Coordination

SRBC began the strategy development process by first defining the scope of work. This was completed in close coordination with the Task Force and Coalition committees. Throughout the process, SRBC staff attended several meetings with each group. In addition, SRBC staff made presentations on the strategy at other forums sponsored by TU, Susquehanna River Heartland Coalition for Environmental Studies, North Central Regional Citizens Roundtable, PADEP, and PADCNR.

Staff solicited input throughout the process and provided opportunities to review draft materials associated with task objectives. Special efforts were made to ensure that the strategy addressed core issues needed to promote restoration activities.

Data Collection

The majority of the effort in developing the strategy was associated with collecting, compiling, and reviewing the vast amounts of existing data and information that are available for the West Branch Susquehanna Subbasin. Given that one of the main focuses of the strategy was to characterize existing water quality conditions, SRBC staff concentrated on gathering flow and chemistry information from water samples collected both from AMD discharges and instream locations. It is important to note that no new water quality samples were collected as part of the strategy development efforts. This document is based entirely on existing data and information.

The two primary sources of information at the regional scale, in terms of the number of water quality and flow observations, were PADEP mining permit information and SRBC monitoring data. However, there were numerous other monitoring efforts that proved invaluable when investigating at the finer scale. Examples of those include the Clearfield Creek Watershed Assessment and the Anderson Creek Assessment, Restoration, and Implementation Plan. Sources for other datasets included county conservation districts, watershed groups, TU chapters, mining companies, water quality laboratories, engineering consulting firms, federal water quality databases, and land conservancy organizations.

Regarding mining permit information, there are more than 1,400 active or completed mining permits within the West Branch Susquehanna Subbasin. As part of their permit requirements, mining companies are responsible for reporting information relating to any discharges within the extent of their affected areas, whether or not the discharge was a result of the permitted operation or existed on the site previously. Basic water quality information commonly includes data on metals, alkalinity, and acidity concentration, pH, and either a measured or estimated flow. SRBC also collected information associated with the discharge location (latitude and longitude), receiving water, treatment status, date sampled, data source, and other information when available.

Data and information from more than 400 permits were reviewed by staff and compiled electronically. Additionally, discharge and instream water quality information from more than 450 permits was acquired from PADEP's Sample Information System (SIS). PADEP SIS data are associated with samples routinely collected by PADEP personnel. The remaining permit data with documented discharges were compiled from various watershed TMDLs that were either completed or under development at the time of strategy construction. As part of the TMDL process, all permitted discharges are required to be included in the TMDL allocations. More than 50 TMDLs have been developed within the West Branch Susquehanna Subbasin, with most including allocations to permitted discharges (Table 3).

As mentioned previously, many completed and ongoing efforts are related to monitoring instream water quality and flow. For instream water quality and flow, the strategy relied heavily on data collected for TMDL monitoring by PADEP, the Pennsylvania State University, and SRBC, as well as data collected by SRBC as part of its West Branch Susquehanna Subbasin Survey (1994 and 2002) and Chesapeake Bay Monitoring (1984 to present) programs.

In addition, SRBC requested and acquired discharge and instream datasets from numerous sources for a number of watersheds as part of stakeholder monitoring and restoration efforts. These watersheds included Anderson Creek, Alder Run, Bear Run, Beech Creek (Bald Eagle Creek Watershed), Bennett Branch Sinnemahoning Creek, Clearfield Creek, Dents Run (Bennett Branch Sinnemahoning Creek Watershed), Kettle Creek, Moshannon Creek, Sterling Run (Driftwood Branch Sinnemahoning Creek Watershed), Trout Run, and the West Branch Susquehanna River mainstem. These solicited data were crucial in the analysis of current conditions and possible future conditions once AMD impacts are resolved.

All water quality data collected prior to 1990 were excluded from the collection process assuring that the most recent water quality data available were being utilized for review and analysis.

The following section describes the review process that staff followed in order to select the most appropriate datasets from the wealth of available information.

Data Review and Database Creation

SRBC staff created a database to manage the vast amount of information gathered as part of the solicitation and collection process. Datasets were identified, compiled, screened for data reliability, and entered into the database. Each AMD discharge and instream water quality sample was assigned a unique database and Geographic Information System (GIS) identifier.

In total, there are nearly 12,000 unique stations in the database, containing more than 106,000 individual samples.

The database includes information on discharges, instream stations, springs, wells, pits, ponds, and impoundments. However, only instream and discharge stations were utilized for the analyses. These datasets represent 8,074 of the nearly 12,000 unique stations. SRBC has continued to update information as appropriate.

Data from these 8,074 unique instream or discharge stations were reviewed to identify those containing four or more samples collected for metal concentrations (iron and aluminum in particular), pH, acidity, and flow. Although a minimum of four observations is not optimal from a statistical standpoint, SRBC concluded that analytical criterion represents an acceptable representation for a management-level study of this scale. When these criteria were applied to the entire dataset, about 30 percent of the data (26 percent of the instream stations and 40 percent of the discharge stations) remained available for use in the analyses (Table 6). This analysis identified a total of 6,110 instream stations and 1,964 discharges with 1,596 instream stations and 788 discharges meeting the analytical criteria.

Given attempts to use the best available, existing data that met the specified analytical criteria, significant discharges may have been eliminated from analysis. With nearly 60 percent of the discharges in the database not used for analysis (because they did not meet the analytical criteria), these discharges will require additional sampling to be included in any future analysis.

The three main reasons for not meeting analytical criteria include sample sites not having a geo-referenced location (no latitude or longitude), samples not containing flow measurements, and samples not containing laboratory aluminum concentration analyses.

Management Unit Designation and Analysis

After the selection of compiled data that met the analytical criteria, SRBC focused on data characterization and data gap analysis. To conduct this phase of the project, SRBC divided the West Branch Susquehanna Subbasin into 34 management units (MUs) comprising nearly 4,663 square miles, or nearly 67 percent of the total West Branch Susquehanna Subbasin (Figure 7 and Table 7).

MUs are named by an alpha numeric system. The alpha portion consists of the abbreviated name of the watershed where the MU is located and the numeric portion describes where the MU is located in the watershed, with "1" being the headwaters and the number sequentially increasing downstream. For example, the Clearfield Creek Watershed has been divided into five MUs, with the headwaters MU being named CLCR1 and the furthest downstream MU being named CLCR5.

MUs were designed to capture clusters of discharges that meet the analytical criteria and to represent changing conditions in the West Branch Susquehanna Subbasin. For example, WBS1, WBS2, and WBS3 in the headwaters of the West Branch Susquehanna River mainstem were delineated separately since all three capture areas with differing AMD impacts. WBS1 captures a portion of the Victor and Sterling Mine Pool discharges, representing the main AMD impacts to the extreme headwaters of the West Branch Susquehanna River. WBS2 captures the remaining Victor and Sterling Mine Pool discharges, as well as inputs from the Barnes and Watkins Coal Refuse Pile and the planned Lancashire #15 (Barnes and Tucker Discharge) Active AMD Treatment Plant. WBS3, on the other hand, captures the influence of several net alkaline AMD discharges in the West Branch Susquehanna River headwaters, which are responsible for changing river conditions from net acidic to net alkaline. In summary, MUs in other sections of the West Branch Susquehanna River Subbasin were delineated based upon such analytical criteria discharge clusters and changes in water quality conditions as well.

Additionally, each MU contains a water quality station at its endpoint to characterize the current background water quality conditions for the entire area. These MU endpoint water quality stations were also selected for possible use in monitoring water quality changes once AMD restoration projects are completed.

MU endpoint water quality stations are named by their GIS identifier so that these sites can be searched and found easily within the database when needed.

For each MU, four sets of data were analyzed and used for characterizing AMD impacts. These data include:

1. measured instream water quality for the MU endpoint station;
2. cumulative acidity loading (lbs/day) and yield (loading/MU area) from all analytical discharges within the MU;
3. cumulative iron loading and yield from all analytical discharges within the MU; and,
4. cumulative aluminum loading and yield from all analytical discharges within the MU.

Discharges "Adjacent" to Federal and State Priority I and II Health and Safety Problem Sites

A significant funding mechanism for the remediation of Pennsylvania's legacy mine land problems resides within Title IV of the Federal SMCRA of 1977. The projected $1.4 billion available to Pennsylvania through the December 2006 SMCRA reauthorization will be used primarily to restore sites designated by OSM and PADEP as Priority I or II Health and Safety Problem Sites (i.e., high walls, mine openings, burning coal refuse piles, etc.). These types of land reclamation activities, however, are often successful at eliminating or reducing impacts from AMD discharges.

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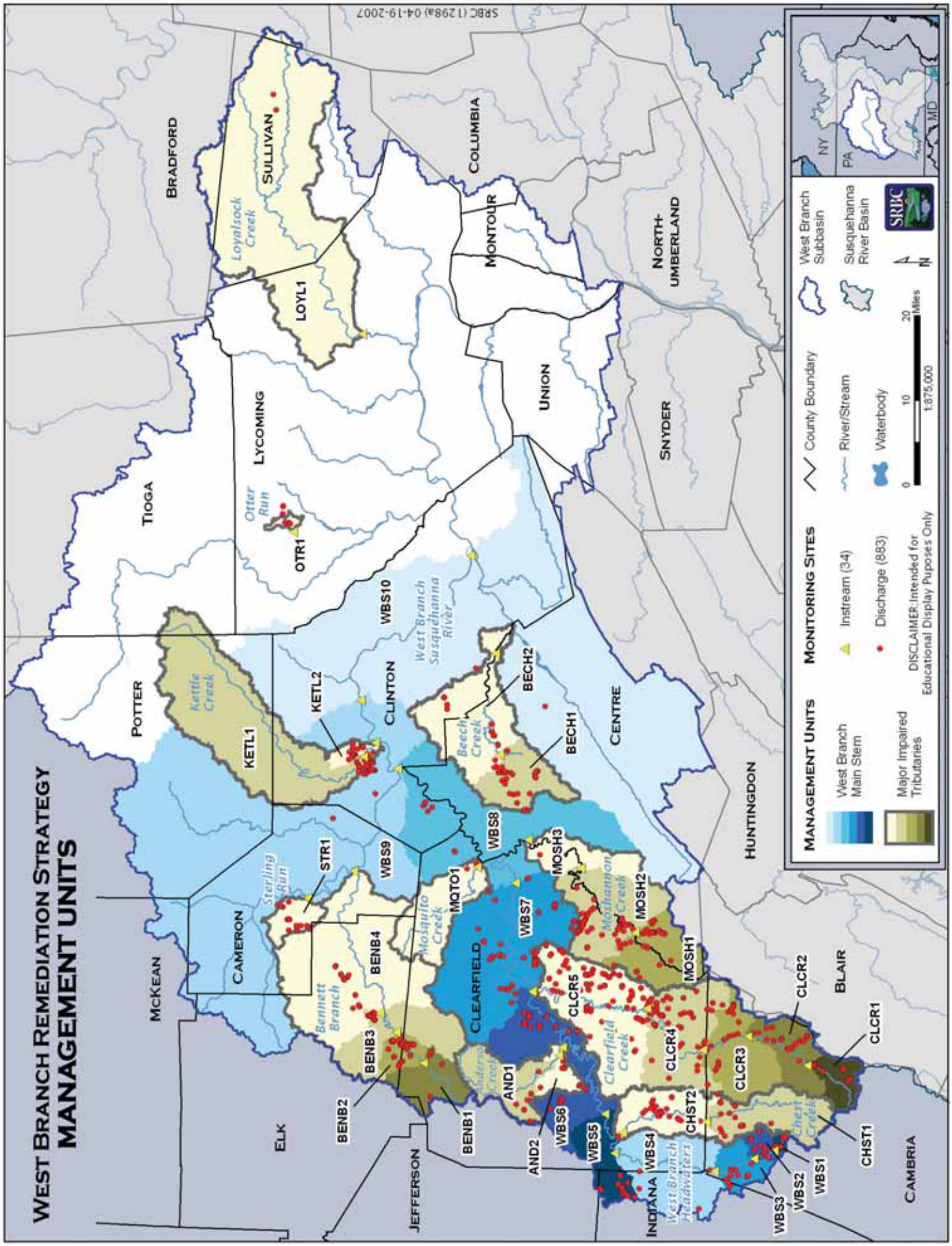
Station Type	# of Stations	# Stations with Analytical Criteria	% Stations with Analytical Criteria
Instream	6,110	1,596	26
Discharge	1,964	788	40
Total	**8,074**	**2,384**	**30**

Table 6. *Instream and Discharge Stations Meeting Analytical Criteria.*



J. Zimmerman

Figure 7. *The 34 MUs of the West Branch Susquehanna Subbasin, the 788 Analytical Criteria Discharges, and the 34 MU Endpoint Water Quality Stations.*

Subwatershed	MU	MU Endpoint Station	Area MI^2	Analytical Criteria Discharges #	Discharge Acid Load lbs/day	Discharge Iron Load lbs/day	Discharge Al Load lbs/day	Priority I and II AMLs Acreage	Total AMLs (PI, PII, and PIII) Acreage	Major AMD Impaired Tributary
West Branch Susquehanna River	WBS1	WBS 27	3.70	14	471	49	34	1.8	96.1	None
	WBS2	WBS 22	12.28	13	2,863	535	196	108.5	402.4	Lesle Run, Fox Run
	WBS3	WBS 17	26.82	14	0	89	10	145.1	530.6	Moss Creek, Emeigh Run
	WBS4	WBS 12	98.27	4	0	3	0	49.5	1,064.1	Cush Creek
	WBS5	WBS 11	44.91	22	963	320	72	46.5	456.4	Bear Run
	WBS6	WBS 171	106.74	27	73	5	9	259.6	2,124.6	Montgomery Run, Hartshorn Run
	WBS7	WBS 06	203.32	50	2,226	675	135	442.4	4,118.0	Alder Run, Deer Creek
	WBS8	WBS 110	221.35	8	274	34	16	154.8	3,519.0	Birch Island Run, Sterling Run
	WBS9	WBS 04	741.30	15	5,162	982	283	136.9	568.7	Cooks Run, Drury Run
	WBS10	WBS 03	975.30	2	91	8	10	41.3	263.3	Tangascootack Creek
		Total	**2433.99**	**169**	**12,123**	**2,700**	**765**	**1,386.4**	**13,143.2**	
Chest Creek	CHST1	2W	69.97	16	812	11	72	294.9	576.0	Rock Run, Brubaker Run
	CHST2	CHST 1.0	59.19	31	183	17	16	249.2	1,506.3	North Camp Run
		Total	**129.16**	**47**	**995**	**28**	**88**	**544.1**	**2,082.3**	
Anderson Creek	AND1	SMPAC 2	58.48	9	1,472	163	131	76.9	460.1	Little Anderson Creek
	AND2	SMPAC 1	19.26	7	192	21	19	87.8	282.1	Bilger Run
		Total	**77.74**	**16**	**1,664**	**184**	**150**	**164.7**	**742.2**	
Clearfield Creek	CLCR1	CLCR 13	27.72	18	4,943	622	457	16.7	53.2	Bradley Run
	CLCR2	CLCR 10	47.98	22	2,737	460	176	59.3	458.8	Brubaker Run, Little Laurel Run
	CLCR3	CLCR 08	72.61	25	1,390	129	117	568.5	1,140.0	Powell Run
	CLCR4	CLCR 04	101.79	58	13,123	3,049	749	434.5	4,398.4	Muddy Run
	CLCR5	CLCR 01	142.91	126	8,060	1,111	482	655.7	6,225.1	Morgan Run, Long Run
		Total	**393.01**	**249**	**30,253**	**5,371**	**1,981**	**1,734.7**	**12,275.5**	

Table 7. *General Characteristics of the 34 West Branch Susquehanna Subbasin Remediation Strategy MUs.*

Table 7. continued

Subwatershed	MU	MU Endpoint Station	Area MI²	Analytical Criteria Discharges #	Discharge Acid Load lbs/day	Discharge Iron Load lbs/day	Discharge Al Load lbs/day	Priority I and II AMLs Acreage	Total AMLs (PI, PII, and PIII) Acreage	Major AMD Impaired Tributary
Moshannon Creek	MOSH1	MOSH 39	68.76	61	10,381	694	905	624.1	2,887.6	Trout Run, Beaver Run
	MOSH2	MOSH 19	93.41	75	19,862	8,163	1,069	287.5	3,132.3	Laurel Run, Cold Stream
	MOSH3	MOSH 05	45.44	1	3	0	0	269.4	1,143.8	Black Moshannon Creek
		Total	**207.61**	**137**	**30,246**	**8,857**	**1,974**	**1,181.0**	**7,163.7**	
Mosquito Creek	MQTO1	MQTO 01	71.29	2	1	2	1	20.6	655.2	Grimes Run, Curley's Run
Sterling Run (Driftwood Branch)	STR1	STR 01	24.55	17	768	16	63	167.3	432.9	May Hollow Run, Finley Run
Bennett Branch	BENB1	BBSC 4.0	42.97	7	3,067	905	189	154.3	278.7	Moose Run, Bark Camp Run
	BENB2	BBSC 3.0	19.66	31	9,200	1,112	729	236.6	392.6	Cherry Run, Tyler Run
	BENB3	BBSC 2.0	72.97	10	1,819	157	139	207.7	537.8	Caledonia Run
	BENB4	BBSC 1.0	230.52	13	2,674	405	183	404.7	897.7	Dents Run
		Total	**3 6 6 .12**	**61**	**16,760**	**2,579**	**1,240**	**1,003.3**	**2,106.8**	
Kettle Creek	KETL1	KCPS 5	233.20	5	440	79	36	35.8	134.8	Short Bend Run, Five Mile Hollow
	KETL2	KETL 01	13.18	33	3,661	453	302	26.6	261.9	Twomile Run
		Total	**246.38**	**38**	**4,101**	**532**	**338**	**62.4**	**396.7**	
Beech Creek	BECH1	90	56.46	30	2,407	201	219	153.8	2,089.2	North and South Fork Beech Creek
	BECH2	25	114.97	15	3,577	587	164	14.0	795.8	Big Run
		Total	**171.43**	**45**	**5,984**	**788**	**383**	**167.8**	**2,885.0**	
Otter Run	OTR1	BR 01	4.65	5	25	1	6	2.4	20.7	Buckeye Run
Loyalsock Creek	LOYL1	WQN 408	436.86	2	44	7	2	26.5	157.8	Birch Creek
		Grand Total	**4,562.79**	**788**	**102,964**	**21,065**	**6,991**	**6,461.3**	**42,062.0**	

Remediation efforts could be enhanced by focusing attention on possible links between water infiltration occurring on some Priority I and II sites, and AMD discharges occurring "adjacent" to such sites. If these links can be proven, OSM rule making through the SMCRA reauthorization may allow for remediation of these AMD discharges in conjunction with Priority I or II land reclamation. Normally this funding would not be available for water quality improvements since those activities are designated as Priority III problems (Acid Mine Drainage). Priority III problems can only be addressed using smaller allocations from the Title IV funds, known as "Set-Aside Funds." Under the 2006 reauthorization changes to SMCRA, as much as $420 million could be requested by Pennsylvania as "Set-Aside-Funds" for Priority III treatment.

In order to assess this possible opportunity, some initial analyses were performed to determine the number of discharges within an arbitrary one-quarter mile buffer of a Priority I or II site using the PADEP Abandoned Mine Land Information System (AMLIS) database. Based on the density of AMD discharges, reclamation activities may have the potential for improving environmental conditions beyond the immediate health and safety concerns associated with the Priority I and II sites.

Analysis of Wild Trout Streams Impaired by AMD or Acid Rain

Many miles of good quality streams in the West Branch Susquehanna Subbasin are sometimes overlooked due to the impairment of adjacent streams. In total, there are about 2,400 stream miles documented to have wild trout reproduction, 660 miles of Class A trout streams (the highest population class obtained), and 250 miles of Wilderness Trout streams within the West Branch Susquehanna Subbasin. It is believed that many more streams with wild trout reproduction have not yet been documented.

More than 25 percent of these streams also contain sections with documented AMD or acid rain impairment. These stream sections may provide unique restoration opportunities for three main reasons.

1. The streams may offer situations where minimal treatment may greatly restore most of the stream and allow impaired miles to be removed from Pennsylvania's list of impaired waters;
2. The streams support biological recolonizers, both in terms of macroinvertebrates and fish, and removal of AMD may promote resurgence in the populations; and
3. The reconnection of tributaries with the West Branch Susquehanna River may produce enhanced ecological benefits.

Using GIS, SRBC identified streams that contained either AMD/acid impaired segments and either Wild Trout, Class A, and Wilderness Trout designated waters. These documented streams were then mapped with the Brook Trout Population Status GIS layer constructed by the Eastern Brook

Surface Mining Control and Reclamation Act (SMCRA) Reauthorized for Another 15 Years in 2006

The reauthorization of the Abandoned Mine Lands (AML) Fund occurred on December 6, 2006, with a provision for mandatory spending from 2008 to 2022 projected to be $1.4 billion for Pennsylvania. Grants awarded to the state, from fees collected from current coal mining to address problems of past mining practices, previously had to be appropriated by committees of jurisdiction in Congress, with the result being only a portion of funds going toward the AML problem.

With the reauthorization of SMCRA, reclamation funding to the state will increase roughly three to four times with a built-in ramp-up period to allow for good planning. While this legislation and funding is directed toward Priority I and II sites (health and safety issues such as dangerous high walls, mine openings, acid mine drainage pits), there is a 30 percent set-aside provision for the treatment of AMD. This is up from a 10 percent set-aside provision in the past.

With up to 30 percent of a state's annual grant "set-aside" specifically to implement projects that eliminate sources of AMD or treat waters degraded by AMD, set-aside funds are placed in an interest-bearing account, with both principle and interest available for AMD projects. Unlike Priority I and II funding, which must be spent within 3 to 5 years, AMD set-aside funding has no time restrictions.

Possible use of set-aside funds is to place a portion, perhaps the interest only, in an interest-bearing account for the operation and maintenance needs of AMD treatment systems in perpetuity. The Commonwealth, however, cannot shift its entire emphasis to AMD. Even if a state takes the full 30 percent, the funding going to Priority I and II sites will still be considerably greater than the funding going to AMD treatment.

Pennsylvania is estimated to be one of a few states not to have completed reclamation of all of its Priority I and II sites by 2022. However, although fees on coal mining will not be collected after this date, it is estimated that the fund will have more than $1 billion remaining to be spent on "uncertified" states. This could mean as much as $500 million in additional funding for Pennsylvania after 2022.

John Dawes, Executive Director
Foundation for Pennsylvania Watersheds

Foundation for Pennsylvania Watersheds

Trout Joint Venture (EBTJV). This classification system is designed to designate watersheds throughout the EBTJV-study area that are either maintaining or not maintaining reproducing populations of brook trout based on the percentage of available habitat in each watershed. The classification scheme can be found in Table 8.

EBTJV Classifications	Summary Characteristics
Unknown: No Data	No data or not enough data to classify further
Extirpated (Regional Extinction):	All historic reproducing populations extirpated
Present: Qualitative	No quantitative data; qualitative data show presence
Present: Large/Strong Population	High percentage (>90%) of historic habitat occupied by reproducing populations
Present: Depressed Population	Between 50% and 90% of historic habitat occupied by naturally reproducing brook trout
Present: Severely Depressed	Between 1% and 50% of historic habitat occupied by naturally reproducing brook trout

Table 8. *Eastern Brook Trout Joint Venture Brook Trout Population Status Classifications.*

AMD Treatment System Modeling

The Watershed Restoration Analysis Model (WRAM), developed by Water's Edge Hydrology Inc., was used to simulate treatment systems for all 788 discharges meeting the analytical criteria. The model conceptualizes both passive and active (chemical) AMD treatment system solutions on all 788 discharges. The data outputs used for the strategy include predictions for the available acidity, iron, and aluminum loading reductions at each discharge, as well as costs associated with the capital funding necessary to construct the adequate passive or active AMD treatment system. The model also estimates the yearly operation and maintenance (O&M) costs of each of those systems. For this study, it is important to note that predicted available loading reductions, passive and active treatment system construction capital costs, and yearly O&M fees were accumulated for each MU to allow comparison.

It is also important to note that WRAM cost estimates do not include any projections on AML reclamation and remining potential in the West Branch Susquehanna Subbasin.

The version of the WRAM model used for this effort is intended to be a watershed-level planning tool, and not to be used for final design of treatment systems. Both passive and active alternatives are included for conceptual comparison. Conceptual passive system designs are based on best current technologies and sizing criteria. Active system designs assume the use of pebble quicklime, which is currently considered a low-cost and low-maintenance form of chemical application that is gaining popularity in both industry and in the watershed restoration community within the Commonwealth. Specific criteria are as follows (Rightnour, 2007):

- ***Vertical Flow Wetlands*** - 25 grams/meter^2/day acidity loading at the compost surface or 16 hours detention time in the limestone substrate, whichever produces the greater sizing.
- ***Oxidation and Precipitation Basins*** - 24 hours detention at average flow, plus an additional 40 percent volume for sludge storage.
- ***Surface Flow Wetlands*** - removal rates are set at 5 grams/meter^2/day for iron. There is no published removal rate for aluminum, but it is assumed to be 2.5 grams/meter^2/day as being half the atomic weight of iron. Also, the wetland bed width is limited to two feet per average influent gallon per minute to prevent soil erosion, resulting in large bed sizing for very large influent flows.
- ***Manganese Oxidizing Bacteria Beds*** - manganese was not considered in this study.
- ***Pebble Quicklime Systems*** - are evaluated as simple neutralization units based on the WRAM default settings. All values are taken from OSM's AMD Treat Version 4.1b (Office of Surface Mining, 2006) or recommendations from the manufacturer of the AquaFix pebble quicklime AMD treatment system.

Do Not Let the Bad Always Overshadow the Good

Yes, there are many examples of good water quality in the West Branch Susquehanna Subbasin. So much attention is focused on the impaired regions that many times the areas with exceptional water quality are overlooked. According to the PA Code Chapter 93 stream designations, the West Branch Susquehanna Subbasin contains 1,249 miles of Exceptional Value streams (the highest classification a stream can obtain), 5,229 miles of High Quality-Cold Water Fisheries, 73 miles of High Quality-Trout Stocked Fisheries, and 359 miles of Trout Stocked Fisheries (West Branch Susquehanna River Task Force, 2005).

These high quality streams hold potential biological "recolonizers." As water quality improves within impaired sections, these recolonizers could move into the restored streams and repopulate, often without needing subsequent restocking.

Thomas Clark
Abandoned Mine Drainage Project Coordinator
Susquehanna River Basin Commission

Restoring Fishable Populations of Brook Trout

The eastern brook trout (Salvelinus fontinalis), Pennsylvania's only native salmonid, has inhabited eastern coldwater streams for several million years. Brook trout are traced back to the retreat of the early continental glaciers and populations were known to thrive in the ancient Appalachian valleys. Prior to colonial times, brook trout were present in nearly every coldwater stream and river not only in Pennsylvania but in all of the eastern United States.

Strong brook trout populations, often used as a surrogate for healthy water, began to decline in the West Branch Susquehanna Subbasin as early agriculture, logging, and mining impacted our local waterways. These activities, although economically significant, instigated the deterioration of streams and rivers with increased sediment and pollution loads. As a result, many of today's streams in the West Branch Susquehanna Subbasin no longer provide the pristine conditions required for sustainable brook trout populations. In fact, the Eastern Brook Trout Joint Venture (EBTJV) estimates that only four percent of watersheds in the West Branch Susquehanna Subbasin are home to strong populations of this important fish. In addition, the EBTJV estimates that 77 percent of West Branch Susquehanna Subbasin watersheds are home to depressed or severely depressed populations, and an additional nine percent of the watersheds are believed to have extirpated populations of the eastern brook trout.

D. Heggenstaller

Bear Run native brook trout.

Despite their ominous present-day condition, hope still remains for the brook trout of the West Branch Susquehanna Subbasin. Countless Trout Unlimited chapters, watershed groups, and dedicated conservation organizations have implemented on-the-ground projects to restore brook trout populations. In addition to these local efforts, several important steps have been taken on the state and regional level.

The EBTJV has completed an assessment of the status and threats of the brook trout, and has published a conservation strategy to improve conditions for these fish on a statewide basis. The Pennsylvania Fish and Boat Commission and the Pennsylvania Game Commission have acknowledged the importance of protecting existing populations by recommending that the eastern brook trout be added to the State Wildlife Action Plan, the document that prescribes conservation measures for species and their critical habitat before they become more rare and costly to protect and restore. Furthermore, as part of its West Branch Susquehanna Restoration Initiative, Trout Unlimited is utilizing the Conservation Success Index, an innovative tool that provides information about brook trout at various geographic scales that can help identify data gaps, analyze threats to population and habitat, and prioritize conservation actions for stakeholders.

For more information on the native brook trout or to learn more about protection, enhancement, and restoration strategies visit **www.brookie.org** or **www.easternbrooktrout.org**.

Rebecca Dunlap, Project Manager of the West Branch Susquehanna Restoration Initiative, Trout Unlimited

A uniform set of defaults was applied to all analytical criteria discharges. Each discharge was treated with successive WRAM selected treatment options until all predicted system effluent water quality defaults were realized. These defaults have been archived and are available upon request from SRBC.

In some cases, the use of the default values produced unreasonable results for passive treatment system sizes and costs, due to extremes in flow or contaminant loading that would not be normally considered acceptable. Passive treatment sizing and costs are much more sensitive to these variables than active systems, and outlying estimates are to be expected when applying a single set of design criteria. The model eliminates discharges that do not require treatment based on default concentration thresholds, but does not eliminate passive systems that may not be feasible based on size or cost.

System construction costs are based on unit sizing costs derived from OSM's AMDTreat Version 4.1b program. Multiple sizes for each type of system component were run in AMDTreat 4.1b to determine an average unit cost. Some modifications were made to round resulting values and account for inflation based on recent Waters Edge Hydrology Inc. experience with similar systems. The model does not account for escalation of costs over time, and system costs will be greater if not implemented in the near future.

O&M costs for passive treatment systems are estimated at 3.5 percent of the construction cost annually. Generally, there is little annual maintenance for most passive systems, and this annual cost is considered more of an accrual value for future maintenance or system replacement. The active system cost estimates also include a 3.5 percent accrual for component replacement, plus the annual chemical consumption and labor costs.

WRAM was only used to simulate possible loading reductions from and costs for AMD treatment systems. WRAM was not used for instream water quality concentration projections following completion of restoration projects.

Hypothetical Examples for West Branch Susquehanna River Subbasin Remediation

Utilizing WRAM data outputs for the 788 analytical criteria discharges, hypothetical examples for remediation were simulated for the West Branch Susquehanna River headwaters and tributaries contributing a majority of the AMD pollution. In addition, one simulation shows an example for a "focused watershed approach" that could apply to any watershed where sufficient data exists. The Clearfield Creek Watershed was used for this particular example.

All simulations focused on the impact of reducing available acidity, iron, and aluminum loadings. The available reductions for each selected discharge were then subtracted from each of the 33 West Branch Susquehanna River TMDL water quality stations located downstream. This simple mass balance approach was used to predict changes in water quality conditions for the West Branch Susquehanna River and Clearfield Creek as a result of the remediation examples.

These examples target areas contributing the most AMD impacts based on existing data, and do not represent the only options available for proceeding with remediation activities in the West Branch Susquehanna Subbasin.

WEST BRANCH SUSQUEHANNA RIVER HEADWATERS

The West Branch Susquehanna River Headwaters example focuses on the mainstem of the West Branch from Cambria County to the entry of Clearfield Creek in Clearfield County. This example includes the completion of three headwater projects and restoration of four headwater MUs.

The three projects include: (1) the Barnes and Watkins Coal Refuse Pile Removal Project, which should be completed by 2008; (2) the addition of treated effluent from the Lancashire #15 (Barnes and Tucker Discharge) AMD Treatment Plant, which should be online

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AMD Impacts on Aquatic Life

The latest estimates show that 1,205 miles of streams within the West Branch Susquehanna Subbasin are impaired by AMD. Often, those impairments are associated with the biological life usually present in healthy streams; essentially, the fish and the stream macroinvertebrates (insects, worms, snails, etc.).

Several researchers have shown that the rate of microbial processing of leaf litter is affected negatively by acidity (Kimmel et al., 1985, Palumbo et al., 1987, and Thompson and Barlocher, 1989). Less food for macroinvertebrates means less food for the fish that depend on these organisms for a large portion of their diet.

Gill tissue is considered the primary target organ of acid stress. Low pH water causes a disturbance in the balance of sodium and chloride ions in the blood (Earle and Callaghan, 1998). Both the efflux and active uptake of sodium are reduced at low pH. This iono-regulation can be the primary cause of death to stream organisms exposed to acid water. It has also been found that oxygen consumption declines at very low pH.

Once AMD enters a healthy stream, chemical reactions occur that often cause the polluting metals (namely iron, aluminum and manganese) to precipitate on the bottom substrate of the stream. These metals form a heavy coating that significantly degrades the habitat utilized by macroinvertebrates, consequently causing a reduction in the stream's productivity. In addition, metal precipitate can smother the eggs of macroinverebrates and fish.

Precipitated metals, particularly iron and aluminum, can also interfere with gas exchange by coating the gill surfaces of fish and macroinvertebrates. This interference can disrupt growth patterns and increase mortality rates among aquatic species (Vuori, 1996).

Neutralizing acid and removing aluminum from streams will often allow some aquatic life to return, even when the polluting iron remains.

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Western Pennsylvania Conservancy
water. land. life.

SRBC

"Addressing AMD impacts in the West Branch Susquehanna River Headwaters could restore water quality conditions from the start of the river in Cambria County to the entrance of Clearfield Creek in Clearfield County."

Watersheds in the West Bra

M. Smith

Heavily AMD-impaired stretch of Moshannon Creek.

WEST BRANCH SUSQUEHANNA SUBBASIN FACTS

Drains 6,978 square miles – 25 percent of the entire Susquehanna basin (SRBC).

Has nearly 1,205 miles of AMD-impaired waterways – nearly 66 percent of the total AMD-impaired mileage in the Susquehanna basin (2006 Draft 303d Listed Streams, PADEP).

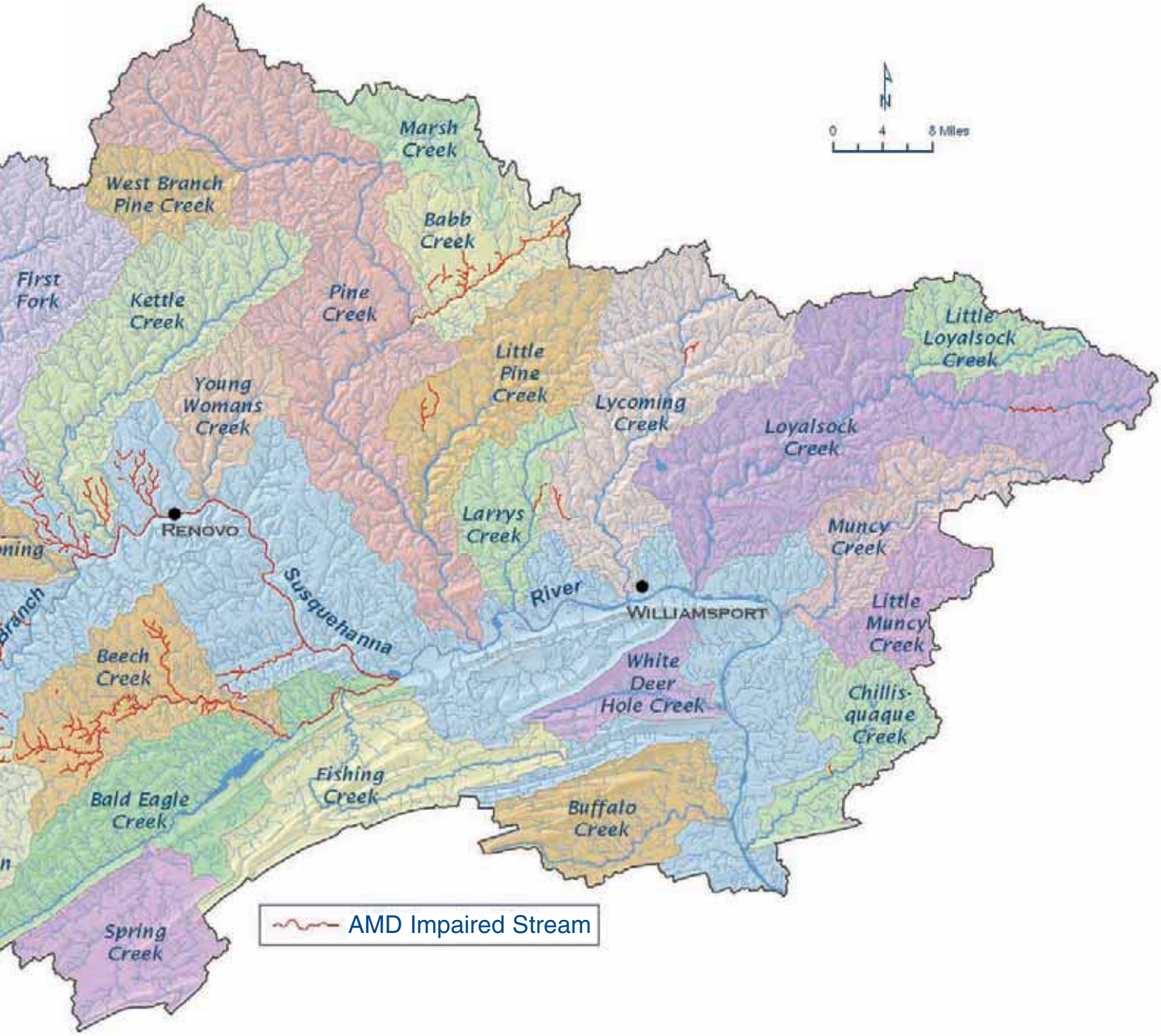
Encompasses 2,190 square miles of public forest lands – 67 percent of the forest lands in the Susquehanna basin (PA Bureau of Forestry and NYSDEC).

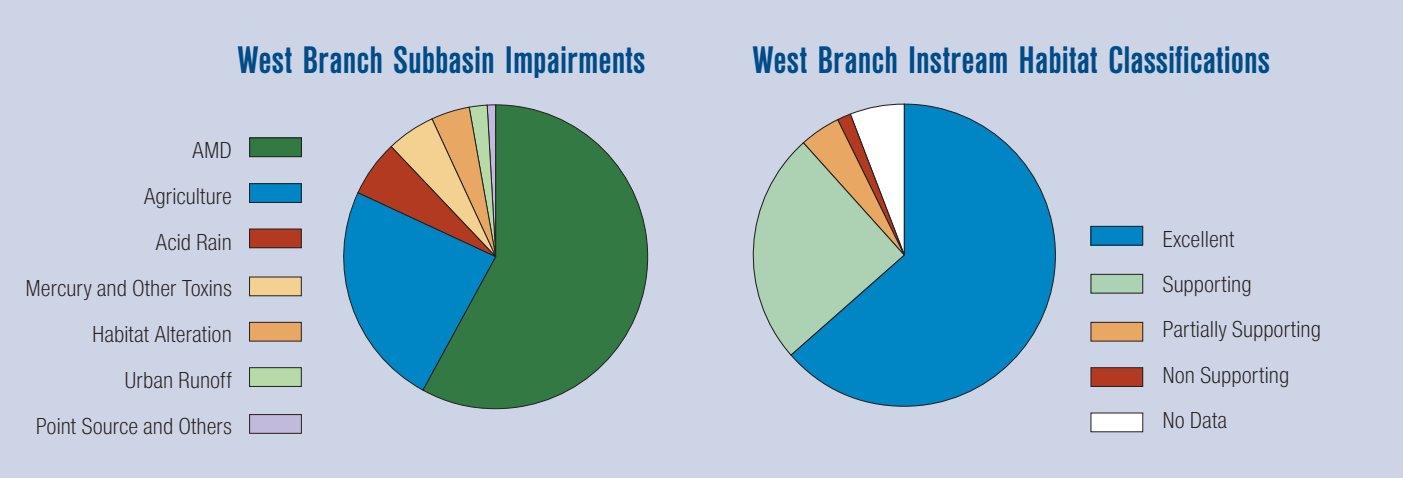
Encompasses 47 percent (~4,000 square miles) of the total PA WILDS area (SRBC).

A. Wolfe

Babb Creek, which has been restored from major AMD impacts.

ANCH SUSQUEHANNA SUBBASIN





in 2009; and (3) the restoration of the Bear Run Watershed, which currently has construction funds to treat several discharges and design funds for several more.

The four MUs to be restored include WBS1, WBS2, AND1, and AND2. WBS1 and WBS2, the two most headwater MUs of the West Branch Susquehanna Subbasin, are impacted by discharges from the Sterling and Victor Mine Pools. AND1 and AND2 represent the AMD impacts in the Anderson Creek Watershed.

Addressing AMD impacts in the West Branch Susquehanna River Headwaters could restore water quality conditions from the start of the river in Cambria County to the entrance of Clearfield Creek in Clearfield County. This section equals a distance of about 70 river miles, or nearly 30 percent of the West Branch Susquehanna River, and should remove nearly 28 river miles from Pennsylvania's list of impaired waters.

MAJOR TRIBUTARIES

The major tributaries example addresses impacts from the top ten ranked tributary MUs based upon AMD loading and yields (Table 9). These ten MUs comprise more than 76 percent of the acidity loading, more than 81 percent of the iron loading, and more than 76 percent of the aluminum loading available within the West Branch Susquehanna Subbasin.

FOCUSED WATERSHED APPROACH – CLEARFIELD CREEK WATERSHED

The Clearfield Creek Watershed served as an example for demonstrating how the approach outlined in this report could be used to focus on a smaller scale. It is important to note that these analyses were only possible due to the extensive amount of water quality data available for this watershed.

The example simulates potential improvements to water quality conditions for Clearfield Creek with treatment of the Cresson #9 discharge, the Gallitzin #10 discharge, the Gallitzin Shaft Mine Complex, and the Dean Clay Mine. The Cresson and Gallitzin sources are located in the headwaters of Clearfield Creek. The Dean Clay Mine is located in the Brubaker Run Watershed, a tributary to Clearfield Creek.

MU	Subbasin	Coverage Area
CLCR1	Clearfield Creek	Beaverdam Run to Headwaters
CLCR2	Clearfield Creek	SR 1026 Bridge to Beaverdam Run
CLCR4	Clearfield Creek	Muddy Run to Turner Run
CLCR5	Clearfield Creek	Mouth to Muddy Run
MOSH1	Moshannon Creek	SR 970 Bridge to Headwaters
MOSH2	Moshannon Creek	Upstream of Six Mile Run to SR 970 Bridge
BENB1	Bennett Branch	Moose Run to Headwaters
BENB2	Bennett Branch	Downstream of Cherry Run to Moose Run
KETL2	Kettle Creek	Mouth of Upstream of Short Bend Run
BECH2	Beech Creek	Mouth to Wolf Run

Table 9. *Tributary MUs with Major AMD Impairments.*

Instream Improvement Modeling Projections

A simple mass balance approach was used to predict changes in water quality conditions for the West Branch Susquehanna River and Clearfield Creek after completion of each remediation example. The predicted AMD loading reduction outputs from WRAM were subtracted from the West Branch Susquehanna River and the Clearfield Creek instream stations directly downstream of the restoration effort, as well as every mainstem instream point thereafter.

Due to apparent errors in the analysis and reporting of acidity concentrations, net alkalinity was calculated using two different methods for the West Branch Susquehanna River and Clearfield Creek instream stations (Figure 8). It has been documented by Kirby and Cravotta (2005) that "pH, alkalinity, and acidity of mine drainage and associated waters can be misinterpreted because of the chemical instability of samples and possible misunderstandings of standard analytical method results." Improvements in the analysis and reporting of these three parameters are being implemented by water quality laboratories; however, since this strategy effort is dealing entirely with historical water quality data, a majority of the samples compiled were sampled prior to these improvements.

As mentioned, calculated net alkalinity values were only completed on the 33 West Branch Susquehanna River TMDL instream stations and the 15 Clearfield Creek TMDL instream stations that were utilized to track subbasin improvements once areas of AMD impact were hypothetically restored. Completing net alkalinity calculations on all samples in the database was beyond the scope of this project. SRBC also determined that it should not tamper with historically reported results from certified laboratories.

If West Branch Susquehanna River and Clearfield Creek Mainstem pH is > 6.0:

$$\text{Net Alkalinity} = \text{Alkalinity}_{\text{reported}} - (50 * (\text{Total Manganese}_{\text{concentration}} * 2 / 55))$$

If West Branch Susquehanna River and Clearfield Creek Mainstem pH is < 6.0:

$$\text{Net Alkalinity} = \text{Alkalinity}_{\text{reported}} - (50 * (\text{Total Iron}_{\text{concentration}} * 2 / 56 + \text{Total Manganese}_{\text{concentration}} * 2 / 55 + \text{Total Aluminum}_{\text{concentration}} * 3 / 27 + 10 \wedge (3 - \text{pH reported}))))$$

Figure 8. *The Net Alkalinity Equations Used on the West Branch Susquehanna River and Clearfield Creek Mainstem Instream Water Quality Stations Used to Predict Improvements.*

In addition, the predicted improvements to the West Branch Susquehanna River and Clearfield Creek mainstems are considered conservative estimates for several reasons. First, the WRAM model may underestimate the extent of acidity loading reduction. Second, mass balance calculations do not account for instream processes that may allow for the precipitation of metals before reaching downstream water quality stations.

The datasets used in the analyses do not represent all discharges contributing pollutant loads to the selected MUs, only those meeting the analytical criteria. For example, the percentage of unaccounted acidity loads in the Moshannon Creek Watershed is 52 percent. The additional loads are from discharges with insufficient data, undocumented discharges, coal refuse piles, groundwater upwellings, acid rain impacts, and possible other sources.

It is also possible that the discharge and instream sampling events occurred at different times and under varying hydrologic conditions since only historical data were utilized for the analyses. Since loading is correlated to flow, these factors can result in significant differences in comparing upstream and downstream conditions. For this reason, focus was placed on characterizing analytical criteria discharges.

"The predicted AMD loading reduction outputs from WRAM were subtracted from the West Branch Susquehanna River and the Clearfield Creek instream stations directly downstream of the restoration effort, as well as every mainstem instream point thereafter."

RESULTS AND DISCUSSION

Management Unit Endpoint Water Quality Stations

*Parameters That Exceed Water Quality Standards Noted In Red For Tables 10-22

West Branch Susquehanna River Mainstem MUs

The West Branch Susquehanna River mainstem was divided into ten separate MUs from the extreme headwaters (WBS1) in the vicinity of Carrolltown, Cambria County, to just downstream of the confluence with Bald Eagle Creek (WB10), the furthest extent of major AMD impacts. The average water quality endpoints for each of those MUs are found in Table 10. Ninety percent of these MU endpoints have at least one parameter that exceeds its water quality standard.

MU	MU Endpoint Station	Year(s) Sampled	Flow GPM	pH Lab	Total Fe mg/l	Total Mn mg/l	Total Al mg/l
WBS1	WBS 27	2004-2005	1,793	5.5	2.2	1.0	3.1
WBS2	WBS 22	2004-2005	7,781	4.2	11.3	1.5	13.6
WBS3	WBS 17	2004-2005	19,359	7.5	2.6	0.6	3.0
WBS4	WBS 12	2004-2005	134,037	7.3	0.6	0.2	1.2
WBS5	WBS 11	2004-2005	269,299	7.4	0.5	0.2	1.0
WBS6	WBS 171	1994	85,725	6.5	0.4	0.5	0.4
WBS7	WBS 06	2004-2005	1,208,582	6.8	1.1	0.7	0.9
WBS8	WBS 110	2002	374,748	7.0	0.5	1.4	0.4
WBS9	WBS 04	2004-2005	3,533,423	6.6	0.4	0.4	1.4
WBS10	WBS 03	2004-2005	3,009,525	6.6	0.5	0.4	0.8

Table 10. *West Branch Susquehanna River MU Endpoint Average Water Quality.*

Chest Creek MUs

The Chest Creek Watershed was divided into two separate MUs: one capturing conditions from the headwaters to the midpoint of the watershed (CHST1), and the other capturing conditions from the midpoint to the mouth (CHST2). The water quality endpoints for each MU are found in Table 11. All water quality parameters for both MU endpoints are within the water quality standard of that parameter.

MU	MU Endpoint Station	Year(s) Sampled	Flow GPM	pH Lab	Total Fe mg/l	Total Mn mg/l	Total Al mg/l
CHST1	2w	Unknown	3,239	7.0	0.4	0.4	0.1
CHST2	CHST 1.0	2002	9,403	8.3	0.2	0.1	0.3

Table 11. *Chest Creek MU Endpoint Average Water Quality.*

Anderson Creek MUs

The Anderson Creek Watershed was divided into two separate MUs: one capturing the first major impairment area, Little Anderson Creek (AND1), and the other capturing the second major impairment area, Bilger Run (AND2). The water quality endpoints for each MU are found in Table 12. AND1 exceeds the water quality standards for pH and aluminum.

MU	MU Endpoint Station	Year(s) Sampled	Flow GPM	pH Lab	Total Fe mg/l	Total Mn mg/l	Total Al mg/l
AND1	SMP-AC2	2004	19,704	4.6	0.2	1.0	0.8
AND2	SMP-AC1	2004	23,697	6.0	0.3	0.8	0.5

Table 12. *Anderson Creek MU Endpoint Average Water Quality.*