A Technical Analysis of Acid Mine Drainage Total Maximum Daily Loads for West Virginia's Buckhannon River and Tenmile Creek

Prepared for:

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This report was prepared during the comment period for the draft metals and pH TMDL reports prepared by the U.S. EPA for the Buckhannon River and Tenmile Creek in West Virginia.

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Acronyms

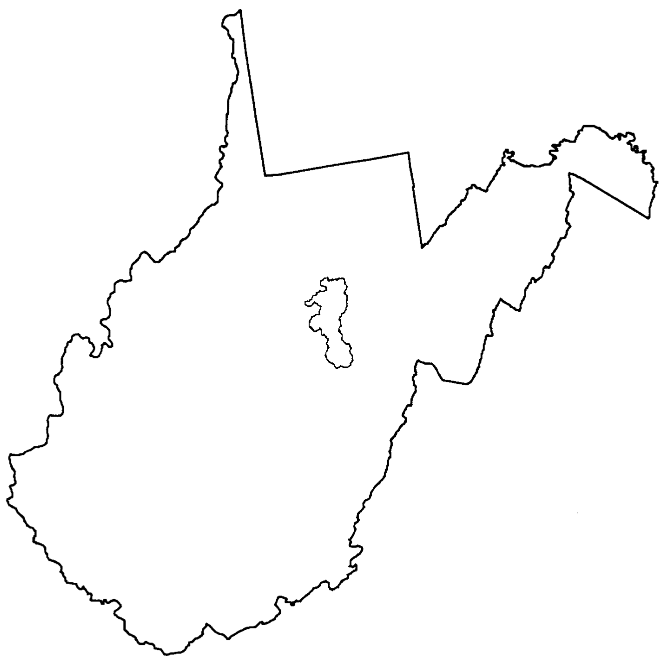
AMD	Acid Mine Drainage
BASINS	Better Assessment Science Integrating Point and Nonpoint Sources
CFR	Code of Federal Regulations
CSR	Code of State Regulations
DMR	Discharge Monitoring Report
gpm	Gallons Per Minute
HSPF	Hydrological Simulation Program–Fortran
l	Liter
mg	Milligram
NPDES	National Pollutant Discharge Elimination System
PDEP	Pennsylvania Department of Environmental Protection
STORET	Storage and Retrieval of Water-Related Data
TMDL	Total Maximum Daily Load
USEPA	United States Environmental Protection Agency
WVDEP	West Virginia Division of Environmental Protection

1. INTRODUCTION

In this report, I evaluate three draft analyses that assess the need for pH and metals pollution reductions from nonpoint and point sources in West Virginia's Buckhannon River and Tenmile Creek (USEPA, 1998a, b, and c). Published in June 1998, these reports rely on a computer model and other analytical techniques to develop total maximum daily loads (TMDLs) and to outline broad strategies for reducing metals loadings to meet state water quality standards. The TMDL reports recommend no pollution reductions related to pH. In addition to assessing the reports themselves, I also outline issues related to implementing these and future acid mine drainage (AMD) TMDLs.

Abandoned and active coal mines are prevalent in the largely forested Buckhannon River watershed. Beginning in its Randolph County headwaters, the Buckhannon flows north through Upshur County, where it passes the city of Buckhannon before entering the Tygart Valley River in Barbour County. Tenmile Creek, a tributary of the Buckhannon, is located entirely in Upshur County. Figure 1 shows the boundaries of the Buckhannon watershed.

Figure 1: Location of the Buckhannon River watershed in West Virginia



Source: USEPA, 1998a. Tenmile Creek watershed is located within the outlined Buckhannon River watershed.

Under Section 303(d) of the Clean Water Act and the U.S. Environmental Protection Agency's (USEPA's) Water Quality Planning and Management Regulations (40 CFR Part 130), states must submit lists of water quality–limited river segments to the USEPA every two years. They must then develop TMDLs for those segments that do not or are not expected to meet water quality standards. West Virginia's draft 1998 303(d) list has been returned by USEPA with comments, and public comments were collected through July 22. The West Virginia Division of

Environmental Protection (WVDEP) is now preparing the final list, which will be submitted to USEPA by August 20. USEPA will then approve or disapprove the list by September 20.

The Buckhannon appears on this list for impairment due to low pH and high metals concentrations. The seventeen-mile listed segment begins at Alexander, at the confluence of the Left and Right Forks, and continues north to Hampton, at the confluence with French Creek. Tenmile Creek is listed for impairment due to aluminum and iron over its entire length. The 303(d) list specifies that aquatic life is affected, and that the primary pollution source is AMD (WVDEP, 1998a). Abandoned and active coal mines are the primary sources of AMD in these watersheds (USEPA, 1998a, b, and c).

A TMDL is defined as the total amount of a pollutant that can be assimilated by a receiving waterbody while still achieving state water quality standards. More specifically, it is the sum of load allocations for nonpoint sources and waste load allocations for point sources, with a margin of safety. The final result of a TMDL analysis is a set of pollutant reduction recommendations—preferably spelled out for specific sources—that is predicted to be sufficient to bring impaired waterbodies into compliance with established standards.

The Buckhannon and Tenmile TMDLs are the first of hundreds of AMD TMDLs to be prepared in coal states in the east and midwest where AMD is a problem. West Virginia's draft 1998 303(d) list contains about 500 stream segments that are impaired by AMD; all of these streams are listed for either pH or metals or both (WVDEP, 1998a). Pennsylvania lists about 300 AMD-impaired watersheds (PDEP, 1998). In these and other states, thousands of miles of streams are impaired by AMD (Ramsey, 1996).

AMD is generated when pyritic materials in coal and rock are exposed to oxygen and moisture. AMD impairs waterbodies due to its acid content and its high concentrations of metals, typically iron, aluminum, and manganese (Skousen, 1995).

In streams faced with acid conditions, biodiversity diminishes as acid-sensitive aquatic species decline. Impacts can be found in birds and mammals as well, as changes in aquatic species make their way up the food chain (Ramsey, 1996). Iron can impact ecosystems through precipitation and through high concentrations. In AMD-impaired streams, precipitates of iron can smother benthic habitats, modify species diversity and abundance, and alter food web dynamics. Toxicity of high iron concentrations has been reported, but these data are not as well documented as those for iron precipitates (Ramsey, 1996). Ramsey (1996) also reports some controversy over the toxicity of aluminum, but discusses recent studies that demonstrate that aquatic invertebrates may accumulate aluminum, which then may be concentrated to toxic levels by predators. High levels of manganese increase the cost of drinking water treatment, and the city of Buckhannon withdraws drinking water from the Buckhannon River downstream from many AMD sources.

Both underground and surface mines, as well as coal refuse piles, can produce AMD. AMD generated by underground mines may continue for hundreds of years, as new pyritic material is exposed and oxidized through the slow collapse of mine roofs and walls, and as groundwater creates AMD that flows into nearby streams. Abandoned surface mines and refuse piles also produce significant quantities of AMD when rainfall and runoff flow through exposed pyritic material.

A variety of methods can reduce AMD generation, prevent AMD from leaving mined areas, or treat AMD after it reaches waterbodies. Proper reclamation of surface mines, through revegetation and diversion of water away from acid-forming material, can reduce AMD generation, but reclaimed mine lands can still can contain seeps. In underground coal mines, old shafts and tunnels can be sealed to prevent AMD from reaching nearby streams. But AMD treatment has generally been the most practical solution. Proven methods include active chemical treatment, where hydrated lime or other chemicals are added to AMD to reduce the acidity and to significantly decrease metal concentrations. Active methods are generally expensive and require constant maintenance, often for decades. Other, more experimental, passive treatment methods include diverting AMD through wetlands, anoxic limestone drains, and open limestone channels. Although passive methods do not require daily maintenance, they still need to be monitored and, when necessary, restored. To treat an entire river rather than individual sources, limestone sand can be dumped directly in streams. This method has been successful in neutralizing the West Virginia's Middle Fork River, an AMD-impaired river that now supports stocked trout. But treating the whole river masks the problem of assigning responsibility for cleanup to those operators who caused the problem in the first place. In addition, treatment with limestone sand does not address metals standards, and may cause metals to precipitate and build up in stream sediments.

In Section 2 of this report, I assess the Buckhannon River and Tenmile Creek metals TMDL analyses. I summarize the pollution loading reductions proposed in the analyses and, to the extent possible, assess the data and computer model used to generate these reductions. In Section 3 I assess the pH TMDL for the Buckhannon, and in Section 4 I discuss TMDL implementation issues, with an emphasis on AMD. In the final section, I present recommendations for improving the Buckhannon and Tenmile TMDLs, and for ensuring that future AMD TMDLs are developed and presented in a manner that imparts confidence in the results, encourages informed public participation, and maximizes the potential for effective implementation.

2. THE METALS TMDLs

In June 1998, USEPA released two separate AMD TMDL reports for metals: one for the Buckhannon River (USEPA, 1998b) and one for Tenmile Creek (USEPA, 1998c). I discuss these reports together in this section.

The Buckhannon River below Beans Mill is designated as a warm water fishery; above this point the Buckhannon is designated as a trout stream. All of Tenmile Creek, including the Right Fork, is designated as a trout stream. Effective July 1, 1998, state water quality standards (46 CSR 1 Appendix E) for aluminum are the same for both designations: 0.75 milligrams per liter (mg/l) total aluminum (acute). Standards for total iron are more stringent in trout streams—0.5 mg/l (chronic)—compared with warm water fisheries where the standard is 1.5 mg/l (chronic). Manganese standards of 1 mg/l apply to public water supplies. Although USEPA has yet to review and approve West Virginia's revised standards submitted on July 1, 1998, the TMDL analyses use these new standards as target values for the pollution reductions.

National Pollutant Discharge Elimination System (NPDES) permits are required for stream discharges from all active coal mining operations. The TMDL reports identify 24 NPDES permits with a total of 89 pipes that discharge into the Buckhannon River and its tributaries, including Tenmile Creek (USEPA, 1998a and b). A search of the NPDES database shows that all 24 permits are for coal mining and coal-related activities (WVDEP, 1998b). In the Tenmile Creek watershed, all four permits and 17 pipes were originally registered to the Island Creek Coal Company (WVDEP, 1998b), and are now held by Upshur Properties, Inc., a subsidiary of Anker. Although abandoned coal mines are located in the greater Buckhannon River watershed, none are located in the Tenmile Creek watershed.

When discussing AMD, the distinction between point and nonpoint sources can blur. Generally, point sources are those that are discharged through a pipe, with discharge limits imposed through NPDES permits. NPDES permits are required for coal mines active after 1977; therefore, these mines generally produce point source discharges. But in reality, some AMD that originates on these mine lands is not collected, treated, and discharged through permitted pipes, and therefore may not be considered a point source. This is apparently the case in the Tenmile Creek TMDL report, where nonpoint sources of AMD actually originate from permitted areas.

Nonpoint sources typically encompass all sources other than point sources. Because NPDES permits have generally not been issued for abandoned coal mines or bond forfeiture sites, these sources are usually considered nonpoint sources. But the Alton Project, a bond forfeiture site in the Buckhannon River watershed, operates under an NPDES permit. Technically, this discharge is a point source.

An additional complication clouds the distinction between point and nonpoint sources. Where an untreated seep discharges AMD into a waterbody and where flow and pollutant data are available for the seep, it may be most convenient to model the seep as a point source. In the Buckhannon River TMDL analysis, certain seeps are indeed modeled this way. These seeps may flow from active or abandoned mine lands or from bond forfeiture sites. Even though they are modeled as point sources, they are considered nonpoint sources from a management perspective.

Other sources, in addition to point and nonpoint sources, can contribute metals loadings to waterbodies. When mobilized by surface runoff, high natural levels of metals in the soil can lead to elevated levels in rivers. Reservoirs of instream sediments, which are composed of historic depositions of metals that still reside on the stream bed, constitute another source of metals.

Tables 1 and 2 summarize the metals loadings from point and nonpoint sources in the Buckhannon River and Tenmile Creek watersheds. In these tables, I convert the loadings from the TMDL reports into common units: pounds per year of “potential” metals loadings. Potential loadings for point sources are based on sites with NPDES permits. Permitted, not actual, discharge concentrations are used to calculate the loadings at these sites. Potential loadings for nonpoint sources are based on loadings coefficients estimated for various land use categories. As described earlier, the blurred distinction between point and nonpoint sources means that nonpoint source loadings in these tables may actually originate on permitted mine lands.

Point source loadings in the Buckhannon River are not provided in the TMDL report; therefore, Table 1 is not complete. As shown in Table 2, point sources generate most of the potential metals loadings in the Tenmile Creek watershed: 80% of aluminum and 69% of the iron. As discussed below, at least one major point source in the Tenmile Creek watershed consistently exceeds its NPDES permit; therefore, the actual point source loadings may be greater than the potential loadings shown in Table 2.

Table 1: Potential loadings calculated in Buckhannon River TMDL report (pounds/year)

Source	Aluminum	Iron	Manganese
Point sources	N/A	N/A	N/A
Nonpoint sources			
Subwatershed 18	17,901	23,312	4,827
Subwatershed 20	12,941	17,974	2,632
Subwatershed 21	12,337	15,291	2,506
All other subwatersheds	439,887	567,109	142,874
Total, nonpoint sources	483,065	623,687	152,839
Total, Buckhannon River	N/A	N/A	N/A

Source: USEPA, 1998b. N/A = not available. Point source loadings are not given in TMDL report. Loadings for individual subwatersheds other than 18, 20, and 21 are also not given in TMDL report. Nonpoint source loadings for all other subwatersheds calculated by subtracting loads in subwatersheds 18, 20, and 21 from total for all subwatersheds. All subwatersheds are within the Tygart River Hydrologic Unit (HUC 05020001).

Table 2: Potential loadings calculated in Tenmile Creek TMDL report (pounds/year)

Source	Aluminum	Iron
Point sources		
Tenmile Creek	7,063	5,913
Right Fork	431	431
Total, point sources	7,493	6,344
Nonpoint sources		
Subwatershed 166	149	252
Subwatershed 167	136	208
Subwatershed 168	181	301
Subwatershed 169	197	347
Subwatershed 170	429	731
All other subwatersheds	742	1,077
Total, nonpoint sources	1,833	2,915
Total Tenmile Creek	9,327	9,259

Source: USEPA, 1998c. Point source loadings calculated by multiplying loads given in pounds/day by 365 days/year. All subwatersheds are within the Tygart River Hydrologic Unit (HUC 05020001).

The TMDL analyses compute a set of loadings reductions that are sufficient to meet water quality standards for aluminum, iron, and manganese. Tables 3 and 4 summarize these loadings reductions. For the Buckhannon River, nonpoint source reductions are proposed for three subwatersheds in the headwaters of the Left Fork; no point sources are targeted. For Tenmile Creek, the TMDL report proposes a combination of point source and nonpoint source reductions. Discharge limits for two pipes are reduced, and in addition, five subwatersheds are targeted for nonpoint source reductions.

2.1 Point source loadings

Data for point sources are readily available. Permit holders are required to monitor flows and pollutant discharges and to submit discharge monitoring reports (DMRs) to WVDEP. Monthly average, minimum, and maximum values, based on the data submitted to WVDEP, are summarized in Appendix A of the Buckhannon River TMDL report for metals; these data were used in the TMDL analyses. In the Tenmile Creek watershed, Upshur Properties, Inc. collects more detailed data than those submitted to WVDEP. Although they would be valuable in developing TMDLs, Upshur Properties, Inc. has not submitted these data for use in the modeling effort. Likewise, more detailed data should be available from other NPDES permit holders within the greater Buckhannon watershed.

Table 3: Metals reductions proposed in Buckhannon River TMDL report (% of loading)

Source	Aluminum	Iron	Manganese
Point sources	0%	0%	0%
Nonpoint sources			
Subwatershed 18	21%	23%	11%
Subwatershed 20	53%	55%	41%
Subwatershed 21	25%	26%	13%
All other subwatersheds	0%	0%	0%
Total, nonpoint sources	8%	8%	3%
Total, Buckhannon River	N/A	N/A	N/A

Source: USEPA, 1998b. N/A = not available. Total reductions cannot be calculated because point source loadings are not given in TMDL report. All subwatersheds are within the Tygart River Hydrologic Unit (HUC 05020001).

Table 4: Metals reductions proposed in Tenmile Creek TMDL report (% of loading)

Source	Aluminum	Iron
Point sources		
Tenmile Creek	15%	31%
Right Fork	0%	0%
Total, point sources	14%	28%
Nonpoint sources		
Subwatershed 166	20%	23%
Subwatershed 167	16%	20%
Subwatershed 168	19%	22%
Subwatershed 169	22%	23%
Subwatershed 170	21%	23%
All other subwatersheds	0%	0%
Total, nonpoint sources	12%	14%
Total, Tenmile Creek	14%	24%

Source: USEPA, 1998c. Point source reductions in Tenmile Creek are to be realized by lowering the discharge concentrations in WV50717 pipes 2 and 6 to 1.0 mg/l for aluminum and 0.5 mg/l for iron. All subwatersheds are within the Tygart River Hydrologic Unit (HUC 05020001).

2.1.1 Tenmile Creek

According to Table 2, point sources generate most aluminum and iron loadings in the Tenmile Creek watershed. Of the total of seventeen permitted pipes that discharge into the creek, the TMDL report identifies five primary sources of metals: pipe 1 (permit WV50717), pipe 2 (WV50717 and WV67601), pipe 3 (WV67601), pipe 4 (WV50717 and WV67601), and pipe 8 (WV50717). Data for the other pipes indicate that they discharge intermittently, or that discharge is not observed. For the five primary pipes, the report then focuses in more detail on pipes 2 and 3, because these are suspected to be the primary aluminum sources. After some analysis, the report concludes that pipe 3 has been the primary aluminum source in 1996 and 1997. According to Figure 2.16 in the report, pipe 3 routinely exceeds its aluminum discharge limit of 0.5 mg/l; in 34 of 46 cases, or 74% of monthly samples, aluminum levels exceed the permitted value (USEPA, 1998c). The report concludes that pipe 3, the most upstream discharge to Tenmile Creek, “is the major source of aluminum and iron loading to Tenmile Creek” (USEPA, 1998c, p. 2-16). Clearly, enforcement action at this discharge is important for meeting water quality standards.

The exceedances reported for pipe 3 raise the question of whether or not other discharges exceed permitted levels. The TMDL report does not perform this analysis, and Appendix A of the Buckhannon River report only shows monthly minimum, maximum, and average flows and metals concentrations for each point source. These data are insufficient to determine the number of historical exceedances for each point source.

Actual point source metals loadings are not entered into the computer model used to create the TMDLs. Instead, loadings are calculated by multiplying permitted metals concentrations by actual average monthly flows. Discharges that exceed permitted levels, like pipe 3 in Tenmile Creek, are considered to be enforcement problems and are not considered to be part of the TMDL.

2.1.2 Buckhannon River

Although the Buckhannon River report lists 24 permitted point sources that discharge through a total of 89 pipes, only a subset of these point sources are explicitly included in the model. Point sources in the Buckhannon River watershed with regular releases of over 75 gallons per minute (gpm) are modeled individually, while those specifically within the Tenmile Creek watershed are modeled separately if regular releases top 40 gpm. Those point sources with flows equal to ten gpm or less are considered to be negligible. All other point sources with intermediate flows are averaged together by subwatershed and modeled as aggregated point sources (Davis, 1998). According to Table A.1 in the Buckhannon River report, forty of eighty-nine NPDES sites discharge ten gpm or less. Although they are considered to be nonpoint sources for management purposes, four abandoned mine lands are also modeled as point sources (Davis, 1998).

Table 4.4 in the Buckhannon River metals TMDL report summarizes these point source discharges. According to Davis (1998), these loadings are given in pounds per hour and correspond to the values used to calibrate the model, not to the values used in the model runs that evaluate pollution reduction strategies. Therefore, they are based on actual flows and concentrations, and not the concentration limits set in the NPDES permits.

2.2 Nonpoint source loadings

To model nonpoint sources, the TMDL analyses assign pollution loading coefficients to different types of land uses—such as forest, reclaimed mine land, or agricultural land—for each subwatershed. Coefficients account for surface runoff, as well as groundwater seepage from natural and impacted land uses. The reports do not discuss how these coefficients were derived, what values were used, or even if the values for particular land uses are the same across subwatersheds. During the calibration process, these coefficients are adjusted. From the limited description in the TMDL reports, it seems as though values were not based on data collected in the watersheds. Instead, values seem to have been chosen in such a way that the model calibrates correctly. The calibration process is described in the following section.

2.3 The model

The Hydrological Simulation Program–Fortran (HSPF) computer model, version 11.0, was used to develop these TMDLs. HSPF is a continuous simulation model of hydrologic and associated water quality processes that models point sources, the buildup and washoff of pollutants due to nonpoint sources, and the transport and flow of the pollutants through stream reaches (USEPA, 1996a). This ability to assess the instream water quality response to nonpoint and point source contributions is essential for developing TMDLs. Although the TMDL reports specifically reference HSPF, HSPF is a component of the BASINS (Better Assessment Science Integrating Point and Nonpoint Sources) model (USEPA, 1996b). BASINS was used for most other 1998 TMDLs in West Virginia, as well as the six West Virginia fecal coliform TMDLs developed in 1997.

The computer model can be thought of as a complex data representation of the watershed that steps through time hour by hour, simulating the real-world pollution loadings, rainfall, runoff, groundwater seepage, and streamflow. At the same time, the model calculates the metals concentrations along the simulated rivers. Data based on point and nonpoint source loading estimates are entered into the appropriate variables to model the pollutant sources. Many other types of data are also required, including physical characteristics of the rivers such as channel geometry, and hydrological characteristics such as rainfall. Hydrological data are based on the rainfall record at Elkins.

Given these data, the model calculates metals concentrations in each subwatershed for each hour over the two-year simulation period. For aluminum, which has an acute water quality standard, the model compares each calculated concentration with the standard. For iron, which has a chronic standard, the model computes four-day averages for comparison with water quality standards. The goal of the modeling effort is to determine a set of metals loading allocations for an appropriate set of point and/or nonpoint sources such that the simulated metals concentrations meet water quality standards at all times and at all points along the listed rivers.

To accomplish this goal, the HSPF user reduces the existing metals loads for one or more sources, and re-runs the model until the simulated monitoring shows no violations. It is important to note that the model itself does not generate these reductions; rather, the analyst generates the reductions and the model indicates only whether or not the reductions are sufficient to meet the water quality standards. Thus, there are many sets of loading reductions, assigned to different sources, that are sufficient to meet water quality standards.

Before the model is run, it must be calibrated for hydrology and metals concentrations. The hydrology calibration ensures that the modeled streamflow as it passes an existing gaging station matches the known data from that station. The analyst performs this calibration by adjusting the groundwater storage, evapotranspiration, soil infiltration capacity, or other variables that relate to the flow of water through the system. According to the Tenmile Creek report, only a slight adjustment of the soil infiltration rate was necessary for that calibration. To test the hydrology calibration, the model was run with Elkins rainfall data to calculate streamflow at Hall. Calculated streamflow was then compared to actual monitoring data from the Hall gaging station. Located near the mouth of the Buckhannon, downstream from the city of Buckhannon's water supply dam, the Hall gaging station is not an ideal data source for the hydrology calibration. But with no closer upstream station available, the modelers are left with no choice. Hydrological variable values are not reported, either before or after calibration, so these values cannot be independently verified.

The metals calibration ensures that the modeled instream metals concentrations match known water quality monitoring data. To perform this calibration, the modelers use observed monthly discharge flows and concentrations from point sources, and adjust the metals loadings at nonpoint sources such that the water quality results match data from the Storage and Retrieval of Water-Related Data (STORET) database and DMRs. Although the reports state that these adjustments are made within reasonable ranges and that they maintain the relative contributions of each source, the unadjusted and adjusted values are not presented to allow confirmation.

2.4 The results

In both Tenmile Creek and the Buckhannon River, the TMDL reports identify a subset of critical subwatersheds for pollution reductions. These are the areas that generate the bulk of the metals loadings that cause downstream segments to be out of compliance with water quality standards.

2.4.1 Tenmile Creek

In the Tenmile Creek watershed, two streams join together before the creek enters the Buckhannon River. The southern tributary is called the Right Fork, while the northern tributary is Tenmile Creek itself. Based on an exceedance analysis of monitoring data at three stations located just upstream and downstream of the confluence of the Right Fork and Tenmile Creek, the TMDL report identifies Tenmile Creek above the confluence as the primary source of high aluminum and iron loads. Modeling results correspond with the exceedance analysis; therefore, the report only proposes loadings reductions from subwatersheds above the confluence with Right Fork: subwatersheds 166 through 170.

Two point sources in these subwatersheds are targeted for reductions: pipes 2 and 6 from permit WV50717. These permits, held by Upshur Properties, Inc., are to be lowered to 0.5 mg/l for iron and 1.0 mg/l for aluminum. According to the report, these new limits will be sufficient to reduce aluminum loads by 2.97 pounds per day (1,084 pounds per year) and iron loads by 4.95 pounds per day (1,807 pounds per year). These reductions add to any other point source reductions gained through enforcement action on discharges that have been exceeding their metals limits.

In addition to these point source reductions, other nonpoint source reductions are proposed for subwatersheds 166 through 170. These reductions vary by subwatershed, and range from 16% to 22% for aluminum and from 20% to 23% for iron. Recall that these nonpoint source reductions may actually originate from permitted mine lands, and are classified as nonpoint sources only because the discharges are not routed through permitted pipes.

As shown above in Table 4, average reductions for all point sources are only slightly higher than average reductions for all nonpoint sources: 14% versus 12% for aluminum and 28% versus 14% for iron.

Tables 4.3 and 4.5 in the Tenmile Creek report suggest that maximum iron and aluminum concentrations are found at low flow conditions. Typically, high concentrations at low flow indicates that point sources rather than nonpoint sources are primarily to blame. This observation suggests that it may be reasonable to target NPDES permit holders for pollution reductions to a larger extent than they have been targeted. Without access to detailed data or the model, it is not possible to test this proposition.

2.4.2 Buckhannon River

Similar to the Tenmile Creek analysis, the Buckhannon River analysis identifies the critical subwatersheds that generate metals loadings. An analysis of historical monitoring data indicates that most exceedances of water quality standards occur on the mainstem upstream of Beans Mill (subwatershed 11), where the stream is designated a trout stream, and further upstream on the Left Fork (subwatersheds 18, 20, and 21). Therefore, the TMDL focuses on reducing metals loadings on these three Left Fork subwatersheds with the goal of meeting water quality standards downstream, including in subwatershed 11.

As shown above in Table 3, the TMDL report proposes nonpoint source loadings reductions for iron, aluminum, and manganese in these three Left Fork subwatersheds. According to the report, these reductions are to be achieved by restoring or remining abandoned mine lands, or by continued diversion and storage of runoff from reclaimed mine lands. Bond forfeiture sites may also contribute AMD in these areas. In addition, the report suggests identifying potential seeps and controlling them through reforestation and passive treatment.

Table 2.4 in the Buckhannon River TMDL report raises questions as to whether subwatersheds 18, 20, and 21 are the appropriate locations for manganese reductions. According to Table 2.4, no manganese exceedances were found on the Buckhannon River upstream of Tenmile Creek, while a 98.4% exceedance rate was found at the mouth of Tenmile Creek (USEPA, 1998b). These data, from 1987-91, suggest that the primary manganese sources are located in the Tenmile Creek watershed, and not in subwatersheds 18, 20, and 21. More recent data are not presented in the TMDL report to confirm whether or not a similar pattern of exceedances still occurs.

The nonpoint source reductions proposed in the Buckhannon and Tenmile reports raise similar implementation questions: How will particular sites be targeted for reductions? What reductions will be required at each site? Who will oversee this process? Who will pay? In Section 4, I present some background related to the implementation of AMD TMDLs.

3. THE pH TMDL

In addition to the two metals TMDL reports described in the previous section, a third TMDL, for pH on the Buckhannon River, was also released in June 1998 (USEPA, 1998a). Although Tenmile Creek also appears on the 1998 draft 303(d) list for pH impairment due to acid rain and the Tenmile Creek report confirms this pH impairment, a pH TMDL has not yet been developed for Tenmile Creek. In this section, I assess the data, model, and results from the Buckhannon pH analysis.

State water quality standards require pH to be between six and nine. According to the TMDL report, stream monitoring data from the 1980s suggest that pH levels in certain segments of the Buckhannon do not meet these standards; most instances were for acidic conditions with pH less than six. Since this time, changes have taken place in the watershed. Some additional mining permits have been issued, but also, some AMD treatment has been initiated. The Alton Project, a bond forfeiture site now run by the state, began operation since these data were collected and treats AMD to levels specified in an NPDES permit. According to the TMDL report, more recent data, collected after these changes in the watershed, suggest that pH problems are less significant than they were in the past.

These recent data are not comprehensive enough to determine, on their own, whether or not pH exceedances are still occurring. But they can still be useful if they are combined in a defensible manner with more comprehensive older data. To accomplish this, the TMDL analysis constructs a simple model that takes as input the acidity and alkalinity at each AMD inflow and tributary confluence point along the Buckhannon, and calculates the pH of each stream segment. In contrast to the metals model, which is a complex computer model, the pH model is based on only a few equations and can be easily run with a spreadsheet. The TMDL analysis first tests the model on the older data alone, to demonstrate that it produces reasonable results. Then, it substitutes more recent data where the data exist, and reruns the model. The model results with the new data suggest that pH violations no longer occur; therefore, acidity loading reductions are not proposed.

3.1 The data

The TMDL report lists eleven sources of water quality data in the Buckhannon River watershed, with data collected between 1980 and 1998. From these sources, a single sweep of 39 sites on the Buckhannon River and its tributaries, conducted by WVDEP in October 1987, provides the data used to construct the original pH model.

Data from a single sweep, rather than from a series of periodic measurements, is most appropriate for the pH model because the model simulates acidity and alkalinity loads that flow quickly through the river system. The pH model predicts pH at a single point in time, and the closer together in time that the monitoring data can be collected, the more accurate the model will be.

The 1987 sweep measured pH, acidity, alkalinity, and other water quality parameters. The TMDL report presents pH results from this sweep for ten points along the main stem of the Buckhannon. All of these points except one, station 25 below the confluence with Tenmile Creek, fall within the acceptable range of six to nine. The drop between station 27 and station 25 indicates an inflow of acidity, which, as the report suggests, is likely to come from AMD.

To construct the most effective pH model, the 1987 sweep sample should include pH, alkalinity, and acidity measurements at all tributary inflows and all AMD-producing seeps. Because the TMDL report only presents pH data at ten mainstem sampling points, I cannot verify that the data are sufficient to construct a valid model, or that the model works as well as the report suggests.

The TMDL report states that data were not sufficient to fully characterize the relationship between pH and flow. Despite the lack of site-specific data, seasonal fluctuations typically impact stream pH. In particular, spring high flows are likely to increase acid loads and depress pH. Therefore, when assessing pH, the most pertinent data would be based on a sweep in spring.

Data from two more recent WVDEP sweeps are used to model current conditions. The first sweep, from September 1997, sampled water quality at 43 sites, while the most recent sweep, conducted in April 1998, covered only ten. The TMDL report does not specify exactly which sites were included in these recent sweeps. Although not mentioned in the report, the city of Buckhannon's water treatment authority also conducted sweeps of the watershed; these data were not collected or used in the model.

3.2 The model

The model used for the Buckhannon pH TMDL is that proposed by Chadderton (1979) to predict AMD effects on stream pH. This model uses chemical equilibrium equations that calculate alkalinity, acidity, and pH at successive points along a stream. The model routes two quantities—alkalinity and carbon dioxide acidity—through the stream network. At each AMD source or tributary inflow, data on the inflow's alkalinity and carbon dioxide acidity must be entered into the model. Then, knowing alkalinity and carbon dioxide acidity at the inflow and on the mainstem just above the inflow, a mixing equation is used to calculate the resulting alkalinity and carbon dioxide acidity. Next, Chadderton's model assumes that alkalinity will be conserved as water flows to the next AMD or tributary inflow point, and that carbon dioxide acidity may decline. At the end of the stream segment, the pH can be calculated based on alkalinity and carbon dioxide acidity. The model then continues down the river, inflow point to inflow point, calculating alkalinity, carbon dioxide acidity, and pH.

This model provides a reasonable representation of AMD effects on stream pH. It improves on other previous models by incorporating carbon dioxide acidity. According to Chadderton (1979), his model results match those from a more complex computer simulation. Therefore, the main question related to the pH TMDLs center on the data, and not the model. As mentioned above, the reports present so little data that the model results cannot be fully evaluated.

3.3 The results

Because the 1987 sweep data include the inputs to the model (flow, alkalinity, and acidity) as well as the output from the model (pH), these data are used as a test. According to the TMDL report, results show a relatively good match between predicted and measured pH along the Buckhannon River. Therefore, the report suggests that the model is good enough to use with more recent data.

The 1997 sweep data found improved conditions at Tenmile Creek and Laurel Run, two tributaries to the Buckhannon. Substituting 1997 alkalinity and acidity data for Tenmile Creek and Laurel Run into the model, while keeping all other data the same as in 1987, the model predicts that pH water quality standards will be met. According to the TMDL report, alkalinity and acidity data for Laurel Run were unavailable, and Big Run data were used instead. It is not clear what parameters were used to find improved conditions at Laurel Run when the two types of data needed for the model, alkalinity and acidity, were unavailable.

The 1998 sweep data provides additional information for testing current water conditions. Using Tenmile Creek data from this sweep, Laurel Run data from the 1997 sweep, and 1987 data for all other sites, pH on the Buckhannon River once again is predicted to meet water quality standards. Again, the 1997 Laurel Run data are actually based on measurements at Big Run.

Based on these two scenarios, the TMDL reports propose that no further pollution reductions need to be made. This conclusion follows from the model chosen for the analysis, but the model results do not provide convincing evidence that pH water quality standards are consistently being met throughout the year. The model simulates the pH along the Buckhannon at a single point in time based on sweep data. Seasonal differences are likely to affect pH levels, with low readings typically found during the high flows of spring. Because the original model is based on data from October, the lowest pH readings are not likely to be captured in the model. This approach contrasts sharply with the HSPF model used in the metals TMDLs, which simulates pollution loadings and associated stream responses daily for a period of years.

4. IMPLEMENTATION ISSUES

The reductions proposed in the Buckhannon and Tenmile metals reports illustrate many of the implementation issues that will arise frequently as hundreds of future AMD TMDLs are completed in West Virginia, Pennsylvania, and other coal states. Where point sources are targeted for pollution reductions, the TMDL analysis clearly identifies the affected source and the more stringent permit levels that are required. But for nonpoint sources, the reports are quite vague. They target subwatersheds but do not clearly target particular nonpoint sources within these subwatersheds.

A second related issue is that the TMDL reports do not include implementation plans. For TMDLs to be effective management tools, implementation is essential. Without a systematic and transparent plan for implementing pollution reductions, TMDL development will devolve into an empty exercise.

The Buckhannon and Tenmile TMDL reports illustrate some of the pitfalls of creating TMDLs without associated implementation plans. The Buckhannon River analysis proposes nonpoint source reductions for three subwatersheds (see Table 3). Although the report suggests that abandoned and reclaimed mine lands should be targeted for cleanup, it presents no information as to which abandoned or reclaimed mine lands are located in the targeted watersheds or the metals loadings that originate from each source. The Tenmile Creek TMDL report also proposes nonpoint source reductions (see Table 4), but for subwatersheds in which no abandoned mine lands are located.

The Federal Advisory Committee on TMDLs, in their July 1998 report, proposes that an implementation plan and schedule should be submitted with each TMDL (USEPA, 1998d). According to the committee, implementation plans should include: (1) a description of actions that will be implemented to achieve the TMDL; (2) a schedule for implementing specific activities; (3) the legal authorities under which the control actions will be carried out; (4) reasonable assurances that nonenforceable actions for nonpoint source reductions will work; (5) an estimate of the time required to attain applicable water quality standards; (6) a monitoring plan; (7) measurable milestones; (8) the ramifications of failing to meet these milestones; and (9) a schedule for revising the state's Continuing Planning Process and applicable Water Quality Management Plans (USEPA, 1998d). USEPA is likely to issue new regulations that address these implementation plans.

Federal and state laws delineate a number of classifications of mine lands: abandoned mine lands, bond forfeiture sites, reclaimed mine lands, and active mine lands. Implementation plans for AMD TMDLs may be complex because they must be tailored to the specific types of mine lands that are targeted for cleanup. For this reason, it is important for TMDL reports to be as specific as possible in targeting particular sources for pollution reductions.

The high cost of AMD cleanup also complicates AMD TMDL implementation. The most common active chemical treatment methods can be extremely expensive and require constant maintenance, often for decades. As shown in Table 5, annualized treatment costs can reach the tens or hundreds of thousands of dollars per year, depending on flow and acidity. Treatment to reduce metals concentrations to meet water quality standards can add a considerable additional expense.

Most passive methods are cheaper and do not require constant maintenance; however, many of these methods are still experimental and have not proven their effectiveness over the decades necessary for long-term solutions. Typically, passive methods also do not remove sufficient quantities of metals to meet water quality standards.

Table 5: A range of annualized costs for active AMD treatment (thousand $)

Chemical	50 gpm flow, 100 mg/l acidity	1,000 gpm flow, 100 mg/l acidity	250 gpm flow, 500 mg/l acidity	1,000 gpm flow, 2,500 mg/l acidity
Soda ash	17	79	95	1,638
Ammonia	10	32	38	568
Caustic soda	11	85	104	1,933
Hydrated lime	15	45	48	314

Source: Phipps et al., 1995. Gpm = gallons per minute. Mg/l = milligrams per liter. Includes installation; annual labor, repair, and reagent costs; and salvage value. Costs are in 1991 dollars, and are based on the net present value over a twenty-year planning horizon with a 6% discount rate.

Despite these cost constraints and the variety of institutions and funding mechanisms involved in AMD cleanup, implementation plans for AMD TMDLs must be developed and carried out.

5. RECOMMENDATIONS

As the first AMD TMDLs completed in the country, the Buckhannon River and Tenmile Creek TMDL reports are important. They set a precedent for the technical content of the analyses: the appropriate metals and pH models to use for AMD-impaired rivers, the types of data to apply, and the specificity of the nonpoint source pollution reductions. They also set a precedent for the clarity, completeness, and usefulness of the report itself for interested parties who wish to participate in the process. Finally, they set a precedent for the process used to educate people about the content of the reports.

Although the following recommendations are based on the Buckhannon and Tenmile TMDLs, they are meant to ensure that future AMD TMDLs are developed and presented in a manner that imparts confidence in the results, encourages informed public participation, and maximizes the potential for effective implementation.

5.1 Improving the Buckhannon River and Tenmile Creek analyses

- Perform a pH exceedance analysis based on recent data. The exceedance analysis for the pH TMDL on the Buckhannon relies on monitoring data from 1986 through 1988. An additional exceedance analysis should be performed based on the more recent Alton Project data from 1995 through 1997. According to the TMDL report, monthly pH data were collected during this period. If this more timely exceedance analysis confirmed the model results, then the recommendation for taking no action would be bolstered. If, however, it contradicted the model results, this would suggest that the simple pH model and the data entered into the model are not sufficient for developing an accurate TMDL.

- Incorporate seasonal variations into the pH model. The pH model overlooks variations over time. High acidity levels and low pH during spring high flows, and other slugs of acidity, are not incorporated into the model. The TMDL report's conclusion that pH exceedances no longer occur may not apply to all situations. The city of Buckhannon's water treatment authority recently conducted sweeps of the watershed. These data should be collected and entered into the model to confirm that the pH problem has actually been solved.
- Clarify categories. The terms "point source" and "nonpoint source" are not used consistently and clearly in the TMDL reports. The reports should clarify how they refer to seeps from permitted areas, permitted bond forfeiture sites, and abandoned mine lands modeled as point sources. Also, where the reports refer to abandoned mine lands, they should clarify whether these abandoned mine lands may actually be bond forfeiture sites.
- Target specific nonpoint sources. When subwatersheds are targeted for nonpoint source reductions, the TMDL report should specify the particular sources for which reductions are required.
- Consider additional permit limits in Tenmile Creek. The Tenmile report suggests that maximum iron and aluminum concentrations are found at low flow. This observation indicates that permitted discharge points may be the primary cause of water quality violations, and corresponds with the assessment that point source loadings far outweigh those from nonpoint sources (see Table 2). Additional reductions in NPDES permit levels may be warranted in the Tenmile Creek watershed.
- Collect and apply all possible data. Upshur Properties, Inc., has not provided its weekly flow measurements and metals analyses. Other NPDES permit holders may also have collected data that was not submitted to USEPA for incorporation into the TMDL analysis. Collecting and applying these data would enhance the quality of the TMDL analyses.

5.2 Encouraging meaningful public participation

- Include a complete set of data in TMDL reports. To facilitate a meaningful review of the TMDL reports, they should include all data related to flows and pollution loadings and concentrations, both before and after calibration. This would allow reviewers to follow the calculations from the raw data and assumptions through the uncalibrated and calibrated variable values used in the model. All important assumptions must be explained and justified in the reports. TMDL reports for West Virginia have consistently omitted these data and have obscured the process through which loadings assumptions are translated into variable values. For stakeholders to provide meaningful comments, at least the following data must be clearly presented:
    1. Nonpoint source loadings coefficients before and after calibration for each type of land use,
    2. Point source flows and pollutant concentrations from all existing monitoring records,
    3. Point source loadings before and after calibration, and
    4. Permit levels for each point source for all pollutants of concern.
- Issue draft TMDL reports well before the public meetings. Most participants at the Buckhannon River and Tenmile Creek public meetings received a copy of the TMDL reports at the meeting. With no ability for advance preparation, the public meetings do not provide for a meaningful dialog. Reports should be distributed well before the meeting date so that the public can read them and generate questions.

5.3 Ensuring implementation

- Create an implementation plan. The Federal Advisory Committee on TMDLs proposes that an implementation plan and schedule should be submitted with each TMDL. According to the committee, implementation plans should include: (1) a description of actions that will be implemented to achieve the TMDL; (2) a schedule for implementing specific activities; (3) the legal authorities under which the control actions will be carried out; (4) reasonable assurances that nonenforceable actions for nonpoint source reductions will work; (5) an estimate of the time required to attain applicable water quality standards; (6) a monitoring plan; (7) measurable milestones; (8) the ramifications of failing to meet these milestones; and (9) a schedule for revising the state's Continuing Planning Process and applicable Water Quality Management Plans (USEPA, 1998d). An implementation plan based on this proposal should be created for the Buckhannon River and Tenmile Creek.
- Enforce the CWA. The Tenmile Creek analysis demonstrates that pipe 3 is often out of compliance with aluminum discharge limits. Enforcement action must be taken at this and at other point sources that are out of compliance with NPDES permits. Even if they are not accounted for in the TMDL model, these excess discharges degrade water quality.
- Continue AMD treatment at the Alton Project and at other sites. Treatment at the Alton Project and at other sites in the Buckhannon River watershed must continue for as long as necessary. Also, the Buckhannon River should remain on the 303(d) list for pH impairment until this treatment is no longer necessary.

The Buckhannon River and Tenmile Creek TMDL reports are important first steps in establishing a foundation for meeting metals and pH water quality standards. However, there are a number of technical questions raised by these reports, as well as questions related to presentation and process. Incorporating these recommendations will generate further confidence in the final Buckhannon and Tenmile TMDL reports, and will help to strengthen the hundreds of future AMD TMDL analyses that will be generated in the future.

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WVRC's mission is to conserve and restore West Virginia's exceptional rivers and streams.

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