pH TMDL Analysis for Buckhannon River, West Virginia

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Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are not meeting designated uses under technology-based controls. The TMDL process establishes allowable loading of pollutants and other quantifiable parameters for a waterbody based on the relationship between the pollution sources and the in-stream water quality conditions. This report summarizes the results of the analysis of pH for the main stem of the Buckhannon River between Hampton and Alexander.

The Buckhannon River is located in Upshur, Randolph, and Barbour counties, West Virginia. The West Virginia Department of Environmental Protection (WVDEP) listed the Buckhannon River on the 1998 303(d) list of water-quality limited-waters due to violations of pH and metals water quality standards (WVDEP 1998). Analysis of the metals loading is provided in a separate report (USEPA 1998 draft). This report discusses the development of a TMDL for pH for the main stem of the Buckhannon River. The portion of the Buckhannon River upstream of Beans Mill is designated by the state as B-2 waters (Cold Water Fishery). The relevant water quality criterion is pH must be within the range 6.0 to 9.0. Several tributaries of the Buckhannon River are listed for pH and/or metals (West Virginia 1998). These listings are not specifically addressed in this report. TMDLs for these additional waters will be addressed as the analysis is completed.

To evaluate the various loads from all potential sources within the watershed and examine instream conditions under various loading conditions, an analytically based pH predictive model was developed. For this study the approach was designed to address both point sources (permitted discharge points) and nonpoint sources (forest, agriculture, residential, industrial, and reclaimed lands).

An evaluation of the available monitoring data was performed to characterize the condition of the river, the frequency of potential violations of water quality standards, the river conditions under which violations occurred, and the relevant processes that might need to be simulated. Historic reports, monitoring studies, and compliance monitoring provided by WVDEP, Anker Mines, and Alton Mines provided data on flow and stream geometry. The greatest amount of data in terms of number of locations and number of observations was collected during the 1980s. More recent data collection consisted of localized compliance monitoring and several sweeps (multiple locations with single observations collected). The most recent data collection focused on characterization of the tributary water quality. The review of historic data indicated exceedances of pH standards, with the majority of these violations in the monitoring period from 1985 to 1988. Examination of the more recently collected data (1990s) shows that conditions have improved considerably.

The model was developed to represent the relationship between acidity, alkalinity, and the resulting pH in the Buckhannon River. The setup of the model was based on literature values and review of the monitoring data. The model was applied to the system for a representative period. The year chosen was 1987 because of the availability of data for that time period. This base run was used for comparison with observed conditions. Two scenarios were then run using more recent inputs from discharges to evaluate current conditions. These simulations show that the Buckhannon River is not expected to violate the water quality standards for pH under current conditions.

ACKNOWLEDGMENTS

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1.0 INTRODUCTION

1.1 Background

The pH of surface waters can fluctuate due to natural processes and human activities. EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waters found to be in violation of water quality standard. The TMDL process establishes allowable loadings of pollutants based on the relationship between pollution sources and instream water conditions. By following the TMDL process, states can establish water-quality-based controls to reduce pollution from both point and nonpoint sources and restore and maintain the quality of their water resources (USEPA 1991). The Buckhannon River is a tributary of the Tygart River. The Buckhannon River watershed consists of approximately 323 square miles in Upshur, Randolph, and Barbour Counties, West Virginia (Figure 1.1). The primary land uses in the watershed are agriculture, mining, and forest.

1.2 Purpose of the Study

The study was conducted to develop a TMDL for waters affected by mine drainage-impacted waters. The West Virginia Division of Environmental Protection (WVDEP) has identified the main stem of the Buckhannon River as being impacted by pH and metals for 16.74 miles, as reported on the 1998 draft 303(d) list of water-quality-limited waters (WVDEP 1998). The determination for impairment and inclusion on the 303(d) list were based on water quality and biological studies. This report addresses the pH listing of the Buckhannon River main stem.

1.3 Selection of TMDL Endpoints

One of the major components of a TMDL is the establishment of instream endpoints, which are used to evaluate the attainment of acceptable water quality. Instream endpoints, therefore, represent the water quality goals that are to be achieved by implementing the load reductions specified in the TMDL. The endpoints allow for a comparison between predicted instream conditions and conditions that are expected to restore beneficial uses; the endpoints are usually based on either the narrative or numeric criteria available in state water quality standards.

For the Buckhannon River, the applicable endpoints and associated target values can be determined directly from the West Virginia water quality standards. The Buckhannon River is currently designated as B-3 (Warm Water Fishery) below Beans Mill and B-2 (Cold Water Fishery) above Beans Mill. West Virginia water quality standards require B-2 and B-3 waters to have a pH in the range from 6 to 9 (WVDEP 1998).

Figure 1.1. Buckhannon River location and subwatersheds.

2.0 SOURCE ASSESSMENT

2.1 Sources of Data

Instream water quality data for the Buckhannon River presented in this report were obtained from a number of different sources. Table 2.1 is a summary of available data sources and their type, frequency of sampling, total number of observations, and sampling period. It can be seen that the available data in the 1990s were mainly composed of single sweeps (i.e., 1997, 1998) of the water quality of the Buckhannon River and its tributaries. Since data from WVDEP were the most comprehensive, those data were used to evaluate the Buckhannon River water quality conditions. Also, the water quality sweep conducted in 1987 provided a basis for examination of the instream pH and various contributing sources of acidity. Figure 2.1 shows the location of Buckhannon River instream sampling stations. Station identification used in this report is consistent with original reports.

2.2 Assessment of Nonpoint Sources

In the Buckhannon River watershed, a variety of nonpoint sources may contribute to the lowered pH. The sources include acid rain, nonpoint source runoff from(including abandoned mine areas, reclaimed areas, and forest areas), and groundwater seepage due to natural and impacted land use conditions. To spatially analyze the metals loadings, the Tenmile Creek watershed was divided into 14 subwatersheds. The land uses in each of the subwatersheds were determined using data from the U.S. Geological Survey (USGS) Land Cover Characterization Program (USGS 1997). As part of the Land Cover Characterization Program, a National Land Cover Data set is being developed. The Federal Region III Land Cover Data Set (USGS 1998), which uses Multiresolution Landscape Characterization (MRLC) data, was used to determine land use coverage in Tenmile Creek. A breakdown of land use types by subwatershed is shown in Table 2.2.

2.3 Assessment of Point Sources

Table 2.3 contains a list of the number of point source discharges in the Buckhannon River watershed. A complete table of point sources and their average flows and effluent concentrations is provided in the appendix.

Table 2.1. Summary of data sources and reports for the Buckhannon River watershed.

Source	Data Type	Parameters[a]	No. of Stations	Frequency	Date
Tygart Valley River AMD Assessment (WVDNR 1982)	Instream Water Quality Buckhannon River and Tributaries	PH, Acid, Alk, SO_4,Fe, Mn	68	Single sweep	1981—1982
CHIA for Tenmile Creek (DOE 1987)	Baseline Monitoring Data Buckhannon River	pH, Acid, Alk, Fe, Mn	7	Monthly	8/80—2/81
	Surface Water Data Buckhannon River	Fe, Mn	4	Monthly	2/86—10/86
	Water Resources Monitoring Data Buckhannon River	pH, Acid, Alk Fe, Mn, Al	9	Multiple/ Monthly	3, 4, 6,7, 10/86
Monitoring Stream Survey Report Buckhannon River (WVDEP 1987)	Water Quality Survey Buckhannon River and Tributaries	pH, Cond, Acid, Alk, Fe, SO_4, Mn, Al, ammonia, Nitrate, Nitrite	39	Single Sweep	10/87
STORET Database	Water Quality Data Buckhannon River	pH, Cond, Alk, SO_4, Fe, Mn, Al	4	Multiple / Monthly	1, 2, 3, 4, 6/88
WVDEP	Water Quality Data	pH, Cond, Alk, SO_4, Fe, Mn, Al	15	Multiple/ Weekly	3/86—6/88
WVDEP	Water Quality Data Buckhannon River Tributaries	pH, Cond, Acid, Al, Fe, Mn, Zn, Ca, Mg	43	Single Sweep	9/97
WVDEP	Water Quality Buckhannon River Tributaries	pH, Acid, Alk, SO_4, Al, Fe, Mn	10	Single Sweep	4/98
Alton Project	Water Quality Buckhannon River and Tributaries	pH, Al, Fe, Mn, Nitrite, SO_4, Ammonia	6	Monthly	1/95—12/97
City of Buckhannon Water Supply	Intake Water Quality		1	Annual Obser-vations	

[a]Alk = Alkalinity

Acid = Acidity

Fe = Iron

Mn = Manganese

Al = Aluminum

SO_4 = Sulfate

Cond = Conductivity

Table 2.2. Land use distribution by subwatershed.

Watershed	Commercial/ Industrial (acres)	Abandoned Mining (acres)	Reclaimed Mining (acres)	Forest (acres)	Agriculture (acres)
0502001-009	10.5	0.0	805.2	6444.5	272.3
0502001-010	275.4	15.68	0.4	6139.3	3567.7
0502001-011	5.1	0.0	296.1	9086.7	418.2
0502001-012	0.5	0.9	12.0	4940.2	493.7
0502001-013	108.7	33.8	416.8	18291.1	6984.2
0502001-014	956.1	68.3	140.1	17247.4	10645.5
0502001-015	111.6	0.9	21.3	22749.5	8188.6
0502001-016	6.5	0.0	74.9	8457.0	1391.2
0502001-017	26.7	22.6	9.3	15541.7	369.5
0502001-018	15.6	91.32	92.3	11940.2	329.2
0502001-019	17.6	14.7	200.5	20210.9	3561.3
0502001-020	0.2	0.0	28.7	4373.3	57.8
0502001-021	0.2	36.29	214.5	6782.3	122.7
0502001-022	1.1	18.69	37.1	11230.1	608.0
Total	1535.8	303.18	2349.2	163434.2	37009.9

Table 2.3. Number of point source discharges in the Buckhannon River watershed.

Subwatershed	Permit Number	Number of pipes
05020001-009	WV0050717	7
	WV0061689	4
	WV0067601	3
	WV0067881	3
05020001-011	WV0042056	12
05020001-013	WV0024619	2
	WV0035998	3
	WV0064955	2
	WV0098388	3
	WV1003313	1
	WV1003461	1
05020001-014	WV1003291	1
	WV1013858	4
05020001-015	WV0039471	7
05020001-018	WV0027031	4
	WV0090344	4
	WV0091901	3
05020001-020	None	0
05020001-021	WV0053929	2
	WV0062910	3
	WV1003321	6
	WV1003356	4
	WV1003585	1
05020001-022	WV1003232	8
	WV1003526	1

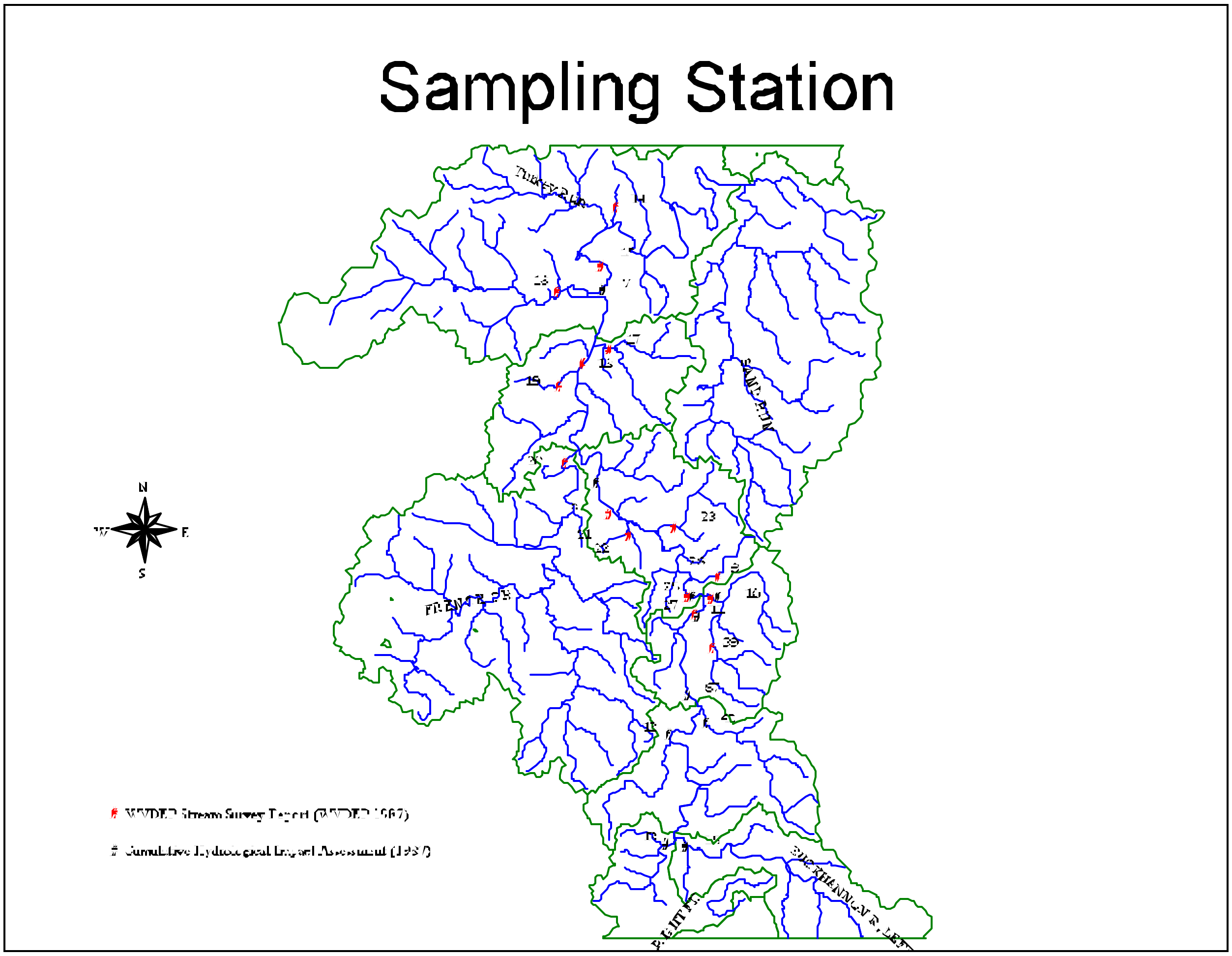


Figure 2.1. Instream monitoring station locations for WVDEP 1987 Buckhannon River survey.

3.0 DISCUSSION OF INSTREAM WATER QUALITY DATA

This section focuses on the analysis of pH observations in the main stem of the Buckhannon River. The 1987 WVDEP stream survey and the 1991 WVDEP data were used to conduct the pH frequency of exceedance analysis in the main stem of the Buckhannon River.

3.1 Observed pH Frequency of Exceedance

Data published in an internal WVDEP report in 1991 were used to perform the pH frequency analysis for the Buckhannon River. Data published in this report include the data that appeared in the *Cumulative Hydrologic Impact Assessment* (WVDOE 1987). In analyzing the WVDEP 1987 and 1991 data, a pH violation was defined as any time the observed pH value did not meet the water quality criterion either by exceeding 9 or being less than 6 (West Virginia Legislative Rule, Title 46).

For the period March 1986 to June 1988, the instream water quality data indicate that the highest frequency of pH exceedance was at the mouth of Buckhannon River and the instream monitoring stations directly downstream of the confluence with Tenmile Creek. At other stations the frequency of exceedance ranged from 0 to 8 in the 2.5-year period. Most sampling stations yielded 64 observations as shown in Table 3.1.

Table 3.1. Frequency of pH exceedance in the Buckhannon River for the period of record March 1986 to June 1988.

Station Number	Number of Observations	pH < 6		pH > 9	
		No.	%	No.	%
5	64	0	0	0	0
6	64	0	0	0	0
7	64	1	1.6	0	0
8	64	5	7.8	0	0
9	64	8	12.4	0	0
10	64	35	54.7	1	1.6
11	64	6	9.4	0	0
67	35	1	2.8	0	0
12	64	6	9.4	0	0

Station Identification:

Station	**Location**
5	Buckhannon River at Carrollton
6	Buckhannon River At Hall
7	Buckhannon River at Buckhannon
8	Buckhannon River at Sago
9	Buckhannon River below Tenmile Creek
10	Buckhannon River at Mouth of Tenmile Creek
11	Buckhannon River above Tenmile Creek
67	Buckhannon River at Beans Mill
12	Buckhannon River at Alton

As seen in Table 3.1, the majority of pH violations were due to pH values in the acidic range (less than 6). Almost no pH violations were observed at the higher range. The locations of these exceedances are in the main stem of the Buckhannon River in the section between Alton and Sago. In this section of the Buckhannon River, tributaries such as Panther, Big Run, Tenmile, Laurel Run, Grassy Run, and Sawmill Run represent the essential inflows to the Buckhannon River. The Buckhannon River generally met the upper limit of the pH water quality criteria. The only time pH exceeded 9 was a single event at the mouth of the Tenmile Creek.

3.2 Distribution of pH in the Main Stem Buckhannon River

Instream monitoring stations located on the Buckhannon River main stem that reflect spatial distribution of pH along the Buckhannon River are shown in Figure 3.1 and are listed in Table 3.2, along with the sampling period indicating the age of the data. The pH time series observations presented in Figure 3.1 show that at station 9 (above Tenmile Creek), the pH of the Buckhannon River was violated frequently. Also, more frequent violations were observed at station 11, which is below Tenmile Creek. The largest number of violations occurred in the periods of February and April of 1988. The observed pH violations might be due to acid mine drainage in the Buckhannon watershed. The primary tributaries that might be contributing acidity to the Buckhannon River above Tenmile Creek are Herods Run, Swamp Run, and Panther Creek. Downstream of Tenmile Creek, Laurel Run, Grassy Run, and Sawmill might be sources of acidity.

Table 3.2. Spatial distribution of pH along Buckhannon River.

Source	Stations	Sampling Period
1987	1 to 31	October 1987
WVDEP 1991	5 to 15	3/86—6-88
Alton Project	1 to 6[a]	1/95—12/97

[a] These stations cover the section of Buckhannon River from Alton to Beans Mill

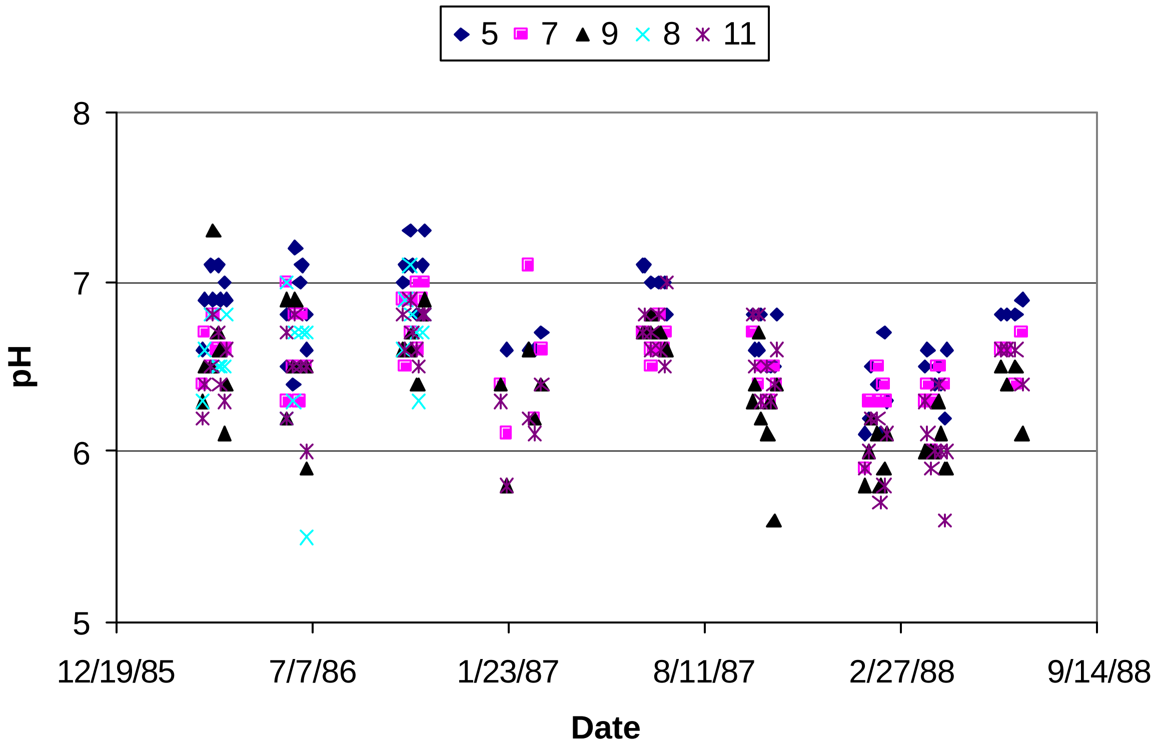
The WVDEP data collected in 1987 was also used to investigate the pH distribution along the main stem of the Buckhannon River. Low pH values were observed at station 25. As shown in Figure 3.2, the pH at this point was 5.6, which violates the water quality criterion. At station 27, the instream pH was 6.4. This decline in pH indicates an inflow of acidity. However, instream monitoring station 21, located at Sago, shows recovery of the pH.

In conclusion, based on the WVDEP 1987 and 1991 data, the pH of the Buckhannon River in the reach between Alexander and Sago might decline to a level that violates the water quality standard for pH. In this particular reach, acid mine drainage from abandoned mine sites or active mining is suspected to be the main contributor of acidity to the river (WVDNR 1982).

Figure 3.1. Instream pH monitoring stations for the Buckhannon River based on WVDEP 1991 report.

3.3 Critical Conditions

An attempt was made to study particular correlations between flow conditions and the pH of the Buckhannon River. Unfortunately, insufficient data did not permit a full characterization of pH-flow relationships. It is important to note that based on the 1987 and 1991 data, pH at the main stem appears to be significantly influenced by tributary inflows.



It is assumed that the evaluation of pH at baseflow conditions is representative of the dominant condition. WVDEP data collected through an intensive spatial survey in 1987 can be used to evaluate the level of allocations needed to establish pH of acceptable range in the Buckhannon River main stem.

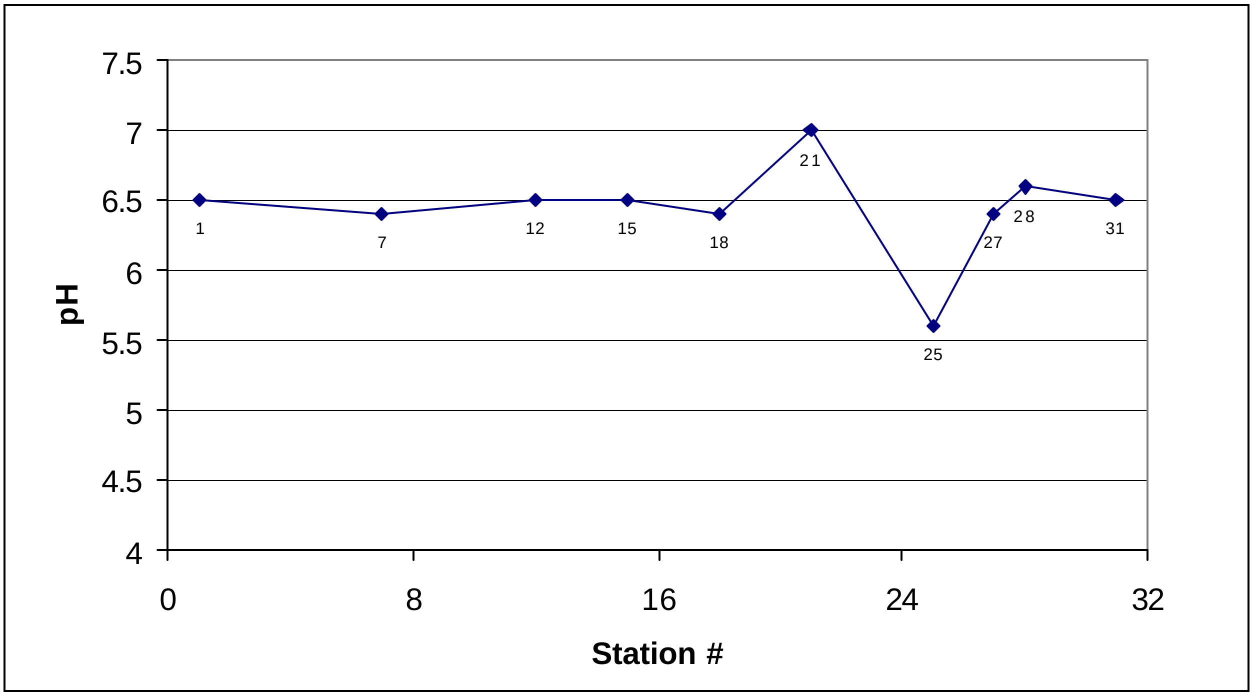


Figure 3.2. pH variations along the Buckhannon River, October 1987 data..

4.0 EVALUATION OF ACIDITY AND ALKALINITY LOADINGS

4.1 Evaluation Methodology

The 1987 sweep sampling was used as the basis for conducting the Buckhannon River pH analysis. Chadderton (1979) successfully used a simple model to predict the impacts of acid mine drainage on streams. The basic assumption of the model was that alkalinity and CO_2 acidity are conservative quantities and therefore can be routed between the mixing points along the stream. The general mixing model used is of the form

$$C_{mix} = \frac{C_1 * Q_1 + C_2 * Q_2}{Q_1 + Q_2}$$

where:

Q_1, Q_2 = flow rates of the streams,

C_1, C_2 = respective concentrations in the streams, and

C_{mix} = concentration after mixing.

At each mixing node of the Buckhannon River main stem, the alkalinity and acidity were computed based on tributary inflow. For alkalinity and acidity greater than zero, the pH of the Buckhannon River was calculated from the expression

$$[H^+] = \frac{[CO_2 + Acidity]}{[Alkalinity]} \times K_1$$

where K_1 is the ionization constant for carbonic acid. Where alkalinity is less than zero, the pH was estimated from

$$[H^+] = |Alkalinity|$$

This model was used to predict the pH of the Buckhannon River by routing the acidity and the alkalinity of the tributaries.

4.2 Application

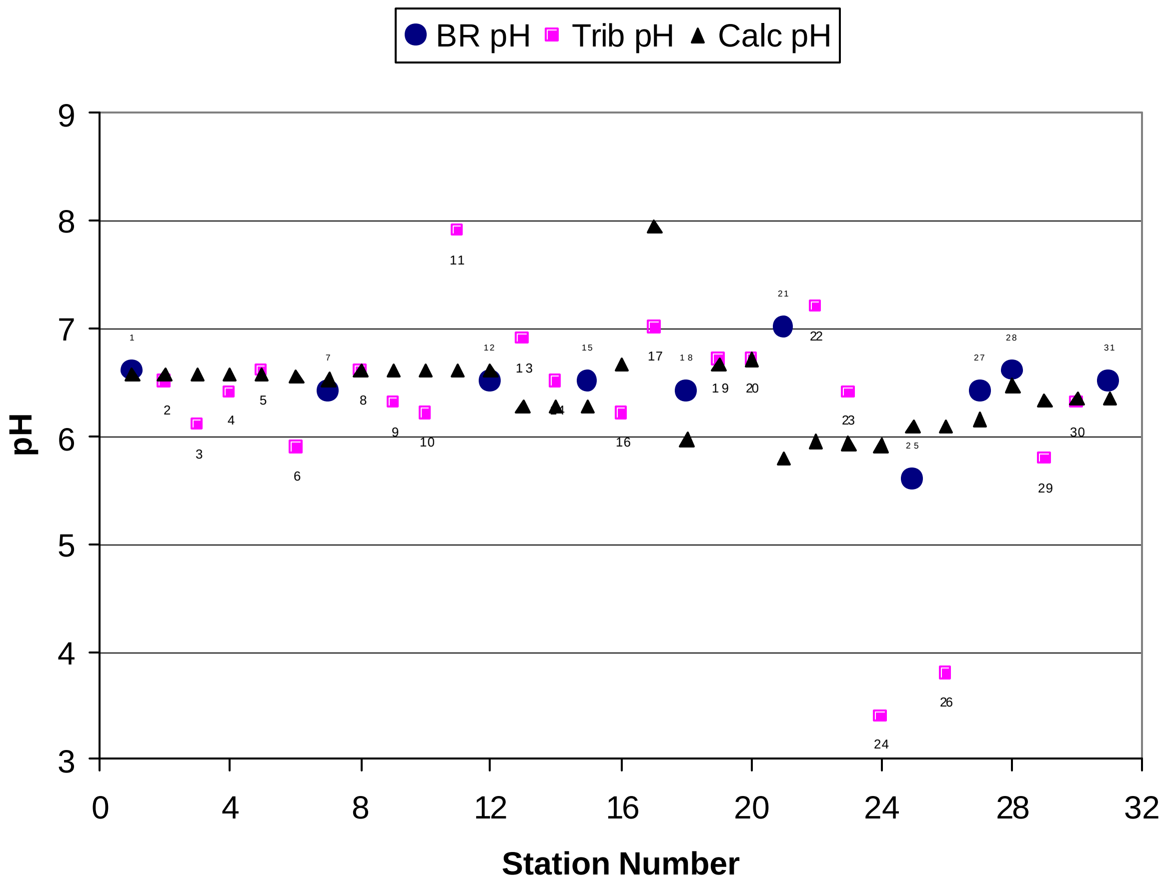
The above model was used to predict the pH of the Buckhannon River below the confluence points of a number of tributaries. The first objective was to use the 1987 data set to determine the spatial pH distribution along the main stem of the Buckhannon River. Second, the methodology was used to identify sections of the river where potential pH violations might occur due to the influx of acidity. Third, the methodology was used to recalculate acidity and alkalinity loadings under various inflow scenarios and to define the allowable load to meet the pH standard at each section of the Buckhannon River.

Figure 4.1 shows the observed pH at the instream monitoring stations and the observed pH values of different tributaries. The predicted pH values for the Buckhannon River instream monitoring stations and at mixing points of the different tributaries are also shown in Figure 4.1. The pH decline was in the upstream stations where high acid loads may be entering the river from the different tributaries. At station 25, which is below the Tenmile Creek tributary, the observed pH was less than 6, violating the water quality standards. The predicted Buckhannon River pH increases, as indicated by the observed pH at instream monitoring station 21. The acid load of the Buckhannon River at instream monitoring stations and at the mouth of each tributary was calculated and is shown in Figure 4.2. The results, based on the 1987 data set, suggests that acidity loads due to mining and acid mine drainage were the primary contributors to the pH decline in the Buckhannon River.

Figure 4.1. Buckhannon River and tributaries measured and predicted pH.

4.3 Conclusions

Based on the analysis of 1987 data, it can be concluded that the pH of the Buckhannon River was reduced to values below 6 due to influx of acidity from tributaries between Alton and Sago. In particular, the effect of Tenmile Creek can be clearly seen in Figures 3.2 and 4.1. Routing of acidity and alkalinity along the stream and consequently pH prediction at the mixing points was shown to be a reasonably good model for the Buckhannon River. The model can be used to extrapolate conditions under current



(1997/98) loading conditions. This model may be further used to estimate the level of alkalinity required in tributary inputs that would minimize the impact on the Buckhannon River pH. The approach would require that the acidity of the stream be kept to a minimum and then that alkalinity be added to the tributary to avoid any pH exceedance.

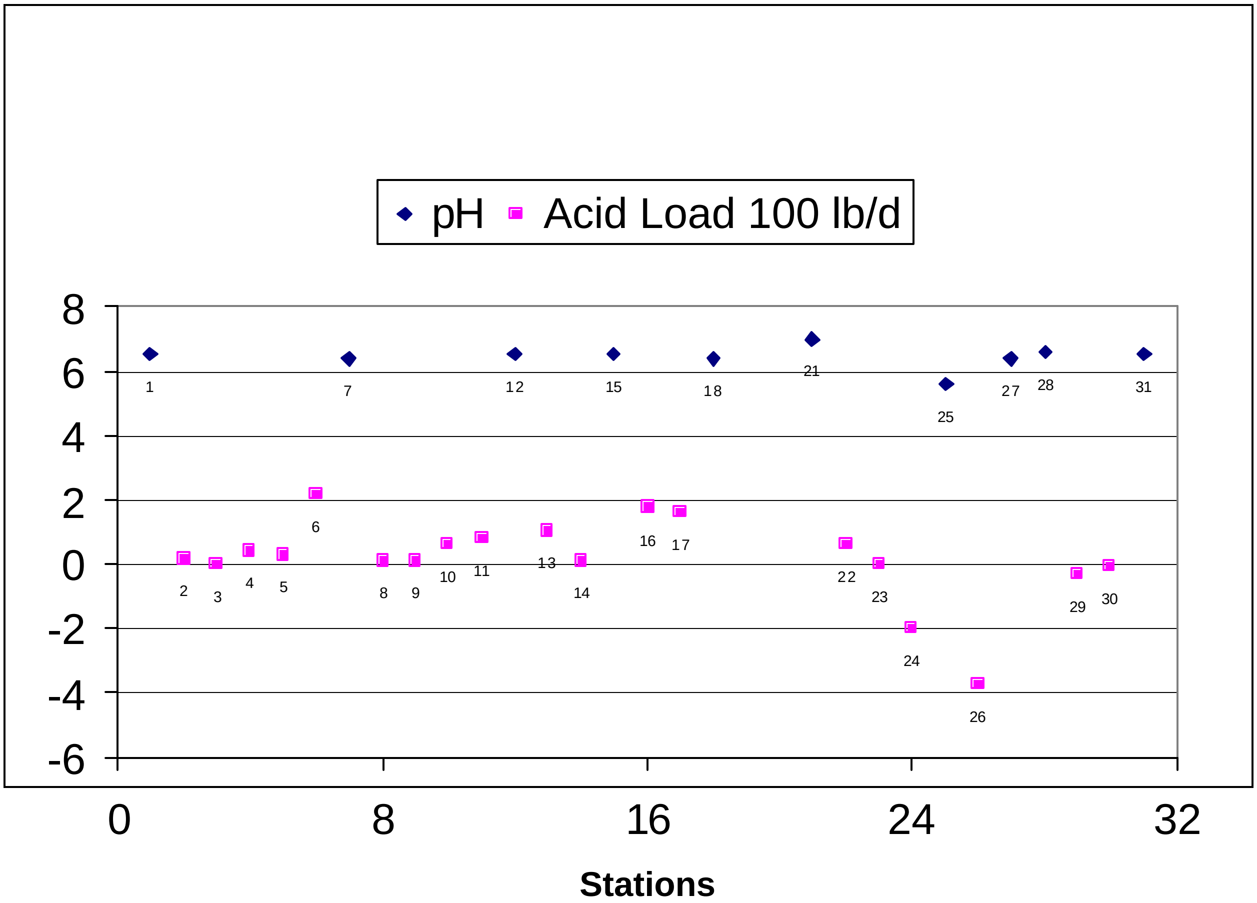


Figure 4.2. Predicted pH and acidity load of tributaries.

5.0 EVALUATION OF LOADING SCENARIOS

Since no comprehensive water quality sweeps were conducted on the Buckhannon River and its tributaries in recent years, the most recent observations of tributary conditions conducted by the WVDEP were used to predict the current pH conditions in the Buckhannon River. Two sweeps were conducted, the first in September 1997 and the second in April 1998.

5.1 Scenario 1

This case study was based on the September 1997 water quality sweep. The most noticeable difference in this data set was the improved conditions at Tenmile Creek and Laurel Run. Although the observed pH at Tenmile creek was 5.8, the acidity was 6 mg/L compared to the 57 mg/L measured in 1987. This represents a 90% reduction in acidity. In 1987, the observed alkalinity was 0 mg/L, whereas in 1997, the observed alkalinity was 6 mg/L. These are substantial improvements in the water quality in the Tenmile Creek tributary. At the Laurel Run tributary, the observed pH was 7.6, but the alkalinity and the acidity where not determined. To estimate the alkalinity and the acidity of Laurel Run, the tributary values for Big Run were used since it is a comparable stream.

The pH of the Buckhannon River was reevaluated based on the analysis discussed above. Conditions were kept constant except for the pH, acidity, and alkalinity of Tenmile Creek and Laurel Run. As a result of the improved conditions at Tenmile Creek and Laurel Run, the Buckhannon River did not violate the water quality standard for pH (Figure 5.1).

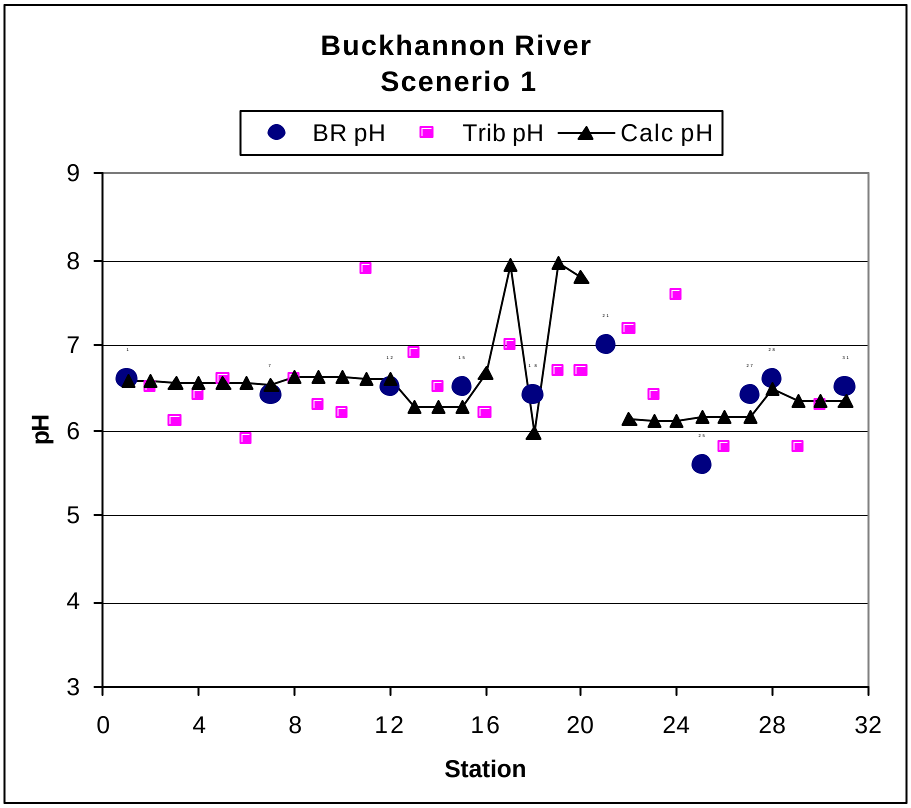


Figure 5.1. Buckhannon River pH estimation under Scenario 1.

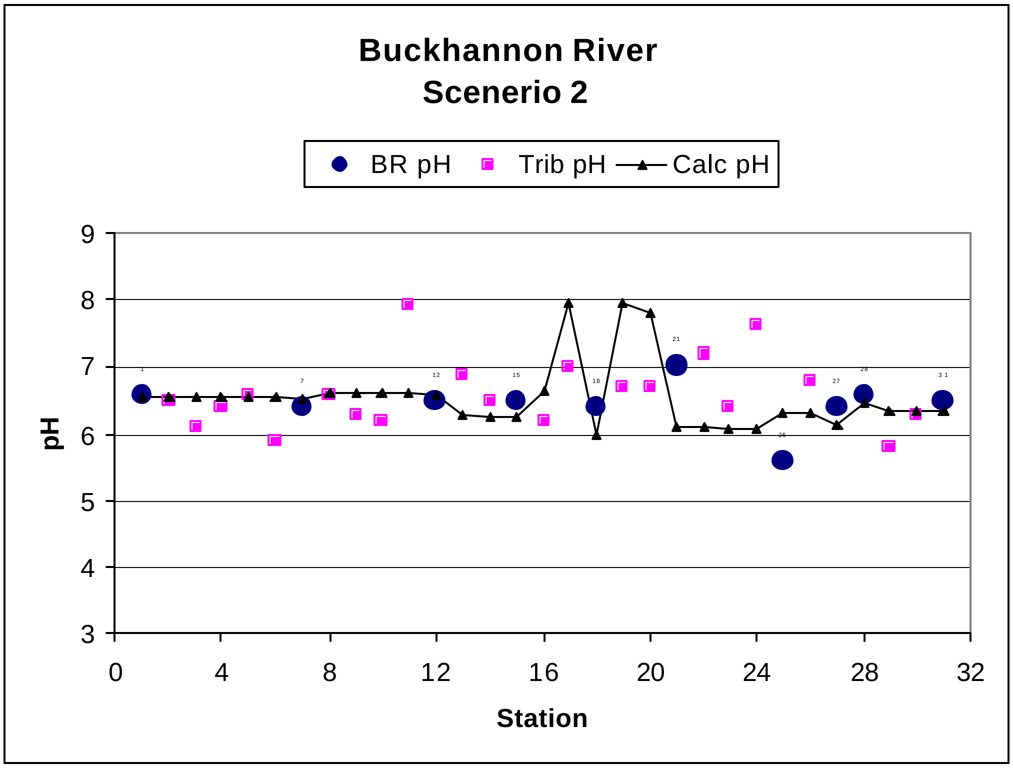


Figure 5.2. Buckhannon River pH estimation under Scenario 2.

5.2 Scenario 2

In this case study, the April 1998 water quality data were used to evaluate the pH condition in the Buckhannon River. The Laurel Run parameters were kept the same as Scenario 1 but the pH, acidity, and alkalinity of Tenmile Creek were updated based on the 1998 sweep. All other parameters were kept constant. The conditions at Tenmile Creek were as follows: pH 6.8, acidity 1.05 mg/L, and alkalinity 8.8 mg/L. These are dramatic improvements over the 1987 water conditions. Under this scenario, the predicted pH of Buckhannon River does not violate the water quality standard for pH as shown in Figure 5.2.

6.0 SUMMARY

6.1 Findings

- The analysis shows historic violations of pH in the main stem Buckhannon River. The majority of the documented violations are during the 1985-88 monitoring period.
- A model was developed to represent the relationship between acidity, alkalinity, and resulting pH in the Buckhannon River due to tributary inflows.
- The model represented the system well for the 1987 simulation.
- The model was applied to two scenarios evaluating the pH condition of the Buckhannon River under more recent inputs from Tenmile Creek and Laurel Run.
- Simulation of the two scenarios showed that the Buckhannon River is not predicted to violate water quality standards.

6.2 Recommendations

The following recommendation is provided to USEPA. No allocation is required under current conditions and permits since no violations are expected to occur. Periodic monitoring should be performed in the future to track continued maintenance of water quality standards within the acceptable range relevant to pH in the Buckhannon River.

Although the Buckhannon River is not violating the pH standard under current conditions, as demonstrated by the recent monitoring data as well as the predictive model, the small tributaries draining direct discharges or abandoned mine areas might demonstrate impairment. The small tributaries will be addressed in separate TMDL submittals. Further improvements of inflows from smaller tributaries will continue to enhance the pH condition in the main stem of the river.

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APPENDIX

Table A.1 Summary of NPDES discharges in the Buckhannon Watershed.

Permit	Pipe			Flow rate		
Number	Number	Num Obs	Min	Max	Value (gpm)	Value (cfs)
Subwatershed 05020001-009						
WV0050717	1	46	1.0	43.0	10.0	0.02
WV0050717	2	48	13.0	3460.0	648.0	1.44
WV0050717	3	1	15.0	15.0	15.0	0.03
WV0050717	4	47	1.0	300.0	47.0	0.10
WV0050717	6	4	2.0	400.0	178.0	0.40
WV0050717	8	12	1.0	13.0	3.0	0.01
WV0050717	9					0.00
WV0061689	1	44	1.0	43.0	10.0	0.02
WV0061689	2	48	1.0	350.0	49.0	0.11
WV0061689	4	3	1.0	5.0	3.0	0.01
WV0061689	21	32	1.0	118.0	9.0	0.02
WV0067601	2	34	1.0	26.0	3.0	0.01
WV0067601	3	46	15.0	3250.0	870.0	1.94
WV0067601	4	32	1.0	15.0	3.0	0.01
WV0067881	2	1	4.0	4.0	4.0	0.01
WV0067881	7	1	5.0	5.0	5.0	0.01
WV0067881	8	5	25.0	700.0	188.0	0.42
Subwatershed 05020001-010						
WV0027031	2	48	36.0	9582.0	1463.0	3.26
WV0027031	4	27	0.0	1528.0	127.0	0.28
WV0027031	5	48	52.0	3134.0	784.0	1.75
WV0027031	104					0.00
Subwatershed 05020001-011						
WV0042056	1	38	0.0	2.0	0.0	0.00
WV0042056	2	39	0.0	1.0	0.0	0.00
WV0042056	3	36	0.0	1.0	0.0	0.00
WV0042056	4	37	0.0	2.0	0.0	0.00
WV0042056	5	20	0.0	0.0	0.0	0.00
WV0042056	6	35	0.0	0.0	0.0	0.00
WV0042056	7	34	0.0	1.0	0.0	0.00
WV0042056	8	39	0.0	0.0	0.0	0.00
WV0042056	9	35	0.0	0.0	0.0	0.00
WV0042056	10	39	0.0	2.0	0.0	0.00
WV0042056	11	38	0.0	1.0	0.0	0.00
WV0042056	12	38	0.0	1.0	0.0	0.00
Subwatershed 05020001-013						
WV0024619	1	1	75.0	75.0	75.0	0.17
WV0024619	3	19	25.0	63.0	43.0	0.10
WV0035998	1	20	5.0	18.0	12.0	0.03
WV0035998	3	16	0.0	250.0	37.0	0.08
WV0035998	5	17	18.0	70.0	32.0	0.07

WV0064955	4	39	30.0	163.0	106.0	0.24
WV0064955	101	1	50.0	50.0	50.0	0.11
WV0098388	1	37	0.0	41100.0	4325.0	9.64
WV0098388	4	1	76.0	76.0	76.0	0.17
WV0098388	5	1	1.0	1.0	1.0	0.00
WV1003313	4	1	15.0	15.0	15.0	0.03
WV1003461	1	19	0.0	250.0	21.0	0.05
Subwatershed 05020001-014						
WV1003291	1	2	6.0	12.0	9.0	0.02
WV1013858	6	14	10.0	40.0	16.0	0.04
WV1013858	7	28	8.0	80.0	38.0	0.08
WV1013858	8	2	18.0	20.0	19.0	0.04
WV1013858	9	9	5.0	18.0	9.0	0.02
Subwatershed 05020001-015						
WV0039471	1	3	0.0	0.0	0.0	0.00
WV0039471	2	3	0.0	0.0	0.0	0.00
WV0039471	3					0.00
WV0039471	5	2	0.0	0.0	0.0	0.00
WV0039471	6	3	0.0	0.0	0.0	0.00
WV0039471	9					0.00
WV0039471	10	1	0.0	0.0	0.0	0.00
Subwatershed 05020001-018						
WV0090344	1	9	3.0	60.0	23.0	0.05
WV0090344	2	2	15.0	25.0	20.0	0.04
WV0090344	3	22	5.0	385.0	43.0	0.10
WV0090344	4	11	3.0	83.0	37.0	0.08
WV0091901	1	25	1.0	212.0	21.0	0.05
WV0091901	2	1	1700.0	1700.0	1700.0	3.79
WV0091901	15	27	1.0	290.0	85.0	0.19
Subwatershed 05020001-020						
Subwatershed 05020001-021						
WV0053929	1	27	15.0	300.0	72.0	0.16
WV0053929	2	14	1.0	30.0	8.0	0.02
WV0062910	1	26	1.0	318.0	70.0	0.16
WV0062910	2	20	11.0	2500.0	824.0	1.84
WV0062910	3	2	1835.0	2100.0	1968.0	4.39
WV1003321	1	8	3.0	20.0	10.0	0.02
WV1003321	3	5	10.0	20.0	14.0	0.03
WV1003321	4	4	5.0	23.0	10.0	0.02
WV1003321	15	5	4.0	29.0	11.0	0.02
WV1003321	16	5	4.0	41.0	13.0	0.03
WV1003321	19	1	76.0	76.0	76.0	0.17
WV1003356	1	36	1.0	88.0	20.0	0.04
WV1003356	2	35	5.0	83.0	18.0	0.04
WV1003356	3	4	5.0	20.0	14.0	0.03
WV1003356	4	6	3.0	25.0	13.0	0.03
WV1003585	1	26	7.0	370.0	72.0	0.16
Subwatershed 05020001-022						
WV1003232	1	5	3.0	30.0	12.0	0.03

WV1003232	2	7	1.0	15.0	5.0	0.01
WV1003232	3	7	1.0	15.0	4.0	0.01
WV1003232	4	5	3.0	45.0	15.0	0.03
WV1003232	5	4	3.0	10.0	5.0	0.01
WV1003526	1	43	1.0	40.0	15.0	0.03
WV1003526	2	44	1.0	25.0	8.0	0.02
WV1003526	3	46	2.0	50.0	27.0	0.06
WV1003526	4	38	1.0	36.0	4.0	0.01

Table A.2 Summary of pH measurements at NPDES Discharge Points in the Buckhannon Watershed.

Permit	Pipe		pH		
Number	Number	Num Obs	Min	Max	Value
Subwatershed 05020001-009					
WV0050717	1	46	6.07	8.90	7.30
WV0050717	2	48	6.50	10.00	7.96
WV0050717	3	1	7.33	7.33	7.33
WV0050717	4	47	6.08	8.70	7.08
WV0050717	6	4	7.20	8.80	7.85
WV0050717	8	12	6.00	8.70	7.36
WV0050717	9	13	6.90	8.90	7.61
WV0061689	1	44	6.24	8.90	7.56
WV0061689	2	48	6.10	7.70	6.85
WV0061689	4	3	6.00	6.90	6.40
WV0061689	21	32	6.20	9.00	7.27
WV0067601	2	34	6.00	7.40	6.47
WV0067601	3	46	6.13	8.90	7.86
WV0067601	4	32	6.00	8.10	6.68
WV0067881	2	1	8.30	8.30	8.30
WV0067881	7	1	8.70	8.70	8.70
WV0067881	8	6	8.10	9.00	8.67
Subwatershed 05020001-010					
WV0027031	2	48	6.29	8.45	7.76
WV0027031	4	27	6.81	8.84	7.65
WV0027031	5	48	6.99	8.37	7.87
WV0027031	104	1	7.21	7.21	7.21
Subwatershed 05020001-011					
WV0042056	1	40	5.00	9.00	7.25
WV0042056	2	41	5.60	8.80	7.26
WV0042056	3	38	6.20	8.00	7.09
WV0042056	4	40	5.20	8.90	7.14
WV0042056	5	41	4.90	9.00	6.80
WV0042056	6	37	4.90	9.00	7.03
WV0042056	7	37	4.80	8.90	7.17
WV0042056	8	41	5.90	8.10	7.35
WV0042056	9	38	5.60	11.70	6.84
WV0042056	10	41	6.10	7.50	6.88
WV0042056	11	39	6.60	9.00	7.62
WV0042056	12	40	5.10	9.30	7.25
Subwatershed 05020001-013					
WV0024619	1	1	7.65	7.65	7.65
WV0024619	3	19	7.73	8.18	8.01
WV0035998	1	20	4.54	7.48	6.59
WV0035998	3	16	6.01	7.58	7.05
WV0035998	5	18	3.65	7.94	7.11

WV0064955	4	39	6.46	7.89	7.41
WV0064955	101	1	7.70	7.70	7.70
WV0098388	1	37	6.77	8.13	7.46
WV0098388	4	1	6.30	6.30	6.30
WV0098388	5	1	6.86	6.86	6.86
WV1003313	4	1	7.80	7.80	7.80
WV1003461	1	23	6.51	8.80	7.54
Subwatershed 05020001-014					
WV1003291	1	2	6.90	7.50	7.20
WV1013858	6	14	6.53	8.12	7.48
WV1013858	7	28	2.22	8.37	7.43
WV1013858	8	2	7.82	7.83	7.83
WV1013858	9	9	7.14	8.01	7.61
Subwatershed 05020001-015					
WV0039471	1	45	6.80	9.00	7.62
WV0039471	2	44	7.00	8.50	7.67
WV0039471	3	32	6.50	8.00	7.28
WV0039471	5	42	6.50	8.50	7.60
WV0039471	6	45	6.90	9.20	7.67
WV0039471	9	1	7.40	7.40	7.40
WV0039471	10	40	6.00	7.00	6.59
Subwatershed 05020001-018					
WV0090344	1	9	6.90	7.80	7.17
WV0090344	2	4	6.60	7.90	7.20
WV0090344	3	40	6.10	8.40	7.22
WV0090344	4	11	6.60	7.30	7.04
WV0091901	1	42	6.40	8.80	7.32
WV0091901	2	1	8.30	8.30	8.30
WV0091901	15	38	6.20	7.80	7.06
Subwatershed 05020001-020					
Subwatershed 05020001-021					
WV0053929	1	47	6.20	8.30	7.15
WV0053929	2	22	6.00	9.00	7.39
WV0062910	1	46	6.60	8.60	7.66
WV0062910	2	29	6.30	8.60	7.86
WV0062910	3	13	6.70	7.40	7.05
WV1003321	1	8	6.85	8.00	7.38
WV1003321	3	5	6.58	7.03	6.75
WV1003321	4	4	6.21	7.27	6.85
WV1003321	15	5	6.71	6.99	6.83
WV1003321	16	5	6.33	6.87	6.60
WV1003321	19	1	6.20	6.20	6.20
WV1003356	1	36	6.05	8.11	7.06
WV1003356	2	35	6.14	7.93	6.74
WV1003356	3	4	6.40	7.35	6.65
WV1003356	4	6	6.28	7.10	6.58
WV1003585	1	44	6.50	8.00	7.13
Subwatershed 05020001-022					
WV1003232	1	5	6.00	7.10	6.70

WV1003232	2	7	6.00	7.20	6.74
WV1003232	3	7	6.40	7.20	6.90
WV1003232	4	5	6.10	7.40	6.79
WV1003232	5	4	6.10	6.90	6.58
WV1003526	1	43	3.70	8.10	6.85
WV1003526	2	44	6.00	7.90	6.73
WV1003526	3	46	6.00	7.80	6.87
WV1003526	4	36	6.00	7.70	6.67