

APPENDIX A: Model Development for the Upper Raccoon Creek

The Watershed Loading Model

Introduction

This section describes the methods used in the loading analysis in the Upper Raccoon Creek TMDL. It is intended to be used as a supplement to the TMDL report and relies on the report to provide a description of the study area, project objectives and results. The purpose of this section is to document the steps and decisions made in the modeling process.

Model Approach

There has been a great deal of research conducted on the relationship between alkalinity, acidity and pH. Research published by the Pennsylvania Department of Environmental Protection (see references) demonstrates that by plotting net alkalinity (alkalinity - acidity) versus pH for 794 mine sample points, the resulting pH value from a sample possessing a net alkalinity of zero is approximately equal to 6.0. Where net alkalinity is positive (greater than or equal to zero), the pH range is most commonly 6 to 8, which is within the USEPA's acceptable range of 6 to 9 and meets the Pennsylvania water quality criteria in Chapter 93 (Bureau of Watershed Conservation Pennsylvania Dept. of Environmental Protection, 2001). Ohio EPA did a similar study of net alkalinity vs. pH with its database of 367 samples and achieved similar results (Figure C1 in Appendix C).

pH, a measurement of hydrogen ion acidity presented as a negative logarithm, is not conducive to standard statistics. Additionally, pH does not measure latent acidity. For this reason, and based on the above information, Ohio EPA used the following approach to address the stream impairments noted on the 303(d) list due to pH. The concentration of acidity in a stream is at least partially chemically dependant upon the metals. For this reason, it is extremely difficult to predict the exact pH values that would result from treatment of abandoned mine drainage. Therefore, net alkalinity will be used to evaluate pH in these TMDL calculations. This methodology assures that the standard for pH will be met because net alkalinity is a measure of the reduction of acidity. When acidity in a stream is neutralized or is restored to natural levels, pH will be acceptable. Therefore, the measured instream alkalinity at the point of evaluation in the stream will serve as the goal for reducing total acidity at that point. The methodology that is applied for net alkalinity (and therefore, pH) is the same as that used for other parameters such as iron, aluminum and manganese for which Ohio EPA does not have water quality criteria.

Each sample point used in the analysis of pH & metals by this method must have measurements for total alkalinity and total acidity. Net alkalinity is alkalinity minus acidity, both measured in units of milligrams per liter (mg/l) CaCO₃. By maintaining a net alkaline stream, the pH value will be in the range between 6 and 8. This negates the need to specifically compute the pH value, which for mine waters are not a true reflection of acidity. This method ensures that the standard for pH is met when the acid concentration reduction or net alkalinity target is met (Bureau of Watershed Conservation Pennsylvania Dept. of Environmental Protection, 2001).

Model Data

Data was available from three sources, Ohio EPA, Raccoon Creek Partners (RCPs) (specifically Ohio Department of Natural Resources and Ohio Valley Resource Conservation and Development), Raccoon Creek Acid Mine Drainage Abatement and Treatment (AMDAT) Plan (ILGARD, 2001) and the Water Quality Assessment of the Raccoon Creek Watershed (WQARC) (Hughes et al., 1996).

Ohio EPA data generally contained either acidity or alkalinity values, but not both. Both were needed to calculate the net alkalinity so where net alkalinity was needed Ohio EPA data was excluded and data from the Raccoon Creek Partners (RCP) and WQARC were used. Ohio EPA data was important in certain data analysis where net alkalinity was not used, such as target development for the sites that meet the warmwater habitat use designation. The data and general knowledge from this AMDAT was the basis for this TMDL and its importance for this TMDL cannot be over stated. The RCPs data coverage of the basin from the headwaters to Bolins Mills was thorough. Data was collected on various days throughout the years of 1996, 2000 and 2001.

The AMDAT study area begins at the headwaters of the Raccoon Creek basin in the East and West Branches and ends at Bolins Mills (river mile 80.6). The study area for the TMDL begins in the headwaters as well, however it ends approximately forty miles downstream of Bolins Mills just upstream from the confluence with Little Raccoon Creek (river mile 40.1), near Vinton. There is chemistry data for the TMDL segment beyond the AMDAT study area, however it is Ohio EPA data and excludes either acidity or alkalinity data. The lack of both samples makes it impossible to calculate the net alkalinity. Therefore, the model that was used for the rest of the study can not be used on this last forty miles. As a result, a number of tributaries and some of the mainstem, which are impaired by metals and pH, will not be assessed in this report. They include: Elk Fork, Wolf Run, Austin Powder Tributary, Pierce Run, Rockcamp Run, Indian Run, Karr Run, Opposum Run, Strongs Run, Sugar Run, Williams Run. A preliminary look at the Raccoon Creek mainstem parameters of concern data versus targets for RM 80 to

RM 40 is shown in Table A1. It shows that the majority of the time targets for the parameters of concern are met. A look at the 1995 Raccoon Creek Technical Support Document, from which the 303d list was compiled, shows that the upper half of this unmodeled mainstem segment (RM 80 to ~RM 60) is in good condition with the lower half dropping to fair condition just below Pierce Run. **The next AMDAT plan, which has already begun, does encompass this area. The same methods used to determine remediation in the headwaters of Raccoon Creek by the RCPs will be used in this segment.**

TABLE A1: Statistical Summary below Bolins Mills

Statistical Summary of the Raccoon Creek Mainstem below the Modeled Segment (RM 80 to RM 40)				
Statistics	Iron	Manganese	Aluminum	TDS
	(ug/l)	(ug/l)	(ug/l)	(mg/l)
Count	68	68	68	53
Min	170	435	100	170
Max	4010	5100	3040	513
Mean	596	1170	100	290
Target	1000	2000	750	1500
no. of times target is exceeded	18	16	13	0
% of time target is exceeded	0.26	0.24	0.19	0.00

Model Structure

An Excel spreadsheet was used to calculate existing and post remediation net alkalinity instream concentrations in the Raccoon Creek study area. The major inputs consist of the adjusted site flow, net alkalinity concentration, net alkalinity load and cumulative instream concentration. The net alkalinity load was calculated for each site by multiplying the site net alkalinity concentration by the site discharge. The load was then added to the next downstream site load, then that total added to the next downstream site and so on. In the same manner, the site flows were cumulated. The cumulative loads were then divided by the cumulative flows at each site to determine the “cumulative concentration” at each site. This site cumulative concentration was then compared to the net alkalinity target of 20 mg/l to determine impairments. If the cumulative concentration was less than 20 mg/l, there was an impairment. If it was greater than 20 mg/l, the target was met.

Calibration

Calibration for flow was accomplished by balancing the cumulative flows from tributaries with mainstem or “end of reach” flow measurements. The balancing was done by determining the difference between the cumulative flow and the mainstem flow and assigning that difference to an “unknown” site flow. The same was done for cumulative load. After the cumulative flow was calculated, it was used to determine how much concentration should be assigned to the unknown site in order to balance the cumulative load to the mainstem site load. The unknown site load, added to the cumulative load, would then equal the mainstem or end of reach load. That tributary, stream section, or model segment would then be considered balanced and/or calibrated. See the model example, Appendix F.

Adjusted Site Flow

Ideally, all the chemistry and flow data would be collected at the same time under the same flow conditions, however this was neither practical nor necessary. Because the data used was collected over time, it was collected under various flow conditions. In order for the flow data from various sites to be comparable so that the loads can be added, the site flows needed to be normalized. To do this, a “reference flow site” was created at the very end of the study area, just upstream of the Raccoon Creek and Little Raccoon Creek confluence (**Figure1**). The average daily flow measurement was calculated using USGS gage flow data for every day for which data was collected for the years of 1996, 2000 and 2001. This data is referred to as the reference flow. Two gages were used to calculate the reference site flow, namely gages 03202000 Raccoon Creek at Adamsville, Oh. and 03201980 Little Raccoon Creek near Ewington. Because the Raccoon Creek gage is downstream of Little Raccoon Creek and the reference site is upstream, the Little Raccoon Creek gage data was needed in order to remove that portion of the total flow. The formula to calculate the reference site flow is Raccoon Creek

Upper Raccoon Creek

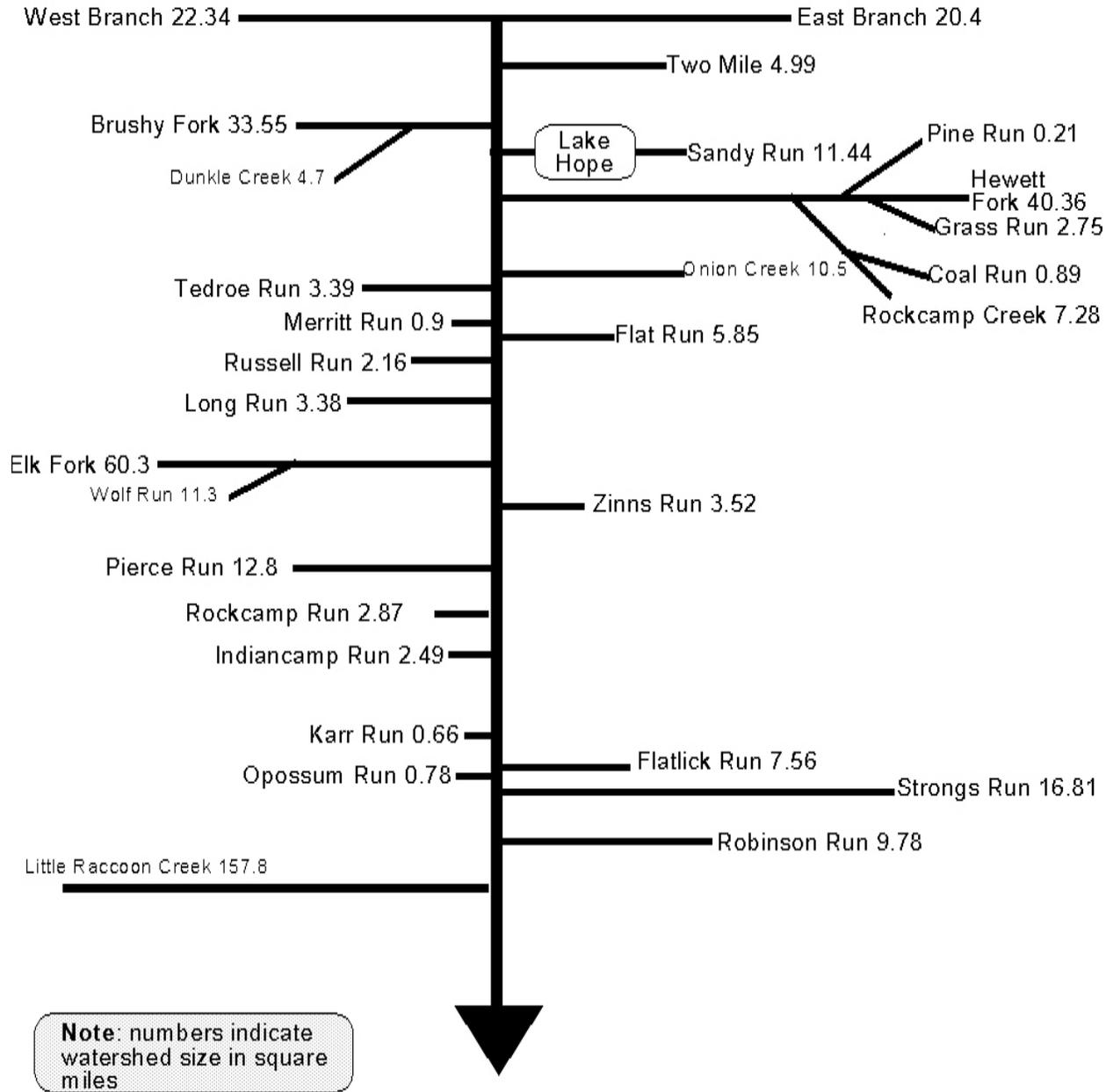


FIGURE1: Schematic representation of Upper Raccoon Creek Watershed

gage flow – Little Raccoon Creek gage flow / 0.643) * 0.898 = reference site flow. Because the Little Raccoon Creek gage is 64.3% down from the headwaters, the gage flow was divided by 0.643 to adjust to the mouth flow. That flow was then subtracted from the Raccoon Creek gage flow then the difference was multiplied by 0.898 to adjust the gage flow to the reference site, which is 89.8% to the gage from the headwaters.

In order to normalize the site flows, a modeling flow had to be selected. The median of the reference flows for all samples used in the model, 36 cfs, was selected as the model flow. With these three values, the site discharge, reference site flow, and the model flow, the site flows could be normalized. For instance, at site EB300 on 8/31/00 the site discharge = .0532 cfs, reference site flow = 24 and model flow = 36. To normalize the site flow: (model flow/reference flow * site discharge flow = adjusted site flow) or $36/24*0.0532 = 0.0798$.

The model flow used for modeling (36 cfs) is not critical, as long as the 300 cfs threshold is not exceeded. The basic assumption is that the site concentrations are unchanged until a threshold of 300 cfs at the reference site is exceeded, at which point the concentrations become more dilute. Net alkalinity concentration is ultimately the important factor because it is the measure that relates to pH and metals. Because the model converts the cumulative load to cumulative concentration the flow is unimportant. The cumulative load is increasing due to the increase in cumulative flow.

Net Alkalinity Concentration and Load

The net alkalinity concentration is calculated by subtracting the alkalinity concentration by the acidity concentration, i.e. alkalinity – acidity = net alkalinity. The net alkalinity load is calculated by multiplying the net alkalinity concentration by the discharge. No conversion is used to bring it to a commonly measured load such as lbs/d or kg/d. The load is simply used as an adding mechanism so that the concentration can be calculated for each site as discussed in the model structure paragraph.

Multiple Samples from Same Sites

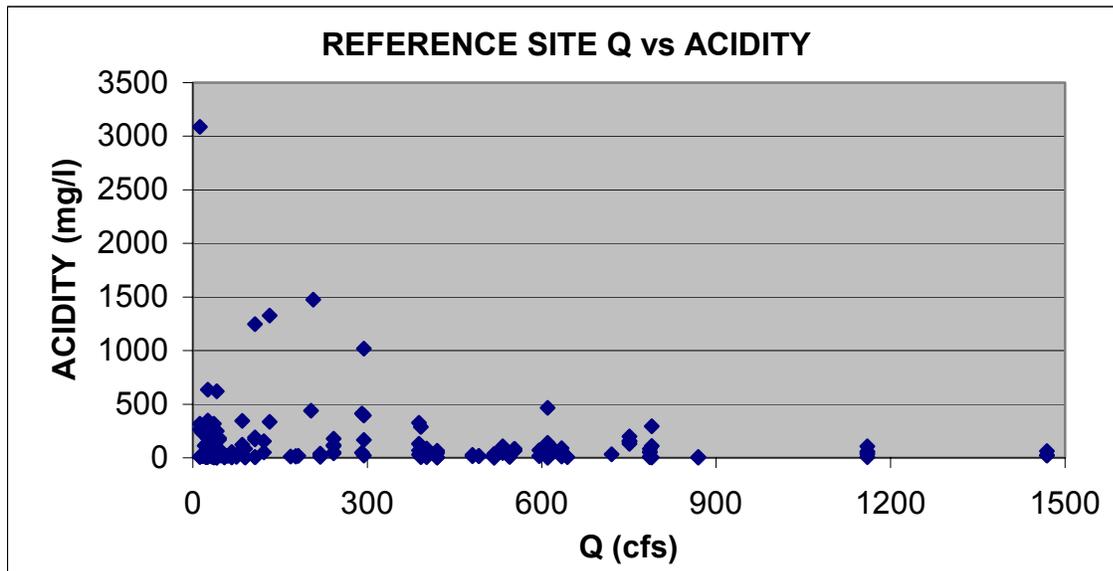
When a single site had more than one sample with accompanying flow, the flow value and the sample concentrations were averaged and that average value for flow and concentration were assigned to that site in the model.

Critical Condition

To determine the critical condition for which to model, certain variables must be known. These variables include the condition and quantity of upstream flow and the condition and quantity of the discharge. In the Raccoon Creek study area, the discharges are the AMD seeps, and due to their pervasiveness, the upstream condition is determined by

the condition of the seeps. Secondly, flow volume was singled out as the variable which could determine the critical condition at which to model. To look at how flow volume could affect the seep concentrations, flow was compared to acidity concentration for all the sites that had flow and acidity values. There were 208 sites. The figure below illustrated reference site (Figure A1). To see how the reference site flow was determined, see the paragraph on adjusted site flow.

FIGURE A1: Reference Site Flow versus Acidity



Model Effectiveness and Advantages

Unknown Flow and Concentrations

With any load based model, the basin flow and accompanying concentration must be known or assumed. The greater the percentage of unaccounted for or unknown flow the greater the potential for model error. For this study, area the amount of unknown/assumed flow and concentration varied from segment to segment. The breakdown is as such: East Br. 47.3%, West Br. 32%, Middle Section Brushy Fork (Brushy Creek in AMDAT) 5.0%, Brushy Fork (Brushy Creek in AMDAT) 51%, Middle Section Lake Hope 8.7%, Hewett Fork 21% and Middle Section Bolins Mills 38%.

The unknown flows and concentrations are accounted for at the end of the each reach. As a result the unknown load occurs all at the end. It was felt that applying it at the end was more appropriate than distributing it evenly throughout the reach since where the loading occurs is unknown and because it was less difficult to account for at the end.

Flow Normalization

In order to be able to compare loads from samples taken on different days under various flow conditions, the flows had to be normalized. To do this a reference site was selected at the most downstream end of the study area and the daily flow was calculated (see the Adjusted Site Flow Section in this Appendix). The relationship between the reference site and the sample sites is assumed to be linear. Both the reference site and sample sites would increase and decrease in the same proportions. Ideally when the flows are normalized, a site where two samples were taken under different flow conditions would result in near equal “site Q adjusted to model Q” flows. Take for instance the two samples taken at site MSBC040. The sample measured on 6/26/00 measured 0.0168 cfs and the reference site measured 35 cfs. The second sample was measured on 10/26/00 and measured 0.0109 cfs and the reference site was 23 cfs. That equates to a sample site flow percent change of –35 and a reference site flow percent change of –34. After normalization, the sites measured 0.0173 cfs and 0.0171 cfs respectively.

Factors that could result in “site Q adjusted to model Q” flows that do not match include: reference site distance from sample sites, localized precipitation, and poor or difficult field flow measurement. For instance, the two samples were taken at site EB220. The sample measured on 8/30/00 measured 0.0418 cfs and the reference site measured 26 cfs. The second sample was measured on 02/06/01 and measured 0.1347 cfs and the reference site was 264 cfs. That is a sample site flow percent change of 222 and a reference site flow percent change of 915. After normalization the sites measured 0.0579 cfs and 0.0184 cfs respectively.

Hewett Fork Basin

Balancing the Hewett Fork flows in the model was particularly challenging. When calibrating the flows, some of the Hewett Fork mainstem sites were skipped. The cumulated tributary flows were not balanced to them due to discrepancies in the total flow. It was noted by the field team leader for the AMDAT that there were difficulties with sampling and measuring flows in this basin for a number of reasons including 1) the upper part of this basin was so heavily mined and landscape reworked that water can change routes under varying flow conditions, 2) streams have been mined through, making accurate flow measurements difficult and 3) sites were very inaccessible making it difficult to get a full coverage of flow measurements in the basin. In order to account

for this in the model, best professional judgment was used to avoid balancing the cumulative flows to mainstem flows that didn't seem to make sense.

Model Advantages

The model used in this study is very simple compared to some used in other AMD streams, which attempt to directly calculate the instream chemical changes in metal or acid concentrations. These models tend to be black boxes with much weight placed on assumptions. The spreadsheet model approach used in this TMDL, takes advantage of the large body of available data and the intimate knowledge of the problems in the Raccoon Creeks by the Raccoon Creek Partners. The result is an easy to grasp scientifically sound assessment of the acidity problem with tangible plans to correct existing problems. The model that demonstrates that the anticipated implementation plan will result in enough of a reduction in the problem parameters to allow Raccoon Creek to harbor a robust biological community.