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West Branch Susquehanna River Task Force

Despite the enormous legacy of pollution from abandoned mine drainage (AMD) in the West Branch Susquehanna Subbasin, there has been mounting support and enthusiasm for a fully restored watershed. Under the leadership of Governor Edward G. Rendell and with support from Trout Unlimited, Pennsylvania Department of Environmental Protection Secretary Kathleen McGinty established the West Branch Susquehanna River Task Force (Task Force) in 2004.

The goal of the Task Force is to assist and advise the department and its partners as they work toward the long-term goal to remediate the region's AMD.

The Task Force is comprised of state, federal, and regional agencies, Trout Unlimited, and other conservation and watershed organizations (members are identified by their logos on the back page). It first convened on September 10, 2004, and among its early actions, the Task Force recognized the need for a comprehensive AMD remediation strategy for the West Branch Susquehanna Subbasin.

A Report Produced by the Susquehanna River Basin Commission in Partnership with the West Branch Susquehanna River Task Force.

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West Branch Susquehanna Subbasin AMD Remediation Strategy:
Background, Data Assessment and Method Development

INTRODUCTION

The West Branch Susquehanna Subbasin, draining a 6,978-square-mile area in northcentral Pennsylvania, is the largest of the six major subbasins in the Susquehanna River Basin (Figure 1).

The West Branch Susquehanna Subbasin is one of extreme contrasts. While it has some of the Commonwealth's most pristine and treasured waterways, including 1,249 miles of Exceptional Value streams and scenic forestlands and mountains, it also unfortunately bears the legacy of past unregulated mining. With 1,205 miles of waterways impaired by AMD, it is the most AMD-impaired region of the entire Susquehanna River Basin (Figure 2).

At its most degraded sites, the West Branch Susquehanna River contains acidity concentrations of nearly 200 milligrams per liter (mg/l), and iron and aluminum concentrations of more than 17 and nearly 27 mg/l, respectively. Instream loadings of iron and aluminum downstream of Moshannon Creek – the most AMD-impacted West Branch Susquehanna Subbasin tributary – are more than 7,000 tons/year and nearly 5,000 tons/year, respectively.

Pristine setting along the West Branch Susquehanna River.

M. Smith

Abandoned mine lands in Clearfield County.

A. Gavin

Products and Tools of the West Branch Susquehanna Subbasin AMD Remediation Strategy

All the water quality data collected for this project are organized in a geodatabase that allows the user to view the data geographically with a combination of layers, including abandoned mine land features, impaired stream segments, regional geology, regional land use, political and watershed boundaries, and others.

This geodatabase, in combination with spreadsheet tools, can be manipulated by the user to simulate treatment for single or clusters of AMD discharges. This process can be used to calculate instream concentration and loading projections for post-discharge treatment. This technique allows the user to predict potential improvements after restoration strategies are completed, which can be helpful when prioritizing projects.

This report contains demonstrations on the use of these tools to determine potential remediation strategies for the West Branch Susquehanna Subbasin.

West Branch Susquehanna Restoration Initiative and Trout Unlimited

In 1998, Trout Unlimited (TU), an organization committed to the conservation, protection, and restoration of North America's coldwater fisheries, embraced the significance of AMD problems in the Kettle Creek Watershed in Clinton County as a component of its nationally renowned Home Rivers Initiative. Since then, TU has been the lead catalyst, working in close partnership with the local Kettle Creek Watershed Association to address severe AMD problems that plague the lower Kettle Creek Watershed. TU and its partners have conducted numerous assessments and developed restoration plans, completed construction of multiple reclamation and remediation projects, and are currently in the planning phases for several more treatment projects and land reclamation projects through remining.

While still actively involved with AMD cleanup in the Kettle Creek Watershed, TU took its AMD remediation work to the next level and established the West Branch Susquehanna Restoration Initiative in 2004, which is aimed at the restoration of coldwater streams and the ultimate recovery of the West Branch Susquehanna River. As the lead non-profit organization for this initiative, TU is working with numerous local, state, and federal government and non-government organizations on a coordinated, strategic, and cost-effective AMD cleanup approach for the entire river basin. TU is also providing organizational support to the West Branch Susquehanna Restoration Coalition, a group that represents the collective efforts of watershed groups, TU chapters, county conservation districts, businesses, and others that are working to address AMD problems throughout the West Branch Susquehanna Subbasin.

Amy Wolfe, Abandoned Mine Programs Director, Trout Unlimited

These pollutants degrade the environment and limit the use of the river as a resource. These losses are not just limited to biology, habitat, and recreation, but affect human health and the region's socioeconomics as well.

A long-term goal of fully restoring the West Branch Susquehanna Subbasin is extremely challenging and ambitious, especially in light of funding limitations. Members of the Task Force determined that a coordinated effort will be critical, starting with a remediation strategy for the AMD-affected areas.

Figure 1. *The Six Subbasins of the Susquehanna River Basin.*

The Susquehanna River Basin Commission (SRBC) was asked to develop an approach to review remediation alternatives and their impact on improving water quality in the West Branch Susquehanna Subbasin. Funding was provided by TU and Pennsylvania's Department of Environmental Protection (PADEP) and Department of Conservation and Natural Resources (PADCNR).

PADEP Bureau of Abandoned Mine Reclamation (BAMR) has estimated that the capital cost to treat all sources of AMD impacting the West Branch Susquehanna Subbasin could range from $279 million to $464 million, not including annual operation and maintenance associated with the necessary treatment systems (West Branch Susquehanna River Task Force, 2005). At the funding levels currently available for AMD restoration projects, it would take decades to address all of the West Branch

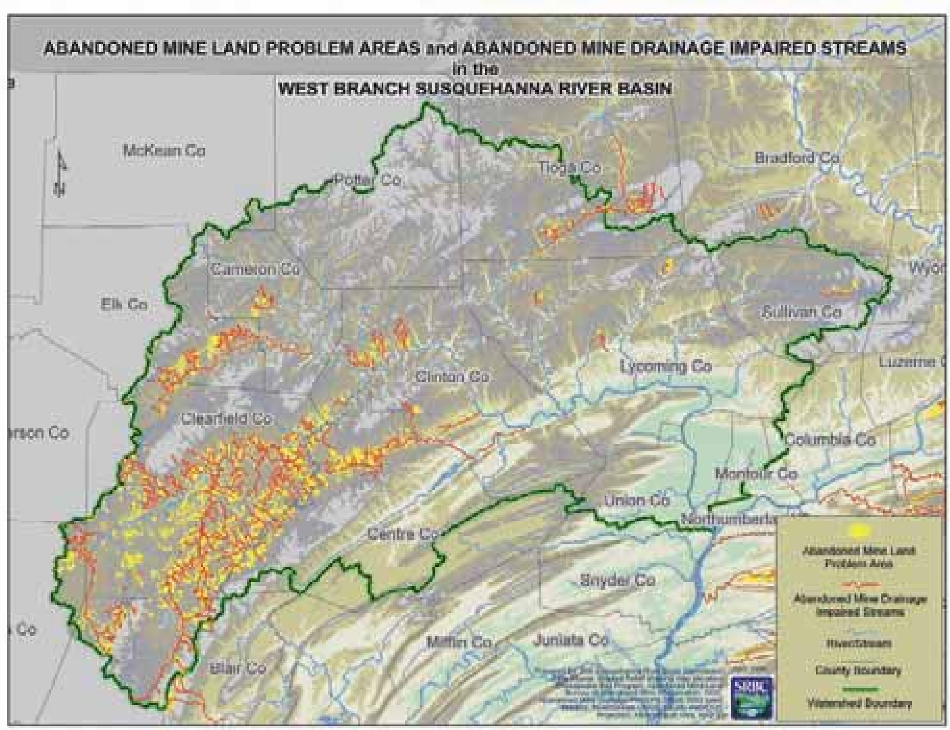


Figure 2. *Abandoned Mine Land Problem Areas and Abandoned Mine Drainage Impaired Streams in the West Branch Susquehanna Subbasin.*

Susquehanna Subbasin's AMD problems. Accordingly, SRBC took those factors into account and developed the remediation strategy as a guide to help resource agencies and organizations achieve comprehensive, region-wide environmental results over the long term.

SRBC developed the strategy using pre-existing (historical) data and information compiled from a wide range of sources to characterize existing conditions in the West Branch Susquehanna Subbasin. From the outset, the purpose of this strategy was to avoid duplicating the efforts of other agencies and organizations in their problem-identification and problem-prioritization initiatives. Instead, the goal was to help identify overlapping goals and opportunities for remediation efforts. To maximize resources, SRBC coordinated strategy efforts while developing a Total Maximum Daily Load (TMDL) assessment for West Branch Susquehanna River AMD impairments.

Scope of the West Branch Susquehanna Subbasin AMD Remediation Strategy

The strategy focuses on water quality and targets opportunities for improving existing conditions. At the outset, SRBC divided the scope of work into the following three major categories to ensure an effective and efficient process:

Formulate Scope of Work -

SRBC was to develop the Scope of Work based on input from TU, PADEP, PADCNR, Task Force, and West Branch Susquehanna Restoration Coalition (Coalition). Information was gathered through meetings with agency and TU technical staff and citizen representatives and SRBC used the input to develop a database, model, and prioritization scheme. SRBC assisted with the coordination and planning process with respect to acquiring Task Force input, either as a group or with separate meetings of individual entities. At a minimum, SRBC met quarterly with Task Force members. In addition, SRBC promoted Task Force goals and encouraged additional partnerships with other relevant entities throughout the process of developing the West Branch Susquehanna Subbasin AMD Remediation Strategy.

Inventory and Analyze Water Quality Data -

SRBC was to compile pre-existing information related to water quality using both instream data and AMD discharge data. PADEP BAMR and District Mining Operations were the two primary sources of information; however, other relevant datasets were incorporated as certain data standards were met. SRBC designed and maintained the database, based on input received from Task Force members. The database contains other subbasin information important to the project, such as extent of active and abandoned mining areas, facility contact information, and information on the receiving waters. SRBC used all the information gathered for the project to formulate options when developing the model.

Develop a Database, Model, and Final Report -

SRBC was to develop an integrated database and model that applies the compiled information to determine existing water quality conditions. Depending on scale considerations, instream and discharge water quality conditions were to be characterized according to severity and extent of influence. The final model has the capability to simulate changes to water quality conditions given a select number of potential water quality improvement options. Input for those options was to be acquired from Task Force members. In addition, SRBC was responsible for developing a process to maintain and update the database and model as conditions change in the watershed.

SRBC participated in several meetings with stakeholders to gather the information used to develop the database and model. More than 20 organizations, representing government, industry, and citizen groups, contributed data for the strategy.


S. Buda

Winter in the West Branch.

DESCRIPTION OF THE WEST BRANCH SUSQUEHANNA SUBBASIN

The West Branch Susquehanna Subbasin drains 6,978 square miles of all or portions of 22 counties: Blair, Bradford, Cambria, Cameron, Centre, Clearfield, Clinton, Columbia, Elk, Indiana, Jefferson, Huntingdon, Lycoming, McKean, Montour, Northumberland, Potter, Snyder, Sullivan, Tioga, Union, and Wyoming Counties. The larger developed areas include Bellefonte, Clearfield, Lewisburg, Lock Haven, Montoursville, Renovo, State College, Wellsboro, and Williamsport.

The West Branch Susquehanna Subbasin contains 17 major watersheds. Listed in order from headwaters to the confluence with the Susquehanna River, they include Chest Creek, Anderson Creek, Clearfield Creek, Moshannon Creek, Mosquito Creek, Sinnemahoning Creek, Kettle Creek, Young Woman's Creek, Bald Eagle Creek, Pine Creek, Larry's Creek, Lycoming Creek, Loyalsock Creek, Muncy Creek, White Deer Hole Creek, Buffalo Creek, and Chillisquaque Creek.

The subbasin is dominated by forested land (about 83 percent or ~5,800 square miles) (Figure 3). Agriculture accounts for about 10 percent (~700 square miles) of the subbasin. The remaining seven percent (~500 square miles) of land use is developed and disturbed lands, where most of the abandoned mine land (AML) impacts exist. Land use is primarily rural, containing more than 1.4 million acres

Appalachian Regional Reforestation Initiative (ARRI)

ARRI is a coalition of groups dedicated to restoring productive forests on coal mined lands in the Eastern United States. ARRI partners pledge to promote the three goals of the initiative: (1) planting more high-value hardwood trees on reclaimed surface mines in Appalachia; (2) increasing the survival rates and growth rates of trees planted; and (3) expediting the establishment of forest habitat through natural succession.

Research conducted by several leading universities has confirmed that highly productive forestland can be created on reclaimed mine lands when proper site preparation and tree species are used. ARRI advocates these techniques with a five-step reclamation process called the Forestry Reclamation Approach (FRA). The ARRI Team and other state and federal regulators have determined that all facets of the FRA comply with existing laws and regulations.

The five steps of the FRA are: (1) restoring a suitable rooting medium using topsoil and/or the best available material; (2) preventing or minimizing compaction of the top four feet of backfill material; (3) using vegetative species as ground cover compatible with growing trees; (4) planting early successional and commercially valuable tree species; and (5) using proper tree planting techniques.

P. Angel

Red oaks growing in an ARRI Forestry Reclamation Approach (FRA) research site in Kentucky.

Prior to being mined for coal, the majority of the land in Appalachia was forested. Coal mining activities have converted thousands of acres to other habitats, including crop land, pasture, and unmanaged wildlife areas. Decades of federal and state mining and reclamation regulations and practices have promoted site stability and erosion control by compacting the mine spoil, which is used to backfill pits and highwalls, and planting thick grasses and other vegetative species. These traditional reclamation methods have worked against the successful restoration of forest lands.

The West Branch Susquehanna Subbasin overlies significant deposits of bituminous coal and continues to be the subject of extensive coal mining activities. In the future, thousands of acres of land will either be newly mined, re-mined or reclaimed through Pennsylvania's Abandoned Mine Land Reclamation Program. This represents an enormous opportunity to help assure the return or restoration of these lands to productive forest use, with the associated benefits of a healthy and diverse wildlife habitat, improved stream quality and fish habitat, increased recreational and tourism opportunities, and provision of forest products.

ARRI Core Team members in Pennsylvania are David Hamilton of the Federal Office of Surface Mining, and Doug Saylor of the Pennsylvania Department of Environmental Protection. David can be reached at **dhamilton@osmre.gov**, (717) 782-4036. Doug can be reached at **lsaylor@state.pa.us**, (814) 342-8200. Contact your ARRI state representative for any questions or suggestions or visit ARRI's web site at **http://arri.osmre.gov** for further information.

David Hamilton, Program Specialist
Molly Sager, Program Specialist
Office of Surface Mining

of state forest land, more than 280,000 acres of state game lands, and nearly 28,000 acres of state park land.

The average annual precipitation is about 40 inches. The region is characterized by warm summers and long, cold winters. Temperatures change frequently and sometimes rapidly.

The headwaters of the West Branch Susquehanna River are located in West Carroll Township, near Carrolltown, Cambria County. This area lies within the Appalachian Plateau Physiographic Province. From its origins, the river flows north into Clearfield County, turns northeast to Renovo, Clinton County, then turns southeast to Lock Haven, Clinton County. At Lock Haven, the West Branch Susquehanna River cuts through the Allegheny Front and turns to the northeast to flow along the northern flank of Bald Eagle Mountain to Muncy, Lycoming County. At Muncy, the river turns south and flows toward its confluence with the Susquehanna River at Northumberland, Northumberland County. The total length of the West Branch Susquehanna River mainstem from headwaters to the confluence with the Susquehanna River is about 245 miles.

At an average slope of about 0.14 percent, the elevation of the river drops 1,800 feet from the headwaters to the confluence with the Susquehanna River.

Coal Geology of the West Branch Susquehanna Subbasin

About 60 percent (~4,200 square miles) of the subbasin is underlain by sandstone rock. The remaining 40 percent (~2,800 square miles) of the subbasin is underlain by inter-bedded sedimentary rock, which can include sandstone, shale, limestone, and coal.

Coal in the West Branch Susquehanna Subbasin is found in three geologic units: the Conemaugh, Allegheny, and Pottsville (Figure 4).

The Conemaugh Group is stratigraphically defined as the rocks located between the Upper Freeport Coal horizon (lower elevation) and the Pittsburgh Coal (Edmunds et al., 1998).

The Conemaugh is subdivided into a lower formation called the Glenshaw, and an upper formation called the Casselman. The division is made at the top of the Ames Marine Limestone. Economically mineable coals are uncommon in the Conemaugh Group; consequently, so are AMD-related issues.

The Brush Creek Coal, or Gallitzin Coal, of the Glenshaw Formation is mineable in portions of the southcentral and southeastern sections of the bituminous coal field; however, this availability is rare (Brady, Hornberger, and Fleeger, 1998). Only a few coals of the Casselman Formation are thick enough to mine economically, and they are mainly centered in the southern and western portions of Pennsylvania, outside of the West Branch Susquehanna Subbasin.

The Allegheny Group contains the majority of economically mineable coals found in the West Branch Susquehanna Subbasin; consequently, this group is the source of much of the AMD pollution affecting the subbasin.

The Allegheny Group contains seven important coal seams. These seams have been mined to some extent in the West Branch Susquehanna Subbasin, and continue to be mined today (Table 1). The seams include, from the deepest to shallowest, the Brookville, Clarion, Lower Kittanning, Middle Kittanning, Upper Kittanning, Lower Freeport, and the Upper Freeport (Figure 5) (Reese and Sisler, 1928).

Cambria and Clearfield Counties contain a majority of the total coal reserves found in the West Branch Susquehanna Subbasin, 5,300 and 3,920 million short tons, respectively (Table 1) (Dodge and Edmunds, 2003). Two other counties, Indiana and Jefferson, also contain large reserves; however, a majority of these two counties are not in the West Branch Susquehanna Subbasin.

Generally, more severe AMD is created by the Lower Kittanning, Middle Kittanning, and Clarion seams. While generally less severe and usually alkaline, AMD also originates from the Upper Kittanning, Upper Freeport, and Lower Freeport seams (Pennsylvania Department of Conservation and Natural Resources, 2007).

The Pottsville Formation contains only one important coal seam, the Mercer, which has been mined in areas of the West Branch Susquehanna Subbasin and can be very problematic in terms of AMD production. However, the Mercer coal exhibits lower recoverability than most other coal seams, making it less significant in terms of AMD production (Reese and Sisler, 1928).

Clay mining within the West Branch Susquehanna Subbasin is another source of AMD production, particularly relevant in the Clearfield Creek and Anderson Creek Watersheds.

Most of the AMD loading entering the West Branch Susquehanna Subbasin is from abandoned underground coal and clay mines.

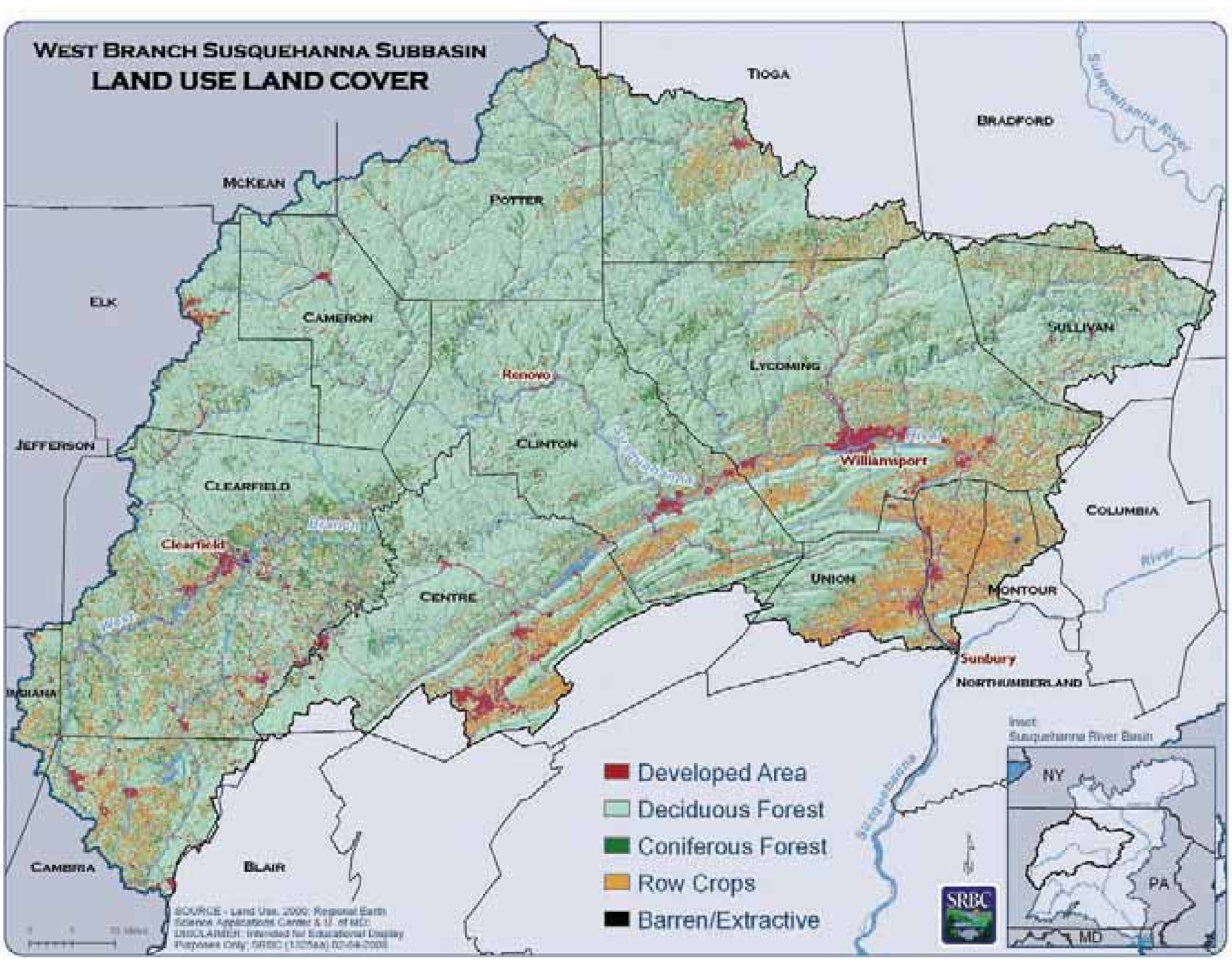
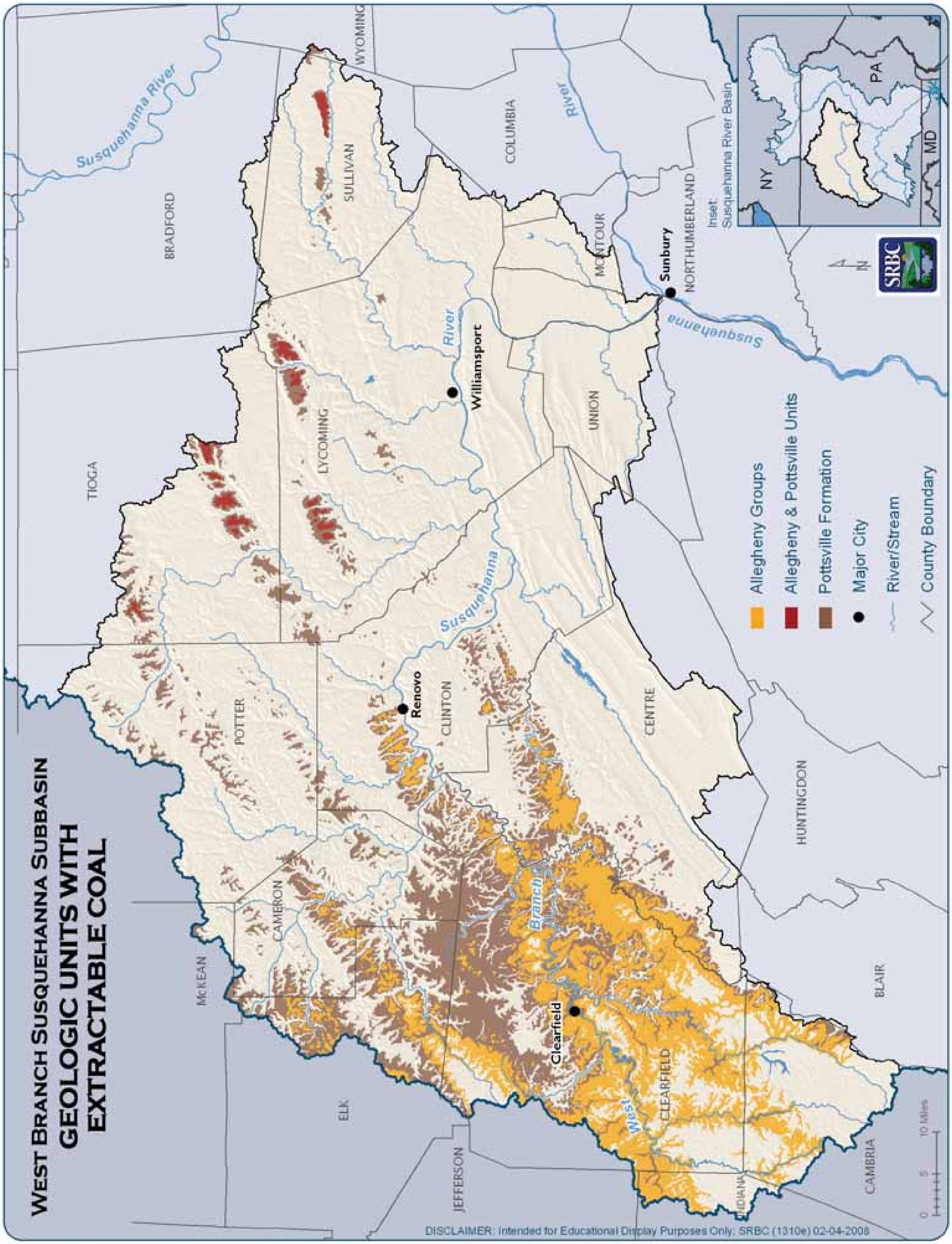


Figure 3. Land Use in the West Branch Susquehanna Subbasin.



J. Zimmerman

Figure 4. *Geologic Units with Extractable Coal in the West Branch Susquehanna Subbasin.*

History of Mining in the West Branch Susquehanna Subbasin

According to Captain Thomas Hutchins, 1760 is the earliest record of bituminous coal mining in Pennsylvania. At that time, a mine was opened on the Monongahela River opposite Fort Pitt, now Pittsburgh (Sisler, 1926).

In the West Branch Susquehanna Subbasin, historical records indicate that in November 1785, Samuel Boyd initiated the idea of furnishing coal to the eastern markets. He purchased a tract of land along the West Branch of the Susquehanna River about three miles upstream of Chincleclenoose, now the Borough of Clearfield (Sisler, 1926). Samuel's son, William, built an ark in 1803, and in the following spring, loaded this ark with coal and transported it 260 miles down the West Branch Susquehanna River and the Susquehanna River proper to Columbia, Pennsylvania (Sisler, 1926).

In 1813, P. A. Karthaus began mining coal at the mouth of "Little Moshannon Creek" and in 1828, he commenced sending coal to Philadelphia by way of Port Deposit, Maryland, through the Chesapeake and Delaware Canals (Sisler, 1926). Mr. Karthaus also sent coal to Baltimore using the Union Canal. This coal sold for 33 cents per bushel.

System	Unit	Member	Character of Member	Unit Description
PENNSYLVANIAN	CONEMAUGH	Lower Mohoning sandstone	Sandstone and sandy shale sometimes separated by thin lenses of coal. Red shale occurs - 40' above Upper Freeport.	Only the lower part of the unit is present – about 40'.
	ALLEGHENY	Upper Freeport coal	Widely persistent average thickness 3' to $3^1/_2$'.	A variable sequence of shale, sandstone, limestone, clay, and valuable beds of coal. Average thickness is about 300'.
		Lower Freeport coal	Variable, average 2' to $2^1/_2$' thick.	
		Freeport s.s.		
		Upper Kittanning coal	Thin, about 1' to $1^1/_2$' thick.	
		Middle Kittanning coal	About 3 seams present at this horizon. Usually 1' to $1^1/_2$' thick.	
		Lower Kittanning coal	Very persistent. Average thickness 2' to $2^1/_2$'.	
		Clarion coal	Thin, variable, about 1' thick.	
		Brookville coal	Thin, variable.	
	POTTSVILLE	Homewood s.s.	Massive s.s. often separated by shale.	Only the upper part of the formation is shown here – about 140'.
		Mercer coal	Variable, often several thin beds present at this horizon.	
		Mercer clay		

Figure 5. *A Stratigraphic Column of the Geologic Units Containing Mineable Seams of Coal.*

County	Coal Mined Out and Lost by 1998 Million Short Tons	Remaining Coal Reserves by 1998 Million Short Tons	Total Historic Coal Resource Million Short Tons	Portion of County in Subbasin Percent
Indiana	1,200	5,100	6,300	7.5
Cambria	1,700	3,600	5,300	40.7
Clearfield	820	3,100	3,920	90.6
Jefferson	510	2,800	3,310	0.2
Elk	120	430	550	32.7
Centre	180	330	510	72.5
McKean	1	420	421	2.5
Tioga	44	110	154	42.9
Clinton	49	65	114	100.0
Blair	39	40	79	0.6
Lycoming	17	55	72	99.1
Cameron	2	59	61	99.7
Bradford	21	23	44	2.0
Sullivan	27	8	35	82.9
Totals	**4,730**	**16,140**	**20,870**	

Table 1. *Estimated Bituminous and Anthracite In-Place Coal Resources by Counties within the West Branch Susquehanna Subbasin (Dodge and Edmunds, 2003).*

Pennsylvania Wilds Initiative and the West Branch

Restoration and conservation efforts over a century in the 12-county northcentral region called the Pennsylvania Wilds have helped shape the character of the people and the region, and have defined the region's legacy of natural resource abundance.

The region has some of the most wild and scenic areas east of the Rocky Mountains represented by:

- More than 1.3 million acres of state forest and 500,000 acres of national forest;
- 300,000 acres for hunting and wildlife on more than 50 state game lands;
- Twenty-seven state parks and hundreds of miles of recreational trails;
- Eight wild areas and 24 natural areas that cover about 150,000 acres;
- 16,000 miles of flowing water and three designated Pennsylvania Water Trails including the 228-mile West Branch;
- The largest elk herd in the northeast; and
- The darkest skies in the eastern U.S. at Cherry Springs State Park, Potter County.

When the unparalleled and diverse natural resource assets of the region and their potential were brought to the attention of Governor Edward G. Rendell back in 2001, the Pennsylvania Wilds initiative was launched as a strategic approach to protect and conserve these treasured natural resources, enhance visitor experiences, and revitalize communities in the region.

Today, the vision of the Pennsylvania Wilds initiative is to be well-known throughout the country as a region that offers authentic recreational experiences, interesting towns, hospitable hosts, and other heritage and cultural attractions in one of the most remote and beautiful settings in the northeast.

The degree of cooperation that is evident in joint funding from multiple state agencies, combined marketing efforts by tourist promotion agencies, proactive and collaborative planning by counties, and efforts to improve business development and support locally-made products is truly refreshing and a national model for how to work together to reap the benefits of nature tourism as an effective economic development strategy.

The West Branch Susquehanna Subbasin, which comprises 48 percent (~ 4,000 square miles) of the Pennsylvania Wilds, is a spectacular natural, scenic, and recreational resource for the region. Through this first-ever comprehensive cleanup plan to address mine drainage pollution on more than one thousand stream miles in the subbasin, we are continuing the region's legacy of restoration and stewardship, ensuring the quality and value of this splendid resource for generations to come.

Michael DiBerardinis, Secretary
Pennsylvania Department of Conservation and Natural Resources

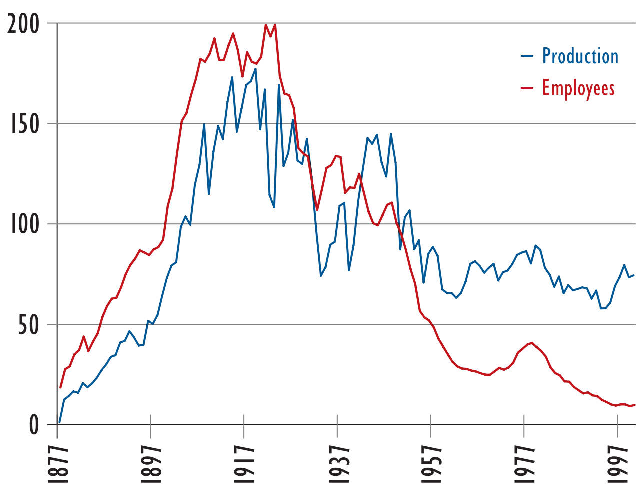


Figure 6. *Pennsylvania Coal Production in Millions of Tons and Number of Mining Employees in Thousands, from 1877 to 2000 (Pennsylvania Department of Environmental Protection, 2006).*

Coal demand in the Pennsylvania coal fields exploded due to the necessities of World War I and the reconstruction of Europe (Figure 6). For instance, the town of Windber in Somerset County was formed by the Berwind-White Coal Company in 1897. At its height in the mid-1900s, the population of Windber swelled to more than 12,000 people comprised mainly of an immigrant workforce (Clark, 2006). Annual coal production in Pennsylvania reached its zenith in 1918, when nearly 276.7 million short tons were mined—a record that stood until 1996, when Wyoming produced 278.4 million short tons (Dodge and Edmunds, 2003). Eventually, however, European countries began to meet their own production needs and coal prices fell as world demand for Appalachian coal declined. This event coincided with the onset of the Great Depression.

With America's entry into World War II, coal demand exploded again, and more extensively than the first boom surrounding World War I. Coal became a strategic mineral in winning the war since it was used to offset fuel needs due to gas shortages, particularly for home heating and transportation. Coal also fueled the steel mills that supplied the armaments industry.

Following World War II, Appalachian mining again declined, although not as abruptly as the earlier decline following World War I. The effects, however, were just as severe. Low coal prices caused company owners to use savings from the previous boom. Those companies not able to update mining equipment could not compete with the combination of increasing costs and mechanization. With the closing of many of the mines by 1970, people from areas like Windber migrated to other parts of the country where employment was stable. By the 2000 census, the population of Windber had dropped to 4,200 residents, one-third of its peak only several decades before (Clark, 2006).

Over time, advances in the coal extraction process through the use of technology allowed companies to increase or maintain production while decreasing their payrolls (Figure 6).

An increase in surface mining activity also contributed to this trend. In addition, regulatory requirements under Pennsylvania's Clean Streams Law and the Federal Surface Mining Control and Reclamation Act (SMCRA) in 1977 created additional costs that needed to be absorbed by coal companies. Coupling these new technologies and reclamation responsibilities with the dramatic decrease in the price of coal, many coal miners lost their jobs.

At present, both surface and deep mine operations are active throughout the West Branch Susquehanna Subbasin. Production has increased slightly in the last decade as energy demands have increased. In addition, electrical cogeneration plants can now utilize lower quality coal for energy production. This lower quality coal was commonly discarded as waste in refuse piles, commonly referred to as culm banks in eastern Pennsylvania or gob piles in western Pennsylvania.

The removal of waste coal and the remining of unreclaimed areas have improved water quality in many areas of the West Branch Susquehanna Subbasin—providing both economic and environmental benefits.

S. Buda

Impacted headwaters of the West Branch Susquehanna Subbasin in Cambria County.

PA Department of Environmental Protection

Tankers hauling alkaline material, which was dumped into Curwensville Lake following the Lancashire #15 (Barnes and Tucker) mine breakout in 1970.

What Exactly is AMD?

AMD is Pennsylvania's largest source of water impairment. Its actual chemical makeup encompasses a spectrum of possibilities, but typically is characterized by high levels of acids with the presence of dissolved metals, especially iron, aluminum, and manganese. Antiquated and unregulated mining practices of the past too often set up the circumstances for AMD's formation. A century's worth of extensive mining of Pennsylvania's rich coal reserves has made AMD ubiquitous in the coal regions.

At the root of AMD formation is the mineral pyrite, commonly and aptly called fool's gold for its yellow, lustrous appearance. Pyrite is comprised of the chemical elements sulfur and iron. Usually found in small percentages in coal seams and surrounding geologic strata, pyrite undergoes a natural chemical reaction similar to rusting when in contact with both water and oxygen. This reaction produces acidity, dissolved iron, and a dissolved ion called sulfate. The dissolved iron goes on to further combine with still more water and oxygen to produce a form of rust called iron hydroxide, with a distinctive rusty yellow to dark orange appearance. The acids can go on to dissolve other minerals, liberating other metals into the water. Clays, for example, are rich in the element aluminum, and result in dissolved aluminum when attacked by acids.

WPCAMR

Mining activities expose pyrite to water and the oxygen in air, which in turn promote the chain of pyrite reactions at levels thousands of times greater than would occur naturally, and for very long periods of time. If these reaction-products find their way to waterways, they deliver a one-two punch of acidity and dissolved metals to ecosystems ill-equipped to handle the onslaught. What results is a stream seriously compromised in its ability to sustain aquatic life and water not suitable for human use or consumption.

Bruce Golden, Regional Coordinator
Western Pennsylvania Coalition for Abandoned Mine Reclamation

AMD and AML Impacts on Human Health

When studying the impairment that AMD creates on waterways, the investigation almost always is on the impacts to fish and macroinvertebrates, not humans. However, AMD does have some human health implications that can be easily overlooked.

It has been documented through numerous studies how metals, including iron, may increase the occurrence of neurodegenerative disease through increases in oxidative stress in the brain and other mechanisms. However, the correlation between AMD metals in water and increases in neurodegenerative diseases is just beginning to be investigated.


PA Department of Environmental Protection

The Barnes and Watkins Coal Refuse Pile, which is in the process of being removed, will not only improve water quality, but should improve the health of the surrounding communities.

Abandoned Mine Lands can contain very dangerous structures such as highwalls and open shafts, which have contributed to past injuries and deaths. Another possible area of concern is airborne exposure to contaminants originating from coal waste piles contributing to toxicity and lung disease.

Brian Schwartz, MD
Geisinger's Environmental Health Institute

GEISINGER
HEALTH SYSTEM

Pennsylvania Coal – Fueling the Industrial Revolution

"Returns that have come to hand lead one to think that the United States has now acquired a position on a par with that of the first coal producing country in the world, having during the last year turned out a quantity equal to that of its former rival, Great Britain. By the returns received from the Secretary of Great Britain, it appears that the grand total of coal production in that country last year was 220,085,393 gross tons. At the same time the coal production of the United States last year was 188,108,012 net tons of bituminous coal and 54,034,224 gross tons of anthracite coal."

"It must be understood that the figures in regard to the anthracite production represent that of Pennsylvania alone, there being a small quantity produced in Colorado. At the same time there were produced in Pennsylvania 73,500,300 net tons of bituminous coal. It will thus be seen that the production of Pennsylvania more than equals that of all the other states, numbering perhaps twenty-six, combined. The next state in point of production last year was Illinois, with some 23,500,000 net tons."

Frederick E. Saward, New York Times, April 8, 1900

Previous Studies

The Pennsylvania Fish and Boat Commission (PFBC) first surveyed the West Branch Susquehanna River in 1931-1932 in Clearfield and Clinton Counties. The surveys found that AMD pollution in the river was so intense that fish could not survive (Sorenson, 1931 and 1932). Several tributaries to the river also were listed as polluted, including Cush Creek, Bear Run, Anderson Creek, Clearfield Creek, Millstone Run, Surveyor Run, Bald Hill Run, Moshannon Creek, and Saltlick Run (Sorenson, 1931). The survey also indicated that Sinnemahoning Creek, Cooks Run, and Kettle Creek were polluted by AMD (Sorenson, 1932).

The first recorded major fish kill on the river occurred in October 1957 in the vicinity of Williamsport, Lycoming County. The reports indicate that about 500,000 fish were killed due to a slug of acid created by heavy rains in the coal mining region of the West Branch Susquehanna Subbasin. Such an event would have normally been neutralized to an extent by Bald Eagle Creek, due to its high alkalinity concentration from limestone geology. The rain event, however, did not affect the Bald Eagle Watershed (Glover, 1957).

During these documented fish kills, the section of the West Branch Susquehanna River near Williamsport had a pH of 4.5 and elevated concentrations of sulfate and iron (Wilt, 1958). Periodic checks of pH in the river at Lock Haven during 1957 and 1958 also documented acidic conditions, with pH ranging from 4.2 to 4.8. For comparison, the pH of the river near Williamsport ranged from 6.2 to 6.8 under normal conditions. Periodic slugs of acid, and associated fish kills, occurred again in July 1958 (Roller, 1958), September 1960 (Drupieski, 1960), and October 1962 (Hempt, 1962). These acid slugs all occurred when heavy rains fell to the west, in the coal-bearing region of the watershed, without corresponding rain events in the neutralizing alkaline tributaries further east. The acid slugs typically had a pH ranging from 4.2 to 4.8, lasted for three to four days, and were recorded downstream as far as Lewisburg, Union County.

The Federal Water Pollution Control Administration, now the United States Environmental Protection Agency (USEPA), performed a mine drainage study of the entire Susquehanna River Basin from 1964 to 1967. The study found that the headwaters of the West Branch Susquehanna River were acidic until the confluence with Chest Creek in Clearfield County. The major sources of acidity were the active Barnes and Tucker pumped discharge from the Lancashire #20 mine, and tributaries Lesle Run and Fox Run. The river was found to be essentially neutral below Chest Creek to Anderson Creek with fish and other aquatic life present, although populations were considered below normal (Federal Water Pollution Control Administration, 1968).

The PFBC initiated a program of continual surveillance on the river in August 1968, to ascertain water quality conditions (Bradford, 1969). The Pennsylvania Department of Environmental Resources (now PADEP) noted a trend in water quality improvement in 1969 at Bower, Clearfield County, due to the Lancashire #20 mine discharge treatment project. In 1969, the PFBC began a sport fish stocking program in Curwensville Lake that was largely successful (Gwin, Dobson, and Foreman, 1972).

In 1972, Gwin, Dobson, and Foreman completed the West Branch Susquehanna River Mine Drainage Pollution Abatement Scarlift Project for PADEP under the authority of the Land and Water Conservation and Reclamation Act (Act 443). The goal of this project was to "establish as accurately as possible a basis for evaluating the conditions and events in the Watkins, Cambria County, area leading to the serious breakout of mine drainage during the summer of 1970, which caused major fish kills in Curwensville Lake and in the West Branch Susquehanna River below Clearfield" (Gwin, Dobson, and Foreman, 1972). This project focused on the West Branch Susquehanna River from its headwaters to Cherry Tree Borough, Indiana County.

> ***"The most impaired site was found at Karthaus, Clearfield County, downstream of the entry of Moshannon Creek, where pH ranged between 3.9 and 4.1...***
> ***(Hainly and Barker, 1993)."***

Additional Scarlift studies were completed on Alder Run, Anderson Creek, Babb Creek, Beech Creek, Bennett Branch Sinnemahoning Creek, Clearfield Creek, Dents Run, Kettle Creek, Loyalsock Creek, Moshannon Creek, Muddy Run (Clearfield Creek), and Philipsburg/Hawk Run and can be found digitally at www.amrclearinghouse.org, a website created and maintained by the Western Pennsylvania Coalition for Abandoned Mine Reclamation.

In 1984, the United States Geologic Survey (USGS) completed a study on the "Water Quality of the Upper West Branch Susquehanna River and Tributary Streams between Curwensville and Renovo" (Hainly and Barker, 1993). During baseflow conditions in May and July 1984, streamflow and water quality were measured at four sites on the West Branch Susquehanna River and near the mouths of 94 tributaries between the Boroughs of Curwensville and Renovo.

In general, the USGS found that Moshannon Creek, Sinnemahoning Creek, Clearfield Creek, and Kettle Creek were the largest tributary sources of acidity and total-recoverable iron to the river. During the May sampling, Moshannon Creek, Sinnemahoning Creek, and Clearfield Creek contributed 63 percent of the acidity loading to the West Branch Susquehanna River (Hainly and Barker, 1993). In addition, Moshannon Creek and Clearfield Creek were found to contribute a majority of the total-recoverable iron at 76 percent.

During the July sampling, Moshannon Creek, Kettle Creek, and Clearfield Creek contributed 60 percent of the acidity loading, while Moshannon Creek and Kettle Creek contributed 51 percent of the total-recoverable iron loading to the West Branch Susquehanna River (Hainly and Barker, 1993).

Along the mainstem of the West Branch Susquehanna River, the least impaired site was found at the most upstream station of the study at Curwensville, Clearfield County, where pH ranged between 5.4 to 6.5 and specific conductance ranged between 267 and 310 microsiemens per centimeter (µS/cm). The most impaired site was found at Karthaus, Clearfield County, downstream of the entry of Moshannon Creek, where pH ranged between 3.9 and 4.1 and specific conductance ranged from 330 and 610 µS/cm (Hainly and Barker, 1993).

More recently, in 1985, 1994, and 2002, SRBC completed West Branch Susquehanna Subbasin Surveys, which assessed water quality, habitat, and biology at sites (137 in 2002) throughout the West Branch Susquehanna Subbasin. The findings of the 1994 and 2002 surveys are addressed in detail in the Present Conditions section of this document.

Since the late 1990s and early 2000s, there have been numerous efforts to develop assessment and restoration plans focused on AMD problems in the West Branch Susquehanna Subbasin. A list of these watershed plans and their status can be found in Table 2. A majority of these plans have been completed using funding from the PADEP Growing Greener Program and/or the USEPA 319 Program. Consequently, most of the plans are currently being implemented through those same funding sources.

In 2004, SRBC, under contract with PADEP, began developing a draft West Branch Susquehanna River Total Maximum Daily Load (TMDL) identifying specific river segments requiring load reductions. The TMDL will be completed and submitted to the USEPA for approval before April 2009. Other watershed TMDLs completed in the West Branch Susquehanna Subbasin can be found in Table 3.

Plan	Watershed	County	Year Completed	Completed By	Completed For
West Branch Susquehanna River Headwaters AMD Assessment and Restoration Plan	West Branch Susquehanna River	Cambria	2002	Vapco Engineering	West Branch Susquehanna Rescue
West Branch Susquehanna River Headwaters AMD Assessment	West Branch Susquehanna River	Cambria	2006	Hedin Environmental	West Branch Susquehanna Rescue
Chest Creek Assessment and Restoration Plan	Chest Creek	Cambria, Clearfield	In Progress	Cambria County Conservation District	Chest Creek Watershed Alliance
Bear Run Restoration Plan	West Branch Susquehanna River	Indiana, Clearfield	2006	Indiana County Conservation District	Indiana County Conservation District
Clearfield Creek Watershed Assessment Phase I and II	Clearfield Creek	Cambria, Clearfield	2004	Melius and Hockenberry Environmental Services Inc.	Clearfield Creek Watershed Association
Morgan Run Assessment and Restoration Plan	Clearfield Creek	Clearfield	2006	New Miles of Blue Stream	Clearfield Conservation District, Morgan Run Watershed Group
Restoration Plan for Little Laurel Run, Cambria County, PA	Clearfield Creek	Cambria	2005	Arthur W. Rose	Clearfield Creek Watershed Association
Anderson Creek Watershed Assessment, Restoration, and Implementation Plan	Anderson Creek	Clearfield	2006	Western Pennsylvania Conservancy	Anderson Creek Watershed Association
Hartshorn Run Assessment	West Branch Susquehanna River	Clearfield	In Progress	Clearfield County Conservation District	Clearfield County Conservation District
Montgomery Creek 319 Watershed Implementation Plan	West Branch Susquehanna River	Clearfield	In Progress	Clearfield County Conservation District, Montgomery Creek Watershed Association	Clearfield County Conservation District, Montgomery Creek Watershed Association
Lick Run Cold Water Assessment and Restoration Plan	West Branch Susquehanna River	Clearfield	2005	Allegheny Mountain Chapter of Trout Unlimited	Allegheny Mountain Chapter of Trout Unlimited
Deer Creek Assessment	West Branch Susquehanna River	Clearfield	In Progress	Clearfield County Conservation District	Clearfield County Conservation District, Deer Creek Watershed Association
Moravian Run Assessment	West Branch Susquehanna River	Clearfield	In Progress	Clearfield County Conservation District	Clearfield County Conservation District
Upper Alder Run Assessment	West Branch Susquehanna River	Clearfield	In Progress	Alder Run Engineering Inc.	West Branch Sportsman's Association
Hubler Run Implementation Plan	West Branch Susquehanna River	Clearfield	2007	Alder Run Engineering Inc.	West Branch Sportsman's Association
Emigh Run Assessment and Restoration Plan	Moshannon Creek	Clearfield	2004	New Miles of Blue Stream	Emigh Run Lakeside Watershed Association
Trout Run Assessment and Restoration Plan	Moshannon Creek	Centre	2006	New Miles of Blue Stream	Moshannon Creek Watershed Coalition
Headwaters of Moshannon Creek Assessment	Moshannon Creek	Clearfield, Centre	In Progress	New Miles of Blue Stream	Moshannon Creek Watershed Coalition
Shimel Run Restoration Plan	Moshannon Creek	Centre	In Progress	New Miles of Blue Stream	Moshannon Creek Watershed Coalition
Moshannon Creek Water Quality Data Clearinghouse	Moshannon Creek	Clearfield, Centre	2006	New Miles of Blue Stream	Moshannon Creek Watershed Coalition
Moshannon Creek Cold Water Assessment and Restoration Plan	Moshannon Creek	Clearfield, Centre	In Progress	Clearfield County Conservation District	Clearfield County Conservation District
Bennett Branch Watershed Assessment and Restoration Plan	Bennett Branch Sinnemahoning Creek	Clearfield, Elk, Cameron	2003	Gannett Fleming Inc.	Bennett Branch Watershed Association
Dents Run Watershed Ecosystem Restoration	Bennett Branch Sinnemahoning Creek	Elk	2001	U.S. Army Corps of Engineers	Bennett Branch Watershed Association
Sterling Run Assessment and Restoration Plan	Driftwood Branch Sinnemahoning Creek	Cameron	2004	Gannett Fleming Inc.	Cameron County Conservation District

Table 2. *AMD-Focused Watershed Restoration Plans in the West Branch Susquehanna Subbasin from Upstream to Downstream.*

Plan	Watershed	County	Year Completed	Completed By	Completed For
Lower Kettle Creek Restoration Plan	Kettle Creek	Clinton	2000	Hedin Environmental	Kettle Creek Watershed Association, Trout Unlimited
West Side of Lower Kettle Creek AMD Remediation Master Plan	Kettle Creek	Clinton	2007	Hedin Environmental	Kettle Creek Watershed Association, Trout Unlimited
Huling Branch Mine Complex: Investigation of AMD and Recommendations for Remediation	Kettle Creek	Clinton	2004	Hedin Environmental	Kettle Creek Watershed Association, Trout Unlimited
Twomile Run Watershed AMD Remediation Master Plan	Kettle Creek	Clinton	2007	Hedin Environmental	Kettle Creek Watershed Association, Trout Unlimited
Rapid Watershed AMD Assessment for Sandy Run, Woodley Draft, and Stony Run	Drury Run	Clinton	2006	Hedin Environmental	Western PA Coalition for Abandoned Mine Reclamation
Loop Run Restoration Plan	West Branch Susquehanna River	Clinton	2004	New Miles of Blue Stream	Rocky Mountain Elk Foundation
Tangascootack Creek Watershed Assessment	West Branch Susquehanna River	Clinton	1998	PADEP Moshannon District Mining Office	Clinton County Conservation District
Acid Mine Drainage Restoration Plan for the Beech Creek Watershed	Beech Creek	Clinton, Centre	2006	Hedin Environmental	Beech Creek Watershed Association
Jonathon Run Restoration Plan	Beech Creek	Centre	2003	Hedin Environmental	Beech Creek Watershed Association
Jonathon Run Site Evaluation	Beech Creek	Centre	2006	GAI Consultants	Penn DOT
Contrary Run and Butts Run Assessment	Beech Creek	Centre	2004	Bucek & Associates	Beech Creek Watershed Association
Lycoming Acidification Assessment	Lycoming Creek	Lycoming	2007	Hedin Environmental	Lycoming Creek Watershed Association

Table 2. *continued*

TMDLs and the West Branch Susquehanna Subbasin

A Total Maximum Daily Load (TMDL) is the maximum amount of any pollutant that a waterbody can receive and still meet state water quality standards. Water quality standards are set to protect and maintain aquatic uses such as drinking, fishing, swimming, irrigation, and others. The Clean Water Act requires states to list all waters that do not meet their water quality standards, as well as the source and cause of the pollution.

A TMDL is a "pollution budget" that calculates the amount of the specific pollutant a stream or river can assimilate without violating the standard identified. It also characterizes the sources of pollution on a watershed basis, considering seasonal factors and environmental uncertainty, and provides a plan for use in improving and protecting water quality. Many TMDLs are implemented through the use of best management practices to prevent or remediate pollution.

The Clean Water Act requires states to submit their TMDLs to U.S. Environmental Protection Agency for approval. A complete list of TMDLs completed in the West Branch Susquehanna Subbasin by 2007 can be found in Table 3. A continuously updated list can be found at **www.dep.state.pa.us/watermanagement_apps/tmdl**.

A completed TMDL prioritizes a stream or watershed for state and federal funding, with the goal of achieving water quality standards and removing the stream from the state's list of polluted waters.

Jennifer Orr, TMDL Program Biologist
Pennsylvania Department of Environmental Protection

WATERSHED	TRIBUTARY	CAUSE	STATUS
Anderson Creek	Mainstem	Metals / pH	Approved
	Kratzer Run	Metals	Approved
	Little Anderson Creek	Metals	Approved
Beech Creek	South Fork Beech Creek	Metals / pH	Under Development
	Logway Run	Metals	Approved
	Middle Branch Big Run	Metals / pH	Approved
	North Fork Beech Creek	Metals / Other Organics	Approved
Chest Creek	Rock Run	Metals	Under Development
	North Camp Run	Metals / Other Organics	Approved
Clearfield Creek	Blue Run	Metals	Approved
	Brubaker Run	Metals / pH / Other Organics	Approved
	Mainstem	Metals	Approved
	Little Muddy Run	Metals / pH	Approved
	North Branch	Metals	Approved
	Upper Morgan Run		
	Sanborn Run	Metals / pH / Other Organics	Approved
Kettle Creek	Mainstem	Metals	Approved
	Twomile Run	Metals / pH	Approved
Loyalsock Creek	Mainstem	Metals	Approved
Moshannon Creek	Cold Stream	Metals / pH	Approved
	Laurel Run	Metals / pH	Approved
	Moshannon Creek	Metals / Siltation	Under Development
Mosquito Creek	Grimes Run	Metals	Approved
	Curleys Run	Metals	Approved
Pine Creek	Babb Creek	Metals	Approved
	Wilson Creek	Metals	Approved
	Otter Run	Metals	Approved
	Right Fork Otter Run	Metals / pH	Approved
Sinnemahoning Creek	Dents Run	pH	Approved
	Spring Run	Metals / pH / Other Organics	Approved
	UNT 24679 to Trout Run	Metals / pH	Approved
	West Creek	Metals / pH	Approved
	Bennett Branch	Metals / pH / Siltation	Under Development
	Sinnemahoning Creek	Metals	Under Development
West Branch Susquehanna River	Mainstem	Metals	Under Development
	Bear Run	Metals	Approved
	Hartshorn Run	Metals / pH / Other Organics	Approved
	Montgomery Creek	Metals	Approved
	Moose Creek	Metals	Approved
	UNT 26641	pH	Approved
	Alder Run	Metals	Approved
	Deer Creek	Metals	Approved
	Lick Run	Metals / pH	Approved
	Big Run	pH	Approved
	Surveyor Run	Metals / pH	Approved
	Little Surveyor Run	Metals / pH	Approved
	Sandy Creek	Metals / Other Organics	Approved
	Trout Run		
	UNT 26041 to Trout Run	Metals / pH	Approved
	UNT 26053 to Pine Run	Metals / pH	Approved
	Cooks Run	Metals / Siltation / pH	Approved
	Camp Run	Metals	Approved
	Crowley Hollow	Metals	Approved
	Rock Run	Metals	Approved
	Cow Hole Run	Metals	Approved
	Drury Run	Metals / pH	Approved
	Milligan Run	Metals	Approved
	Tangascootack Creek	Metals / pH	Approved
	Birch Island Run	Metals / pH	Approved
	Little Birch Island Run	Metals	Approved
	Sterling Run	Metals	Approved

Table 3. *AMD TMDL Efforts Within the West Branch Susquehanna Subbasin.*

Present Conditions

In 2005, the Task Force completed the West Branch Susquehanna River State of the Watershed Report. In the report, the Task Force, citing data from SRBC's West Branch Susquehanna Subbasin Surveys of 1994 and 2002, concluded that water quality degradation is the main reason for impairment of aquatic life throughout most of the West Branch Susquehanna Subbasin, whereas the physical stream habitat is in relatively good condition (West Branch Susquehanna River Task Force, 2005). Of all the impaired stream miles in the subbasin, 1,205 miles are degraded by AMD. This represents 66 percent of the total AMD-impaired mileage in the entire Susquehanna River Basin. In addition, 42,062 acres of unreclaimed AML features, or nearly 23 percent of the entire Commonwealth's share, are found within the West Branch Susquehanna Subbasin. Nearly 6,462 of those acres are considered Priority I or II Health and Safety Problem sites, as designated by the U.S. Office of Surface Mining (OSM).

> ***"Two main stretches of the West Branch Susquehanna River are significantly influenced by AMD: the headwaters in Cambria County to about the town of Mahaffey, Clearfield County, and from the entry of Clearfield Creek to Williamsport, Lycoming County."***

This impairment causes massive losses in recreational uses and significantly impacts the economic potential of the region. In addition, PADEP BAMR has estimated that water quality restoration of the entire West Branch Susquehanna Subbasin will require capital costs ranging from $279 million to $464 million, with annual operation and maintenance costs ranging from $22 million to $55 million (West Branch Susquehanna River Task Force, 2005). Reclamation of all AML features is estimated at an additional $288 million (Pennsylvania Department of Environmental Protection, 2004).

S. Buda

AMD precipitate on Kettle Creek.

In 2003, SRBC published its West Branch Susquehanna Subbasin Survey, which was conducted between July and November 2002. This effort was similar to surveys completed for the West Branch Susquehanna Subbasin in 1985 and 1994. The study indicated only slight improvement in conditions between 1994 and 2002. Of the sections of the West Branch Susquehanna Subbasin studied, AMD degradation was documented in the headwaters region, as well as along the mainstem of the West Branch Susquehanna River from Clearfield Creek in Clearfield County, to Pine Creek in Lycoming County (LeFevre, 2003). Degraded watersheds included Muddy Run (Clearfield Creek Watershed), Clearfield Creek, Moshannon Creek, Beech Creek (Bald Eagle Creek Watershed), Twomile Run (Kettle Creek Watershed), Dents Run (Bennett Branch Sinnemahoning Creek Watershed), Cooks Run, Alder Run, Bear Run, Deer Creek, Little Anderson Creek (Anderson Creek Watershed), and Montgomery Run. The highest quality watersheds documented included Pine Creek, First Fork Sinnemahoning Creek, Driftwood Branch Sinnemahoning Creek, Young Women's Creek, Hyner Run, Paddy Run, Lick Run, and White Deer Creek.

In 1994, 47 percent of the sites sampled by SRBC were either classified as moderately or severely impaired in terms of water quality. The percentage of impaired sites decreased to 43 percent in 2002. In addition, of the eight sites that showed significant changes from 1994 to 2002, six were improved. Additionally, most of the sites in the West Branch Susquehanna Subbasin were classified as having excellent or supporting habitat; 91 percent in 1994 and 88 percent in 2002 (LeFevre, 2003).

During 2004 and 2005, streamflow and water quality data were collected at 33 locations along the mainstem of the West Branch Susquehanna River for the development of a TMDL assessment for metals pollution, specifically related to iron, aluminum, and manganese. This dataset represents the most recent source of information describing present water quality conditions along the West Branch Susquehanna River.

Two main stretches of the West Branch Susquehanna River are significantly influenced by AMD: the headwaters in Cambria County to about the town of Mahaffey, Clearfield County, and from the entry of Clearfield Creek to Williamsport,

The Babb Creek Watershed: An AMD Restoration Success Story

When the cleanup of the Babb Creek Watershed was started in 1990, more than 13 miles of the mainstem and parts or all of four tributaries were severely polluted due to AMD. The cleanup effort started with the installation of two limestone diversion wells on Lick Creek, near the village of Arnot, Tioga County.

Over the next 15 years, 2 more limestone diversion wells, 15 vertical flow ponds, 3 limestone cells, 1 anoxic limestone drain, and a treatment plant were constructed on AMD discharges within the watershed.

In 2005, the Pennsylvania Fish and Boat Commission did an intensive survey of the mainstem and found large numbers of fish and aquatic insects in the previously dead section. Naturally reproducing brook and brown trout were also found in the section upstream from the village of Morris. Due to these results, more than eight miles of the mainstem were reclassified by the Commission as a “wild trout stream” in July 2006.

After being polluted with AMD for more than 100 years, Babb Creek is again a productive stream.

William Beacom, President
Babb Creek Watershed Association

The late Bob McCullough, past president of the Babb Creek Watershed Association, stocking trout into Babb Creek for the first time in 100 years due to the restoration of AMD impacts.

Lycoming County. In between those sections, the river is still impaired, but in a state of recovery both in terms of water quality and biological communities.

In terms of net alkalinity concentration for the 33 TMDL sites, the West Branch Susquehanna River is net acidic from the vicinity of Carrolltown and Bakerton, Cambria County (River Mile (RM) 241.8), to just upstream of the town of Northern Cambria, Cambria County (RM 237.8). The remaining sections of the river are net alkaline, although just slightly along certain reaches. From the entry of Moshannon Creek (RM 132.6) to the entry of Pine Creek (RM 55.6), the net alkalinity is consistently below 20 mg/l, which is within the range that PFBC considers acid sensitive. Acid sensitive stretches account for about 88 river miles of the West Branch Susquehanna River, or nearly 36 percent of the total mileage.

In terms of total iron concentration for the 33 TMDL sites, the West Branch Susquehanna River exceeds the 1.50 mg/l water quality standard (Table 4) from the extreme headwaters of the West Branch Susquehanna River in Cambria County (RM 242.8) to just downstream of Cherry Tree, Indiana County (RM 228.4), and from the town of Karthaus, Clearfield County (RM 132.6), to downstream of the entry of Kettle Creek in Clinton County (RM 97.7). This represents about 49 river miles not meeting the designated water quality standard for iron, or slightly more than 20 percent of the total West Branch Susquehanna River mileage.

In terms of total aluminum for the 33 TMDL sites, the West Branch Susquehanna River exceeds the 0.75 mg/l water quality standard (Table 4) from the very extreme headwaters of the West Branch Susquehanna River near Carrolltown, Cambria County (RM 243.4), to downstream of the entry of Pine Creek in Jersey Shore, Lycoming County (RM 55.6). This represents about 188 river miles not meeting the designated water quality standard for aluminum, or nearly 77 percent of the total West Branch Susquehanna River mileage.

In terms of water quality trends throughout the West Branch Susquehanna Subbasin, most areas have seen a significant improvement in the last two decades (Table 5). For instance, at the town of Keating in Clinton County, the West Branch Susquehanna River has increased nearly three pH units, while iron and aluminum concentrations have dropped 38 and 81 percent, respectively. The pH at the mouth of Clearfield Creek has increased two and one-half pH units, while iron and aluminum concentrations have dropped approximately 46 and 79 percent, respectively. Moshannon Creek is an exception, with pH remaining fairly constant and aluminum concentrations increasing approximately 94 percent.

Parameter	Criterion Value (mg/l)	Total Recoverable/Dissolved
Aluminum (Al)	0.75	Total Recoverable
Iron (Fe)	1.50	30-Day Average Total Recoverable
	0.30	Dissolved
Manganese (Mn)	1.00	Total Recoverable
pH*	6.0-9.0	NA

**The pH values shown will be used when applicable. In the case of freestone streams with little or no buffering capacity, the TMDL endpoint for pH will be the natural background water quality. These values are typically as low as 5.4 (Pennsylvania Fish and Boat Commission).*

***Table 4.** Applicable Water Quality Criteria (Commonwealth of Pennsylvania, 2005).*

WEST BRANCH SUSQUEHANNA RIVER STATIONS

Location	Sample Year	Collection Agency	pH SU	Total Fe mg/l	Total Al mg/l
Curwensville, Clearfield County	1984	USGS	6.0	0.4	0.2
	1994	SRBC	7.7	0.1	0.3
	2004/2005	SRBC	7.3	0.4	1.1
Karthaus, Clearfield County	1984	USGS	4.0	1.3	2.4
	1994	SRBC	3.8	0.7	2.9
	2004/2005	SRBC	6.6	2.0	1.3
Keating, Clinton County	1984	USGS	4.1	0.8	2.1
	1994	SRBC	4.1	0.1	1.0
	2002	SRBC	7.0	0.5	0.4
Renovo, Clinton County	1984	USGS	4.2	0.5	1.5
	1994	SRBC	4.7	0.2	1.0
	2004/2005	SRBC	6.6	0.5	1.4

MAJOR TRIBUTARY STATIONS

Location	Sample Year	Collection Agency	pH SU	Total Fe mg/l	Total Al mg/l
Anderson Creek	1984	USGS	4.4	0.6	1.5
	1994	SRBC	5.1	0.4	0.9
	2004/2005	WPC	6.0	0.3	0.5
Clearfield Creek	1984	USGS	4.9	2.6	2.4
	1994	SRBC	4.6	0.2	2.0
	2003/2004	SRBC	6.4	1.4	0.5
Moshannon Creek	1984	USGS	3.5	3.8	3.5
	1994	SRBC	3.4	2.9	5.5
	2002	SRBC	3.3	1.0	6.8
Mosquito Creek	1984	USGS	4.8	0.3	0.4
	1994	SRBC	6.2	0.1	1.2
	2002	SRBC	5.4	<0.1	<0.1
Sinnemahoning Creek	1984	USGS	6.3	0.3	0.3
	1994	SRBC	6.0	0.1	0.1
	2002	SRBC	7.2	<0.1	<0.1
Kettle Creek	1984	USGS	5.1	1.5	1.3
	1994	SRBC	6.4	0.2	0.3
	2001	TU	6.8	0.4	0.6

***Table 5.** Water Quality Trends Over the Last Two Decades at Four Sites Along the West Branch Susquehanna River and at the Mouths of Six Major AMD Impacted Tributaries.*

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.

Continued on page 22

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.*

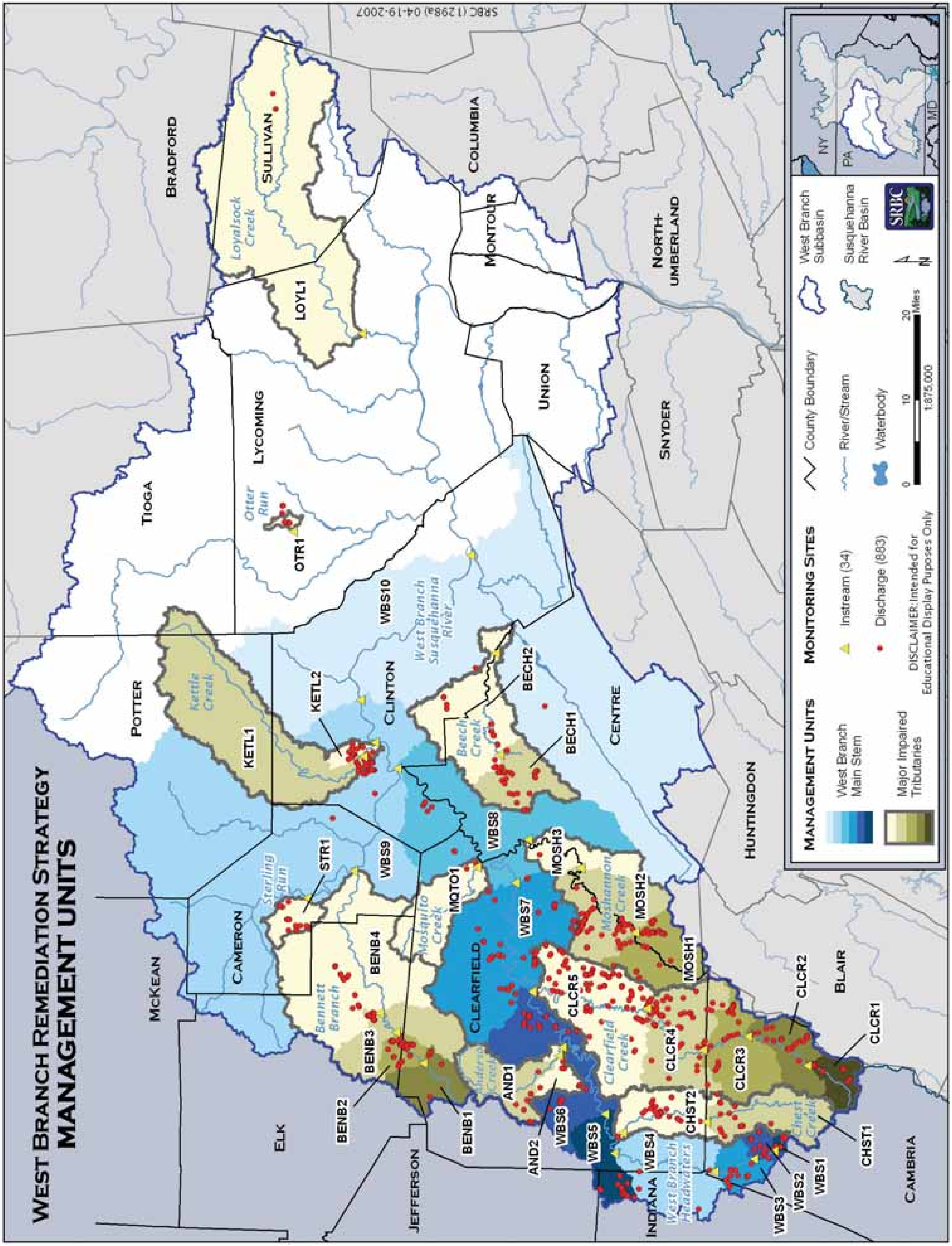


Figure 7. *The 34 MUs of the West Branch Susquehanna Subbasin, the 788 Analytical Criteria Discharges, and the 34 MU Endpoint Water Quality Stations.*

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 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
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.

SRBC

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.

Mark Killar, Watershed Manager, Freshwater Conservation Program
Western Pennsylvania Conservancy

Thomas Clark, Abandoned Mine Drainage Project Coordinator
Susquehanna River Basin Commission

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).

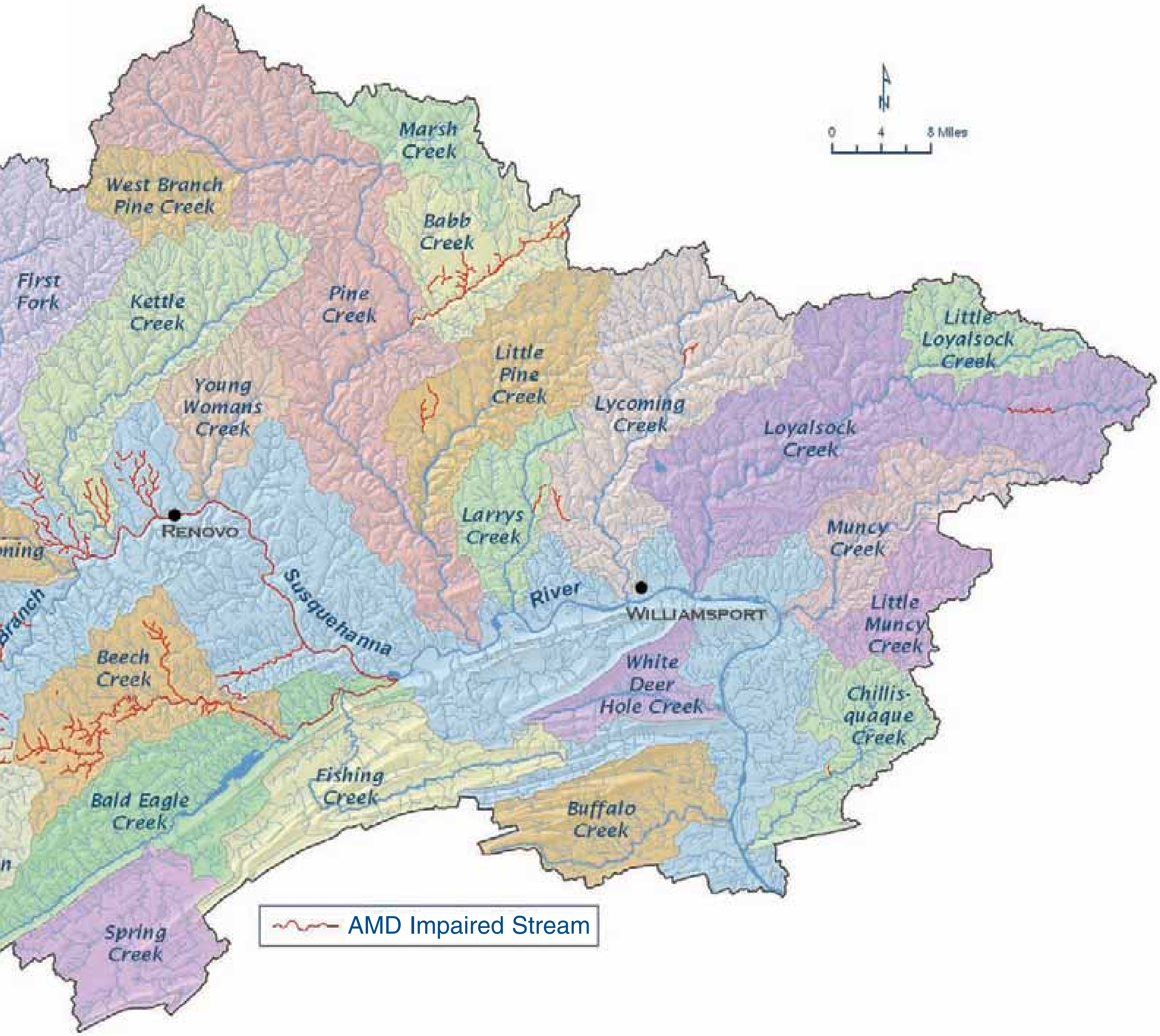
Encompasses 2,190 square miles of public forest lands – 67 percent of the forest lands in the Susquehanna basin (PA Bureau of Forestry and NYSDEC).

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

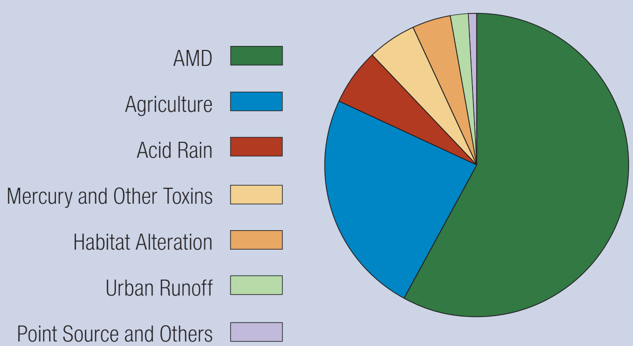
A. Wolfe

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

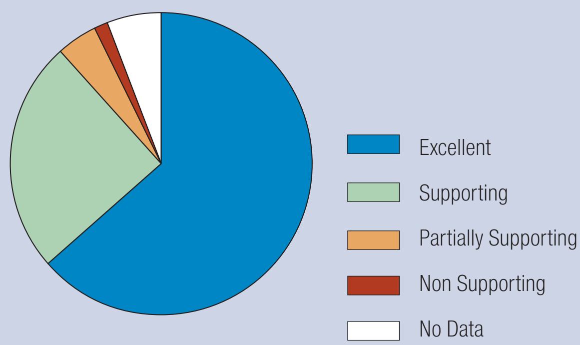
ANCH SUSQUEHANNA SUBBASIN



West Branch Subbasin Impairments



West Branch Instream Habitat Classifications



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

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.

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

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.*

Clearfield Creek MUs

The Clearfield Creek Watershed was divided into five separate MUs due to the severe impairment found within this West Branch Susquehanna River tributary. CLCR1 captures from the entry of Beaverdam Run, near the town of Ashville, Cambria County, to the headwaters of Clearfield Creek. CLCR2 represents conditions from Frugality, Cambria County, to Beaverdam Run near Ashville and includes Brubaker Run, the largest acid source to Clearfield Creek. CLCR3 captures from Turner Run to Frugality and includes Powell Run, a major AMD input to Clearfield Creek. CLCR4 includes from just downstream of the Muddy Run confluence, possibly the largest overall AMD input to Clearfield Creek, to Turner Run. CLCR5 captures from the mouth of Clearfield Creek to Muddy Run. The water quality endpoints for each MU are found in Table 13. Three of the five MU endpoints have at least two parameters that exceed 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
CLCR1	CLCR 13	2003-2004	17,320	7.0	1.5	0.2	1.0
CLCR2	CLCR 10	2003-2004	51,955	6.6	2.5	2.0	1.3
CLCR3	CLCR 08	2003-2004	91,042	7.1	1.2	1.2	0.8
CLCR4	CLCR 04	2003-2004	163,527	6.9	1.8	1.6	0.6
CLCR5	CLCR 01	2003-2004	235,819	7.1	1.4	1.9	0.7

Table 13. *Clearfield Creek MU Endpoint Average Water Quality.*


M. Smith

The wilderness and AMD-impacted character of Clearfield Creek.

Moshannon Creek MUs

The Moshannon Creek Watershed was divided into three separate MUs due to the severe impairment found within this West Branch Susquehanna River tributary. MOSH1 captures from State Highway 970 in Osceola Mills, Clearfield County, to the headwaters of Moshannon Creek, which includes several highly AMD-impaired areas. MOSH2 represents conditions from just upstream of Six Mile Run, about six miles downstream of Philipsburg, Centre County, to State Highway 970 in Osceola Mills. MOSH2 is the most AMD-impaired area in the entire West Branch Susquehanna Subbasin. MOSH3 captures from the mouth of Moshannon Creek to the entry of Six Mile Run. The water quality endpoints for each MU are found in Table 14. Each MU endpoint has at least three parameters that exceed the water quality standard for 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
MOSH1	MOSH 39.9	2002	12,445	3.6	4.1	6.2	4.4
MOSH2	MOSH 19.1	2002	24,805	3.3	4.4	5.8	6.4
MOSH3	MOSH 5.1	2002	42,048	3.3	1.0	6.2	6.8

Table 14. *Moshannon Creek MU Endpoint Average Water Quality.*


M. Smith

The confluence of "Red" Moshannon Creek with the West Branch Susquehanna River.

> **"MOSH2 is the most AMD-impaired area in the entire West Branch Susquehanna Subbasin."**

Mosquito Creek MU

Due to minor AMD impairment on Mosquito Creek (primary cause of impairment on Mosquito Creek is acid deposition), the entire subbasin was represented as one MU, MQTO1. The water quality endpoint for this MU is found in Table 15 and exceeds the water quality standard for pH.

MU	MU Endpoint Station	Year(s) Sampled	Flow GPM	pH Lab	Total Fe mg/l	Total Mn mg/l	Total Al mg/l
MQTO1	MQTO 1.0	2002	3,340	5.4	<0.01	0.1	<0.01

Table 15. *Mosquito Creek MU Endpoint Average Water Quality.*

Bennett Branch Sinnemahoning MUs

Due to major AMD impairment, the Bennett Branch Sinnemahoning Creek was divided into four separate MUs. BENB1 captures everything from the entry of Moose Run to the headwaters of the Bennett Branch, which includes AMD-impaired Moose Run and Bark Camp Run. BENB2 includes from just downstream of Cherry Run's confluence with the Bennett Branch to Moose Run, one of the more AMD-impacted areas in the entire West Branch Susquehanna Subbasin. BENB3 captures from Caledonia Run, a major AMD input, to just downstream of Cherry Run. BENB4 represents conditions from the Bennett Branch's confluence with the Driftwood Branch to Caledonia Run, and includes the major AMD input of Dents Run. The water quality endpoints for each MU are found in Table 16. Each MU endpoint has at least one parameter that exceeds a 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
BENB1	BBSC 4.0	2003-2004	40,623	4.3	0.4	0.8	0.2
BENB2	BBSC 3.0	2003-2004	64,619	6.0	2.0	0.1	1.2
BENB3	BBSC 2.0	2003-2004	85,144	5.2	0.5	5.5	0.4
BENB4	BBSC 1.0	2003-2004	327,572	4.7	0.1	2.0	0.2

Table 16. *Bennett Branch MU Endpoint Average Water Quality.*

Sterling Run (Driftwood Branch) MU

Due to Sterling Run's small size (less than 25 square miles), all impacts were represented by one MU, STR1. Despite its small size, Sterling Run does impact the Driftwood Branch Sinnemahoning Creek with AMD loading. The water quality endpoint for this MU is found in Table 17 and exceeds the water quality standard for pH.

MU	MU Endpoint Station	Year(s) Sampled	Flow GPM	pH Lab	Total Fe mg/l	Total Mn mg/l	Total Al mg/l
STR1	STR 1	2003	36,944	5.7	0.6	0.3	0.6

Table 17. *Sterling Run MU Endpoint Average Water Quality.*

Kettle Creek MUs

For a majority of its length, Kettle Creek is a high quality watershed with several stretches either classified as EV, or as HQ-CWF. However, Kettle Creek is impaired by AMD near its confluence with the West Branch Susquehanna River. These impacts are mainly located within the Twomile Run Watershed and just upstream of its confluence with the mainstem of Kettle Creek. Consequently, Kettle Creek was divided into two separate MUs. KETL1 captures all impacts upstream of Twomile Run, and KETL2 captures Twomile Run and adjacent impacts. The water quality endpoints for each MU are found in Table 18 and both are within the water quality standard of each parameter.

MU	MU Endpoint Station	Year(s) Sampled	Flow GPM	pH Lab	Total Fe mg/l	Total Mn mg/l	Total Al mg/l
KETL1	KCPS 5	2002	93,671	6.7	0.2	0.1	0.2
KETL2	KETL 01	2001	100,987	6.8	0.4	0.5	0.6

Table 18. *Kettle Creek MU Endpoint Average Water Quality.*

S. Buda

Tri-colored substrate in Kettle Creek downstream of Twomile Run confluence.

Beech Creek MUs

Beech Creek is the last major AMD-impaired subbasin that impacts the West Branch Susquehanna River. Beech Creek has been divided into two separate MUs that capture the two major areas of AMD impacts: the headwaters (BECH1), and within and adjacent to the Big Run Watershed (BECH2). The water quality endpoints for each MU are found in Table 19. Each MU endpoint has at least three parameters that exceed the 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
BECH1	90	2004	29,277	4.2	4.0	2.6	1.8
BECH2	25	2004	118,639	4.6	0.4	2.0	1.1

Table 19. *Beech Creek MU Endpoint Average Water Quality.*

Otter Run (Little Pine Creek) MU

With Babb Creek almost completely restored from AMD impacts, Otter Run represents the only other area of impairment in the Pine Creek Watershed. Otter Run is a small tributary of Little Pine Creek, and is captured by one MU. The water quality endpoint for this MU is found in Table 20 and exceeds the water quality standard for manganese.

MU	MU Endpoint Station	Year(s) Sampled	Flow GPM	pH Lab	Total Fe mg/l	Total Mn mg/l	Total Al mg/l
OTR1	BR 01	1999	2,148	6.2	0.3	2.6	0.5

Table 20. *Otter Run MU Endpoint Average Water Quality.*

Loyalsock Creek MU

Water quality conditions in the Loyalsock Creek Watershed are generally very good, and represent some of the best conditions in the West Branch Susquehanna River Subbasin. However, there are certain areas affected by AMD. The entire Loyalsock Creek Watershed is captured by one MU. The water quality endpoint for this MU is found in Table 21, and shows the stream meets water quality standards.

MU	MU Endpoint Station	Year(s) Sampled	Flow GPM	pH Lab	Total Fe mg/l	Total Mn mg/l	Total Al mg/l
LYOL1	WQN 408	1962 - 1998	313,594	6.6	0.1	<0.1	0.1

Table 21. *Loyalsock Creek MU Endpoint Average Water Quality.*


S. Buda

Loyalsock Creek near Forksville, Sullivan County.

Other Areas of AMD Impairment

Small tributaries entering the West Branch Susquehanna River between Anderson Creek and Bald Eagle Creek (contained within the WBS6 - WBS10 MUs) should also be given special attention, although these streams do not contain adequate discharge and/or instream sampling coverage to constitute a separate MU (Table 22). The limited data available indicates that all but one of these tributaries contain at least one parameter that does not meet water quality standards. Additionally, mainstem tributairies such as Milligan Run and Alder Run exhibit some of the highest concentrations of metals found in streams within the entire West Branch Susquehanna Subbasin.

Minor areas of AMD impairment can be found in other West Branch Susquehanna Subbasins not designated as separate MUs as well, including Larry's Creek and Lycoming Creek. However, acid deposition impacts these subbasins more than AMD. In addition, there are still some tributaries to Babb Creek that are impacted by AMD, even though the watershed is considered to be generally restored.

Stream	Dates	MU	Area mi²	Flow GPM	pH Lab	Fe mg/l	Mn mg/l	Al mg/l
Hartshorn Run	2002-2003	WBS6	4.6	2,187	5.6	<0.30	0.28	<0.50
Montgomery Creek	2001-2002	WBS6	16.5	13,465	4.3	0.28	6.11	2.47
Moose Creek	2003	WBS6	12.3	7,464	5.4	<0.30	1.44	1.08
Lick Run	2002-2003	WBS7	27.5	18,885	5.8	0.27	0.71	0.46
Trout Run	2002	WBS7	41.7	1,665	4.9	0.08	0.25	0.34
Millstone Run	Unknown	WBS7	1.4	nd	5.0	<0.30	3.00	<0.50
Surveyor Run	2002	WBS7	5.8	3,778	3.9	0.73	6.04	6.66
Bald Hill Run	2002	WBS7	2.7	1,799	5.3	1.22	6.11	0.69
Moravian Run	2002	WBS7	18.5	7,810	5.3	1.19	0.72	0.32
Deer Creek	2002-2003	WBS7	23.5	15,978	5.1	2.62	3.20	1.55
Big Run	2002-2003	WBS7	3.1	2,168	6.6	14.30	0.60	nd
Sandy Creek	2002	WBS7	17.3	10,209	4.6	2.15	5.12	1.83
Alder Run	2002-2004	WBS7	24.0	14,403	3.2	21.42	6.72	11.34
Rolling Stone Run	2002	WBS8	1.7	1,043	5.8	7.18	0.57	7.98
Saltlick Run	2003	WBS8	4.9	4,889	7.6	2.62	5.17	2.45
Sterling Run	2003	WBS8	15.7	20,348	5.0	0.30	0.40	0.50
Birch Island Run	2002	WBS8	15.3	9,266	5.1	0.30	0.20	0.50
Cooks Run	2000-2001	WBS9	26.0	7,774	3.4	6.90	1.48	5.64
Milligan Run	2000-2001	WBS9	1.35	485	2.7	13.18	8.12	19.44
Drury Run	2002	WBS9	11.5	534	4.7	0.05	1.00	0.85
Tangascootack Creek	2002	WBS10	36.5	1,279	6.3	0.03	1.00	0.04

Table 22. *West Branch Susquehanna River Tributaries Entering Between the Entrance of Anderson Creek and Bald Eagle Creek Contained Within WBS6 – WBS10.*

Management Unit Analysis

The 34 MUs captured discharges with predicted available loading reductions of 102,964 lbs/day of acidity, 21,065 lbs/day of iron, and 6,991 lbs/day of aluminum.

The first analyses were completed on AMD-loading yields (lbs/day/area). Figure 9 illustrates that concentrated acidity loading is located primarily in MUs WBS1, WBS2, CLCR1, CLCR4, MOSH1, MOSH2, BENB2, and KETL2, and to a lesser extent in MUs CLCR2, CLCR5, and BENB1.

Figure 10 illustrates that concentrated iron loadings are located primarily in MUs WBS2, CLCR4, MOSH2, BENB2, and KETL2, and to a lesser extent in MUs WBS1, CLCR1, MOSH1, and BENB1.

Figure 11 illustrates that concentrated aluminum-loading areas are located primarily in MUs WBS2, CLCR1, MOSH1, MOSH2, BENB2, and KETL2, and to a lesser extent in MUs WBS1 and CLCR4.

Upon completion of the final analyses, 11 MUs (the 10 top ranked tributary MUs and one West Branch Susquehanna River mainstem MU), covering only 10 percent of the West Branch Susquehanna Subbasin, contain available loading reductions of more than 79 percent for acidity (81,474 lbs/day), nearly 84 percent for iron (17,691 lbs/day), and nearly 78 percent for aluminum (5,418 lbs/day) (Table 23). The remaining 23 MUs, covering 56 percent of the West Branch Susquehanna Subbasin, only comprise available loading reductions of 20 percent for acidity (21,490 lbs/day), 16 percent for iron (3,374 lbs/day), and 23 percent for aluminum (1,573 lbs/day).

However, seven of those remaining 23 MUs (WBS7, WBS9, AND1, CLCR3, BENB3, BENB4, and BECH1), covering nearly 21 percent of the West Branch Susquehanna Subbasin, still contribute significant AMD loading to the West Branch Susquehanna River Subbasin. These seven MUs contain additional available loading reductions of 10 percent for acidity, nearly 13 percent for iron, and more than 17 percent for aluminum.

As shown in Table 23, 8 of the 11 priority MUs are located in only three watersheds of the West Branch Susquehanna Subbasin: Moshannon Creek, Clearfield Creek, and Bennett Branch Sinnemahoning Creek. These three watersheds alone contain more than 69 percent of the available acidity loading, more than 76 percent of the available iron loading, and more than 68 percent of the available aluminum loading.

MU	Acid Load lbs/day	Percentage %	Fe Load lbs/day	Percentage %	Al Load lbs/day	Percentage %
CLCR1	4,943	4.80	622	2.95	457	6.54
CLCR2	2,737	2.66	460	2.18	176	2.52
CLCR4	13,123	12.75	3,049	14.47	749	10.71
CLCR5	8,060	7.83	1,111	5.27	482	6.89
MOSH1	10,381	10.08	694	3.29	905	12.95
MOSH2	19,862	19.29	8,163	38.75	1,069	15.29
BENB1	3,067	2.98	905	4.30	189	2.70
BENB2	9,200	8.94	1,112	5.28	729	10.43
KETL2	3,661	3.56	453	2.15	302	4.32
BECH2	3,577	3.47	587	2.79	164	2.35
WBS2	2,863	2.78	535	2.54	196	2.80
Predicted Reductions	**81,474**	**79.13**	**17,691**	**83.98**	**5,418**	**77.50**
Remaining 23 MUs	**21,490**	**20.87**	**3,374**	**16.02**	**1,573**	**22.50**

Table 23. *The Eleven MUs, Covering only Ten Percent of the West Branch Susquehanna Subbasin, that Contain Nearly 80 Percent of the AMD Loading.*

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

Of the 1,964 total discharges located in the database, 558 discharges (more than 28 percent) are within one-quarter mile of a Priority I and II site. A majority of these discharges (70 percent) are located in the Clearfield Creek and Bennett Branch Sinnemahoning Creek Watersheds, and along the mainstem of the West Branch Susquehanna River. Water quality loads were not calculated for these discharges since 345 of the 558 within one-quarter mile of a Priority I or II site, or nearly 62 percent, do not meet the analytical criteria.

Of the 788 discharges meeting the analytical criteria, 213 (27 percent) are within one-quarter mile of a Priority I and II site. These 213 discharges contribute 14,535 gallons per minute (gpm) of flow, with predicted available loading reductions of 31,453 lbs/day of acidity, 3,279 lbs/day iron, and 2,410 lbs/day of aluminum.

A majority of the analytical criteria discharge flow and loading located within one-quarter mile of a Priority I or II site are found in only five of the 34 MUs. CLCR4, MOSH1, AND1, BENB2, and BENB3 contain 66 percent of the flow, 81 percent of the acidity loading, 87 percent of the iron loading, and 81 percent of

MU	Watershed	Flow GPM	Percent %	Acid Load lbs/day	Percent %	Fe Load lbs/day	Percent %	Al Load lbs/day	Percent %
CLCR4	Clearfield Creek	3,265	22.5	9,745	31.0	1,857	56.6	598	24.8
MOSH1	Moshannon Creek	2,072	14.3	8,599	27.3	575	17.5	757	31.4
BENB2	Bennett Branch	3,440	23.7	4,572	14.5	172	5.2	383	15.9
AND1	Anderson Creek	447	3.1	1,458	4.6	164	5.0	130	5.4
BENB3	Bennett Branch	381	2.6	1,077	3.4	76	2.3	77	3.2
	Total	**9,605**	**66.1**	**25,451**	**80.9**	**2,844**	**86.7**	**1,945**	**80.7**
	Remaining 29 MUs	**4,930**	**33.9**	**6,002**	**19.1**	**435**	**13.3**	**465**	**19.3**

Table 24. *The Five MUs Containing the Majority of the Analytical Criteria Discharge Flow and Loading Within One-Quarter Mile from a Priority I or II Site.*

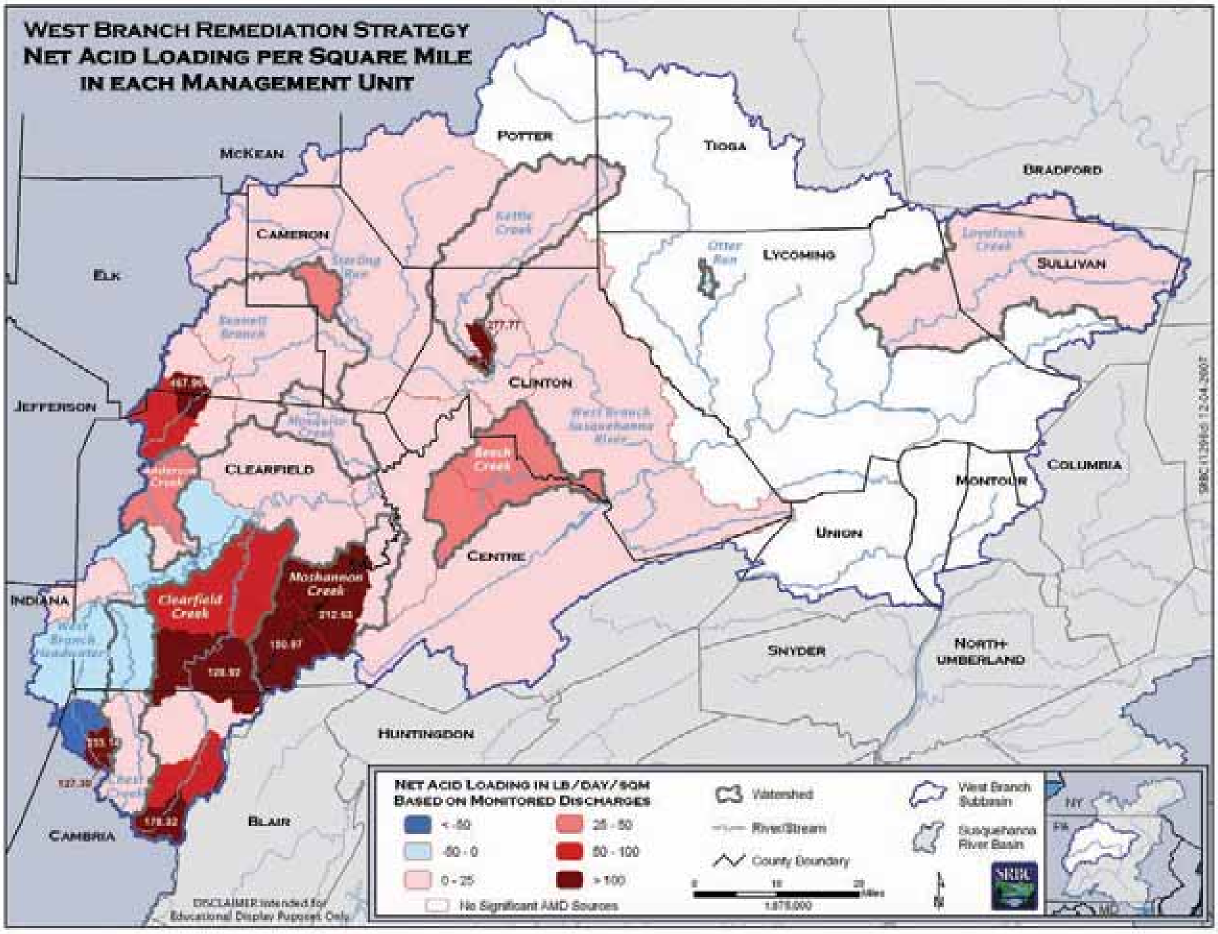


Figure 9. Acid Loading Yield in Each West Branch Susquehanna Subbasin MU.

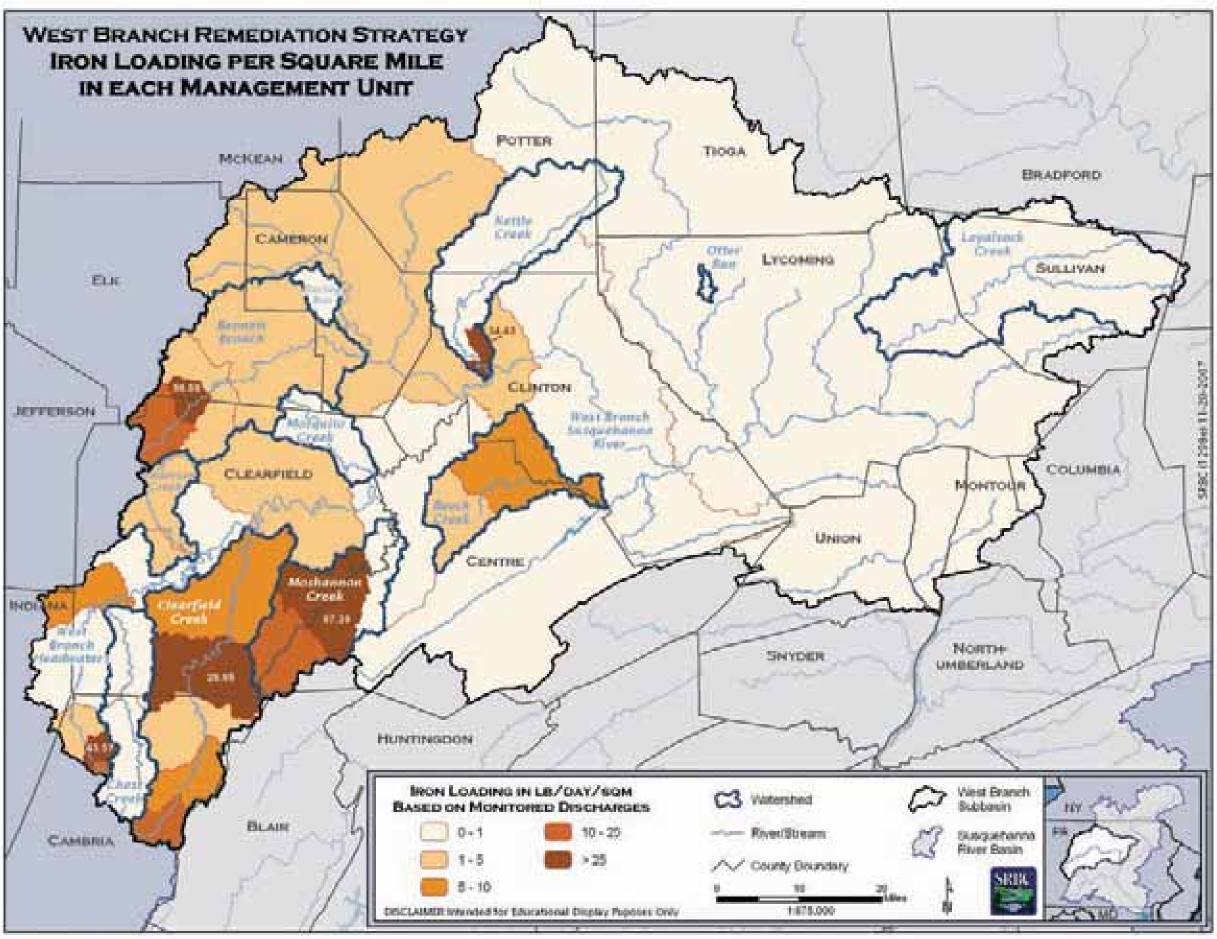


Figure 10. Iron Loading Yield in Each West Branch Susquehanna Subbasin MU.

J. Zimmerman

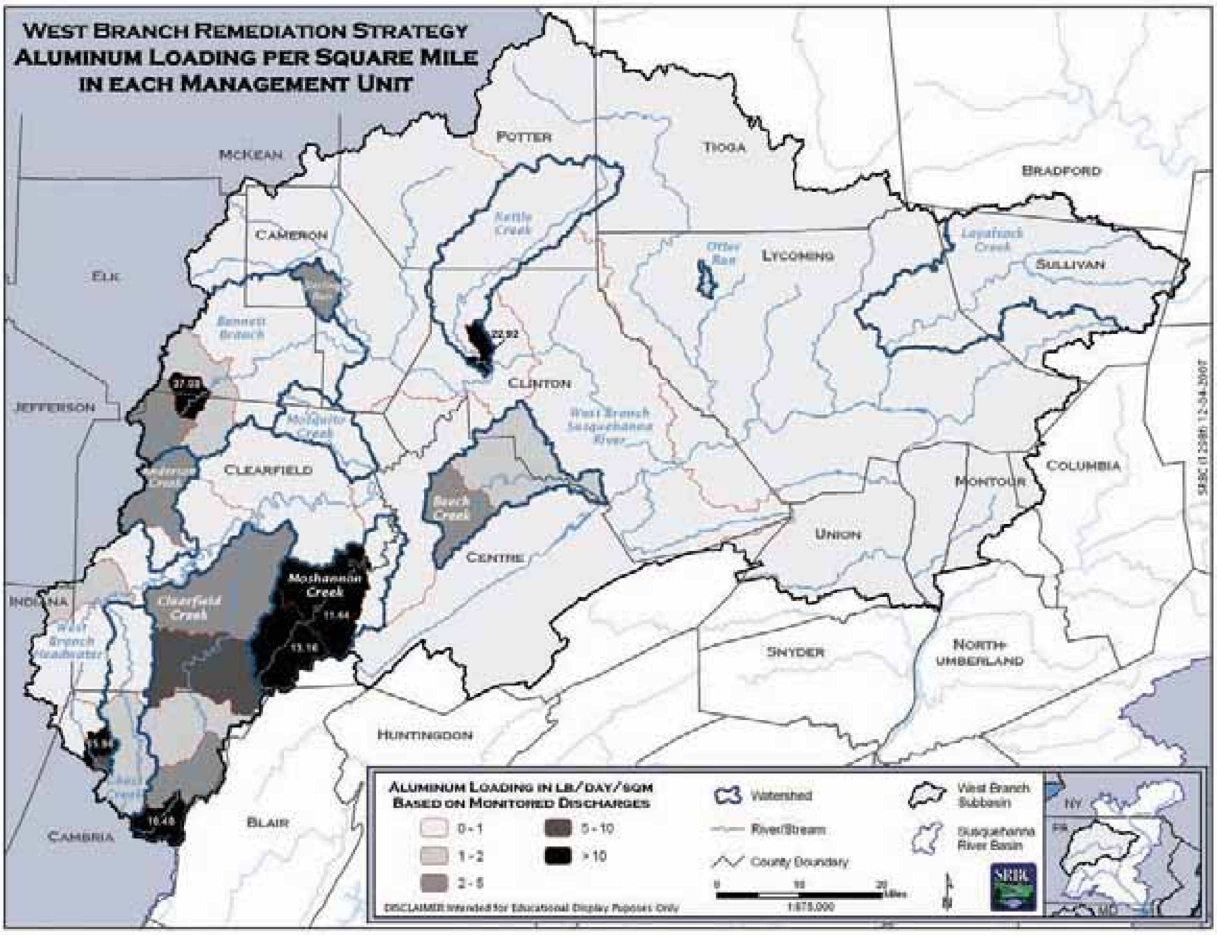


Figure 11. *Aluminum Loading Yield in Each West Branch Susquehanna Subbasin MU.*

the aluminum loading within one-quarter mile of a Priority I or II site (Table 24).

The potential exists for three other MUs to improve with Priority I and II site restoration, since a majority of their analytical criteria discharges are within one-quarter mile of a Priority I or II site (Table 25). However, the possible improvement of these three MUs through AML reclamation would not improve the West Branch Susquehanna Subbasin substantially since these MUs do not impact the subbasin with a high percentage of AMD loading.

MU	Watershed	% Total MU Discharge Acid Load Within One-Quarter Mile Mile of PI or PII	% Total MU Discharge Fe Load Within One-Quarter Mile Mile of PI or PII	% Total MU Discharge AL Load Within One-Quarter Mile Mile of PI or PII
CHST1	Chest Creek	74	90	80
CHST2	Chest Creek	100	51	70
WBS6	West Branch	83	100	83

Table 25. *Three West Branch MUs with a Majority of Their Analytical Criteria Discharges Within One-Quarter Mile of a Priority I or II Site.*

The percent land coverage of Priority I and II Health and Safety Problem Sites in each MU can be found in Figure 12.

In addition, total AML coverage (Priority I, II, and III sites) is generally concentrated in the same areas as the AMD loading (Table 7). The Clearfield Creek, Moshannon Creek, and Bennett Branch Sinnemahoning Creek Watersheds contain 51 percent of the total AML acreage in the entire West Branch Susquehanna Subbasin. The 11 priority MUs in Table 22, which cover only 10 percent of the West Branch Susquehanna Subbasin, contain 46 percent of the AML acreage.

M. Smith

Hazardous highwall in the West Branch Susquehanna Subbasin.

J. Zimmerman

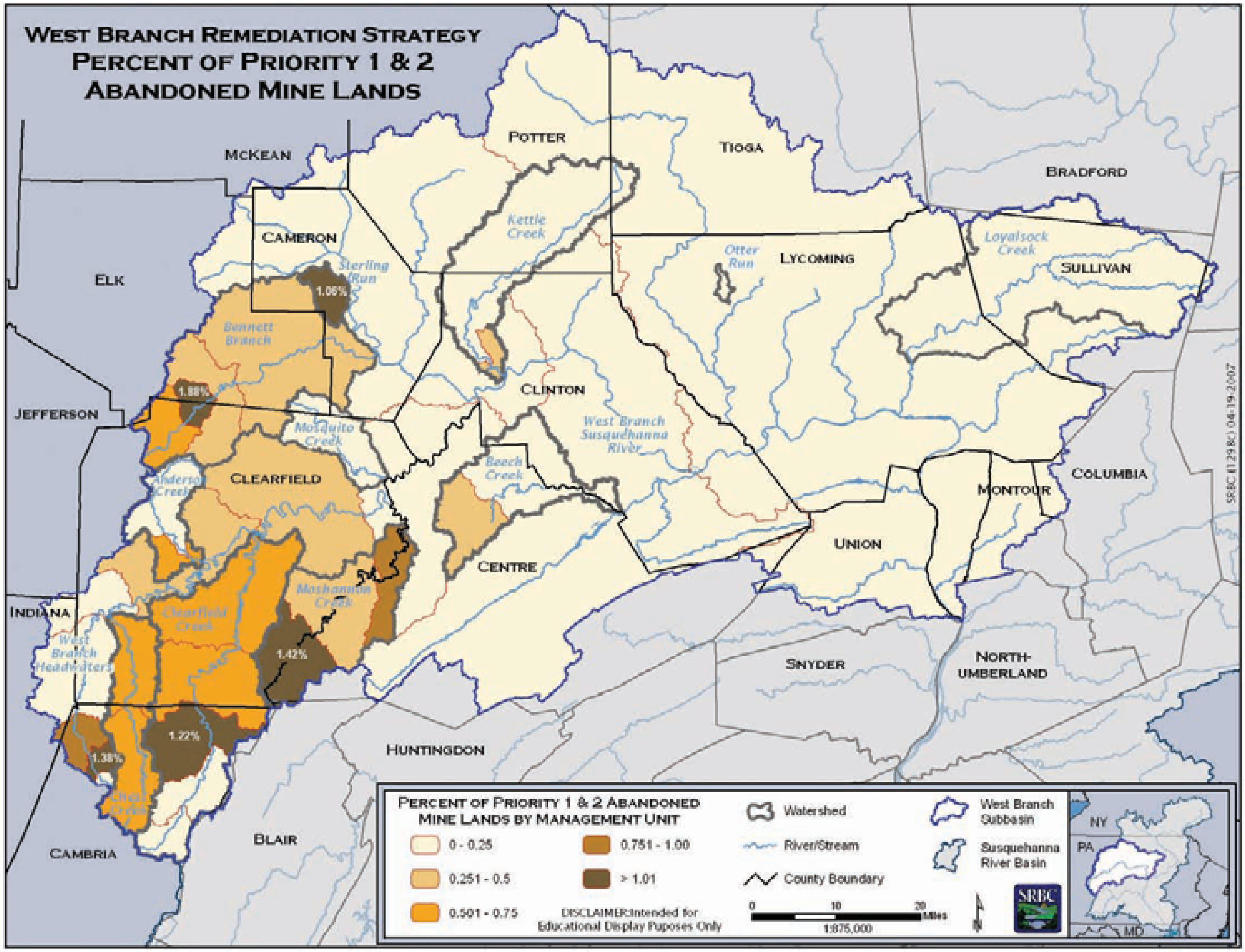


Figure 12. *Percent Land Coverage of Priority I and II Health and Safety Problem Sites in Each West Branch Susquehanna Subbasin MU.*

Pennsylvania Wilds Initiative and the West Branch

Remining is the extraction of remaining coal reserves from previously mined areas through surface mining methods. When an area is remined, it must be reclaimed to current environmental standards and completed in such a way that abandoned mine drainage from previously mined areas will be abated wherever possible. Because the mining of remaining coal reserves pays for the cost of remining, the resulting reclamation is done at no cost to the taxpayer and without spending any of the Abandoned Mine Land Fund.

Remining will be an important component of any strategy to restore the West Branch Susquehanna Subbasin. Since 2000, remining permits and contracts issued by the Pennsylvania Department of Environmental Protection provided for the reclamation of approximately 2,700 acres of abandoned surface mines, and the elimination of 38 miles of abandoned highwall. The estimated value of this reclamation, if it were publicly funded, is nearly $17 million.

What does this reclamation equate to in terms of water quality improvement? Simply eliminating abandoned pits and regrading and revegetation of the surface can markedly decrease flows of water into acid bearing rock. Eliminating underground mine voids and using lime in backfills are also effective at reducing AMD loads. A recent study of more than 100 remining sites in Pennsylvania showed that, on average, remining operations reduced acidity loading by 61 percent, iron loading by 35 percent, and aluminum loading by 43 percent (Smith et. al., 2002).

In another example, recent studies by Hedin Environmental (2007) in the lower Kettle Creek Watershed have shown that contaminated baseflow contributes 30-50 percent of the pollution loads to the Twomile Run Watershed. As a result, reliance upon only conventional "collect and treat" methods of the point source discharges would not lead to successful stream recovery. Reclamation through remining must be part of the overall remediation strategy as it is the only way to effectively address the contaminated baseflow.

Michael Smith, District Mining Manager
Pennsylvania Department of Environmental Protection

Amy Wolfe, Abandoned
Mine Programs Director
Trout Unlimited

Analysis of Wild Trout Streams Impaired by AMD or Acid Deposition

Upon analysis, 48 focus watersheds in the West Branch Susquehanna Subbasin are documented by PFBC as having, at a minimum, sections with Wild Trout designation and sections documented by PADEP as being impaired by AMD or acid deposition. These 48 focus watersheds contain nearly 634 miles of Wild Trout classification, nearly 99 miles of Class A designations, and nearly 55 miles of Wilderness Trout designations. However, PADEP has also listed these 48 focus watersheds as impaired due to AMD (438 miles) and/or acid deposition (89 miles). The 48 focus watersheds cover nearly 1,540 square miles (22 percent) of the West Branch Susquehanna Subbasin. The location of these watersheds and their EBTJV Brook Trout Population Status classification can be found in Figure 13.

It is important to note that 24 of these 48 focus watersheds (50 percent) are located between Anderson Creek and Sinnemahoning Creek, generally considered the most impaired section of the West Branch Susquehanna River. Biological recolonizers are already present in these streams. Restoration of AMD and/or acid deposition impairment could promote biological reconnection with the West Branch Susquehanna River mainstem.

In addition, 29 of these 48 focus watersheds (60 percent) are located in the PA WILDS section of the West Branch Susquehanna Subbasin. Many of these streams may be located within public lands, which may allow restoration to occur more easily in order to promote recreation.

According to the EBTJV Brook Trout Population Status classifications, brook trout have been extirpated in 6.5 percent of the West Branch Susquehanna Subbasin. Only 3.7 percent of the subbasin is classified as containing a large/strong population, with 29.5 percent and 54.7 percent of the subbasin classified as containing depressed and severely depressed populations, respectively. The remaining 5.6 percent is either classified as containing only qualitative presence of brook trout populations or no data.

Hypothetical Examples for West Branch Susquehanna River Subbasin Remediation

The results using the approach outlined in this document targeted the largest AMD sources in the West Branch Susquehanna River Subbasin. The examples represent only one set of potential options for water quality restoration. As described in the methods section, the examples included the West Branch Susquehanna River Headwaters, select MUs within the major contributing tributaries, and the Clearfield Creek Watershed.

The analysis of treatment costs only considered active or passive technology applied to discharges meeting the analytical criteria. The projected costs for the Barnes and Watkins Coal Refuse Removal Project and the Lancashire #15 (Barnes and Tucker) Active AMD Treatment Plant were provided by PADEP BAMR. Land reclamation and remining that would lead to possible water quality improvements were not considered in the cost estimates. Treatment costs displayed are not intended to represent costs for complete West Branch Susquehanna Subbasin restoration, since there are data gaps for parts of the subbasin.

> *"Only 3.7 percent of the subbasin is classified as containing a large/strong population [of trout], with 29.5 percent and 54.7 percent of the subbasin classified as containing depressed and severely depressed populations, respectively."*

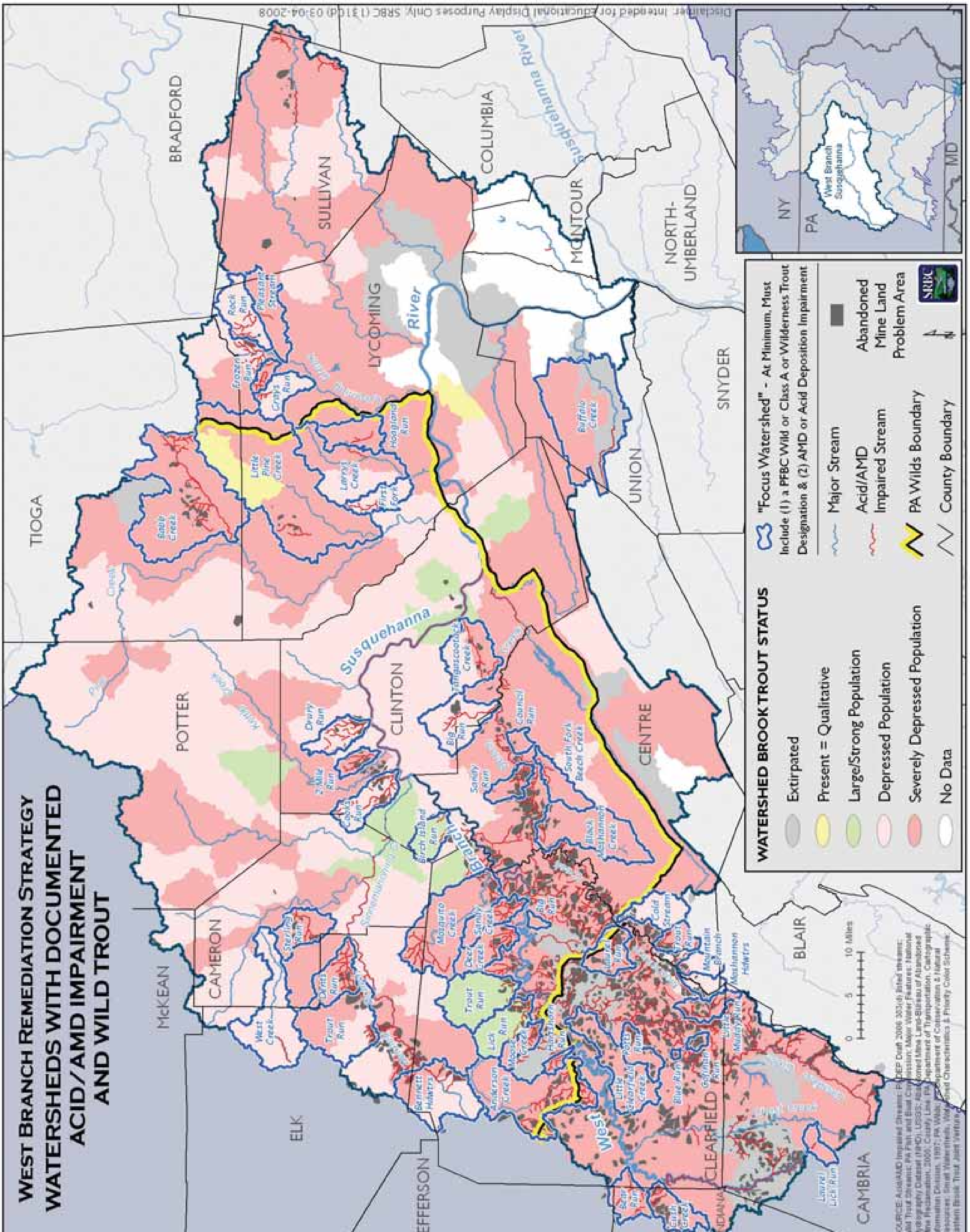
WEST BRANCH SUSQUEHANNA RIVER HEADWATERS

Load reductions from the removal of the Barnes and Watkins coal refuse pile were estimated using water quality samples collected upstream and downstream of the pile. Predicted loading reductions are 9,217 lbs/day of acidity, 594 lbs/day of iron, and 1,143 lbs/day of aluminum. The $4.8 million cost for this effort has already been funded by the Commonwealth of Pennsylvania.

Acidity-load reductions from the addition of the Lancashire #15 (Barnes and Tucker Discharge) AMD Treatment Plant were estimated based on information provided by PADEP BAMR. The predicted acidity-loading reductions are 16,695 lbs/day. Iron and aluminum concentrations will also be reduced with the addition of about 5,000 gpm of treated effluent to the West Branch. Just downstream of the entry of the future plant effluent near Watkins, Cambria County (RM 238.1), iron and aluminum concentrations are predicted to be reduced by nearly 77 percent and 49 percent, respectively. The projected cost of this active AMD treatment plant at the time of this publication is between $8-11 million, with SRBC providing an additional $3.9 million for the 10 million gallons per day that will be added to the West Branch Susquehanna River for a portion of the agricultural consumptive use mitigation. This $3.9 million will be used to establish a trust fund to provide assistance for continued O&M.

Load reductions from the restoration of the Bear Run Watershed were calculated by adding the reductions of all eight AMD treatment system construction phases recommended by the Bear Run Restoration Plan (Clark, 2006). Completion of these eight phases could lead to loading reductions of 2,052 lbs/day of acidity, 298 lbs/day of iron, and 62 lbs/day of aluminum.

Load reductions from the restoration of WBS1 were calculated by adding the reductions of all 14 discharges meeting analytical criteria. Treatment of these 14 discharges could lead to loading reductions of 471 lbs/day of acidity, 49 lbs/day of iron, and 34 lbs/day of aluminum.



J. Zimmerman

Figure 13. *Watersheds with Documented Acid/AMD Impairment and Wild Trout in the West Branch Susquehanna Subbasin.*

Load reductions from the restoration of WBS2 were calculated by adding the reductions of all 13 discharges meeting analytical criteria. Treatment of these 13 discharges could lead to loading reductions of 2,863 lbs/day of acidity, 535 lbs/day of iron, and 196 lbs/day of aluminum.

Load reductions from the complete restoration of Anderson Creek (AND1 and AND2) were calculated by adding the reductions of all 16 discharges meeting analytical criteria. Treatment of these 16 discharges could lead to loading reductions of 1,664 lbs/day of acidity, 184 lbs/day of iron, and 150 lbs/day of aluminum.

All projected construction and O&M costs can be found in Table 26.

WEST BRANCH SUSQUEHANNA RIVER HEADWATERS – WATER QUALITY IMPROVEMENT

The West Branch Susquehanna River Headwaters example shows approximately four river miles shifting from net acidic to net alkaline. Net acidic sections are limited in the headwaters due to the acidity buffering capacity of several large alkaline discharges entering the West Branch Susquehanna River in the vicinity of the town of Northern Cambria, Cambria County. However, a generous surplus of alkalinity would greatly improve about 58 additional river miles prior to the confluence of Clearfield Creek. For example, near Cherry Tree, Indiana County (RM 228.4), the predicted net alkalinity of the West Branch Susquehanna River could be increased by nearly 73 percent after completion of restoration activities in the headwaters (Table 26 and Figures 14 and 15). However, significant sections of the West Branch Susquehanna River, particularly between Moshannon Creek and Bald Eagle Creek, would still be considered acid sensitive (net alkalinity < 20 mg/l). For example, after restoration of the headwaters, the predicted net alkalinity downstream of Moshannon Creek (RM 132.6) could be only 12 mg/l.

Iron concentrations are predicted to drop below the water quality standard (1.50 mg/l) for approximately 13 river miles of the West Branch Susquehanna River. The headwaters example shows that nearly 86 percent (more than 210 river miles) of the West Branch Susquehanna River could meet the water quality standard for iron (Table 26 and Figures 16 and 17).

Aluminum concentrations are predicted to drop below the water quality standard (0.75 mg/l) for about 79 river miles of the West Branch Susquehanna River. The headwaters example shows that more than 32 percent of the West Branch Susquehanna River could meet the water quality standard for aluminum (Table 26 and Figures 18 and 19).

Project	Watershed	Acid Load lbs/day	Fe Load lbs/day	Al Load lbs/day	Removal Cost Million $	Construction Capital Million $	O&M Costs Million $/Year
West Branch Susquehanna River Headwaters							
Barnes and Watkins	West Branch	9,217	594	1,143	4.80		
Lancashire #15	West Branch	16,695	-	-		8.00 - 11.00	na*
Bear Run	West Branch	2,052	298	62		0.77 - 1.67	0.08 - 0.12
WBS1	West Branch	471	49	34		0.55 - 0.73	0.03 - 0.11
WBS2	West Branch	2,863	535	196		1.05 - 4.24	0.19 - 0.20
AND1	Anderson Creek	1,472	163	131		0.63 - 2.26	0.11 - 0.12
AND2	Anderson Creek	192	21	19		0.34 - 0.40	0.02 - 0.06
Total		**32,962**	**1,660**	**1,585**	**4.80**	**11.34 - 20.30**	**0.43 - 0.61+**
Major Tributaries							
CLCR1	Clearfield Creek	4,943	622	457		2.57 - 11.06	0.40 - 0.53
CLCR2	Clearfield Creek	2,737	460	176		1.36 - 4.18	0.20 - 0.25
CLCR4	Clearfield Creek	13,123	3,049	749		3.32 - 23.06	0.72 - 1.10
CLCR5	Clearfield Creek	8,060	1,111	482		6.29 - 12.68	0.60 - 1.18
MOSH1	Moshannon Creek	10,381	694	905		3.28 - 15.87	0.72 - 0.75
MOSH2	Moshannon Creek	19,862	8,163	1,069		4.39 - 41.76	1.05 - 1.98
BENB1	Bennett Branch	3,067	905	189		0.71 - 4.42	0.16 - 0.21
BENB2	Bennett Branch	9,200	1,112	729		2.65 - 15.93	0.53 - 0.76
KETL2	Kettle Creek	3,661	453	302		1.67 - 5.43	0.25 - 0.34
BECH2	Beech Creek	3,577	587	164		1.06 - 5.24	0.22 - 0.25
Total		**78,611**	**17,156**	**5,222**	**0.00**	**27.30 - 139.63**	**4.85 - 7.35**
Complete Total		**111,573**	**18,816**	**6,807**	**4.80**	**38.64 - 159.93**	**5.28 - 7.96+**

Table 26. *Description of the Headwaters and Major Tributaries Remediation Examples with Predicted Load Reductions, Capital Cost Ranges, and Yearly Operation and Maintenance Cost Ranges.*

* *Exact operation and maintenance costs for the Lancashire #15 (Barnes and Tucker) Discharge Active Treatment Plant are not known at the time of drafting this remediation strategy publication.*

Potential Net Alkalinity Concentrations Along the Mainstem of the West Branch Susquehanna River

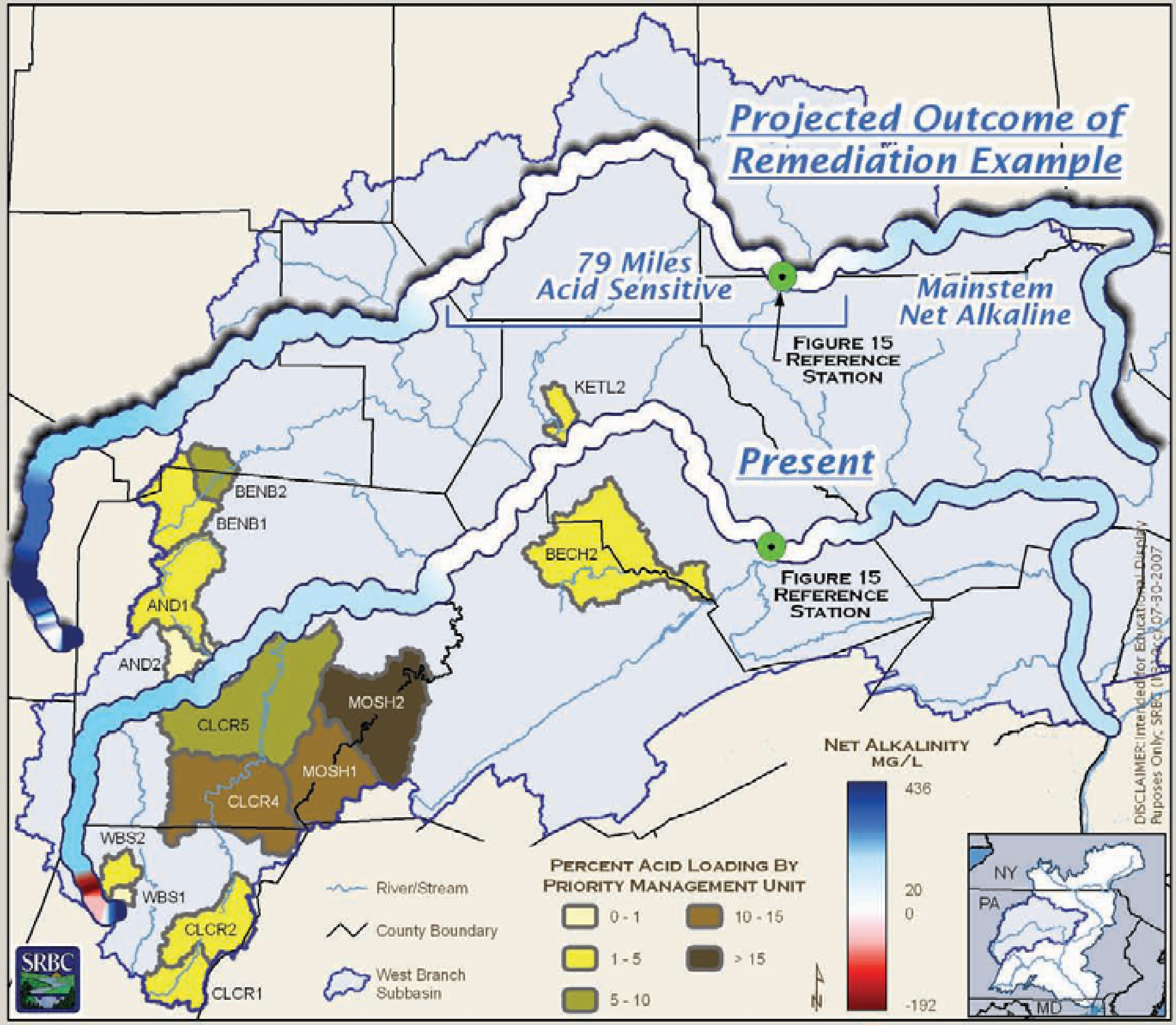


Figure 14. *Map Showing Changes in Net Alkalinity Concentration from Present Conditions to Completion of Headwaters and Major Tributaries Remediation Examples.*

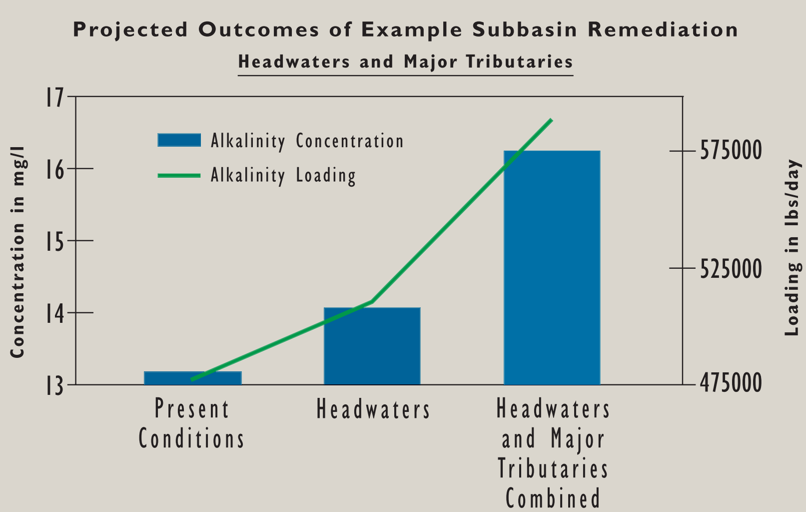


Figure 15. *The Predicted Alkalinity Concentration and Loading Improvement for the West Branch Susquehanna River at a Station Just Upstream of the Entry of Bald Eagle Creek After Completion of Headwaters and Major Tributaries Remediation Examples.*

MAJOR TRIBUTARIES

As mentioned previously, the example for the major tributaries focuses on the top ranked tributary MUs based upon AMD loading and loading yields. This example attempts restoration along the section of the West Branch Susquehanna River from the entry of Clearfield Creek to Pine Creek near Williamsport, Lycoming County. Mass balance projections indicate this section would still be considered acid sensitive, and would contain sections that have iron and aluminum concentrations greater than the water quality standard for each, even after the completion of restoration activities in the headwaters of the West Branch. Projected loading reductions and costs for each of these MUs can be found in Table 26.

Although the tributaries example would increase net alkalinity loadings significantly from the entry of Clearfield Creek to the mouth of the West Branch Susquehanna River, the extent of the AMD loading contributed throughout this section prevents an acceptable level of water quality restoration to be achieved, especially in terms of converting acid sensitive stretches into alkaline "rich" stretches (Figure 14). However, iron and aluminum loadings are greatly reduced, and in some cases would drop below water quality standards for many miles of the West Branch.

MAJOR TRIBUTARIES – WATER QUALITY IMPROVEMENT

With the West Branch Susquehanna River predicted to have net alkaline concentrations throughout its entire length after completion of the headwaters example, the major tributaries example attempts to demonstrate the potential for increasing the buffering capacity for the acid sensitive stretches of river between Alder Run (RM 143.5) and Pine Creek (RM 55.6). The goal for this example was to achieve alkalinity concentrations greater than 20 mg/l. The mass balance projections fall short of this target, but still improve conditions significantly. For example, predicted alkalinity concentrations at a station upstream of Bald Eagle Creek (RM 68.7) could be increased by more than 23 percent from conditions under the headwaters example. A 23 percent increase in net alkalinity in this section of the West Branch is extremely significant considering the volume of flow (Figure 15).

Iron concentrations are predicted to drop below the water quality standard (1.50 mg/l) for nearly 36 additional river miles. After completing the tributaries example, the entire West Branch Susquehanna River should meet the water quality standard for iron (Figures 16 and 17).

Aluminum concentrations are predicted to drop below the water quality standard (0.75 mg/l) for an additional 16 river miles. After completing the tributaries example, nearly 55 percent (more than 134 river miles) of the West Branch Susquehanna River should meet the water quality standard for aluminum (Figures 18 and 19).

FOCUSED WATERSHED APPROACH – CLEARFIELD CREEK WATERSHED

As mentioned in the methods section, the Clearfield Creek example demonstrates potential improvements targeting AMD sources at a smaller scale. Results focus on treatment of the Cresson #9 discharge, the Gallitzin #10 discharge, the Gallitzin Shaft Mine Complex, and the Dean Clay Mine.

The Cresson and Gallitzin discharges are all located within the headwaters of Clearfield Creek. Using treatment effluent projections based upon loading of the current discharges and effluent projections of a similar style active treatment plant that will be built to treat the Lancashire #15 (Barnes and Tucker) Discharge, the treatment of the Cresson and Gallitzin discharges has the capability of removing nearly 1,200 lbs/day of acidity, more than 200 lbs/day of iron, and 90 lbs/day of aluminum. In addition, the treated effluent could add up to 1,400 lbs/day of alkalinity.

Brubaker Run enters Clearfield Creek at Dean, Cambria County, and represents the largest acid source entering the southern half of Clearfield Creek. Three abandoned clay mines are the major sources of acid to Brubaker Run. One of these major abandoned clay mine discharges, the Dean Mine, enters untreated into Brubaker Run. Watershed volunteers have monitored the Dean Clay Mine discharge since 2002. The flow from the abandoned clay mine averages around 250 gpm. The pH of the water is 3.1 with concentrations of 180 mg/l of iron, 13-25 mg/l of aluminum, and an acidity of 400-700 mg/l (Clearfield Creek Watershed Association, 2007).

Studies completed by the Clearfield Creek Watershed Association recommend some additional study to verify the source of water fueling the Dean Clay Mine discharge, followed by a combination of mine sealing, grouting, and treatment of the remaining flow.

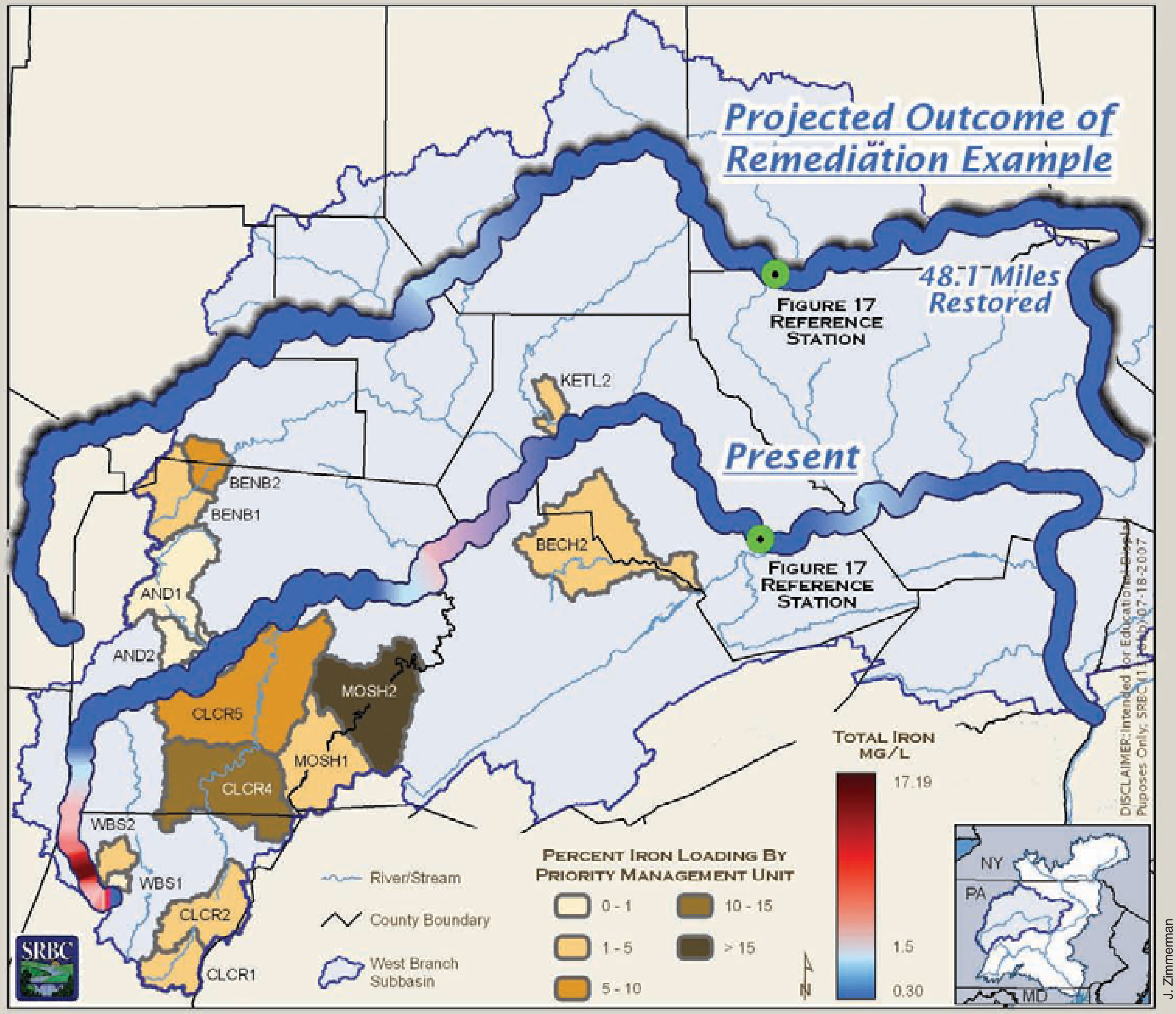
CLEARFIELD CREEK WATERSHED – WATER QUALITY IMPROVEMENT

Even though the Clearfield Creek Watershed is one of the most AMD-impaired tributaries of the West Branch Susquehanna River, it is able to assimilate the entering acidity loading, remaining net alkaline from headwaters to mouth. However, the treatment of the Cresson #9, Gallitzin #10, Gallitzin Shaft, and Dean AMD discharges does improve the net alkalinity greatly since there are stretches of Clearfield Creek considered to be acid sensitive (alkalinities less than 20 mg/l). For example, the net alkalinity of instream station CLCR 14, which is downstream of the Cresson and Gallitzin discharges, may increase 34 percent (32 mg/l to 43 mg/l). In addition, the net alkalinity of CLCR 10, collected below the confluence with Brubaker Run, may increase by as much as 40 percent (15 mg/l to 21 mg/l).

The projected iron concentration along the Clearfield Creek mainstem after completion of the headwaters and Brubaker examples shows the most significant improvement. Currently,

Continued on page 44

Potential Iron Concentrations Along the Mainstem of the West Branch Susquehanna River



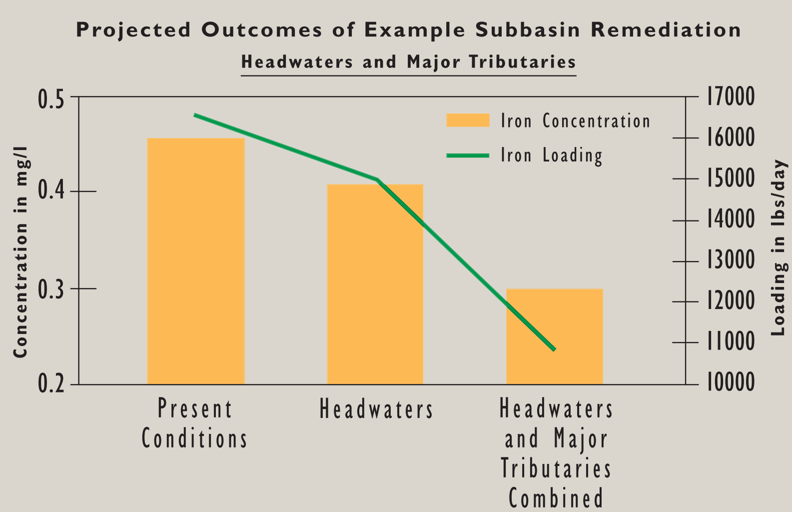


Figure 16. *Map Showing Changes in Iron Concentration from Present Conditions to Completion of Headwaters and Major Tributaries Remediation Examples.*

Figure 17. *The Predicted Iron Concentration and Loading Improvement for the West Branch Susquehanna River at a Station Just Upstream of the Entry of Bald Eagle Creek After Completion of Headwaters and Major Tributaries Remediation Examples.*

Potential Aluminum Concentrations Along the Mainstem of the West Branch Susquehanna River

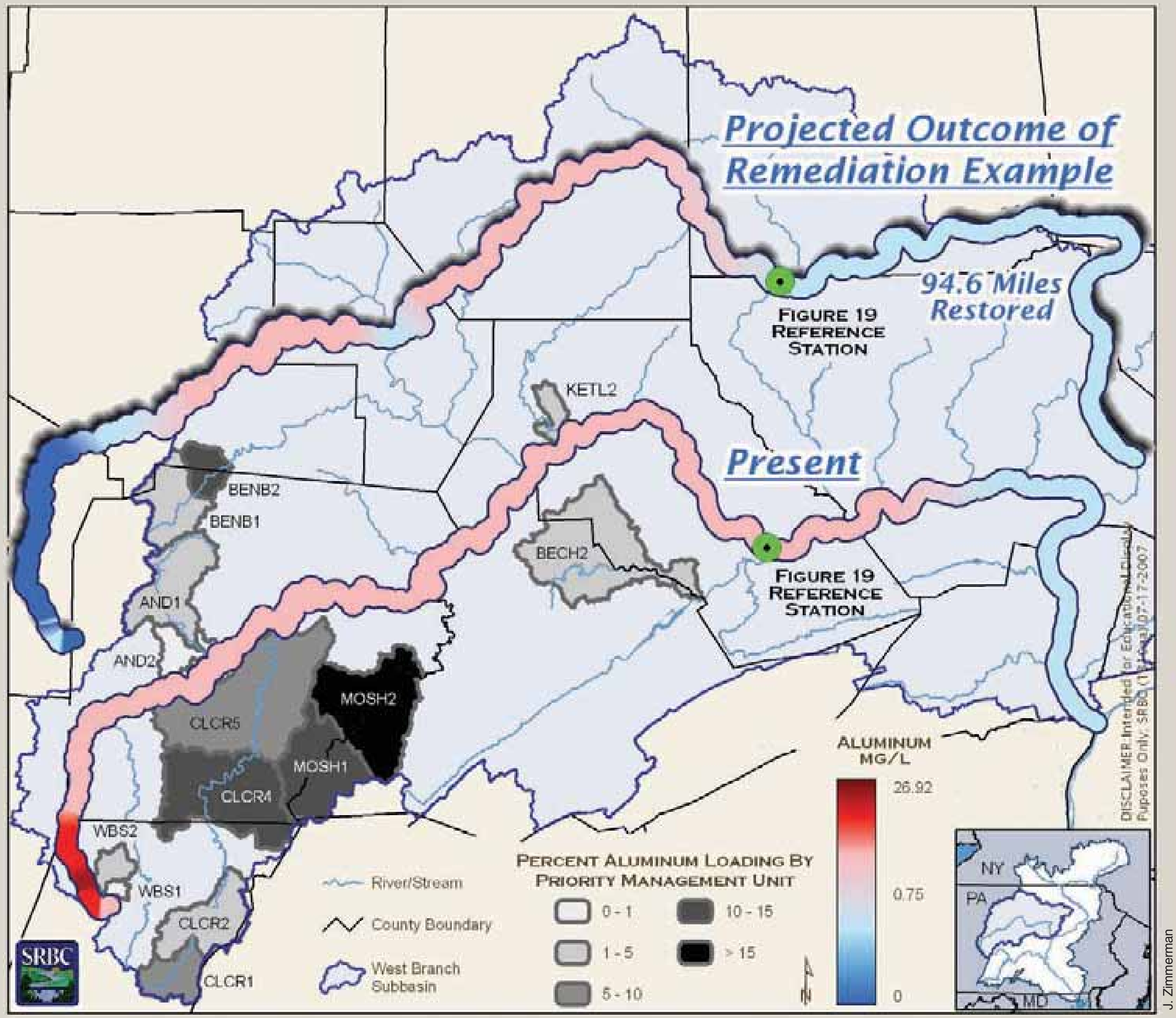


Figure 18. Map Showing Changes in Aluminum Concentration from Present Conditions to Completion of Headwaters and Major Tributaries Remediation Examples.

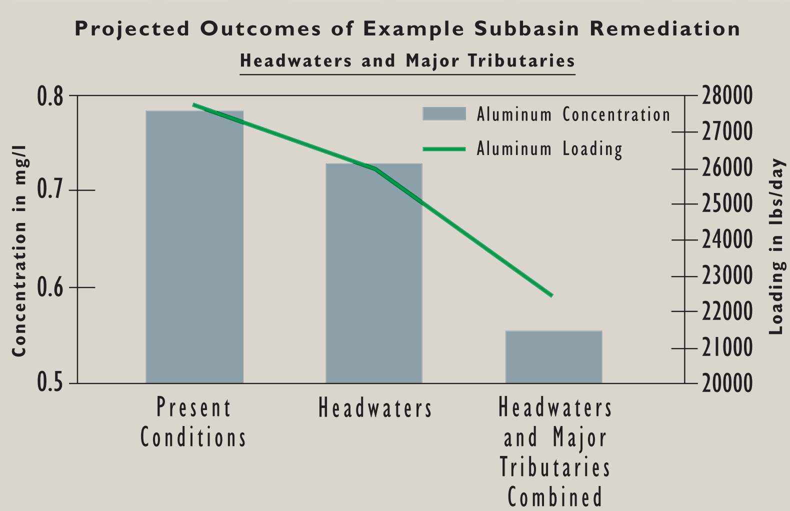


Figure 19. The Predicted Aluminum Concentration and Loading Improvement for the West Branch Susquehanna River at a Station Just Upstream of the Entry of Bald Eagle Creek After Completion of Headwaters and Major Tributaries Remediation Examples.

29 miles of Clearfield Creek (~ 45 percent) exceed the 1.5 mg/l water quality standard for iron. The restoration of those areas would result in slightly more than nine stream miles exceeding the water quality standard, or a reduction of impaired miles by 31 percent (Figure 20).

The most significant improvement may be found at CLCR 09, near Fallen Timber, Cambria County, where iron concentrations may decrease nearly 78 percent (1.43 mg/l to 0.32 mg/l).

Currently, the first 24 miles (~37 percent) of the Clearfield Creek mainstem contain aluminum concentrations above the PADEP water quality standard of 0.75 mg/l. After completion of the two restoration examples, the length of the mainstem with concentrations above the water quality standard for aluminum decreases to 16 stream miles, or a reduction of 12 percent.

The most significant improvement may be found at CLCR 13, at the State Route 53 Bridge near Ashville, Cambria County, where aluminum concentrations could decrease nearly 38 percent from 1.09 mg/l to 0.68 mg/l.

J. Zimmerman

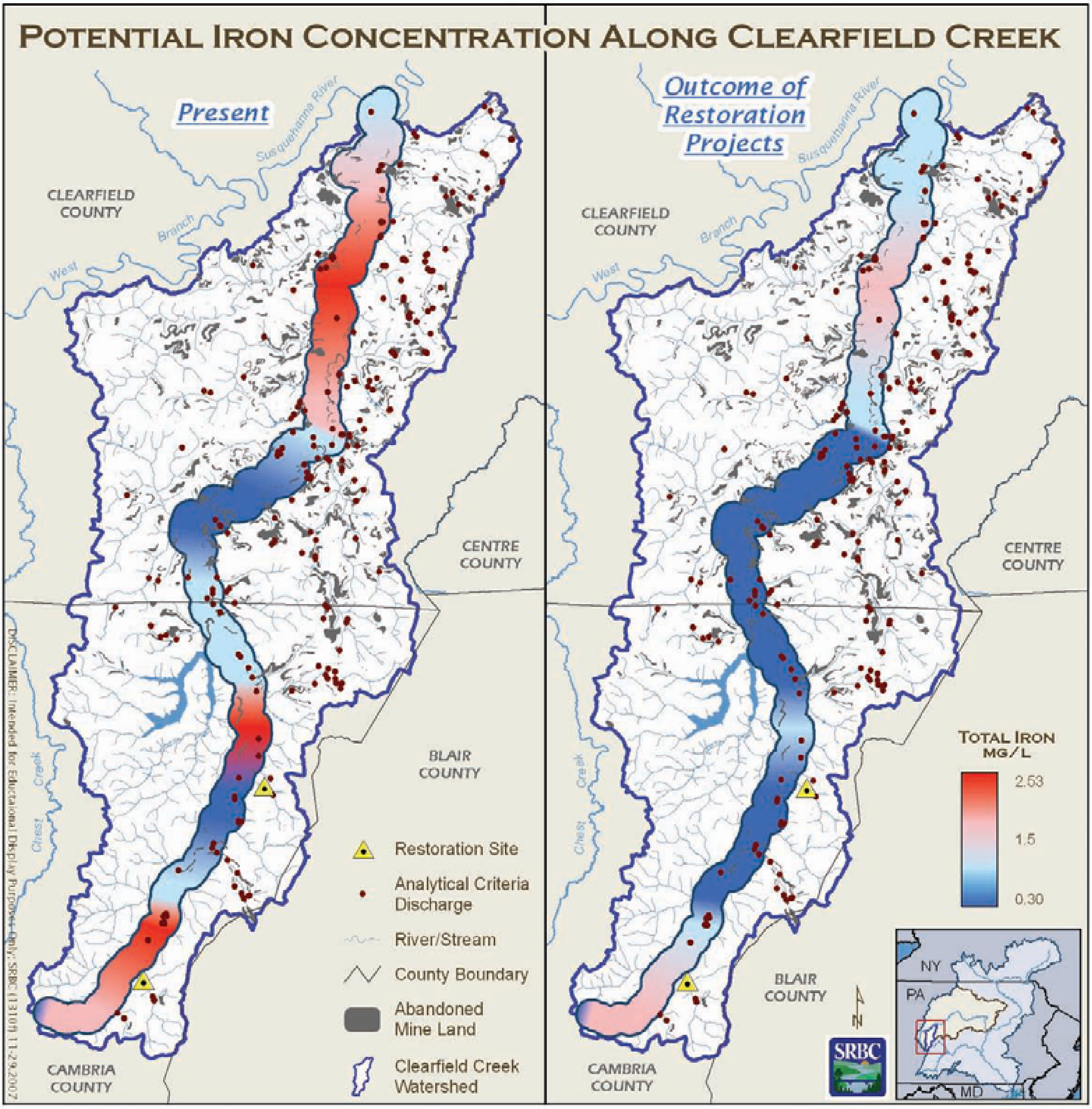


__Figure 20.__ Map Showing Potential Improvements in Iron Concentration for Clearfield Creek.

■ CONCLUSIONS

A majority of the AMD pollution impacting the West Branch Susquehanna Subbasin is found in six areas: the West Branch Susquehanna River Headwaters; multiple MUs within the Clearfield Creek, Moshannon Creek, and Bennett Branch Sinnemahoning Creek Watersheds; and single MUs in the Kettle Creek and Beech Creek Watersheds. In one possible remediation example, focused effort on the ten MUs contributing the largest pollution loads and yields from each of these areas, along with the other planned restoration projects, are projected to result in a nearly restored West Branch Susquehanna River. Additional sampling of the discharges not meeting analytical criteria (nearly 60 percent of the total discharges) would be needed for more complete restoration projections as these discharges were not used in any calculations.

The West Branch Susquehanna River Headwaters and Major Tributaries examples show alkaline conditions for the length of the mainstem, as well as iron concentrations below water quality standards. Aluminum poses a greater challenge, but the remediation examples show where further efforts are needed to define the problem and propose solutions, particularly for sources generating loads between Clearfield Creek and Bald Eagle Creek. It is also important to note that with the West Branch Susquehanna River being net alkaline after the remediation examples from headwaters to mouth, and consequently containing a circum-neutral pH, aluminum concentrations should be in a precipitated non-toxic state. The dissolved form of aluminum found in acidic waters is very toxic to aquatic organisms even at concentrations below the 0.75 mg/l water quality standard for aluminum.

With respect to treatment costs, this document outlines one possible remediation example with WRAM estimated capital construction costs between $43 and $165 million dollars, depending on the selection of passive or active treatment technologies. An additional WRAM estimated $5 - $8 million, and possibly more with the addition of the Lancashire #15 (Barnes and Tucker) Discharge active treatment plant, would be needed annually for operation and maintenance of those systems. It is important to note that these costs are based on the best available data, particularly those discharges with water quality data meeting analytical criteria, and the examples represented in this document do not provide for complete restoration of the West Branch Susquehanna River Subbasin. In addition, at sites where remining and mine land reclamation are viable options to eliminate or reduce AMD loading, projected restoration costs could be decreased, particularly the annual operation and maintenance costs.

Cost estimates only address the 788 discharges that met the analytical criteria defined for this study. These discharges only comprise 40 percent of the total discharges compiled for this project. Adding in the 60 percent of the discharges that did not meet analytical criteria, total West Branch Susquehanna Subbasin restoration capital construction costs could be in the realm of $400 million, which are comparable to PADEP estimates (West Branch Susquehanna River Task Force, 2005).

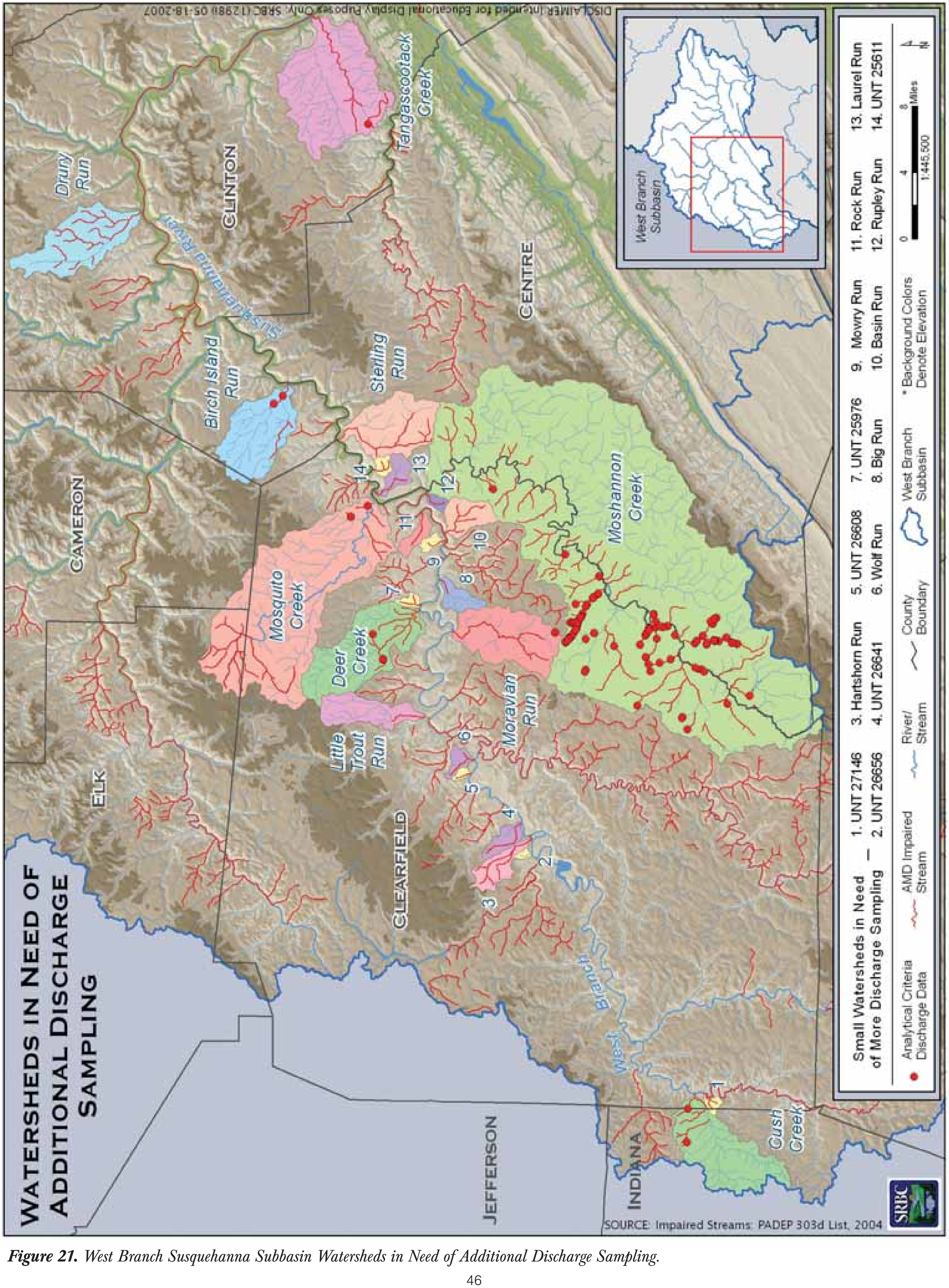
The Task Force recognizes that the areas contributing the largest AMD-pollutant loads represent one part of the problem. Other areas can be just as important for restoring AMD impacts and should be considered within the framework of a stakeholder's restoration goals, which can vary greatly depending on the intended use of the resource and local interest.

In terms of the discharges “adjacent" to Priority I and II sites, there are opportunities to improve conditions within eight MUs through reclamation of these hazard sites. Reclamation of abandoned mine lands often has proven to be an effective method in improving water quality conditions. AML reclamation focused in CLCR4, MOSH1, BENB3, BENB2, and AND1 could directly improve the West Branch Susquehanna River since these MUs contain a majority of the discharge loading that is within one-quarter mile from a Priority I or II site. Additionally, work in CHST1, CHST2, and WBS6 could improve conditions within each of these MUs since a large majority of their analytical criteria discharges are in close proximity to Priority I and II hazard sites. If OSM rules allow, Priority I and II funding could be utilized in these areas to correct a Priority III problem.

Other areas of interest include tributaries containing sections of high quality wild trout fisheries with adjacent sections of stream impaired by AMD or acid deposition. Half of these focus watersheds (24 out of the 48 documented) are found between Anderson Creek and Sinnemahoning Creek along the West Branch Susquehanna River, which is arguably the most impaired section of the river. In addition, 29 out of the 48 focus watersheds are found in the PA Wilds designated area. A significant opportunity exists to bolster existing restoration efforts in these areas with the ultimate goal of population reconnection with the West Branch Susquehanna River.

Continued water quality monitoring is critically important to support the West Branch Susquehanna Subbasin restoration effort. Within areas of the West Branch Susquehanna Subbasin, water quality monitoring data are still needed to properly characterize AMD impacts (Figure 21). In addition, sites need to be monitored as restoration occurs. Instream monitoring sites, such as those used in this strategy, help document improvement and support future restoration planning.

Restoration of the West Branch Susquehanna Subbasin offers a tremendous opportunity to greatly enhance the subbasin’s resources by creating considerable environmental, recreational, and socioeconomic benefits.



J. Zimmerman

Figure 21. *West Branch Susquehanna Subbasin Watersheds in Need of Additional Discharge Sampling.*

West Branch Susquehanna Subbasin AMD Remediation Strategy Recommendations Summary

Encourage restoration activities within the management units contributing to a majority of the AMD-pollutant loads;

Utilize the tools outlined in this document to assist with decision making on restoration planning, including maintaining the water quality database through periodic updates;

Develop restoration plans for areas where none currently exist;

Investigate other factors contributing to aluminum loading issues in the West Branch Susquehanna Subbasin;

Encourage efforts to combine the restoration of Priority I and II Health and Safety Sites with the elimination/ treatment/improvement of "adjacent" AMD discharges (Priority III sites);

Investigate opportunities to restore wild trout streams affected by AMD for the ultimate goal of reconnecting populations within the West Branch Susquehanna Subbasin;

Encourage collection of flow measurements when water quality data are collected from streams and discharges;

Complete assessments of areas lacking discharge and instream water quality data; and,

Continue to monitor instream water quality for the 34 management unit endpoint stations so that any improvements can be documented.

Major Highlights of the West Branch Susquehanna Subbasin AMD Remediation Strategy

- ✔ Water quality impairment, mainly from AMD, of the West Branch Susquehanna Subbasin is the only major hindrance to biological expansion since nearly 90 percent of the subbasin has been documented as containing either excellent or supporting habitat (LeFevre, 2003).
- ✔ 1,205 stream miles of the West Branch Susquehanna Subbasin are impaired by AMD, which is 66 percent of the total AMD-impaired mileage in the entire Susquehanna River Basin. However, the subbasin also contains 1,249 of Exceptional Value waters and 5,229 stream miles of High Quality Cold Water Fisheries (West Branch Susquehanna River Task Force, 2005).
- ✔ There are approximately 1,964 AMD discharges in the West Branch Susquehanna Subbasin, however, only 788 (40 percent) contained enough data to meet analytical criteria standards.
- ✔ 11 Management Units (10 tributary MUs and one West Branch Susquehanna River MU), comprising only 10 percent of the West Branch Susquehanna Subbasin area, contain nearly 80 percent of the analytical criteria discharge loading.
- ✔ 8 of the 11 priority Management Units are found within the Clearfield Creek, Moshannon Creek, and Bennett Branch Sinnemahoning Creek Watersheds.
- ✔ The hypothetical examples for West Branch Susquehanna Subbasin remediation would allow for a completely net alkaline West Branch Susquehanna River mainstem with iron concentrations that meet Pennsylvania Department of Environmental Protection water quality standards. Aluminum concentrations, however, may still exceed water quality standards between the entry of Clearfield Creek and Bald Eagle Creek. The capital cost needed for this remediation has been estimated to be between $43 and $165 million.
- ✔ Treatment of Cresson #9 discharge, Gallitzin #10 discharge, Gallitzin Shaft Mine Complex, and Dean Clay Mine in Brubaker Run could lead to a majority (~ 86 percent) of the Clearfield Creek mainstem attaining water quality standards for iron.
- ✔ Out of the 788 analytical criteria discharges, 213 (27 percent) are within one-quarter mile of a Priority I or II Health and Safety Problem Site. Land reclamation of these sites could pay water quality dividends, particularly in the Clearfield Creek, Moshannon Creek, Bennett Branch Sinnemahoning Creek, Anderson Creek, and Chest Creek Watersheds due to possible hydrologic connections.
- ✔ 48 focus watersheds in the West Branch Susquehanna Subbasin contain, at minimum, sections of Pennsylvania Fish and Boat Commission documented wild trout and sections of Pennsylvania Department of Environmental Protection documented AMD and/or atmospheric deposition (acid deposition) impairment. These 48 focus watersheds contain 634 miles of Wild Trout classifications, 99 miles of Class A Wild Trout designations, 55 miles of Wilderness Trout designations, but also 438 miles and 89 miles of AMD and acid deposition impairment, respectively. Only 3.7 percent of the subbasin contains large/strong populations of wild brook trout.
- ✔ Total capital costs of complete West Branch Susquehanna Subbasin remediation from AMD impacts could be as high as $400 million; however, true costs ultimately will not be known until projects are competitively bid.

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West Branch Susquehanna Rescue

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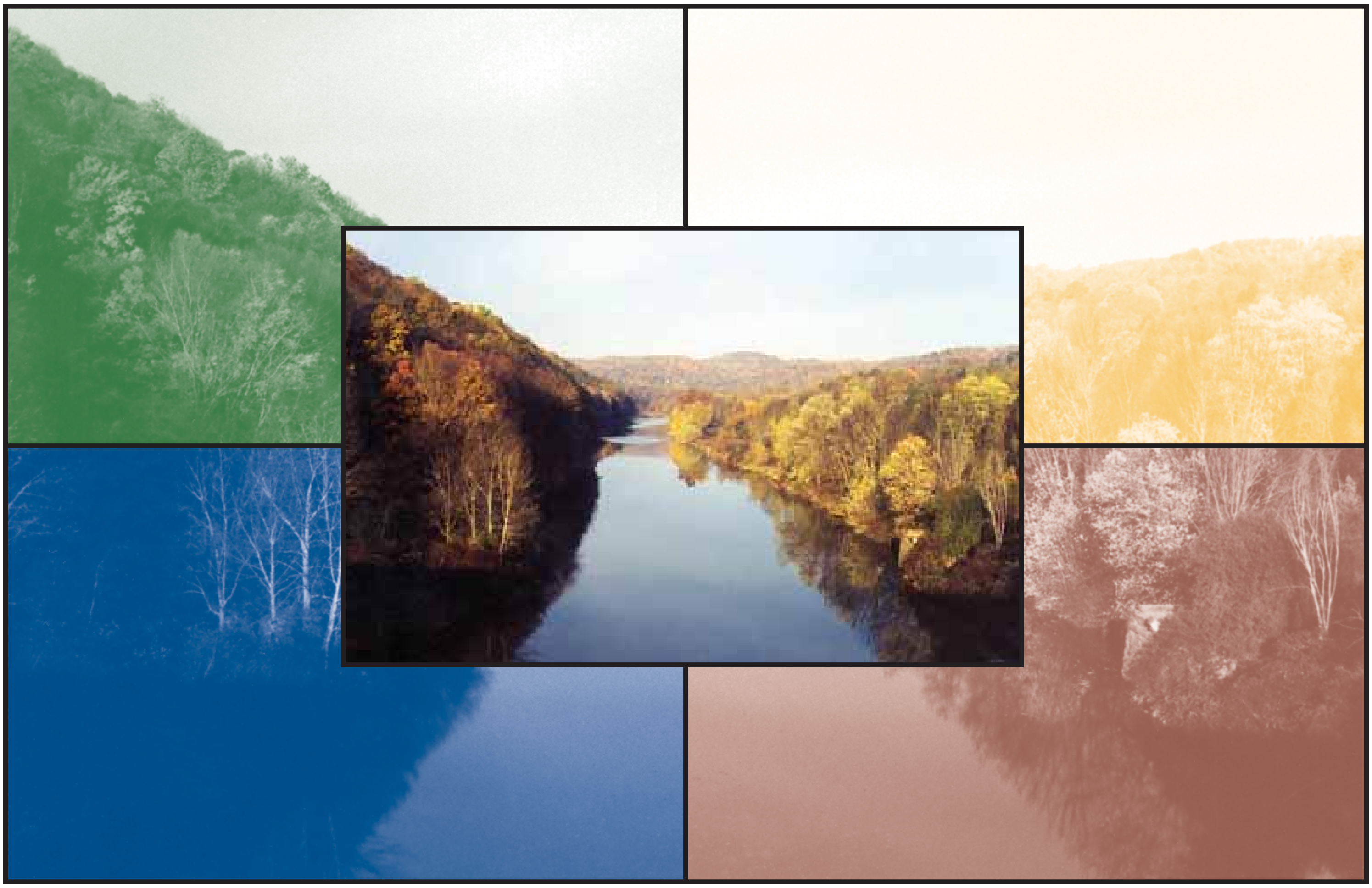

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