Susquehanna River at Milton, PA, has been recording continuous water quality data since 2011, but only data collected from April to September 2015 are presented in this report.

Water Chemistry and Discharge

Staff measured *in situ* temperature, specific conductance, pH, and dissolved oxygen simultaneously using a multi-meter YSI sonde at all sites. The probes of all meters were rinsed with distilled water and sample water prior to collecting water quality data and were calibrated as detailed in the Quality Assurance Project Plan (QAPP).

Water samples were collected at all sites using depth-integrated water sampling methods (Guy and Norman, 1969), placed on ice, and delivered to ALS Environmental, Inc., in Middletown, PA, for analysis. Water samples collected at long-term, probabilistic, and RWQMN sites were analyzed for parameters listed in Table 1. Water samples collected at mine drainage sites were analyzed for a reduced site list focused on metals, ions, and other indicators of mine drainage pollution. Suspended sediment samples were collected at the same time and analyzed in-house. Results received from ALS Environmental were compared to water quality standards and aquatic life tolerances and recommendations (Table 2). Those values which exceeded these standards and recommendations were noted and flagged. Phosphorus results were not usable due to lab error and are consequently not included in this report.

Table 1. Water Quality Parameters Sampled in the West Branch Subbasin

Field Parameters		
Flow (cfs)	Conductivity (µmhos/cm)	Temperature (^{o}C)
Dissolved oxygen (mg/l)	pH	
Laboratory Analysis		
Alkalinity (mg/l)	Total calcium (mg/l)	Total sodium (mg/l)
Total dissolved solids (mg/l)	Total bromide (mg/l)*	Chloride (mg/l)
Total suspended solids (mg/l)	Total strontium (mg/l)*	Sulfate (mg/l)
Total nitrogen (mg/l)	Gross beta (pCi/l)*	Total iron (mg/l)
Nitrite-N (mg/l)	Gross alpha (pCi/l)*	Total manganese (mg/l)
Nitrate-N (mg/l)	Total barium (mg/l)*	Total aluminum (mg/l)
Turbidity (NTU)	Total lithium (mg/l)*	Total orthophosphate (mg/l)
Total organic carbon (mg/l)	Hot acidity (mg/l)	Total phosphorus (mg/l)
Total hardness (mg/l)	Total magnesium (mg/l)	Suspended sediment

cfs = cubic feet per second
µmhos/cm = micromhos per centimeter
mg/l = milligram per liter
NTU = nephelometric turbidity units
pCi/l = picoCuries per liter
*only at select sites

Table 2. Water Quality Standards and Recommendations

Parameter	Preferred Limits	Reference Code
Based on water quality standards:		
Alkalinity	≥ 20 mg/l	a
Dissolved Oxygen	≥ 4 mg/l	a
Gross Alpha	< 15 pCi/l	b
Gross Beta	4 millirems/yr	b
pH	≥ 6.0 and ≤ 9.0	a
Temperature	≤ 30.5 ºC	a
Total Aluminum	≤ 0.75 mg/l	c
Total Barium	< 2.0 mg/l	b
Total Chloride	≤ 250 mg/l	a
Total Dissolved Solids	≤ 500 mg/l	d
Total Iron	≤ 1.5 mg/l	a
Total Magnesium	≤ 35 mg/l	d
Total Manganese	≤ 1.0 mg/l	a
Total Sodium	≤ 20 mg/l	d
Total Strontium	< 4.0 mg/l	e
Total Sulfate	≤ 250 mg/l	a
Total Suspended Solids	≤ 25 mg/l	a
Turbidity	≤ 50 NTU	f
Other background levels, aquatic life tolerances, or recommendations		
Acidity	≤ 20 mg/l	g
Calcium	≤ 100 mg/l	g
Conductivity	≤ 800 µmhos/cm	h
Total Bromide	< 0.05 mg/l	i
Total Hardness	≤ 300 mg/l	j
Total Lithium	< 0.7 mg/l	k
Total Nitrate	≤ 0.6 mg/l	l
Total Nitrite	≤ 1 mg/l	d
Total Nitrogen	≤ 1 mg/l	l
Total Organic Carbon	≤ 10 mg/l	m
Total Orthophosphate	≤ 0.02 mg/l	l
Total Phosphorus	≤ 0.1 mg/l	j

a. www.pacode.com/secure/data/025/chapter93/s93.7.html
b. water.epa.gov/drink/contaminants/index.cfm
c. www.pacode.com/secure/data/025/chapter93/s93.8.html
d. www.dec.ny.gov/regs/4590.html#16132
e. www.pabulletin.com/secure/data/vol42/42-27/1292.html
f. www.dsd.state.md.us/comar/comarhtml/26/26.08.02.03-3.htm
g. Based on archived data at SRBC
h. www.uky.edu/WaterResources/Watershed/KRB_AR/wq_standards.htm
i. wilkes.edu/include/waterresearch/pdfs/waterbooklet070610.pdf
j. www.uky.edu/WaterResources/Watershed/KRB_AR/krww_parameters.htm
k. http://www.vdh.virginia.gov/Epidemiology/dee/PublicHealthToxicology/documents/pdf/factsheets/Lithium2014.pdf
l. water.usgs.gov/pubs/circ/circ1225/images/table.html
m. Hem (1970)

Discharge measurements at sites near USGS gaging stations were obtained from the USGS database. At other sites, Commission measured discharge using a FlowTracker and standard USGS procedures (Buchanan and Somers, 1969). Discharge was not measured during higher flows deemed unsafe or when the transect area was otherwise not wadeable.

Macroinvertebrates

Benthic macroinvertebrates were sampled at probabilistic, long-term, and RWQMN sites according to PADEP Wadeable, Freestone Streams Sampling Protocol (PADEP, 2013). Benthic macroinvertebrates are organisms that live on the stream bottom, including aquatic insects, crayfish, clams, snails, and worms.

At each site, staff identified an estimated 100-meter reach containing riffle-run or best available habitat for macroinvertebrate sampling. Staff collected six D-frame (500-micron mesh net) samples from representative riffle-run habitats in the reach by kicking the substrate and allowing dislodged material to flow downstream into the net. These six D-frame samples were composited into one sample and preserved in 95-percent denatured ethyl alcohol. Each sample was subsampled to 200 (± 20 percent) organisms per sample. Each organism was identified to genus when possible, except for midges, which were identified to family, and worms, which were identified to class.

Macroinvertebrate data were then used to calculate the PADEP IBI. Multi-metric indices like the IBI allow for standardized comparison of data from a study site against a large pool of fixed, established reference sites. To calculate a PADEP IBI score at a site, data from each 200-count subsample were reduced to six metrics, including total taxa richness, total Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa richness, Beck's Index (version 3), Shannon Diversity, Hilsenhoff Biotic Index, and percent sensitive individuals. These metrics were then standardized and used to calculate an IBI score, ranging from 0-100, for each site.

IBI scores are used by PADEP to determine the regulatory status of a stream and whether the stream is meeting aquatic life use as defined by PA Code Chapter 93, Water Quality Standards. The Commission does not have regulatory authority in determining whether a stream meets designated use, so a biological community rating scale that corresponds to the calculated IBI at a site was used (Table 3; D. Shull, personal communication).

Table 3. Commission Biological Community Rating Scale (based on recommendations from PADEP)

PADEP IBI Score	Commission Rating
≥ 90	Very good
78-89	Good
53-77	Fair
≤ 52	Poor
Fewer than 160 organisms in subsample	Very poor

Physical Habitat

At each site visit, staff evaluated habitat conditions at long-term, probabilistic, and RWQMN sites using a modified version of RBP III (Plafkin and others, 1989; Barbour and others, 1999). This RBP approach allows for staff ratings of 11 physical stream characteristics pertaining to substrate, pool and riffle composition, shape of the channel, conditions of the banks, and the riparian zone on a scale of 0-20 (20 being optimal). A total RBP habitat score (ranging from 0 to 220) was then calculated for each site. During field evaluation, staff also noted recent precipitation events, substrate material composition, surrounding land use, other relevant features in the watershed, and the presence of common terrestrial and aquatic invasive species at the site and surrounding area.

RESULTS and DISCUSSION

What are the major water quality issues in the subbasin?

Section 303(d) of the Clean Water Act requires a Total Maximum Daily Load (TMDL) to be developed for any waterbody designated as impaired for not meeting the state water quality standards or its designated use. In Pennsylvania, PADEP assesses streams as part of the Statewide Surface Waters Assessment Program. If PADEP determines a stream to be impaired, a TMDL may be required for the corresponding watershed. Impaired streams are listed in the Pennsylvania Integrated Report (IR), which is updated every two years. The 2014 IR was reviewed to determine the number of stream miles listed as needing a TMDL (Category 5) since the 2009 subbasin survey was completed (Table 4; PADEP, 2014).

Table 4. Number of Stream Miles Listed in the West Branch Subbasin for Aquatic Life Impairment and Requiring a TMDL (PADEP 2014 Integrated Report)

Source	listed between 1996 & 2009	newly listed from 2010-2014	Total	Causes	
Mine Drainage	1162.89	19.82	1182.71	metals pH siltation	habitat alterations other inorganics (sulfates)
Agriculture	550.21	0	550.21	siltation nutrients	organic enrichment low dissolved oxygen
Other*	192.93	5.06	197.99	siltation metals nutrients habitat and flow alterations	organic enrichment thermal modifications low dissolved oxygen
Atmospheric Deposition	112.15	83.40	195.55	pH	
Subtotal	**2018.18**	**108.28**	**2126.46**		

*Sources include small residential runoff, industrial point sources, urban runoff, storm sewers, etc.

Most of the stream miles (56 percent) that are currently impaired for aquatic life use in the subbasin are related to impacts from mine drainage. Twenty-six percent of these currently impaired stream miles are affected by impacts from agriculture. Nine percent of currently impaired stream miles are affected by atmospheric deposition.

Since the 2009 West Branch subbasin survey, 114.1 stream miles (6 percent of stream miles) within this subbasin that were previously impaired for aquatic life were reassessed by PADEP and delisted (T. Clark, 2016). The Commission continues to work with PADEP to reassess additional impaired streams for the ultimate goal of moving these streams off the 303(d) list.

<u>What did this 2015 survey say about water chemistry in the subbasin?</u>

Survey sites were distributed throughout the entire subbasin, but sites chosen specifically for monitoring mine drainage were concentrated in the western portion of the subbasin around Clearfield and Philipsburg, PA. Most of these sites (87 percent) had at least one parameter exceeding a standard (Appendix B). Low or non-detectable alkalinity occurred at just over 70 percent of all subbasin sites (Figure 4). Low alkalinity in a stream is largely influenced by underlying geology. Elevated nitrate occurred at just over 20 percent of all sites. The same basic patterns were observed when analyzing just the probabilistic sites, with low or non-detectable alkalinity and elevated nitrate occurring at 70 and 30 percent of probabilistic sites, respectively.

Indicators of mine drainage problems such as acidity, aluminum, iron, manganese, sulfate, and low pH were largely isolated to documented mine drainage-affected sites. Water quality at each site is depicted in Figure 5 as the number of parameters that exceeded standards listed in Table 2, and not surprisingly, most of the water quality problems within the subbasin occur where mine drainage or other land disturbance occurs.

While atmospheric deposition is tied to 9 percent of impaired sites in the West Branch subbasin (Table 4), none of the sites sampled in this survey were located on streams that are listed for impairment by atmospheric deposition. Closer analysis of water chemistry and biological communities does not indicate effects of atmospheric deposition on sampled streams that are not currently listed for impairment.

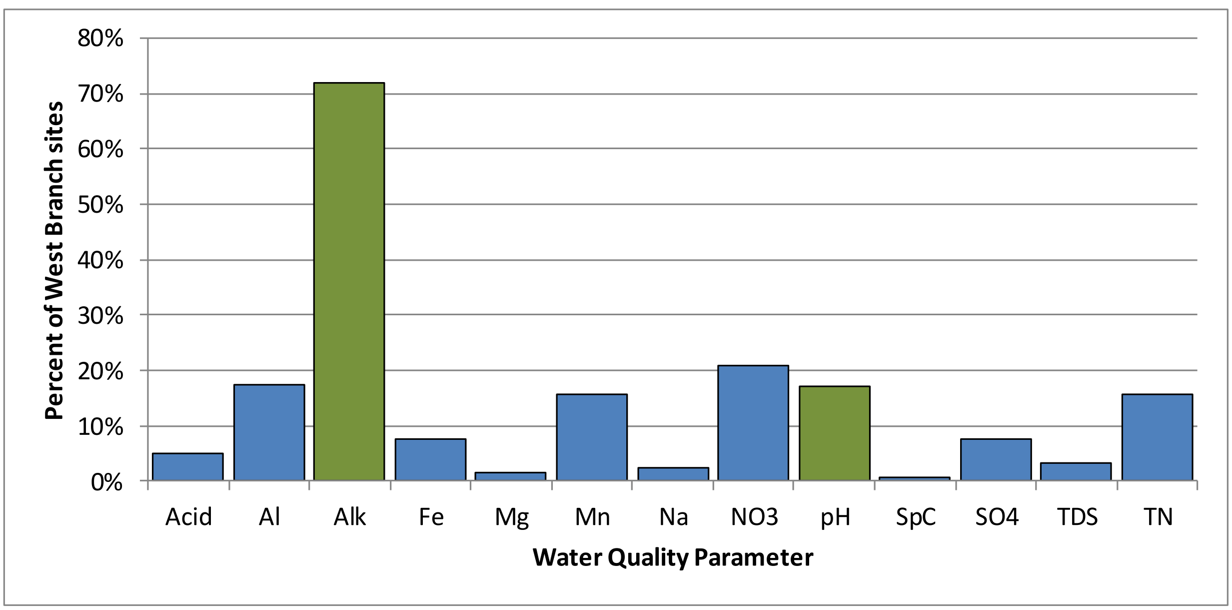

Figure 4. ***Percent of West Branch Subbasin Sites with Elevated (blue) or Depressed (green) Water Chemistry Parameter Values (2015; n = 104)***

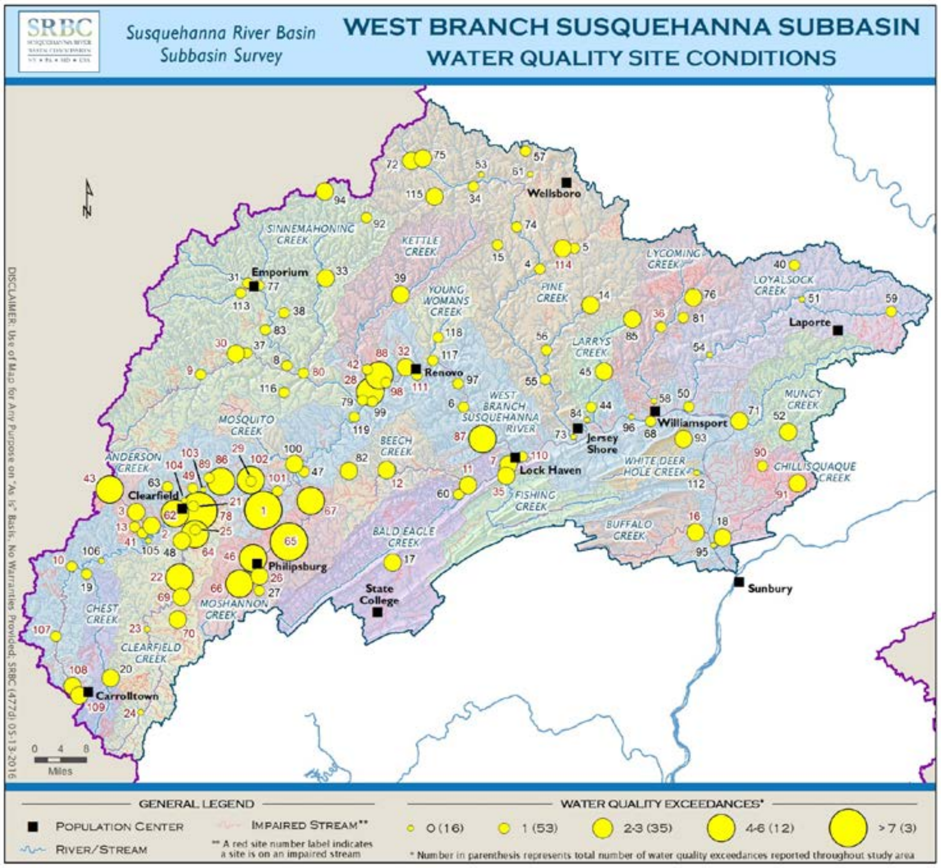

Figure 5. Number of Water Quality Parameter Exceedances at West Branch Subbasin Sites (2015; n = 104)

Biological ratings at most sites are presented in Figure 6. Macroinvertebrates were not collected at mine drainage sites because of budget limitations. Overall, healthier biological communities were observed at sites in the northcentral portion of the subbasin where undisturbed natural vegetation is still largely present and water chemistry was better. Lower biological ratings were also located in the southeastern portion of the subbasin, where land is more developed and cultivated.

Poor and very poor biological communities were largely found in the southwestern portion of the subbasin where mine drainage issues were concentrated and water quality is poor. Most of these sites are located on impaired streams.

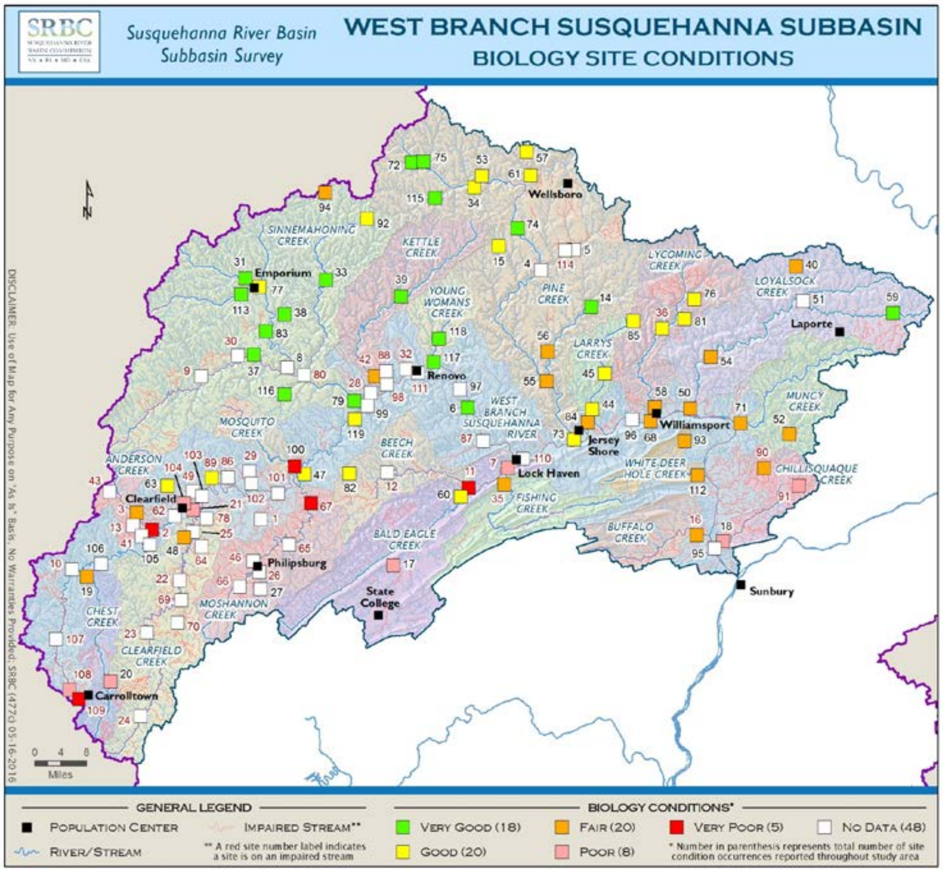

***Figure 6.	Biological Conditions at West Branch Subbasin Sites (2015; n = 104)***

The stream conditions seen in this study are characteristic of a region containing urban and agricultural development, underlain by non-carbonate geology, and with a mine drainage development history.

<u>What did continuous monitoring show?</u>

Nearly all of the water draining this subbasin passes through the West Branch Susquehanna River at Milton, PA, before joining the mainstem Susquehanna at Sunbury, PA. The Commission maintains a water quality sonde in this location, near site WBSR 5.0. Continuous water quality parameters for the study period are summarized in Table 5 and depicted in Figures 7 and 8. Discharge measurements were not available before September 2015, and turbidity data were not available after July 2015. All water chemistry parameters were within acceptable limits outlined in Table 2.

Table 5. Summary Statistics for Continuous Water Chemistry Parameters from April to September 2015 at Milton, PA

Parameter	Unit	Median	Mean	Minimum	Maximum
Temperature	°C	21.8	20.1	4.1	27.4
pH	--	7.6	--	7.1	8.4
Dissolved Oxygen	mg/l	9.8	10.1	8.3	14.1
Specific Conductance	µS/cm	214.4	232.2	99.1	420.4
Turbidity*	NTU	5.0	8.9	0.9	79.7

*Incomplete dataset

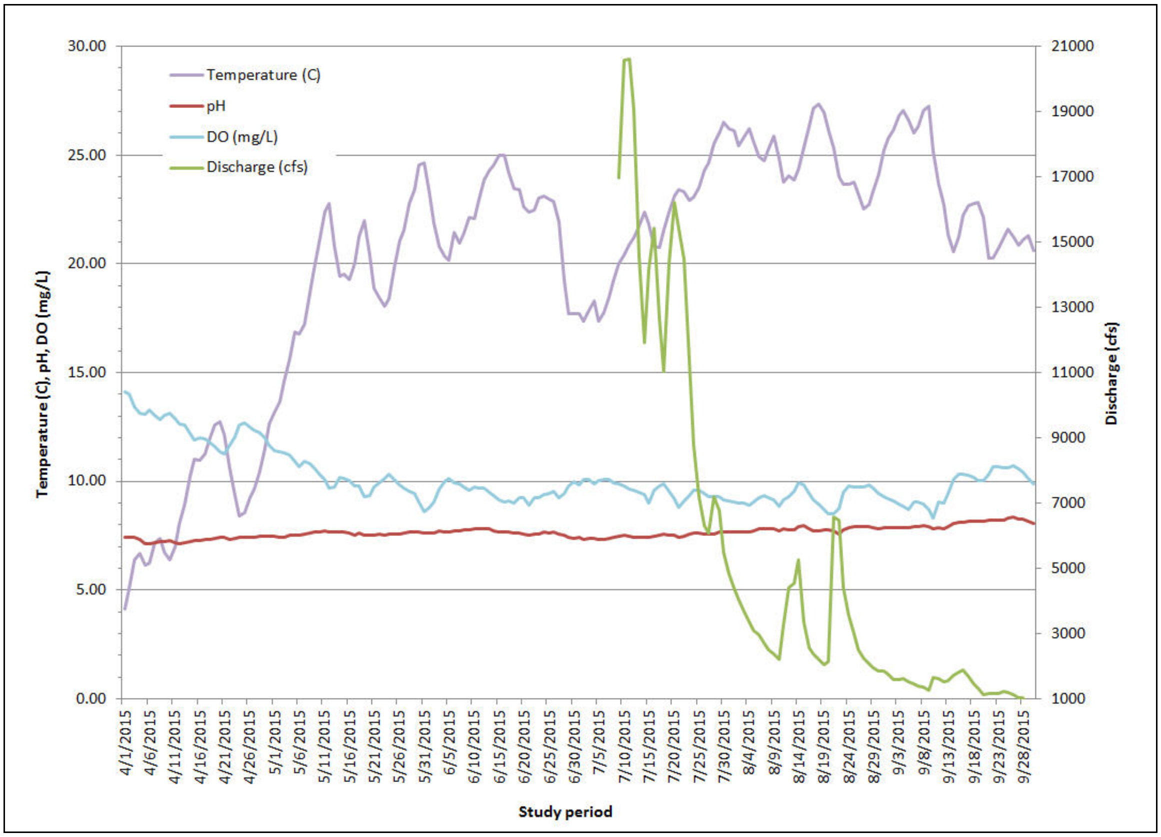

Figure 7. Temperature, pH, Dissolved Oxygen, and Discharge at West Branch Susquehanna River at Milton, PA, from April to September 2015

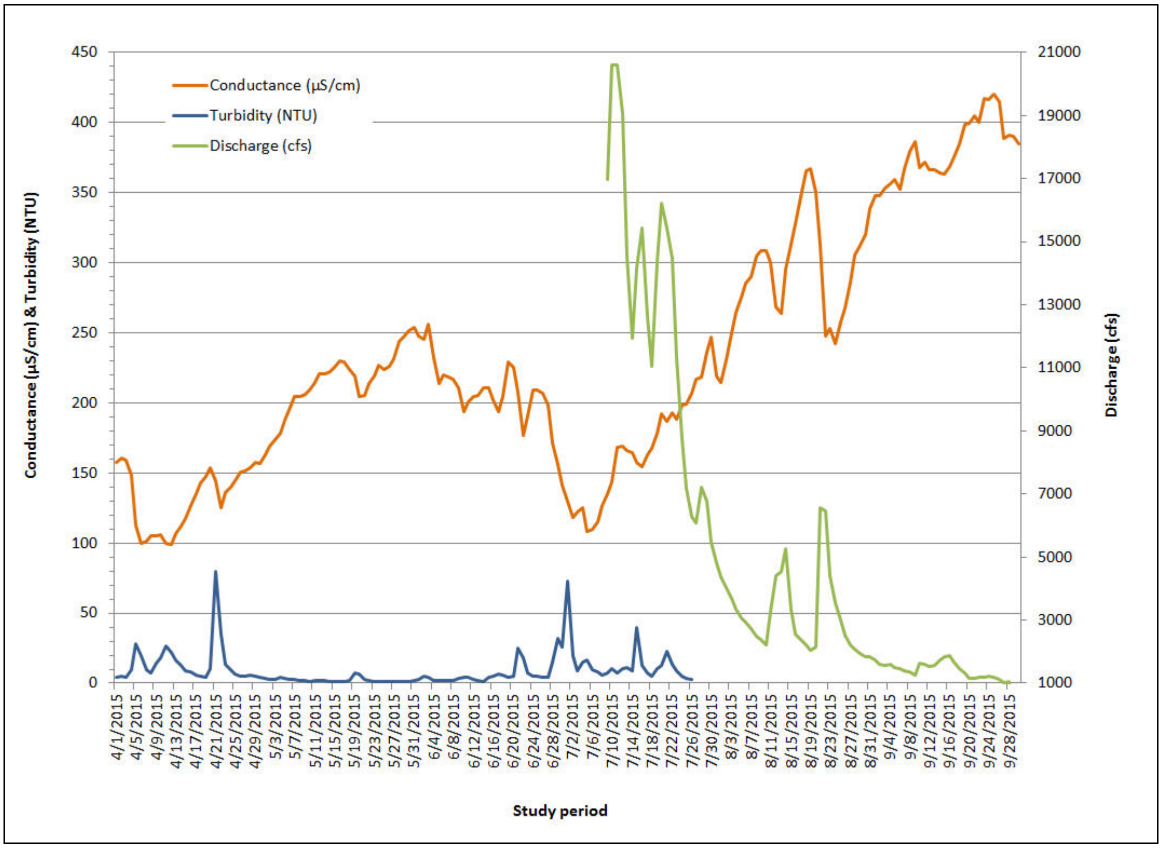

Figure 8. ***Turbidity, Specific Conductance, and Discharge at West Branch Susquehanna River at Milton, PA, from April to September 2015***

Review of the continuous data, while isolated to a small period of time from April through September 2015, indicates that field chemistry parameters follow expected patterns. Not surprisingly, dissolved oxygen decreased as temperature increased. pH values remained fairly constant, although pH values trended slightly higher as the study period progressed. Discharge decreased dramatically from mid-July through the end of September 2015. Conductance increased as discharge decreased. Discharge and turbidity data do not overlap because of incomplete datasets.

<u>How do water chemistry parameters relate to each other?</u>

Pearson r correlation coefficients were calculated to quantify relationships between water chemistry results at the 71 sites with complete datasets (Table 6). Numerous significant correlations were discovered. Calcium, specific conductance, and magnesium had the most frequent positive correlations of Pearson r values greater than 0.7 with other parameters in the dataset.

Two strongly negative and significant relationships were noted—between pH and aluminum and between pH and manganese. Low pH values and high concentrations of aluminum, manganese, iron, and sulfate are associated with mine drainage and have the tendency to co-occur, so strong correlations among these parameters are not unexpected.

Table 6. ***Significant (p ≤ 0.05) Pearson's r values for all West Branch Susquehanna Subbasin Sites with Complete Datasets (n=71; 2015) (Bolded values indicate Pearson r greater than 0.7.)***

	Alkalinity	Aluminum	Calcium	Chloride	Hardness	Iron	Magnesium	Manganese	Nitrate	pH	Sodium	Specific Conductance	Sulfate	TDS	TOC	TSS	Turbidity
Aluminum																	
Calcium	**0.721**	0.369															
Chloride	0.618	0.266	**0.720**														
Hardness	0.685	0.421	**0.993**	0.686													
Iron		0.570	0.562	0.540	0.540												
Magnesium	0.623	0.484	**0.953**	0.616	**0.982**	0.484											
Manganese		**0.867**	0.450	0.234	0.516	0.416	0.595										
Nitrate	0.678		0.489	0.544	0.431	0.290	0.333										
pH	0.391	-0.607						-0.600	0.359								
Sodium	0.496	0.280	0.697	**0.854**	0.666	0.552	0.599	0.272	0.364								
Specific Conductance	0.688	0.404	**0.975**	**0.747**	**0.978**	0.506	**0.954**	0.504	0.434		**0.757**						
Sulfate		0.620	**0.769**	0.433	**0.804**	0.597	**0.824**	**0.789**			0.535	**0.782**					
TDS	0.570	0.483	**0.964**	0.674	**0.972**	0.586	**0.953**	0.603	0.367		0.697	**0.962**	0.875				
TOC					0.242							0.271					
TSS				0.255	0.329	0.447	0.340				0.287	0.293		0.276			
Turbidity				0.290	0.237	**0.700**			0.344		0.285		0.247	0.269		0.517	
Suspended Sediment				0.322	0.338	0.246	0.358		0.321	0.009	0.297	0.319				**0.775**	0.342

Table 7. ***Significant (p ≤ 0.05) Pearson's r Values for West Branch Susquehanna Subbasin Sites with Complete Datasets (n=71; 2015)***

All West Branch Subbasin Sites (n = 71)		Ratings		Watershed Characteristics				
		Habitat Score	IBI Score	Drainage Area	% Forest	% Ag	% Developed	% Barren/ Extractive
Ratings	IBI Score	0.461						
Catchment Characteristics	Drainage Area		-0.235					
	% Forest	0.502	0.336					
	% Ag	-0.546	-0.359		**-0.966**			
	% Developed	-0.358	-0.630		-0.375	0.381		
	% Barren/Extractive		-0.529	0.383			0.347	
Water Chemistry	Total Alkalinity	-0.237	-0.329		-0.437	0.457	0.597	
	Total Aluminum		-0.606				0.339	0.688
	Total Calcium	-0.299	-0.635	0.249	-0.374	0.389	**0.774**	0.646
	Total Chloride	-0.251	-0.538		-0.342	0.362	**0.911**	0.320
	Hardness	-0.255	-0.637	0.262	-0.314	0.331	**0.734**	**0.702**
	Total Iron	-0.238	-0.597				**0.741**	0.433
	Total Magnesium		-0.616	0.270		0.234	0.650	**0.762**
	Total Manganese		-0.649	0.301			0.264	**0.743**
	Total Nitrate	-0.412	-0.352		-0.634	0.629	0.584	
	pH		0.334		-0.279	0.259		
	Total Sodium	-0.335	-0.527		-0.291	0.306	**0.837**	0.381
	Specific Conductance	-0.290	-0.629		-0.317	0.340	**0.763**	0.656
	Total Sulfate		-0.615	0.293			0.515	**0.837**
	Total Dissolved Solids	-0.273	-0.671	0.287	-0.278	0.290	**0.731**	**0.742**
	Total Organic Carbon	-0.424			-0.494	0.505		
	Total Suspended Solids						0.307	0.252
	Turbidity	-0.347	-0.297				0.475	
	Suspended Sediment						0.328	

How do land use and water quality affect the streams?

As previously discussed, water chemistry patterns and biological ratings tend to visually overlap with gradients of land use disturbance (Figures 6 and 7). To quantify these relationships, Pearson r correlation coefficients were calculated between total habitat scores, IBI scores, watershed-level variables, and water chemistry parameters (Table 7) for the 71 sites with complete datasets. This correlation analysis shows that, not surprisingly, many of the water chemistry parameters increased in concentration as drainage area sizes and land disturbance (agriculture, development, and barren/extractive) increased.

IBI scores tended to increase as habitat scores increase (Figure 9). As drainage area and all forms of land disturbance increased, IBI scores decreased (Figure 10). Habitat scores did not correlate to drainage area and decreased with increasing agriculture and development (Figure 11). Higher IBI and habitat scores were found in watersheds with higher percentages of forested land.

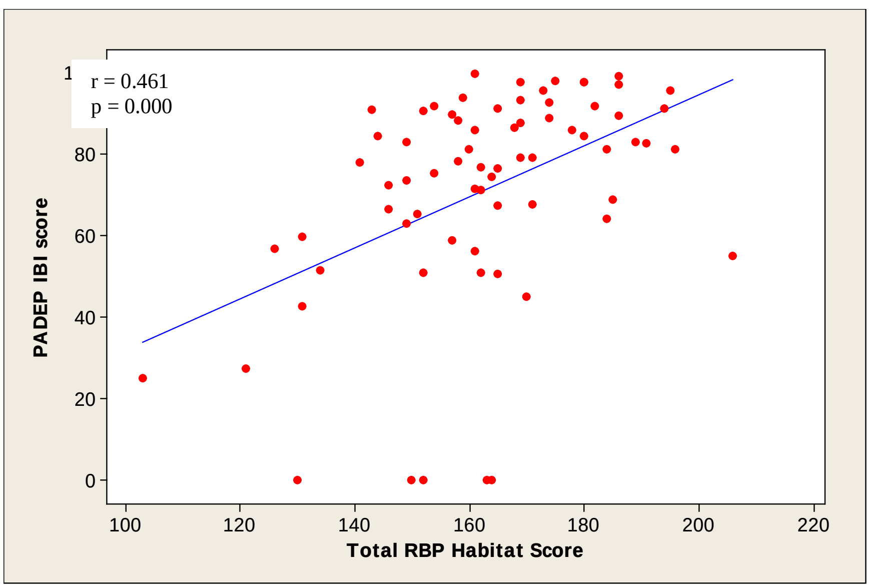

Figure 9. Scatterplot of PADEP IBI Score vs. Habitat Score within the Subbasin (2015; n=71; Pearson r)

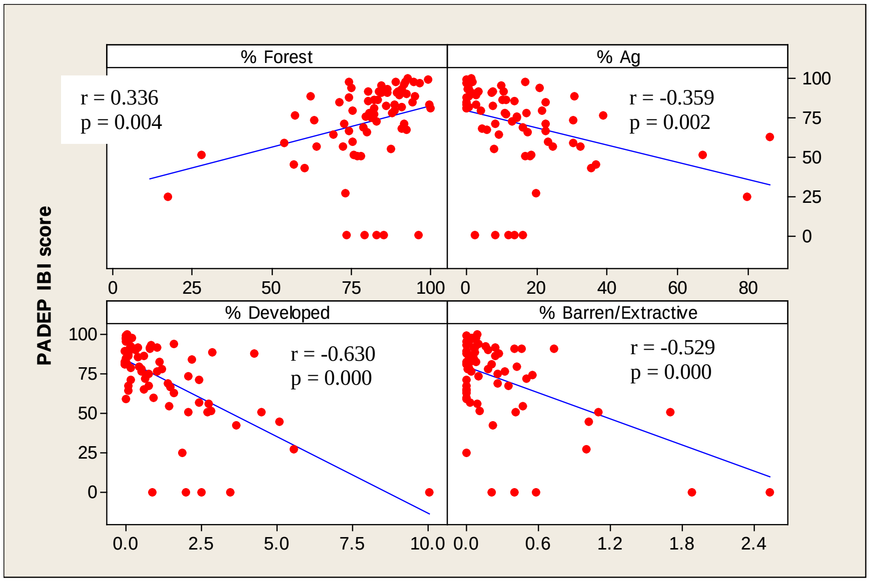

Figure 10. ***Scatterplots of PADEP IBI Score vs. Land Uses within the Subbasin (2015; n=71; Pearson r)***

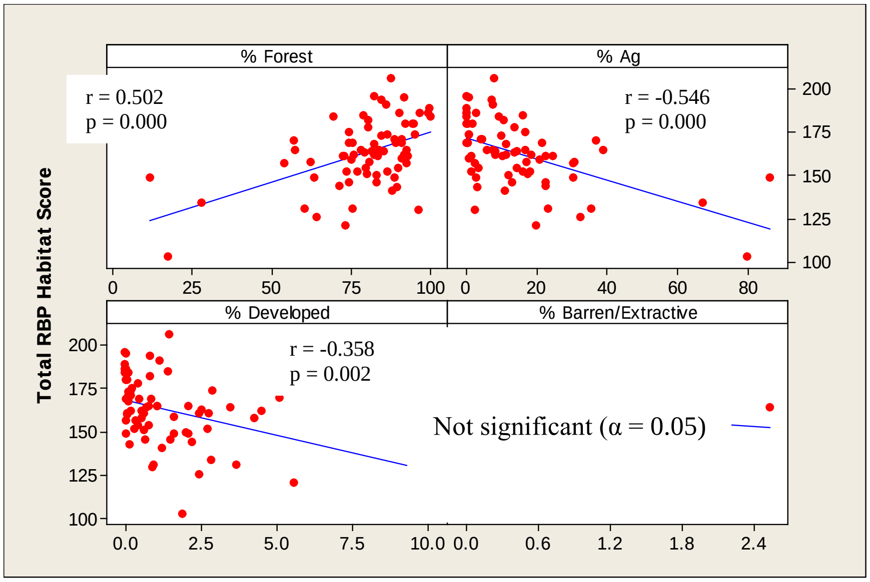

Figure 11. ***Scatterplots of Total RBP Habitat score vs Land Uses within the Subbasin (2015; n=71; Pearson r) (The five sites with IBI scores of 0.0 are AMD-affected sites with <200 organisms in a macroinvertebrate sample.)***

The dataset used for this correlation analysis includes a blend of targeted sites (RWQMN and long-term sites) and probabilistic sites. Consequently, this dataset covers a wide range of drainage areas, land uses, and known problem areas throughout the subbasin. Not surprisingly, data collected at these sites validate that watershed characteristics such as drainage area size and degree of land development are associated with decreasing habitat quality, which in turn is associated with decreasing IBI scores.

<u>What patterns exist at the long-term sites?</u>

Over the past 21 years, 21 long-term sites have each been surveyed four times. However, biological data were only usable for two years and habitat data for three years. Grouped results are compiled in Figures 12, 13, and 14 and site-specific results presented in Appendix C. Forty-three percent of the long-term sites are impaired for aquatic life use, while 57 percent of these sites attain aquatic life use. Impaired sites consistently had lower average IBI scores than attaining sites (Figure 12). Both median and mean IBI scores increased at attaining sites (Figure 12). Both median and mean IBI scores increased at attaining sites. At impaired sites, the median IBI increased in 2015, but the low number of macroinvertebrates at four impaired sites in 2015 dragged down the range and mean IBI score compared to 2009.

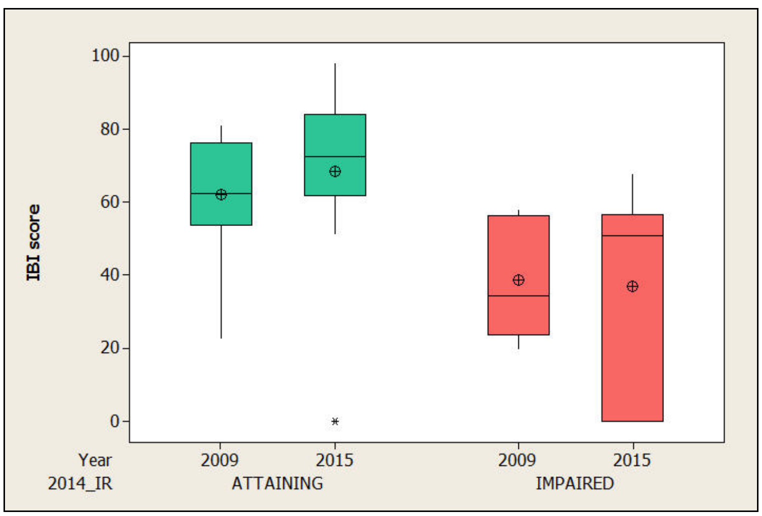

Figure 12. ***IBI Scores at Long-term Sites (2009 and 2015; n=21; median indicated by horizontal bar, mean indicated by circle)***

Habitat scores were relatively consistent across the years at attaining sites (Figure 13). More variance was observed in habitat scores at impaired sites through the years, with the highest scores observed in 2009. Scoring of habitat features through the RBP process can be extremely subjective and is dependent upon the experience of the observer.

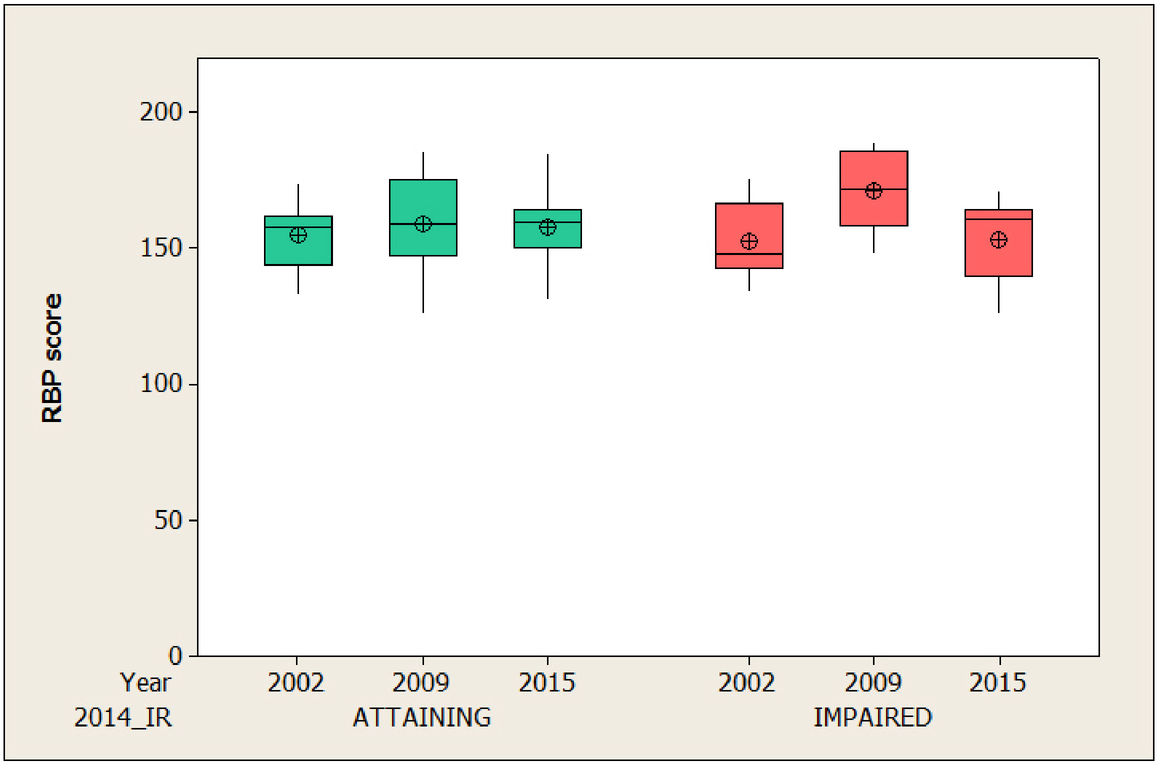

Figure 13. Habitat Scores at Long-term Sites (2002, 2009, and 2015; n=21; median indicated by horizontal bar; mean indicated by circle)

Figure 14 displays the number of water quality parameters that exceeded standard values (Table 2) at both attaining and impaired sites. Attaining sites had consistently few numbers of exceeding parameters, although the mean number decreased over time. The same median number at impaired sites was seen in all four sampling periods, but the narrower range around lower values in 2009 and 2015 pulled the means down. More water chemistry problems existed in the past (2002 and 1994) compared to later years (2015 and 2009) at impaired sites.

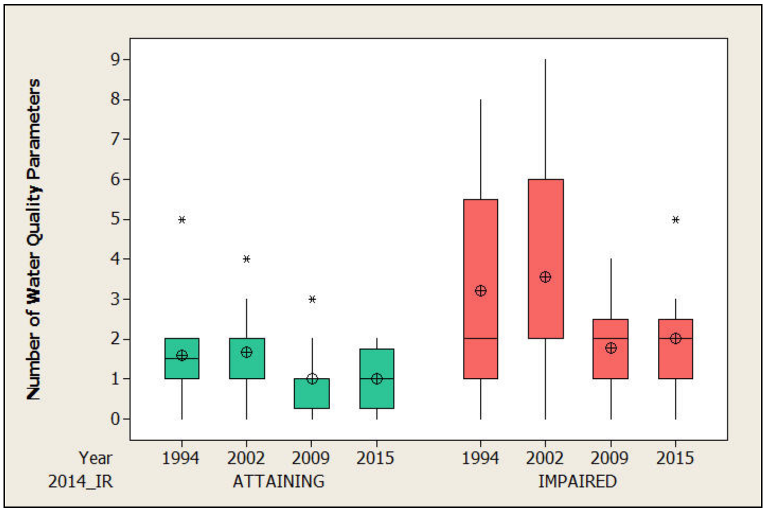

Figure 14. Number of Water Quality Parameters at Long-term Sites that Exceed Standards (1994, 2002, 2009, and 2015; n=21; median indicated by horizontal bar; mean indicated by circle)

Appendix C lists IBI scores, habitat scores, and specific water chemistry parameters that exceeded standards at each site during the past four sampling events. Low alkalinity was documented at 86 percent of samples at these long-term sites over the last four years, followed by elevated nitrate (62 percent) and total nitrogen (57 percent). Low alkalinity was measured at both impacted sites as well as attaining sites, while elevated nitrate, total nitrogen, and total orthophosphate were slightly more frequent at sites that were not impaired. Elevated acidity, aluminum, iron, hardness, magnesium, manganese, and specific conductance as well as depressed pH were most commonly found at impaired sites.

IBI scores at four long-term sites affected by mine drainage (ANDR 0.4, BECH 1.7, MOSH 5.1, and WBSR 131.0) dropped from poor in 2009 to very poor (less than 200 organisms) in 2015. All of these sites had fewer water chemistry issues during more recent surveys, but habitat quality has decreased at all but WBSR 131.0, where habitat scores have held.

Some impaired sites (BALD 4.5, BUFF 2.0, and FISH 2.1) demonstrated fair biological ratings in the presence of slightly elevated nutrient concentrations and siltation. BALD 4.5 is impaired for metals from mine drainage sources, but the Commission has never documented metals as a problem at this site. Several impaired sites (CLFD 0.9, KTTL 0.2, and WBSR 172.3) showed increased biological ratings from poor to fair from 2009 to 2015.

Most other sites that have always been listed as attaining aquatic life use continued to experience similar or increased IBI scores since the last sampling round. WBSR 131.0 has not been listed on the Integrated Report as impaired, but a poor biological rating in 2009 and a depressed macroinvertebrate population in 2015 indicate problems continue to exist.

CONCLUSIONS

With the execution of a new study design and statistical analysis, data collected through this subbasin survey are more robust than in the past. The sampling of probabilistic sites will eventually allow for a generalization of water quality conditions across the Basin as a whole. Four surveys across 21 years at long-term sites allow for some analysis of patterns. Reviewing results at targeted monitoring sites such as RWQMN and mine drainage sites enables tracking of specific impacts.

As with all subbasin survey assessments, these results were based on a one-time sampling event and are meant to provide an overview of stream conditions at that point in time. Several of the sites included in this report are sampled more frequently as part of other ongoing Commission projects (RWQMN and Large Rivers). As previously mentioned, PADEP intensely monitors 32 sites in this subbasin as part of the WQN, the results of which are not covered in this report.

About 60 percent of the 21 long-term sites were listed in the 2014 IR as attaining aquatic life use, with about 40 percent impaired for aquatic life use. Results of this subbasin survey generally affirm these 2014 IR listings, with exceptions on Bald Eagle Creek (BALD 4.5) and the headwaters of the West Branch Susquehanna River (WBSR 131.0). Better water quality and biological conditions are present in the northcentral portion of the subbasin, with regional water quality problems related to mine drainage and development pressures and agriculture located in the southwest and southeast.

This survey revealed that habitat was largely compromised by siltation leading to sedimentation and embeddedness issues. Compromised riparian conditions caused by development can result in increased streambank erosion and subsequent sedimentation in downstream reaches, affect the temperature of the stream and associated dissolved oxygen levels, and reduce the input of organic material into the stream that organisms require as a food source. Degraded instream conditions provide less varied habitat to support a diversity of macroinvertebrates and can allow pollution-tolerant and adaptable species to dominate the community.

Elevated sodium and nutrients (mostly total nitrogen, primarily as nitrate) as well as depressed alkalinity and pH were the most widespread water quality issues in the subbasin. Sites directly affected by mine drainage experienced issues including elevated metals, sulfate, and dissolved solids. No parameters indicative of unconventional gas drilling were found to be elevated at RWQMN sites neither during the course of this survey nor during the span of more comprehensive project monitoring.

In addition to habitat changes, chemical pollution can also directly affect the macroinvertebrate assemblage. Chemical pollution can have both acute and chronic effects that can range from shifts in community structure to inability to support any aquatic life. Either way, changes in macroinvertebrate communities can affect the food web and the efficiency of energy processing within the stream.

The Commission is currently conducting a focused study on the relationship between flow and habitat availability in the Bald Eagle Creek Watershed in the West Branch Subbasin, funded in part through Section 106 funds from USEPA. A report on this study will be available in October 2017.

Upon completion of sampling at probabilistic sites in all six subbasins, these data will be analyzed to make generalizations of water quality conditions throughout the Basin as a whole. The next subbasin survey for the West Branch Susquehanna Subbasin is scheduled to take place in 2021.

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APPENDIX A
West Branch Susquehanna Subbasin Sites

Sample Site #	Site Name	Location Description	Site Category	PADEP Chp 93 Designated Use	Latitude	Longitude	Drainage (sq mi)	Stream Order	ARC
1	ALDR 4.7	Alder Run	MD	CWF	41.01415	-78.19902	12.5	2	3
2	ANDR 0.4	Anderson Creek	LT	CWF	40.97246	-78.52754	76.6	3	5
3	ANDR 4.2	Anderson Creek	GRTS	CWF	40.99353	-78.57543	56.9	3	4
4	BABB 0.1	Babb Creek	MD	CWF	41.55450	-77.38111	129.7	3	5
5	BABB 7.2	Babb Creek	MD	CWF	41.59944	-77.28222	42.7	2	4
6	BAKR 0.1	Baker Run	RWQMN	HQ-CWF	41.24707	-77.60661	35.0	2	4
7	BALD 4.5	Bald Eagle Creek	LT	WWF	41.12068	-77.47182	765.0	4	6
8	BBSC 0.1	Bennett Branch Sinnemahoning Creek	MD	WWF	41.33571	-78.13359	366.1	4	6
9	BBSC 17.6	Bennett Branch Sinnemahoning Creek	MD	WWF	41.31227	-78.38959	176.1	3	5
10	BEAR 0.1	Bear Run	MD	CWF	40.88220	-78.76271	19.3	2	4
11	BECH 1.7	Beech Creek	LT	CWF	41.07368	-77.59169	170.7	3	5
12	BECH 20.3	Beech Creek	MD	CWF	41.10630	-77.83468	68.5	3	4
13	BILG 0.1	Bilger Run	MD	CWF	40.97262	-78.57109	7.2	1	3
14	BLOC 1.3	Blockhouse Creek	RWQMN	CWF	41.47393	-77.23044	38.0	2	4
15	BUCK 0.2	Buck Run	GRTS	EV	41.60743	-77.50834	2.4	1	2
16	BUFF 2.0	Buffalo Creek	LT	TSF	40.97158	-76.91727	131.0	3	5
17	BUFR 2.2	Buffalo Run	GRTS	HQ-CWF	40.90158	-77.81378	25.1	2	3
18	CHLL 0.9	Chillisquaque Creek	LT	WWF	40.94067	-76.85474	112.0	3	5
19	CHST 1.0	Chest Creek	LT	CWF	40.86596	-78.71820	128.0	3	5
20	CHST 25.0	Chest Creek	RWQMN	CWF	40.63682	-78.64256	44.0	2	5
21	CLFD 0.9	Clearfield Creek	LT	WWF	41.01781	-78.40759	393.0	4	5
22	CLFD 22.8	Clearfield Creek	MD	WWF	40.86119	-78.44387	263.3	4	5
23	CLFD 42.2	Clearfield Creek	MD	WWF	40.74594	-78.53799	159.0	3	5
24	CLFD 60.5	Clearfield Creek	MD	WWF	40.56103	-78.55186	42.5	2	5
25	CLFD 8.2	Clearfield Creek	MD	WWF	40.96976	-78.40684	326.3	4	5
26	COLD 1.1	Cold Stream	MD	CWF	40.90093	-78.20990	21.3	2	3
27	COLD 3.6	Cold Stream	MD	HQ-CWF	40.86760	-78.20749	14.3	2	3
28	COOK 0.1	Cooks Run	MD	CWF	41.27860	-77.88539	25.7	2	3
29	DEER 0.2	Deer Creek	MD	CWF	41.08026	-78.23749	23.6	2	3

Sample Site #	Site Name	Location Description	Site Category	PADEP Chp 93 Designated Use	Latitude	Longitude	Drainage (sq mi)	Stream Order	ARC
30	DENT 0.6	Dents Run	MD	HQ-CWF	41.35946	-78.27194	24.4	2	4
31	DRFT 22.0	Driftwood Branch Sinnemahoning Creek	RWQMN	TSF	41.51639	-78.25389	83.0	3	5
32	DRUF 0.7	Drury Run	MD	CWF	41.33386	-77.78085	18.6	2	3
33	EFFF 6.9	East Fork Sinnemahoning Creek	RWQMN	HQ-CWF	41.52961	-78.02160	33.0	3	4
34	ELKR 0.5	Elk Run	RWQMN	HQ-CWF	41.73642	-77.58154	21.0	2	4
35	FISH 2.1	Fishing Creek	LT	CWF	41.09559	-77.47967	180.0	3	5
36	GRAY 0.5	Grays Run	RWQMN	HQ-CWF	41.42653	-77.01929	16.0	2	3
37	HICK 0.3	Hicks Run	RWQMN	HQ-CWF	41.36235	-78.25348	34.0	1	1
38	HUNT 0.1	Hunts Run	RWQMN	HQ-CWF	41.45256	-78.14458	30.7	1	1
39	KETT 27.0	Kettle Creek	RWQMN	EV	41.49445	-77.79765	81.2	3	4
40	KING 5.9	Kings Creek	GRTS	HQ-CWF	41.56318	-76.62038	1.8	1	2
41	KRAT 0.1	Kratzer Run	MD	CWF	40.97660	-78.54764	15.4	2	4
42	KTTL 0.2	Kettle Creek	LT	TSF	41.30045	-77.84078	247.0	4	5
43	LAND 1.7	Little Anderson Creek	MD	CWF	41.05403	-78.65591	9.9	1	3
44	LARR 2.9	Larrys Creek	LT	WWF	41.24916	-77.22638	81.2	3	4
45	LARR 9.6	Larrys Creek	RWQMN	HQ-CWF	41.32739	-77.18943	29.0	2	3
46	LAUR 0.1	Laurel Run	MD	CWF	40.90683	-78.22697	21.9	2	3
47	LAUR 2.3	Laurel Run	GRTS	HQ-CWF	41.10117	-78.07929	1.4	1	2
48	LCLF 0.1	Little Clearfield Creek	RWQMN	HQ-CWF	40.97000	-78.40722	44.0	2	4
49	LICK 0.3	Lick Run	MD	HQ-CWF	41.05067	-78.38555	27.5	2	3
50	LLSK 1.2	Loyalsock Creek	LT	TSF	41.24994	-76.93537	495.0	4	6
51	LLSK 37.2	Loyalsock Creek	MD	CWF	41.48611	-76.59917	132.2	3	5
52	LMUN 10.4	Little Muncy Creek	RWQMN	CWF	41.19353	-76.64148	51.0	3	5
53	LONG 1.3	Long Run	RWQMN	CWF	41.76142	-77.55928	21.0	2	3
54	LOYS 12.4	Loyalsock Creek	GRTS	TSF	41.36427	-76.87430	391.9	4	6
55	LPIN 0.2	Little Pine Creek	RWQMN	TSF	41.30995	-77.36285	180.0	3	5
56	LPIN 5.6	Little Pine Creek	GRTS	CWF	41.37518	-77.36117	163.4	3	5
57	LSTR 1.6	Left Straight Run	GRTS	HQ-CWF	41.81577	-77.42595	1.6	1	2
58	LYCO 2.0	Lycoming Creek	LT	WWF	41.25275	-77.04162	270.0	4	5

Sample Site #	Site Name	Location Description	Site Category	PADEP Chp 93 Designated Use	Latitude	Longitude	Drainage (sq mi)	Stream Order	ARC
59	LYSK 54.4	Loyalsock Creek	RWQMN	CWF	41.45880	-76.33104	27.0	2	4
60	MARS 0.8	Marsh Creek	RWQMN	CWF	41.06022	-77.60997	44.0	2	4
61	MARS 1.5	Marsh Creek	RWQMN	CWF	41.76312	-77.41347	78.0	3	4
62	MONT 0.2	Montgomery Creek	MD	CWF	41.00334	-78.46115	16.5	2	3
63	MOOS 1.7	Moose Creek	RWQMN	HQ-CWF	41.04564	-78.46158	3.0	1	2
64	MORG 0.2	Morgan Run	MD	CWF	40.95810	-78.40104	14.5	2	3
65	MOSH 19.1	Moshannon Creek	MD	TSF	40.94518	-78.12141	162.2	3	4
66	MOSH 39.9	Moshannon Creek	MD	TSF	40.85042	-78.26595	69.3	3	4
67	MOSH 5.1	Moshannon Creek	LT	TSF	41.03642	-78.05899	208.0	4	4
68	MOSQ 0.2	Mosquito Creek	LT	CWF	41.22214	-77.03822	16.1	2	3
69	MUDD 0.3	Muddy Run	MD	CWF	40.81903	-78.43687	35.3	2	4
70	MUDD 4.5	Muddy Run	MD	CWF	40.76898	-78.44730	12.1	2	3
71	MUNC 1.1	Muncy Creek	LT	TSF	41.21777	-76.78666	203.0	4	6
72	NINE 0.1	Ninemile Run	RWQMN	HQ-CWF	41.79146	-77.76387	16.0	2	3
73	PINE 1.1	Pine Creek	LT	HQ-TSF	41.18195	-77.28070	979.0	4	6
74	PINE 48.8	Pine Creek	RWQMN	HQ-TSF	41.64694	-77.45056	385.0	4	5
75	PINE 77.1	Pine Creek	RWQMN	HQ-CWF	41.79011	-77.76123	35.0	2	4
76	PLES 3.5	Pleasant Stream	RWQMN	HQ-CWF	41.49143	-76.92300	20.6	2	3
77	PORT 0.4	Portage Creek	RWQMN	CWF	41.51169	-78.22029	71.0	3	5
78	ROAR 0.9	Roaring Run	MD	CWF	41.00944	-78.39028	11.9	2	3
79	SINN 0.2	Sinnemahoning Creek	LT	WWF	41.26104	-77.90724	1030.0	5	7
80	SINN 11.9	Sinnemahoning Creek	MD	WWF	41.31925	-78.08390	694.8	4	7
81	SLAK 1.6	Slacks Run	GRTS	HQ-CWF	41.44743	-76.95248	5.1	1	2
82	SNDY 5.8	Sandy Run	GRTS	CWF	41.10299	-77.94563	1.7	1	2
83	STER 0.1	Sterling Run	RWQMN	CWF	41.41389	-78.19917	24.5	2	4
84	STEW 0.9	Stewards Run	GRTS	WWF	41.21956	-77.24117	1.2	1	2
85	STMV 2.6	Steam Valley Run	GRTS	HQ-CWF	41.44299	-77.10505	1.4	1	2
86	SURV 0.3	Surveyor Run	MD	CWF	41.07668	-78.32524	6.0	1	3
87	TANG 0.2	Tangascootack Creek	MD	CWF	41.17613	-77.54973	36.7	2	4
88	TMIL 0.1	Twomile Run	MD	TSF	41.31604	-77.85903	9.1	1	3

Sample Site #	Site Name	Location Description	Site Category	PADEP Chp 93 Designated Use	Latitude	Longitude	Drainage (sq mi)	Stream Order	ARC
89	TROT 0.3	Trout Run	RWQMN	HQ-CWF	41.06979	-78.35950	33.0	2	4
90	UCLB 0.6	UNT to County Line Branch	GRTS	WWF	41.11834	-76.71709	0.7	1	2
91	UMDC 0.4	UNT to Mud Creek	GRTS	WWF	41.07859	-76.61464	2.3	1	3
92	UPRT 0.5	UNT to Prouty Run	GRTS	HQ-CWF	41.66574	-77.90096	2.6	1	2
93	USPR 3.4	UNT to Spring Creek	GRTS	TSF	41.17767	-76.95337	3.1	1	2
94	USWB 0.4	UNT to South Woods Branch	GRTS	HQ-CWF	41.72162	-78.02805	1.1	1	2
95	WBSR 5.0	West Branch Susquehanna River	LR	WWF	40.94142	-76.86531	6832.9	7	6
96	WBSR 45.0	West Branch Susquehanna River	LR	WWF	41.22577	-77.10737	5365.9	7	6
97	WBSR 85.0	West Branch Susquehanna River	LR	WWF	41.31969	-77.63248	3139.3.	7	5
98	WBSR 103.8	West Branch Susquehanna River	MD	WWF	41.30042	-77.83818	2676.2	5	7
99	WBSR 110.0	West Branch Susquehanna River	LR	WWF	41.26088	-77.90123	1597.3	5	6
100	WBSR 131.0	West Branch Susquehanna River	LT	WWF	41.11720	-78.10824	1390.0	5	6
101	WBSR 142.0	West Branch Susquehanna River	MD	WWF	41.05721	-78.15729	1096.9	5	6
102	WBSR 147.0	West Branch Susquehanna River	LR	WWF	41.07809	-78.23529	1020.8	6	5
103	WBSR 164.2	West Branch Susquehanna River	MD	WWF	41.04789	-78.38205	898.9	4	6
104	WBSR 172.3	West Branch Susquehanna River	LT	WWF	41.03251	-78.43373	497.0	4	6
105	WBSR 181.4	West Branch Susquehanna River	MD	WWF	40.97422	-78.51977	445.6	4	6
106	WBSR 200.0	West Branch Susquehanna River	MD	WWF	40.89470	-78.67633	315.6	4	6
107	WBSR 224.0	West Branch Susquehanna River	MD	WWF	40.72712	-78.80536	59.0	3	4
108	WBSR 227.0	West Branch Susquehanna River	RWQMN	WWF	40.59840	-78.74453	3.1	1	3
109	WBSR 242.5	West Branch Susquehanna River	GRTS	CWF	40.59600	-78.73379	1.0	1	2
110	WBSR 69.0	West Branch Susquehanna River	MD	WWF	41.13858	-77.43149	3344.9	5	7
111	WBSR 97.0	West Branch Susquehanna River	MD	WWF	41.32630	-77.74580	2975.8	5	7
112	WDHC 1.9	White Deer Hole Creek	LT	TSF	41.10226	-76.91405	61.5	3	5
113	WEST 2.0	West Creek	RWQMN	HQ-CWF	41.49431	-78.27495	59.0	3	4

Sample Site #	Site Name	Location Description	Site Category	PADEP Chp 93 Designated Use	Latitude	Longitude	Drainage (sq mi)	Stream Order	ARC
114	WILS 0.5	Wilson Creek	MD	CWF	41.59819	-77.29653	23.0	2	3
115	WPIN 1.5	West Branch Pine Creek	RWQMN	HQ-CWF	41.71255	-77.69911	70.0	3	4
116	WYKF 4.8	Wykoff Run	GRTS	HQ-CWF	41.27553	-78.14123	12.8	2	3
117	YGWO 0.5	Young Womans Creek	LT	HQ-CWF	41.34976	-77.69835	86.6	3	5
118	YGWO 4.5	Young Womans Creek	RWQMN	EV	41.40139	-77.68472	41.0	2	4
119	YOST 0.3	Yost Run	GRTS	EV	41.22307	-77.93086	7.2	1	3

APPENDIX B

West Branch Susquehanna Subbasin Sites with 2015 Water Quality Values Exceeding Levels of Concern

Site Type	Site Name	Acidity mg/l	Alkalinity mg/l	Total Aluminum mg/l	Total Iron mg/l	Magnesium mg/l	Manganese mg/l	Nitrate-N mg/l	Total Nitrogen mg/l	pH	Total Sodium mg/l	Specific Conductance umhos/cm	Sulfate mg/l	TDS mg/l	TOTAL
Long-term sites	ANDR 0.4		**ND**					0.68		5.95					**3**
	BALD 4.5							1.3	1.3						**2**
	BECH 1.7		**ND**							5.09					**2**
	BUFF 2.0							1.3	1.3						**2**
	CHLL 0.9							1.9	1.9						**2**
	CHST 1.0							0.96							**1**
	CLFD 0.9												255		**1**
	FISH 2.1							**2.8**	**2.8**						**2**
	KTTL 0.2		8												**1**
	LARR 2.9								1.49						**1**
	LLSK 1.2								1.66						**1**
	MOSH 5.1	25	**ND**	2.6			1.5			3.84					**5**
	MOSQ 0.2		15												**1**
	MUNC 1.1							1.2	1.2						**2**
	SINN 0.2		7												**1**
	WBSR 131.0		6	0.92											**2**
	YGWO 0.5		10												**1**
Probabilistic sites	ANDR 4.2		**ND**	0.77						4.56					**3**
	BUCK 0.2		10												**1**
	BUFR 2.2							1.9	1.9						**2**
	KING 5.9		4												**1**
	LAUR 2.3		9												**1**
	LPIN 5.6		13												**1**
	LSTR 1.6		14												**1**
	SLAK 1.6		18												**1**
	SNDY 5.8		2							5.01					**2**
	STMV 2.6		16					1.1	1.1						**3**
	UCLB 0.6							0.63							**1**

Site Type	Site Name	Acidity mg/l	Alkalinity mg/l	Total Aluminum mg/l	Total Iron mg/l	Magnesium mg/l	Manganese mg/l	Nitrate-N mg/l	Total Nitrogen mg/l	pH	Total Sodium mg/l	Specific Conductance umhos/cm	Sulfate mg/l	TDS mg/l	TOTAL
	UMDC 0.4							1.8	1.8						**2**
	UPRT 0.5		8												**1**
	USPR 3.4		3							5.84					**2**
	USWB 0.4		10					1	1						**3**
	WBSR 242.5				2.5			2	2						**3**
	WYKF 4.8		7												**1**
	YOST 0.3		**ND**												**1**
Large River sites	WBSR 83		11												**1**
	WBSR 110.0		7										305	527	**3**
	WBSR 147												259		**1**
Mine Drainage sites	ALDR 4.7	55.1	**ND**		2.3		4			3.8			252		**6**
	BABB 0.1		12												**1**
	BABB 7.2		5												**1**
	BBSC 0.1		6												**1**
	BBSC 17.6		7												**1**
	BEAR 0.1		6												**1**
	BECH 20.3		2							5.7					**2**
	BILG 0.1		6												**1**
	CLFD 22.8		15	1	1.7		1.4								**4**
	CLFD 8.2		13	0.79			1.3								**3**
	COLD 1.1		**ND**							4.63					**2**
	COLD 3.6		5												**1**
	COOK 0.1	**67**	**ND**	3.9	**5.1**					**3.16**					**5**
	DEER 0.2		**ND**	1.2			1.8			5.14					**4**
	DENT 0.6		11	1.8			1.3								**3**
	DRUF 0.7		**ND**	1						5.4					**3**
	KRAT 0.1		11												**1**

Site Type	Site Name	Acidity mg/l	Alkalinity mg/l	Total Aluminum mg/l	Total Iron mg/l	Magnesium mg/l	Manganese mg/l	Nitrate-N mg/l	Total Nitrogen mg/l	pH	Total Sodium mg/l	Specific Conductance umhos/cm	Sulfate mg/l	TDS mg/l	TOTAL
	LAND 1.7	39.9	**ND**	3.7	2.6		2.8			3.69					**6**
	LAUR 0.1		6	0.92		**35.4**	2.6						257		**5**
	LICK 0.3		**ND**												**1**
	MONT 0.2		**ND**	0.86			1.5			5.73					**4**
	MORG 0.2		**ND**	1.8			4			4.71					**4**
	MOSH 19.1	31	**ND**	2.6		35.2	2.5			3.54		**820**	**334**	**624**	**9**
	MOSH 39.9		**ND**	2.2	2.7		1.6			5.59					**5**
	MUDD 0.3						1.8						270		**2**
	MUDD 4.5			1.6			2.7								**2**
	ROAR 0.9	27.6	**ND**	2.7	2		**4.8**			4.53			299	544	**8**
	SINN 11.9		13												**1**
	SURV 0.3		**ND**	2.5			2.1			5.99			332	547	**6**
	TANG 0.2		**ND**	**13.7**	7		1.4				**53.8**				**5**
	TMIL 0.1		**ND**	1.5			1.5			3.75					**4**
	WBSR 103.8		11												**1**
	WBSR 142.0		14												**1**
	WBSR 224.0										28.6				**1**
	WBSR 69.0		6												**1**
	WBSR 97.0		11												**1**
	WILS 0.5		7	3.1	1.5		2.3								**4**
RWQMN sites	BAKR 0.1		**ND**												**1**
	BLOC 1.3		11					0.82							**2**
	CHST 25.0		20					2.3	2.3						**3**
	DRFT 22.0		6												**1**
	EFFF 6.9		4					0.77							**2**
	ELKR 0.5		16												**1**
	GRAY 0.5		3												**1**
	HICK		4												**1**

Site Type	Site Name	Acidity mg/l	Alkalinity mg/l	Total Aluminum mg/l	Total Iron mg/l	Magnesium mg/l	Manganese mg/l	Nitrate-N mg/l	Total Nitrogen mg/l	pH	Total Sodium mg/l	Specific Conductance umhos/cm	Sulfate mg/l	TDS mg/l	TOTAL
	0.3														
	HUNT 0.1		2												**1**
	KETT 27.0		6					0.65							**2**
	LARR 9.6		7					0.99	2.39						**3**
	LCLF 0.1							0.77							**1**
	LMUN 10.4		15					1.5	1.5						**3**
	LONG 1.3		20												**1**
	LPIN 0.2		7												**1**
	LYSK 54.4		1												**1**
	MARS 0.8		12												**1**
	MOOS 1.7		**ND**												**1**
	NINE 0.1		6					0.64	1.84						**3**
	PINE 48.8		14												**1**
	PINE 77.1		9					0.95	2.05						**3**
	PLES 3.5		4					0.62	1.62						**3**
	PORT 0.4		7												**1**
	STER 0.1		1												**1**
	TROT 0.3		**ND**												**1**
	WBSR 227.0							0.66			28				**2**
	WEST 2.0		5												**1**
	WPIN 1.5		5					0.63	1.73						**3**
	YGWO 4.5		3												**1**
	TOTAL	**6**	**85**	**21**	**9**	**2**	**19**	**25**	**19**	**20**	**3**	**1**	**9**	**4**	**104**
	% of sites	**5%**	**71%**	**18%**	**8%**	**2%**	**16%**	**21%**	**16%**	**17%**	**3%**	**1%**	**8%**	**3%**	**87%**

Total Phosphorus was also collected at all sites, but the data were compromised at the contract laboratory.
Red bolded values were the most extreme values for that parameter measured during this study.

APPENDIX C

Comparison of Results for West Branch Susquehanna Subbasin Long-term Sites (1994, 2002, 2009, and 2015 Data)

Site	Source (cause) of Aquatic Life Use Impairment (PADEP 2014 Integrated Report)	Biology: PADEP IBI score				Habitat: Total RBP Habitat score				Water Chemistry: Parameters with Exceeding Values			
		2015[a]	2009	2002	1994	2015	2009	2002	1994	2015	2009	2002	1994
ANDR 0.4	AMD (metals, pH)	0.0	49.3			150	172	172		Alk, pH, NO_3	Alk	Alk, Mn	Al, Alk, Mn, pH
BALD 4.5	AMD (metals)	51.0	57.1			162	165	145		NO_3, TN	NO_3, TN	NO_3, TN	NO_3
BECH 1.7	AMD (metals, pH)	0.0	27.3			130	148	143		Alk, pH	Alk, pH	Al, Alk, Fe, Hard, Mg, Mn, SpC	Al, Alk, Mn, pH
BUFF 2.0	Ag (siltation)	56.7	55.8			126	152	143		NO_3, TN	NO_3, TN, TOP	NO_3, TN, TOP	NO_3, TN
CHLL 0.9	--	51.4	59.7			134	156	133		NO_3, TN	NO_3, TN, TOP	NO_3, TN	NO_3, TN
CHST 1.0	--	71.4	62.8			161	152	174		NO_3	--	Hard, SO_4	Hard, SO_4
CLFD 0.9	AMD (metals)	50.6	19.9			165	185	161		SO_4	Mg	Alk, Hard, Mg, Mn, SO_4	Al, Alk, Hard, Mg, Mn, pH, SO_4
FISH 2.1	Urban runoff (siltation)	56.3	57.9			161	168	148		NO_3, TN	NO_3, TN	NO_3, TN	NO_3, TN
KTTL 0.2	AMD (metals, pH)	67.7	25.3			171	189	154		Alk	Alk	Alk, pH	Alk
LARR 2.9	--	78.3	78.5			158	161	150		TN	Alk	NO_3, TN	--
LLSK 1.2	--	75.3	77.2			154	167	161		TN	Alk	Alk	Alk
LYCO 2.0	--	68.8	61.3			185	186	159		--	Alk	Alk, NO_3, TN	Alk, NO_3
MOSH 5.1	AMD (metals)	0.0	22.1			164	186	176		Acid, Al, Alk, Mn, pH	Al, Alk, Mn, pH	Acid, Al, Alk, Ca, Hard, Mn, pH, SpC, SO_4	Al, Alk, Fe, Hard, Mn, pH, SpC, SO_4
MOSQ 0.2	--	67.4	51.7			165	157	157		Alk	--	--	TOP
MUNC 1.1	--	73.7	67.1			149	146	167		NO_3, TN	NO_3, TN	NO_3, TN	NO_3, TN
PINE 1.1	--	86.0	62.0			161	136	159		--	--	--	--
SINN 0.2	--	91.9	81.0			154	178	156		Alk	Alk	Alk	Alk
WBSR 131.0	--	0.0	22.9			163	163	142		Al, Alk	Alk	Al, Alk, Mn, SO_4	Al, Alk, Mn, pH, SO_4
WBSR 172.3	Impoundment/road runoff (nutrients, siltation)	50.8	34.3			152	175	134		--	--	--	--
WDHC 1.9	--	59.8	47.3			131	126	137		--	TOP	NO_3, TN	NO_3, TN
YGWO 0.5	--	97.9	73.1			180	184	162		Alk	Alk	Alk	Alk
Impaired for Aquatic Life	**Mean**	**37.0**	**38.8**			**153.4**	**171.1**	**152.9**		**2.0**	**1.8**	**3.6**	**3.2**
	Standard Deviation	***28.2***	***16.1***			***15.8***	***14.6***	***14.2***		***1.4***	***1.2***	***2.9***	***2.8***
Meeting Designated Use	**Mean**	**68.5**	**62.1**			**157.9**	**159.3**	**154.8**		**1.0**	**1.0**	**1.7**	**1.6**
	Standard Deviation	***25.1***	***16.2***			***15.7***	***18.2***	***12.2***		***0.7***	***0.9***	***1.2***	***1.3***

*a Zero value indicates that subsample requirements were not met (<160 bugs)

AMD= Acid Mine Drainage
Acid=Total Acidity
Al=Total Aluminum
Alk=Total Alkalinity
Ca= Calcium
Fe=Iron
Hard=Hardness
Mg=Magnesium
Mn=Manganese
NO_3=Total Nitrate
TN=Total Nitrogen
TOP Total Orthophosphate
SpC=Specific Conductance
SO_4=Sulfate