THE POTENTIAL FOR WATER QUALITY TRADING TO HELP IMPLEMENT THE CHEAT WATERSHED ACID MINE DRAINAGE TOTAL MAXIMUM DAILY LOAD IN WEST VIRGINIA

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TABLE OF CONTENTS

TABLE OF TABLES

TABLE OF FIGURES

SUGGESTED REFERENCE

ACKNOWLEDGEMENTS

ABBREVIATIONS

AMD	acid mine drainage
AML	abandoned mine land
AMLIS	Abandoned Mine Land Inventory System
BFS	bond forfeiture site
CEC	current ecological condition
CFR	Code of Federal Regulation
CSR	Code of State Rules
CTDEP	Connecticut Department of Environmental Protection
CWA	Clean Water Act
CWRA	Cheat Watershed Restoration Authority
DEP	West Virginia Department of Environmental Protection
DLF	dominant limiting factor
EUI	ecounit index
Fe	iron
GHG	greenhouse gas
HEC	historic ecological condition
kg/d	kilogram per day
km	kilometer
gpm	gallon per minute
mg/L	milligram per liter
mL	milliliter
Mn	manganese
NPDES	National Pollutant Discharge Elimination System
NYSDEC	New York State Department of Environmental Conservation
OSM	Office of Surface Mining, Reclamation and Enforcement
PA	problem area
PAD	problem area description
PRC	potential restored condition
REL	relative ecounit index loss
SLF	subdominant limiting factor
SMCRA	Surface Mining Control and Reclamation Act
SS	settleable solid
TBEL	technology-based effluent limitation
TMDL	total maximum daily load
tpy	ton per year
TSS	total suspended solid
uS/cm	microsiemen per centimeter
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
UT	unnamed tributary
WEL	weighted ecounit index loss
WQBEL	water quality–based effluent limitation
WVSCI	West Virginia Stream Condition Index

EXECUTIVE SUMMARY

In March 2001, the United States Environmental Protection Agency released total maximum daily load cleanup plans for 55 segments of the Cheat River and its tributaries. The impaired stream segments in the watershed do not meet water quality standards for pH, iron, aluminum, manganese, and/or zinc due to acid mine drainage from coal mines.

These plans now must be implemented to reduce pollutant loads and clean up impaired streams. When successfully implemented, discharges from specific, regulated point sources as well as nonpoint sources in each polluted subwatershed of the Cheat will meet specified targets. Implementation is likely to proceed very slowly. The fundamental reason is that most pollutant reductions are required of orphan sites that are not subject to permits, and government agencies responsible for remediating these sites do not have adequate funding to make the drastic reductions necessary in the near future. Even if every allocation for permitted sources were implemented immediately, water quality would not improve noticeably.

River of Promise, a collaboration among citizens, organizations, and agencies determined to improve water quality in the Cheat watershed, convened a stakeholder group to find ways to accelerate implementation of this cleanup plan. Trading is one of several policy options that may help jumpstart implementation. If a water quality trading program could facilitate private investment in the remediation of orphan sites, additional funds might be available sooner to help reduce pollutant loads and revitalize the Cheat watershed.

This report summarizes and expands on over two years of discussions that have taken place under a pilot water quality trading project. It includes environmental, economic, and other analyses to support a decision on whether or not a water quality trading program may be helpful in implementing the Cheat total maximum daily load. This report also analyzes key options to help agency staff and local stakeholders understand the implications of several important decisions that ultimately must be made regarding the final details of the trading program.

Among all of the Cheat watershed's environmental stressors, acid mine drainage is the dominant limiting factor. Acid mine drainage is discharged from three categories of coal mines: active operations, abandoned mine lands, and bond forfeiture sites. Although active mines operate under permits and various government funding sources are geared toward orphan sites, these existing water management frameworks are unlikely to result in rapid or complete remediation of the watershed.

Potential credit buyers. For water quality trading to succeed, there must be incentives for private entities to purchase pollution reduction credits. In the Cheat watershed, three initiatives can be considered drivers of the trading process: the Cheat total maximum daily load, West Virginia's antidegradation implementation procedures, and a power plant's desire to cost-effectively meet environmental obligations. The total maximum daily load may provide incentives for active mines to trade by requiring more stringent permit limits. Analysis of discharge monitoring reports, however, suggests that most mines are already meeting these new limits. Antidegradation rules provide incentives for active or new coal mines, or other new facilities, to purchase pollution reduction credits instead of making extra investments onsite to

meet strict permit limits. The desire for a power plant to renew a Clean Water Act Section 316(a) thermal variance provides an incentive to purchase credits to avoid the cost of further reducing thermal pollution.

Potential credit generators. A variety of government agencies, organizations, or private entities may generate acid mine drainage pollution reduction credits by eliminating acid mine drainage sources on abandoned mine lands or bond forfeiture sites, by providing instream treatment, or by reducing discharges on permitted sites below permit limits.

The Cheat Watershed Restoration Authority. A new organization—the Cheat Watershed Restoration Authority—is proposed to manage the credit bank and perform many other tasks that will ensure that trading succeeds in meeting the restoration goals for the watershed. The Authority would help organize and manage Cheat remediation projects on a watershed basis by developing a restoration plan and coordinating funding and program opportunities. As currently envisioned, trading would be but one of its many responsibilities. The Authority's facilitation of the trading process will help ensure that all trades are consistent with the trading framework and the watershed restoration plan, are acceptable to local stakeholders, and take full advantage of the funding sources available for acid mine drainage remediation. If cross-pollutant trading were allowed, the Authority would also facilitate such trades by calculating the cost, on average across the watershed, for treating acidity to allow the watershed to recover. Other calculations would result in equivalencies between acidity, ecounits, and dollars, which would help facilitate cross-pollutant trades.

Geographical restrictions on trades. A final trading framework would have to state whether credits must be generated upstream, or can be generated anywhere in the same subwatershed or anywhere within the entire Cheat watershed. The more relaxed the geographical restrictions, the greater the number of potential trading partners eligible to participate in the program. Conversely, relaxing such restrictions raises additional legal and policy obstacles to the potential implementation of a trading program.

Cross-pollutant trading. A final trading framework would also have to state whether only same-pollutant trades for acid mine drainage pollutants are allowed, or whether cross-pollutant trades within acid mine drainage or cross-pollutant trades outside of acid mine drainage can also be considered. Each type of trade might use a different currency. Same-pollutant trades would likely use pounds of metals as the currency. Cross-pollutant trades within acid mine drainage might use acidity. Because aluminum and iron contribute to acidity, using acidity as a currency, rather than loads of aluminum or iron alone, simplifies a trading scheme. Cross-pollutant trades outside of acid mine drainage might use ecounits, a new unit that allows for the comparison of the effects of different pollutants on the ecological health of a stream. While allowing cross-pollutant trades would result in more possible trades, it would also raise legal and policy issues, including whether or not water quality standards are protected. Allowing cross-pollutant trades would also increase the complexity of administering a trading program and verifying its water quality benefits.

Trading ratios. The Cheat trading framework requires trading ratios to ensure environmental or ecological improvements from each trade and to help account for risk and uncertainty. Although

the framework leaves specific ratios to be determined in the future, it identifies three situations in which ratios will be higher or lower. To encourage trades with less uncertainty, trades in which the credit seller and buyer are in close proximity, and in which the credit seller is upstream, are generally preferred. The framework recommends lower trading ratios for such trades. Second, the framework allows the Authority to adjust trading ratios to favor trades that contribute to strategic watershed restoration goals. In this manner, reduced ratios could be used as incentives to promote the generation of credits in priority locations. Finally, the framework specifies that trading ratios for same-pollutant trades will be lower than those for cross-pollutant trades. Cross-pollutant trades that use a common currency such as ecounits would be measured based on their ecological effect, which is one step removed from the actual changes in pollutant loads. The higher trading ratio required for cross-pollutant trades reflects this greater uncertainty.

An ecological index to facilitate trading. Cross-pollutant trading may be necessary to produce significant improvements in the chemical and ecological condition of the Cheat watershed. A method is developed for assessing the ecological benefits of cross-pollutant trades. The method employs an ecological index that can be used as a common currency when calculating the expected environmental gains and losses of a specific trade. The method also allows for the calculation of pollution/ecological condition/dollar equivalencies. The index is applied to the Cheat watershed to demonstrate its value in assessing a potential thermal for acid mine drainage cross-pollutant trade.

Multiple market environmental trading. In addition to water quality trading, other market-based environmental credit trading programs—both existing and emerging—could be evaluated and encouraged by the Cheat Watershed Restoration Authority to further private investment in Cheat watershed restoration activity. Market-based programs include wetlands mitigation banking, conservation banking, and the emerging market for carbon sequestration. These rapidly evolving and growing environmental commodity programs can provide landowners with economic incentives to offset the adverse environmental impacts of certain activities such as wetland, water quality, and habitat degradation and excess carbon emissions by enhancing and restoring ecosystem functions. Moreover, when developed in combination or "stacked," these multiple market programs may be complementary, with the potential to result in greater net ecosystem improvements more quickly and at less cost.

Absent a water quality trading program, the Cheat cleanup plan is likely to be implemented very slowly. The trading framework developed for the Cheat watershed, if implemented properly, shows promise for increasing remediation investments and improving water quality. As such, trading is one of several policy options that may help jumpstart implementation.

In the Cheat watershed, more research is needed before a trading program can be implemented. In particular, more data are needed, more complete inventories of orphan sites must be developed, and more research must be conducted into the ecological services of small tributaries.

Finally, implementing water quality trading will require action by the state Department of Environmental Protection. Whether Cheat stakeholders propose pilot trades or propose the implementation of the framework as a whole, trading in the Cheat watershed can only proceed with approval and assistance from the agency.

Part I: Background on the Cheat watershed

This report presents a proposed water quality trading program for the Cheat watershed. Part I introduces the watershed and describes the motivation for this trading program. It then provides background on acid mine drainage and other pollution found in the watershed.

1. INTRODUCTION AND OVERVIEW

In March 2001, the U.S. Environmental Protection Agency (USEPA) released total maximum daily loads (TMDLs) for 55 segments of the Cheat River and its tributaries.[1] Located primarily in north-central West Virginia, the Cheat River flows north to the Monongahela River at Point Marion, Pennsylvania, near Morgantown, West Virginia, as shown in Figure 1. The impaired stream segments in the watershed do not meet water quality standards for pH, iron, aluminum, manganese, and/or zinc due to acid mine drainage (AMD) from coal mines. The TMDLs outline pollution reductions for point and nonpoint sources that are necessary to prevent continuing violations of these standards (USEPA, 2001).

Figure 1: The Cheat watershed

This report summarizes over two years of discussions and analyses that have taken place under a pilot water quality trading project funded primarily by USEPA. It includes environmental, economic, and other analyses to support a decision regarding whether or not a water quality

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[1] Although USEPA has committed to reissuing a revised Cheat TMDL, a new version has not been released as of April 2004.

trading program may be helpful in implementing the Cheat TMDL. This report also analyzes key options to help agency staff and local stakeholders understand the implications of several important decisions that ultimately must be made regarding the final details of the trading program.

Appendix A includes a proposed trading framework, developed collaboratively by a local stakeholder group. This framework reflects several recommendations regarding these decisions, but also remains flexible enough that a final framework can be fine-tuned as more local information is gathered and more practical experience with trading programs across the country is collected.

Since 1999, the Cheat TMDL Stakeholder Group has met frequently and has participated in all phases of the TMDL process. Members include representatives of non-governmental organizations (e.g., Friends of the Cheat, the Cheat Lake Environment and Recreation Association), government agencies (e.g., West Virginia Department of Environmental Protection (DEP) Office of Innovation, Division of Mining and Reclamation, and Division of Water and Waste Management), private industry (e.g., Anker Energy, Allegheny Energy, and the recreation and forestry industry), and academia (e.g., West Virginia University professors, researchers, and students).

While early meetings focused on the TMDL development process, in 2001 the group turned to implementation issues. With USEPA support provided in 2002, the stakeholder group has been investigating water quality trading as a potentially powerful element of a successful TMDL implementation strategy.

AMD is the state's most widespread water quality problem: Of the 722 stream segments on West Virginia's 1998 303(d) list, 70% are listed for AMD (DEP, 1998). A large percentage of AMD-impaired segments are also included on the 2002 list (DEP, 2003).[2] Therefore, a trading framework for AMD has the potential for wide applicability in West Virginia as well as in other coal and hard rock mining states. Existing trading programs across the United States typically focus on nutrients and do not address the unique aspects of AMD pollution.

Absent a water quality trading program, the Cheat TMDL and most other AMD TMDLs are likely to be implemented very slowly. The fundamental reason is that most pollutant reductions are required of orphan sites, and government agencies responsible for remediating these sites do not have adequate funding to make the drastic reductions necessary in the near future. Even if the point source TMDL allocations were implemented immediately, water quality would not improve noticeably.

Trading is one of several policy options that may help jumpstart TMDL implementation.[3] If such a program could facilitate private investment in the remediation of orphan sites, additional funds might be available sooner to help reduce pollutant loads and revitalize the Cheat watershed.

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[2] Starting with the 2002 303(d) list, DEP places previously listed waters for which TMDLs have been developed in Supplemental Table B. Many of the state's AMD-impaired streams now appear in this table.

[3] Other options for jumpstarting implementation of the Cheat TMDL include transferring all possible money from the federal AML Trust Fund to West Virginia, allowing more of these funds to be used for water quality

This report is divided into four parts. Part I introduces the Cheat watershed and provides background on AMD and other pollution found in the watershed.

Part II discusses current water quality management efforts in the watershed and considers the potential for water quality trading to succeed. In particular, it enumerates the potential credit buyers and generators in the watershed, as well as the locations on which credits may be generated.

Part III proposes a water quality trading framework that is tailored to AMD and the conditions found in the Cheat watershed. After a brief overview of the kind of trading program envisioned for the Cheat, it introduces the Cheat Watershed Restoration Authority (CWRA), which would play a central role in a successful trading program. Part III then discusses two important decisions that will affect the success of the program: whether or not credits must be generated upstream, and whether or not cross-pollutant trading is allowed. The following section outlines several considerations regarding trading ratios. Part III then provides a detailed analysis of ecounits, a currency proposed to quantify and administer cross-pollutant trades. Finally, the trading discussion is broadened to consider what role multiple market environmental trading can play to provide further incentives for remediating the Cheat watershed.

After the conclusions and recommendations in Part IV, Appendix A presents the consensus-based pollutant trading framework developed by the Cheat TMDL Stakeholder Group. Appendix B places the Cheat framework within the context of USEPA's trading policy and statewide and regional water quality trading policy development processes. Appendix C discusses several trading programs across the United States, and highlights important lessons learned from each.

Appendix D presents a detailed economic analysis of the Cheat trading framework. After providing the economic rationale for such a system, a model is developed and applied to the Cheat watershed.

Finally, Appendix E presents the results of a trading scenario run through a dynamic water quality model. These results confirm that certain trades would, indeed, improve water quality as envisioned by the trading framework.

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improvements, adequately funding the state's Special Reclamation Fund so that it is sufficient to clean up all bond forfeiture sites, aggressively targeting Clean Water Act Section 319 funds toward acid mine drainage remediation, and ensuring that all remediation projects are designed to meet water quality standards.

2.   THE SETTING

The Cheat River[4] is one of the larger tributaries to the Monongahela River, which, with the Allegheny River, forms the Ohio River in Pittsburgh, Pennsylvania. Its watershed—1,426 square miles—is located almost entirely in West Virginia, although 7% lies in Pennsylvania and a small fraction is in Maryland.

As shown in Figure 2, two major branches meet in Parsons to form the Cheat River: Shavers Fork flows north-northwest from Pocahontas County, and the unlabeled Black Fork gathers several smaller tributaries (Blackwater River, Dry Fork, Laurel Fork, Glady Fork, and Red Creek) from Tucker and Randolph Counties. The mainstem of the Cheat River flows north 84 miles from Parsons to its confluence with the Monongahela River at Point Marion, Pennsylvania, just north of the border with West Virginia. The river is dammed a short distance upstream from its mouth to form Cheat Lake, also known as Lake Lynn. Upstream from Cheat Lake, the Cheat is advertised as the largest uncontrolled watershed in the eastern United States by whitewater guide companies (Canaan Valley Outfitters, 2003).

Both Shavers Fork and the five major tributaries that form the Black Fork rise in sparsely settled mountainous terrain, much of which is part of the Monongahela National Forest. Four of the five federally designated wilderness areas in the forest lie within the Cheat watershed.

The sparsely populated and very rural Cheat watershed has no major population centers. Incorporated towns in the watershed include Kingwood, the Preston county seat (population 2,944); Parsons, the Tucker County seat (population 1,463); as well as Terra Alta (1,456), Rowlesburg (613), parts of Tunnelton (336), Albright (247), and Bruceton Mills (74) (U.S. Census Bureau, 2003). Many of these towns are shown in Figure 2.

About 16% of the total population of 45,970 lives in Pennsylvania. The overall population density is just over 32 persons per square mile based on the 2000 Census. Overall, using block level information from the 2000 Census, 25% of the population lives on less than 5% of the land, which lies within most of the towns in the watershed. The density then decreases quickly: 50% of the population lives on 25% of the watershed area. A significant portion of the watershed is very sparsely populated. In total, 99% of all inhabitants are found on 70% of the land area. This implies a population density of about one person per square mile in the least densely populated 30% of the watershed. By any measure, the Cheat watershed is an extremely rural landscape with a significant portion of the population scattered in individual homes or small communities. Figure 3 provides a graphical representation of the population density.

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[4] The Cheat watershed is hydrologic unit code 05020004.

Figure 2: Major subwatersheds and towns in the Cheat watershed
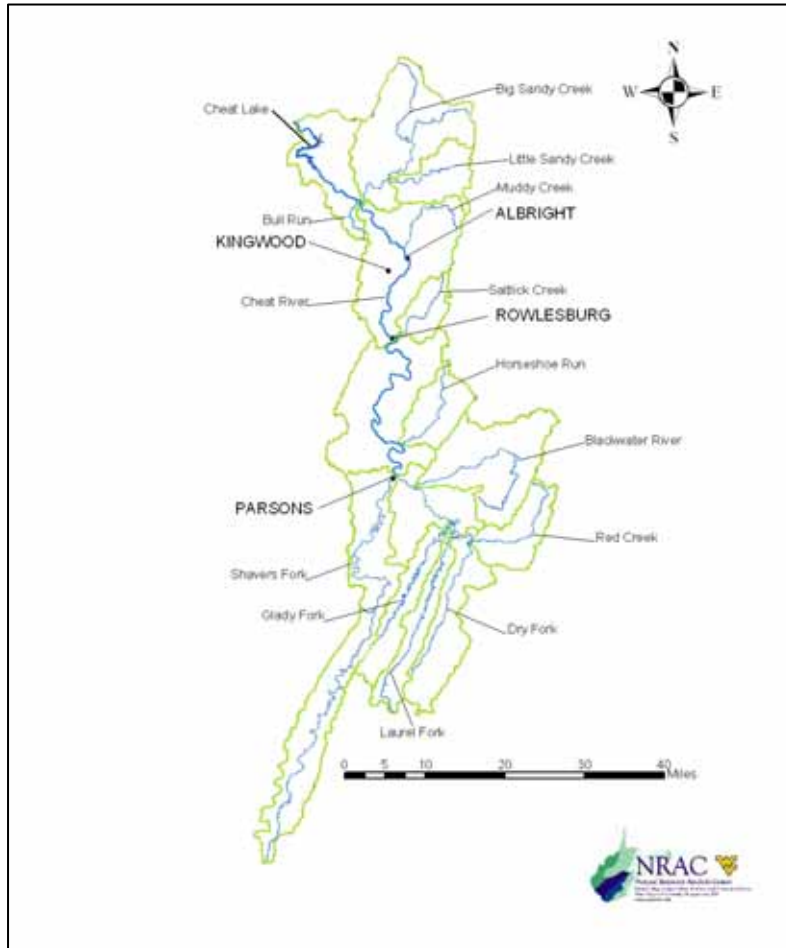
2.1. Geology

The entire watershed is underlain by Devonian, Mississippian, and Pennsylvanian strata, which were formed in sediments washed down from ancient mountain ranges to the east (WVGES, 1968). Coal is found only in the Pennsylvanian strata in this region. Pennsylvanian rocks underlie the northern third of the watershed—the lower Cheat watershed—and a band through the southern part of the watershed, including roughly the Shavers Fork and North Fork of the Blackwater watersheds. Although some coal mining has occurred in the Shavers Fork watershed, most of the impact of coal mining occurs in the lower Cheat subwatersheds and in the North Fork of the Blackwater River subwatershed (OSM, 2003).

The Allegheny Formation contains the coals most frequently mined in the Cheat watershed, including the Kittanning (Lower, Middle and Upper) and Freeport (Lower and Upper) seams. Bakerstown coal is mined from the Conemaugh Group in the lower Cheat subwatersheds. The Monongahela Group contains the Pittsburgh coal, which is mined from the western border of the northernmost end of the watershed, especially to the west of Cheat Lake (WVGES, 2002a).

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Figure 3: Cheat watershed population density

All of these coals contain approximately 3% sulfur. Pyritic sulfur values[5] range from approximately 0.5% in Pittsburgh coals to 2% in the Upper Freeport, which is the coal seam most frequently associated with serious AMD problems (WVGES, 2002b). The Upper Freeport coal is also surrounded by rock strata with little potential for buffering acid production. AMD from Bakerstown coal, on the other hand, is often managed using rock from a limey shale layer that overlies the coal seam (Skousen et al., 2002).

2.2. Land use/land cover

As shown in Figure 4 and Table 1, the Cheat watershed is primarily forested. Together, forested, pasture/grassland, and shrubland make up 95% of the total land area in the watershed. Mined land, the source of AMD, accounts for just over 1% of the total (U.S. Geological Survey, 1992). While this is an underestimate as reclaimed sites may now be classified as forested or pasture/grassland, it suggests the relatively small percentage of land area that is contributing to AMD-related water quality problems.

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[5] Sulfur in coal may be in the form of pyrite, or in other forms that are not associated with the production of AMD.

Figure 4: Land use/land cover in the Cheat watershed

Source: U.S. Geological Survey, 1992.

Table 1: Land cover summary for the Cheat watershed

Land cover	Area (mi^2)	Percent of watershed
Forested	1,135.1	80.0%
Pasture/grassland	184.8	13.0%
Shrubland	25.9	1.8%
Wetland	22.4	1.6%
Surface water	18.4	1.3%
Mined	15.2	1.1%
Urban developed	10.2	0.7%
Row crop agriculture	4.0	0.3%
Barren	3.4	0.2%
Total	1,419.4	100.0%

Source: U.S. Geological Survey, 1992.

2.3. Aquatic resources

Although less diverse than the fish fauna of southern Appalachian watersheds, more than 30 species are known to inhabit streams of the Cheat watershed. The cleanest, highest-elevation

tributaries have self-sustaining populations of the region's only native trout species: brook trout (*Salvelinus fontinalis*). Many other streams contain stocked rainbow and brown trout. Larger and lower-elevation streams support various eurythermal and warm-water fish species, including creek chubs, stonerollers, numerous minnows (*Notropis spp.*), blacknose and longnose dace, white suckers, hognose suckers, fantail and greenside darters, bluegills, redbreast sunfish, and smallmouth bass.

AMD pollution, described in Section 3, decimates fish communities through several mechanisms. First, AMD changes the pH of streams to levels that harm or eliminate fish. Hydroxides that form as AMD is neutralized can interfere with biological processes in stream sediments, by cementing particles to the stream bottom or by filling in the interstices among particles on the bottom. The destruction of the streambed eliminates habitat for benthic invertebrates, an important part of the food web (e.g., Kondolf, 2000). AMD also often adds aluminum to the water column. In its monomeric form, this element has been shown to decrease fish growth and reproduction at low concentrations (Jordahl and Benson, 1987).

2.4. Economy

Coal mining in Preston County, which contains most of the AMD problems in the watershed, started at the beginning of the twentieth century. The first reports of mining activity from Preston County to the Division of Mines were from the Tunnelton area. A mining boom followed the spread of railroads along the Cheat River. During this period, coal mining and related services employed a large portion of the population in the coal-mining regions.

Coal production peaked once during World War II and remained strong in the 1950s and 1960s. Since then, the thin, sloped seams of Preston County have competed poorly with thicker, flatter seams further south in the state, as well as those in the western United States. As DEP stopped most permitting of acid-producing coal seams with long-term treatment liabilities in the 1990s, it became more difficult to obtain permits to mine the Upper Freeport seam in Preston County. Also, as a result of the Clean Air Act, West Virginia mining has generally shifted from the Cheat watershed and other nearby areas, where high-sulfur and relatively low-energy coal are typically found, to West Virginia's southern coalfields.

Allegheny Power operates a coal-fired power plant in Albright, on the Cheat River. Other large employers in Preston County include the Preston County Board of Education, hospitals (Preston Memorial Hospital and Hopemont State Hospital), a coal mining company (Coastal Coal West Virginia), small manufacturers (Hollinee, a maker of fiberglass air filters, and Matthews International, a maker of gravestones and caskets), and wood products companies (Allegheny Wood Products and Coastal Lumber Company). There are no employers with more than 250 employees, and only eight with 100 or more employees (PCEDA, 2003). A thriving white-water rafting tourism industry brings tourists to the region.

Preston County has developed into a bedroom community for surrounding areas. The 2003 County Data Profiles developed by the Bureau of Business Research at West Virginia University provide a summary of Preston County economic conditions (Bureau of Business Research, 2003). Less than 55% of employed residents of Preston County actually work in Preston County. Nearly 27% work in nearby Monongalia County, West Virginia while the remaining 19%

primarily work in a number of surrounding counties in Maryland, Pennsylvania, and West Virginia. Conversely, fewer than 19% of workers in Preston County commute in. While the local economy is not strong, unemployment is relatively low. In 2001, the 4.6% unemployment rate in Preston County was lower than that for the state (4.9%) or the nation (4.7%). Income levels, however, paint a somewhat different picture. The 2001 per capita personal income of Preston County residents was $17,998, only 78% of the state average of $22,862 and 59% of the national average, $30,413.

In summary, the mining industry, historically the source of most high paying private sector jobs, has declined significantly during the 1990s. The 2001 data indicate that the mining sector provided 381 jobs, both full- and part-time. This is less than one-third of the employment in this sector throughout the 1980s. In addition, relatively few of these jobs are in direct production positions. Preston County residents are increasingly working outside the county. Employment is relatively high but increasingly concentrated in low paying occupations, resulting in a low overall standard of living.

3. ACID MINE DRAINAGE: THE DOMINANT LIMITING FACTOR

The concept of a stream's or a watershed's dominant limiting factor (DLF) is crucial to the proposed Cheat trading framework, because it is envisioned that trades would by and large target improvements in the DLF. A DLF is any physical, chemical, or biological factor that causes a significant ecological impact.

DLFs are scale dependent. At the reach scale, there usually is only one DLF, even though multiple factors may interact to influence ecological condition. This is because one factor will usually override the effect of other factors. At the reach scale, the DLF is any factor that, if removed, would improve the ecological condition by 10% or greater.

At the watershed scale, there may be multiple DLFs. It is proposed that, at the watershed scale, a DLF is any factor that is responsible for more than 20% of the ecological loss in the watershed. A factor causing measurable loss, but loss less than 20% of the total loss, is called a subdominant limiting factor (SLF). Watershed-scale SLFs may be reach-scale DLFs. Also, whole watershed SLFs may be subwatershed-scale DLFs.

To illustrate these concepts, Table 2 shows DLFs and SLFs for several scales in the Cheat watershed. AMD is by far the DLF in the entire Cheat watershed, and is also the DLF at several subwatershed scales and for many river reaches. However, in some locations, such as the Cheat River from Albright to Muddy Creek, other DLFs cause more significant ecological impacts..

In a watershed suffering from such a variety of environmental stresses, DLFs and SLFs can be used to ensure that trades improve the watershed in the most important ways. For example, if cross-pollutant trades are allowed, such trades could be required to target factors that are DLFs at the whole-watershed scale. In other words, because AMD is the Cheat watershed's most significant DLF, it could be required that all cross-pollutant trades must produce a net reduction in AMD.

As shown in Figure 5, 55 AMD-impaired stream segments in the Cheat watershed were listed on West Virginia's 1998 303(d) list, the list used as a basis for the Cheat TMDL (DEP, 1998). Many actions and policies are responsible for the widespread, severe degradation of the Cheat watershed. Operators of old coal mines before the 1977 Surface Mining Control and Reclamation Act (SMCRA) did not typically reclaim their sites to current standards. Policies implemented as a result of SMCRA—to clean up mines abandoned before and since the law was enacted—have not worked. And until recently, the West Virginia DEP has not generally assigned strict water quality–based effluent limitations (WQBELs) to coal mines, even when they discharge to impaired streams.

Table 2: Dominant and subdominant limiting factors at various scales in the Cheat watershed

Scale	Dominant limiting factor	Subdominant limiting factor
Watersheds		
Cheat watershed	AMD (70%) Acid precipitation (20%)	Sedimentation (1%) Channel alteration (1%) Fecal coliform (3%) Thermal effluent (5%)
Shavers Fork subwatershed	Acid precipitation (90%)	Sedimentation (2%) Channel alteration (2%) Fecal coliform (6%)
Dry Fork subwatershed	Acid precipitation (90%)	Sedimentation (2%) Channel alteration (2%) Fecal coliform (6%)
Blackwater subwatershed	AMD (90%)	Sedimentation (2%) Channel alteration (2%) Fecal coliform (6%)
Lower Cheat subwatershed	AMD (85%)	Sedimentation (2%) Channel alteration (2%) Fecal coliform (3%) Thermal effluent (8%)
Muddy Creek subwatershed	AMD (65%) Acid precipitation (20%)	Fecal coliform (12%) Channel alteration (3%)
Stream reaches		
Cheat: Lower mainstem	AMD (88%)	Thermal effluent (12%)
Cheat: Pringle Run to Albright	AMD (100%)	
Cheat: Albright to Muddy Creek	Thermal (75%) AMD (25%)	
Shavers: Upper mainstem	Acid precipitation (50%) Channel alteration (40%)	Sedimentation (10%)

Source: Estimates by Petty.

The impact of AMD can be evaluated using chemical or biological data. DEP used chemical data— pH and iron, aluminum, manganese, and zinc concentrations—to qualify stream segments for the 1998 303(d) list.

Biological data, including indices of fish and benthic macroinvertebrate communities, can also be used. DEP uses an index of stream health, based on benthic macroinvertebrate communities, to evaluate the ecological condition of streams in the Cheat watershed and watersheds throughout the state (DEP, 1999; USEPA, 2000a). As discussed in detail in Section 13 (See, for example, Table 20), these communities are extremely unhealthy in the parts of the Cheat watershed most impacted by AMD.

Figure 5: AMD-impaired streams in the Cheat watershed
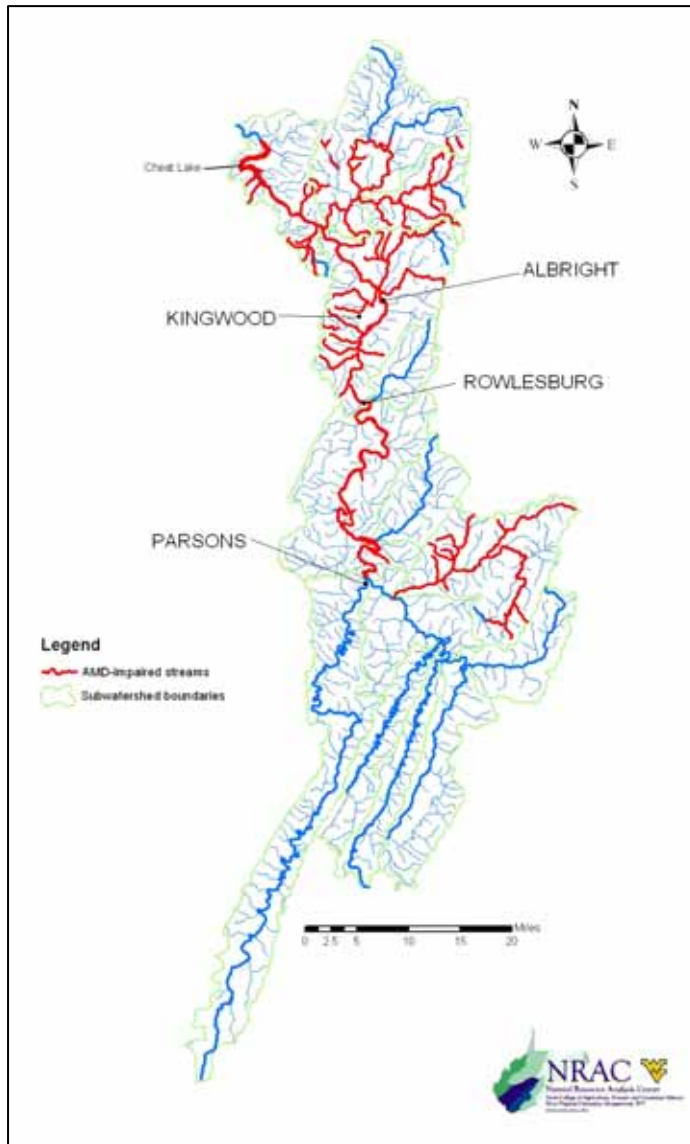
3.1. The science of acid mine drainage

As illustrated in Equations 3.1 through 3.4 (Stumm and Morgan, 1996), AMD is generated when minerals disturbed during coal extraction, especially pyrite, come in contact with air and water. Sulfur in these minerals oxidizes and becomes sulfuric acid. This acidic solution dissolves the metals, usually iron and manganese, that formed the sulfide mineral and can dissolve additional metals, such as aluminum, from soil and rock that the solution contacts. The acidity often causes receiving streams to violate the pH water quality criteria. In addition, AMD-impacted streams often have aluminum and iron concentrations that violate criteria protecting aquatic life, and iron and manganese concentrations that violate public water supply criteria. A further environmental harm from AMD occurs when iron and aluminum settle out and coat stream beds, harming aquatic habitat.

$$FeS_2 + 7/2\ O_2 + H_2O = Fe^{2+} + 2\ SO_4^{2-} + 2\ H^+ \tag{3.1}$$
$$Fe^{2+} + 1/4\ O_2 + H^+ = Fe^{3+} + 1/2\ H_2O \tag{3.2}$$
$$Fe^{3+} + 3\ H_2O = Fe(OH)_3 + 3\ H^+ \tag{3.3}$$
$$FeS_2 + 14\ Fe^{3+} + 8\ H_2O = 15\ Fe^{2+} + 2\ SO_4^{2-} + 16\ H^+ \tag{3.4}$$
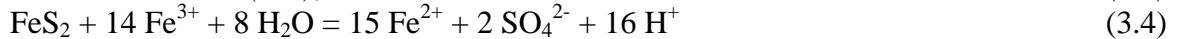
While these AMD pollutants are regulated by different criteria, their chemical similarities and differences are important when considering the possibility of cross-pollutant trades (see Section 11). Iron and aluminum do not remain dissolved in streams that satisfy West Virginia's pH criteria.[6] Aluminum combines with hydroxide ions and precipitates from streams with pH above about 5.5. Iron in the ferric state (Fe^{3+}) precipitates from solutions with pH above about 4.5. Therefore, one single chemical treatment, the addition of alkalinity to water, has the potential to remove both pollutants.

On the other hand, as these metals combine with hydroxide, they release H^+, or acid, back to streams. These relationships complicate the water quality modeling necessary for predicting the results of specific remediation measures, including those involved in trades. Concentrations of metals will not change according to simple mixing: dilution of acidic, metal-laden waters may raise pH enough that metals precipitate from solution. Acidity, a quantity not regulated by the TMDL, should be conserved.

Manganese loads are also addressed by the Cheat TMDL. Removal of manganese from AMD, however, is more difficult than removal of iron and aluminum. Removal of iron and manganese have many similarities. Both metals are present in AMD mostly in reduced forms (Fe^{2+} and Mn^{2+}). Both of these metals in their reduced form require very high pH values before they precipitate from solution (pH above 8 to 12, depending on carbonate concentration). At these high pH levels, aluminum becomes soluble again. Furthermore, iron and manganese, if allowed to oxidize, precipitate at lower pH values. Oxidized iron (Fe^{3+}) precipitates at pH values much lower than circumneutral (below 4.5), whereas oxidized manganese (Mn^{4+}) precipitates at circumneutral pH values. At circumneutral pHs, oxidation of iron is more rapid than oxidation of manganese, making it more difficult to remove manganese. Passive systems designed to remove manganese usually require feed water from which all aluminum, iron, and acidity have been removed. Because of slow oxidation rates and the need for clean feed water, removal of manganese from water with all three metals will usually require a second settling pond or leach bed.

AMD is discharged from three categories of coal mines—active permitted operations, abandoned mine lands (AMLs), and bond forfeiture sites (BFSs)—to the Cheat River and its tributaries. These three sources are introduced in turn below.

3.2. Permitted coal mines

The Cheat watershed contains more than 100 permitted coal operations.[7] These operations are concentrated in two regions: the lower Cheat subwatersheds and the Blackwater River

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[6] Exceptions include iron or aluminum complexed by organic matter or by inorganic "ligands," or in polymeric forms, which are rare at low concentrations, and may be transient steps during the formation of precipitates.

[7] Coal operations are assigned two different types of permits: NPDES permits and mining permits. The inventory of NPDES permits in the Cheat watershed was compiled from a number of sources. First, Appendix B of the TMDL

subwatershed. Figure 6 shows the locations of permitted outlets from coal mining operations that are targeted for pollutant reductions by the TMDL in the lower Cheat and Blackwater subwatersheds.

Clean Water Act (CWA) National Pollutant Discharge Elimination System (NPDES) permits for most of these operations limit discharges of iron and manganese, and require pH to be within an acceptable range. Some permits also limit the discharge of aluminum. Section 5.1 discusses these permit requirements in detail. As discussed in Section 6.1, the Cheat TMDL targets 21 of these permits with stricter wasteload allocations, which may provide operators with the incentive to engage in a water quality trading program to buy credits rather than making pollutant reductions onsite.

SMCRA mining permits are also required for each mine. Mining permits do not contain numeric effluent limitations, but they require, among other things, that operators plan in advance for reclamation of water quality problems.

3.3.   Abandoned mine lands

Polluted water flows from a number of features at AMLs. The largest flows are probably from underground mines, either through abandoned, collapsed, or sealed portals or through blowouts, where water pressure has broken out the mine wall where there was no portal. Unpolluted surface water may also flow through piles of refuse or spoil and become polluted.

There is no up-to-date, complete list of water quality issues on AMLs in the Cheat watershed. For each site, DEP collects data and information on problem area descriptions (PADs). But these PADs do not necessarily include careful estimates of water flow and pollutant loads.[8] Even though they are not well catalogued, certain sites are well documented by DEP, which regularly collects water quality data at AMLs.[9]

Despite this uncertainty, it is known that AMLs with water quality problems abound in the lower Cheat subwatersheds and in the Blackwater River subwatershed (Figure 7). Although the exact number of AMLs are not known, the federal Abandoned Mine Land Inventory System (AMLIS) references 245 sites in the Cheat watershed, including 57 with water quality problems.

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lists a number of mining and corresponding NPDES permits (USEPA, 2001). Second, Appendix D of the TMDL identifies a number of mining permits that contribute pollutants to the Cheat River system, but are not mentioned in Appendix B (USEPA, 2001) Third, DEP maintains a geographical information system file at www.wvdep.org/data/vector/npdes.zip of NPDES permits related to mining, which includes records omitted from other sources. Finally, DEP maintains Internet query services, which provide location information for permitted mines (www.wvdep.org/WebApp/_dep/search/Permits/Omr/Permitsearchpage.cfm?office=OMR) and for outfalls of many mining-related NPDES permits. (www.wvdep.org/WebApp/_dep/search/Permits/HPU/ HPUPmtsearchpage.cfm?office=HPU). DEP provides spatial information on a set of 62 NPDES permits related to mining operations. The Cheat TMDL lists 104 such permits. Only 43 of the permits were in both sets.
[8] OSM now requires state AML programs to enter PADs for Priority 1 and 2 sites into the national, Internet-linked AMLIS. However, designation of water quality problems as a high priority (Priority 2) and their addition to AMLIS is optional; therefore, the list of AMLs with AMD may not be complete.
[9] The Stream Restoration Group within the DEP's Office of Abandoned Mine Lands collects these data.

Figure 6: Mining NPDES permits targeted by the TMDL in lower Cheat and Blackwater subwatersheds
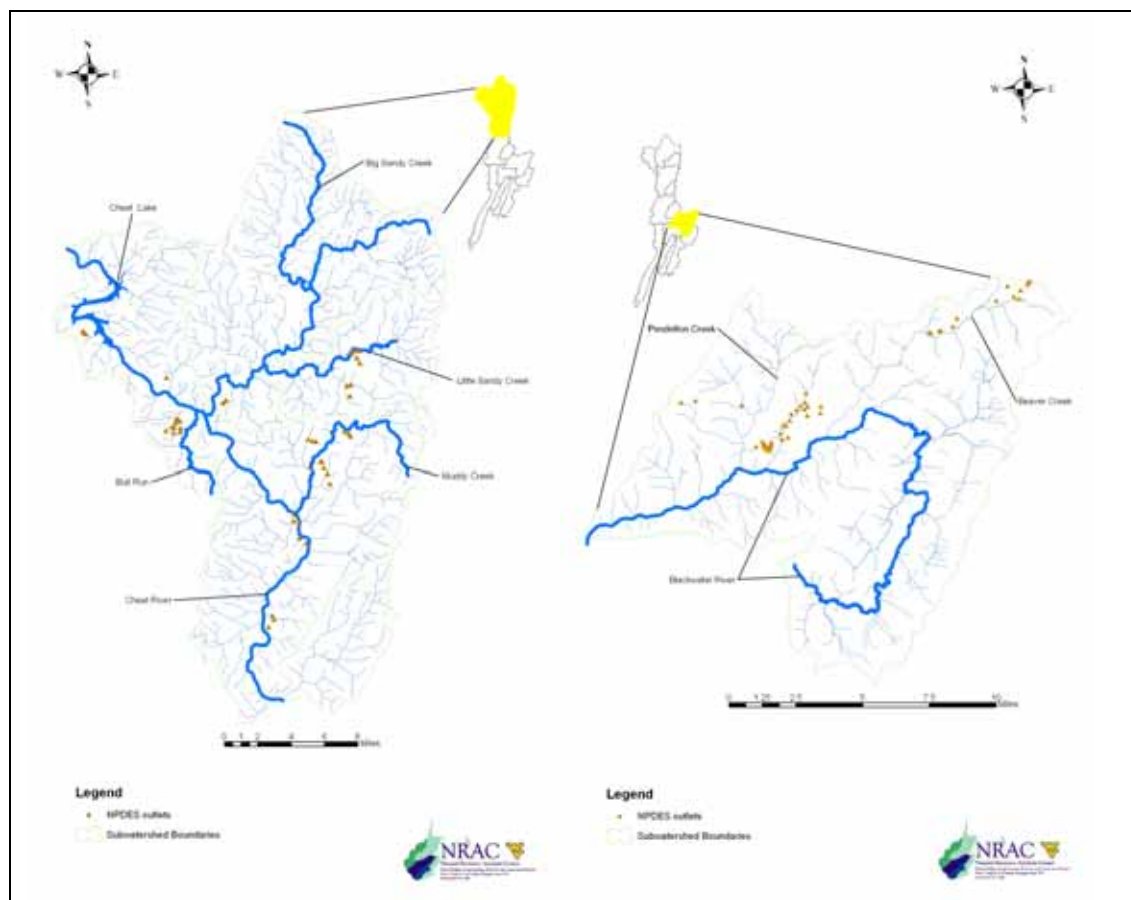
In AMLIS, more than one complaint can be filed on a single site. Of the 506 AMLIS complaints[10] in the Cheat watershed, 173 have been addressed through projects valued at approximately $29.5 million in total. Costs of needed projects addressing 294 additional complaints are estimated to be $161 million. $4.4 million worth of projects addressing an additional 21 complaints are funded, but are not yet completed. Of the 59 complaints that identify water quality problems, projects have been completed that address 15 of them at a cost of $31.6 million. Projects addressing an additional three complaints are funded at a cost of $409 thousand. Estimates for addressing the remaining 41 complaints total $55.9 million.

Typically, passive AMD treatment systems are used at these sites. Average costs of these systems are presented in Table 3. These systems are designed mainly to treat acidity in the water, and thereby also remove aluminum and iron from solution. Passive treatment systems that also remove manganese have generally not been installed at AMLs because of the added expense.

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[10] AMLIS is a database of complaints. A single AML site may have more than one complaint, and may therefore have more than one record. Examples of complaints include "highwall;" "dangerous highwall;" and "polluted water, agriculture and industrial."

Figure 7: AMLs with water quality problems in lower Cheat and Blackwater subwatersheds

Table 3: Average costs of passive AMD treatment systems

System type	Average total cost ($)	Average acid treated (tpy)	Average cost ($/ton)
Anoxic limestone drain	36,744	24.5	75
Open limestone channel	27,409	10.9	126
Limestone leach bed	68,997	18.3	189
Vertical flow wetland	51,151	11.1	230
Anaerobic wetland	126,110	13.1	481

Source: Ziemkiewicz et al., forthcoming. Average costs are 20 year life-cycle costs.

Because of the large backlog of complaints of various kinds that need to be addressed, DEP may not be able to address all water quality complaints in the foreseeable future. Many sites have not been reclaimed at all, and sites that have been reclaimed often still leak AMD and contribute to violations of water quality standards. At many sites, data are lacking and it is difficult to determine exactly what remains to be done. Table 4 lists AMLs with known water quality problems.

Table 4: AMLs with water quality problems

Name	PAD	County	Watershed
Albert Highwall #1	WV001622	Tucker	North Fork Blackwater River
Beaver Creek/Auman Road AMD	WV005784	Preston	Little Sandy
Benson Highwall #20	WV002682	Preston	Muddy Creek
Big Knob Highwall	WV002491	Randolph	Shavers Fork
Blackwater Manor	WV000004	Tucker	North Fork Blackwater River
Blaser Refuse & Portals	WV001829	Preston	Pringle Run
Blazer Portals	WV001063	Preston	Pringle Run
Borgman Highwall	WV003488	Preston	Heather Run
Bull Run #27	WV001764	Preston	Bull Run
Bull Run #35	WV001765	Preston	Bull Run
Bull Run PA #37	WV001756	Preston	Bull Run
Camp Ground Refuse And Portal	WV001059	Preston	Pringle Run
Cheat Bridge #2	WV003744	Randolph	Shavers Fork
Cherry Run #3	WV000854	Preston	Little Sandy
Church Creek Highwall	WV001056	Preston	Morgan Run
Davidson Highwall	WV003912	Monongalia	Cheat Lake Area
Douglas Highwall #2	WV001623	Tucker	North Fork Blackwater River
Fickey Run Portals & Refuse	WV001760	Preston	Muddy Creek
Fort Milroy #2	WV003746	Randolph	Shavers Fork
Glade Run (AMD) II	WV000340	Preston	Muddy Creek
Greens Run Refuse & AMD	WV001048	Preston	Greens Run
Heather Run Area #2	WV001058	Preston	Heather Run
Hopkins Deep Mine	WV005414	Randolph	Shavers Fork
Howesville Site	WV001548	Preston	Lick Run
Jessop Highwall #10	WV002412	Preston	Pringle Run
Jessop Portals #1	WV003056	Preston	Pringle Run
Jessop Portals #2	WV003058	Preston	Pringle Run
Jessop Strip #2	WV001698	Preston	Pringle Run
Jessop Strip #4	WV001546	Preston	Pringle Run
Kingwood (Pace) Portals	WV001064	Preston	Greens Run
Lake Lynn Complex	WV003940	Monongalia	Cheat Lake Area
Lawson Highwall #35	WV003067	Preston	Muddy Creek
Lick Run #2	WV001822	Preston	Lick Run
Lick Run Portal #4	WV001820	Preston	Lick Run
Livengood Highwall & AMD	WV005150	Preston	Little Sandy
Livengood Water Supply	WV004915	Preston	Little Sandy
Long Run	WV000003	Tucker	North Fork Blackwater River
Martin Creek Refuse	WV004542	Preston	Muddy Creek
Masontown #4	WV002821	Preston	Bull Run
Masontown Refuse & Portal	WV004912	Preston	Bull Run
McCarty Highwall	WV005821	Preston	Little Sandy
Middle Fork Greens Run	WV001815	Preston	Greens Run
Morgan Run PA #2	WV001770	Preston	Morgan Run
Philip Thorn Highwall & Portals	WV002745	Preston	Lick Run
Point Marion Maintenance	WV000219	Monongalia	Cheat Lake Area
Pringle Run PA #2	WV001817	Preston	Pringle Run
Red Run/Stonecoal	WV002267	Randolph	Shavers Fork
Roaring Creek #2	WV001039	Preston	Roaring Creek
Rosati Mine Drainage/Herring Complex	WV001755	Preston	Bull Run
Skidmore Site (Canyon Mine) Maintenance	WV002977	Monongalia	Cheat Lake Area
South Fork Greens Run #2	WV001814	Preston	Greens Run
Sovern Run Mine Drainage	WV005112	Preston	Big Sandy
Sovern Run Site #62 AMD	WV005785	Preston	Big Sandy
Tub Run Strip	WV001752	Tucker	Blackwater River
Valley Point Portals & Drainage	WV005056	Preston	Muddy Creek
Webster Refuse	WV002509	Preston	Little Sandy
Webster Run Portal & AMD	WV005157	Preston	Little Sandy

Source: OSM AMLIS Query, October, 2003. Note: The query retrieved all AML sites in West Virginia for which "PWAI" and "WA" complaints were recorded. Sites within the Cheat watershed were selected using ArcView. Four sites were excluded. WV003549 refers to a creek in the Tygart watershed. WV004011 (Muddy Creek) and WV003925 (Blackwater River) refer to watersheds that have become AML projects, rather than actual AML sites. A second location with the PAD WV003549 was also excluded: it is a limestone drum station in the Blackwater watershed, and not an actual mine site. Three additional sites were added based on data from DEP.

Table 5: Extreme values characterizing AMD samples from AMLs

Site	PAD	Measurement	Value	Year	Subwatershed
Point Marion Maintenance	WV000219	pH	2.3	1998	Cheat Lake
Point Marion Maintenance	WV000219	Conductivity	5,160 uS/cm	1996	Cheat Lake
Lick Run #4	WV001820	Sulfate	3,495 mg/L	2000	Lick Run
Masontown #4	WV002821	Iron	640 mg/L	1980	Bull Run
Sovern Run Mine Drainage	WV005112	Aluminum	160 mg/L	1997	Big Sandy
Rosati Mine Drainage	WV001755	Manganese	48 mg/L	1998	Bull Run

Source: DEP Office of Abandoned Mine Lands, Stream Restoration Group.

Table 6: Summary of AMD data at selected AMLs

Subwatershed/Site	PAD	Flow (gpm)	Concentration (mg/L) Alum.	Iron	Mang.	Load (tpy) Alum.	Iron	Mang.	No. samples
Little Sandy Creek									
McCarty Highwall	WV005821	122.2	0.4	0.3	0.5	0.1	0.1	0.1	34
Auman Road	WV005784	580.5	4.9	1.6	2	6.3	2.0	2.6	5
Sovern Run site #62	WV005785	101.4	22	25.9	5.2	4.9	5.8	1.2	48
Muddy Creek	N/A	59.3	14.4	8.9	6.3	1.9	1.2	0.8	7
Greens Run									
Middle Fork	WV001815	1754	48.6	120.7	4.8	187.5	465.8	18.5	11
North Fork	N/A		8.8	110.8	328.9	16	2.2	6.4	0.3	13

Source: West Virginia Water Resources Institute, unpublished data. Note: No PADs match the Muddy Creek site or the North Fork Greens Run sites.

Table 7: Acid load reductions at AMLs

Site	Pre-treatment Flow (gpm)	Acidity (mg/L)	Acid load (tpy)	Post-treatment Flow (gpm)	Acidity (mg/L)	Acid load (tpy)	Acid load Treated (tpy)	Percent change
Cherry Run #3	118.8	479.1	78.5	118.8	99.2	36.0	42.5	-54%
Douglas Highwall	174.8	259.8	76.4	174.8	80.6	45.6	31.3	-40%
Martin Creek	50.4	-46.1	121.8	50.4	-43.4	119.3	2.6	-2%
Masontown #4	28.2	848.9	57.3	28.2	727.1	50.5	6.8	-12%
Rosati Mine Drainage	19.7	1,077.9	25.1	13.4	331.4	3.8	21.3	-85%
Sovern Run Portal	175.0	212.6	71.9	175.0	140.9	47.8	24.1	-34%
Webster Refuse	41.0	131.2	11.8	43.2	-56.9	-7.0	18.8	-159%

Source: Ziemkiewicz et al., forthcoming. Note: Some of these treatment systems likely do not currently achieve the levels of treatment shown in this table. Acid inputs vary over time and performance of treatment measures may decrease over time.

At some sites, periodic sampling has been sufficient to characterize flows, concentrations, and loads. Table 5 summarizes the most extreme values found at AMLs in the Cheat watershed, and Table 6 summarizes monitoring data at selected sites that have been monitored relatively frequently. Table 7 shows acid load reductions at selected AMLs in the Cheat watershed for which remediation has begun.

As discussed at the start of Section 5, most pollutant reductions called for in the Cheat TMDL are assigned to orphan sites, which include AMLs. Although the TMDL does not target specific sites, it outlines reductions for each subwatershed, and these reductions often approach 100%. AMLs are prime sites on which pollutant reduction credits may be generated in a water quality trading program.

3.4. Bond forfeiture sites

Figure 8 shows the locations of most known BFSs with water quality problems in the Cheat watershed,[11] which are concentrated in the lower Cheat subwatersheds. Unlike permitted operations and AMLs, no BFSs are located in the Blackwater subwatershed. Table 8 lists these sites, along with their original mining permit number, county, and receiving stream.

Figure 8: BFSs with water quality problems in lower Cheat subwatersheds
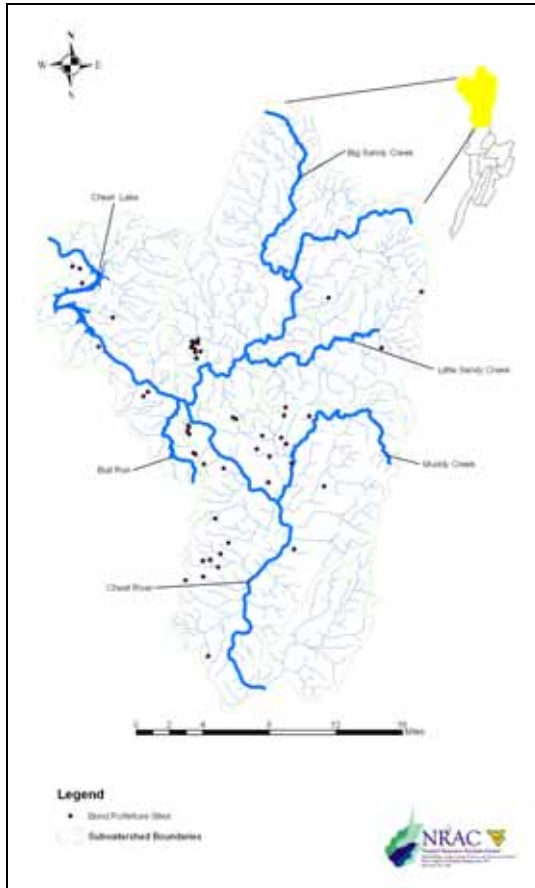
Note: No BFSs with water quality problems are located in the Blackwater subwatershed

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[11] Two permitted mining operations in the Cheat watershed forfeited their bonds while this study was taking place, thus decreasing the number of NPDES permittees and increasing the pool of BFSs.

Table 8: BFSs with water quality problems in the Cheat watershed

Company	Mining Permit	County	Receiving stream
Alan Blosser	S-1010-87	Monongalia	Cheat Lake
Bjorkman Mining Co.	S-37-81	Preston	Morgan Run
Bolingreen Mining Co.	S-1024-88	Preston	Beech Run
Borgman Coal Co.	EM-32	Preston	Heather Run
Crane Coal Co., Inc.	S-27-83	Preston	Glade Run of Martin Creek of Muddy Creek
Daugherty Coal Co.	124-79	Preston	UT Cheat River
Daugherty Coal Co.	17-81	Preston	Bull Run
Daugherty Coal Co.	192-77	Preston	Gum Run and Bull Run
Daugherty Coal Co.	246-74	Preston	UT Cheat River
Daugherty Coal Co.	65-77	Preston	UT Cheat River
Daugherty Coal Co.	S-1009-86	Preston	Gum Run and Bull Run
Daugherty Coal Co.	S-73-83	Preston	UT Cheat River
Edward E. Thompson	S-1041-89	Monongalia	Cheat Lake
F & M Coal Co.	46-79	Preston	Ashpole Run
F & M Coal Co.	S-1026-87	Preston	Hogback & UT Cheat River
Farkas Coal Co.	34-81	Monongalia	UT Cheat River
Freeport Mining Corp.	S-1004-88	Preston	UT Big Sandy Creek
Freeport Mining Corp.	S-1005-95	Preston	UT Big Sandy Creek
Hallelujah Mining	40-81	Preston	Greens Run
Hidden Valley Coal Co.	S-60-84	Preston	UT of Mill Run of Little Sandy Ck. of Big Sandy Ck.
Inter-State Lumber Co.	S-112-80	Preston	Cheat River
Inter-State Lumber Co.	S-176-77	Preston	Roaring Creek
J. E. B., Inc.	S-1063-86	Preston	UT Morgan Run
J. E. B., Inc.	S-61-82	Preston	Church Creek of Morgan Run
J. E. B., Inc.	S-62-84	Preston	Church Creek of Morgan Run
Jones Coal Co.	S-1030-86	Preston	Glade Run of Big Sandy Creek
Lakeview Coal Co.	S-55-84	Monongalia	UT Coles Run
Lobo Capitol, Inc.	UO-204	Preston	Glade Run of Martin Creek of Muddy Creek
Rockville Mining Co.	237-76	Preston	Conner Run and Sovern Run of Big Sandy Creek
Rockville Mining Co.	65-78	Preston	UT Glade Run of Martin Creek of Muddy Creek
Rockville Mining Co.	S-1035-86	Preston	Sovern Run of Big Sandy Creek
Rockville Mining Co.	S-65-82	Preston	Glade of Martin of Muddy and Conner Run
Rockville Mining Co.	S-91-85	Preston	Fickey Run of Muddy Creek
Southern Eagle Mining Co.	U-32-84	Randolph	UT Shavers Fork
T & J Coal Co.	P-177-85	Preston	UT Pringle Run
T & T Fuels, Inc.	EM-113	Preston	Muddy Creek
T & T Fuels, Inc.	U-125-83	Preston	Muddy Creek
Valley Mining Co.	S-64-83	Monongalia	Buzzard Run and Maple Run
Viking Coal Company	UO-519	Preston	UT Fickey Run of Martin Creek of Muddy Creek
Weter Co.	S-71-79	Preston	UT Cheat River
Williford Excavating	4-76	Preston	UT Muddy Creek
Wocap Energy Resources	S-26-85	Preston	UT Church Creek of Morgan Run
Zinn Coal Co.	60-79	Preston	Fickey and Cherry Run of Little Sandy of Big Sandy Ck.

Source: Sheehan, 2003.

Discharges from these sites can be significant sources of AMD. At the T&T Fuels site on Muddy Creek, which has by far the most data, aluminum and iron concentrations are extremely high, as summarized in Table 9.

Table 9: Summary of AMD data at the most data-rich BFS

| Subwatershed/Site | Flow (gpm) | Concentration (mg/L) | | | Load (tpy) | | | No. sam-ples |
		Alum.	Iron	Mang.	Alum.	Iron	Mang.	
Muddy Creek								
T & T Fuels, Inc.	238.1	43.2	156.1	2.2	22.6	81.8	1.1	48

Source: West Virginia Water Research Institute, unpublished data.

As summarized in Table 10, acid load reductions at some BFSs in the Cheat watershed have been significant, but post-treatment acidity concentrations are still generally high. Until recently, DEP did not reclaim these sites to meet the same standards that the sites would have been held to had the bonds not been forfeited.

Table 10: Acid load reductions at BFSs

| Site | Pre-treatment | | | Post-treatment | | | Acid load | |
	Flow (gpm)	Acidity (mg/L)	Acid load (tpy)	Flow (gpm)	Acidity (mg/L)	Acid load (tpy)	Treated (tpy)	Percent change
Daugherty North	16.3	850.0	30.5	16.3	362.8	11.2	19.3	-63%
Daugherty South	4.1	407.1	4.0	4.1	197.2	2.0	1.7	-50%
Inter-state Lumber	258.3	40.6	23.1	258.3	7.1	3.7	19.4	-84%
Lobo Capitol	110.0	1310.6	96.7	113.3	763.9	85.8	10.9	-11%

Source: Ziemkiewicz et al., forthcoming. Note: Some of these treatment systems likely do not currently achieve the levels of treatment shown in this table. Acid inputs vary over time and performance of treatment measures may decrease over time.

As discussed at the start of Section 5, most pollutant reductions called for in the Cheat TMDL are assigned to orphan sites, which include BFSs. Although the TMDL does not target specific sites, it outlines reductions for each subwatershed, and these reductions often approach 100%. Pollutant reduction credits may be generated on BFSs with water quality problems.

4.   OTHER POLLUTION

While the Cheat TMDL was written for AMD, parts of the watershed suffer from other types of pollution such as acid deposition, heat, bacteria, sediment, and nutrients. The Cheat trading framework described in this report is geared toward the DLF in the watershed: AMD. But as discussed in Section 11, cross-pollutant trades may provide a mechanism for additional investments in AMD remediation. This chapter therefore introduces other forms of water pollution in the watershed.

4.1.   Acid deposition

Acid deposition is caused by emissions of sulfur dioxide and nitrogen oxides, primarily from the burning of coal in power plants and gasoline in cars. In the atmosphere, these pollutants become the anions sulfate and nitrate. Certain soils and terrestrial ecosystems have the capacity to remove these anions from water as it moves through the soil and into streams. Rapidly growing forests, for example, usually remove nitrate from soil water. Soils with high clay content have the capacity to adsorb sulfate. If the soil in a watershed is acidic, and if the ecosystem does not have the capacity to retain these anions, then ion-exchange reactions in the soil will bring aluminum into solution. Aluminum impairs streams because it is extremely toxic to fish, especially trout (Van Sickle et al., 1996).

As shown in Figure 9, DEP lists fourteen Cheat watershed streams as impaired by acid deposition (DEP, 2003). Additional streams are impacted by acid deposition but are not listed because limestone treatments maintain pH above 6 (DEP, 1999), for example, in the Otter Creek Wilderness in Tucker County.

4.2.   Heat

Water is used to cool power plants, and if plants are not equipped with proper cooling towers, that water is discharged to a river while hot. Allegheny Energy operates a coal-fired power plant on the Cheat River in Albright without hyperbolic cooling towers.[12] This plant heats the river substantially, especially when demand for electricity is high and water in the river is low. During summer in years with relatively little rainfall, temperatures greater than 100°F have been measured near the Albright plant. The power plant can prevent this segment of the Cheat River from supporting fish, even when AMD levels are relatively low.

The Albright plant operates under a CWA Section 316(a) variance, which allows cooling water discharges to exceed state thermal water quality standards as long as a balanced, indigenous population of aquatic life is maintained instream. DEP granted this variance in 1977 because the thermal pollution was not expected to cause additional degradation to the Cheat River, which was already degraded by AMD. The variance is reviewed every five years, and is now up for renewal. Continuation of the variance is contingent upon demonstrating to DEP that a balanced, indigenous population of aquatic life is now being maintained. The potential for this facility to

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[12] The plant has mechanical towers that operate during conditions of high temperature and low flow. If hyperbolic towers were installed, evaporation would significantly lower stream flow in the Cheat River.

participate in a water quality trading program as a credit buyer in a cross-pollutant trade with AMD is discussed in Section 6.5.

Figure 9: Streams in the Cheat watershed impaired by acid deposition

4.3.   Bacteria

A number of sources of fecal coliform bacteria and other components of sewage pollute the Cheat watershed. Many small towns have substandard or nonexistent sewage treatment facilities. Failed septic tanks and "straight pipes" allow the discharge of poorly treated or untreated sewage. In addition, cattle grazing is a common land use in the watershed, but cattle are not always fenced from streams.

Bacteria from sewage have the potential to transmit disease to swimmers or to those consuming fish from the river. Sewage may also add so much organic material to waters that bacteria

consume the oxygen, leaving an inadequate supply for fish. Although not included in DEP's 303(d) list, bacteria impair a significant number of streams in the Cheat watershed. DEP samples at 225 sites showed violations of the 400 colony forming units/100 mL standard at 26% of sites. Violations of the 200 colony forming units/100 mL standard are not reported, but must occur at least as frequently as violations of the higher standard (DEP, 1999).[13] Low dissolved oxygen levels have not been observed in the Cheat River.

Observations show lower than expected bacteria levels in stream segments where AMD pollutants are precipitating out of solution. It is suspected that these precipitates somehow remove bacteria, masking what might otherwise be a bacteria pollution problem. Although AMD is now the DLF in the Cheat watershed (See Section 3), this link between AMD and bacteria suggests that as AMD loads are reduced, instream bacteria levels may rise.

4.4.   Sediment

West Virginia's streams are typically not monitored for sediment, at least in part due to the lack of easily enforceable sediment-related water quality criteria. However, sediment may be a significant water quality problem in the Cheat watershed. Sources of sediment pollution to creeks include carelessly executed timber harvests, poorly controlled construction runoff, inappropriate agricultural practices, and coal mining operations. Consequences of sediment pollution include loss of fish spawning habitat, reduced benthic invertebrate productions, and reduced fish feeding opportunities from high turbidity (Waters, 1992). Despite these potential problems, sediment is not currently the watershed's DLF.

4.5.   Nutrients

West Virginia has begun a process for setting criteria for nutrient pollution of surface waters, but except for several lakes across the state with clearly visible problems, the state's 303(d) list does not include nutrient-impaired waters (DEP, 2003). Sources of nutrients to the Cheat and its tributaries include sewage from humans, livestock, and wildlife; natural weathering; and fertilizer from agricultural fields. Certain forests within the Cheat watershed are known to release relatively high concentrations of nitrate to the streams that drain them (Peterjohn et al., 1996). While nitrate production in those soils is fast, the ultimate source of the nitrogen is probably atmospheric deposition of nitrogen released to the atmosphere from anthropogenic sources.

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[13] West Virginia's water quality criterion for fecal coliform bacteria is as follows: "Maximum allowable level of fecal coliform content for Primary Contact Recreation (either MPN or MF) shall not exceed 200/100 mL as a monthly geometric mean based on not less than 5 samples per month; nor to exceed 400/100 mL in more than ten percent of all samples taken during the month." (46 CSR 1 Appendix E, Section 8.13).

Part II: The potential for trading in the Cheat watershed

Part II begins with a summary of current water quality management activities in the Cheat watershed, and the potential for these activities to solve the watershed's AMD problems. It then catalogs the potential credit buyers and generators in the Cheat watershed, as well as the types of sites on which credits are likely to be generated.

5.   CURRENT WATER QUALITY MANAGEMENT ACTIVITIES

The major motivation for this proposed water quality trading program is the Cheat TMDL, which calculates loads of iron, aluminum, manganese, and zinc that can be discharged to the Cheat River and its tributaries without violating water quality criteria for these metals and for pH (USEPA, 2001). Subwatershed by subwatershed, the TMDL assigns pollution reductions to orphan nonpoint sources (AMLs and BFSs) and to active permitted operations. The pollutant reductions required to return many impaired stream segments to health are extremely large, and approach 100% in some subwatersheds. To the extent possible, USEPA assigned reductions to nonpoint sources. When necessary, reductions were also assigned to permitted mines.

Implementation of this TMDL is proceeding very slowly, and will be virtually impossible to complete in the near future. Technological and resource problems make it extremely difficult to realize the vast pollutant reductions called for at many AMLs and BFSs. But even if remediation practices were simple, a lack of funding to install them at these orphan sites would delay action. The need for additional investments to help implement the TMDL is a major motivation for the proposed trading program.

The state's new antidegradation implementation procedures, described in Sections 6.3 and 6.4, are only now starting to be implemented, and may also provide some incentives to trade. Taken together, the TMDL is designed as a roadmap to bring polluted waters back into compliance with water quality standards, while antidegradation is supposed to prevent clean waters from becoming impaired.

The sections below detail the current regulatory situations for the three types of AMD sources in the watershed—active permitted coal mines, AMLs, and BFSs—and discuss why these current activities are unlikely to result in rapid implementation of the TMDL.

5.1.   NPDES permits for active coal mines

Water discharges from permitted mines are regulated by the state using NPDES permits, so that discharges from well-operated permitted mines should be much less concentrated than those from AMLs or BFSs. To prevent AMD formation, permittees isolate acid-producing materials from air and water, and surround them with alkaline materials to neutralize any acid that is produced. If AMD forms, alkaline materials are added, and the water is held in a settling pond to allow metals to precipitate from solution before being discharged to the receiving stream.

NPDES permits are issued for a number of mining activities—including underground mines, surface mines, haul roads, and preparation plants—and for mines in a number of stages. These permits are not released until the associated SMCRA mining permits are completely released

("Phase III release"). Coal mines in the Cheat watershed are in various stages, including Phase I, II, and III release.

DEP assigns either technology-based effluent limitations (TBELs) or WQBELs for pollutants in water from these operations. USEPA established TBELs, shown in Tables 11 and 12, as minimum limits that mining operations can achieve using standard pollutant control technologies. Table 11 contains TBELS for active coal-mining operations, while Table 12 shows the less stringent TBELs that must be met for reclamation areas.

Table 11: TBELs for active coal mining operations

	Discharge Limitations (mg/L)	
Parameter	**Maximum daily**	**Average monthly**
Sediment (TSS)	70	35
Iron	6	3
Manganese	4	2

pH must be between 6 and 9 at all times

Source: 40 CFR 434.

Table 12: TBELs for reclamation areas until bond release

Parameter	**Maximum daily (mL/L)**
Sediment (SS)	0.5

pH must be between 6 and 9 at all times

Source: 40 CFR 434.

TBELs also allow several types of coal mines to discharge more pollution when it rains; these alternative storm limitations appear in Table 13. Thus, discharge limits that apply in dry weather cannot necessarily be used to predict loads to receiving streams in wet weather.

Table 13: Alternative storm limitations for coal mining in AMD areas

Effluent type	Dry weather	Discern-able precipi-tation	1-year 24-hour storm	2-year 24-hour storm	10-year 24-hour storm
a. Discharges from underground workings of underground mines not commingled	TSS pH Fe Mn (No alternative limitations)				
b. Discharges from underground workings of underground mines commingled	TSS pH Fe Mn				pH
c. Controlled surface mine drainage (except steep slope and mountaintop removal mining)	TSS pH Fe Mn				pH
d. Non-controlled surface mine drainage (except steep slope and mountaintop removal mining)	TSS pH Fe Mn	SS pH Fe Mn		SS pH	pH
e. Discharges from coal refuse disposal areas	TSS pH Fe Mn		SS pH		pH
f. Discharges from steep slope and mountaintop removal mining areas	TSS pH Fe Mn	SS pH			pH
g. Discharges from preparation plants and preparation plant associated areas (excluding coal refuse piles)	TSS pH Fe Mn	SS pH			pH
h. Discharges from reclamation areas	SS pH				pH

Source: 40 CFR 434.63. Note: Discernable precipitation is defined as any discharge or increase in volume of a discharge caused by precipitation within any 24 hour period. Dry weather limitations for TSS, pH, Fe, and Mn are the TBELs shown in Table 11. All SS limits are as follows: SS < 0.5 mL/L maximum daily.

In contrast to TBELs, which do not take into account a mine's effect on its receiving stream, WQBELs are calculated specifically to protect water quality in receiving streams. In many cases, these WQBELs are more stringent than TBELs. Permits must include more stringent WQBELs if a discharge, after the application of a TBEL, has the reasonable potential to cause or contribute to a violation of water quality standards.[14]

Well-run mines that consistently meet their NPDES permit limits, even when it rains, likely contribute only a very small portion of the AMD that impairs the Cheat River and its tributaries.[15] Even if every mine assigned more stringent permit limits by the TMDL were to meet these limits immediately, water quality in the Cheat River and its tributaries would not likely improve significantly. The NPDES program is therefore not sufficient to address the significant AMD problems faced in the watershed.

5.2.   The AML Trust Fund and other programs for abandoned mine lands

Before 1977, when SMCRA was enacted, regulations concerning AMD concentrations in mine runoff were less stringent. Mines were not required to comply with stringent discharge limits, and generally did not manage acid-producing material to prevent AMD or treat the AMD that was produced. Many operators chose to abandon these mines rather than bring them up to SMCRA reclamation standards. These "pre-law" mines continue to be significant AMD sources (See Section 3.3).

To address these orphan sites, SMCRA established the AML Trust Fund to pay for their reclamation. This fund, supported by a per-ton tax on mined coal, is allocated to coal mining states for remediation projects, according to a formula that takes states' current coal production into account.

For many reasons, the AML Trust Fund has failed to address AMD at an adequate pace and is unlikely to do so in the future:
- The priorities for disbursed monies places health and safety hazards ahead of water quality issues.
- Even though the federal Office of Surface Mining, Reclamation and Enforcement (OSM) allows states to assign water quality problems a priority equal to that of potential health and safety problems, DEP has been slow to change its priorities accordingly.
- Only part of the AML Trust Fund's income is disbursed each year, so that less money is available for remediation than the legislation initially envisioned.
- Some of the money that is disbursed from interest generated by the fund pays for black lung benefits for former miners.
- At least half of the AML fees collected in each state are allocated back to the state of origin, and are not available for AML reclamation in other states; therefore, much of the AML monies are earmarked for states with few AML problems.

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[14] 40 CFR 122.44 (d)(i).

[15] Discharge monitoring report data from active mines are simply not sufficient to know, with certainty, what is discharged from coal mines. DEP almost always requires monitoring with grab samples taken only twice each month, and dischargers can report "no flow" if there happens to be no flow on the day samples are taken. Furthermore, there is no requirement to quantify pollutant loads washed out during heavy rains. Flows at such times often carry a disproportionate load of pollutants.

- Some of the money allocated to West Virginia from the AML Trust Fund is used for water-line extensions, because deep mines are responsible for the failure of a number of private wells.
- Funds that are sent back to West Virginia are spent on agency staff salaries in addition to on-the-ground remediation.

Still, DEP has funded many AMD remediation projects on AMLs. But these projects are typically not designed to meet stringent water quality goals like those set out by the Cheat TMDL. The agency uses a small number of cost-effective techniques, such as open limestone channels, and chooses the layout for these measures based on how much land is available (for example, the distance between a mine portal and the boundary of properties for which the agency has right-of-entry agreements).

Unless significantly more money were allocated to West Virginia's AML program and these augmented funds were spent on water quality problems, the AML Trust Fund will not be sufficient to implement the AML pollutant reductions in the Cheat TMDL in the foreseeable future.

However, there are alternative sources of funding for remediating AMLs, and DEP has started coordinating the use of this variety of funding sources. The 10% AMD Set-Aside Program allows states to reserve up to 10% of their annual trust fund allocations as an endowment for use on water quality projects. Additional funds for projects include CWA Section 319 funds for nonpoint source remediation projects, Public Law 566 funds under the jurisdiction of the Natural Resources Conservation Service, Water Resources Development Act Section 206 funds spent by the U.S. Army Corps of Engineers (USACE), and Watershed Cooperative Agreement Program funds administered by OSM.

Although these new programs are increasingly important for addressing AMD, the sum of available funding is still not sufficient to treat all AML sites sufficiently or rapidly. Perhaps the most fundamental obstacle is that no government agency or individual is required by law to perform these cleanups. Without responsible parties, these orphan AML sites may remain polluted for decades, unless market-based environmental trading programs are developed and implemented to incentivize the restoration process, or unless other new programs are implemented.

5.3.   The Special Reclamation Fund for bond forfeiture sites

Coal mining operators must post performance bonds to receive mining permits;[16] these bonds are only released after sites are reclaimed according to SMCRA standards, and after raw water from sites no longer requires treatment. Often, operators choose to forfeit their bonds instead of performing the required reclamation or treating water in perpetuity. Across West Virginia, more than 120 BFSs have water quality problems, and DEP is currently treating about 20% of those sites (Miller, 2003). As shown above in Section 3.4, dozens of these sites with water quality problems are located in the Cheat watershed.

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[16] In addition to Clean Water Act NPDES permits, coal mines must also receive mining permits under SMCRA.

Forfeited bonds are deposited into DEP's Special Reclamation Fund to be used to reclaim the sites. This fund also receives money from a per-ton tax on coal. Starting in 2002, this tax was increased, and DEP committed to an aggressive approach to treat all BFSs to meet TBELs. It is too early to tell whether or not these new commitments will solve the AMD pollution problems at BFSs in the Cheat watershed. Even with this new tax, DEP's Special Reclamation Fund advisory council recently revealed that the fund is expected to be in a deficit by 2006, and the deficit is projected to reach $6 million by 2010 (Ward, 2003).

6. POTENTIAL CREDIT BUYERS IN THE CHEAT WATERSHED

Trades require a credit buyer, a credit generator, and a site of credit generation. Careful analysis of all entities related to coal mining in the watershed reveals that certain entities might be able to play unexpected roles. Current AMD remediation programs—NPDES permits, the AML Trust Fund, and the Special Reclamation Fund for BFSs—are unlikely to result in rapid implementation of the Cheat TMDL. A water quality trading program might help spur investments by private parties in AMD remediation. The objective of this chapter is to list entities that might invest in remediation measures and to examine their incentives for doing so.

For water quality trading to succeed, there must be incentives for private entities to purchase pollution reduction credits. In the Cheat watershed, three initiatives can be considered drivers of the trading process: the Cheat TMDL, West Virginia's antidegradation implementation procedures, and a power plant's desire to cost-effectively meet environmental obligations. These drivers are summarized in Table 14, and are discussed in detail in the following sections.

Table 14: Drivers for buying credits in the Cheat watershed

Driver	Potential credit buyer	Incentive to trade
Cheat TMDL	Active or new coal mine	Strict WQBELs. Extra investments needed to meet strict limits.
Antidegradation	New coal mine or other new facility	Strict WQBELs. Extra investments needed to meet strict or zero-discharge limits.
Thermal variance	Power plant	Current 316(a) thermal variance renewal under review. Extra investments needed to control thermal pollution.

6.1. Active permitted coal mines targeted by the Cheat TMDL

Operations targeted by the TMDL may have an incentive to purchase credits. Permits targeted for reductions are assigned WQBELs based upon the wasteload allocations in the TMDL; these WQBELs are more stringent than the TBELs typically used as permit limits. Also, the alternative storm limitations in Table 13 no longer apply to these more stringent limits, so limits are in force at all times, no matter how much rain has fallen. Therefore, to implement the TMDL, operators may have to invest in upgrades of their treatment systems to meet the more stringent limits, and they may have to meet these limits at all times, even when it rains.

Only a fraction of the permitted operations in the Cheat watershed are targeted by the TMDL. As shown in Table 15, new limits are assigned to 21 NPDES permits.[17] But not all operations listed in these tables must invest to meet their new limits, because they may already treat to such a degree that they will comply with new, stricter limits.[18]

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[17] Wasteload allocations are assigned by mining permit, and not by NPDES permit. Some mining permits assigned wasteload allocations do not have associated NPDES permits. Wasteload allocations assigned to these mining permits are not considered in this report. Wasteload allocations assigned to BFSs are also not considered.

[18] Even if discharge monitoring reports show that discharges already meet wasteload allocations, permittees may decide to invest in added pollution control to address the risk that large storms or random chance might cause violations. Even after accounting for possible risk-management approaches to decisions, however, the number of permits with significant load reductions will be small.

Table 15: New TMDL limits for permitted operations in the Cheat watershed

Subwatershed	NPDES permit	Mining permit	Permittee	Type of operation	New average monthly permit limits (mg/L)		
					Iron	Mang.	Alum.
Big Sandy Creek	WV1002791	s000981	Patriot Mining Co.	Coal Surface	1.4	1.0	0.4
	WV1002791	s014879	Patriot Mining Co.	Coal Surface	0.5	2.0	0.4
	WV1006983	z000781	Primrose Coal	Coal Surface	1.4	1.0	0.4
	WV1007220	s100188	Patriot Mining Co.	Coal Surface	1.4	1.0	0.4
Bull Run	WV1007009	s102887	Sharon Coal Co.	Coal Surface	1.4	1.0	0.4
	WV1007009	s102887	Sharon Coal Co.	Coal Surface	1.4	1.0	0.4
Cheat Lake	WV1006738	z001881	Primrose Coal	Coal Surface	3.0	2.0	1.2
Greens Run	WV1007688	s100393	Patriot Mining Co.	Coal Surface	1.4	1.0	0.4
	WV1007688	s101389	Patriot Mining Co.	Coal Surface	1.4	1.0	0.4
Joes Run	WV1007815	s001483	R. K. Co.	Coal Surface	1.4	1.0	0.4
Little Sandy Creek	WV1002791	s000981	Patriot Mining Co.	Coal Surface	0.5	2.0	2.3
	WV1002791	s014879	Patriot Mining Co.	Coal Surface	1.4	1.0	2.3
	WV1006983	z000781	Primrose Coal	Coal Surface	0.5	2.0	2.3
Muddy Creek	WV0063576	r067300	Coastal Coal-WV	Other	1.4	1.0	0.4
	WV0063576	r067300	Coastal Coal-WV	Other	0.5	1.0	0.4
	WV0063576	r067300	Coastal Coal-WV	Other	1.4	1.0	0.4
	WV1007386	s101588	Mary Ruth Corp.	Coal Surface	0.5	1.0	0.4
	WV1007696	s100989	Loyal G Forman & Son	Coal Surface	0.5	1.0	0.4
	WV1017420	s100299	Loyal G Forman & Son	Coal Surface	0.5	1.0	0.4
Blackwater River	WV0051501	s007379	Buffalo Coal Co.	Coal Surface	3.0	2.0	2.5
	WV0051519	o004583	Buffalo Coal Co.	Other	3.0	2.0	2.5
	WV0051519	s000780	Buffalo Coal Co.	Coal Surface	3.0	2.0	2.5
	WV0051616	o200695	Buffalo Coal Co.	Other	3.0	2.0	2.5
	WV0051616	s007476	Buffalo Coal Co.	Coal Surface	3.0	2.0	2.5
	WV0051616	s014677	Buffalo Coal Co.	Coal Surface	3.0	2.0	2.5
	WV0051616	s201892	Buffalo Coal Co.	Coal Surface	3.0	2.0	2.5
	WV0051616	s202392	Buffalo Coal Co.	Coal Surface	3.0	2.0	2.5
	WV0060372	o009783	Buffalo Coal Co.	Other	1.4	1.8	2.5
	WV0060372	o009783	Buffalo Coal Co.	Other	3.0	2.0	0.6
	WV0091936	u003885	Buffalo Coal Co.	Coal Undergr.	3.0	2.0	2.5
	WV0091936	u003885	Buffalo Coal Co.	Coal Undergr.	1.4	1.8	0.6
	WV0092398	q002574	Stanley Industries	Quarry	3.0	2.0	2.5
	WV0092398	q002574	Stanley Industries	Quarry	1.4	1.0	0.4
	WV0092398	q002574	Stanley Industries	Quarry	1.4	1.0	0.6
	WV0094871	s201888	Buffalo Coal Co.	Coal Surface	3.0	2.0	2.5
	WV0094871	s201888	Buffalo Coal Co.	Coal Surface	1.4	1.8	0.6
	WV0098311	s006185	Buffalo Coal Co.	Coal Surface	3.0	2.0	2.5
	WV1013971	s200595	Buffalo Coal Co.	Coal Surface	3.0	2.0	2.5
	WV1013971	s200595	Buffalo Coal Co.	Coal Surface	3.0	2.0	0.4
	WV1013971	s200595	Buffalo Coal Co.	Coal Surface	1.4	1.0	0.9
	WV1014111	s200796	Buffalo Coal Co.	Coal Surface	3.0	2.0	2.5

Note: Mining permit and wasteload allocation from the Cheat TMDL Appendix D, Table D-5 (USEPA, 2001). Corresponding NPDES permit, permittee, and type of operation from Appendix B (USEPA, 2001). Wasteload allocations are converted to average monthly permit limits by multiplying iron values by 0.95, manganese values by 1.0, and aluminum values by 0.58, in accordance with USEPA, 1991. The TMDL assigns more than one set of wasteload allocations to single permits when reductions must be made to meet TMDLs for more than one impaired stream segment. In the TMDL, mining permit s100188 was incorrectly linked with NPDES permit WV1007270, and has been switched to WV1007220. Also, mining permit s100299 was incorrectly linked with NPDES permit WV1017331, and has been switched to WV1017420. The permittee for this mine was also corrected from Ali Co. to Loyal G Forman & Son.

Based on a review of discharge monitoring report data, Figure 10 compares recent iron discharge concentrations with these new limits from the TMDL. Only nine outlets in the lower Cheat subwatersheds are discharging iron at concentrations greater than would be allowed under the TMDL. In the Blackwater subwatershed, where wasteload allocations are generally higher, all permittees are already meeting the new TMDL limits.

Figure 10: Recent iron discharges compared with new TMDL limits
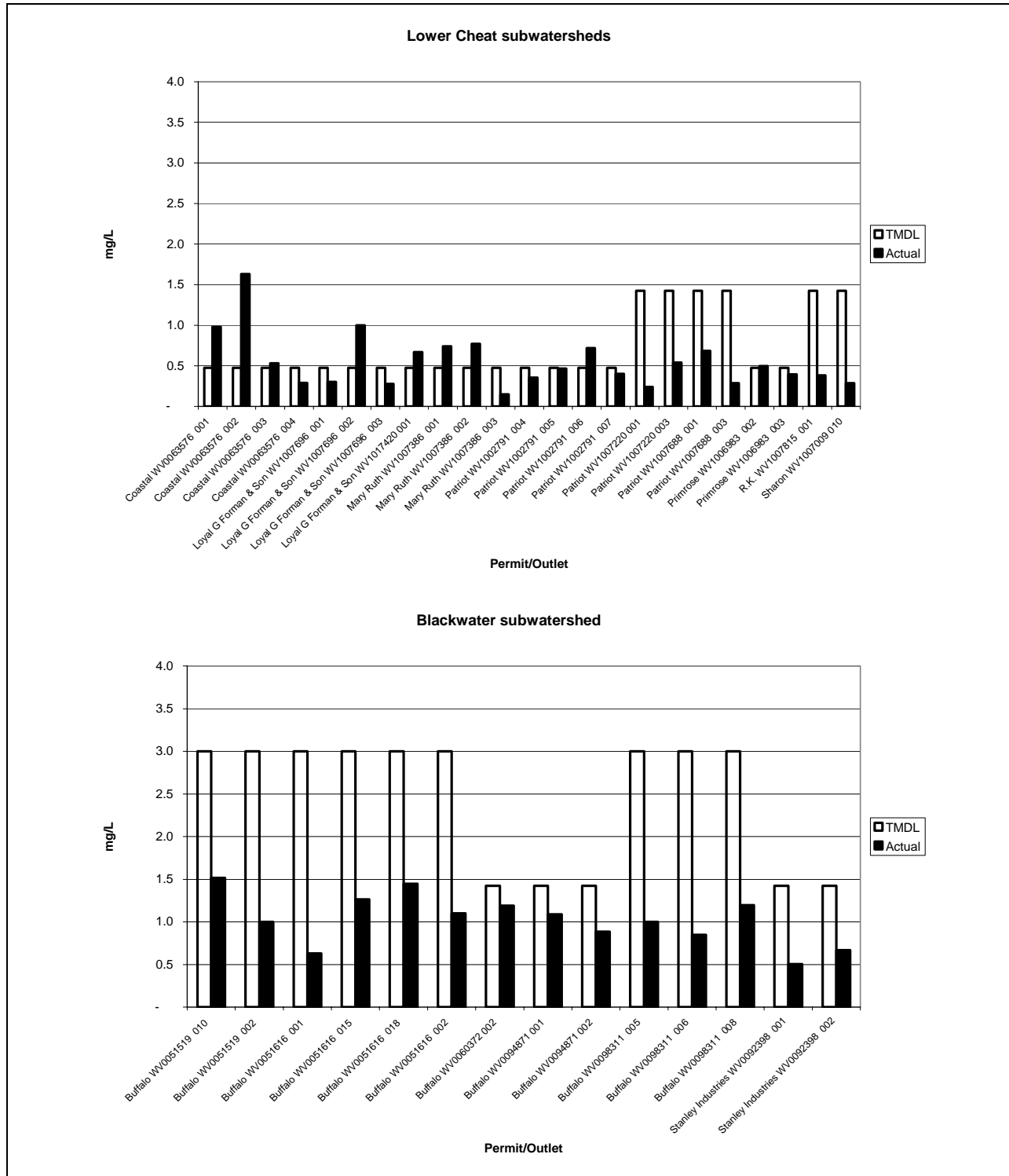
Notes: TMDL concentrations are average monthly limits calculated by multiplying the wasteload allocations from the TMDL by 0.95, as specified in USEPA, 1991. Actual concentrations are recent averages calculated from discharge monitoring reports submitted to DEP. Outlets are shown only if wasteload allocations are assigned in the TMDL and if more than one piece of monitoring data are available.

For manganese, a similar picture emerges. As shown in Figure 11, recent discharges at seven outlets in the lower Cheat subwatersheds exceed the new TMDL limits. And, as is the case with iron, generally less stringent wasteload allocations in the Blackwater region mean that all permittees are meeting the new TMDL limits.

Aluminum results are similar for the lower Cheat subwatersheds: seven outlets exceed the new TMDL limits, as shown in Figure 12. But in the Blackwater region, the picture is different. Unlike iron and manganese, for which all targeted outlets already meet the new TMDL limits, two outlets exceed the new TMDL aluminum limits.

In summary, incentives for existing permitted coal operations to purchase credits are strongest in the lower Cheat subwatersheds, where iron, manganese, and aluminum discharges from some outlets, on average, exceed the new TMDL limits. There may also be limited incentives to purchase aluminum credits in the Blackwater subwatershed.

The strength of these incentives depends to a large degree on how expensive it would be to improve treatment onsite, versus the cost of purchasing credits. The higher the costs to be incurred by permittees to meet more stringent limits, the more incentive they will have to buy credits elsewhere in the watershed. In other words, if targeted permittees can purchase relatively cheap pollutant reduction credits at AMLs and BFSs, they can alleviate the need to treat onsite to meet the new TMDL limits.

Onsite AMD treatment requires an investment in the treatment facility, as well as annual operating expenses. Facility investments usually include a system to add alkalinity and a settling pond.

When designing a treatment system for new, stricter TMDL limits for manganese, permittees are faced with a choice. They may increase the input of alkaline material to raise pH to where manganese will precipitate, or they may build an additional pond to use for manganese precipitation at lower pH. One byproduct of raising pH to treat manganese is that aluminum comes back into solution at these high pH values. Therefore, the decision on which method to use will likely hinge on the quality of feed water and the strictness of the permit limit for aluminum. If the new permit did not include stringent aluminum limits, the permittee would likely add more alkalinity. If, however, the permittee must also meet stringent aluminum limits, he would likely invest in an additional pond for manganese precipitation at lower pH.

Table 16 shows generic costs for treating typical mine drainage. The cost per ton of acidity removed varies considerably, and depends on the characteristics of the water and the type of treatment system. Generally, passive treatment systems are cheaper, ranging from $24 to $604 per ton of acidity removed. Active treatment systems range from $536 to $1,294.

Figure 11: Recent manganese discharges compared with new TMDL limits
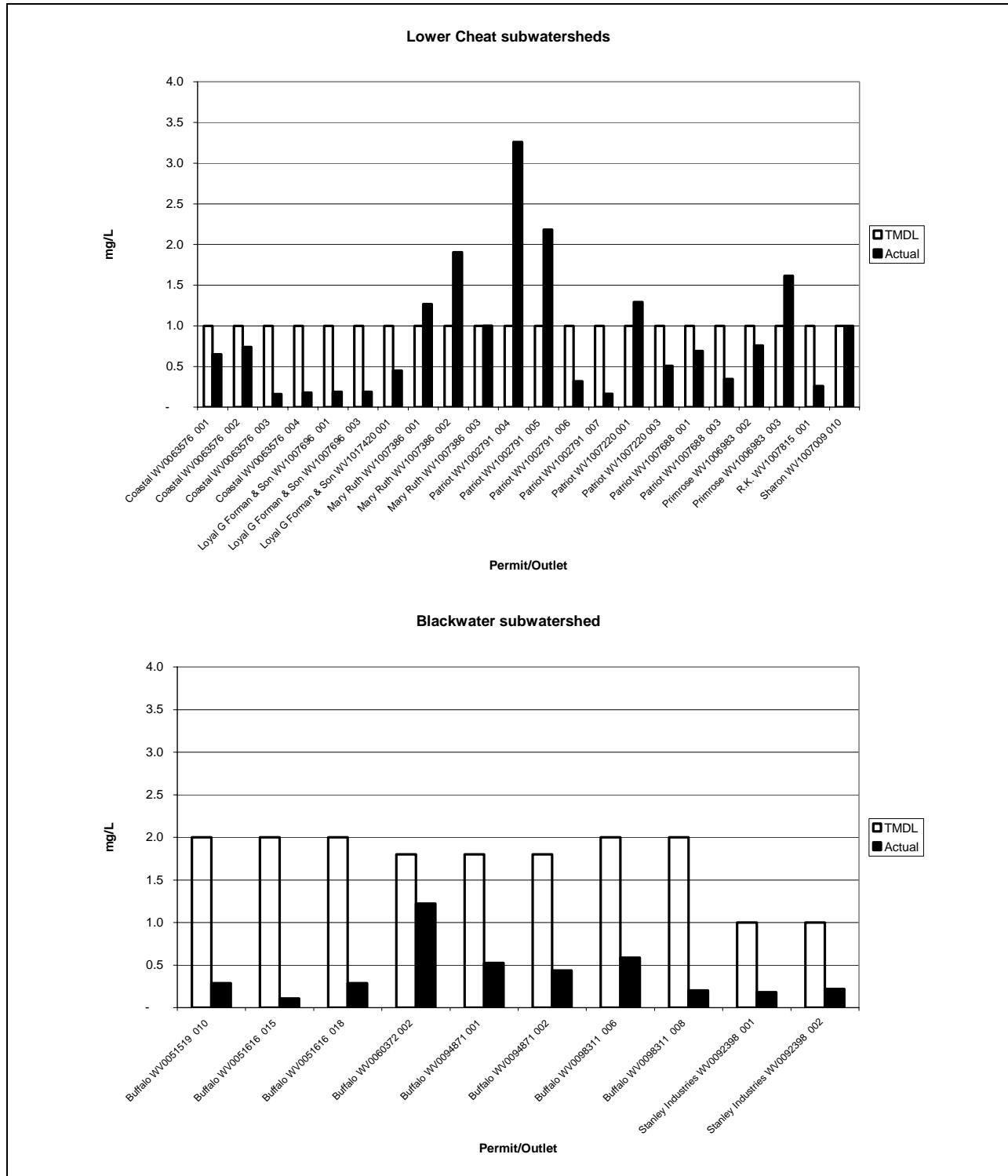
Lower Cheat subwatersheds

Blackwater subwatershed

Notes: TMDL concentrations are average monthly limits calculated by multiplying the wasteload allocations from the TMDL by 1.0, as specified in USEPA, 1991. Actual concentrations are recent averages calculated from discharge monitoring reports submitted to DEP. Outlets are shown only if wasteload allocations are assigned in the TMDL and if more than one piece of monitoring data are available.

Figure 12: Recent aluminum discharges compared with new TMDL limits
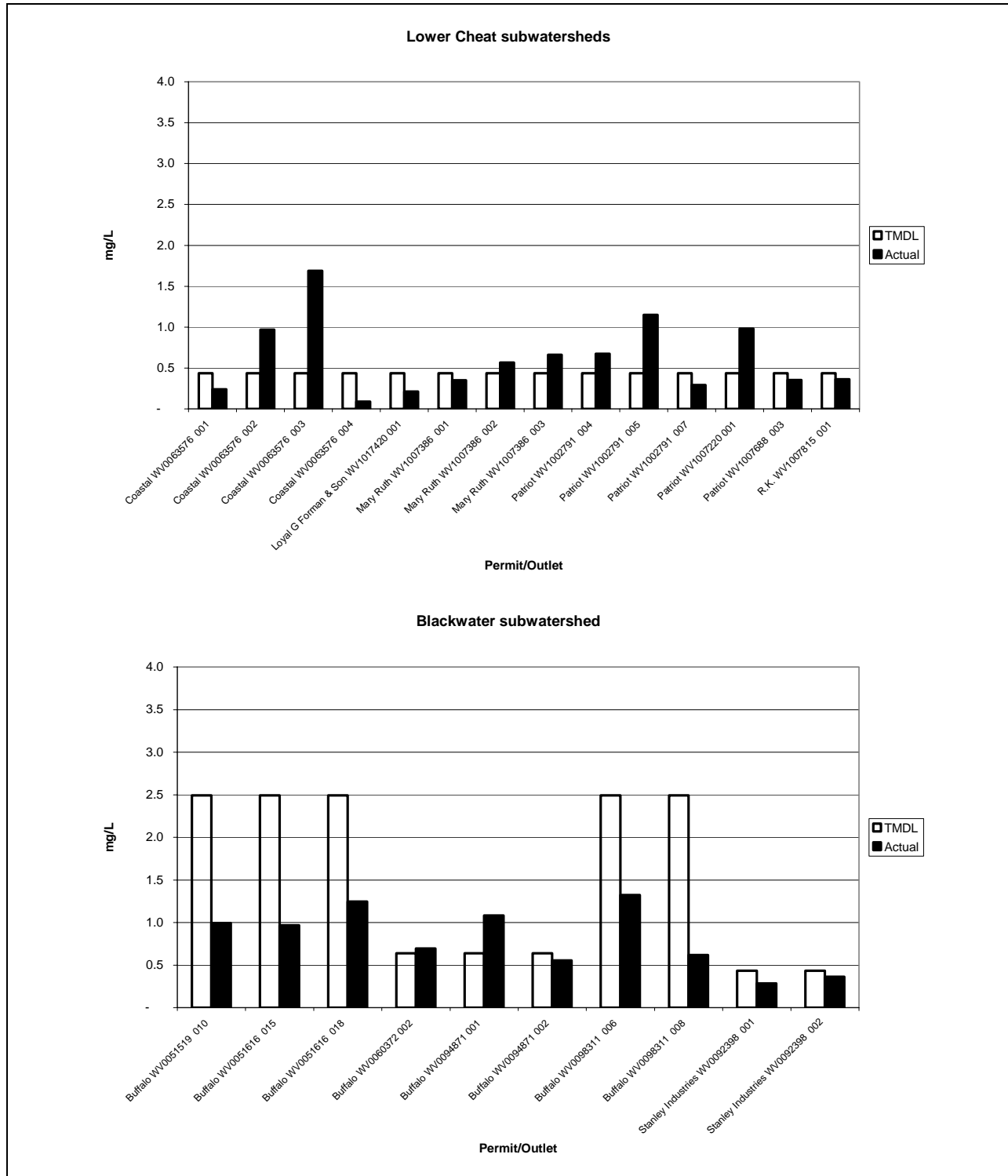
Lower Cheat subwatersheds

Blackwater subwatershed

Notes: TMDL concentrations are average monthly limits calculated by multiplying the wasteload allocations from the TMDL by 0.58, as specified in USEPA, 1991. Actual concentrations are recent averages calculated from discharge monitoring reports submitted to DEP. Outlets are shown only if wasteload allocations are assigned in the TMDL and if more than one piece of monitoring data are available.

To add context to these generic costs, Table 17 illustrates the added cost to treat an actual site to meet its new TMDL limits. Patriot's Pleasant mine discharges to Little Sandy Creek in the Big Sandy subwatershed. Manganese discharges from outlets 004 and 005 are significantly higher than the new TMDL limits, as shown above in Figure 11. The additional annual cost to meet the new manganese limits from the TMDL totals $3,340. This total includes the additional chemical cost, as well as a factor to account for pond cleanout, labor, and other expenses. It does not include, however, treatment that the water may require should it dissolve aluminum at the elevated pH.

If these costs are representative of the scale of investments needed for active operations to meet new TMDL limits, then the TMDL likely provides limited incentives to trade. Operators faced with an additional investment of a few thousand dollars may be unwilling to engage in a trade, given the potentially high transaction cost and the uncertainty of participating in a new policy initiative without a track record.

It is important to note that if there is no tradeoff between manganese and aluminum treatment, then a small increase in operations money (in the form of chemicals, energy, and waste disposal) can increase the capacity of the existing infrastructure for pollution control. If characteristics of the effluent cause a tradeoff between manganese and aluminum treatment, additional infrastructure (such as a second pond and a second treatment system) might be required.

Table 16: Ranges of AMD treatment costs for passive and active systems for 100 gpm flows ($)

Treatment system	Fixed costs			Annual costs			Cost per ton acidity removed
	Capital cost	Primary settling pond	Secondary settling pond	Chemicals	Labor	Maintenance	
Manganese: 25 mg/L, pH: 6.2, acidity: 45.5 mg/L							
Active treatment							
Caustic soda	2,387	5,000	5,000	982	10,920	434	1,294
Hydrated lime	82,673	5,000	5,000	187	10,920	3,244	1,897
Soda ash	500	5,000	5,000	187	10,920	368	1,199
Passive treatment							
Manganese leach bed	42,167					597	270
Iron: 25 mg/L, pH: 3.0, acidity: 117 mg/L							
Active treatment							
Caustic soda	2,387	5,000	5,000	11,495	10,920	434	912
Hydrated lime	82,173	5,000	5,000	2,193	10,920	3,226	814
Soda ash	500	5,000	5,000	12,794	10,920	368	956
Passive treatment							
Open limest. channel	12,766	5,000				128	39
Vertical flow wetland	291,095	5,000				742	604
Aerobic wetland	28,039	5,000				455	82
Anaerobic wetland	41,864	5,000				594	114
Anoxic limest. drain	20,961	5,000				385	65
Aluminum: 25 mg/L, pH: 3.0, acidity: 189 mg/L							
Active treatment							
Caustic soda	4,387	5,000	5,000	16,881	10,920	504	698
Hydrated lime	82,173	5,000	5,000	3,543	10,920	3,226	536
Soda ash	500	5,000	5,000	20,668	10,920	368	781
Passive treatment							
Open limest. channel	12,766	5,000				128	24
Vertical flow wetland	102,253	5,000				1198	158
Aerobic wetland *							
Anaerobic wetland *							
Anoxic limest. drain	33,681	5,000				512	59

Source: OSM's AMD Treat. Notes: * cannot be sized without iron concentrations. Treatment is based on neutralization of all acidity, including protons as well as metal ions, with the exception of manganese, which will be unaffected. The passive treatment systems each have settlement ponds. Cost per ton acidity removed based on 20-year life cycle costs.

Table 17: Cost to improve treatment at Pleasant mine to meet new TMDL limits ($/year)

Source	Existing cost	Additional cost to meet TMDL
Outlet 004		
Lower Seep	$0	$520
Upper Seep	$0	$260
Outlet 005		
Ammonia Site No. 1	$4,490	$1,280
Ammonia Site No. 2	$5,770	$1,280
TOTAL		$3,340

Source: Hamric, 2003. Note: This mine operates under NPDES permit WV1002791.

6.2. New permitted coal mines subject to the TMDL

Active permitted mines are not the only sites to be affected by the TMDL: new mines must also conform to it. The Cheat TMDL addresses new sources in its discussion of future growth:

> This TMDL does not include specific future growth allocations to each subwatershed. Because of the general allocation philosophy used in this TMDL, such allocations would be made at the expense of active mining point sources in the watershed. However, the absence of specific future growth allocations does not prohibit new mining in the watershed. Future growth could occur in the watershed under the following scenarios:
>
> 1. A new facility could be permitted anywhere in the watershed, provided that effluent limitations are based upon the achievement of water quality standards end-of-pipe for the pollutants of concern in the TMDL.
> 2. Remining could occur without a specific allocation to the new permittee, provided that the requirements of existing State remining regulations are achieved. Remining activities are viewed as a partial nonpoint source load reduction from Abandoned Mine Lands.
> 3. Reclamation and release of existing permits could provide an opportunity for future growth provided that permit release is conditioned upon achieving discharge quality better than the wasteload allocation prescribed by the TMDL.
>
> It is also possible that the TMDL may be refined in the future through remodeling. Such refinement may incorporate new information and/or…redistribute pollutant loads. Trading may provide an additional opportunity for future growth, contingent upon the State's development of a statewide or watershed-based trading program (USEPA, 2001, p.9-23).

According to this strategy, new coal mining operations, by default, will be assigned WQBELs based on meeting water quality standards at end-of-pipe. Permittees desiring less stringent TBELs would have to engage in a trades.

The financial incentive to trade would be the difference in cost between treating to meet WQBELs versus TBELs. If the cost at the Pleasant mine summarized in Table 17 is representative of other mines in the area, these costs may not be especially high.

The TMDL report does not specify whether its strategy for allowing future growth applies only to 303(d)-listed segments for which TMDLs were developed, or to all streams in the Cheat watershed. Even if it only applies to 303(d)-listed segments, another policy may provide incentives for new mining operations to purchase credits: the state's antidegradation rules.

6.3. New coal mining operations subject to antidegradation rules

Antidegradation provisions, included in West Virginia's water quality standards, protect clean waters from impairment. Four tiers provide different levels of protection to different waters.

Tier 1 applies to all waters of the state and requires the maintenance of water quality that supports existing uses.[19] Tier 2 waters meet standards; these high quality waters can only be degraded when it is necessary for important local economic or social development.

Tier 2.5 includes waters of special concern: naturally reproducing trout streams; waters in state parks and forests; waters with unique or exceptional aesthetic, ecological, or recreational value; and other waters. Tier 2.5 waters can only be degraded by a certain fixed amount, after which no

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[19] Existing uses are those uses actually attained in the water body on or after November 28, 1975, whether or not they are included as designated uses within the water quality standards (46 CSR 1-4.1.a).

further degradation will be allowed. Tier 3 absolutely protects outstanding waters of particular state or national importance.

In 2001, the West Virginia legislature passed, and USEPA approved, West Virginia's antidegradation implementation procedures.[20] The procedures were challenged in court, and several provisions were recently overturned.[21] The status of these procedures is therefore uncertain at this time.

But DEP has already developed detailed guidance on the procedures, and the agency has started to implement antidegradation by issuing permits with WQBELs when TBELs are predicted to degrade Tier 2 streams by more than 10 percent.[22] Significantly, these permits do not include alternative precipitation limits.

West Virginia's antidegradation regulations specifically provide for water quality trading to offset new discharges:

> A proposed activity that will result in a new or expanded discharge in a water subject to Tier 2 protection may be allowed where the applicant agrees to implement or finance upstream controls of point or nonpoint sources sufficient to offset the water quality effects of the proposed activity from the same parameters and insure an improvement in water quality as a result of the trade. The basis of the trade will be documented and will be consistent with the trading assessment procedure that has been approved by the Secretary. A trade may be made between more than one stream segment where removing a discharge in one stream segment directly results in improved water quality in another stream segment. In addition, (1) the effluent trade must be for the same parameter; (2) where uncertainty exists regarding the effluent trade, an adequate margin of safety will be required; (3) dischargers cannot claim offsets for water quality improvements that are required or will occur irrespective of the proposed new or expanded discharge; and (4) the trades must be enforceable (60 CSR 5-5.6.f).[23]

Trades under these antidegradation rules may therefore allow new coal mines to be permitted in the Cheat watershed, where they otherwise would not be allowed because of a lack of assimilative capacity.

The rules contain some restrictions, however. Credits must be generated upstream, and trades must be made for the same parameter. See Sections 10 and 11, which discuss the implications of these decisions for the Cheat watershed.

New discharges into streams of different tiers would have unique incentives to trade. Without a trade, discharges into Tier 1 waters would be assigned water quality–based effluent limits equal to water quality standards at end-of-pipe. This is the same level of protection required by the TMDL. New permittees might decide to trade in order to relax their WQBELs to TBELs.

Permittees proposing new discharges into Tier 2 waters have a choice. They could accept WQBELs calculated to use 10% of the remaining assimilative capacity. Or, TBELs could be assigned if the permittee undergoes the antidegradation review process, which includes an assessment of alternatives as well as a demonstration of important local economic or social development as a result of the new discharge. Permittees that accept the WQBELs, or that fail to

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[20] 60 CSR 5.

[21] Ohio Valley Environmental Coalition et al. vs. Christie Whitman, Administrator, USEPA.

[22] WQBELs are not issued for minor outlets that discharge directly from benches.

[23] Virtually identical language is included in 60 CSR 5 for trading in Tier 1, 2.5, and 3 waters.

justify less stringent limits through the antidegradation review process, may wish to engage in a trade to receive TBELs.

Discharges into Tier 2.5 waters are similar to those into Tier 2, except that remaining assimilative capacity may be zero. Permittees proposing new discharges into Tier 2.5 waters are likely to have even greater incentives to trade to receive TBELs.

Finally, discharges cannot degrade Tier 3 streams. Potential new mining operations on Tier 3 streams would therefore face the choice between zero discharge permits or trades that would offset the new discharge.

6.4.   Other new facilities subject to antidegradation rules

Antidegradation rules may also require stringent or zero-discharge permit limits for other, non-coal facilities. Such facilities may wish to purchase credits rather than investing in the required onsite pollution control equipment necessary to meet the antidegradation-based limits. If the Cheat trading framework limits trades to same-pollutant trades, these trading opportunities are likely to be small. But if cross-pollutant trading were allowed, these facilities might be allowed to purchase AMD pollution reduction credits. See Section 11 for a discussion of cross-pollutant trading issues.

6.5.   A coal-fired power plant

As discussed in Section 4.2, a coal-fired steam electric generating plant operates along the Cheat River in Albright. This facility, built in the 1950s, has a generating capacity of 292 megawatts. The facility burns approximately 600,000 tons of coal per year. In 2002, 87 people worked at the power plant (Allegheny Energy, 2002).

Although the facility has made some environmental improvements over the years—including the installation of electrostatic precipitators and low nitrogen-oxide burners—it still operates without hyperbolic cooling towers. CWA Section 316(a) thermal variances have been granted for these thermal discharges, which would otherwise violate state water quality standards.

These variances allow less stringent alternative thermal effluent limits to be included in NPDES permits if the discharger demonstrates that otherwise applicable limits are more stringent than necessary to assure the protection and propagation of a balanced, indigenous community of shellfish, fish, and wildlife in and on the body of water into which the discharge is made. This demonstration takes into account the cumulative impact of its thermal discharge together with all other significant impacts on the species affected.[24]

In 1977, when the plant received its first variance, the Cheat River at Albright was significantly polluted by AMD, and the thermal discharge arguably had little impact on stream life that was already severely impacted. Since then, DEP has required various fish and benthic surveys over the years to justify a continuance of the variance (Lapcevic, 2003). The NPDES permit and variance are once again up for renewal; however, the Cheat River has now recovered to the extent that DEP is requiring a more detailed analysis to justify a continuation of the variance.

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[24] Clean Water Act Section 316(a) and 40 CFR 125.70-73.

Allegheny Energy has a significant financial incentive to continue the variance: If the variance were denied, Allegheny would be required to install new cooling towers, reduce load during critical periods, augment upstream flow, or possibly retire the plant.

If cross-pollutant trading is allowed between heat and AMD (See Section 11), the desire to continue the thermal variance may provide an incentive to purchase credits. In return for a continuation of its thermal variance, Allegheny Energy might agree to finance AMD treatment in significantly impaired tributaries upstream from Albright. If other types of credits were integrated into a trading program (See Section 14), air emissions of mercury and acid deposition precursors—and their resulting water quality impacts—might also enter the accounting system and affect the amount of credits required to be purchased.

7. POTENTIAL CREDIT GENERATORS IN THE CHEAT WATERSHED

Credit buyers, as discussed in the previous section, can only purchase credits that have been generated. Table 18 shows some of the variety of government agencies, organizations, or private entities that may generate AMD pollution reduction credits.

Credit generators may include government agencies or nonprofit organizations that remediate AMD on orphan AMLs or BFSs, or that provide instream treatment to reduce metals loads and acidity in streams polluted with AMD. The CWRA, described in Section 9.1, may also generate credits by funding AMD remediation projects.

Credit generators may also include credit users that generate their own credits. Existing coal mining operations facing new TMDL limits, or new operations faced with TMDL or antidegradation restrictions, may fall into this category. If cross-pollutant trades are allowed, the Albright power plant may prefer to generate its own credits by remediating AMD, rather than purchasing credits generated by others.

Finally, some entities may generate credits for sale to others. Coal mines—whether or not they are targeted by the TMDL—may be treating their discharges sufficiently well that they can generate credits for sale. Entrepreneurs may find it profitable to invest in the generation of credits, provided that these credits could be sold or traded for a profit.

Table 18: Potential credit generators in the Cheat watershed

Potential credit generator	Funding source	Site where credits are generated
Agencies and organizations (credits generated on behalf of the public)		
DEP	AML Trust Fund	AML
	Special Reclamation Fund	BFS
	CWA Section 319	AML
USACE	Water Res. Dev. Act Section 206	AML
Natural Resources Conservation Service	Public Law 566	AML
Friends of the Cheat	OSM Watershed Cooperative Agreement Program	AML
CWRA	Fees paid to buy credits	AML, BFS, instream
Credit users (credits generated for own use)		
Existing coal mine	Self	AML, BFS, instream
New coal mine or other new facility	Self	AML, BFS, instream
Coal-fired power plant	Self	AML, BFS, instream
Others (credits generated for sale to others)		
Existing coal mine	Self	Onsite
Entrepreneur	Self	AML, BFS, instream

7.1. Agencies and organizations

Several state and federal agencies have the authority to fund AMD remediation projects: DEP, USACE, and the Natural Resources Conservation Service. Each agency's funding sources place restrictions on how the money can be spent. For example, AML Trust Fund money, channeled through DEP, can only be spent on AML remediation, while Special Reclamation Fund money can only be spent on BFSs.

OSM provides funds to watershed organizations to remediate AMLs. Friends of the Cheat has already taken advantage of this Watershed Cooperative Agreement Program, and may do so in the future.

Finally, the CWRA, described in Section 9.1, may invest in its own remediation projects and generate credits. The Authority's funding may include government grants or may be provided by credit buyers, who pay the Authority to purchase credits that were generated in the past and that are available from the credit bank. The Authority would then spend this money to generate additional credits.

It is envisioned that credits generated by all of these agencies and organizations could be banked, helping to capitalize the credit bank and ensure that credit users have a pool of credits to purchase that have already been generated (See Section 9.2). Such a system would also help guide the generation of credits toward those sites considered by the Authority to be most important in meeting the watershed's restoration goals.

7.2. Credit users that generate credits for their own use

All of the potential credit buyers detailed in Section 6 may decide to generate their own credits for use, rather than purchasing already-generated credits from the credit bank. See Section 9.2 for a discussion of the credit bank and how such transactions could be tracked.

7.3. Others that generate credits for sale

Many existing coal mines already treat to the point that discharges are cleaner than permitted levels. As shown in Figures 10 through 12, even many mines targeted by the TMDL are already meeting these new, stricter limits. Because they are treating over and above what is required by their permits, these permittees may choose to offer pollution reduction credits for sale to other coal mines or other potential credit buyers.[25]

If the potential exists to profit from the sale of credits, entrepreneurs may also enter the market. Entrepreneurs would invest their own funds in remediation projects, generating credits for sale.

7.4. Sites where credits can be generated

While they can be generated by the range of entities described in Sections 7.1-7.3, most AMD pollution reduction credits will likely be generated at orphan AMLs or BFSs, on land that is not

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[25] On the other hand, they may choose to view the difference between their low discharges and the WQBELs established by the TMDL as insurance against the risk of change in their effluent.

typically owned by the credit generator. Credits may also be generated in some cases by providing instream treatment to remove metals and lower acidity.

7.4.1. Abandoned mine lands

As discussed in Section 5.2, AMLs are coal mines left unreclaimed by their operators before reclamation standards and a permitting process were instituted under SMCRA in 1977. AMLs are orphan sites because, under SMCRA, the mines' original operators are not legally responsible for their reclamation. While several entities may reclaim these sites—as shown in Table 18—none are legally required to do so. Thus, although AMD remediation on AMLs does in fact take place, there are no guaranteed funding sources, no legal requirements to provide treatment, and no signs that remediation, when funded, will be sufficient or rapid.

As illustrated earlier in Tables 5 through 7, high AMD concentrations and loads are often found at AMLs. At sites with little or no previous remediation investments, the cost of treating the next unit of AMD will generally be lower than on permitted mines, where treatment is already taking place. Therefore, AMLs are likely to be attractive sites on which to generate pollutant reduction credits as part of a trading program.

The cost of remediating AMLs varies widely, and depends on the characteristics of each site and the type of treatment system installed. Generally, as shown above in Table 16, passive treatment systems such as open limestone channels are cheaper than active chemical treatment systems, such as the addition of caustic soda.

AMD remediation options are also evolving. While researchers focused on chemical systems in previous decades, many have shifted their emphasis to passive systems. Passive treatment systems are generally cheaper, but their long-term efficacy is uncertain.

The Cheat TMDL does not include specific allocations for AMLs. Instead, the TMDL specifies nonpoint source loading reductions for each subwatershed. An issue of importance to the success of trading in the Cheat is whether or not credits can be generated at AMLs by remediating to meet the TMDL's load allocations. In other words, would credits only be generated for remediation over and above the reductions in the TMDL? Because no entity is legally required to make pollutant reductions at these orphan AMLs, the program envisioned for the Cheat watershed assumes that credits can be generated for *all* investments in AMLs.

7.4.2. Bond forfeiture sites

As described in Section 5.3, BFSs are similar to AMLs, in that the original coal operators are no longer responsible for treatment. But they are different because they were abandoned after 1977. In accordance with SMCRA, the operators forfeited their performance bonds to DEP, which then took over the responsibility for treatment.

BFSs are unique. In a sense they are orphan sites, because the operators no longer must remediate them. But on the other hand, DEP has assumed the responsibility for treatment and has committed to treating them to meet the TBELs that would have been in place had the bond not been forfeited.

As with AMLs, remediation costs depend on the characteristics of each site and the type of treatment system installed. Estimates in Table 16 apply to BFSs as well.

The Cheat TMDL handles BFSs in the same manner as AMLs: by specifying nonpoint source loading reductions for each subwatershed and not assigning detailed load allocations for each site. Therefore, the same issue arises regarding whether or not credits can be generated at BFSs by remediating to meet the TMDL's load allocations. Even though DEP has committed to meeting TBELs on BFSs, no government agency is legally required to make pollutant reductions at these sites to meet the WQBELs required to meet the TMDL. The trading program envisioned for the Cheat watershed therefore assumes that credits can be generated for *all* investments in BFSs.

7.4.3. Instream treatment

In addition to onsite remediation of AMLs and BFSs, credit generators may prefer to install instream remediation systems. Several types of instream systems can be used to add alkalinity, thereby removing metals and raising pH:

- limestone leach beds at tributary headwaters,
- limestone-lined stream channels,
- limestone sand added to streams, and
- dosers that add limestone or chemicals to streams.

Instream treatment systems essentially use the stream itself as a settling pond to remove iron, aluminum, and, to a minor extent, manganese. The settling of metals in streams may produce its own harmful effects on aquatic life. But in some situations—where streams are heavily polluted by AMD or where on-site treatment systems are not technically feasible—instream treatment can be a reasonable alternative. Instream treatment may also be a reasonable short-term solution. Alkalinity additions can be decreased as on-site remediation progresses.

Part III: Trading as an alternative to improve water quality in the Cheat watershed

Part III presents a more detailed vision of a trading program for the Cheat watershed. Section 8 first summarizes the key components of the trading framework. The CWRA and the credit bank are described in Section 9. Section 10 then examines different possible geographical restrictions on trades and considers the effect of these restrictions on the number of potential trades. Section 11 considers the effect of cross-pollutant trading on the number of potential trades in the Cheat watershed. Trading ratios are introduced in Section 12. An ecological index is proposed for evaluating cross-pollutant trades in Section 13. Finally, Section 14 recommends expanding the proposed water quality trading framework to include multiple environmental markets.

8.   A PROPOSED TRADING FRAMEWORK FOR THE CHEAT WATERSHED

As documented in Part II, the TMDL is not likely to be implemented quickly or completely by relying on existing water management programs. Even if permitted coal mines implemented new TMDL limits immediately, they likely do not discharge enough pollution to significantly improve water quality. For a variety of reasons, the AML Trust Fund is not adequate to remediate AMD pollution on AMLs. And although DEP has committed to remediating BFSs to meet standard NPDES permit limits, it is too early to tell whether or not this goal will be realized.

Part III, therefore, expands on the consensus-based Cheat trading framework developed by local stakeholders (See Appendix A) by explaining the implications of various decisions that still must be made before the framework can be implemented. If these decisions are made and a successful trading program is instituted, private entities would have incentives to invest in AMD pollution reductions over and above what would otherwise take place. And these reductions would occur sooner and cheaper than under the existing management framework.

While the Cheat framework incorporates lessons learned from other water quality trading frameworks across the United States (See Appendix C), most frameworks have been developed for nutrients and are not necessarily directly applicable. The Cheat framework recognizes some of the unique aspects of AMD and the Cheat watershed:

- AMD is composed of several pollutants, all of which contribute to acidity and harm receiving streams.
- Few permitted coal mines remain in the watershed, and few of these mines are targeted by the TMDL. Of those that are targeted, many already meet the new TMDL limits.
- Remediation efforts would be most successful if they followed a watershed management plan, which would guide investments toward those sites where environmental and ecological improvements could be generated more quickly and economically.
- An active and established stakeholder-driven watershed organization, Friends of the Cheat, is in place to further the trading program

Figure 13 summarizes the sites where credits can be generated, credit generators, and credit sellers, which were introduced in the previous sections. A typical trade envisioned for the Cheat would involve an active coal mine assigned new, stricter discharge limits by the TMDL. If these

limits would require a significant investment, the permittee may prefer to purchase pollution reduction credits elsewhere, rather than investing onsite in additional reductions. Typically, this would involve purchasing credits generated through remediation at an AML or BFS. Several other combinations of credit buyers, credit sellers, and sites where credits can be generated are possible.

The following sections move beyond this conceptual model and delve into the details regarding how such a program should be managed, as well as geographical restrictions, cross-pollutant trades, trading ratios, and other issues of critical importance to the success of a trading program.

Figure 13: Summary of sites where credits are generated, credit generators, and credit buyers

Sites where credits are generated	Credit generators	Credit buyers
Abandoned mine land	Agencies and organizations (on behalf of the public)	Active coal mine
		New coal mine
Bond forfeiture site	Credit users (for own use)	Other new facility
Instream treatment	Others (for sale to others)	Power plant
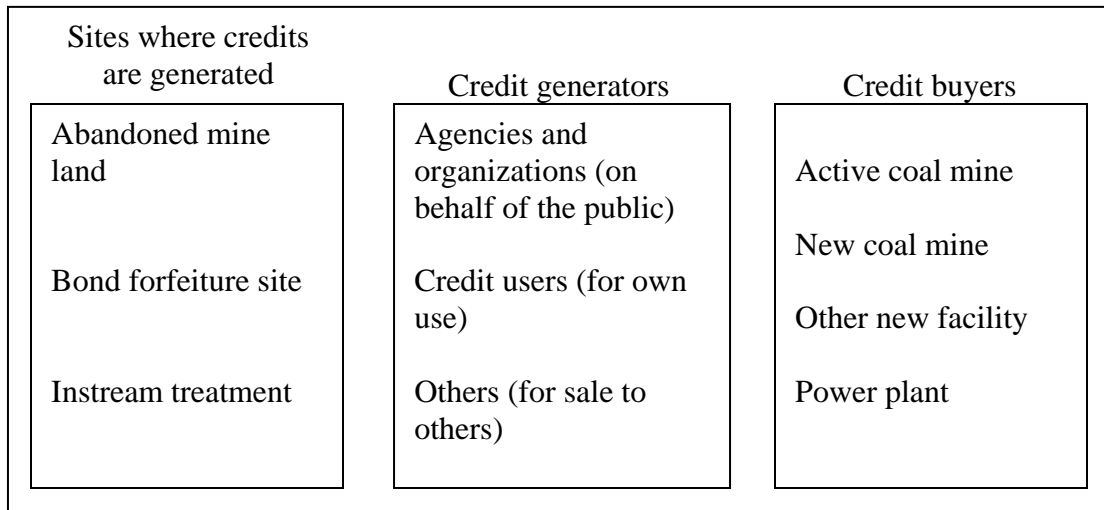
9.   MANAGING A TRADING PROGRAM

No matter how the Cheat watershed's trading rules are structured, management protocols must be in place to ensure that trades are consistent with the rules. The management structure must also track the generation and purchase of credits.

But in addition to these standard management functions, which are a part of every water quality trading program, additional functions are envisioned to make trading work for the Cheat. A new organization—the CWRA—is proposed to not only manage the credit bank, but also to perform many other tasks that will ensure that trading succeeds in meeting the restoration goals for the watershed. Before discussing the credit bank envisioned for the Cheat watershed, the CWRA is described in detail.

9.1.   The Cheat Watershed Restoration Authority

As detailed in Sections 10 and 11, the most comprehensive trading program, and the one with the most potential trading partners, would allow credits to be generated and purchased from anywhere in the watershed, and would allow also cross-pollutant trading. But such a system, applied without proper safeguards, could fail. The CWRA would ensure that trades under such a system effectively reduce pollution and lead toward the attainment of the water quality and ecological goals for the watershed. The CWRA, as detailed below, would be part restoration planner, part trading program manager, and part accountant.

Despite the broad responsibilities envisioned for the CWRA, it would not infringe in any way on DEP's current permitting authority. All trades would still be incorporated into NPDES or other permits or legal documents that are overseen by the agency. DEP would maintain final responsibility for approving or disapproving all trades and for ensuring that monitoring and enforcement take place.

But the CWRA would play a unique and important role in facilitating trading. The CWRA would help organize, plan, and manage Cheat remediation projects on a watershed basis by coordinating funding and program opportunities. Trading would be one of its many responsibilities. The CWRA's facilitation of the trading process would help overcome barriers to trading and would ensure that all trades are consistent with this framework, acceptable to local stakeholders, and take full advantage of the funding sources available for AMD remediation.

Specific tasks envisioned for the CWRA include:
- Develop, update every five years according to DEP's watershed management program cycle, and implement a strategic cleanup plan for the watershed. Trading will be one of many tools available to implement this plan.
- Create and manage a Watershed Management Trust Fund to pay for its operating expenses and to use for watershed remediation projects. This fund will be financed by the purchase of credits that were generated by public entities, grants from governments and foundations, and contributions.
- Manage the credit registry and bank used to track and transact trades.

- Calculate and update periodically the price of credits purchased through the trading program. A series of prices and equivalencies would be calculated for iron, manganese, aluminum, acidity, and ecounits (See Section 13.3.5, and particularly Table 24). These prices and equivalencies would be updated periodically.
- Create a menu of potentially beneficial trades based on its strategic plan.
- Bring together potential trading partners.
- Evaluate proposed trades to ensure that they satisfy the requirements of the trading framework.
- Make recommendations regarding proposed trades to permitting authorities. The CWRA may recommend that trades be approved, denied, or approved with conditions.
- Build, operate, and maintain water treatment units, including those that involve trades if both trading partners agree.
- Monitor and report on the implementation of the watershed management plan.

Two aspects of the CWRA deserve further explanation. First, the development of a watershed management plan—and the evaluation of trades against this plan—is considered fundamental to the CWRA's success. Past investments in remediating AMD from orphan sites, while often successful, have not always been strategic and have therefore not led to optimal environmental and ecological gains. A management plan developed with strong local input can help guide trades toward the highest priority sites.

Second, if cross-pollutant trading were allowed, the CWRA would also facilitate such trades by calculating the cost, on average across the watershed, for treating acidity to allow the watershed to recover. Other calculations would result in equivalencies between acidity and ecounits, which would help facilitate cross-pollutant trades based on these ecounits. The goal of these calculations would be to require credit buyers to pay the average cost across the Cheat watershed when purchasing credits, so that credit buyers do not just remediate the cheapest sites, leaving the most expensive remediation work for the future.

Several institutional structures could succeed: The CWRA could be a non-profit, government, or hybrid organization, so long as it is responsive to the stakeholders in the Cheat watershed. For example, West Virginia code provides for the creation of watershed improvement districts, whenever "…the conservation, development, utilization, or disposal of water will be promoted by the construction of improvements…"[26] The remediation of AMD in the Cheat watershed would fit this definition.

Watershed improvement districts can cut across standard soil conservation district boundaries. If the CWRA were to organize under this statute, it would then operate under these pre-written rules. The CWRA would be a governmental division of West Virginia, governed by the supervisors of the soil conservation districts in which the watershed improvement district is situated. Supervisors could appoint three trustees to oversee the CWRA, and these trustees could then hire professional staff.

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[26] W.Va. Code 19-21B-2.

Alternatively, a more traditional non-profit organization could be created. A board of directors could be appointed by local stakeholders, and a small, professional paid staff could be hired. Other possible institutional structures are also possible.

No matter which structure is chosen, there are opportunities for combining or making use of existing institutions in the watershed. Friends of the Cheat, an existing non-profit organization, may have overlapping goals and resources and be able to share office space or staff. River of Promise, which is already performing some similar functions but strictly through volunteer efforts, may also play a role. Considerable thought must be given to exactly how to organize the CWRA and how to integrate it into existing institutions so as not to duplicate efforts.

9.2.   The credit bank

As utilized in other water quality trading programs (See Appendix C), a credit bank, administered by the CWRA, would be used to track trades. In most cases, credit generators would deposit credits into the bank, and credit buyers would purchase credits from the bank. In some cases, when credit buyers generate credits for their own use, credits may not necessarily pass through the credit bank.

As discussed in Section 11, trades could be limited to same-pollutant trades, cross-pollutant trades within AMD, or cross-pollutant trades outside of AMD. Depending on which system is ultimately approved, the units of trade, and therefore the credit bank, would be different.

To manage same-pollutant trades, the credit bank would track loads of iron, aluminum, and manganese separately. If acidity were used as the unit of trade for cross-pollutant trades, then the credit bank would track acidity loads and would not need to track loads of individual metals. And if ecounits were the units of trade, then the credit bank would hold ecounits. Figures 15 through 17 in Section 11 illustrate these different types of credit banks.

Once a framework is ultimately approved, it may be necessary for the credit bank to track multiple units of trade. For example, it is possible that pollutant loads for individual metals and ecounits would both be banked when credits are generated. And depending on whether the credit buyer is engaging in a same- or cross-pollutant trade, it would purchase the appropriate type of credit from the bank.

The trading framework envisioned for the Cheat watershed would allow the banking of publicly financed credits. In fact, allowing the banking of credits generated by DEP, USEPA, USACE, or other public agencies or nonprofit organizations are critical to the success of this program, because remediation projects completed in the near term would capitalize the credit bank. Credit users would then be able to quickly buy credits that have already been generated. The CWRA would then, in turn, invest the funds used to purchase publicly-financed credits in even more remediation projects, which would generate a new round of credits that could be purchased. Allowing the banking of publicly financed credits would jumpstart the trading process and would allow it to retain its momentum over time.[27]

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[27] Such a process is fundamentally different from allowing farmers to bank credits generated through Farm Bill funding. In the case of Farm Bill programs, public funds are directed to private farmers. In the Cheat watershed, public funds are used to remediate orphan sites.

10. GEOGRAPHICAL RESTRICTIONS ON TRADES

No matter which types of trades are allowed in the Cheat watershed, the question of spatial scale is important. Must credits be generated upstream from the point in which they are used? Must they be generated in the same subwatershed? Can they be generated anywhere in the Cheat watershed? This section considers these three possibilities, and discusses how this choice affects the number of potential trades. Generally, the broader and more flexible the trading rules regarding spatial scale, the more trades would be possible but the more legal obstacles would result.

To gain some insight into these questions, Figure 14 illustrates the spatial relationships between credit generators and buyers in three small subwatersheds: Muddy Creek, the North Fork of the Blackwater River, and Bull Run. These subwatersheds were chosen because they include a large number of orphan sites on which pollutant reduction credits could be generated. The following sections refer to this figure to illustrate the implications of three levels of spatial strictness.

Figure 14: Potential trading partners in the Muddy Creek, North Fork Blackwater River, and Bull Run subwatersheds
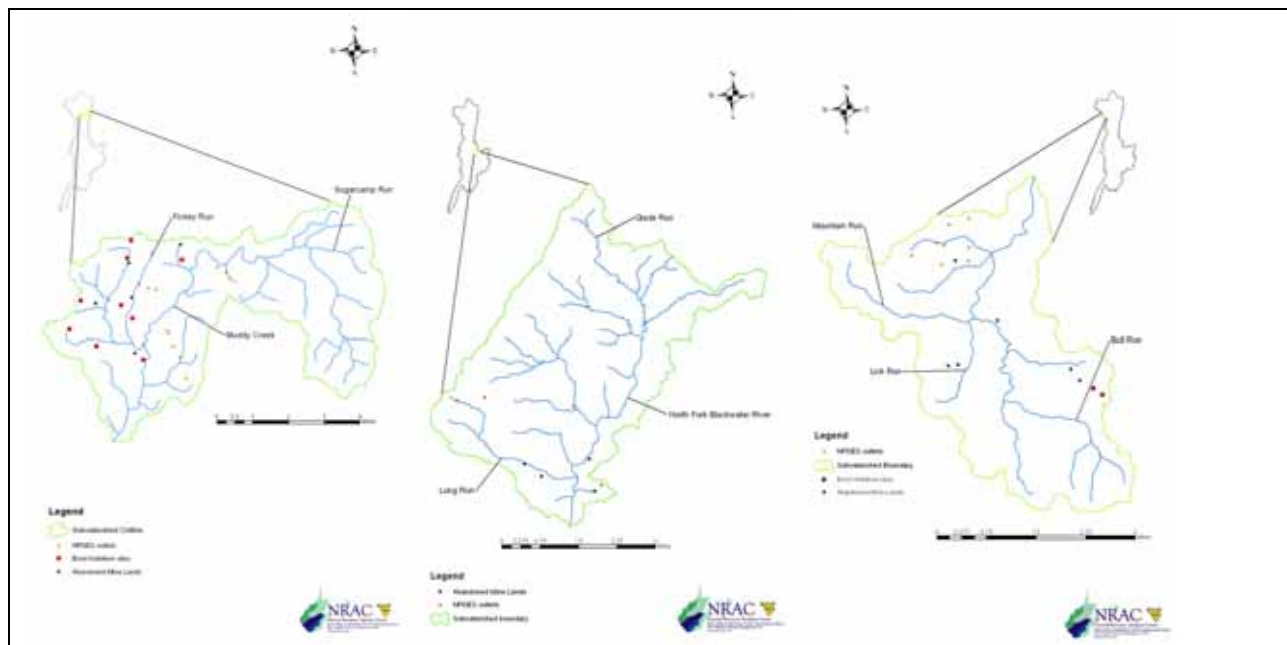
10.1. Credits generated upstream

The Cheat trading program could restrict trades such that credits must be generated upstream. Such a system would be consistent with West Virginia's antidegradation implementation rules, and would guarantee that reduced pollution loads due to credit generation impact the same stream where credits are used.

In most cases, credits would be generated on AMLs or BFSs, and credits would be used at coal mines operating under NPDES permits. As shown in Figure 14, the Muddy Creek subwatershed

includes many potential credit generators and buyers. However, restricting the generation of credits to be upstream from their use would limit the potential trades, because virtually no AMLs or BFSs are located upstream from permitted coal mines.

In the North Fork Blackwater River subwatershed, the situation is even more restrictive. No AMLs are located upstream from a permitted coal mine, and there are no BFSs in the area. No permitted operations in this subwatershed would be able to engage in a trade with such a restriction.

Finally, the Bull Run subwatershed shows similar results: A single AML is located upstream from a permitted coal mine.

Although requiring credits to be generated upstream would restrict the number of potential trades, it would also limit the legal and regulatory concerns. It would fit squarely within USEPA's trading policy, it would mirror West Virginia's current trading rules for antidegradation, and it would be similar to the existing water quality trading programs across the country (See Appendix C).

10.2. Credits generated within the same subwatershed

A broader approach would allow credits to be generated anywhere in the same subwatershed as the credit user.[28] If the Cheat trading framework allowed such trades, then it is more likely that trades would actually take place. As illustrated in Figure 14, permitted mines would have many orphan sites with which to trade, if trades were allowed between any sites in the Muddy Creek watershed. Many more trading opportunities would also exist in the North Fork Blackwater River and Bull Run subwatersheds.

This approach might be attractive in the Cheat watershed if it were thought that the main AMD pollution problems were in the Cheat mainstem, as opposed to the tributaries. If this were the case, it would not matter if the credit purchaser and buyer discharged to the same stream; instead, it would only matter that the trade results in a pollutant reductions by the time both discharges reach the Cheat River.

Allowing such trades would directly contradict West Virginia's antidegradation implementation procedures (See Sections 6.3 and 6.4). But even in impaired waters, whether before or after the development of TMDLs, such trades would run into several other regulatory hurdles.

The main challenge would be to show that such trades are consistent with the credit buyer's WQBELs, whether these limits are derived from TMDL wasteload allocations or from standard permitting procedures.[29] Another challenge would be to show that such trades lead toward the attainment of standards in impaired streams. In short, while some stakeholders may be most concerned about the Cheat River itself, the CWA applies to all waters, including tributaries. Allowing trades that do not reduce pollution upstream may sacrifice water quality in tributaries

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[28] The watershed boundaries used in this section are arbitrary; other sizes of subwatersheds could be used as well. If this option were to be pursued, agreement would have to be reached on the appropriate scale of the subwatershed.
[29] 40 CFR 122.33(d) lays out the requirements for issuing WQBELs, whether or not a TMDL has been developed.

for improvements in the Cheat River, and runs up against the CWA's promise of clean water for all rivers and streams.

10.3. Credits generated anywhere within the Cheat watershed

The least restrictive system would allow credits to be generated anywhere in the Cheat watershed. Such an approach might be useful because stream ecosystem stressors stem from multiple, diffuse sources scattered throughout the watershed, and ecological impairment often is the result of the cumulative and interactive effects of these stressors. Consequently, one model for an effective restoration and management system would consider multiple stressors and sources as a whole rather than in isolation. Such an approach requires a watershed scale perspective, without losing sight of the importance of remediating individual streams.

This system might be attractive in the Cheat watershed if appropriate management structures and safeguards were established. In particular, if a CWRA were established as described in Section 9.1, it would develop a watershed restoration plan and evaluate each trade based on its contribution toward meeting the goals of the plan. If such a plan were being systematically implemented, then this broader system might be beneficial if it could help generate a consistent flow of funds that would be used for continued reclamation projects. Such a system might be justified if the single goal of the trading program were to reduce acid loads basin-wide, and if it did not matter where these reductions took place.

This system would likely result in the most possible trading partners, because there would be no spatial limitations. Every NPDES permittee in the watershed could purchase credits generated on any AML or BFS in the watershed. But because trades would need to fit within the priorities of the CWRA's watershed management plan, trading partners would be somewhat more limited than this.

The same legal and regulatory challenges raised in the previous section would apply here. The CWA and its regulations, as currently written, prohibit such trades.

11.   CROSS-POLLUTANT TRADING

During the development of the Cheat trading framework (See Appendix A), the stakeholder group considered a variety of trades. Of the three types of trades under consideration, same-pollutant trades are relatively easy to measure and the least controversial. In contrast, cross-pollutant trades are more difficult to measure, fit less neatly into existing laws and regulations, and are more likely to face controversy. The added complexity in administering such trades also makes it more difficult to verify whether trades are actually improving water quality. This section assesses three categories of trades that may be allowed in the Cheat watershed:

1. same-pollutant trades for AMD pollutants,
2. cross-pollutant trades within AMD, and
3. cross-pollutant trades outside of AMD.

The stakeholder group's trading framework allows all three types of trades, and contemplates different rules for each category. This assessment considers each category separately, because a trading program implemented in the Cheat watershed ultimately may be limited to one or more of these categories. This section helps explain the significance of this decision in the Cheat watershed, and helps inform decision makers as they consider AMD trading in other watersheds.

11.1.   Same-pollutant trades for AMD pollutants

AMD is generally composed of iron, aluminum, and manganese;[30] it would be most transparent to account for trades on a pollutant-by-pollutant basis for each of these metals separately. Figure 15 illustrates one such trade. The credit generator, which in this example could be DEP, would fund a remediation project on an AML and would generate separate iron, aluminum, and manganese reductions, which would then be placed in the credit bank. Three separate trading currencies would be used to account for such trades: pounds of iron, aluminum, and manganese.

The credit purchaser, in this case a permitted coal mine, is faced with stricter discharge limits due to the TMDL. The permittee would calculate the amount of credits to buy based on maintaining its current discharge limits and applying the required trading ratio. In this hypothetical example, the permittee only needs to buy 10 tons/year of manganese credits. The discharger would not need to purchase iron or aluminum credits.

This illustration bypasses the question of spatial scale discussed in Section 10, and the question of whether a government agency should be able to use public funds to generate credits, as discussed in Section 9.2. It simply shows that trades could, in principle, be accounted for on a pollutant-by-pollutant basis.

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[30] Coal mines generally also discharge other pollutants that are not measured.

Figure 15: A same-pollutant trade for AMD pollutants

Credits generated on an AML	Credits placed in credit bank	Credits purchased by NPDES discharger
100 tpy iron ⟶	<u>Iron</u> 100 tpy	
70 tpy aluminum ⟶	<u>Aluminum</u> 70 tpy	
60 tpy manganese ⟶	<u>Manganese</u> 60 tpy ⟶	10 tpy manganese

TMDL calls for NPDES discharger to reduce by 10 tpy manganese
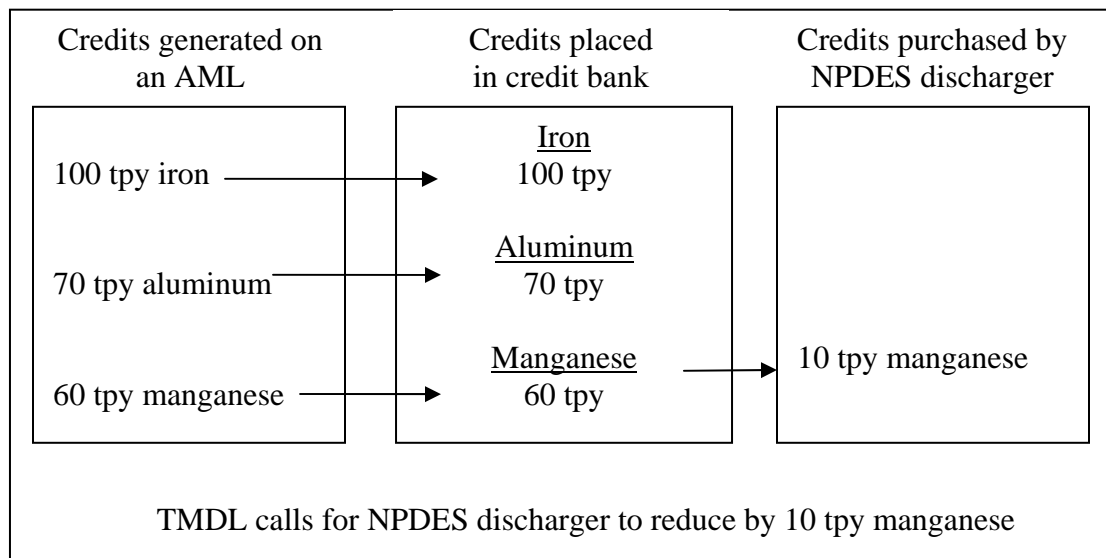
Note: For illustrative purposes, this trade assumes no trading ratio.

The potential benefits of same-pollutant trades would be reductions of the loads of iron, aluminum, and/or manganese. Compared with cross-pollutant trades, the risks and uncertainties are relatively low, because iron would be traded for iron, aluminum for aluminum, and manganese for manganese. Uncertainty would be lowered because these three metals are relatively easily monitored.

Such trades are also attractive because they are explicitly approved in USEPA's water quality trading policy (USEPA, 2003b) and because they are similar to trades that have already been approved in existing same-pollutant trading programs across the country.

However, in the context of AMD, same-pollutant trades may have limited utility. Trades such as the one shown in Figure 15 are unrealistic and unlikely to take place if a passive treatment system is installed at the AML. Manganese is only removed by certain passive treatment systems. These are generally expensive and usually not used because the tons of acid load removed is low compared to the investment. Therefore, it would be difficult to justify the expense of generating manganese credits through investments in passive treatment systems on AMLs.

In contrast, credits could more easily be generated for iron and aluminum reductions generated through less expensive passive treatment systems at AMLs or BFSs. But permitted operations faced with more stringent limits for all three metals would have no incentive to buy only iron and aluminum credits, only to be left to treat for manganese onsite, because treating for manganese by raising the pH to about 10 would also result in treatment of iron and aluminum. Therefore, accounting for AMD-for-AMD trades pollutant-by-pollutant will generally not provide the necessary incentive for a permitted operation to trade.

An exception would be when permitted operations do not discharge manganese or are not

targeted with stricter manganese limits by the TMDL. In these cases, a trade would only be used to buy the appropriate number of iron and/or aluminum reduction credits.

To determine whether a same-pollutant trade has actually been carried out, loads of each metal in runoff from the site of credit generation can be measured. The documentation for the trade would probably require a regime of monitoring reports similar to the discharge monitoring reports currently required of NPDES permittees.

11.2.   Cross-pollutant trades within acid mine drainage

A second option for accounting for AMD-for-AMD trades would be to treat them as cross-pollutant trades. In this manner, separate accounting for each of the three metals would be unnecessary. Instead, acidity can be used as a common currency.

Acidity is a common unit used in water quality analyses, and can be directly calculated from concentrations of iron, aluminum, and manganese.[31] When credits are generated by reducing discharges of one or more of these metals, these reductions could be converted into a single reduction of acidity. Credit purchasers, faced with the need to reduce loadings of one or more of these metals, would convert their required reductions into acidity loadings, and purchase the appropriate amount of acidity credits by applying the required trading ratio. Figure 16 illustrates one such hypothetical trade.

Figure 16: An acidity-based trade for AMD pollutants

Credits generated on an AML	Credits placed in credit bank	Credits purchased by NPDES discharger
100 tpy iron		
	Acidity 268 + 389 + 109 = 766 tpy	18.2 tpy acidity
70 tpy aluminum		
		(equivalent to 10 tpy manganese)
60 tpy manganese		

TMDL calls for NPDES discharger to reduce by 10 tpy manganese
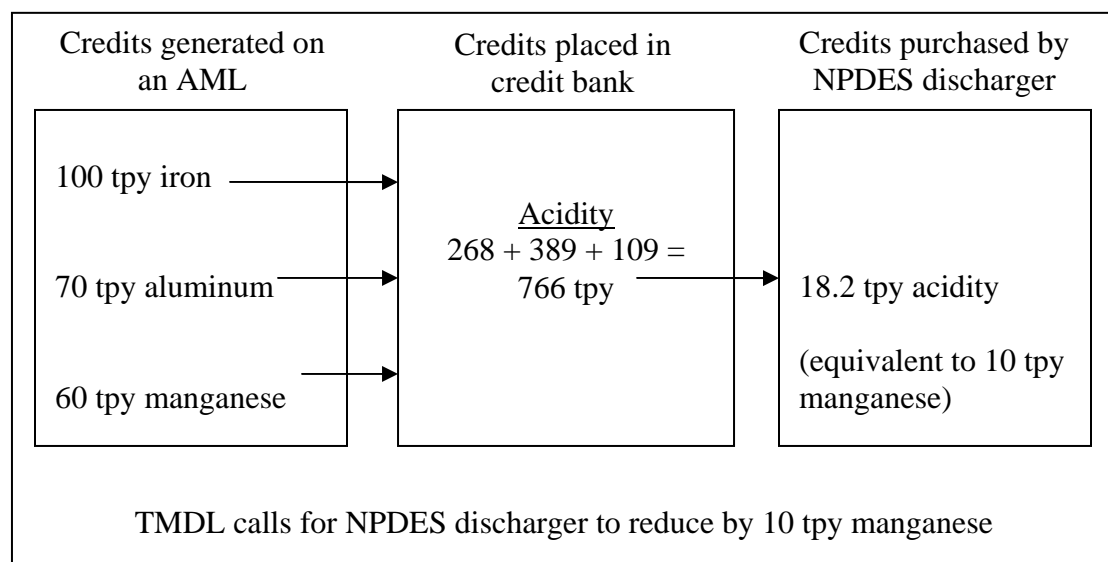
Notes: Tons of acidity calculated as follows: 1 ton iron at valence 3 = 2.68 ton acidity, 1 ton aluminum at valence 3 = 5.56 ton acidity, 1 ton manganese at valence 2 = 1.82 ton acidity. For illustrative purposes, this trade assumes no trading ratio.

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[31] Acidity due to each component of AMD (Fe^{2+}, Fe^{3+}, Al^{3+}, and Mn^{2+}) is calculated by multiplying its concentration (in mg/L) by its valence, dividing by its molecular weight, and multiplying by 50 g/equivalent (one mole of $CaCO_3$ can neutralize two moles of acid). Results are in mg/L $CaCO_3$ equivalents, the standard unit of acidity.

Such a system would focus trades on reducing acidity, which would greatly improve the Cheat River and many polluted tributaries. However, West Virginia has no water quality criteria for acidity.[32] Acidity-based trades would not necessarily lead toward the attainment of water quality criteria for iron, aluminum, and manganese.

Compared with same-pollutant trades, acidity-based cross-pollutant trades are more likely to raise thorny legal and policy issues. Such trades may be inconsistent with USEPA's water quality trading policy, which specifically endorses cross-pollutant trades only for oxygen-demanding substances (USEPA, 2003b).[33] In addition, NPDES permitting regulations do not allow such trades because they may allow credit buyers to continue causing or contributing to violations of water quality standards.[34] Questions include: Will water quality standards be protected for each pollutant? Will new variances be required? Will permanent use attainability analyses need to be generated?

Allowing acidity-based cross-pollutant trades would also increase the complexity of administering a trading program, because calculated acidity values, rather than measured pollutant loadings, would need to be tracked.

Although they may be controversial, such trades, if legal and allowed, are more likely to take place. The situation described in the previous section, in which permitted operations with manganese discharges would have no incentive to trade, no longer applies. Because trades are made for acidity, each trading partner's specific iron, aluminum, and manganese discharges and pollutant reductions would not be relevant.

To determine whether a acidity-based cross-pollutant trade has actually been carried out, acidity loads in runoff from the site of credit generation can be measured. Again, the documentation for the trade would probably require a regime of monitoring reports.

11.3.   Cross-pollutant trades outside of acid mine drainage

Some trades contemplated in the Cheat watershed involve pollutants other than AMD. In particular, the potential heat-for-AMD trade would need a currency that allows these two dissimilar pollutants to be traded in a meaningful and fair manner. Ecounits, described in detail in Section 13, measure the ecological condition of a stream segment, and are one such currency. In short, ecounits measure a stream's health as measured through benthic macroinvertebrate monitoring. Biological health can be impacted by the discharged AMD, heat, or any other pollutant.

As shown in Figure 17, credits generated by AMD remediation can be tracked by predicting and measuring improvements in biological health downstream from the site. Plugging these scores into the ecounits equation would result in a number of ecounits that could be banked.

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[32] West Virginia has criteria for pH, which is directly influenced by acidity.
[33] Although USEPA's water quality trading policy leaves the door open for other kinds of cross-pollutant trades, such an approach would certainly face more legal hurdles than same-pollutant trading.
[34] 40 CFR 122.44(d).

In this example, AMD pollutant reductions from the AML result in improved benthic life in the receiving stream, and this improvement is measured as 100 ecounits/year. These credits are placed in the bank. The power plant, as a condition of renewing its 316(a) variance, is required to purchase a certain number of ecounits to make up for the impact of its thermal discharge. It purchases 50 ecounits from the credit bank, and its thermal variance is renewed.

Figure 17: An ecounit-based trade

Credits generated on an AML	Credits placed in credit bank	Credits purchased by power plant
Increase in biological health by 100 ecounits/yr	Ecounits 100 ecounits/yr	50 ecounits/yr (equivalent to effect of plant's thermal discharge)

Thermal discharge from power plant degrades watershed by 50 ecounits/yr
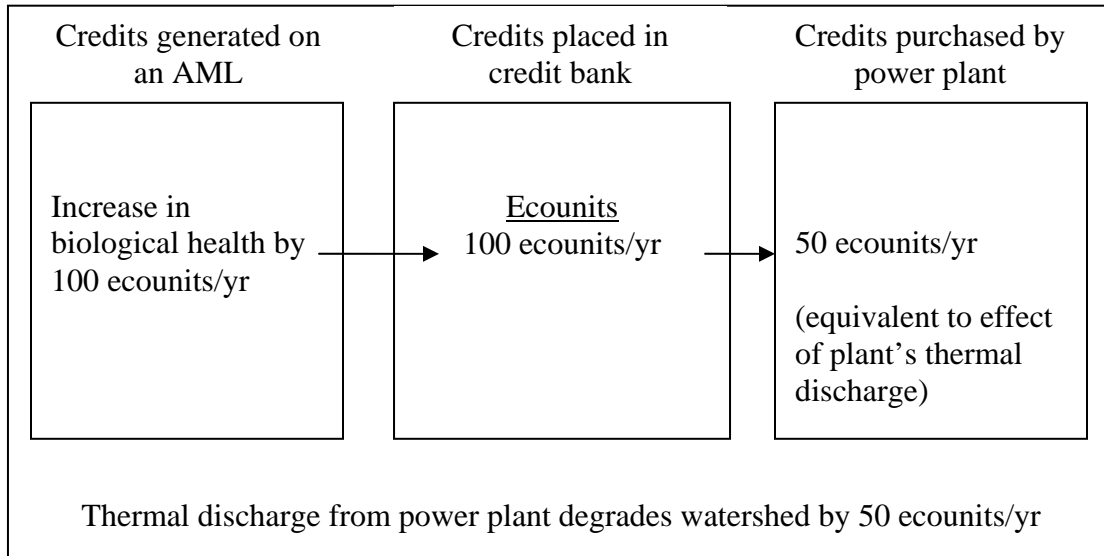
Notes: Numbers of ecounits chosen for illustrative purposes only. Also, for illustrative purposes, this trade assumes no trading ratio.

Such a system is attractive because it allows dissimilar pollutants to be traded using a single currency, and because that currency measures the ecological response of the receiving streams to trading activities. While ecological responses—benthic macroinvertebrate and associated fish populations—are not the only concerns in the Cheat watershed, they are significant concerns and the ultimate barometers of the health of the streams, at least in terms of their ability to support aquatic life.[35]

The use of ecounits, however, raises certain difficulties. The issues raised above regarding the use of acidity as a currency apply here: ecounit-based trades may be inconsistent with USEPA's water quality trading policy, and NPDES permitting regulations do not currently allow such trades.

Allowing ecounit-based cross-pollutant trades would also increase the complexity of administering a trading program, because calculated ecounits values, rather than measured pollutant loadings, would need to be tracked. It would be difficult to prove that the generation of ecounit credits are real and quantifiable because instream monitoring would have to show improvements in benthic macroinvertebrate communities, the fundamental component of the ecounit. It may take years for these communities to respond to remediation projects. And in some cases it would be impossible to determine whether or not changes in these communities are

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[35] Benthic macroinvertebrate and fish populations may not accurately predict stream health for other uses, such as drinking water supply.

directly related to specific remediation projects. In particular, it may be impossible to assign causes for small or moderate changes in the index. However, large changes, such as the elimination of one major kind of pollution, should be easily read in the index.

An alternative to measuring changes in ecounits would be to base the number of ecounit credits generated on the dollar investment multiplied by the expected ecounit gain per dollar invested as calculated by the CWRA's standard equivalencies (See Table 24). While this system would greatly simplify the problem of quantifying credits, it is performance-based instead of results-based, and is unlikely to hold up against legal challenges. Using this system, credits would be neither real nor quantifiable; instead they would simply be expected. Therefore, ecounit credits must be verified by monitoring.

A second alternative may solve this problem: credits can be measured in terms of acid load reductions, which are real and easily quantifiable through monitoring. Using the equivalencies in Table 24, acid load reductions could be converted into ecounits for use in cross-pollutant trades. Credit generators would be held responsible for proving that they generated the appropriate acidity reductions, not ecounits improvements.

Such a system depends on a clear system for measuring ecounits and calculating equivalencies. These and other related issues are described in Section 13.

12.   TRADING RATIOS

According to the Cheat trading framework in Appendix A, trading ratios will be required to ensure environmental or ecological improvements from each trade. Ratios also help account for risk and uncertainty.

There are several sources of uncertainty in calculations used to design fair trades. The smallest sources of uncertainty are those related to individual measurements of chemical composition or effluent flow, from either a permitted or an orphan site. Extrapolating from instantaneous pollutant loads to longer term, such as annual loads adds much more uncertainty to the measurement. Although there is a clear relationship between chemical and biological condition in a stream, this relationship supports only general predictions of biotic improvement with improved chemical conditions. Comparison of the predicted biological effect of one pollutant to the predicted biological effect of another pollutant is the most uncertain situation.

Although the framework leaves specific ratios to be determined in the future, it identifies three situations in which ratios will be higher or lower.

First, to encourage trades with less uncertainty, trades in which the credit seller and buyer are in close proximity, and in which the credit seller is upstream, are generally preferred. The framework recommends lower trading ratios for such trades.

Second, the framework allows the CWRA to adjust trading ratios to favor trades that contribute to strategic watershed restoration goals, such as the improvement or maintenance of water quality in a particular subwatershed. In this manner, reduced ratios could be used as incentives to promote the generation of credits in priority locations.

Finally, the framework specifies that trading ratios for same-pollutant trades will be lower than those for cross-pollutant trades. As discussed in Section 11, three separate trading currencies would be used to account for same-pollutant AMD trades: pounds of iron, aluminum, and manganese. And there would be little uncertainty in the outcome of a trade if the credit generator and buyer were affecting the same pollutant. In contrast, cross-pollutant trades that use a common currency such ecounits would be measured based on their ecological effect, which is one step removed from the actual changes in pollutant loads. The higher trading ratio required for cross-pollutant trades reflects this greater uncertainty.

13.   AN ECOLOGICAL INDEX TO FACILITATE TRADING

Cross-pollutant trading may be necessary to produce significant improvements in the chemical and ecological condition of the Cheat watershed (see Section 11). This section presents and demonstrates a method for assessing the ecological benefits of same-pollutant and cross-pollutant trade scenarios. The method employs an ecological based index, which can be used as a common currency when calculating the expected environmental gains and losses of a specific trade. The method also allows for the calculation of pollution/ecological condition/dollar equivalencies. Specific objectives are as follows:

1. Identify ecological issues critical to a trading program.
2. Develop and justify an ecological index for use in the Cheat watershed.
3. Demonstrate how the index can be used to calculate equivalencies between pollutants, ecological condition, and dollars.
4. Demonstrate how the index can be used to identify priorities for restoration.
5. Demonstrate how the index can be used to calculate the net ecological benefit of various trade scenarios.

This approach may prove invaluable in developing a far reaching trading program that can allow, under certain restrictive conditions, trades involving multiple stressor types and sources. However, for such a system to be used effectively, and not abused, it must be embedded into a holistic watershed restoration and management program managed by an entity such as the CWRA (See Section 9.1).

13.1.   Ecological issues critical to a water quality trading program

The foundation of this approach to a holistic water quality trading program rests on three basic tenets of stream ecology, and ecosystem assessment and restoration. From this foundation, an ecological index is developed, and this section demonstrates how the index can be used to guide trade decisions to facilitate recovery of watershed condition in the Cheat watershed.

13.1.1. Environmental and ecological condition

The first tenet is that at any given time, the overall condition of a watershed is influenced simultaneously by a variety of human influences and environmental stressors (Figure 18). For example, active forestry practices that include road and skid trail development typically produce an increased load of sediments to water bodies within the watershed. Typical agricultural practices also produce increased sediment loads, in addition to increased rates of nitrogen and phosphorus loading. Although it may be difficult to quantify, it also is generally agreed that biological communities within a watershed (e.g., algae, invertebrates, and fishes) are impacted by the cumulative and interactive effects of multiple environmental stressors (Figure 18). Consequently, changes in biological communities can be measured in a way such that they provide an indication of the level of impairment within the watershed (Karr and Chu, 1999; Simon, 1999), and therefore, provide a measure of ecological condition. For example, ecologists and state regulatory agencies have spent considerable time and resources developing benthic invertebrate and fish community–based indices of ecological condition. These indices are used regularly to guide aquatic ecosystem assessment and management throughout North America and the world (Hilsenhoff, 1988; Yoder and Smith, 1999).

Figure 18: Interactive effects of multiple human activities and environmental stressors
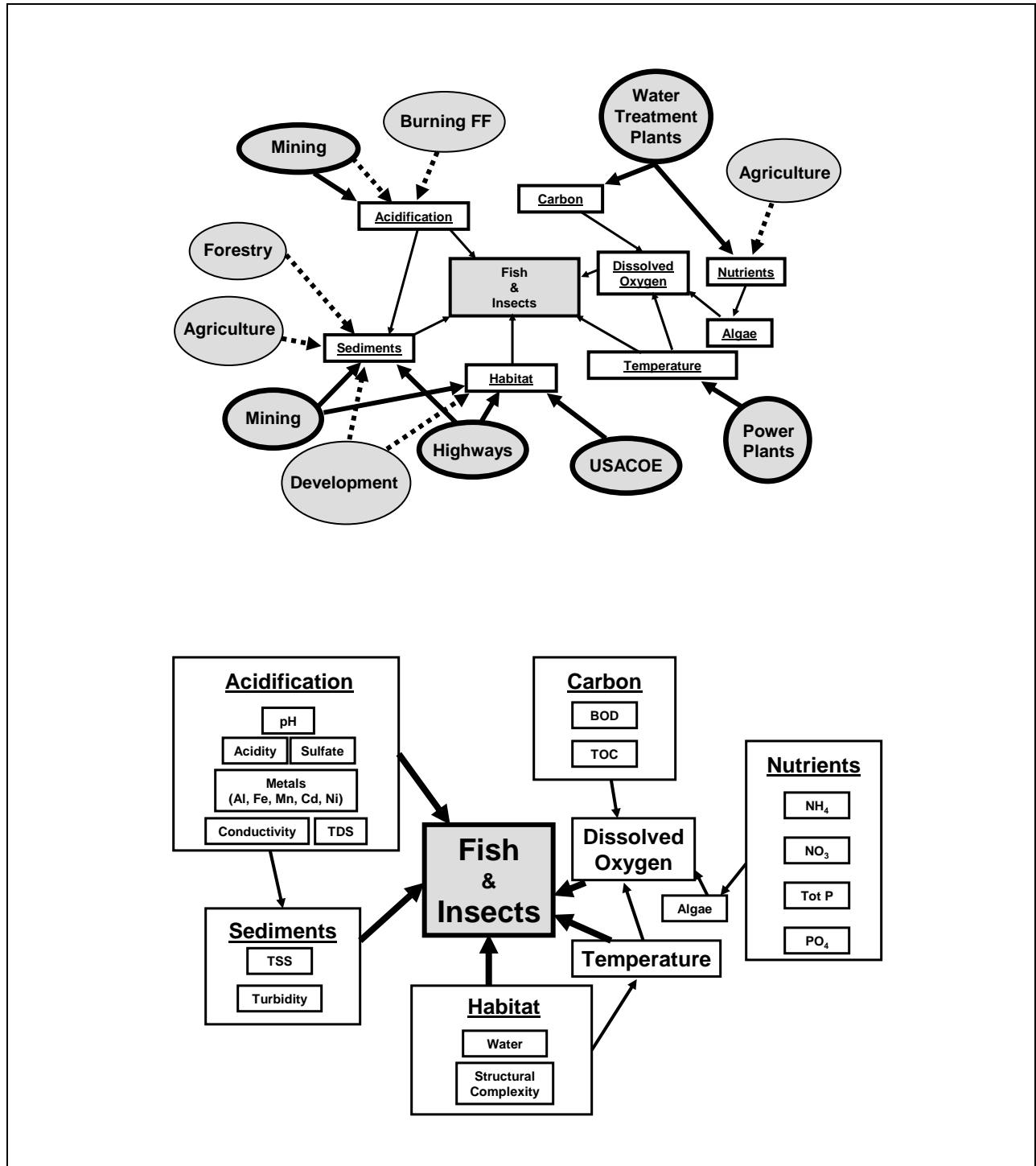
For the purposes of this report, "Environmental Condition" is defined as a measure of the overall condition of a watershed as defined by physical (e.g. habitat, sediment, temperature, stream flow) and chemical (e.g., pH, conductivity, metals, nutrients, dissolved oxygen) properties. Consequently, the environmental condition of a watershed is simply a measure of the suite of environmental variables that describe the watershed. Likewise, "Net Environmental Benefit" is

defined as a net improvement in the physical and chemical conditions of a watershed. In contrast, "Ecological Condition" is a measure of the overall condition of a watershed as defined by biological communities, especially benthic invertebrate and fish assemblages. Furthermore, "Net Ecological Benefit" is defined as a net improvement in the condition of biological communities in the watershed.

Quantifying "Net Environmental Benefit" requires a comparison of like environmental variables. *It is impossible to calculate "Net Environmental Benefit" if two actions influence different environmental properties.* For example, if Action 1 increases acidity by 1 tpy and Action 2 reduces acidity by 3 tpy, then the "Net Environmental Benefit" is equal to 2 tons of acidity/year. However, if Action 1 increases phosphorus levels by 1 tpy and Action 2 reduces acidity by 3 tpy, then "Net Environmental Benefit" cannot be calculated. As a consequence, "Net Environmental Benefit" can be applied to same-pollutant trades, but not to cross-pollutant trades.

On the other hand, quantifying "Net Ecological Benefit" can potentially be used to reduce multiple stressors to a single common denominator, and as a consequence, provide a mechanism for assessing benefits associated with cross-pollutant trades. For example, if Action 1 increases phosphorus by 1 tpy and reduces ecological condition by 100 units/year, and Action 2 reduces acidity by 3 tpy and increases ecological condition by 300 units/year, then "Net Ecological Benefit" of Action 2 relative to Action 1 is 200 units/year. In fact, the primary objective of developing a measure of "Net Ecological Benefit" is to provide a means for objectively determining the potential environmental gains and losses of a cross-pollutant trading program.

13.1.2. Hierarchical structure of watersheds

The second tenet is that aquatic ecosystems exist as hierarchically nested subsets, where each subset represents a different spatial scale (Frissell, 1986). For example, as shown in Figure 19, microhabitats (areas less than one square meter) are nested within hydraulic channel units (e.g., pools and riffles), channel units are nested in stream reaches, reaches are nested in stream segments, segments are nested in local drainage networks, and drainage networks are nested within whole watersheds. The approach introduced in this section explicitly considers the hierarchical structure of watersheds and multiple spatial scales and attempts to quantify ecological condition across these scales. Specifically, it focuses on scales ranging from the stream segment scale (1 km) up to whole watersheds (100-200 km^2 basin area). Although this section stops at the scale of the Cheat watershed, it may be possible to extend this approach to larger scales, such as the upper Monongahela River basin or even the upper Ohio River basin.

Figure 19: Hierarchical structure of stream habitats

Drainage Network	Segment	Reach	Channel Unit	Microhabitat
>10 km	1 km	100 – 1000 m	10 – 100 m	1 – 10 m
10,000 yrs	100 – 1000 yrs	10 – 100 yrs	1 – 10 yrs	1 day – 1 year

*Modified from Inter-Federal Agency Report on "Stream Corridor Restoration." 1998.
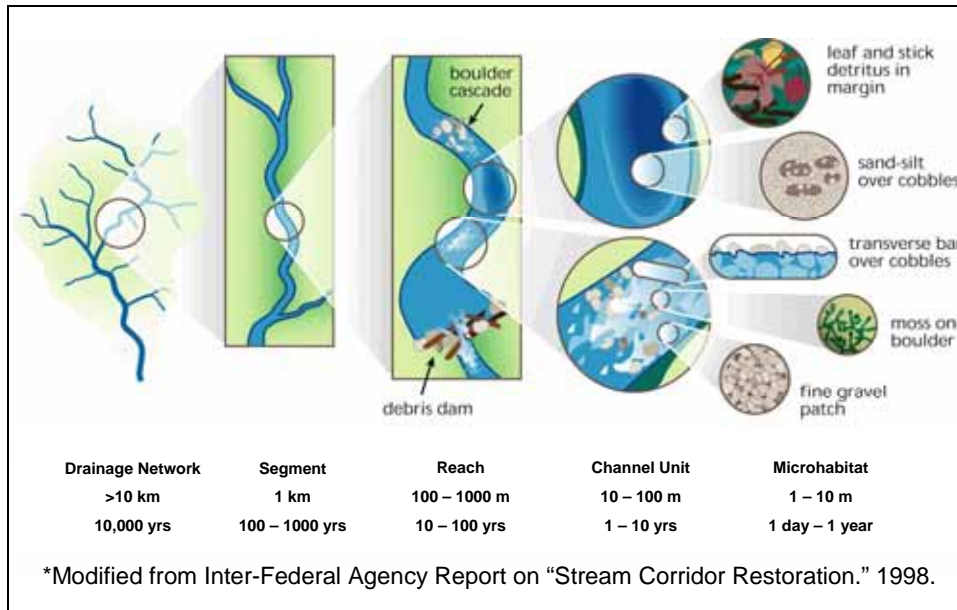
Note: An effective assessment and trading program must consider ecological condition at each hierarchical level.

13.1.3. Watershed degradation and restoration

The final conceptual foundation is illustrated in Figure 20, which is a modified version of a general model of aquatic ecosystem restoration presented by the National Research Council (National Research Council, 1992). Briefly, the model recognizes that watershed and instream attributes interact to determine present ecological condition. Stream condition is measured by the health of the stream biotic community and is a function of physical habitat, the stream hydrograph, and water chemistry. Any changes in the stream's functional attributes will likely affect its condition. In most cases, because of historic or active land use practices, the current ecological condition of a watershed is below its historic condition. An objective of this section is to describe a process that can be used to quantify each of the critical variables illustrated in Figure 20. In doing so, the section illustrates how the ecological costs and benefits of alternative management scenarios can be assessed.

Figure 20: A general model of watershed condition and aquatic ecosystem restoration and management
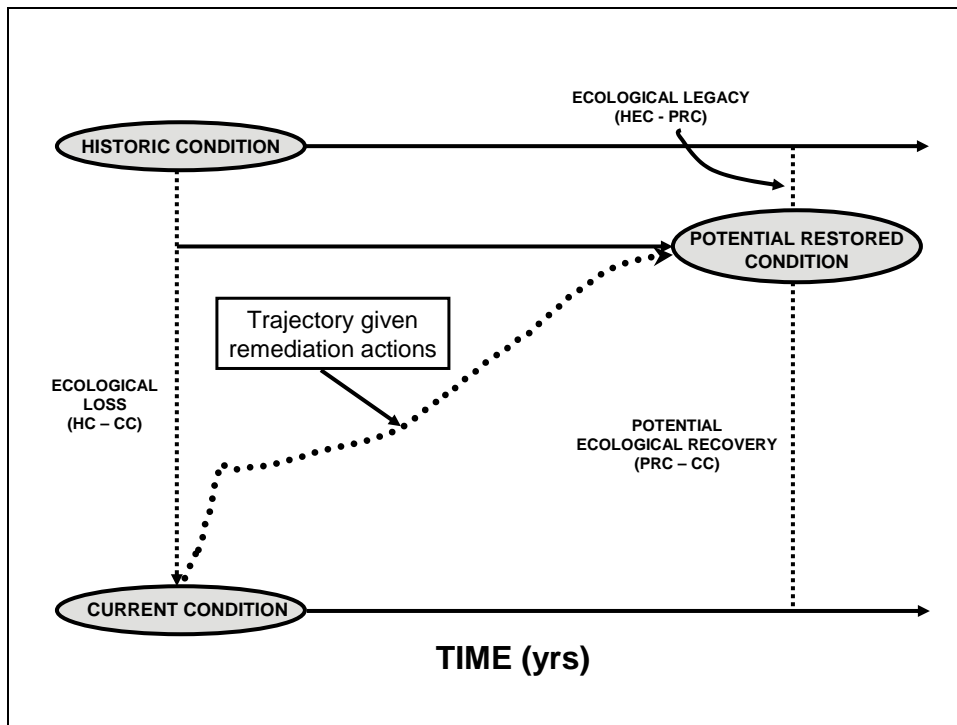
Note: The model recognizes that all water bodies within a watershed, regardless of spatial scale, can be categorized with regard to present ecological condition, restoration potential, and vulnerability to future impact. Restoration potential is the likelihood of improving the ecological condition of a water body after some specified remediation action. Vulnerability is the likelihood of reduced ecological condition following some specified impact. The specific objectives of this proposal are placed on the diagram for context.

13.2.   An ecological index for the Cheat watershed

An ecological index can be used to quantify ecological condition at multiple spatial scales. The index may also be used to measure the Net Ecological Benefit of alternative management scenarios in the Cheat watershed. To this end, a useful index must include at least two components: 1) the area of stream affected by an action, and 2) the ecological condition of that area.

13.2.1. Stream size

The simplest measure of affected area is stream miles. However, this measure does not consider variation in the width or flow volume of streams within a watershed. Other potential measures for the area of influence include: stream surface area (length times width), stream order (Strahler), and watershed area drained by the stream segment. Each of these alternatives, in some way, captures spatial variability in stream size. Of these alternatives, stream area is preferred because it is simple, it gives greater weight to larger streams, and it is a continuous rather than ordinal measure.

The surface area was calculated for all stream segments recognized by DEP in the lower Cheat River basin. This includes all perennial streams in the watershed that could potentially be placed on the state's 303(d) list. A stream segment was defined as a stream reach bounded at the

upstream and downstream ends by perennial tributary confluences. In other words, a stream segment is a reach with no significant surface water inputs. Surface area was calculated for each segment in one of two ways. Method 1 was used for smaller first to third order stream segments. In this method, ArcGIS was used to estimate the length of the stream segment. A regression equation relating active channel width to basin area was then used to estimate the average width of the stream segment. The regression equation used data from 50 locations distributed throughout the Cheat watershed (Petty et al., unpublished data) and was of the following form:

$$\text{Active Channel Width} = 0.31 \text{ (basin area in km}^2) + 3.97$$

Method 2 was used for larger stream segments, including the Big Sandy Creek mainstem and the Cheat River mainstem. This approach simply used ArcGIS to estimate surface area directly from digital photographs of the watershed.

13.2.2. Ecological condition

Numerous ecological condition indices exist and may be of potential value in a trading program. The most commonly used measures for ecological condition are based on benthic macroinvertebrate and fish communities. Benthic invertebrate–based examples include the West Virginia Stream Condition Index (WVSCI) (USEPA, 2000a), the Hilsenhoff Biotic Index (HBI) (Hilsenhoff, 1988), and the Save-Our-Streams Index. Fish community–based examples include the Mid-Atlantic Highlands Index of Biotic Integrity (USEPA, 2000b), Fish Diversity, or Biomass of Targeted Species (trout and/or smallmouth bass).

The family level WVSCI is used to develop an ecological condition index for the Cheat River basin. Family level means that it was developed based on identification of invertebrate taxa at the family level of taxonomic resolution. The WVSCI score was selected for two reasons. First, this index is used widely by DEP as part of the statewide watershed assessment program. Second and more importantly, it is extremely powerful as a continuous measure of impairment in watersheds impacted by AMD. The WVSCI declines continuously as a function of several important chemical measures of AMD impairment, including pH, iron concentration, aluminum concentration, and manganese concentration (Figure 21). The ability to predict ecological condition as a function of environmental conditions is of critical importance in determining the utility of a particular ecological condition index (Karr and Chu, 1999).

The WVSCI is a multi-metric index of ecological condition that integrates numerous measures of the benthic invertebrate community into a single value (USEPA, 2000a). The metrics included in the final index include: 1) total number of families (i.e., total family richness), 2) number of families in the orders Ephemeroptera, Plecoptera, and Trichoptera (i.e., EPT family richness), 3) percent of all families that are EPT taxa (i.e., % EPT), 4) percent of all families that are considered pollution tolerant (i.e., % tolerant taxa), and 5) percent of the total community of invertebrates that are in the top two dominant taxa (i.e., % dominant taxa). Metrics 1-3 of the WVSCI are expected to increase with decreasing levels of environmental impairment. In contrast, metrics 4 and 5 are expected to decrease with decreasing levels of environmental impairment. The final value is standardized, such that the highest quality stream segments in a watershed receive scores of 100. The lowest score possible is a WVSCI of 10 (USEPA, 2000a).

Figure 21: Relationship between WVSCI for a given stream segment and various water chemistry parameters
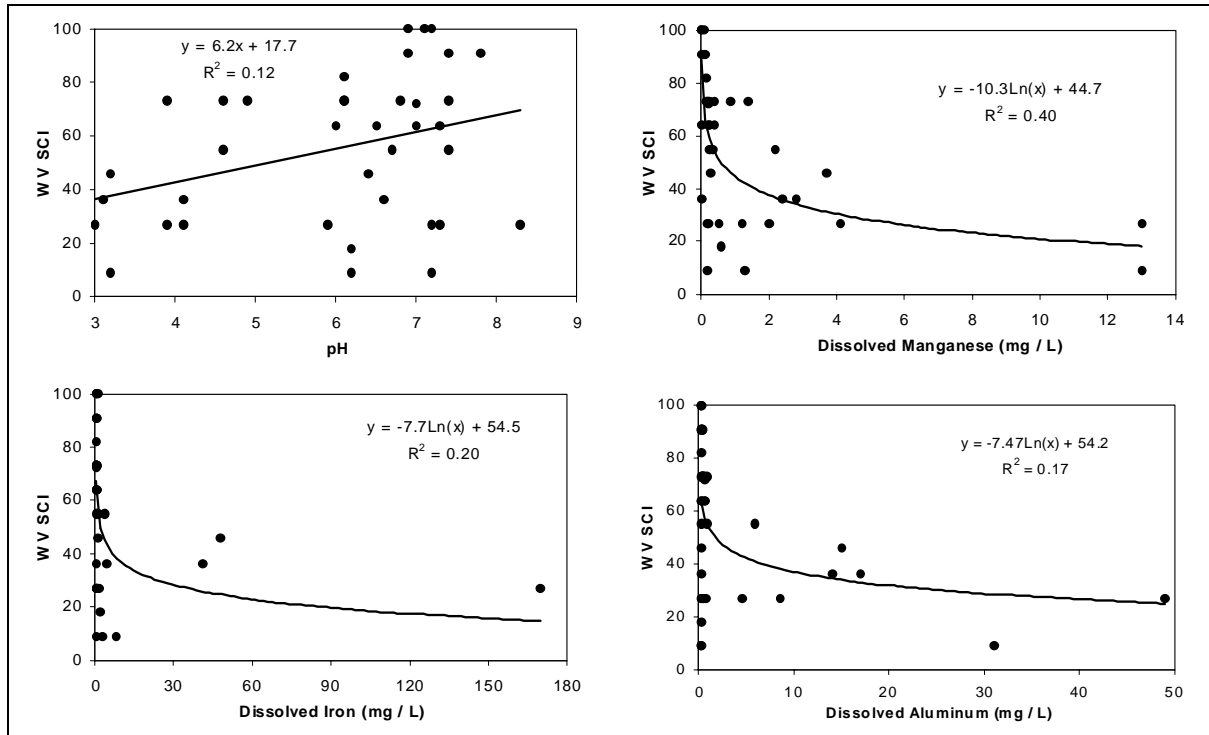
Source: DEP, 1999. Note: Consistent correlations illustrate the power of the WVSCI in describing continuous levels of impairment from AMD in the Cheat watershed. This is especially true for manganese concentration, which provides a good indication of mining impact.

13.2.3. Ecounit index

The index proposed for calculating ecological condition and Net Ecological Benefit in the Cheat River basin incorporates a measure of stream surface area and ecological condition as the WVSCI. It is referred to as the "ecounit index" (EUI), because each stream segment within the watershed—and the watershed as a whole—possesses a measurable number of ecological units that are a function of the surface area and ecological condition of the segment.

The basic structure of the EUI is:

EUI = Stream Surface Area (acres) x Observed WVSCI / Max WVSCI

The resulting index produces a value in units of acres. The value itself can be interpreted as the surface area of the stream segment weighted by the ecological condition of the segment. Consequently, the EUI for a stream segment will equal the surface area of the segment when ecological condition within the segment is equal to the condition of the highest quality segment in the watershed. EUI is calculated separately for each stream segment in the watershed. A score for an entire watershed or subwatershed can be calculated by summing segment level EUI across all segments within the watershed of interest.

13.2.4. Shortcomings and alternatives to the ecounit index

The utility of this index for managing trades will be developed in subsequent sections. However, several shortcomings of the EUI should be considered now. First, the index places a greater

67

weight on larger streams (because they are wider) than smaller streams. On a pure ecological basis, this decision is difficult to justify because of the extreme importance of small streams to stream ecosystem processes (Vannote et al., 1980). However, although it is counterintuitive, calculating EUIs based on area rather than width may actually lead to greater restoration of tributary streams. In situations where credits are generated on tributaries and used on the Cheat River, the higher the weight given to the Cheat River, the more credits must be purchased on tributaries. Nevertheless, if deemed necessary, the EUI can be easily modified to use stream length instead of surface area as a measure of the area of management influence. For the purposes of this report, however, surface area is used in all subsequent analyses.

Second, the effects of ecological condition and surface area on the EUI are given equal weight. This is not particularly important when simply describing the current condition of the watershed. However, it is extremely important when comparing the ecological costs and benefits of alternative mitigation scenarios. For example, say Action 1 will reduce the modified WVSCI score from 1.0 to 0.5 over an area of 10 acres. The result is a change from 10 EUIs (1 x 10) to 5 EUIs (0.5 x 10) or a loss of 5 ecounits. Now, say that Action 2 will increase the WVSCI score from 0.5 to 0.6 over an area of 50 acres. The result is a change from 25 EUIs (0.5 x 50) to 30 EUIs (0.6 x 50) or a gain of 5 ecounits. Obviously these are two very different actions that produced significant changes to the ecological condition of the watershed but no net loss of ecounits in the watershed.

Finally, there are numerous measures of stream condition that are not included in the EUI. For example, the Kentucky USACE have adopted a similar procedure to assess stream fill permits. The index that they use combines the following elements: stream length, an invertebrate-based condition score, conductivity, and key components of the USEPA rapid visual habitat assessment score (riparian condition, substrate embeddedness). This variety of physical and chemical parameters are not included within the EUI for the Cheat River basin for a couple of reasons. First, the purpose of the EUI is to describe the ecological condition and not the environmental condition of stream segments in the watershed. Adding measures of habitat and chemistry to the index would result in an admixture of environmental and biological variables. Second, data show a relationship between ecological condition and measures of physical and chemical condition. For example, WVSCI score tends to decrease in streams with high conductivity and low visual habitat assessment scores (Petty et al., unpublished data). Consequently, it would be inappropriate to include multiple, non-independent variables in the equation used to calculate the EUI.

13.2.5. Uses for EUI
The EUI can be used in numerous ways to facilitate the management and restoration of the Cheat watershed (Table 19). These uses can be split into three categories: those that are essential for the development and implementation of watershed management plans, those that are essential for the development and success of a cross-pollutant trading program, and those that are essential for both watershed management and cross-pollutant trading. The objective of the following section is to illustrate each of these uses and the potential of the EUI in guiding TMDL implementation and a water quality trading framework.

Table 19: Potential uses for the EUI

1. Estimate variables in the watershed restoration timeline. Variables include: current ecological condition, historic condition, potential restored condition, ecological loss, potential ecological gain, and ecological legacy.

2. Estimate measures of current condition, ecological loss, and potential restored condition at multiple spatial scales.

3. Calculate the intensity and extent of ecological loss in a watershed.

4. Predict changes in ecological condition as a function of expected improvements or reductions in water quality.

5. Develop ecological loss equivalencies among different stressors (in isolation or combined).

6. Develop equivalencies between ecological condition and dollars.

7. Compare ecological gains and losses (i.e., Net Ecological Benefit) of alternative management or trade scenarios.

13.3.   Application of the index to the Cheat watershed

13.3.1. Description of the Cheat River basin

Detailed descriptions of the Cheat River basin are given in other sections of this report. However, certain elements of the watershed need to be emphasized for the purposes of this chapter. The most important element is the amount of variability in water chemistry and ecological condition that occurs at both the stream segment scale and at the sub-basin scale. Because of large scale variation in coal geology, the watershed can be separated into an upper and a lower sub-basin. The upper sub-basin includes all tributaries draining to the Cheat River beginning at the confluence of the Shavers Fork and Black Fork in Parsons, downstream to Pringle Run. With the exception of the Blackwater area, mining is essentially absent from the upper sub-basin, and it provides an ideal, low impact reference against which to compare environmental and ecological conditions in the lower sub-basin. The lower sub-basin begins at Pringle Run and continues downstream to Cheat Lake. In this region, surface and deep mines are prevalent and there exists a high degree of variability in surface water quality.

13.3.2. Variation in the WVSCI scores for stream segments in the Cheat watershed

Data from the DEP Watershed Assessment Program (DEP, 1999) and Dr. Petty's lab (Petty et al., unpublished data) were used to calculate WVSCI scores and water quality for stream segments of tributaries in the Cheat River basin. Benthic macroinvertebrate data for the Cheat River mainstem, however, are currently unavailable. Consequently, best professional judgment was used to assign WVSCI scores to mainstem reaches. Because values for ecological condition in the mainstem are unknown, the following analyses should be interpreted as hypothetical. Furthermore, it is important to realize that these analyses are for the purpose of demonstrating the analytical process of assessing cross-pollutant trades. Results should not be construed as verified results suitable for making regulatory decisions.

A total of 455 perennial stream segments were identified in the Cheat River basin downstream of Parsons. Of these, 209 segments are located in the upper Cheat River basin (i.e., upstream of the

Pringle Run confluence) and the remaining 246 segments are located in the lower basin (i.e., from Pringle Run downstream to Cheat Lake). Significant differences in the WVSCI scores of stream segments located in the upper and lower basins were observed (Figures 22 and 23). WVSCI scores for stream segments in the upper basin ranged from 65 to 93 with a mean score of 84. These values can be interpreted to represent the range of scores observed in a watershed with no mining impact. In contrast, WVSCI scores for lower basin streams ranged from 10 to 93 and possessed a mean score of 62 (Figure 22). These values represent a broad range of impact from AMD present in the lower Cheat River basin.

DEP (2003) considers the WVSCI score of 68 to be the break between impaired and non-impaired water bodies. Virtually no stream segments in the upper basin would be classified as impaired, whereas more than half of the lower basin segments possess impaired biological communities. As a further summary of these data, Table 20 lists the poorest and highest quality stream segments in the lower basin. Again, it should be noted that values for the Cheat River mainstem are based on best professional judgment at this time. This list illustrates the broad range of stream ecological condition present in the lower Cheat River basin. Almost all of the ecological impairment to streams in the lower basin is a direct result of AMD.

Figure 22: Frequency distribution of WVSCI scores from upper, lower, and total basin stream segments
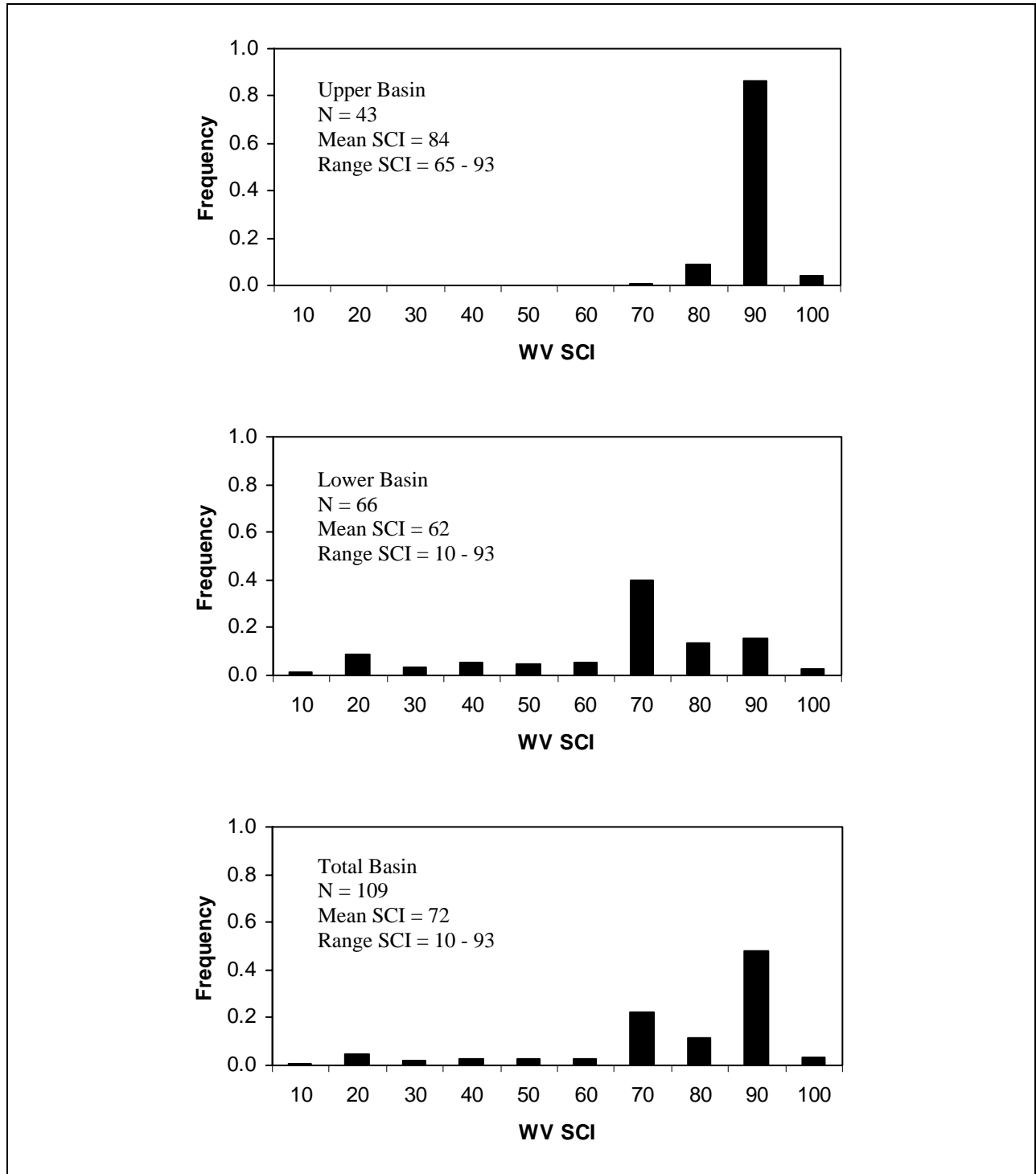
Source: WVSCI data are from DEP, 1999 or Petty et al., unpublished data. Note: Data from tributaries are real data, whereas Cheat River mainstem estimates are based on best professional judgment.

Figure 23: Cumulative frequency distribution of WVSCI scores from the upper and lower basins
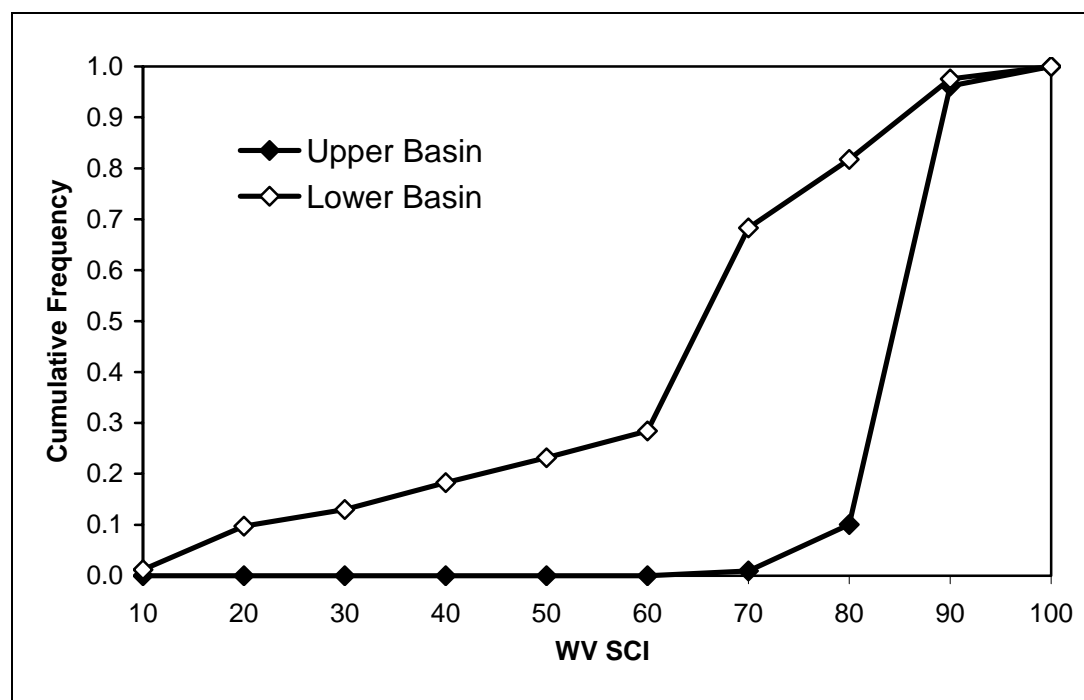
Source: WVSCI data are from DEP, 1999 or Petty et al., unpublished data. Note: Data from tributaries are real data, whereas Cheat River mainstem estimates are based on best professional judgment.

Table 20: Poorest and highest quality stream segments in the lower basin as determined by the WVSCI

Poorest quality			Highest quality		
Stream	Rank	WVSCI	Stream	Rank	WVSCI
Fickey Run	1	10	Upper Roaring Creek	1	93
Middle Fork Greens Run	1	10	Laurel Run	2	92
Cheat Riv. (Muddy-Big Nasty)	1	10	Upper Muddy Creek	2	92
Cherry Run	4	13	Ryan Hollow	4	90
Martin Creek	5	14	Dority Run	4	90
Muddy Creek (below Martin)	5	14	Darnell Hollow	6	89
Lower Bull Run	5	14	Mill Run	7	88
SF Greens Run	8	15	Johnson Hollow	8	86
Glade Run	9	16	Long Hollow	9	85
Lick Run	10	17	UT Big Sandy Creek	9	85
Heather Run	11	19	Daugherty Run	11	84
Church Run	12	20	Elsey Run	11	84
Morgan Run	12	20	Gibson Run	11	84
Cheat River (Albright-Muddy)	12	20	South Laurel Run	11	84
Five others	12	30	Rubles Run	11	84

Source: WVSCI data are from DEP, 1999 or Petty et al., unpublished data. Note: Data from tributaries are real data, whereas Cheat River mainstem estimates are based on best professional judgment.

13.3.3. Ecounits and elements of the restoration timeline

Estimates of WVSCI scores and surface areas (in acres) were used to calculate ecounits (i.e., EUIs) for each stream segment in the watershed. Estimates of EUIs were then used to calculate the following variables for each stream segment: Current Ecological Condition (CEC), Historic

Ecological Condition (HEC), Potential Restored Condition (PRC), Total Econunit Loss (HEC –
CEC), Potential Econunit Recovery (PRC – CEC), and Expected Econunit Legacy (HEC – PRC).
Each variable was calculated separately for each stream segment and then summed across
segments to obtain measures at multiple scales.

HEC can be interpreted as the condition of stream segments prior to mining impact. The average
condition of stream segments in the upper basin (WVSCI = 85) is used as an estimate of HEC.
PRC is defined as the expected ecological condition of a stream segment following AMD
remediation. Although very little data exist with regard to ecological recovery in AMD-impaired
watersheds, there is some indication that many water bodies can recover up to 90% of the
condition of reference streams (Petty et al., unpublished data). On average, however, observed
recovery is somewhere around 80% of reference conditions (Petty et al., unpublished data).[36]
Consequently, PRC is set equal to 78, which is 80% of 85 or 80% of expected reference
conditions. Observed condition (CEC) was then used along with HEC and PRC to calculate
measures of ecological loss, potential ecological recovery, and the expected ecological legacy
following remediation.

The entire Cheat watershed possesses 4,699 acres of surface water. Estimates indicate that 682
EUIs (15%) have been lost from the watershed and of that 662 EUIs have been lost in the lower
basin alone (Table 21). Full restoration of the watershed could expect to retrieve approximately
500 EUIs. Table 21 also provides a summary of EUI values estimated for various watersheds
across a range of spatial scales. For example, Daugherty Run is a small unimpaired watershed in
the lower basin and accounts for 29 of 1,427 EUIs (2%) currently present in the lower Cheat
River basin. Furthermore, the lower Cheat River mainstem is a heavily impacted portion of the
watershed and accounts for 320 of 662 EUIs (48 %) that have been lost from the watershed as a
result of mining related impact.

Table 21: Current, historic, and potential restored EUI values at various spatial scales

Sub-basin	Acres	WVSCI	Historic Ecolo-gical Condition	Current Ecolo-gical Condition	Restored Ecolo-gical Condition	Eco-Unit Loss	Potential Econunit Gain	Expected Econunit Legacy
Daugherty Run	32	85	29	29	29	0	0	0
Beaver Creek	46	69	42	35	39	7	3	4
Roaring Creek	59	70	55	46	51	9	5	4
Greens Run	44	23	40	10	37	30	27	3
Muddy Creek	161	50	147	90	136	57	46	11
Lower Cheat Riv. Mainstem	881	43	805	485	739	320	254	66
Lower Basin	2282	62	2089	1427	1931	662	505	168
Entire Watershed	4699	72	4306	3623	4131	682	508	174

Source: WVSCI data are from DEP, 1999 or Petty et al., unpublished data. Note: Data from tributaries are real data, whereas Cheat River mainstem estimates
are based on best professional judgment. All values except WVSCI are in units of acres.

13.3.4. Intensity and extent of ecological loss at multiple spatial scales
One of the most powerful uses of this approach is the ability to obtain relative measures of
ecological loss within the watershed at different spatial scales. To facilitate this process, two

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[36] For some streams, PRC might be as low as 40%, while for other streams, PRC might even be 100%. A PRC of
80% is a conservative estimate of what realistically can be recovered in an AMD-impaired stream.

separate measures of relative ecological loss for each stream segment are calculated. The first measure, called "Weighted EUI Loss" (WEL), is calculated as:

WEL = 1 – (Current EUI / Historic EUI)

This measure can be interpreted as the proportion of historically available EUIs that have been lost from the stream segment. WEL is a measure of the intensity of ecological loss from a stream segment regardless of the size of the segment (i.e., the measure is standardized by surface area).

The second measure, called "Relative EUI Loss" (REL), is calculated as:

REL = Segment EUI Loss / Total Watershed EUI Loss

REL can be interpreted as the proportion of total ecological loss in the watershed that can be attributed to a given stream segment. REL summed across all segments is equal to 1. REL summed across all segments in a particular subwatershed represents the proportion of total loss that can be attributed to that specific subwatershed. Ultimately, the value is a measure of the extent of ecological loss associated with the focal stream segment or subwatershed.

Measures of "Weighted EUI Loss" and "Relative EUI Loss" will be invaluable in setting restoration priorities at both the watershed and stream segment scales. As an initial summary of these data, Tables 22 and 23, respectively, identify stream segments suffering the most intense ecological loss (i.e., greatest WEL) and the most extensive ecological loss (i.e., greatest REL) in the lower Cheat River basin. Table 22 ranks stream segments on the basis of EUI loss intensity and illustrates that many of the most severely impacted streams have lost up to 90% of their historical ecological resources. Also, note that these segments represent a combination of small tributaries (e.g., Cherry Run) and larger water bodies (e.g., Cheat River mainstem and Bull Run).

In contrast, Table 23 ranks stream segments on the basis of the extent of EUI loss. This table illustrates that the most extensive loss of ecological resources has occurred in the Cheat River mainstem and the larger tributaries. For example, by summing the Relative EUI Loss for the first four rows in Table 22, it can be calculated that the Cheat River mainstem from Pringle Run downstream to Big Sandy Creek is responsible for more than 27% of the total loss of ecological resources in the entire Cheat watershed.

Table 22: Stream segments suffering the most intense loss of ecological resources (i.e., greatest Weighted EUI Loss) in the lower Cheat watershed

Stream Name	Current EUI	Weighted EUI Loss	Relative EUI Loss
Cheat River (Muddy Creek – Big Nasty)	60	0.882	0.088
Middle Fork Greens Run	13	0.882	0.019
Fickey Run	5	0.882	0.007
Cherry Run	4	0.847	0.006
Muddy Creek (below Martin Creek)	25	0.835	0.040
Lower Bull Run	8	0.835	0.010
Martin Creek	6	0.835	0.008
South Fork Greens Run	6	0.824	0.008
Glade Run	5	0.812	0.004
Lick Run	7	0.800	0.010
Heather Run	5	0.776	0.008
Cheat River (Albright – Muddy Creek)	52	0.765	0.076
Morgan Run	8	0.765	0.007
Church Run	5	0.765	0.005
Greens Run	8	0.647	0.012

Source: WVSCI data are from DEP, 1999 or Petty et al., unpublished data. Note: Data from tributaries are real data, whereas Cheat River mainstem estimates are based on best professional judgment. "Weighted EUI Loss" is the proportion of historic EUIs that have been lost due to current environmental impairment. For example, 88% of the historic EUIs have been lost from the Cheat River mainstem below Muddy Creek. Values of "Relative EUI Loss," which is the proportion of total watershed scale EUI loss that can be attributed to a specific segment, are presented for comparison. Values in this table are based on stream segments, and may not match the values for sub-basins in Table 21.

Table 23: Stream segments suffering the most extensive loss of ecological resources (i.e., greatest Relative EUI Loss) in the lower Cheat watershed

Stream Name	Current EUI	Weighted EUI Loss	Relative EUI Loss
Cheat River (Muddy Creek – Big Nasty)	60	0.882	0.088
Cheat River (Albright – Muddy Creek)	32	0.765	0.076
Cheat River (Big Nasty – Big Sandy)	42	0.529	0.061
Cheat River (Pringle – Albright)	40	0.412	0.050
Muddy Creek (below Martin)	25	0.835	0.040
Little Sandy Creek	25	0.290	0.040
MF Greens Run	13	0.882	0.019
Greens Run	8	0.835	0.012

Source: WVSCI data are from DEP, 1999 or Petty et al., unpublished data. Note: Data from tributaries are real data, whereas Cheat River mainstem estimates are based on best professional judgment. "Relative EUI Loss" is the proportion of total EUI loss in the watershed that can be attributed to that specific stream segment. For example, 8.8% of the total ecological loss in the Cheat watershed can be attributed to the Cheat River mainstem from Muddy Creek to the "Big Nasty" rapid. "Weighted EUI Loss" for each segment is presented for comparison. Values in this table are based on stream segments, and may not match the values for sub-basins in Table 21.

Bivariate plots with Total EUI Loss on the x-axis and Weighted EUI Loss on the y-axis provide another way to visualize the range of ecological impairment in the watershed (Figure 24). These plots can be used to identify stream segments characterized by both intensive local impairment and extensive EUI loss (upper right-hand quadrant of Figure 24). They also can be used to identify priority areas for restoration. For example, if the goal of a restoration program is to maximize the recovery of ecological resources, then restoration should focus initially on stream segments that are responsible for a large proportion of the total ecological loss in the watershed (i.e., stream segments in the right-hand quadrants of Figure 24). However, because it may be difficult to fully restore streams suffering intense ecological losses, moderately impaired streams may take precedence over severely impaired streams (i.e., stream segments in the lower quadrants of Figure 24).

Figure 24: Relationship between total ecounit loss in a stream segment and the intensity of ecological impairment (i.e. Weighted EUI Loss)
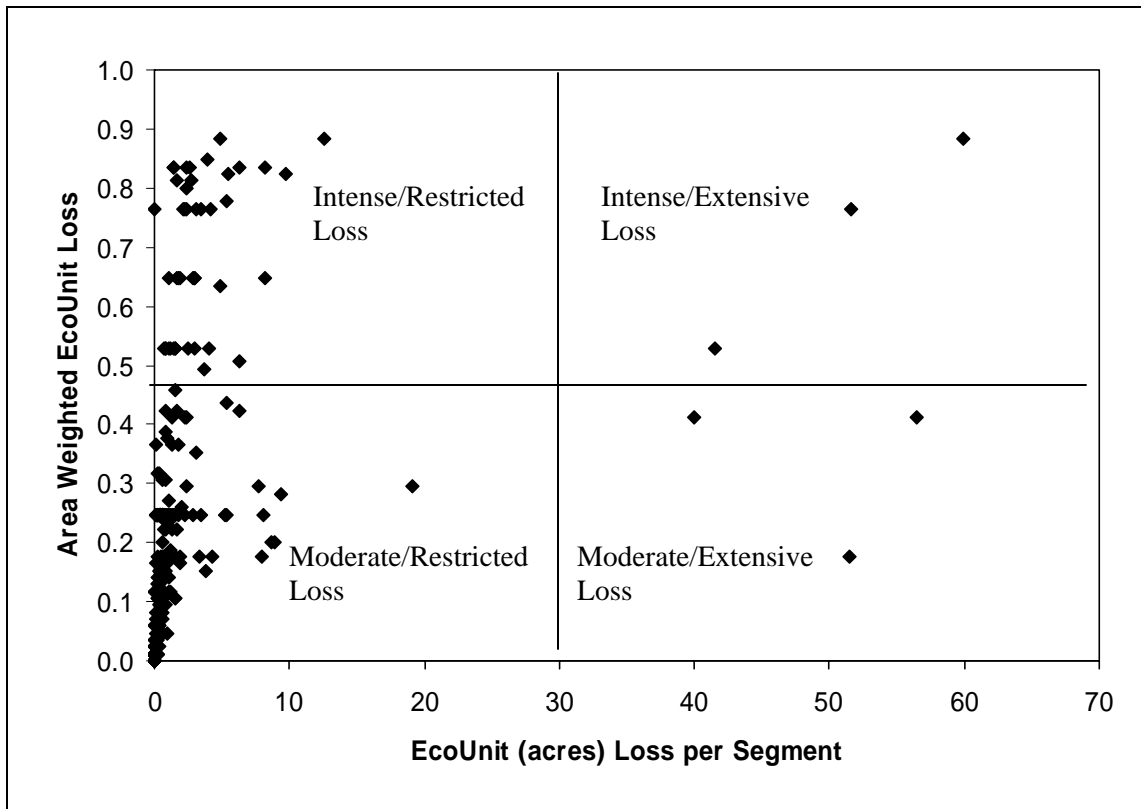
Note: "Moderate/Restricted Loss" refers to stream segments that possess moderate levels of impairment over a relatively small area. "Intense/Restricted Loss" refers to stream segments with intense levels of ecological impairment over small areas. Segments in right-side quadrants possess intense or moderate ecological losses over relatively large areas. Values are presented for stream segments in the lower Cheat River basin (i.e., all stream segments downstream of Pringle Run).

The process described above is useful for identifying priorities at the stream segment scale. A similar process can be used to prioritize water bodies at the watershed scale (Figure 25). Measures of WEL and total EUI loss can be summed across all stream segments in a watershed to give watershed scale values. Figure 25 shows a bivariate plot using these values for several watersheds in the lower Cheat River basin. This plot illustrates that the lower Cheat River mainstem is undoubtedly the highest restoration priority in the watershed. It possesses moderate levels of local impairment and extensive loss of ecological resources. Muddy Creek and Greens Run are two large, severely impaired tributaries of the Cheat River. Total EUI loss is more extensive in Muddy Creek than Greens Run, because it is a larger water body. Greens Run has suffered more intense ecological loss, because it is impacted by AMD essentially from its headwaters down to its confluence with the Cheat River. In contrast, the headwaters of Muddy Creek are not impaired and represent one of the highest quality regions in the lower Cheat River basin. Data for the Daugherty Run watershed, which possesses no mining impact, is presented for comparison.

Figure 25: Relationship between total ecounit loss in a watershed and the intensity of ecological impairment (i.e., Weighted Ecounit Loss)
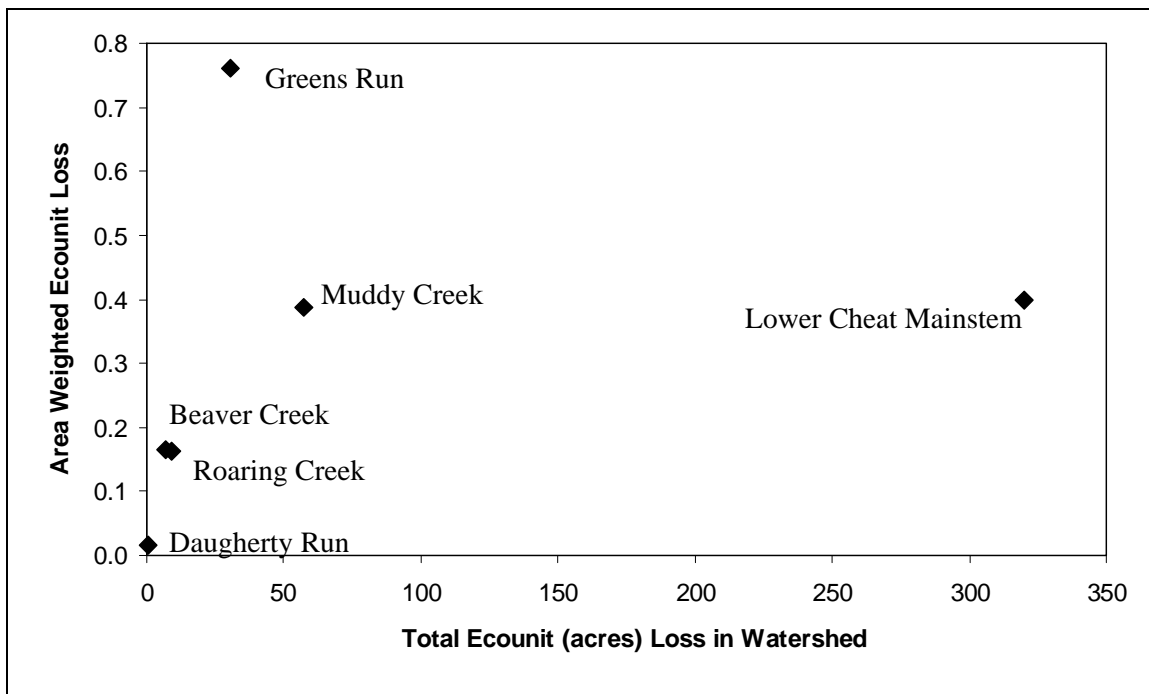
Notes: High values along the x-axis represent watersheds possessing extensive loss of ecological resources.
High values along the y-axis represent watersheds possessing intensive loss of ecological resources.

13.3.5. Equivalencies between ecounits, environmental stressors, and dollars

The development of an effective cross-pollutant trading program is wholly dependent on the ability to calculate equivalencies between ecological condition and different environmental stressors. This section demonstrates how the ecounit currency can be used to calculate equivalencies between ecological condition, environmental stressors, and dollars. Such equivalencies can then be used to determine how much a particular trader must pay to ensure Net Ecological Benefit in the watershed.

For several reasons, the development of these equivalencies focuses on AMD from active and abandoned mines and thermal effluent from an electrical power plant. First, AMD is responsible for most of the ecological impairment in the Cheat watershed. Second, the existing TMDL for the Cheat River focuses on AMD. Third, thermal effluent likely has a measurable effect on the ecological condition of the Cheat River. Fourth, the most likely trade scenario in the near future would involve trading thermal mitigation requirements for AMD remediation. Consequently, the following equivalencies are calculated:

1. EUI equivalent of 1 tpy acidity added to the watershed
2. EUI equivalent of 1 tpy acidity removed from the watershed
3. Dollar equivalent of 1 tpy acidity removed from the watershed
4. Dollar equivalent of 1 EUI recovered through AMD remediation
5. EUI equivalent of the thermal effluent
6. Acidity equivalent of the thermal effluent
7. Dollar equivalency between acidity and thermal effluent

The results of these analyses are presented in Table 24. These values are for demonstration purposes only, because stream condition scores for the mainstem are not based on real data but rather on best professional judgment. Given this caveat, calculations show that 0.036 EUIs are lost, on average, for every 1 tpy acidity added to the watershed. Because of the imperfect nature of AMD remediation, however, a gain of only 0.029 EUIs is expected for every 1 tpy acidity removed through AMD remediation actions (Table 24). Based on WVSCI values used for the Cheat River mainstem, 32 EUIs were attributed to thermal effluent. Given this impact, the thermal effluent has an ecological effect that is equivalent to 1,110 tpy acidity. Ultimately, given the cost of AMD remediation ($300/ton acidity/year), the dollar equivalency between thermal effluent and AMD is calculated at $333,087/year.[37]

Table 24: Summary of equivalency calculations

Current Ecological Condition (EUIs)	485 acres
Historic Ecological Condition (EUIs)	805 acres
Ecological Losses (EUIs)	
Total	320 acres
Heat	32 acres
AMD	288 acres
Recoverable EUIs	
Total	263 acres
Heat	32 acres
AMD	231 acres
Acid load (tpy acidity)	8,000 tpy
EUIs lost per acid tpy added	0.036 acres
EUIs gained per acid tpy removed	0.029 acres
AMD – Heat equivalency (tpy acidity)	1,110 tpy
Cost to treat acidity ($/tpy acidity)	$ 300/year
Cost to treat total acid load ($/year)	$ 2,400,000/year
Cost to recover 1 EUI via AMD remediation ($/year)	$ 10,409/year
Cost equivalency between heat and AMD	$ 333,087/year

Note: Equivalencies were calculated for the following contrasts: ecological loss from AMD vs. heat; ecological gain from AMD remediation vs. dollars; cost equivalence between heat remediation and AMD (i.e., cost for AMD remediation needed to offset ecological loss from heat). These equivalencies were calculated for the lower Cheat River mainstem only. All values are preliminary and should be viewed simply as conceptually representative of the value of the ecological condition accounting approach. Also, the value of $300/year to treat 1 tpy acidity is simply an estimate of the average cost. The true average cost to treat AMD in the watershed is currently unknown.

It is critical to realize that these equivalencies represent values that are averaged across the entire Cheat watershed. For example, every single ton of acidity probably does not produce an EUI loss of 0.036. Some acid sources may produce no detectable effect on biological resources. Other acid sources may produce complete ecological losses. The ultimate effect of 1 tpy acidity is influenced by numerous factors, but the most important factor is the chemical properties of the receiving body. For example, 1 tpy acidity that enters a stream with a high alkaline load may have little or no ecological effect on the stream. However, that same load of acidity entering a stream with no alkaline load may have a devastating effect. This same issue applies to the calculation of the EUI equivalent of 1 tpy acidity removed, as well as the calculation of the cost

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[37] Such an equivalency does not take into account trading ratios, which, if greater than 1:1, would require a greater investment. Also, these calculations should be viewed as preliminary and should not be considered as justification for or against a trading program. These values are intended for demonstrative purposes only.

equivalent of acidity removal. In all cases, estimates are based on watershed-scale averages and can be interpreted as an expectation of ecological gains and costs of a full, watershed-scale restoration program.

A second critical issue is that all equivalencies calculated are specific to the current conditions of the watershed, both in terms of acid loads and EUI losses. This is especially true for equivalencies relating thermal effluent to acidity and thermal effluent to dollars to treat acidity. In the event that acid loads and/or the ecological condition landscape change, equivalencies among EUIs, stressors, and dollars will also change.

These issues lead to two important conclusions. First, trading programs will necessarily be watershed specific. The EUI equivalent of 1 tpy acidity probably is not constant across all AMD impacted watersheds in West Virginia. Second, successful trading programs will require regular sampling of water chemistry and ecological condition at the watershed scale. This sampling should focus on providing information needed to update equivalencies among EUIs, stressors, and dollars.

13.4. Calculating net ecological benefit of a thermal for AMD trade

The EUI was designed explicitly for use in quantifying ecological costs and benefits of alternative management actions. This section presents the results of analyses comparing the relative ecological benefits of a cross-pollutant trade scenario involving the trade of thermal effluent impacts for reductions in AMD within the Cheat River watershed.

To conduct this analysis, the total number of EUIs that have been lost from the lower Cheat River mainstem is calculated. Then, the numbers of lost EUIs that can be attributed to AMD pollutants and thermal effluent are calculated separately. The analysis then considers the number of EUIs that could be regained through a series of management options, which include: no action, heat remediation only, AMD remediation only, and heat and AMD remediation together.

Comparison of the expected ecological gains associated with alternative mitigation actions in the lower Cheat River mainstem are presented in Figure 26. These analyses were conducted at the stream segment scale and the scale of the entire lower mainstem. The three kilometer reach immediately downstream of the Albright Power Station was used as the focal reach for reach scale analyses. Because thermal effluent is the dominant factor limiting ecological condition in this segment, significant improvements at the reach scale require mitigation of the thermal effluent. For example, AMD remediation is expected to produce negligible gains in ecological condition at the reach scale, as compared to an increase in 32 EUIs following heat remediation (Figure 26). In contrast, because AMD is the DLF at a watershed scale, AMD remediation will produce the most pronounced improvements at the larger spatial scale (i.e., at the scale of the entire lower mainstem). Specifically, AMD remediation is expected to increase EUIs by more than 200 at the mainstem scale as opposed to an increase of only 32 EUIs following heat remediation only. Consequently, at the mainstem scale, AMD remediation is expected to produce an increase in EUIs that is more than seven times the recovery expected from heat mitigation alone.

Figure 26: Variation in expected EUI gains as the result of various remediation options
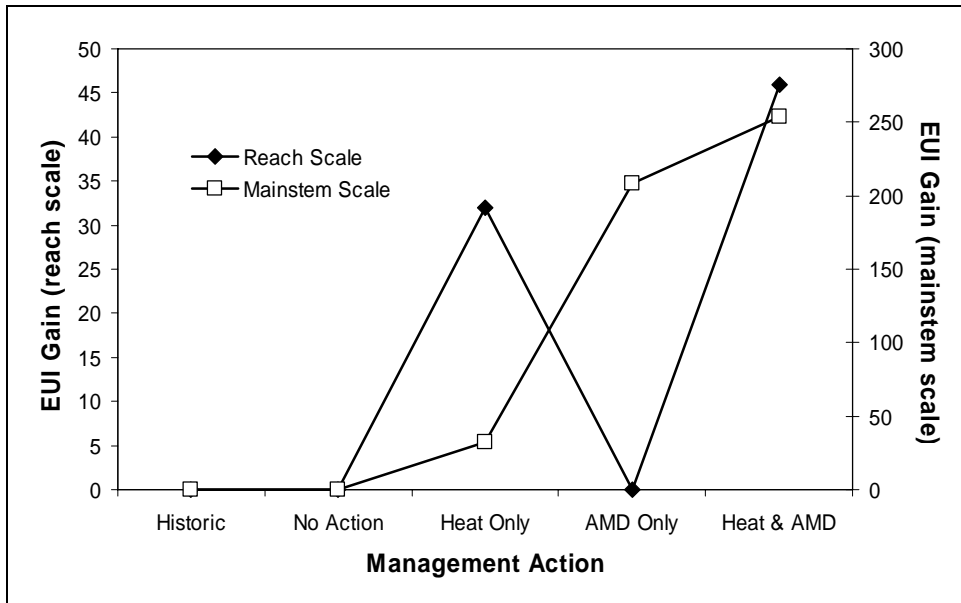
As a further analysis, Figure 27 shows the intensity and extent of ecological loss associated with alternative mitigation actions in the lower Cheat River mainstem. These analyses support the conclusion that AMD remediation is needed to produce significant levels of ecological recovery at larger spatial scales, whereas mitigation of thermal effluent is needed to produce significant recovery at the reach scale.

Figure 27: Variation in the intensity of ecological loss (i.e., Weighted EUI Loss) and extent of ecological loss (i.e., Relative EUI Loss) as the result of various remediation options
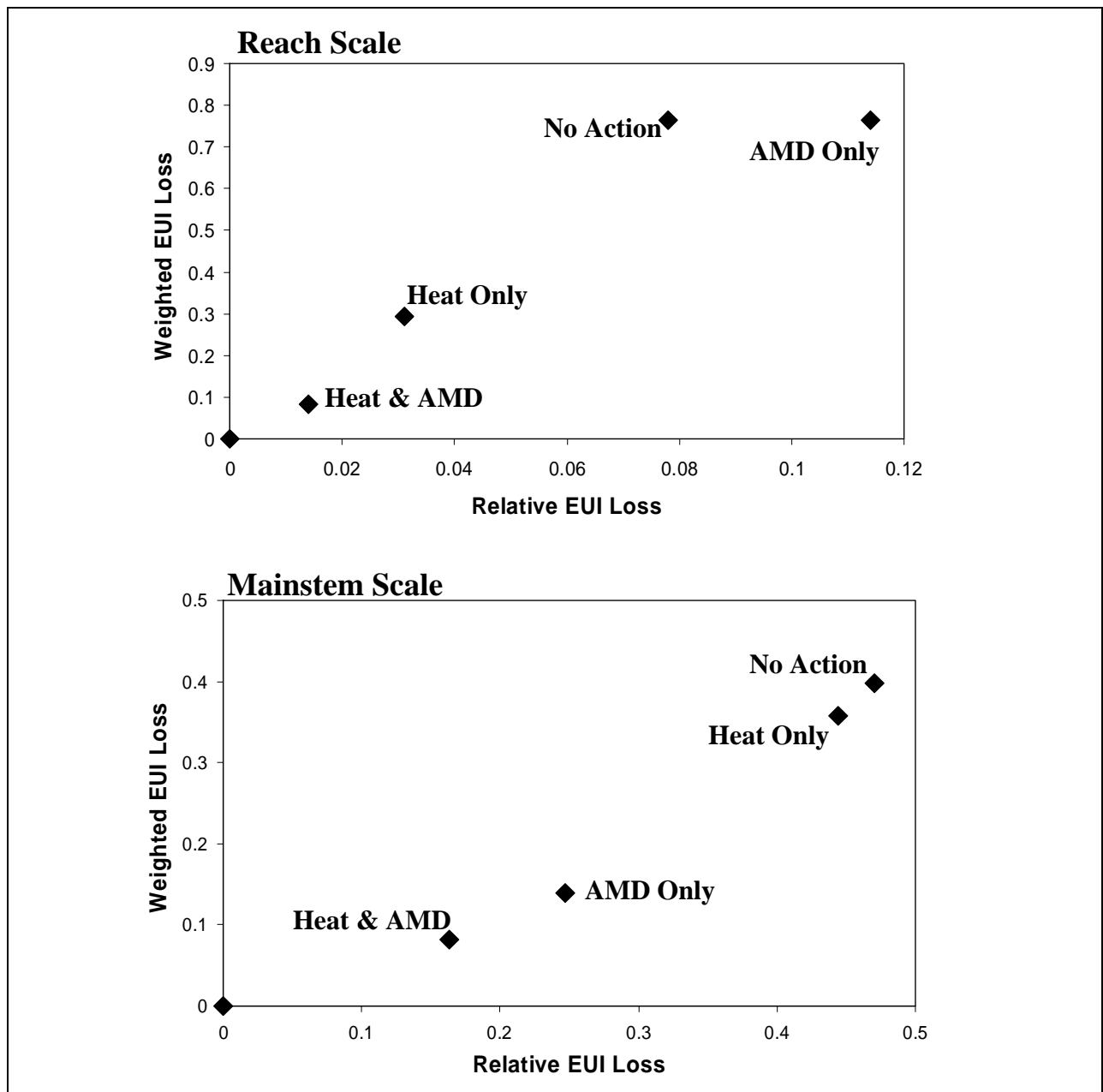
Note: Points at the origin are for the presumed historic condition. The reach scale includes the Cheat River Mainstem from Albright to Muddy Creek, and the Relative EUI Loss is relative to the Lower Cheat basin as a whole.

13.5.

<u>Conclusions</u>

Cross-pollutant trading provides an opportunity to produce significant improvements in the overall ecological condition of severely impaired watersheds like the Cheat basin. Cross-pollutant trading can allow managers to focus restoration efforts and money on environmental stressors that represent the dominant factors limiting watershed health. In the Cheat basin, AMD-related pollutants are clearly the most important factors limiting the ecological condition of the watershed. In fact, nearly half of the historic condition of the lower Cheat basin has been lost, and 90% of that loss can be directly attributed to AMD. This section presents an analytical approach that makes it possible to place secondary stressors in a watershed into context with the dominant stressors. In this case, the ecological effects of thermal effluent are compared to those of AMD. A procedure was developed to calculate ecological and cost equivalencies between thermal effluent and acidity. Through these calculations, it is possible to quantify the ecological costs and benefits of following strict regulation of thermal effluent and compare this to an alternative mitigation scenario that would allow AMD remediation in lieu of heat reductions. In doing so, various stakeholders in the Cheat River watershed can make more informed decisions about the expected costs and benefits of a cross-pollutant trading program.

14. MULTIPLE MARKET ENVIRONMENTAL TRADING TO FURTHER RESTORATION IN THE CHEAT WATERSHED

In addition to water quality trading, other market-based environmental credit trading programs—both existing and emerging—could be evaluated and encouraged by the CWRA to further private investment in Cheat watershed restoration activity. These market-based programs include wetlands mitigation banking, conservation banking, and the emerging market for carbon sequestration. These rapidly evolving and growing environmental commodity programs can provide landowners with economic incentives to offset the adverse environmental impacts of certain activities such as wetland, water quality, and habitat degradation and excess carbon emissions by enhancing and restoring ecosystem functions. Moreover, when developed in combination or "stacked," these multiple market programs may be complementary, with the potential to result in greater net ecosystem improvements more quickly and at less cost.

Even when orphan AMLs are reclaimed by DEP or other agencies, they are typically back filled to contour and planted with minimal grass cover to control erosion. Agencies have no incentive to fully restore the ecosystem function of the land by reforestation. Therefore, an alternate approach is needed that will provide incentives for private investors to engage landowners to restore the environmental, social, and economic benefits these lands can produce. An integrated environmental multi-market framework can help achieve the holistic goal of restoring and protecting ecosystem functions while providing financial returns on environmental investments in the watershed. If actively promoted, this approach has significant potential to maximize cost-effectiveness of restoration investments by diversifying revenue sources.

14.1. Background

Environmental commodity trading markets are based on the desire to achieve greater and faster environmental restoration and protection at less cost. These programs provide economic incentives to go beyond minimal environmental control requirements contained in various federal and state environmental statutes. Over the past thirty years these legal mandates significantly advanced protection of natural resources and reversed the increasing trend in air and water pollution. However, regulatory agencies are pursuing more flexible, holistic performance-based approaches, such as water quality trading, that provide incentives for restoration and protection. With properly developed and implemented market mechanisms and sufficient buyers and sellers, these credit trading programs can promote private investment in innovative pollutant reduction approaches, new technology, and more ecologically holistic improvements that can lead to ecologically sustainable economies.

14.2. Opportunities for multi-market credit trading programs

Under current regulatory programs and through the application of existing and developing market-based programs, three additional environmental commodities are available to complement the proposed water quality trading program and further increase restoration investment in the Cheat watershed: 1) wetland mitigation banking, 2) conservation banking, and 3) carbon sequestration.

14.2.1. Wetland mitigation banking

The national wetlands mitigation bank and trade program regulated by USACE is a robust program with over 400 banks in operation. The program permits development of compensatory wetlands that mitigate or offset unavoidable adverse wetland impacts. Developers can use "credits" to offset the impacts of their own activity or credits can be sold to other parties.

Credits are determined and certified and trading ratios established by USACE in accordance with national guidance. Nationally, credit prices range from $5,000 to over $250,000 per acre depending primarily on location, supply, and demand.

14.2.2. Conservation banking

Conservation banks are mitigation banks for restoration and preservation of species habitats. The national conservation banking program is administered by the U.S. Fish and Wildlife Service. Similar to the wetland mitigation banking program, conservation banking provides a collaborative, incentive-based approach to mitigating unavoidable adverse impacts to rare, endangered, and candidate species. The policies and procedures for bank establishment are applicable to public, private, and third party conservation banks and allow for both on-site and off-site mitigation. California, under the Natural Communities Conservation Planning Act, leads the country with the establishment of over 50 conservation banks with credits selling in the range of $10,000 to over $100,000 per acre. The U.S. Fish and Wildlife Service has authority to approve conservation banks and certify the credits.

14.2.3. Carbon sequestration

A carbon sequestration commodities market is rapidly developing both in the United States and abroad. However, because there is no formal regulatory program in the United States, the market remains fragmented with certain risks and uncertainties. The United States has refused to ratify the Kyoto Protocol that calls for international reductions in greenhouse gas (GHG) emissions in developed countries. Even though there is continued debate over the merits of the supporting science of climate change, many countries including those of the European Union have implemented a carbon cap and trade program. Moreover, in lieu of a federal regulatory program on GHG emissions a number of states are developing a carbon emission cap and trade program including, most recently, neighboring Pennsylvania as part of the ten Northeast States Governors Pact. Additionally, with increasing public pressure for control of GHG emissions many large emitters of GHGs such as fossil fuel-fired electric generating companies are positioning themselves to reduce their financial exposure when and if a carbon cap and trade program is promulgated. Many of these proactive corporations in the United States are investing in voluntary pilot carbon sequestration projects that use changes in land management such as reforestation to offset their emissions. It is anticipated that these projects will allow them to benefit from their investments should regulations be adopted. It is evident that these organizations are developing these projects not only to pick the low hanging fruit for offsetting their emissions, but also to gain experience, achieve collateral benefits such as enhancement of biodiversity and economic development, as well as to gain greater access to ongoing policy discussions and public relations opportunities.

One of the major criteria for determining the validity of a carbon sequestration project and resulting credits is "additionality." Additionality refers to whether the carbon offset generating

activity would have taken place in the absence of the project. In other words, are the actions additional to, or above and beyond, business as usual. In the case of reforestation of AML sites, a case can easily be made that in the absence of carbon project funds and resulting management, carbon storage is not likely to have been restored and maintained. For active mine sites, a demonstration must be made that reforestation and management would not occur without the carbon project.

At this time the primary domestic drivers for voluntary GHG trading are the Department of Energy's Climate Challenge program and President Bush's Global Climate Change Initiative. Although there is not yet a formal scheme, credits are being created, verified, registered, and traded by private parties. A number of consultants and brokers are specializing in developing, quantifying, and verifying credits and creating deals between sellers and buyers. The Chicago Climate Exchange, a pilot project of the Chicago Board of Trade, began a voluntary GHG trading program September 30, 2003. It is estimated that nationally over 200 million tons of carbon equivalent credits have been traded in the range of $0.60 to $8.00 per ton.

A project demonstrating the efficacy of a multi-market-based approach is currently being undertaken in the Cheat watershed under a Department of Energy grant to the Electric Power Research Institute. The project's objective, at a 35 acre AML site near Valley Point, is to demonstrate the efficacy of using environmental multi-markets to incentivize third party investment in AML restoration. The project is an outcome of the 2001 Memorandum of Understanding between OSM and the Department of Energy that provides for the use of multiple market-based trading programs to encourage mine land reclamation. The demonstration project seeks to use coal combustion products as a soil amendment to enhance productivity and to plant various hardwood trees and warm season grasses. Measurements will be made to establish an environmental baseline and determine over time the environmental improvements resulting from the restoration. These real water quality, carbon sequestration, habitat and wetland credits will be quantified and verified. Their current and projected future value will be determined and used in an economic evaluation to determine the viability of this approach for encouraging private investment in mine land restoration. The project is premised on the assumption that development of multiple environmental credits will result in greater private investments producing greater environmental, social, and economic benefits at a faster rate than would otherwise occur.

14.3. Developing a multiple environmental market framework

A central clearinghouse such as the proposed CWRA is an ideal entity for evaluating, developing, facilitating, coordinating, and administering a multiple market framework and trading program. A successful environmental commodity market must have the following components: a commodity that provides real, surplus, and verifiable environmental benefits or pollution reductions beyond regulatory requirements; buyers; sellers; and the market mechanisms governing the transactions. Buyers of environmental credits can include regulated entities such as developers and industries; government agencies such as highway departments; utilities; municipalities; nonprofit conservation and environmental organizations; private investors; environmental commodity brokers; and environmental security traders. Credit sellers can include landowners, regulated entities, entrepreneurs, nonprofit conservation and environmental organizations, and environmental broker and securities traders. Market mechanisms must function to ensure real environmental improvements and reasonable economic returns on

environmental investments. The CWRA could function to educate watershed landowners of environmental market opportunities, provide technical and regulatory advice and assistance for developing agreements and credits, form a registry of potential credit buyers and/or traders, and assist with compliance monitoring programs.

Part IV: Conclusions and recommendations

15.   CONCLUSIONS AND RECOMMENDATIONS

The Cheat TMDL is likely to be implemented very slowly, but a trading program has the potential to accelerate the recovery of the river and its tributaries. The trading framework developed for the Cheat watershed, if implemented properly, shows promise for increasing investments in AMD remediation and improving water quality. As such, trading is one of several policy options that may help jumpstart TMDL implementation.

The proposed trading framework targets AMD reductions, because AMD is the watershed's most significant type of pollution. However, trades are not limited to the major components of AMD: iron, manganese, and aluminum. Cross-pollutant trades that will help reduce AMD pollution are also contemplated. In particular, a possible thermal for AMD trade could produce a significant reduction in AMD.

A new organization—the CWRA—is proposed to not only manage the credit bank, but also to perform many other tasks that will ensure that trading succeeds in meeting the restoration goals for the watershed.

This report considers the implications of different geographical restrictions on trades, the implications of allowing cross-pollutant trades, and the potential reasons for setting different trading ratios. But it does not endorse one set of rules over another. Specific rules will ultimately be developed by the agencies responsible for their implementation. Continued stakeholder involvement in this process would be valuable.

While water quality trading may prove to be beneficial for the Cheat watershed, it should not be assumed that the same system would work automatically in other watersheds. Without the same level of study and stakeholder participation, processes and institutional structures proposed for the Cheat may not succeed. Water quality trading is new, and trading of AMD pollutants has not yet been attempted. Hindsight may be the only way to truly determine whether such a program benefits or harms water quality in the Cheat or elsewhere.

Several conclusions can be drawn:
- The large proportion of pollution that is produced by orphan sites creates obstacles for trading, but these obstacles are likely surmountable.
- If cross-pollutant trades are allowed, they must target dominant factors limiting the ecological condition in a watershed (AMD pollutants in the case of the Cheat River).
- The trading program must be managed at a watershed scale to produce meaningful benefits, and therefore should be part of a holistic watershed management plan.
- Quantifying ecological equivalencies between dominant and subdominant stressors is critical to a cross-pollutant trading program. Subdominant stressors for which equivalencies cannot be estimated should not be included in such a program. Without equivalencies, it is impossible to predict ecological gains and losses expected from alternative mitigation options, and therefore it is impossible to justify a cross-pollutant trade.

- Variables used to calculate EUIs probably will vary from watershed to watershed.
- The procedure presented for quantifying cross-pollutant trades requires large amounts of information on the physical, chemical, and biological conditions of the target watershed. In order to facilitate cross-pollutant trading, industry, watershed groups, and regulatory agencies will need to invest in data collection that can be used to quantify the current condition landscape and calculate ecological and cost equivalencies among primary and secondary stressors in watersheds. Without this information, trading programs such as the one contemplated in this report cannot be implemented.

15.1. Recommendations for further research

In the Cheat watershed, more research will be needed before a trading program can be implemented:

- More data are needed. The careful analysis of the potential for a trading program to help solve the Cheat watershed's AMD problems requires excellent data on the loads of AMD contributed by all sources. Those data were not available for the development of the TMDL nor for this report. While more accurate data would probably not alter the main conclusions of this report, better data will be needed before actual trades are established in permits.
- More complete inventories of AMLs and BFSs will be essential, and should include recent water quality data from all sites.
- Research into the ecological services of small tributaries will help inform a final decision regarding how ecounits are calculated.
- Tradeoffs between instream and onsite treatment systems should be better quantified. In particular, the longevity of different treatment systems and the ecological services they affect should be documented.

Finally, implementing water quality trading will require action by DEP. Whether Cheat stakeholders propose pilot trades or propose the implementation of the framework as a whole, trading in the Cheat watershed can only proceed with approval and assistance from the agency.

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Part VI: Appendices

16. APPENDIX A: A CONSENSUS-BASED TRADING FRAMEWORK FOR THE CHEAT WATERSHED

The following framework was finalized February 18, 2004.

16.1. Preface

This framework is the result of a series of Cheat Trading Stakeholder Group meetings from 2002 through 2004. Stakeholders represent a variety of interests in the watershed, and have reached consensus on many broad issues regarding how water quality trading should be implemented. Many details are left to the future, when specific rules are developed.

As scientific data, regulations, priorities, and environmental conditions evolve over time, the framework may be modified to achieve the goal of net environmental and ecological benefits.

16.2. Introduction

The Cheat River and many of its tributaries face environmental challenges, most significantly from AMD from coal mines. AMD pollutes streams, harms aquatic life, limits recreational opportunities such as fishing and boating, and degrades stream aesthetics. A TMDL cleanup plan was released by USEPA in 2001 for 55 AMD-impaired segments of the Cheat River and its tributaries. The TMDL provides specific pollutant reduction goals for returning these waters to health.

AMD is generated by active coal mining operations as well as mines abandoned before the 1977 Surface Mining Control and Reclamation Act (AMLs) and those abandoned since 1977 (BFSs). The amount of AMD generated by AMLs and BFSs is significant. While the state is responsible for remediating these sites, currently available public funding is not adequate to complete the work in the foreseeable future or to clean up the sites to the level called for in the TMDL. These AMLs and BFSs are therefore clear targets for additional investments so that water quality in the Cheat watershed can be improved more quickly and more completely.

To help implement this TMDL, and to provide incentives for other activities that will improve and maintain water quality, a water quality trading framework is proposed. This framework, detailed below, provides a mechanism to spur public and private investments that will improve water quality, reestablish aquatic life, expand recreational opportunities, and improve the aesthetics of the Cheat River and its tributaries, thus improving the quality of life for people throughout the region.

This framework consists of two linked parts, both of which are essential for trades to result in water quality improvements:
  I. the trading program framework itself, and
 II. the creation of the Cheat Watershed Restoration Authority ("The Authority") to manage trades and other investments in water quality.

16.3. Definitions

"Credit" is defined as a reduction in a pollutant load or an activity that impacts surface water quality, which produces an environmental benefit over and above—or outside of—regulatory requirements, and which may be traded under this program.

"Credit seller" is defined as an entity that generates credits and offers them for sale or uses them to offset other environmental liabilities or obligations. A credit seller may be an individual, a business, the Authority, a government body or agency, or a nonprofit organization. Credits may be generated on or off sites owned by credit sellers.

"Credit buyer" is defined as an entity that purchases or uses credits for any purpose. Purposes may include retiring credits, fulfilling regulatory requirements, offsetting other environmental liabilities or obligations such as those imposed by the Cheat TMDL or by antidegradation regulations, or demonstrating compliance with voluntary pollutant reduction programs. A credit buyer may be an individual, a business, the Authority, or a government body or agency.

"Trading ratio" is defined as the improvement in the unit of exchange generated by the credit seller compared with the reduction in the same unit of exchange caused by the credit buyer.

"Unit of exchange" is defined as the common unit used to account for a trade.

16.4. Part I: Trading program framework

What can be traded
1. The main focus of the Cheat trading framework is to reduce AMD pollutants; therefore, credits will be based on reductions of iron, aluminum, manganese, zinc, and acid loads. Other pollutants, stressors, or activities that impact water quality may also be included in the Cheat trading framework. Trading of any pollutant or activity will require that (a) the specific pollutant or activity is explicitly approved by the Authority as part of the framework with an appropriate method for measuring credits, and (b) including the pollutant or activity is consistent with state and federal laws, regulations, and policies.

2. Trades are allowed for the same pollutant or activity that impacts water quality ("same-pollutant trades").

3. Trades may be considered among different pollutants and activities that impact water quality ("cross-pollutant trades").

4. When credits are traded, they must have a common unit of exchange. The unit of exchange required for specific trades must be approved by the Authority and DEP. A strong preference will be given to units of exchange designed so that trades are considered to be same-pollutant trades for the pollutants for which state water quality standards exist (such as iron, aluminum, manganese, and zinc). Approval may also be granted for the use of pounds of acidity for the unit of exchange for cross-pollutant trades involving AMD pollutants, or ecounits for the unit of exchange for cross-pollutant trades involving other stressors (such as temperature and trace metals).

Assuring environmental and ecological benefits
1. Same-pollutant trades must provide net reductions in pollutant loadings.

2. Cross-pollutant trades must provide net ecological benefits.

3. Trading program rules will specify analytic approaches and monitoring regimes to be used to demonstrate reductions in pollutant loadings and net ecological benefits.

Trading ratios
1. **Spatial issues.** To encourage trades with less uncertainty, trades in which the credit seller and buyer are in close proximity, and in which the credit seller is upstream, are generally preferred. Lower trading ratios will be required for such trades.

2. **Contributing to watershed restoration goals.** The Authority may adjust trading ratios to favor trades that contribute to strategic watershed restoration goals, such as the improvement or maintenance of water quality in a particular subwatershed.

3. **Same vs. cross-pollutant trades.** Trading ratios required for same-pollutant trades will be lower than those required for cross-pollutant trades.

Who can trade: Attracting investors and trading partners to the watershed
1. Any parties may trade, provided they meet the criteria in the Cheat trading framework.

2. Trades may be considered between point sources, nonpoint sources, and activities that impact water quality.

16.5.   Part II: The Cheat Watershed Restoration Authority

The trading program outlined in Part I allows cross-pollutant trading and allows credits to be generated and purchased from anywhere in the watershed. Such a system, applied without proper safeguards, could fail. The Authority would ensure that trades under such a system effectively reduce pollution and lead toward the attainment of the water quality and ecological goals for the watershed. The Authority would be part restoration planner, part trading program manager, and part accountant. It would accumulate relevant ecological, environmental, economic information and serve as a repository for the expertise and data necessary to evaluate the ecological state of the watershed and to predict the effects of trades

Managing the trading process
1. All trades will be incorporated into NPDES or other permits or legal documents that are overseen by appropriate state and federal agencies. These agencies will maintain final responsibility for approving or disapproving all trades and for ensuring that monitoring and enforcement take place.

2. The trading process in the Cheat watershed will be facilitated by the Cheat Watershed Restoration Authority. The Authority will help organize, plan, and manage Cheat remediation

projects on a watershed basis by coordinating funding and program opportunities. Trading will be one of its many responsibilities.

3. The Authority's facilitation of the trading process will help overcome barriers to trading and will ensure that all trades are consistent with this framework, acceptable to local stakeholders, and take full advantage of the funding sources available for AMD remediation.

4. The Authority will:

> (a) Develop, update every five years according to DEP's watershed management framework cycle, and implement a strategic cleanup and management plan for the watershed. Trading will be one of many tools available to implement this plan.

> (b) Create a menu of potentially beneficial trades based on its strategic plan, or calculate equivalent prices for water quality credits.

> (c) Bring together potential trading partners.

> (d) Evaluate proposed trades to ensure that they satisfy the requirements of this trading framework.

> (e) Make recommendations regarding proposed trades to permitting authorities. The Authority may recommend that trades be approved, denied, or approved with conditions.

> (f) Build, operate, and maintain water treatment units, including those that involve trades if both trading partners agree.

> (g) Monitor and report on performance of the watershed management plan.

5. The Authority may be organized as a watershed improvement district, nonprofit corporation, or other institutional structure that is recognized by state law, accountable to local stakeholders, and able to enter into formal agreements with state agencies.

6. The Authority will create a Watershed Management Trust Fund to pay for its operating expenses and for watershed remediation projects. This Fund will be financed by trades, grants from governments and foundations, and contributions.

7. The Authority will oversee a credit bank used to track the generation and use of credits.

8. The Authority may encourage the development of additional market mechanisms to further enhance watershed restoration. Examples of these mechanisms include trading programs for carbon sequestration and conservation and wetland banks.

17. APPENDIX B: TRADING POLICIES AND PROGRAMS THAT AFFECT WEST VIRGINIA

17.1. USEPA's water quality trading policy

In January 2003, USEPA finalized its water quality trading policy, which aims to provide greater flexibility and to achieve water quality and environmental benefits greater than would otherwise be achieved under more traditional regulatory approaches (USEPA, 2003b). The 2003 policy compliments USEPA's draft 1996 framework (USEPA, 1996). Several aspects of USEPA's new policy are relevant to the Cheat.

First, the USEPA policy explicitly supports trading of nutrients or sediment loads, neither of which are the most significant problems in the Cheat watershed. USEPA recognizes that trading other pollutants has the potential to improve water quality, but that such trades may pose a higher level of risk and should receive a higher level of scrutiny. The policy continues: "USEPA may support trades that involve pollutants other than nutrients and sediments on a case-by-case basis where prior approval is provided through an NPDES permit, a TMDL or in the context of a watershed plan or pilot trading project that is supported by a state, tribe or USEPA" (USEPA, 2003b, p. 4). Therefore, a trading program such as that contemplated in this report is likely to be consistent with USEPA's policy.

Cross-pollutant trading is also an issue of importance in the Cheat watershed, because AMD includes several pollutants and because dischargers of non-AMD pollutants may have incentives to purchase AMD pollutant reduction credits. However, USEPA's policy only explicitly supports cross-pollutant trading of oxygen-related pollutants (USEPA, 2003b).

17.2. West Virginia's water quality trading stakeholder committee

In West Virginia, the DEP Secretary convened a stakeholder group in July 2002 to provide recommendations regarding water quality trading in the state. The committee's mission was twofold: to develop consensus-based recommendations on whether or not a trading program is appropriate for West Virginia, and if so to develop consensus-based recommendations on a conceptual framework for that program. This group met monthly through April 2004.

Stakeholder members represented the private sector (West Virginia Manufacturer's Association, West Virginia Coal Association, West Virginia Chamber of Commerce, West Virginia Forestry Association, Dominion Energy), non-governmental organizations (West Virginia Environmental Council, West Virginia Rivers Coalition, Appalachian Center for the Economy and the Environment, West Virginia Chapter of Trout Unlimited), and wastewater treatment facilities (West Virginia Municipal Water Quality Association). Non-voting resource members represent government agencies (DEP, West Virginia Development Office, West Virginia Conservation Agency, West Virginia Division of Highways, West Virginia Department of Agriculture), academia (West Virginia University), and a non-governmental organization: Canaan Valley Institute. The committee reported to DEP, but was facilitated by the National Institute for Chemical Studies.

While the committee reached consensus on many provisional recommendations, it did not agree to recommend that water quality trading be pursued in West Virginia. Now that the committee's work is completed, DEP will consider its recommendations and make a formal decision regarding trading in West Virginia. Facilitating trading may require legislative action to modify state laws or rules, and may also require new DEP policies. While water quality trading in West Virginia, at the earliest, is not likely to take place for several years, it is possible that special agreements on time-sensitive issues could take place prior to the formal approval of a statewide trading program, if one is ever proposed.

Even absent recommendations from this committee, West Virginia does have some trading rules on the books: The state's antidegradation implementation procedures[38] allow trading in some limited situations, as discussed in Sections 6.3 and 6.4. However, these procedures require that trades "be consistent with the trading assessment procedure that has been approved by the Secretary,"[39] and presumably these procedures will not be developed until DEP acts on the water quality trading stakeholder committee's work.

17.3. West Virginia and the Gulf of Mexico

Most of West Virginia drains to the Ohio River, which eventually drains to the Gulf of Mexico; the Gulf is experiencing problems due to nutrient over-enrichment. Several contributing sub-basins are developing committees to formulate strategies for nutrient reductions. One of these committees, the Ohio Gulf Sub-basin Committee, is being convened by the Ohio River Valley Water Sanitation Commission. The Commission is envisioning a pilot nutrient trading program for the Ohio River watershed, which may include West Virginia.

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[38] 60 CSR 5.
[39] 60 CSR 5-5.6.f.

18. APPENDIX C: OTHER TRADING FRAMEWORKS RELEVANT TO THE CHEAT WATERSHED

Several efforts have been undertaken across the country to develop trading frameworks; most of these frameworks address nutrients. Still, this section summarizes several of these frameworks from which lessons can be learned, and parallels can be drawn, as a Cheat trading framework is developed and implemented.

18.1. Michigan

After many years of development, Michigan's Department of Environmental Quality enacted water quality trading rules in November 2002 (Michigan Department of Environmental Quality, 2002). According to these rules, point and nonpoint source dischargers may trade, so long as the generation, use, and trading of credits occur within the same receiving water or designated watershed. Credits must be generated before or contemporaneously with the time that they are traded. All trading activities must be consistent with TMDLs or other management plans.[40]

The Michigan rules prohibit the use of credits that would cause water quality standards violations, as well as the trading of 23 bioaccumulative chemicals of concern. Credits are not to be used to comply with TBELs.[41] To be eligible for the generation of credits, load reductions must be real, surplus, and quantifiable.[42]

These rules focus on the trading of nutrients without a TMDL or management plan ("open" nutrient trading)[43] or after the development of a TMDL or management plan ("closed" nutrient trading).[44] Same-pollutant trades are explicitly supported by the rules.

However, trading of pollutants other than nutrients and cross-pollutant trading may also be allowed, so long as the trading partners demonstrate that the trade will lead to local social or economic development, water quality is not lowered, and USEPA approves of NPDES permits that are affected by the trade.[45]

Trading ratios, called "water quality contributions" and "discount factors," are also specified. When generating credits, non-storm water point sources must contribute 10% of their discharge reductions to the Department of Environmental Quality to address uncertainty and to provide a net water quality benefit. Permitted storm water sources and all nonpoint sources may be required to contribute up to 50%.[46]

When using credits, discount factors may apply. In some situations, depending on whether or not a TMDL has been developed and whether or not the trading partners are separated by a wetland,

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[40] Michigan Rule 323.3004.
[41] Michigan Rule 323.3005.
[42] Michigan Rule 323.3006.
[43] Michigan Rule 323.3007.
[44] Michigan Rule 323.3008.
[45] Michigan Rule 323.3009.
[46] Michigan Rule 323.3016.

pond, lake, or impoundment, credit users may be required to purchase an extra 10% of credits. [47] If applied, this discount factor would be calculated over and above any water quality contribution required of the credit generator.

18.2. Long Island Sound, Connecticut

A nitrogen TMDL was developed for the Long Island Sound to address recurrent late-summer hypoxia problems. According to the TMDL, point sources contributed almost three-quarters of the total in-basin nitrogen load of about 53,000 tpy. Nonpoint sources and atmospheric deposition contribute the rest. The TMDL calls for a 58.5% reduction in nitrogen loadings. Dozens of wastewater treatment plants in Connecticut and New York are assigned nitrogen reductions to meet this goal. The TMDL provides for water quality trading among wastewater treatment plants in order to optimize pollution reduction investments (NYSDEC and CTDEP, 2000).

The generation and purchase of nitrogen credits in Connecticut are not governed by the free market. Instead, a Nitrogen Credit Advisory Board manages a credit exchange system. The board sets the value of nitrogen credits and purchases and sells all available credits. At the end of each year, each facility that fails to meet that year's wasteload allocation is invoiced by the board, in effect forcing the facilities to buy the appropriate number of credits. In contrast, the board purchases credits from those facilities that have made reductions over and above those required by that year's wasteload allocation (Johnson, 2003).

Such a system has several parallels to the system contemplated for the Cheat. As detailed in Section 9.1, the proposed CWRA would manage the trading process and set the price for pollution reduction credits. The success of the Connecticut program since 2000 suggests that such a managed system, with prices that are not set by the free market, could work.

18.3. Cherry Creek, Colorado

In response to the nutrient impairment of the Cherry Creek Reservoir in Colorado, wastewater treatment plants in the watershed are subject to total maximum annual phosphorus loads, set in the 1985 Cherry Creek Basin Water Quality Master Plan. Local counties, cities, and utility districts formed the Cherry Creek Basin Water Quality Authority to develop and administer a water quality trading program. The authority aims to jumpstart the Cherry Creek pilot trading program, which has been in effect for years but under which very few trades have taken place (USEPA, 2003a).

The Authority, a state-empowered government agency, serves several purposes. It generates phosphorus reduction credits by financing projects that go over and above mandatory BMPs. The Authority then banks these credits and offers them for sale. Proceeds from these sales are then used to generate further pollution reductions. In addition, credits generated by other entities can be banked, and the Authority manages their sale to credit users (USEPA, 2003a).

Not all credits that are generated can be sold: project-specific trading ratios are applied. These ratios are set by the Authority and vary between 2:1 and 3:1 based on the relative load of soluble

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[47] Michigan Rule 323.3017.

and non-soluble phosphorus between the trading partners and/or the attenuation of discharged phosphorus as it moves through the watershed (USEPA, 2003a).

Although the Authority approves trades, the state NPDES regulatory agency is still responsible for any permit modifications that may be necessary to codify the trade. As such, the permitting agency, not the Cherry Creek Basin Water Quality Authority, has final say on whether or not a trade will proceed (USEPA, 2003a).

Another important function of the Authority is to set the price for each credit. The price takes into account the costs incurred by the authority in building, operating, and monitoring current and future phosphorus reduction projects. The price of credits also reflects the Authority's costs of establishing and administering the trading market (USEPA, 2003a).

The Cherry Creek Basin Water Quality Authority is fundamentally similar to the CWRA contemplated for the Cheat, and described in detail in this report:
- The authorities would evaluate potential trades according to their consistency with watershed management plans (See Section 9.1).
- The authorities would generate pollution reduction credits through the use of public funds, and would offer those credits for sale through a trading program (See Section 9.2).
- Funds received by the authorities from trades would be used for further pollution reduction projects. In the Cheat, it is envisioned that these projects would, in turn, generate additional credits available for purchase (See Section 9.2).
- The authorities would set the price of each credit based on an average cost of remediating the pollutants of concern, taking into account past and future costs (See Sections 9.1 and 13.3.5).

18.4. Moshanon Creek, Pennsylvania

In Pennsylvania, a workgroup of diverse representatives evaluated several trading simulations, including one related to AMD. In this simulation, AMD treatment is being performed on drainage from a coal mine under an NPDES permit, which discharges into a significantly AMD-impaired creek: Moshanon Creek, a tributary of the Susquehanna River. Well upstream, untreated AML sites contribute toward this impairment (Marshall, 1999).

The work group considered a trade in which treatment would be decreased—or would cease—at the NPDES site, and money saved would be used to install control systems at the upstream AML sites. The trade might actually result in a net increase in metals loads. But the benefit would be five new miles of fishable waters (Marshall, 1999).

This simulation raises several issues:
- Would it be acceptable for the permittee to treat below technology-based permit limits at the mine where water is now treated?
- Could the trade be assessed based on the number of stream miles improved, instead of on pollutant loads?
- If the trade were to save money and if a watershed management plan were written in conjunction with the trade, would leverage be created to attract new federal and state funds for AMD remediation in the creek?

These issues are similar to those raised in the Cheat watershed. In particular, the Cheat trading framework in Appendix A specifically allows the use of ecological measures to evaluate trades (See Section 13). The Cheat framework also explicitly integrates the development of a watershed management plan as a way to help guide trades toward the most beneficial projects, and as a way to integrate trades within the broader framework of AMD remediation efforts (See Section 9.1).

18.5. Clear Creek, Colorado

Orphan mine sites pollute the Clear Creek watershed in Colorado with AMD. A trading framework was developed that would allow permitted discharges to "adopt" abandoned mines and control their discharge, in exchange for discharge credits. Because most of these abandoned mines discharge metals—different pollutants than those discharged by the permitted facilities— the framework recognizes that multi-media and cross-pollutant trades would be necessary. In developing the framework, participants recognized that multi-media and cross-pollutant trades are very complicated issues, and the lack of clear authority in the CWA ultimately halted discussions (Environomics, 1999).

Although this framework was never fully developed, it recognized similar issues that are faced in the Cheat watershed. The Cheat framework envisions, among other things, permitted sites paying for remediation at old AMLs as a way of generating credits. The Cheat framework also recognizes the importance of cross-pollutant trades to ensure that enough trading partners with enough incentives participate in the program (See Section 11).

19. APPENDIX D: AN ECONOMIC ANALYSIS OF SPATIAL AND TEMPORAL ISSUES

An economic analysis of the water quality trading framework proposed as part of the implementation strategy for the Cheat River watershed AMD TMDL should make clear the assumptions used in the analysis and point out the possible benefits and costs associated with implementation. There are two fundamental questions that must be addressed: (1) What is the best allocation of scarce resources to restore the Cheat River watershed? and (2) What institutional arrangements are needed to support implementation of the remediation plan outlined in the answer to (1)?

19.1. Background

Economic forces are strong, persistent, and touch virtually all aspects of our lives. When markets work, the power of market forces and the ability of private markets to produce the goods and services we consume is well known and accepted. From an economic perspective, environmental problems arise when market fail, usually because of forces or factors referred to as externalities of some type. That is, most environmental problems can be traced to factors that are not traditionally reflected in market transactions. Externalities can arise from technical factors or from lack of fully developed and enforced property rights. Since the market does not act to regulate such factors to meet the goals of society, society must develop an alternative institutional structure to bring about social goals. A regulatory framework is one structure often used to manage issues characterized by market failure. Initial attempts to manage environmental problems in the United States by the USEPA and other agencies depended upon one of two quite different approaches: (1) direct command and control – primarily for point source problems or (2) voluntary programs (perhaps complemented by financial incentives) – primarily for nonpoint source problems. While effective to varying degrees, increasing costs and the limitations inherent in these approaches have led policymakers, legislators, and responsible agencies to consider additional alternatives that may prove more efficient.

Economists have suggested developing public policy approaches to environmental management that harness the power of market forces to achieve environmental improvements. Environmental trading programs constitute one alternative approach. A desire to lower the cost of improving air quality led to the initial markets for sulfur dioxide emissions. Basically, such programs use an environmental quality target developed by the appropriate agency but let market forces drive the final solution as to how this goal is to be attained. The economic argument for efficiency remains the primary driving force for environmental trading programs.

The perceived success of air quality trading programs led to an increased interest in applying similar approaches to water quality. The economic rational for water quality trading is based on fundamental economic principles and the accumulated evidence of applied economic studies. These include recognition that a decentralized market, given appropriate incentives derived from the centralized oversight necessary to meet regional or national goals, can accomplish most objectives at lower cost and with more desirable results than can be accomplished by a centralized authority. Reasons given for lower costs include (1) incentives to innovate, (2) the development of technical innovations that adapt technology to problems, (3) access to detailed

information and knowledge for a given situation that is available only at the local level, (4) an ability to organize and manage projects more efficiently, and (5) flexibility to adapt to local or site specific conditions.

Trading in an organized market supposes that there are both willing buyers (entities that will use, consume, and purchase) and sellers (entities that will produce and sell) a specified good or service. Both actions rely on well defined, enforceable, property rights to the goods or services to be traded and an understanding of the degree of risk and uncertainty that participants face. The quantity traded is expected to depend on price which, in the standard market, is determined by an interaction of the costs of production and market power of sellers and the value or demand of the buyers. The appropriate method of price determination for water quality trades will depend on the extent of and participants in the market.

The economic efficiency argument requires that appropriate incentives be introduced so that the decisions of individual decision makers following their own self interest will produce the outcome that society desires. In the case of watershed management, this is provided by state and federal environmental rules and regulations designed to implement and manage water quality policy. Clear incentives require coordination and consistency of the rules and regulations. While the behavior of a market is governed by the institutional structure in which it operates, such structure are often implicitly assumed or given little direct attention. Since the institutions needed to support a trading program as outlined for the Cheat River watershed have not yet been fully developed, it is insightful to see how the institutions and structures proposed in this report may be expected to affect economic outcomes.

A full understanding of the economic issues that surround the development and implementation of TMDLs requires knowledge of environmental, technical, and socioeconomic factors. These include an understanding of the underlying physical processes that drive water quality, the cost of alternative control methods, and the societal concerns that relate water quality to values. USEPA's watershed management approach to water quality improvement employs a consensus-based approach designed to gain support from all stakeholders within hydrological-defined geographic areas. This watershed approach implicitly considers spatial interrelationships among natural ecosystems, anthropogenic forces, and the underlying physical system (Fletcher, et al., 2001).

Possible solutions to the two fundamental questions posed above for the Cheat River watershed trading program are discussed in detail in the remainder of this chapter. The first, more technical question is addressed first. The next two sections discuss the spatial and temporal factors of particular importance and discuss the economic implications of alternative approaches. The following sections present a modeling approach to evaluating and managing water quality trading in a watershed framework. A spatially and temporally explicit optimization model built upon an underlying water quality model where net pollution loads are derived from source loads and control strategies is described. The model provides a method to explicitly summarize the economic and ecological implications of alternative TMDL implementation strategies in the Cheat River watershed and can be used to assess the implications of including water quality trading as a component of the TMDL implementation process. By comparing the ecological value of alternative scenarios, the model of the Cheat River watershed can be used to

demonstrate the impacts of watershed-based AMD pollutant trading among sources across both space and time. An economic rational for the institutional arrangements proposed in this report is contained in Section 19.6. Finally, an example of the type of analysis that the optimization model can support is described.

19.2. Spatial factors

Where water quality problems occur and where and how they are treated are important factors in any analysis of watershed restoration. The physical effects of space on water quality are reflected in any water quality model or analysis. Pollution in headwater streams affects not only the stream where the pollution occurs but in all downstream segments where the pollution is transported by the natural flow of water. From an economic perspective, the more segments affected, the higher the cost.

How pollutants affects people is also an important consideration from an economic perspective. The cost of pollution, or conversely, the potential benefits of remediation, depends not only on the quality of the water but the effect of the water quality on the welfare of the users of all affected stream segments. If the recreational, ecological, or other value of rivers and streams varies within a watershed, restoring streams with the highest potential value will provide higher economic returns to a given investment. Models that can reflect such factors in the decision making process will enable decision makers to improve the overall efficiency of watershed management programs.

19.3. Temporal factors

Time enters the analysis of the Cheat trading program in three distinct ways: how to compare benefits and costs at different time periods, how long of a time period should be considered, and at what time should actions be taken.

The comparison of values across time is a key determinant of the preferred management alternative. In any empirical model, this discount rate or rate of time preference represents the guiding principal to compare current and future values. The higher (lower) the rate of discount, the lower (higher) the weight placed on future outcomes, decisions, and activities relative to those of the present. While the choice of rate remains controversial, there is widespread acceptance in the public policy arena that the appropriate rate is one of the primary factors that determine public policy options. The choice may be dictated by policy or reflected in the outcomes that follow from selecting alternative rates. In any case, a consistent rate of discount is necessary to develop comparable outcomes over alternative decisions.

The length of time considered in the analysis also influences the order and magnitude of preferred decisions. While the preferred goal would be to meet all environmental goals immediately, such an alternative is usually neither technically practical nor economically reachable. There is, however, an understanding and feeling of urgency that the goals should be met in a reasonable time – the length of this reasonable time can be expected to remain a topic of public debate. The choice of planning horizon depends on the individual situation. While a longer planning horizon may be used to develop an initial plan, primary emphasis is most likely on the early years with the implicit (or explicit) assumption that the plan will be revisited and revised on an ongoing basis. This is similar in intent to most strategic planning activities that

public institutions, government agencies, and private industry use on a regular basis. We do the best we can for now but realize that additional information, changes in goals, or changes in matters beyond the control of the decision maker must be incorporated in future decisions.

Finally, when actions occur in time is an important determinant of the ability to reach the goal of the CWA for the Cheat watershed– to achieve ambient water quality that meets all water quality standards for all waters within the Cheat watershed. If there is agreement that all goals cannot be met immediately, it follows that management actions should focus on problems that will provide the most benefit in the shortest time given available resources. From a practical perspective, this is the ability to include socially beneficial prioritization methods in the program. The model that follows is an attempt to include an economic perspective that outlines the benefits and costs of alternative remediation programs over space and time. It would be one of many decision aids that a watershed management organization would be expected to use in the rational management of a public resource such as the Cheat River watershed.

19.4.   A spatial-temporal economic optimization model

An appropriate analytical framework must reflect both the spatial aspects of water quality values and treatment and the way the system will react over time to both management options and natural forces. Most studies of water quality management concentrate on the inter-temporal allocation problem (for example, see Makris, 2001 and Opaluch, 1981), or, more recently, the spatial dynamics (Funk III, 1993; Greiner and Cacho, 2001; and Ali, 2002), but not both. Much of the literature focuses on spatial-temporal dynamics in other fields such as landfills, hedonic prices for environmental goods, dynamic equilibrium in coal market, transportation, climatology, biological population, real estate, and infectious disease, instead of water quality management (Gaudet et al., 1998; Riddel, 2001; Labys, et al., 1989; Zawack and Thompson, 1983; Jagger, Niu, and Elsner, 2002; Renshaw, 1993; Pace et al., 2000; and Deal et al., 1999). Studies that involve both time and space dimensions in water allocation include Ejeta (2000) and Brozovic et al. (2002). Models that combine spatial-temporal issues in an optimization model for water quality management like the one presented here by Fletcher and Zhao are rare (Fletcher and Zhao, 2003 and Zhao and Fletcher, 2003).

The model as presented assumes that the goal of the decision maker is to maximize the ecological services from the watershed over the planning horizon given a specified amount of money to use each year for remediation or management projects. The level of pollution is assumed to be known but declining slightly over time as the AMD sources evolve. Everything else in the watershed is assumed stable as well – no additional economic development or mining activities that would affect water quality are included. Resources are assumed to be spent on remediation projects that produce long term but declining treatment results. The primary goal of the model presented is to distribute the available resources over the watershed by investing in restoration projects for targeted streams each year that will maximize the ecological return on this investment. The model reflects both the spatial reality of variations in flow, in pollution, in treatment, and in the ecological benefits produced and the intertemporal constraints of limited resources and the inability to move remediation programs once the initial investment is made. For those that would like to understand the insight that this approach can give, it is sufficient to

understand the overall problem and then consider Section 19.5 which discussion the interpretation of the model as presented.

The spatially and temporally explicit economic watershed optimization model is presented in detail. The objective function is built upon an underlying water quality model where pollution loads are driven by pollution sources and alternative pollution control strategies. The objective function represents the present value of ecological services measured by an additively separable ecological condition index, for each stream segment, measured as a function of water quality over a specified planning horizon. Given the total funds available for treatment and other exogenously determined factors in the study area, the problem is specified as the maximization of ecological services subject to a series of dynamic constraints – an inter-temporal investment constraint and spatial water quality constraints – and other constraints imposed by other physical and behavioral aspects of the problem. Temporal dynamic elements are introduced in the modeling process through the timing of investments in site specific treatment systems. The level of treatment that a specific system produces in any period t can be considered a function of the cumulative investment in the system. Spatial dynamics are introduced by the spatial distribution of investments in treatment within the watershed and interactions with exogenous pollutant inputs that determine water quality at all points.

For expository purposes, we use the following terminology to describe the model. The initial segment of a stream from the source to the first confluence with another stream is called a headwater stream; the point where two or more streams join is called a node, and a stream between two nodes is a downstream segment. A watershed is defined relative to a pour point and includes all areas where, if a raindrop falls, surface runoff will drain through the pour point. Similarly, each stream segment is associated with a catchment area defined by points from which overland flow directly enters the stream segment. The ecological services provided by each stream segment are taken to be an ecological index of performance weighted by the water surface area.

19.4.1. Model description
The objective function is to maximize the present value of ecological services (TEI) from all streams in the watershed over the planning horizon:

$$Max_{\{C_{i,t}\}}(TEI) = Max_{\{C_{i,t}\}} \sum_{t=0}^{T} \sum_{i=1}^{I} \frac{EI_{i,t}}{(1+r)^t}$$

where:
$\quad i = 1, 2, \ldots, I$ is the index of stream segments;
$\quad t = 0, 1, \ldots, T$ is the index of time periods in years;
$\quad r$ is the rate of time preference for ecological services;
$\quad EI_{i,t}$ is the value of the ecological index for segment i at time t.

For the Cheat River watershed,

$\quad i = 1, 2, \ldots, 1793$, the number of stream segments in NHD 1:100,000-scale coverage of the
$\qquad$ Cheat River watershed;

$t = 0, 1, \ldots, 20$, the planning horizon in years.

The choice of the time preference, r, is controversial. A high r lowers the weight of ecological values received in the future which leads to the argument that discounting discriminates against future generations. Recent studies have utilized a value for r ranging from 3% (real rate of interest) to 7% (Office of Management and Budget's estimate of the opportunity cost of private capital) (Fletcher et al., 2001). For this example, a value of 5% is used. The ecological index function depends on the pollution load which measures $a_{i,t}$ as net acidity in segment i at time t in mg/L.

Potential ecological condition indices include species diversity, total biological productivity, targeted fish biomass, invertebrate based condition index, and fish based condition index. Ecologists working on the project have recommended the invertebrate based condition index, partially on scientific considerations and in part because this index is currently used in the Cheat by monitoring and regulatory agencies. Commonly used measures relevant to ecological services that could serve as a weight for the primary index include stream miles, stream area, stream order, and the maximal area of the watershed drained by the stream segment. The technical team for the Cheat project chose to use stream surface area, a continuous cardinal measure, to weight the ecological coefficient based on the observation that ecological productivity is roughly proportional to surface area.

The ecological index for segment i at time t, $EI_{i,t}$, is the product of the stream surface area in segment i, SA_i, and the stream's ecological condition in segment i at time t, $EC_{i,t}(a_{i,t})$, which depends on water quality or pollutant concentration, $a_{i,t}$. That is:

$$EI_{i,t} = SA_i EC_{i,t}(a_{i,t})$$

where $a_{i,t} = y_{i,t} / wf_{i,t}$, $y_{i,t}$ is pollution loading in segment i during time t, and $wf_{i,t}$ is water flow. $EC_{i,t}(a_{i,t})$ is modeled as a step function to reflect ecologically based threshold responses of aquatic populations to changes in pollutant concentration. In the Cheat River watershed, $a_{i,t}$ is net acidity concentration which has the following properties:

$$a_{i,t} > 0 \quad if \quad pH < 7$$
$$a_{i,t} = 0 \quad if \quad pH = 7$$
$$a_{i,t} < 0 \quad if \quad pH > 7$$

From an ecological perspective, either excess alkalinity or acidity reduces ecological services. This is represented in the ecological condition function as:

$$EC_{i,t}(a_{i,t}) = e_{-N} \quad if \quad a_{i,t} < A_{-N}$$

$$\vdots$$

$$EC_{i,t}(a_{i,t}) = e_{-1} \quad if \quad A_{-2} \le a_{i,t} < A_{-1}$$

$$EC_{i,t}(a_{i,t}) = e_0 \quad if \quad A_{-1} \le a_{i,t} < A_1$$

$$EC_{i,t}(a_{i,t}) = e_1 \quad if \quad A_1 \le a_{i,t} < A_2$$

$$\vdots$$

$$EC_{i,t}(a_{i,t}) = e_K \quad if \quad A_K \le a_{i,t}$$

where $e_{-N}, e_{-(N-1)}, ..., e_{-1}, e_0, e_1, ..., e_{K-1}, e_K$ are the ecological values associated with each step and $A_{-N}, A_{-(N-1)}, ..., A_{-1}, 0, A_1, ..., A_{K-1}, A_K$ are net acidity concentrations corresponding to the threshold levels that separate the $K + N + 1$ steps. Note that there are N steps that are net alkaline and K steps that are net acid. The step that includes pH=7, the neutral state, is represented as a net acidity of 0.

Numerous factors relevant to the watershed management framework are included via sets of constraints including the level of treatment as a function of total investment in water quality improvement projects, inter-temporal equations of motion which depend on the level of investment in treatment in each segment, spatial equations of motion which correspond to the imposition of a mass balance water quality model, and exogenously determined investment constraints.

Treatment constraints are:

$$u_{i,t} = u_i CC_{i,t}$$

where:

$u_{i,t}$ is the level of treatment in segment i during period t and is directly proportional to the cumulative investment (costs) $CC_{i,t}$ (i.e., the effective capital investments defined as the effectiveness of all investments through all t years within segment i).

Note that the traditional approach to AMD relies on active treatment that uses alkaline chemical reagents and a mechanical system to neutralize the acidity. Recently, a variety of passive treatment systems such as open limestone channel and limestone leach beds have been developed to treat AMD with a low cost and little maintenance (Skousen and Ziemkiewicz, 1996). Within the Cheat River watershed, earlier work by the River of Promise (i.e. ROP, which is a shared commitment for the restoration of the Cheat River) focused on passive systems to fix AMD problems in the Big Sandy sub-basin and has proven successful. Application of passive systems to other AMD impaired streams is strongly recommended. In this paper, AMD is assumed treated by passive systems including open limestone channels and limestone leach beds. u_i is 0.033 for these passive systems in the Cheat River watershed since limestone leachbeds and open limestone channels cost about \$30 per ton of acid treated per year (Ziemkiewicz, 2003).

Intertemporal equations of motion are:

$$CC_{i,t} = \frac{CC_{i,t-1}}{(1+\delta)} + C_{i,t} = \sum_{\tau=0}^{t-1} \frac{C_{i,t-\tau}}{(1+\delta)^{\tau}}$$

where:

$C_{i,t}$ is investment in watershed remediation/water treatment in segment i during time t, and

δ is the degradation or depreciation rate of investments in passive treatment which reflects the physical depreciation of the quality of the investment over time.

In the Cheat River watershed, δ is assumed to be 0.02. Generally, alkalinity production is maximum at project initiation. Over time, the ability of a passive treatment system to generate alkalinity falls. δ represents the diminishing rate of alkalinity generation.

Spatial equations of motion are:

$$y_{i,t} = \left(\sum_{l \in \{i\}^{upstream}} y_{l,t} \right) + x_{i,t} - u_{i,t} \text{ for downstream segments}$$

where:

$\{i\}^{upstream}$ represents the set of segments directly upstream of segment i (i.e., those segments that flow directly into segment i);

$y_{i,t}$ is pollution loadings and can be equivalently given as $y_{i,t} = a_{i,t} wf_{i,t}$ within each segment during each time period. For AMD, $y_{i,t}$ is the annual acid load in segment i at time t. The current application uses average water flow in each segment so that $y_{i,t} = a_{i,t} wf_i$;

$x_{i,t}$ is the exogenously determined pollution load generated within the drainage area of segment i during period t.

The above equation represents a mass-balance model of pollution generation and control. For headwater streams (i.e., those streams in the upper end of a watershed that only include direct flow), this reduces to:

$$y_{i,t} = x_{i,t} - u_{i,t} \text{ for headwater stream segments}$$

In the Cheat River watershed, exogenously determined AMD generation for each segment during each period, $x_{i,t}$, is slowly decreasing over time. To reflect this, AMD generated by abandoned mines is assumed to decrease over time at the rate α. That is,

$$x_{i,t} = \frac{x_{i,t-1}}{1+\alpha} \text{ with initial conditions } x_{i,0} = \overline{x_{i,0}} \ \forall \text{ segments } i$$

Since many of the mining sites in the Cheat River watershed have a long history (over 50 years), a relatively low value for α (0.01) is used.

Investment constraints are:

$$\sum_{i=1}^{I} C_{i,t} \le C_t^{\max}, \quad C_{i,t} \ge 0 \quad \forall i,t$$

where $C_t^{\max}$ is the maximum level of investment for water quality projects available during time period t. Available remediation funds may be divided among segments but investment in any segment is non-negative. In the Cheat River watershed, $C_t^{\max}$ is selected as \$50,000.

Assuming that the mass balance model is a reasonable approximation to a true water quality model and that sufficient information is available on concentrations and flow to calculate loadings in each segment during the base period, the exogenous loadings can be calculated by:

$$\overline{x_{i,0}} = \overline{y_{i,0}} - \sum_{l \in \{i\}^{upstream}} \overline{y_{l,0}} \text{ for downstream segments, and}$$

$$\overline{x_{i,0}} = \overline{y_{i,0}} \text{ for headwater stream segments}$$

This defines exogenous pollution from the drainage to segment i from respective sub-watersheds at the initial time period. In the Cheat River watershed, given measured pollution loadings in each segment at time period 0, $\overline{y_{i,0}}$, the AMD generation to each segment at time period 0, $\overline{x_{i,0}}$, can be estimated. Then, assuming that the AMD generation declines at the annual rate α, one notes:

$$x_{i,t} = \frac{x_{i,t-1}}{1+\alpha} \text{ with initial conditions } x_{i,0} = \overline{x_{i,0}} \quad \forall \text{ segments } i$$

for any time period, t = 1, 2, ..., 20.

There are two vectors of state variables in the model: pollution loadings in each segment during each time period, $y_{i,t}$, and the level of treatment in each segment during each period, $u_{i,t}$. There is a single vector of choice variables during each time period: the additional investment in treatment within each segment, $C_{i,t}$. The level of treatment in each segment is defined by the cumulative treatment from current and past investment and can be considered an intertemporal variable. The pollution loadings in each segment during each period represent spatial variables determined by the level of the intertemporal state and the spatial equations of motion.

19.4.2. Describing the solution: The Kuhn-Tucker conditions
From the above section, we get the general model:

$$\underset{\{C_{i,t}\}}{Max}(TEI) = \underset{\{C_{i,t}\}}{Max} \sum_{t=0}^{T}\sum_{i=1}^{I} \frac{SA_i EC_{i,t}(a_{i,t})}{(1+r)^t} \tag{1}$$

where:

$$a_{i,t} = \frac{y_{i,t}}{wf_{i,t}} \qquad (2)$$

$$EC_{i,t}(a_{i,t}) = e_{-N} \quad if \quad a_{i,t} < A_{-N}$$
$$\vdots$$
$$EC_{i,t}(a_{i,t}) = e_{-1} \quad if \quad A_{-2} \le a_{i,t} < A_{-1}$$
$$EC_{i,t}(a_{i,t}) = e_0 \quad\;\; if \quad A_{-1} \le a_{i,t} < A_1$$
$$EC_{i,t}(a_{i,t}) = e_1 \quad\;\; if \quad A_1 \le a_{i,t} < A_2$$
$$\vdots \qquad\qquad (3)$$
$$EC_{i,t}(a_{i,t}) = e_K \quad if \qquad A_K \le a_{i,t}$$

Subject to:

Treatment constraints:

$$u_{i,t} = u_i CC_{i,t} \qquad (4)$$

Intertemporal equations of motion:

$$CC_{i,t} = \frac{CC_{i,t-1}}{(1+\delta)} + C_{i,t} = \sum_{\tau=0}^{t-1} \frac{C_{i,t-\tau}}{(1+\delta)^\tau} \qquad (5)$$

Spatial equations of motion:

$$y_{i,t} = (\sum_{l \in \{i\}^{upstream}} y_{l,t}) + x_{i,t} - u_{i,t} \text{ for downstream segments} \qquad (6)$$

$$y_{i,t} = x_{i,t} - u_{i,t} \text{ for headwater stream segments}$$

Investment constraints:

$$\sum_{i=1}^{I} C_{i,t} \le C_t^{\max}, \quad C_{i,t} \ge 0 \quad \forall i,t \qquad (7)$$

In addition, the following initial conditions hold:

$$\overline{x_{i,0}} = \overline{y_{i,0}} - \sum_{l \in \{i\}^{upstream}} \overline{y_{l,0}} \quad \text{for downstream segments, and}$$
$$\qquad (8)$$
$$\overline{x_{i,0}} = \overline{y_{i,0}} \quad \text{for headwater stream segments}$$

The Lagrangian expression for the constrained optimization problem may be written as:

$$L = \sum_{t=1}^{T} \sum_{i=1}^{I} \frac{(SA_i EC_{i,t}(\frac{y_{i,t}}{wf_{i,t}}))}{(1+r)^t}$$
$$\qquad (9)$$
$$+ \lambda_{i,t}\{y_{i,t} - [(\sum_{l \in \{i\}^{upstream}} y_{l,t}) + x_{i,t} - u_i \sum_{\tau=0}^{t-1} \frac{C_{i,t-\tau}}{(1+\delta)^\tau}]\} + \eta_t(\sum_{i=1}^{I} C_t^{\max} - C_{i,t})$$

The Kuhn-Tucker conditions are a series of necessary conditions that must be satisfied for an optimal solution. The Kuhn-Tucker conditions for a maximum for the Lagrangian given in equation (9) are:

$$\frac{\partial L}{\partial C_{i,t}} = \lambda_{i,t} u_i - \eta_t \leq 0$$

$$\frac{\partial L}{\partial C_{i,t}} C_{i,t} = (\lambda_{i,t} u_i - \eta_t) C_{i,t} = 0 \tag{10}$$

$$\frac{\partial L}{\partial \lambda_{i,t}} = y_{i,t} - [(\sum_{l \in \{i\}^{upstream}} y_{l,t}) + x_{i,t} - u_i \sum_{\tau=0}^{t-1} \frac{C_{i,t-\tau}}{(1+\delta)^\tau}] = 0 \tag{11}$$

$$\frac{\partial L}{\partial \eta_t} = \sum_{i=1}^{I} C_t^{max} - C_{i,t} \geq 0$$

$$\frac{\partial L}{\partial \eta_t} \eta_t = (\sum_{i=1}^{I} C_t^{max} - C_{i,t}) \eta_t = 0 \tag{12}$$

$$C_{i,t} \geq 0, \quad \eta_t \geq 0, \quad \lambda_{i,t}: \text{free} \tag{13}$$

19.5. Model interpretation

Fundamentally, these highly technical mathematical equations can be interpreted simply and provide straightforward implications for management decisions. First consider an interpretation of the model structure. Equation (1) represents the objective of the decision maker – to choose the best treatment strategy given the amount of resources anticipated to maximize the value of ecological services (*TEI*) generated within the Cheat River watershed. Equation (2) is a definition that says that ambient water quality, $a_{i,t}$, is given by the ratio of the acid load to the stream flow. The third set of equations, (3), defines the level of the ecological index ($EC_{i,t}(a_{i,t})$) that corresponds to a range of acidity for each segment during each time period. While clearly a simplification of reality, this approach reflects the ecological thresholds that occur across a range of water quality parameters. The forth equation indicates, at least for passive systems, that the treatment produced (alkalinity) and provided ($u_{i,t}$) is proportional to the current level of effective investment in remediation projects within the direct drainage of each stream segment. Equation (5) indicates that the amount of alkalinity generated from each investment will decline over time as projects age. The effective investment at any time is the accumulation of past investments after accounting for any depreciation in output. The water quality within each segment is represented by equation (6) which accounts for the pollution added in each segment as well as treatment and includes that coming from all upstream segments after appropriate reductions for all treatment programs. The resources available for additional remediation programs each year is given in (7) where C_t^{max} is the amount of money available each year for additional investment. Equation (8) provides the initial conditions for the model where the amounts of treatment from any past activities or natural occurring alkalinity sources are calculated from source data or from

113

the output of any available water quality model. Equation (9) represents the augmented equation for final solution. This indicated that an equivalent problem can be solved where the original objective is augmented by the constraints specified. This is a mathematical restatement and adds little to the understanding of the model.

The operational information is provided by the elements included as equations (10) – (13). First consider two variables, $\lambda_{i,t}$ and η_t. The first, $\lambda_{i,t}$, represents the increase in ecological services over the entire planning horizon that would be obtained by investing an additional dollar in remediation in the *ith* segment during period *t*. The second, η_t, represents the increase in ecological services over the entire planning horizon that could be obtained by investing another dollar in remediation during time period *t*. While seemingly similar, they are significantly different. The first reflects the spatial effect of a particular segment and measures the ecological return to a dollar invested in a specified location. The second reflects the temporal effect of an investment at the most advantageous point in the watershed during a specified period. Equation (10) states that, at the optimum, the ecological return in each segment when an investment is made must equal the maximum possible for the watershed during that period. Equation (11) just says that the water quality model must be satisfied or imposed. Equation (12) is a simple statement that, in order to justify expenditures each year, there must be a positive benefit in terms of ecological services. Equations (12) is a restatement of the constraints on the choice variables.

Equation (10) is clearly the crux of the problem. A solution that satisfies this constraint will provide a spatially explicit solution for remediation investment throughout the planning horizon. This is just the information that a manager must have to make appropriate investment decisions. The empirical solution to these equations are developed using the GAMS computer software package.

19.5.1. Model solution

The model can be solved using mixed integer programming (MIP) based on the assumptions presented in Ali (2002). The GAMS integer solutions show the spatial and temporal distribution of AMD treatment investments, AMD reductions, the spatial and temporal distribution of water quality, and the value of ecological index. Investments over time and space are important information and provide useful insight for stakeholders. Initial model runs based on hypothetical data for the Cheat River watershed indicate that an optimal allocation of available investment funds concentrate in heavily impaired stream segments. It is anticipated that additional empirical work will provide the information necessary to solve this model for all impaired segments of the Cheat River watershed.

19.6.   Institutional implications

Any market to support water quality trading in the Cheat River watershed must be based on prices of the commodities traded. The usual market price discovery mechanism requires sufficient transactions to support price formation. As the number of trades in the Cheat Watershed is expected to be small, an alternative mechanism of price formation ins necessary to support market-like transactions.

The Cheat River technical group has proposed that a watershed management organization be developed and charged with implementing a trading framework. With the expertise currently available, this body could be charged with developing cost based prices to facilitate trades. That is, the price of a trade could be based on the cost of providing the required AMD remediation within a selected watershed.

Current studies indicate that a significant amount of remediation could be accomplished at very low cost. The cost per unit of remediation is expected to rise substantially as the average water quality improves. That is, the marginal cost for initial improvement is expected to be substantially below the average cost of full watershed remediation. On an aggregate basis, this scenario is outlined as the cost of remediation curve in Figure 28.

The other side of the market is composed of current or potential operations that would like to be able to maintain or obtain the necessary permits for operations with restrictions less stringent that the water quality based permits required on TMDL listed streams or by the TMDL allocations. The number of such participants in the Cheat River watershed is expected to be small but the willingness to pay for initial trades fairly high. The aggregate demand for such a scenario is depicted as the demand for AMD trades in Figure 28. As depicted, the willingness to pay for initial trades is significantly higher than the cost of initial remediation actions. This seems consistent with empirical observation at the current time. In a general trading scenario, this leaves significant room to bargain between buyer and seller. The allocation of rent can be captured by the better negotiator. For a market constructed by a watershed management organization, this indicates a wide variation between cost and price may be initially anticipated. It also indicates that sufficient resources may be obtained from a small number of constructed trades to offset significantly greater amounts of remediation. This can be reflected in the monetary price of trades or in a trading ratio significantly higher than one if the trades are specified as units of AMD, however measured.

This discussion implies that development of an alternative mechanism to support trades is most likely a requirement for developing a trading program in the Cheat River watershed. With a small number of anticipated trades, traditional markets are unlikely to develop. In addition, if the primary goal is to utilize resources efficiently to maintain both economic activity and support remediation efforts, it will be necessary to develop a pricing structure that is acceptable by the potential buyers of AMD credits while providing the resources to support further remediation efforts. Such an outcome seems feasible and in the best interest of all concerned.

Figure 28: Relative supply and demand for AMD trading units in the Cheat watershed
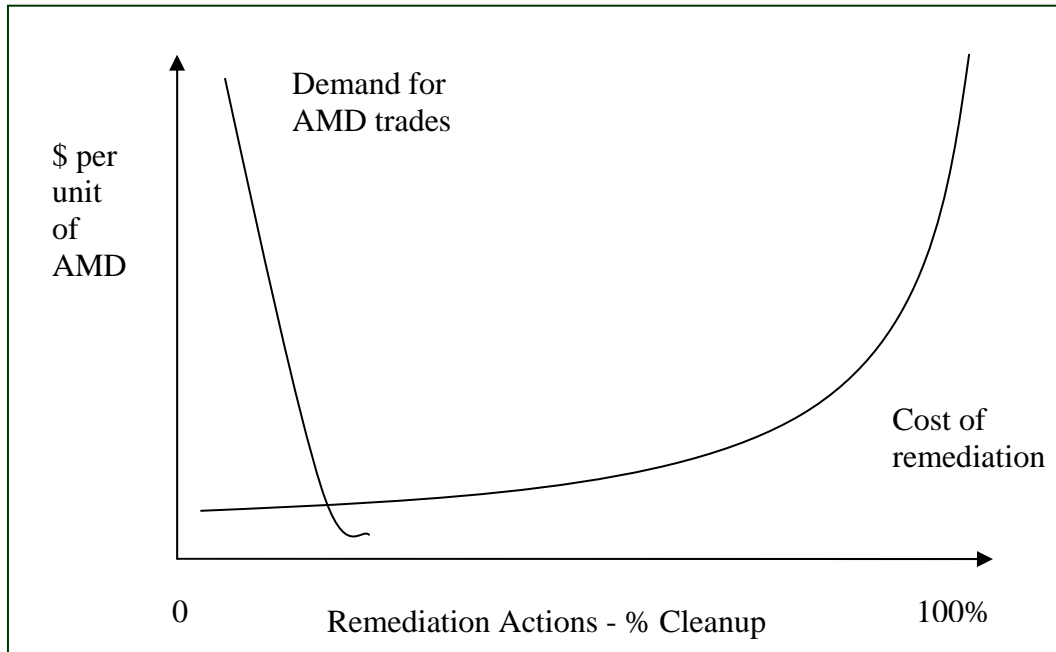
19.7. Discussion

The optimization model provides a technical approach to watershed planning. Such a model provides general parameters to guide management decisions. While such a plan is instructive and points out many of the tradeoffs that may occur, such models can never include the implications of uncertainty and other considerations that must be factored into decisions acceptable to stakeholders, regulators, and market participants and capable of being implemented in a given time frame. In addition, the solution to the model outlined in the previous sections provides an estimate of the outcomes measured as ecological services. Given the currently available data on preferences and values, the state of economic science in not yet sufficiently advanced to map these ecological outcomes into dollar values. While work in this area is progressing, it will be some time before defensible decisions could be based on these values. The final prioritization must, of necessity, be made based on a variety of criteria which includes ecological services as one of many factors that must be included.

The development of a watershed management organization could provide the needed institutional arrangements to facilitate the market-like transactions needed to support trading activities. The details of the final plan will necessarily dictate the market structure but the initial review indicated that such a plan is both feasible and beneficial.

20. APPENDIX E: TRADING SCENARIOS

The scenario described in this appendix was prepared by Systech Engineering, Inc. in San Ramon, California. This scenario investigates a hypothetical manganese trade in which Pleasant mine outlet #5 uses credits generated through AMD remediation at an upstream AML site on Cherry Run.

20.1. The credit buyer: Pleasant mine outlet #5

This site, which discharges to Little Sandy Creek, is operating under existing discharge permits for aluminum, iron, and manganese. Additional loading reduction is necessary, however, to restore the creek and meet its beneficial uses. Removing loading from Pleasant mine outlet #5 is likely to be less cost-effective than removing loading from a separate site already discharging pollutants at a higher concentration. This appendix evaluates a trade that would remove loading from an alternate site in return for maintaining the existing pollution control at Pleasant mine outlet #5.

Pollutant Loading

In establishing the conditions of the trade, the baseline conditions for the Pleasant mine are existing flow and loading from outlet #5. The following baseline is based on the average from discharge monitoring data:

Table 25: Baseline flow and concentrations, outlet #5 of the Pleasant mine

Flow	93 gpm
Aluminum	1.31 mg/L
Iron	0.222 mg/L
Manganese	3.71 mg/L

Following in Table 26 are the permit requirements from the Cheat River TMDL.

Table 26: Discharge limits under Cheat River TMDLs

Aluminum	0.44 mg/L
Iron	0.5 mg/L
Manganese	1.0 mg/L

Based on the average discharge concentrations, only aluminum and manganese exceed their discharge requirements under the Cheat TMDLs. To reduce the aluminum discharge from 1.31 to 0.44 mg/L, a loading reduction of 0.44 kg/d is needed. A loading reduction of 1.37 kg/d is required to meet the manganese discharge limit. The next step is to analyze the aluminum and manganese loading from the site where credits are generated to see what reduction is reasonable.

20.2. The site where credits are generated: Catchment 127

The proposed site for credit generation is upstream of the Pleasant mine, discharging to a tributary of Little Sandy Creek called Cherry Run. Within the Watershed Analysis Risk

Management Framework model, this area is part of catchment 127.[48] The model calibration was modified to better match the monitoring data collected at the site.

Flow
In catchment 127, a total of 0.24 km^2 has been surface mined. The trading site is a subset of the mined area. To determine the fraction of the mined area represented by the trading site, the measured flow rate at the site can be compared with the simulated flow rate from all of the mined area of the catchment. There are three data points that fall within the simulation period and can be used for comparison, as shown in Table 27.

Table 27: Measured flow from the trading site and simulated flow from all catchment 127 mines

Date	Measured trading site flow (gpm)	Simulated mined area flow (gpm)	Portion of flow from trading site
10/16/1996	41.3	137	30%
2/25/1997	50.3	119	42%
6/2/1997	46.2	89.5	52%

Given these data points, the trading site represents on average 40% of the simulated flow from the catchment's mined area. This can be used as a basis to determine the amount of loading reduction available by treating the discharge at the catchment 127 trading site.

Pollutant loading
The mine discharge from catchment 127 was originally calibrated in the model using instream monitoring data. The catchment's mine discharge was recalibrated based on data representing discharge from the site itself. There are two sets of data generated by DEP at this site: "Source at ALD Discharge Pond" and "Discharge from Wetland 1." The wetland, downstream of the ALD discharge pond, removes primarily iron from the mine area discharge. For calibration purposes, the model should match the mine discharge source, because it does not simulate the wetland metals removal processes. The wetland discharge concentration may be important, however, when analyzing trading scenarios. Tables 28 and 29 show the mine discharge, simulated, and wetland discharge concentrations of aluminum and manganese, the pollutants to be traded.

Table 28: Observed and simulated aluminum concentrations at the trading site (mg/L)

Date	ALD discharge pond	Simulated	Wetland discharge
10/16/1996	0.21	0.04	0.12
2/25/1997	0.10	0.25	0.10
6/2/1997	0.10	0.14	0.42

Simulated aluminum concentrations do not follow the pattern of aluminum concentrations, being 19%, 250%, and 140% of observed at the ALD discharge pond. The net bias, however, is +5%.

Table 29: Observed and simulated manganese concentrations at the trading site (mg/L)

Date	ALD discharge pond	Simulated	Wetland discharge
10/16/1996	8.91	7.99	7.63
2/25/1997	8.33	8.22	9.10
6/2/1997	9.75	9.95	8.96

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[48] This model was used to develop the Cheat TMDL. A modified version is used for these trading scenarios.

Simulated manganese concentrations were 90%, 99%, and 102% of observed at the ALD discharge pond, indicating a model bias of –3%.

The simulated pollutant loading from the trading site is 40% of the loading from the catchment 127 mined area, based on the flow ratio calculated above. The resulting simulated aluminum loading from the trading site is 0.01 kg/d. The manganese discharge from the trading site is 1.81 kg/d.

20.3. Trading opportunities

It was determined above that 0.44 kg/d of aluminum and 1.37 kg/d of manganese should be traded from the Pleasant mine site to the trading site near Cherry Run. The trading ratio is the amount of pollutant removed from the trading site divided by the amount of pollutant *not* removed from outlet #5 of the Pleasant mine. A trade will typically involve a trading ratio greater than 1 to ensure improved water quality and allow for a margin of error in analysis.

The flow from the trading site is one half of the flow from the Pleasant mine and the measured aluminum concentrations at the trading site are one tenth that of the Pleasant mine. The simulated aluminum from the trading site was 0.01 kg/d, much less than the desired 0.44 kg/d reduction from the Pleasant mine. As a result, there is no trading opportunity for aluminum at the chosen trading site.

The simulated manganese loading from the trading site was 1.81 kg/d. The maximum theoretical trading ratio available is then 1.32. Not all of the simulated manganese may be available for trading, however. As indicated in Table 28, the actual discharge from the site may be lower than the raw mine discharge because of treatment systems already in place. On average, the treated manganese concentration is 4% less than the raw mine discharge. In addition, the manganese removal process will not be 100% efficient. For this case, a trading ratio of 1.25 will be used.

Three model scenarios were run:
- "Trading 2a Base", the present condition base case with no reduction in manganese
- "Trading 2a Pleasant Reduction", the loading reduction at the source case with manganese loading reduced at the Pleasant mine by 1.37 kg/d
- "Trading 2a Trade", with manganese loading reduced by 1.71 kg/d at the trading site instead of reducing at the Pleasant mine.

The Pleasant mine reduction scenario is the same as the base case except that the manganese discharge from the Pleasant mine is reduced from 3.71 mg/L to 1 mg/L. The pollution trading scenario is the same as the base case except that the varying manganese concentration at the trading site was replaced by a fixed concentration of 0.46 mg/L. Simulation results for manganese are shown in Figures 29 and 30. At Cherry Run, there is no difference between the base case and the Pleasant mine reduction case, but a significant reduction in manganese occurred under the trading case. In Little Sandy Creek, there is a slight reduction in manganese concentration for the Pleasant mine reduction case and a slightly larger reduction for the trading case.

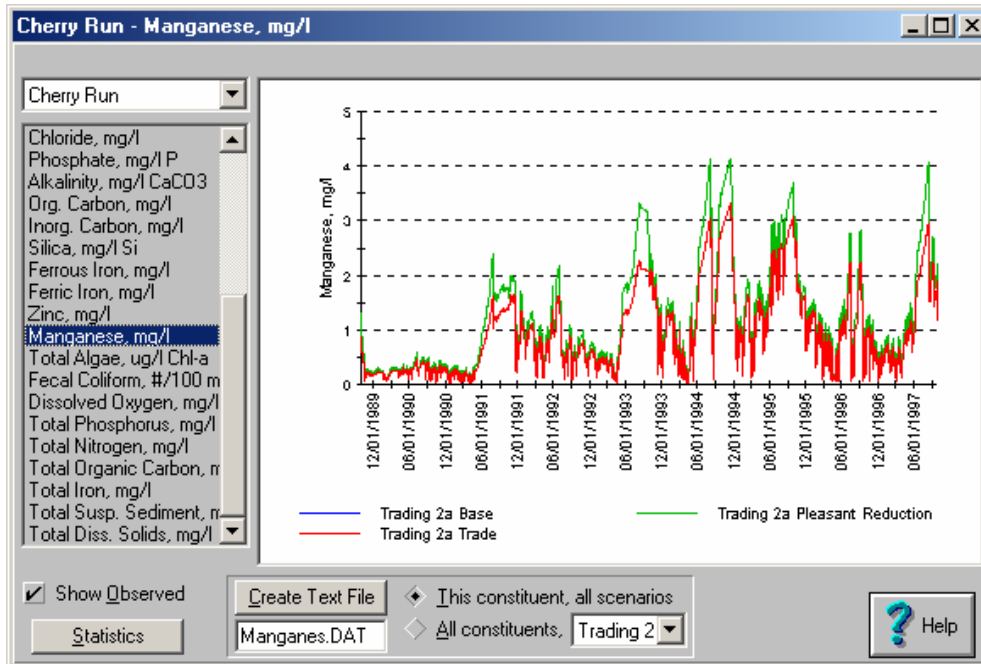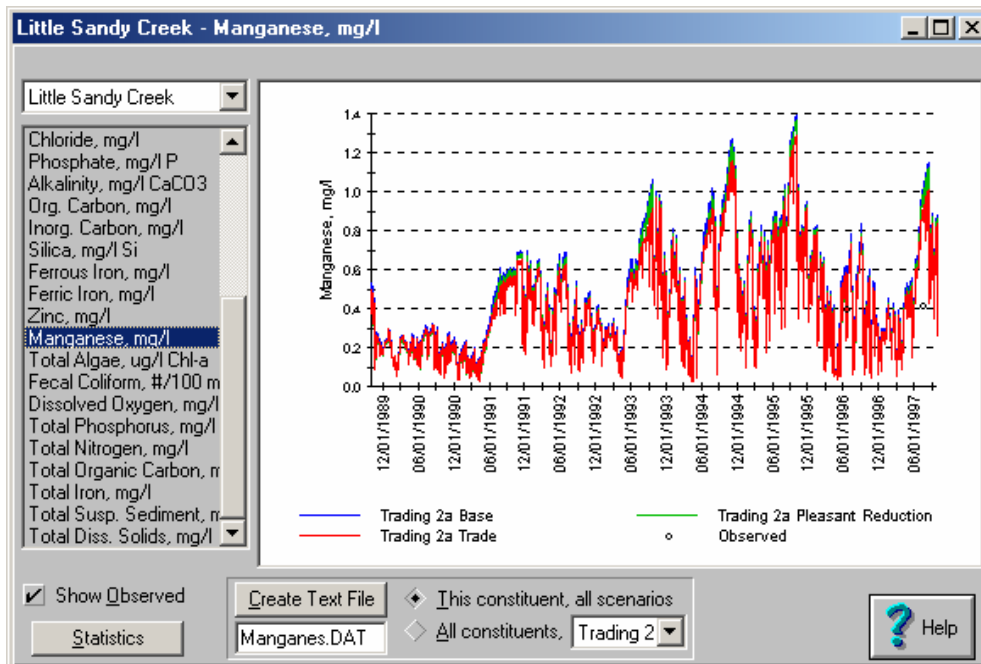**Figure 29: Simulated manganese in Cherry Run for the three trading scenarios**

Figure 30: Simulated manganese in Little Sandy Creek for the three trading scenarios

The average concentrations for all three cases are shown in Table 30.

Table 30: Average manganese concentrations for each trading scenario (mg/L)

Scenario	Cherry Run	Little Sandy Creek
Trading 2a Base	1.203	0.454
Trading 2a Pleasant Reduction	1.203	0.436
Trading 2a Trade	0.977	0.424

The average daily loading of manganese for each scenario is shown in Table 31. The loading is to the entire watershed in each case. The Cherry Run loading is included in the Little Sandy Creek loading.

Table 31: Average manganese loading for each trading scenario (kg/d)

Scenario	Cherry Run	Little Sandy Creek
Trading 2a Base	11.1	33.4
Trading 2a Pleasant Reduction	11.1	32.0
Trading 2a Trade	9.4	31.7

20.4.   Conclusion

The discharge concentrations at the Pleasant mine exceed the TMDL requirements for aluminum and manganese, but not iron. The existing pollutant loading at the Pleasant mine and the trading site indicates there is an opportunity to conduct a manganese trade, but there is not enough aluminum loading at the trading site to make a trade feasible. The manganese trade shows clear benefit by reducing overall loading of manganese by a greater amount than if the Pleasant mine were to restrict its own discharge. It also improves more river miles by reducing the loading upstream of the Pleasant mine.