

FINAL

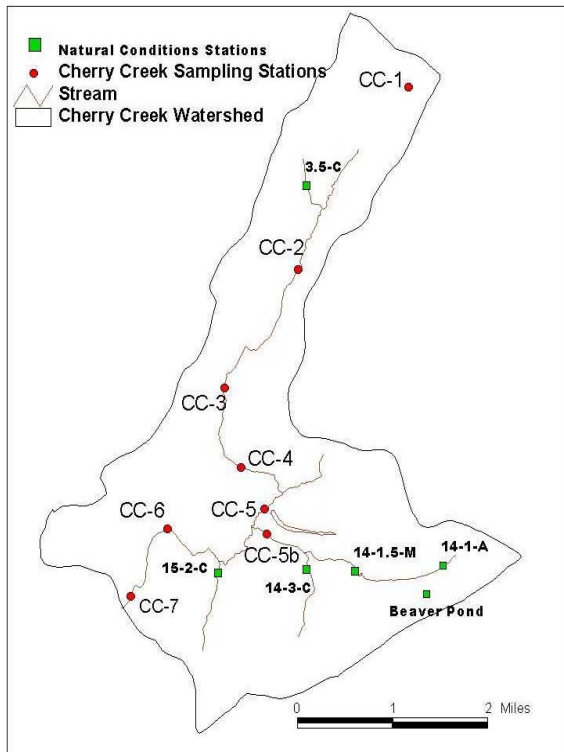
**Total Maximum Daily Loads  
to Address Low pH in  
Cherry Creek in the Deep Creek Watershed  
Garrett County, Maryland**

**APPENDICES**

**APPENDIX A****Natural Background Water Quality Sampling Data and Estimation of Endpoint Values**

Six sites known to be unaffected by acid mine drainage were selected for sampling and calculation of the natural conditions of Cherry Creek. These stations were located as follows:

- Station 3.5-C: located in an unnamed tributary near the headwaters of the creek, between CC-1 and CC-2.
- Station 14-1-A: located at the headwaters of an unnamed tributary of the creek that meets Cherry Creek downstream of CC-5.
- Station 14-1.5-M: Located in the same tributary where 14-1-A is located, closer to where it meets Cherry Creek.
- Station 14-3-C: located in a small tributary south of the tributary where 14-1-A and 14-1.5-M are located.
- Station 15-2-C: Located in an unnamed tributary in the southern area of the Cherry Creek watershed between CC-5 and CC-6
- Beaver Pond: Located in a pond near station 14-1-A.



**Figure A1: Location of Sampling Stations Used to Estimate the Natural Conditions of Water Quality in Cherry Creek**

Data associated with these sites are shown in the following table:

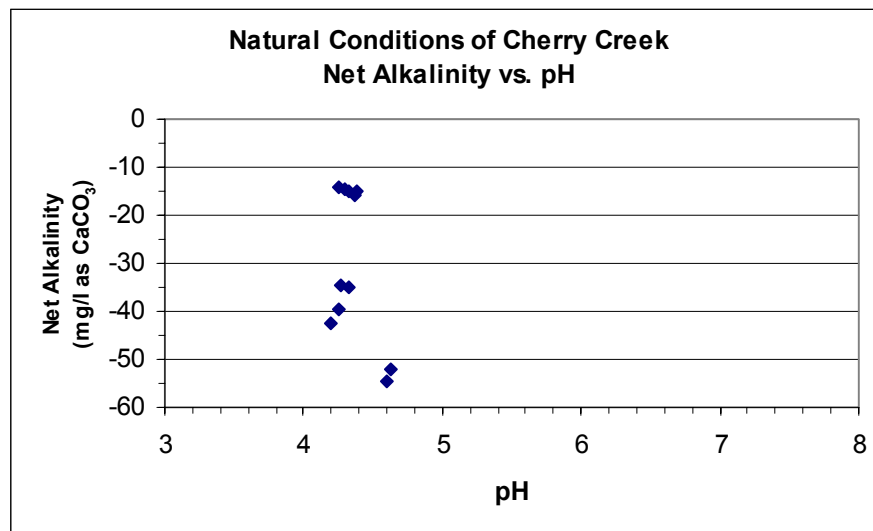
**Table A1: Natural Background Water Quality Data and Statistical parameters for Unaffected areas in Cherry Creek**

Station	Lab pH (pH units)	[H <sup>+</sup> ] mol/l	Acidity	Alkalinity	Fe	Sulfate
14-3-C	4.27	5.37E-05	34.6	0.0	0.47	11.6
3.5-C	4.63	2.34E-05	52.0	0.0	1.79	5.1
15-2-C	4.19	6.46E-05	42.6	0.0	0.33	12.9
14-1.5-M / G785	4.26	5.50E-05	14.0	0.0	0.59	8.6
Beaver Pond / G783	4.39	4.07E-05	14.9	0.0	1.25	9.7
14-1.5-M / G781	4.30	5.01E-05	14.6	0.0	1.65	9.3
14-1.5-M / G780	4.33	4.68E-05	15.2	0.0	1.24	9.6
Beaver Pond / G784	4.37	4.27E-05	15.7	0.0	2.20	8.8
14-1.5-M	4.26	5.50E-05	39.4	0.0	0.48	9.7
14-1-A	4.32	4.79E-05	35.2	0.0	0.59	7.9
14-1-A	4.60	2.51E-05	54.6	0.0	0.41	6.5
<b>Average</b>		4.59E-05	30.25	0.00	1.00	9.06
<b>St. Dev</b>		pH = 4.34	15.90	0.00	0.66	2.15
<b>Minimum</b>	4.19	2.34E-05	14.00	0.00	0.33	5.10
<b>Maximum</b>	4.63	6.46E-05	54.60	0.00	2.20	12.90
<b>Average</b>	4.34	4.59E-05	30.3	0.0	1.0	9.1
<b>Median</b>	4.32	4.79E-05	34.6	0.0	0.6	9.3

All parameters in mg/l unless otherwise noted. Acidity and alkalinity in mg/l as CaCO<sub>3</sub>

As explained before in section 4.2.1, data from the 6 sites used to determine the natural pH conditions, show that the net alkalinity varies from -14 to -55 mg/l as CaCO<sub>3</sub>, with an average of -30.3 mg/l as CaCO<sub>3</sub>; and the pH varies from 4.2 to 4.6 with an average of 4.34 (calculated from the average concentration of the hydrogen ion). The data show that, if an average value for net alkalinity remains above -30 mg/l, then the pH water quality target of 4.3 will be maintained. Because the alkalinity of this system is consistently zero, the previous result corresponds to maintaining an acidity concentration of 30 mg/l as CaCO<sub>3</sub> or less.

**Figure A2: Natural Conditions Net Alkalinity vs. pH for the Cherry Creek**





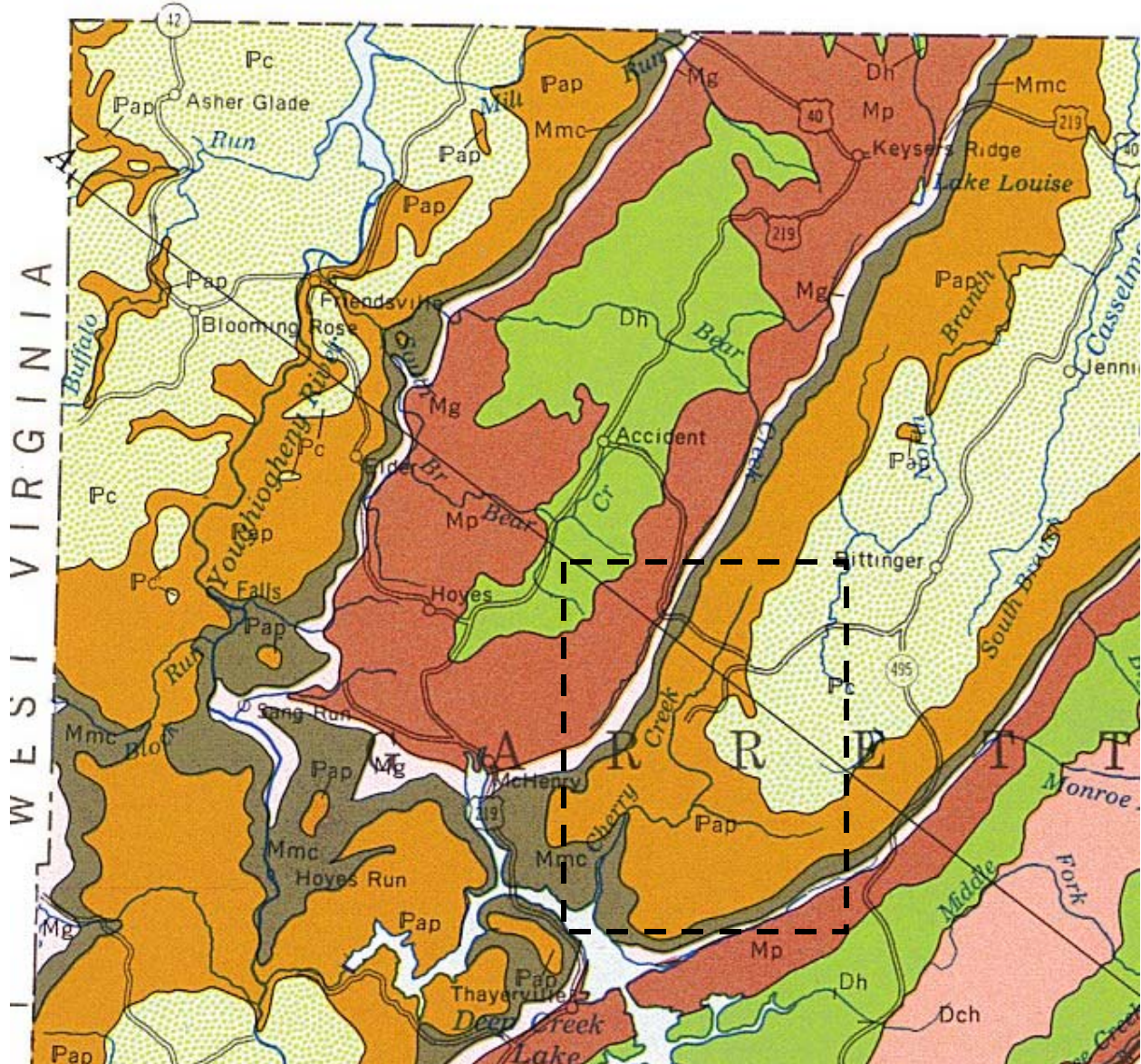
**APPENDIX B**

**Figure B1:  
Maryland Geological Survey / Geologic Map  
Garrett County Detail - NW (1968)**

**Allegheny Plateau and Valley and Ridge**

Key / Legend: Description of the formations for the Cherry Creek can be found in Section 3.1.1(b) of the main document

- Pap:  Allegheny Formation, Pottsville Formation
- Mmc:  Mauck Chunk Formation



**APPENDIX C****Statistical Comparative Analysis between Cherry Creek 1972 Water Quality Data Set and 1988-1994 Water Quality Data Set**

Two sets of pH related water quality data were available for the Cherry Creek TMDL analysis. One set was data collected in a survey performed in 1972 and the other set was from different surveys that took place between 1988 and 1994. Acidity (in mg/l as CaCO<sub>3</sub>) and pH from these two sets of data were compared to estimate the possibility of using the 1972 data in the current TMDL analysis. An analysis of variance (ANOVA) found that the conditions of the Cherry Creek in 1972 were significantly different from the more current conditions (pH:  $p < 0.01$ , acidity:  $p = 0.10$ ), consequently the 1972 data set was not used in the estimation of the TMDL. The Statistical Analysis System (SAS) program was used to do the comparison.

Results from the SAS runs are as follows:

**TABLE C1: 1972 Data and 1988 to 1994 Data Statistics**

	<b>Variable</b>	<b>Mean</b>	<b>N</b>	<b>Minimum</b>	<b>Maximum</b>	<b>Std Error</b>	<b>Variance</b>
<b>1988 to 1994 Data</b>	<b>Lab_pH</b>	4.68	77	3.0	6.7	0.75	0.57
<b>1972 Data</b>		4.30	60	3.1	5.2	0.55	0.31
<b>1988 to 1994 Data</b>	<b>Acidity (mg/l as CaCO<sub>3</sub>)</b>	46.02	11	0	359.4	47.53	2258.84
<b>1972 Data</b>		64.61	60	6.0	428.0	81.43	6631.26

**APPENDIX D****Lognormal Distribution Statistical Model**

Some of the most valuable classes of statistical models are those in which the observed variable is the limit of a large number of “causal” variables. The value of the observed variable may be the result of a combined effect of a large number of contributing causes, each difficult to observe and isolate. The many possible values of these many underlying causal variables leads to the uncertainty that is observed in the outcome variable of interest. In our case, the outcome variable is the pH value in water.

There are two fundamental models that result from two basic ways in which causal variables can be combined to produce the variable of interest. One way is to add the causes together, that is, a statistical “model of sums.” If the causal variables are independent of each other and randomly distributed, the sum of these variables results in an observed variable that tends toward a normal distribution (Benjamin and Cornell, 1970). An example would be the length of a line of vehicles  $L_n$ , which is made up of the sum of a number of vehicle lengths  $V_n$ .

$$L_n = V_1 + V_2 + V_3 + \dots + V_n$$

The other basic way to combine smaller causes is to multiply them together. The outcome of a “model of products” is an observed variable that has a lognormal distribution. That is,

$$Y_n = Y_o W_1 W_2 W_3 \dots W_n$$

The reason for the name “log normal distribution” is revealed when the logarithm is taken of both sides of the previous equation. The result is a model of sums of logs, which is normally distributed:

$$\ln Y_n = \ln Y_o + \ln W_1 + \ln W_2 + \ln W_3 + \dots + \ln W_n$$

## **APPENDIX E**

### **Data Used for the Calculation of the TMDL and Excel Files Used to Run Monte Carlo Simulation with @Risk Software**

The following Microsoft Excel files show the data used for the Cherry Creek TMDL analysis. Each page represents a file for an individual sampling station. There are eight stations in total: CC-1, CC-2, CC-3, CC-4, CC-5, CC-5b, CC-6, and CC-7. For each station, the pH related water quality data is presented first with its statistical parameters: mean, standard deviation, maximum and minimum; and second, the table with the parameters and formulas used in the Monte Carlo Simulation is presented.

The TMDL and load allocations for acidity were determined using the Monte Carlo Simulation. Allocations were applied uniformly for the watershed area specified for each allocation point. Each point or station selected in the stream was evaluated separately using @Risk<sup>1</sup>. Five thousand iterations of the Monte Carlo Simulation were performed to determine the required percent reduction so that the water quality criteria will be met 100% of the time.

For each point under consideration, an existing acidity concentration is estimated with the following equation:

Existing Concentration = RiskLognorm (Mean, Standard Deviation)  
where: Mean = average of the observed acidity concentration data  
Standard Deviation = standard deviation of the observed data

@Risk will perform 5,000 iterations to estimate the long-term average acidity of that point and the different values of acidity concentration at different percentiles in the log-normally distributed curve.

Based on the existing concentration, a reduction will be made to meet the water quality standard 100% of the time. For each iteration, the required percent reduction is estimated as:

PR: maximum {0, (1-Cc/Cd)}  
where: PR = require percent reduction for the current iteration  
Cc = acidity criterion in mg/l  
Cd = randomly generated acidity source concentration in mg/l based on the observed data  
Cd = RiskLognorm(Mean, Standard Deviation)  
where: Mean = average of the observed acidity concentration data  
Standard Deviation = standard deviation of the observed data

The overall percent reduction required is the 100<sup>th</sup> percentile value of the probability distribution generated by the 5,000 iterations, so that the allowable long-term average (LTA) concentration is:

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<sup>1</sup> @Risk – Risk Analysis and Simulation Add-in for Microsoft Excel, Palisade Corporation, Newfield, NY, 2001.

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$LTA = \text{Mean Existing Concentration} * (1-PR) = \text{allowable LTA source concentration in mg/l.}$

Once the required percent reduction for acidity was determined, mass balance equations were performed to determine the actual load reduction needed at each station.

The Monte Carlo Simulation was applied under average annual stream flow conditions. Analyses of data for acidity for other watersheds near Cherry Creek indicated that there was no significant correlation between source flows and acidity concentration, and that there was no single critical flow condition for pollutant sources (see Appendix G for the results of this analysis). Furthermore, most points in this particular watershed did not have enough paired flow/acidity data to calculate correlations.

Seasonal variation is implicitly accounted for in this TMDL because the data represent all seasons, and the reductions specified at each point apply at all flow conditions. A critical flow condition could not be identified from the data used for the analysis. An average annual flow estimated, as explained below, was used to derive loading values for the TMDL.

Average annual flows for all points in Cherry Creek were estimated based on a regression analysis, making use of the historical average flow data from the USGS flow gage station #3077940, South Branch Casselman River near Bittinger, MD. Data available from that station is for the period 1976 to 1981.



Cherry Creek TMDL Site	Date	Acidity Alkalinity Net Alk			pH	Sulfates	Iron	Average Flow	[H+]	WQ standard for [H+]	
		mg/l	mg/l	mg/l	pH units	mg/l	mg/l	(m <sup>3</sup> /s)		pH=6.5 =>[H+]=10 <sup>-6.5</sup> 3.16E-07	
CC-1	04/11/1988	20.0	0.0	-20.0	5.10	57.5	0.27	0.0246	7.9433E-06		
	10/04/1988	40.0	0.0	-40.0	4.70	48.7	1.93		1.9953E-05		
	03/16/1989	16.0	0.0	-16.0	4.60	58.1	0.60		2.5119E-05		
	05/26/1989	17.6	0.0	-17.6	4.30	107.7	1.13		5.0119E-05	Based on Natural Conditions	
	11/02/1989	16.9	0.0	-16.9	5.20	44.1	6.00		6.3096E-06	[H <sup>+</sup> ]=5.011E-05	
	04/30/1990	132.2	0.0	-132.2	3.90	60.5	0.79		1.2589E-04	pH=4.3	
	08/15/1990	34.2	0.0	-34.2	5.40	67.5	10.30		3.9811E-06		
	11/01/1990	75.8	0.0	-75.8	4.80	45.8	0.90		1.5849E-05		
	04/08/1991	47.0	0.0	-47.0	4.30	73.4	1.25		5.0119E-05		
	06/19/1991	19.0	0.0	-19.0	6.30	33.8	7.00		5.0119E-07		
	04/11/1994	52.0	0.0	-52.0	5.63	37.8	0.28		2.3442E-06		
	07/14/1994	2.2	0.0	-2.2	6.26	5.2	7.31		5.4954E-07		
			<b>Acy</b>	<b>Alkalinity</b>	<b>Net Alk</b>	<b>pH from</b>	<b>[H+]</b>	<b>Sulfate</b>	<b>Iron</b>	<b>Flow (m<sup>3</sup>/s)</b>	<b>[H+]</b>
		<b>Average =</b>	39.4	0.0	-39.4	4.59	53.3	3.1	0.0246	2.57E-05	
	<b>StDev =</b>	35.5	0.0	35.5		24.8	3.5				
This simulation endpoint will be based on water quality of the reference sites which are not affected by AMD	<b>Minimum =</b>	2.2	0.0	-132.2	3.9	5.2	0.3				
	<b>Maximum =</b>	132.2	0.0	-2.2	6.3	107.7	10.3				

**Summary**

Baseline Conditions	Average	St Dev
CC-1 Alkalinity	0.0	0.0
CC-1 Acidity	39.4	35.5
CC-1 Net Alk	-39.4	35.5

**Water Quality Standard  
Acidity @ stations not  
affected by AMD  
Acidity Cb =  
\*See "WQ standard  
spreadsheet"**

<b>Acy WQ St</b>
<b>30.3</b>

TMDL Endpoint	CC-1	1 perc	5 perc	10 perc	50 perc	90 perc	99 perc	100 perc
Existing Concentration	39.4	4.5	8.1	10.7	29.7	76.9	173.5	499.57
Computed Percent Reduction	0.23					61.80%	82.50%	94.20%
Percent Reduction (check 1)	0.618	61.8% acidity reduction for 90% level of protection						
Allowable Concentration 90% LP	15.05	1.8	3.2	4.2	11.0	30.2	69.1	204.3
Percent Reduction (check 2)	0.825	82.5% acidity reduction for 99% level of protection						
Allowable Concentration 99% LP	6.90	0.90	1.47	1.94	5.1	13.5	30.0	108.6
Percent Reduction (check 3)	0.942	94.2% acidity reduction for 100% level of protection						
Allowable Concentration 100% LP	2.29	0.54	0.83	1.05	2.40	5.5	10.60	30.3

<u>Summary</u>	90% LP	99% LP	100% LP
Acidity Reduction =	61.8%	82.5%	94.2%
Allowable Acidity Concentration (mg/l) =	15.1	6.9	2.3
Final Net Alkalinity (mg/l) =	-15.1	-6.9	-2.3
pH values = 4.3 or higher	(based on all MD data)		
pH values = 4.3 or higher	(based on CC data only)		

Cherry Creek TMDL Site	Date	Acidity	Alkalinity	Net Alk	pH	Sulfates	Iron	Average Flow	[H+]	WQ standard for [H+]
CC-2		mg/l	mg/l	mg/l	pH units	mg/l	mg/l	(m <sup>3</sup> /s)		pH=6.5 =>[H+]=10 <sup>-6.5</sup> 3.16E-07
	04/11/1988	30.0	0.0	-30.0	4.70	40.0	0.33	0.1567	1.9953E-05	
	07/28/1988	20.0	0.0	-20.0	4.50	149.0	1.30		3.1623E-05	
	10/04/1988	40.0	0.0	-40.0	4.00	40.4	0.86		1.0000E-04	
	03/16/1989	16.0	0.0	-16.0	4.30	29.0	0.30		5.0119E-05	
	05/26/1989	12.9	0.0	-12.9	4.20	37.1	0.70		6.3096E-05	
	11/02/1989	57.6	0.0	-57.6	4.80	31.3	4.00		1.5849E-05	
	04/30/1990	93.2	0.0	-93.2	3.80	30.7	1.42		1.5849E-04	
	08/15/1990	0.0	0.0	0.0	5.70	68.8	18.90		1.9953E-06	
	11/01/1990	99.6	0.0	-99.6	4.70	24.3	1.16		1.9953E-05	
	04/08/1991	41.0	0.0	-41.0	4.30	38.8	1.07		5.0119E-05	
	06/19/1991	19.2	0.0	-19.2	6.50	43.8	5.67		3.1623E-07	
	04/11/1994	43.2	0.0	-43.2	4.51	29.3	18.90		3.0903E-05	
		<b>Acy</b>	<b>Alkalinity</b>	<b>Net Alk</b>	<b>pH from</b>	<b>[H+]</b>	<b>Sulfate</b>	<b>Iron</b>	<b>Flow (m<sup>3</sup>/s)</b>	<b>[H+]</b>
	<b>Average =</b>	39.4	0.0	-39.4	4.34	46.9	4.6	0.1567	4.52E-05	
	<b>StDev =</b>	31.0	0.0	31.0		34.1	6.9			
	<b>Minimum =</b>	0.0	0.0	-99.6	3.8	24.3	0.3			
	<b>Maximum =</b>	99.6	0.0	0.0	6.5	149.0	18.9			

Based on Natural Conditions  
[H<sup>+</sup>]=5.011E-05  
pH=4.3

**Summary**

Baseline Conditions	Average	St Dev
CC-2 Alkalinity	0.0	0.0
CC-2 Acidity	39.4	31.0
CC-2 Net Alk	-39.4	31.0

**Water Quality Standard  
Acidity @ stations not affected by AMD**

**\*See "WQ standard spreadsheet"**

<b>Acy WQ St</b>
<b>30.3</b>

TMDL Endpoint	CC-2	1 perc	5 perc	10 perc	50 perc	90 perc	99 perc	100 perc	
Existing Concentration	39.4	6.61	10.5	13.19	30.69	75.19	150.15	353.3	
Computed Percent Reduction	0.23					60.65%	81.01%	91.14%	
Percent Reduction (check 1)	0.607	60.7%	acidity reduction for 90% level of protection						
Allowable Concentration 90% LP	15.50	2.4	3.9	5.1	12.3	30.4	63.5	184.8	
Percent Reduction (check 2)	0.810	81.0%	acidity reduction for 99% level of protection						
Allowable Concentration 99% LP	7.48	1.13	1.86	2.43	5.8	14.1	29.6	72.6	
Percent Reduction (check 3)	0.911	91.1%	acidity reduction for 100% level of protection						
Allowable Concentration 100% LP	3.49	0.52	0.88	1.1	2.7	6.8	14.2	30.2	

<u>Summary</u>	90% LP	99% LP	100% LP
Acidity Reduction =	60.7%	81.0%	91.1%
Allowable Acidity Concentration (mg/l) =	15.5	7.5	3.5
Final Net Alkalinity (mg/l) =	-15.5	-7.5	-3.5
pH values = 4.3 or higher			(based on all MD data)
pH values = 4.3 or higher			(based on CC data only)

Cherry Creek  
TMDL Site  
CC-3

Date	Acidity mg/l	Alkalinity mg/l	Net Alk mg/l	pH pH units	Sulfates mg/l	Iron mg/l	Average Flow (m <sup>3</sup> /s)	[H <sup>+</sup> ]
04/11/1988	30.0	0.0	-30.0	4.70	63.8	4.70	0.2248	1.9953E-05
07/28/1988	80.0	0.0	-80.0	3.90	427.0	3.90		1.2589E-04
10/04/1988	40.0	0.0	-40.0	3.90	112.4	3.90		1.2589E-04
03/16/1989	16.0	0.0	-16.0	4.40	48.0	4.40		3.9811E-05
05/26/1989	14.8	0.0	-14.8	4.50	72.4	4.50		3.1623E-05
11/02/1989	58.6	0.0	-58.6	4.90	46.1	4.90		1.2589E-05
04/30/1990	91.2	0.0	-91.2	3.60	91.2	3.60		2.5119E-04
08/15/1990	90.2	0.0	-90.2	3.90	393.9	3.90		1.2589E-04
11/01/1990	89.2	0.0	-89.2	5.10	58.0	5.10		7.9433E-06
04/08/1991	48.4	0.0	-48.4	4.40	91.6	4.40		3.9811E-05
06/19/1991	359.4	0.0	-359.4	3.70	428.4	3.70		1.9953E-04
04/11/1994	43.8	0.0	-43.8	4.99	32.5	4.99		1.0233E-05
	<b>Acy</b>	<b>Alkalinity</b>	<b>Net Alk</b>	<b>pH from [H<sup>+</sup>]</b>	<b>Sulfate</b>	<b>Iron</b>	<b>Flow (m<sup>3</sup>/s)</b>	<b>[H<sup>+</sup>]</b>
<b>Average =</b>	80.1	0.0	-80.1	4.08	155.4	4.3	0.2248	8.25E-05
<b>StDev =</b>	92.2	0.0	92.2		159.1	0.5		
<b>Minimum =</b>	14.8	0.0	-359.4	3.6	32.5	3.6		7.943E-06
<b>Maximum =</b>	359.4	0.0	-14.8	5.1	428.4	5.1		2.512E-04

<b>WQ standard for [H<sup>+</sup>]</b>
pH=6.5 =>[H <sup>+</sup> ]=10 <sup>-6.5</sup> 3.16E-07

<b>Based on Natural Conditions</b>
<b>[H<sup>+</sup>]</b> 5.0119E-05 pH=4.3

Summary

Baseline Conditions	Average	St Dev
CC-3 Alkalinity	0.0	0.0
CC-3 Acidity	80.1	92.2
CC-3 Net Alk	-80.1	92.2

Water Quality  
Standard  
Acidity @ stations  
not affected  
by AMD

Acidity Cb =  
See "WQ standard  
spreadsheet"

<b>Acy WQ St</b>
<b>30.3</b>

TMDL Endpoint	CC-3	1 perc	5 perc	10 perc	50 perc	90 perc	99 perc	100 perc
Existing Concentration	80.1	6.2	11.6	16.2	52.5	170.4	442.7	1786.2
Computed Percent Reduction	0.62					82.30%	93.20%	98.50%
Percent Reduction (check 1)	0.823	82.3% acidity reduction for 90% level of protection						
Allowable Concentration 90% LP	14.18	1.1	2.1	2.9	9.3	30.2	78.6	300.9
Percent Reduction (check 2)	0.932	93.2% acidity reduction for 99% level of protection						
Allowable Concentration 99% LP	5.45	0.40	0.80	1.10	3.6	11.6	30.2	151.9
Percent Reduction (check 3)	0.985	98.5% acidity reduction for 100% level of protection						
Allowable Concentration 100% LP	1.20	0.09	0.17	0.24	0.8	2.6	6.7	26.2

	Summary 90% LP	99% LP	100% LP
Acidity Reduction =	82.3%	93.2%	98.5%
Allowable Acidity Concentration (mg/l) =	14.2	5.4	1.2
Final Net Alkalinity (mg/l) =	-14.2	-5.4	-1.2
pH values = 4.3 or higher	(based on all MD data)		
pH values = 4.3 or higher	(based on CC data only)		

Cherry Creek TMDL Site	Date	Acidity mg/l	Alkalinity mg/l	Net Alk mg/l	pH pH units	[H+] [H+]	Sulfates mg/l	Iron mg/l	Average Flow (m <sup>3</sup> /s)
CC-4	04/11/1988	30.0	0.0	-30.0	4.70	1.9953E-05	60.0	0.53	0.2693
	07/28/1988	40.0	0.0	-40.0	5.40	3.9811E-06	192.7	14.00	
	10/04/1988	40.0	0.0	-40.0	4.20	6.3096E-05	72.4	1.59	
	03/16/1989	14.0	0.0	-14.0	4.20	6.3096E-05	47.4	0.25	
	05/26/1989	12.2	0.0	-12.2	4.30	5.0119E-05	61.6	0.69	
	11/02/1989	42.6	0.0	-42.6	4.70	1.9953E-05	47.1	1.77	
	04/30/1990	90.8	0.0	-90.8	3.60	2.5119E-04	65.1	1.64	
	08/15/1990	2.0	0.0	-2.0	6.20	6.3096E-07	105.6	16.80	
	11/01/1990	78.0	0.0	-78.0	4.55	2.8184E-05	54.9	1.60	
	04/08/1991	55.8	0.0	-55.8	4.20	6.3096E-05	76.9	1.74	
	06/19/1991	18.4	0.0	-18.4	5.00	1.0000E-05	167.1	5.91	
	04/11/1994	41.8	0.0	-41.8	4.69	2.0417E-05	34.6	0.56	
	<b>Average =</b>	<b>38.8</b>	<b>0.0</b>	<b>-38.8</b>	<b>4.31</b>	<b>4.95E-05</b>	<b>82.1</b>	<b>3.9</b>	<b>0.2693</b>
	<b>StDev =</b>	<b>26.5</b>	<b>0.0</b>	<b>26.5</b>			<b>49.3</b>	<b>5.6</b>	
	<b>Minimum =</b>	<b>2.0</b>	<b>0.0</b>	<b>-90.8</b>	<b>3.6</b>	<b>6.3E-07</b>	<b>34.6</b>	<b>0.3</b>	
	<b>Maximum =</b>	<b>90.8</b>	<b>0.0</b>	<b>-2.0</b>	<b>6.2</b>	<b>2.5E-04</b>	<b>192.7</b>	<b>16.8</b>	

<b>WQ standard for [H+]</b>
pH=6.5 =>[H+]=10 <sup>-6.5</sup>
3.16E-07

<b>Based on Natural Conditions</b>
[H <sup>+</sup> ]
5.0119E-05
pH=4.3

Summary

Baseline Conditions	Average	St Dev
CC-4 Alkalinity	0.0	0.0
CC-4 Acidity	38.8	26.5
CC-4 Net Alk	-38.8	26.5

Water Quality  
Standard  
Acidity @  
stations not  
affected by AMD

Acidity Cb = 30.25

\*See "WQ  
standard  
spreadsheet"

Acy WQ St
30.3

TMDL Endpoint	CC-4	1 perc	5 perc	10 perc	50 perc	90 perc	99 perc	100 perc	
Existing Concentration	38.8	7.82	11.9	14.6	32.2	70.7	135.23	311.8	
Computed Percent Reduction	0.22				Reduction =>	58.60%	78.80%	91.89%	
Percent Reduction (check 1)	0.586	58.6% acidity reduction for 90% level of protection							
Allowable Concentration 90% LP	16.06	3.2	4.8	6.0	13.3	29.6	57.9	95.7	
Percent Reduction (check 2)	0.788	78.8% acidity reduction for 99% level of protection							
Allowable Concentration 99% LP	8.23	1.49	2.48	3.01	6.7	15.1	28.3	78.8	
Percent Reduction (check 3)	0.919	91.9% acidity reduction for 100% level of protection							
Allowable Concentration 100% LP	3.15	0.6	0.94	1.2	2.7	5.6	11.0	29.6	

	90% LP	99% LP	100% LP
<u>Summary</u>			
Acidity Reduction =	58.6%	78.8%	91.9%
Allowable Acidity Concentration (mg/l) =	16.1	8.2	3.2
Final Net Alkalinity (mg/l) =	-16.1	-8.2	-3.2
pH values = 4.3 or higher	(based on all MD data)		
pH values = 4.3 or higher	(based on CC data only)		



Cherry Creek TMDL Site		Date	Acidity	Alkalinity	Net Alk	pH	[H <sup>+</sup> ]	Sulfates	Iron	Average Flow	WQ standard for [H <sup>+</sup> ]
CC-5			mg/l	mg/l	mg/l	pH units		mg/l	mg/l	(m <sup>3</sup> /s)	pH=6.5 =>[H <sup>+</sup> ]=10 <sup>-6.5</sup> 3.16E-07
		04/11/1988	20.0	0.0	-20.0	4.90	1.2589E-05	56.8	0.56	0.3818	<div style="border: 1px solid black; padding: 5px; text-align: center;"> <b>Based on Natural Conditions</b>  <b>[H<sup>+</sup>]</b>                      5.0119E-05                 </div>
		07/28/1988	20.0	0.0	-20.0	6.20	6.3096E-07	168.4	8.00		
		10/04/1988	40.0	0.0	-40.0	4.70	1.9953E-05	70.1	1.44		
		03/16/1989	14.0	0.0	-14.0	4.60	2.5119E-05	42.9	0.29		
		05/26/1989	11.8	0.0	-11.8	4.70	1.9953E-05	62.5	1.19		
		11/02/1989	39.0	0.0	-39.0	4.90	1.2589E-05	42.0	1.71		
		11/01/1990	94.6	0.0	-94.6	5.50	3.1623E-06	83.4	1.25		
		04/08/1991	52.8	0.0	-52.8	5.20	6.3096E-06	71.6	1.06		
		04/11/1994	37.4	0.0	-37.4	4.82	1.5136E-05	32.5	0.53		
			<b>Acy</b>	<b>Alkalinity</b>	<b>Net Alk</b>	<b>pH from</b>	<b>[H<sup>+</sup>]</b>	<b>Sulfate</b>	<b>Iron</b>	<b>Flow (m<sup>3</sup>/s)</b>	
		<b>Average =</b>	36.6	0.0	-36.6	4.89	1.28E-05	70.0	1.8	0.3818	
		<b>StDev =</b>	25.8	0.0	25.8			40.3	2.4		
		<b>Minimum=</b>	11.8	0.0	-94.6	4.6	0.0	32.5	0.3		
		<b>Maximum=</b>	94.6	0.0	-11.8	6.2	0.0	168.4	8.0		

Summary

Baseline Conditions	Average	St Dev
CC-5 Alkalinity	0.0	0.0
CC-5 Acidity	36.6	25.8
CC-5 Net Alk	-36.6	25.8

Water Quality  
Standard  
Acidity @ stations  
not affected by  
AMD  
Acidity Cb = 30.25  
\*See "WQ  
standard  
spreadsheet"  
Acy WQ St  
30.3

TMDL Endpoint	CC-5	1 perc	5 perc	10 perc	50 perc	90 perc	99 perc	100 perc
Existing Concentration	36.6	6.8	10.5	13.3	29.9	67.5	131	366.9
Computed Percent Reduction	0.17				Reduction =>	55.20%	76.87%	91.42%
Percent Reduction (check 1)	0.552	55.2% acidity reduction for 90% level of protection						
Allowable Concentration 90% LP	16.40	3.1	4.7	5.9	13.4	30.2	58.6	195.5
Percent Reduction (check 2)	0.769	76.9% acidity reduction for 99% level of protection						
Allowable Concentration 99% LP	8.47	1.50	2.40	3.10	6.9	15.6	30.3	75.9
Percent Reduction (check 3)	0.914	91.4% acidity reduction for 100% level of protection						
Allowable Concentration 100% LP	3.14	0.6	0.9	1.1	2.6	5.8	11.2	30.2

**Summary 90% LP 99% LP 100% LP**  
**Acidity**  
 Reduction = 55.2% 76.9% 91.4%  
**Allowable Acidity**  
 Concentration (mg/l) = 16.4 8.5 3.1  
**Final Net**  
 Alkalinity (mg/l) = -16.4 -8.5 -3.1  
 pH values = 4.3 or higher (based on all MD data)  
 (and based on CC data)

Cherry Creek TMDL

Site	Date	Acidity mg/l	Alkalinity mg/l	Net Alk mg/l	pH pH units	[H+]	Sulfates mg/l	Iron mg/l	Average Flow (m <sup>3</sup> /s)
CC-5b									
14-3.5-M	11/05/1997	35.8	0.0	-35.8	4.38	4.1687E-05	10.9	0.31	0.1800
14-3-A	11/05/1997	33.6	0.0	-33.6	4.40	3.9811E-05	10.6	0.35	
14-3-B	11/05/1997	34.8	0.0	-34.8	4.34	4.5709E-05	10.3	0.29	
14-4-C	11/05/1997	41.2	0.0	-41.2	4.41	3.8905E-05	13.4	0.38	
		<b>Acy</b>	<b>Alkalinity</b>	<b>Net Alk</b>	<b>pH from</b>	<b>[H+]</b>	<b>Sulfate</b>		<b>Flow (m<sup>3</sup>/s)</b>
	<b>Average =</b>	36.4	0.0	-36.4	4.38	4.15E-05	11.3	0.3	0.1800
	<b>StDev =</b>	3.4	0.0	3.4			1.4	0.0	
	<b>Minimum</b>	33.6	0.0	-41.2	4.34		10.3	0.29	
	<b>Maximum</b>	41.2	0.0	-33.6	4.41		13.4	0.38	

<b>WQ standard for [H+]</b>
pH=6.5 =>[H+]=10 <sup>-6.5</sup> 3.16E-07

<b>Based on Natural Conditions</b>
[H <sup>+</sup> ] 5.0119E-05 pH=4.3

Summary

Baseline Conditions	Average	St Dev
CC-5b Alkalinity	0.0	0.0
CC-5b Acidity	36.4	3.4
CC-5b Net Alk	-36.4	3.4

Water Quality  
Standard  
Acidity @  
stations not  
affected by  
AMD

Acidity Cb = 30.25

\*See "WQ  
standard  
spreadsheet"

<b>Acy WQ St</b>
<b>30.3</b>

TMDL Endpoint	CC-5b	1 perc	5 perc	10 perc	50 perc	90 perc	99 perc	100 perc
Existing Concentration	36.4	29.23	31.14	32.34	36.25	40.69	44.74	52.14
Computed Percent Reduction	0.17				<b>Reduction =&gt;</b>	25.88%	32.36%	44.34%
Percent Reduction (check 1)	0.259	25.9%	acidity reduction for 90% level of protection					
Allowable Concentration 90% LP	26.98	21.7	23.0	23.9	26.8	30.1	33.3	38.2
Percent Reduction (check 2)	0.324	32.4%	acidity reduction for 99% level of protection					
Allowable Concentration 99% LP	24.62	19.82	21.08	21.72	24.5	27.6	30.7	35.5
Percent Reduction (check 3)	0.443	44.3%	acidity reduction for 100% level of protection					
Allowable Concentration 100% LP	20.23	16.16	17.27	17.87	20.1	22.6	25.0	29.1

<u>Summary</u>	90% LP	99% LP	100% LP
Acidity Reduction =	25.9%	32.4%	44.3%
Allowable Acidity Concentration (mg/l) =	27.0	24.6	20.2
Final Net Alkalinity (mg/l) =	-27.0	-24.6	-20.2
pH values = 4.3 or higher	(based on all MD data) (and based on CC data)		

Cherry Creek TMDL Site	Date	Acidity	Alkalinity	Net Alk	pH	[H+]	Sulfates	Iron	Average Flow	WQ standard for [H+]
CC-6		mg/l	mg/l	mg/l	pH units		mg/l	mg/l	(m <sup>3</sup> /s)	pH=6.5 =>[H+]=10 <sup>-6.5</sup> 3.16E-07
	04/11/1988	50.0	0.0	-50.0	4.10	7.9433E-05	44.5	1.79		
	07/28/1988	140.0	0.0	-140.0	3.00	1.0000E-03	251.2	9.00		
	10/04/1988	70.0	0.0	-70.0	3.40	3.9811E-04	77.6	6.07		
	03/16/1989	30.0	0.0	-30.0	3.80	1.5849E-04	44.7	1.75		
	05/26/1989	35.2	0.0	-35.2	3.70	1.9953E-04	55.9	2.63		
	04/30/1990	84.4	0.0	-84.4	3.30	5.0119E-04	30.7	5.64		
	07/14/1994	486.8	0.0	-486.8	3.56	2.7542E-04	116.2	12.10		
	05/15/1996	26.9	0.0	-26.9	4.06	8.7096E-05	74.0	1.65		
	03/11/1999	62.4	0.0	-62.4	4.22	6.0256E-05	40.5	0.15		
	07/14/1999	100.8	0.0	-100.8	3.55	2.8184E-04	116.0	3.53		
	10/05/1999	91.8	0.0	-91.8	3.82	1.5136E-04	115.9	3.17		
	01/03/2000	74.2	0.0	-74.2	3.99	1.0233E-04	40.3	1.20		
	<b>Average =</b>	<b>104.4</b>	<b>0.0</b>	<b>-104.4</b>	<b>3.56</b>	<b>2.75E-04</b>	<b>84.0</b>	<b>4.1</b>	<b>0.6503</b>	
	<b>StDev =</b>	<b>124.8</b>	<b>0.0</b>	<b>124.8</b>			<b>61.6</b>	<b>3.5</b>		
	<b>Minimum</b>	<b>26.9</b>	<b>0.0</b>	<b>-486.8</b>	<b>3.00</b>		<b>30.7</b>	<b>0.15</b>		
	<b>Maximum</b>	<b>486.8</b>	<b>0.0</b>	<b>-26.9</b>	<b>4.22</b>		<b>251.2</b>	<b>12.10</b>		

<b>Based on Natural Conditions</b>
<b>[H+]</b>
<b>5.01E-05</b>

Summary

Baseline Conditions	Average	St Dev
CC-6 Alkalinity	0.0	0.0
CC-6 Acidity	104.4	124.8
CC-6 Net Alk	-104.4	124.8

Water Quality  
Standard  
Acidity @  
unaffected  
stations

Acidity Cb = 30.25

\*See "WQ  
standard  
spreadsheet"

Acy WQ St	100th value
30.3	160.8

TMDL Endpoint	CC-6	1 perc	5 perc	10 perc	50 perc	90 perc	99 perc	100 perc
Existing Concentration	104.4	7.93	14.13	19.83	64.92	216.56	564.07	1786.44
Computed Percent Reduction	0.71				Reduction =>	86.54%	95.14%	98.49%
Percent Reduction (check 1)	0.865	86.5% acidity reduction for 90% level of protection						
Allowable Concentration 90% LP	14.05	0.9	1.9	2.6	9.3	30.3	82.3	221.9
Percent Reduction (check 2)	0.951	95.1% acidity reduction for 99% level of protection						
Allowable Concentration 99% LP	5.07	0.37	0.68	0.97	3.3	11.0	28.2	74.7
Percent Reduction (check 3)	0.985	98.5% acidity reduction for 100% level of protection						
Allowable Concentration 100% LP	1.58	0.11	0.21	0.3	1.0	3.35	8.8	30.5

**Summary 90% LP 99% LP 100% LP**

Acidity Reduction = 86.5% 95.1% 98.5%

Allowable Acidity  
Concentration (mg/l) = 14.1 5.1 1.6

Final Net  
Alkalinity (mg/l) = -14.1 -5.1 -1.6

pH values = 4.3 or higher (based on all MD data)  
(and based on CC data)

Cherry Creek TMDL Site		Acidity	Alkalinity	Net Alk	pH	[H <sup>+</sup> ]	Sulfates	Iron	Average Flow	WQ standard for [H <sup>+</sup> ]	
Date	CC-7	mg/l	mg/l	mg/l	pH units		mg/l	mg/l	(m <sup>3</sup> /s)	pH=6.5 =>[H <sup>+</sup> ]=10 <sup>-6.5</sup> 3.16E-07	
04/11/1988		20.0	0.0	-20.0	4.80	1.5849E-05	36.0	0.38	0.7282	<div style="border: 1px solid black; padding: 5px; text-align: center;"> <b>Based on Natural Conditions</b>                      [H<sup>+</sup>]                      5.0119E-05                      pH=4.3                 </div>	
07/28/1988		20.0	0.0	-20.0	4.50	3.1623E-05	109.4	0.82			
10/04/1988		30.0	0.0	-30.0	4.30	5.0119E-05	62.2	0.60			
03/16/1989		16.0	0.0	-16.0	4.40	3.9811E-05	31.2	0.29			
05/26/1989		10.5	0.0	-10.5	4.60	2.5119E-05	35.3	0.61			
11/02/1989		51.8	0.0	-51.8	4.70	1.9953E-05	32.9	1.01			
04/30/1990		87.6	0.0	-87.6	4.20	6.3096E-05	39.9	1.04			
08/15/1990		15.3	0.0	-15.3	5.20	6.3096E-06	77.6	1.37			
11/01/1990		79.4	0.0	-79.4	4.80	1.5849E-05	36.1	0.37			
04/08/1991		45.6	0.0	-45.6	4.90	1.2589E-05	43.2	0.69			
06/19/1991		17.0	0.0	-17.0	5.30	5.0119E-06	54.0	0.63			
04/11/1994		40.8	0.0	-40.8	4.80	1.5849E-05	35.7	0.88			
					<b>pH from</b>						
		<b>Acy</b>	<b>Alkalinity</b>	<b>Net Alk</b>	<b>[H<sup>+</sup>]</b>	<b>[H<sup>+</sup>]</b>	<b>Sulfate</b>		<b>Flow (m<sup>3</sup>/s)</b>		
	<b>Average =</b>	36.2	0.0	-36.2	4.60	2.51E-05	49.5	0.7	0.7282		
	<b>StDev =</b>	25.8	0.0	25.8			23.5	0.3			
	<b>Minimum</b>	10.5	0.0	-87.6	4.20		31.2	0.29			
	<b>Maximum</b>	87.6	0.0	-10.5	5.30		109.4	1.37			

Summary

Baseline Conditions	Average	St Dev
CC-7 Alkalinity	0.0	0.0
CC-7 Acidity	36.2	25.8
CC-7 Net Alk	-36.2	25.8

Water Quality  
Standard  
Acidity @  
unaffected stations

Acidity Cb = 30.25

\*See "WQ standard  
spreadsheet"

1th value	Acy WQ St	100th value
8.46	30.3	160.8

TMDL Endpoint	CC-7	1 perc	5 perc	10 perc	50 perc	90 perc	99 perc	100 perc
Existing Concentration	36.2	6.79	10.5	13.3	30.3	68.7	128.2	295.5
Computed Percent Reduction	0.16				Reduction =>	53.07%	76.31%	91.46%
Percent Reduction (check 1)	0.531	53.1% acidity reduction for 90% level of protection						
Allowable Concentration 90% LP	16.99	3.0	4.8	6.1	13.8	31.3	60.6	125.3
Percent Reduction (check 2)	0.763	76.3% acidity reduction for 99% level of protection						
Allowable Concentration 99% LP	8.58	1.56	2.36	3.02	4.9	16.1	30.5	147.5
Percent Reduction (check 3)	0.915	91.5% acidity reduction for 100% level of protection						
Allowable Concentration 100% LP	3.09	0.52	0.85	1.07	2.5	5.73	10.3	27.6

	Summary 90% LP	99% LP	100% LP
Acidity Reduction =	53.1%	76.3%	91.5%
Allowable Acidity Concentration (mg/l) =	17.0	8.6	3.1
Final Net Alkalinity (mg/l) =	-17.0	-8.6	-3.1
pH values =	4.3 or higher		(based on all MD data) (and based on CC data)



**APPENDIX F**

**Cherry Creek Acidity Loads Calculation**

The load allocation for this stream was computed using the results from the Monte Carlo Simulation as explained in Appendix E at points CC-1, CC-2, CC-3, CC-4, CC-5, CC-5b, CC-6, and CC-7; and the flows estimated as explained also in Appendix E.

For each station the load allocation is as follows:

Cherry Creek Station	A Existing Concentration	B Allowable Concentration for a 100% Level of Protection	C Flow	D Existing Load	E Reduction Identified	F Allowable Load	G Total Load to be reduced at this station	H Total Load Reduced upstream of this station	I Remaining Load	J Additional Reduction Needed at this point	K Final Load
	mg/l	mg/l	m <sup>3</sup> /s	kg/day	%	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day
CC-1	39.4	2.3	0.0246	83.7	94.2	4.9	78.9	0.0	83.7	78.9	4.9
CC-2	39.4	3.5	0.1567	533.4	91.1	47.4	486.0	78.9	454.6	407.2	47.4
CC-3	80.1	1.2	0.2248	1,555.8	98.5	23.3	1,532.5	486.0	1069.7	1046.4	23.3
CC-4	38.8	3.2	0.2693	902.8	91.9	74.5	828.3	1,532.5	0.00	0	0.0
CC-5	36.6	3.1	0.3818	1,207.3	91.4	102.3	1,105.1	1,532.5	0.00	0	0.0
CC-5b	36.4	20.2	0.1800	566.1	44.3	314.2	251.9	0.0	566.1	251.9	314.2
CC-6	104.4	1.6	0.6503	5,865.8	98.5	89.9	5,775.9	1,784.4	4,081.4	3,991.5	89.9
CC-7	36.2	3.1	0.7282	2,277.6	91.5	195.0	2,082.5	5,775.9	0.0	0	0.0

<b>Total Load Reduced=&gt;</b>	5,775.91 kg/day
<b>in the whole watershed</b>	12,707.01 lb/day

**Overall % reduction = 88.6%**

**TMDL = 742.9 kg/day = 271,155 kg/year**

- Existing Concentration (A)** = Estimated from Monte Carlo Simulations as explained in Appendix E
- Allowable Concentration (B)** = Estimated from Monte Carlo Simulations as explained in Appendix E
- Flow (C)** = Average annual flow estimated as explained in Appendix E
- Existing Load (D)** = A x C
- Reduction Identified (E)** = Estimated from Monte Carlo Simulations as explained in Appendix E
- Allowable Load (F)** = B x C
- Total load to be reduced at this station (G)** = D - F
- Total load reduced upstream of this station (H)** = Sum of all upstream load reductions Sum(J<sub>i</sub>,J<sub>i</sub>)
- Remaining Load (I)** = IF H<G, then I = D20-H20 otherwise I = 0
- Additional Reduction needed at this station (J)** = I - F
- Final Load (K)** = D - (H+J), (K should be equal or less than F)

## APPENDIX G

**Analysis of Linear Association Between Flow and Acidity in Cherry Creek**

A Pearson correlation coefficient analysis was performed to measure if there is linear association between the flow and acidity variables that have been measured on different stations in the Youghiogheny River watershed, a watershed located in Garrett County, Western Maryland, the same area where Cherry Creek is located. The data for each station included flow and acidity data for each month for one year (total of twelve samples for each station). The data and the location of the stations are available upon request.

A correlation coefficient is a number between -1 and 1 which measures the degree to which two variables are linearly related. If the variables are directly related, then the coefficient is equal to 1. If the variables are inversely related, the coefficient is equal to -1. A correlation of 0 between two variables means that each variable has no linear relation to the other. The closer the correlation coefficient to 1 or -1, the greater the linear relation between the two variables. The program also calculates the probability (p-value) that the correlation is significant (i.e., that the correlation coefficient is not zero). Typically a p-value of  $<0.10 - 0.05$  is used for a determination of a significant correlation. The results of the analysis are shown below:

**Table G1: Correlation Coefficient for Flow – Acidity in the Youghiogheny River Watershed**

<b>STATION</b>	<b>Flow – Acidity Pearson Correlation Coefficient</b>	<b>Probability that Correlation is Zero<sup>2</sup></b>
900	-0.177	0.54
901	-0.024	0.93
902	-0.469	0.11
903	0.600	0.40
904	-0.359	0.31
905	-0.289	0.34
906	-0.143	0.69
907	-0.282	0.33
908	-0.303	0.39
909	-0.259	0.37
910	0.337	0.24

<sup>2</sup> Significance =  $P \leq 0.10$