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

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

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

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

RESULTS AND DISCUSSION

Management Unit Endpoint Water Quality Stations

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

West Branch Susquehanna River Mainstem MUs

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

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

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

Chest Creek MUs

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

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

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

Anderson Creek MUs

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

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

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

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 mi^2	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

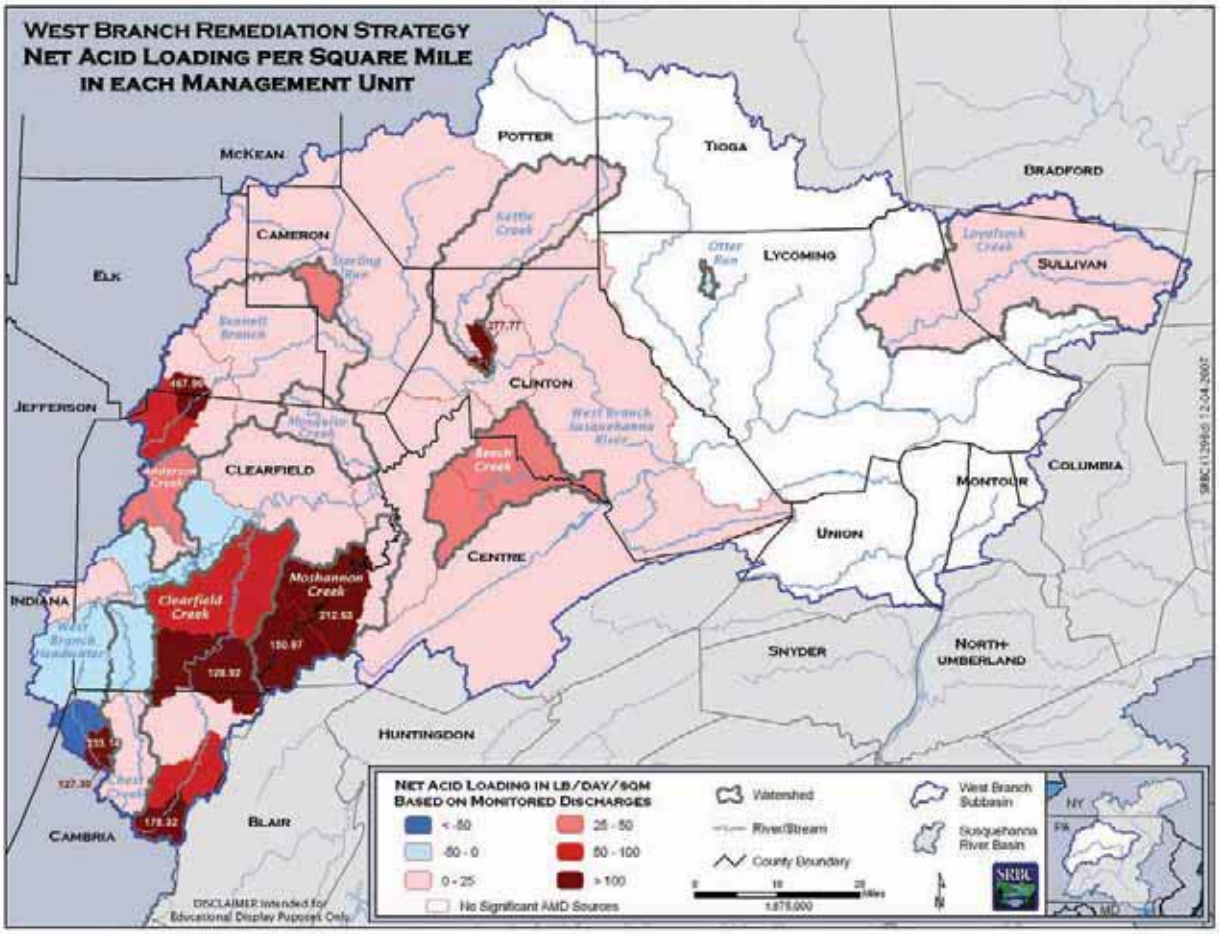
Of the 1,964 total discharges located in the database, 558 discharges (more than 28 percent) are within one-quarter mile of a Priority I and II site. A majority of these discharges (70 percent) are located in the Clearfield Creek and Bennett Branch Sinnemahoning Creek Watersheds, and along the mainstem 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

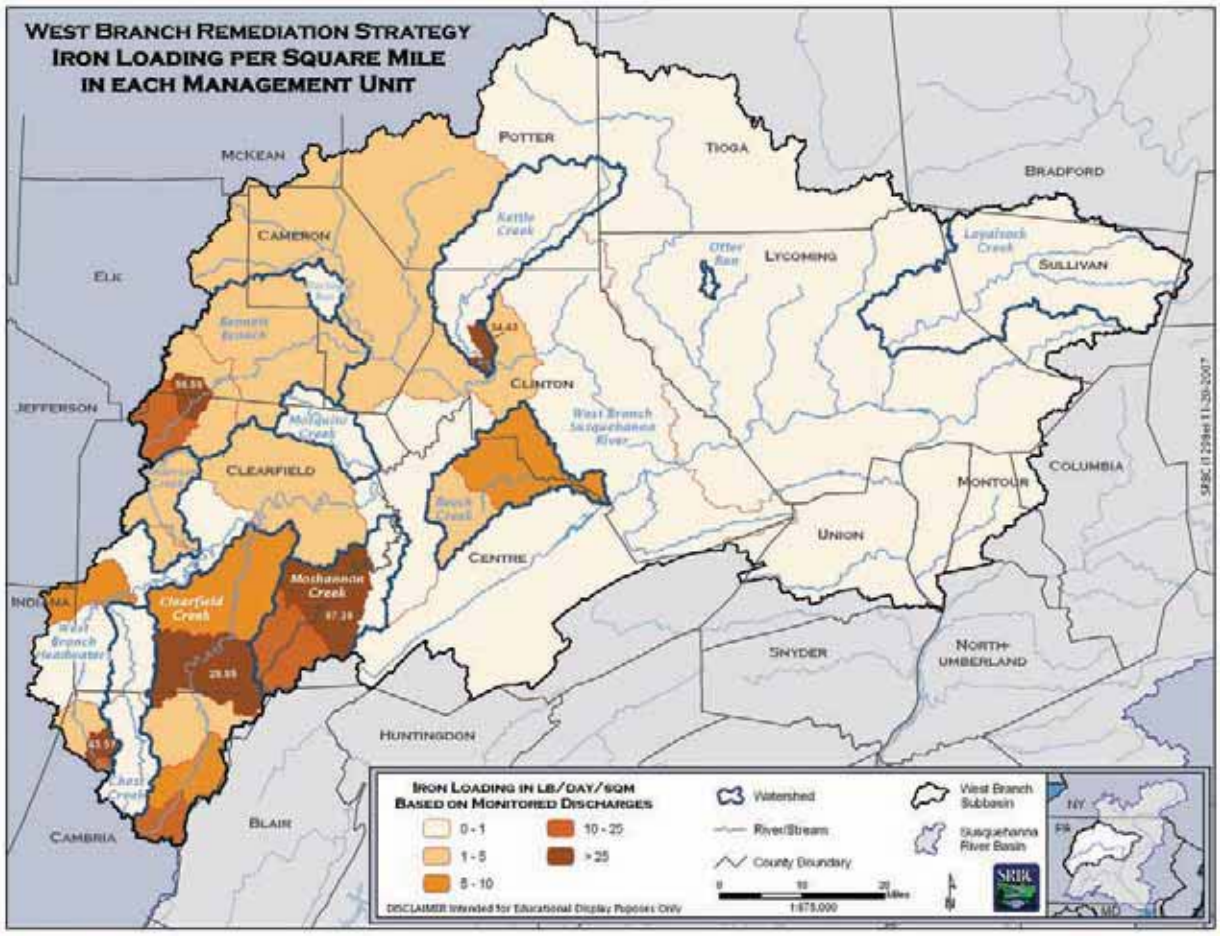
MU	Watershed	Flow GPM	Percent %	Acid Load lbs/day	Percent %	Fe Load lbs/day	Percent %	Al Load lbs/day	Percent %
CLCR4	Clearfield Creek	3,265	22.5	9,745	31.0	1,857	56.6	598	24.8
MOSH1	Moshannon Creek	2,072	14.3	8,599	27.3	575	17.5	757	31.4
BENB2	Bennett Branch	3,440	23.7	4,572	14.5	172	5.2	383	15.9
AND1	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.*



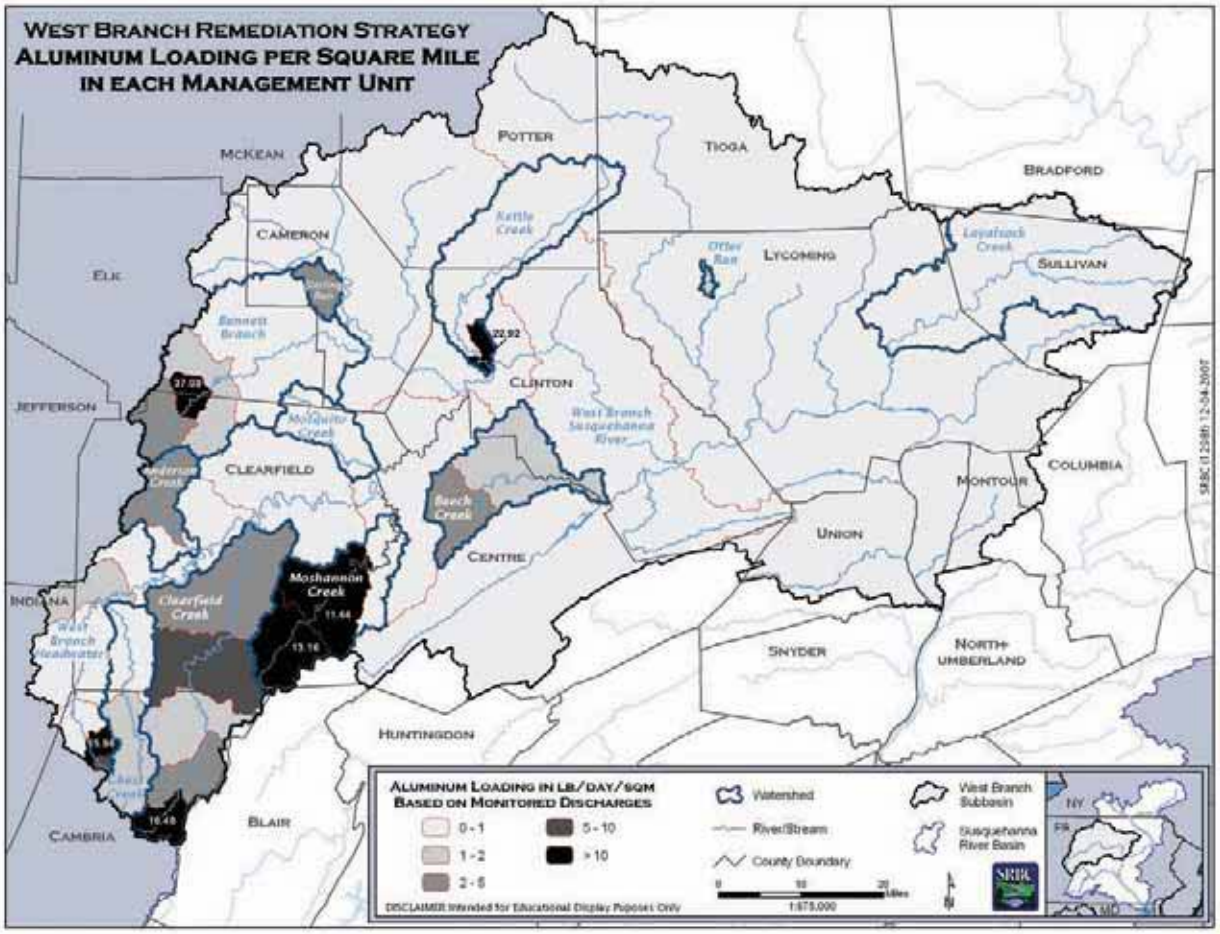
J. Zimmerman

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



J. Zimmerman

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.

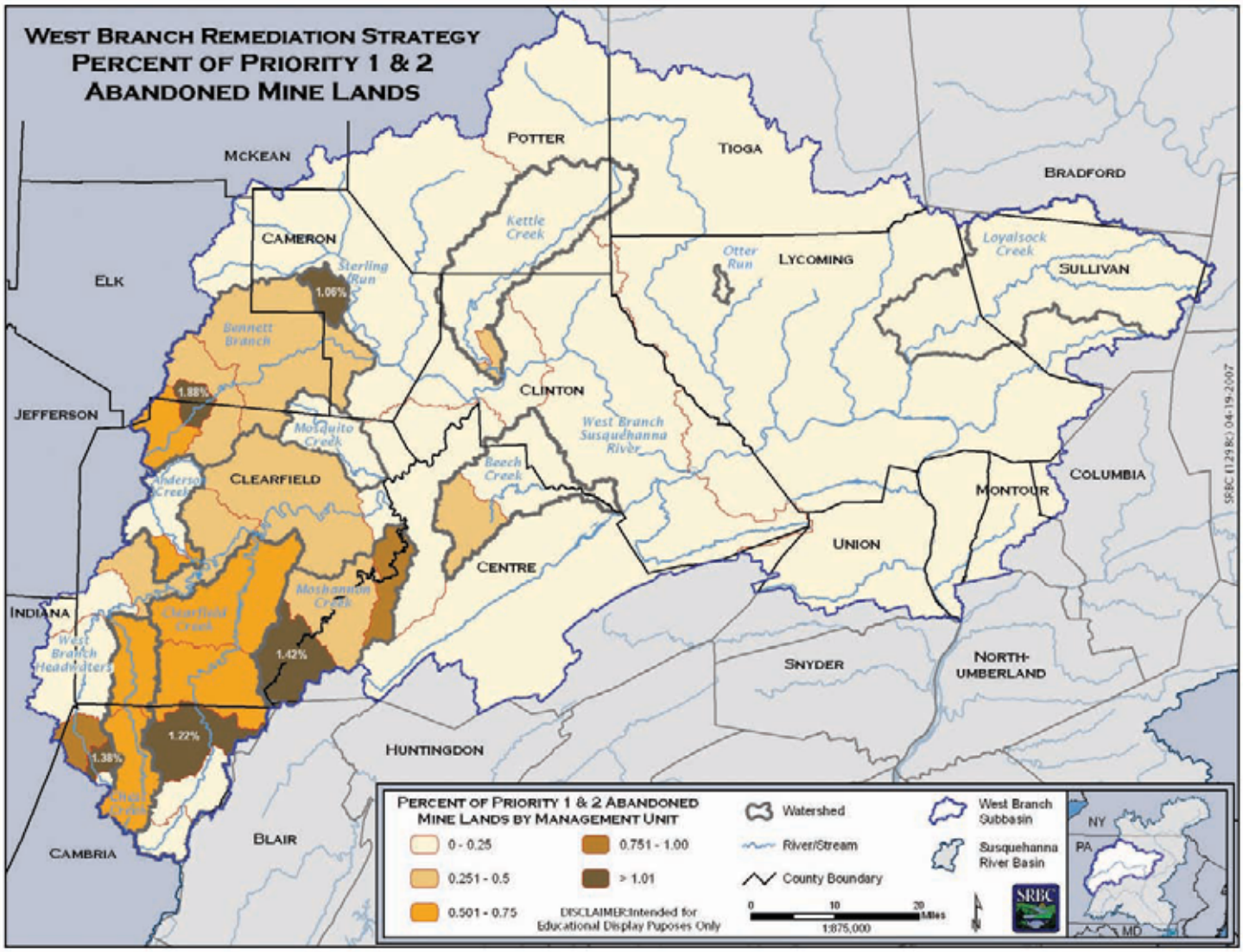


Figure 12. *Percent Land Coverage of Priority I and II Health and Safety Problem Sites in Each West Branch Susquehanna Subbasin MU.*

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
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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.

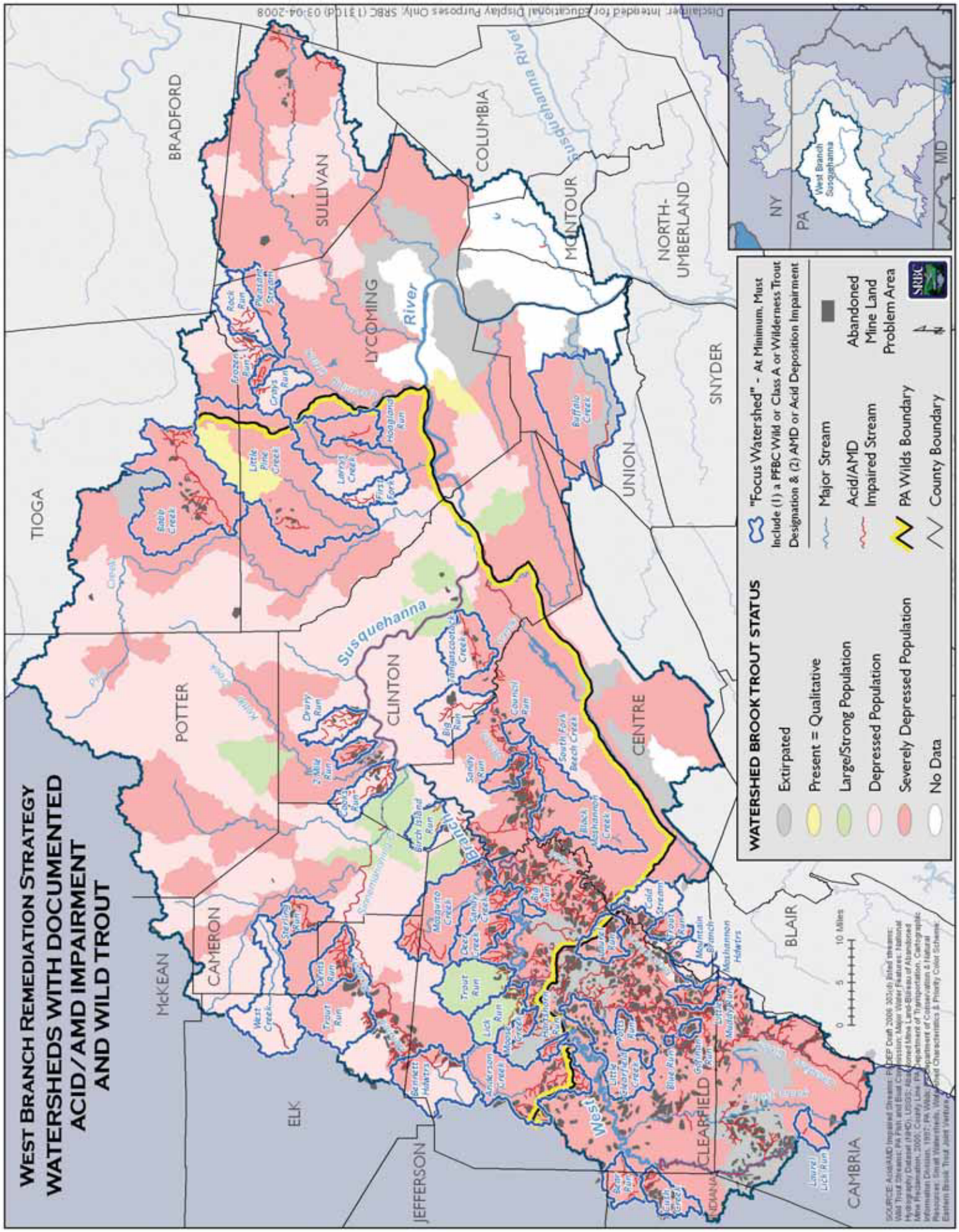

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Figure 13. *Watersheds with Documented Acid/AMD Impairment and Wild Trout in the West Branch Susquehanna Subbasin.*

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).

West Branch Susquehanna River Headwaters

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
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

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
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

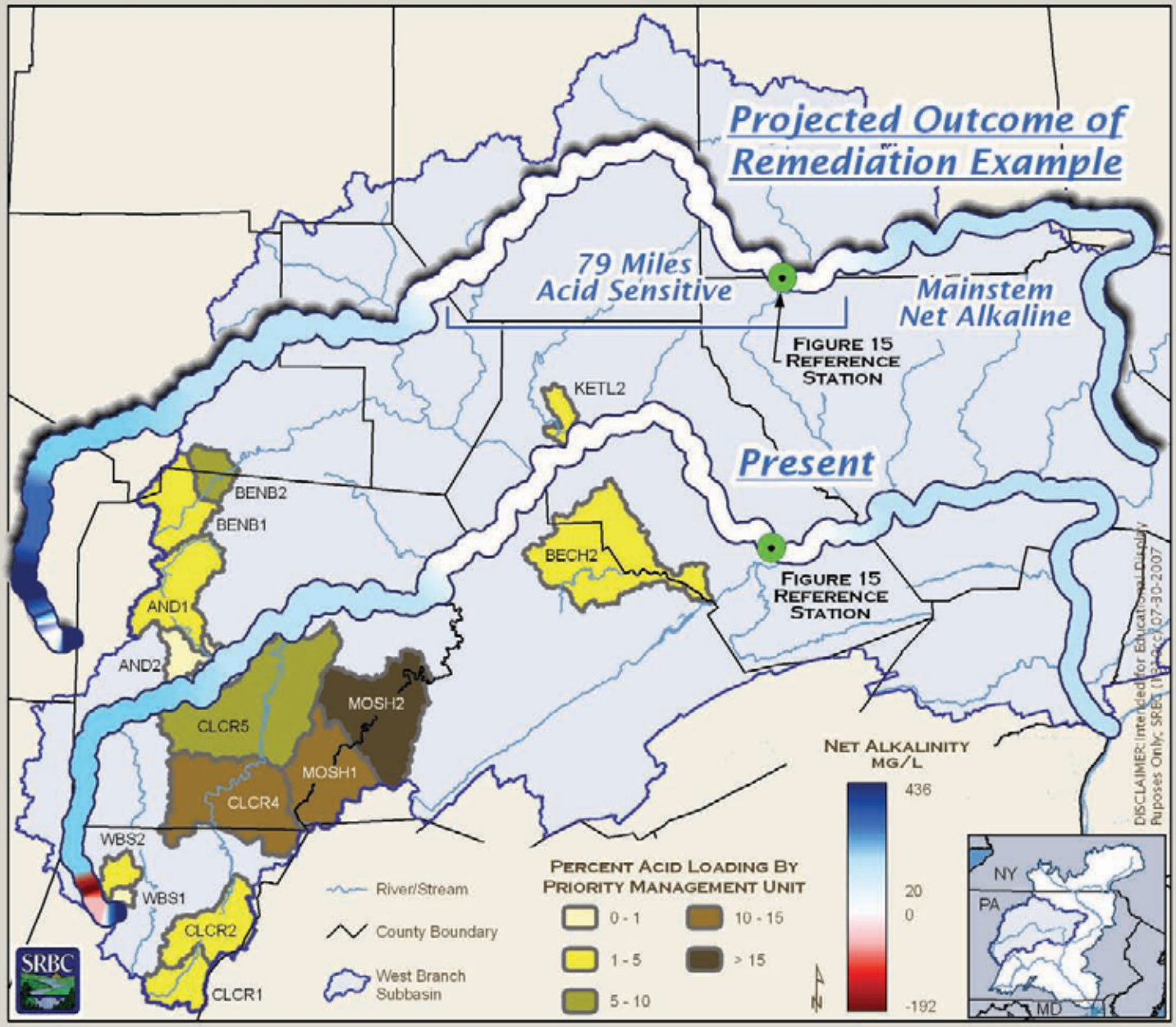

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Figure 14. *Map Showing Changes in Net Alkalinity Concentration from Present Conditions to Completion of Headwaters and Major Tributaries Remediation Examples.*

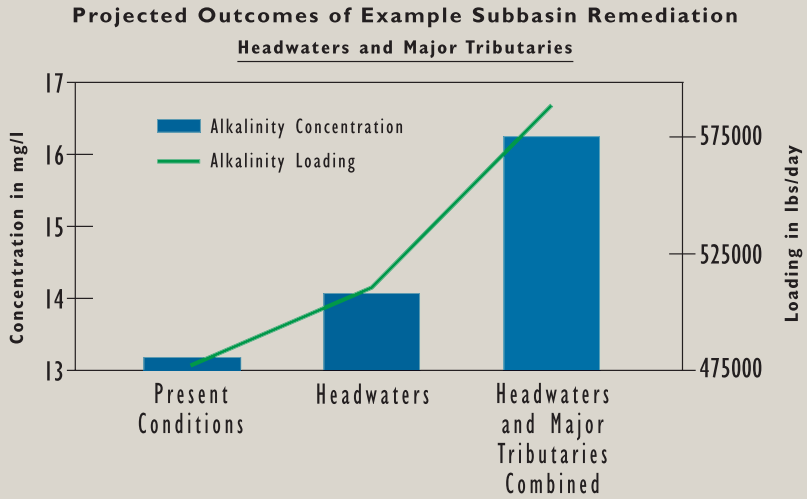

Figure 15. *The Predicted Alkalinity Concentration and Loading Improvement for the West Branch Susquehanna River at a Station Just Upstream of the Entry of Bald Eagle Creek After Completion of Headwaters and Major Tributaries Remediation Examples.*

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

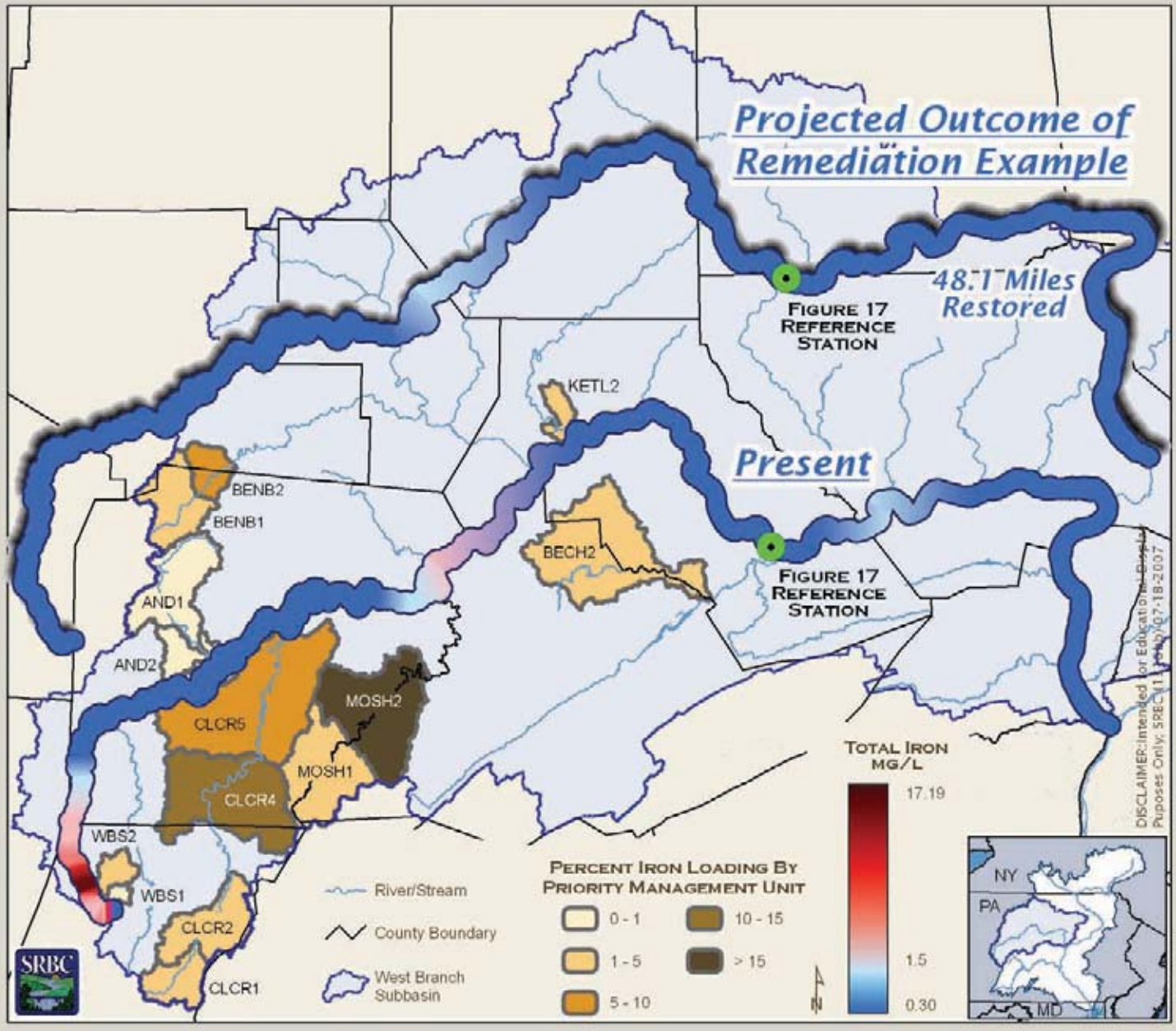

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Figure 16. *Map Showing Changes in Iron Concentration from Present Conditions to Completion of Headwaters and Major Tributaries Remediation Examples.*

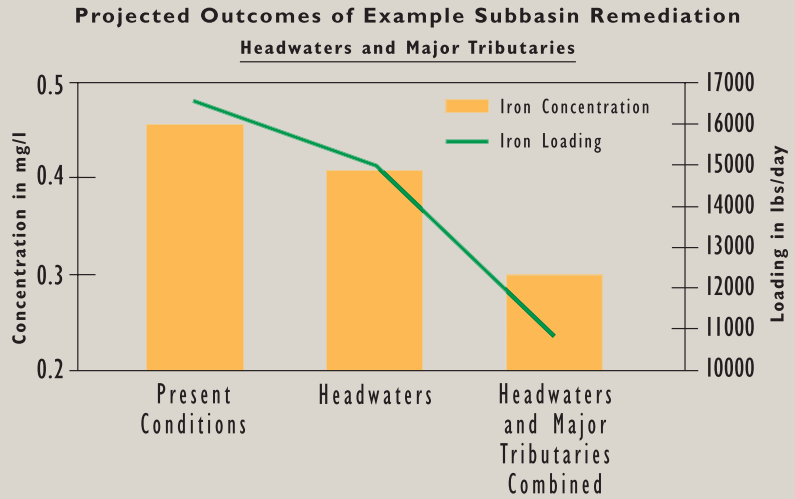

Figure 17. *The Predicted Iron Concentration and Loading Improvement for the West Branch Susquehanna River at a Station Just Upstream of the Entry of Bald Eagle Creek After Completion of Headwaters and Major Tributaries Remediation Examples.*

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

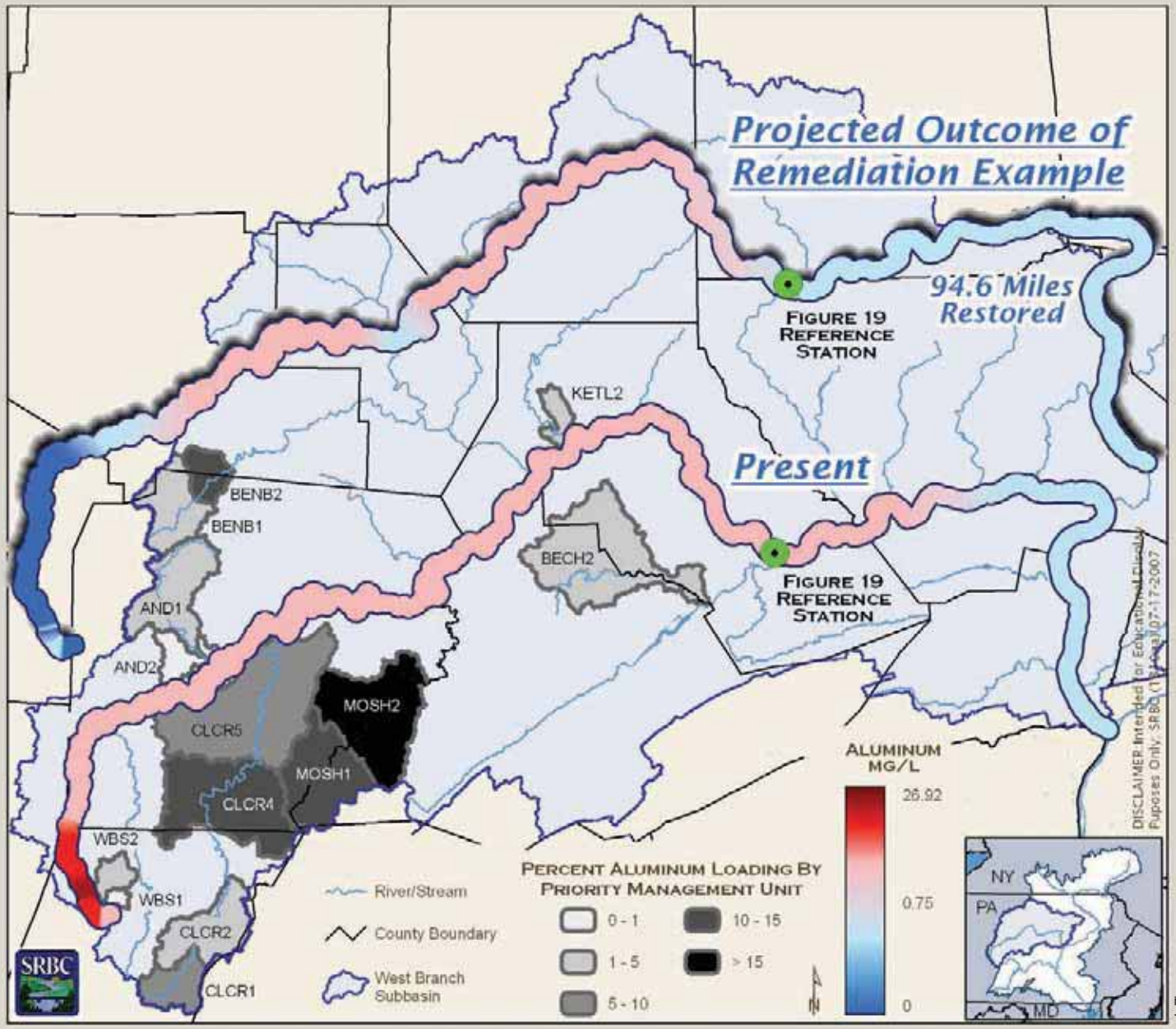

Figure 18. *Map Showing Changes in Aluminum Concentration from Present Conditions to Completion of Headwaters and Major Tributaries Remediation Examples.*

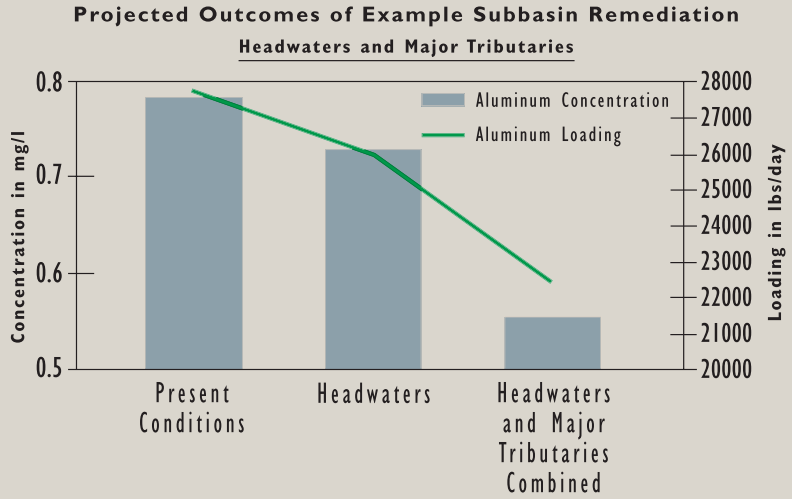

Figure 19. *The Predicted Aluminum Concentration and Loading Improvement for the West Branch Susquehanna River at a Station Just Upstream of the Entry of Bald Eagle Creek After Completion of Headwaters and Major Tributaries Remediation Examples.*

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.

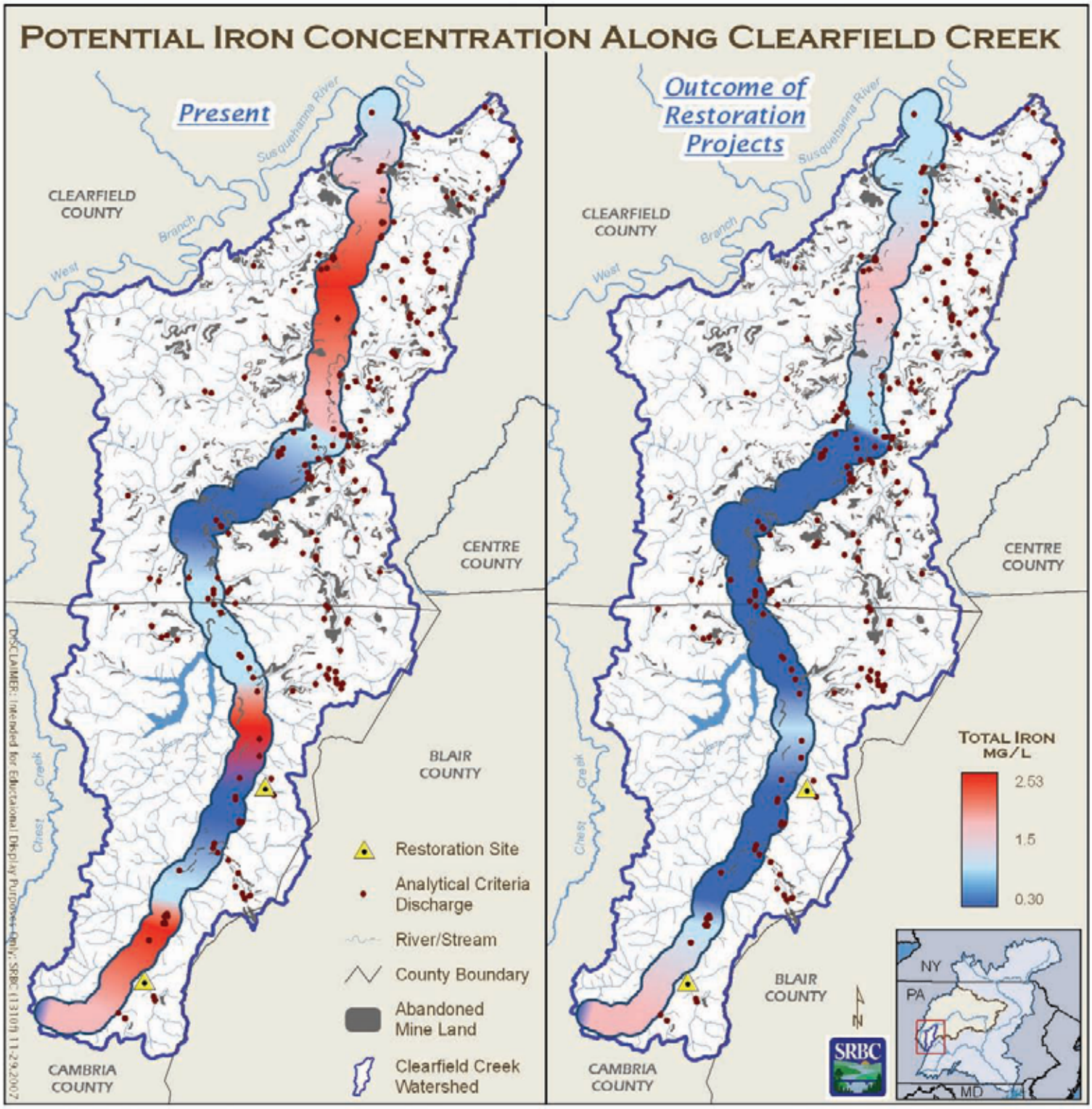

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Figure 20. Map Showing Potential Improvements in Iron Concentration for Clearfield Creek.