APPROACH TO THE PROBLEM

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Scope of this Investigation

As the goal of this undertaking is to identify changes in the quality and quantity of acid mine drainage discharging to the Casselman River from SMC, we shall confine our investigation to the three points of mine discharge to the River, namely Coal Run (Station 13), Weir 11 (Station 11) and Shaw Mines Run (Station 3), as well as the upstream and downstream sampling points on the Casselman, Stations 6 and 7, respectively. The two streams which are AMD-input sources, Shaw Mines Run and Coal Run, each represent the total flow of many smaller discharges, many of which have been monitored individually as described earlier. However, it is beyond the scope of this report to attempt to analyze this larger volume of data.

In our earliest reviews of the data, it quickly became evident that the Casselman River stations, 6 and 7, were the least useful because of the absence of flow measurements, precluding calculation of chemical loads, and the very small magnitude of variability in the concentrating of mine drainage indicators, i.e., acidity, iron, and sulfate. We concluded that a more detailed analysis of the three individual AMD-contributors, Station 13, 11 and 3, and the sum of their AMD loads would provide the most accurate assessment of mine drainage impact from SMC on the Casselman.

Data Analysis

For each of the five monitoring stations, 3, 6, 7, 11 and 13, we analyzed the variability through time of concentrations and loads of acidity, total iron and sulfate, and flows. After expanding the basic data files to include the chemical loads, we used the statistical software package "BMDP"[1]

[1]Dixon, W.J. and M.B. Brown, 1981, BMDP Statistical Software. 1981 ed., University of California Press, Berkeley, CA, 726 pp.

programs available at the Penn State University Computation Center. These programs offer a variety of graphical and statistical routines.

Program BMDP-2D can quickly generate the descriptions of a sample group, i.e., mean, median, mode, standard deviation, variance, maximum, minimum and sample size. The accompanying histograms show the frequency and magnitude of the individual observations within a sample group, and provide a graphical description of the data distribution.

To provide graphical illustrations of the trends of concentration and loads through time, we utilized BMDP-6D "Bivariate (Scatter) Plots." These are adequate for describing general trends, but we found them to be most useful in demonstrating the complexity and variability of the observations through time, and the inherent difficulty in attempting to analyze the data graphically. We also produced CalComp[1] plots in three colors of acid, iron and sulfate concentrations through time for Stations 3, 11 and 13.

The next level of analysis utilizes BMDP-7D for multiple comparisons of several sample groups. In our application, we subdivided concentrations, loads and flows into several smaller time groups, based primarily on sampling frequency. For example, Shaw Mines Run Station 3 data starts with July 1967, and we created five time groups: 1967-68, 1969-71, 1972-73, 1974-79, and 1980-83. Each group is statistically described, histograms plotted, then the groups are compared to identify statistically significant differences. The first level of differentiation between time groups is done by calculating an "F-ratio," which compares "between-group" variance to "within-group" variance. High F-ratios with probability values below 0.05 indicate that at least two of the groups are significantly different from each other. The second and more powerful test is to compare two groups at a time, calculate

[1]California Computer Products, Inc.

a "t" statistic, then check for significant differences; all possible pairs of time groups are compared this way.

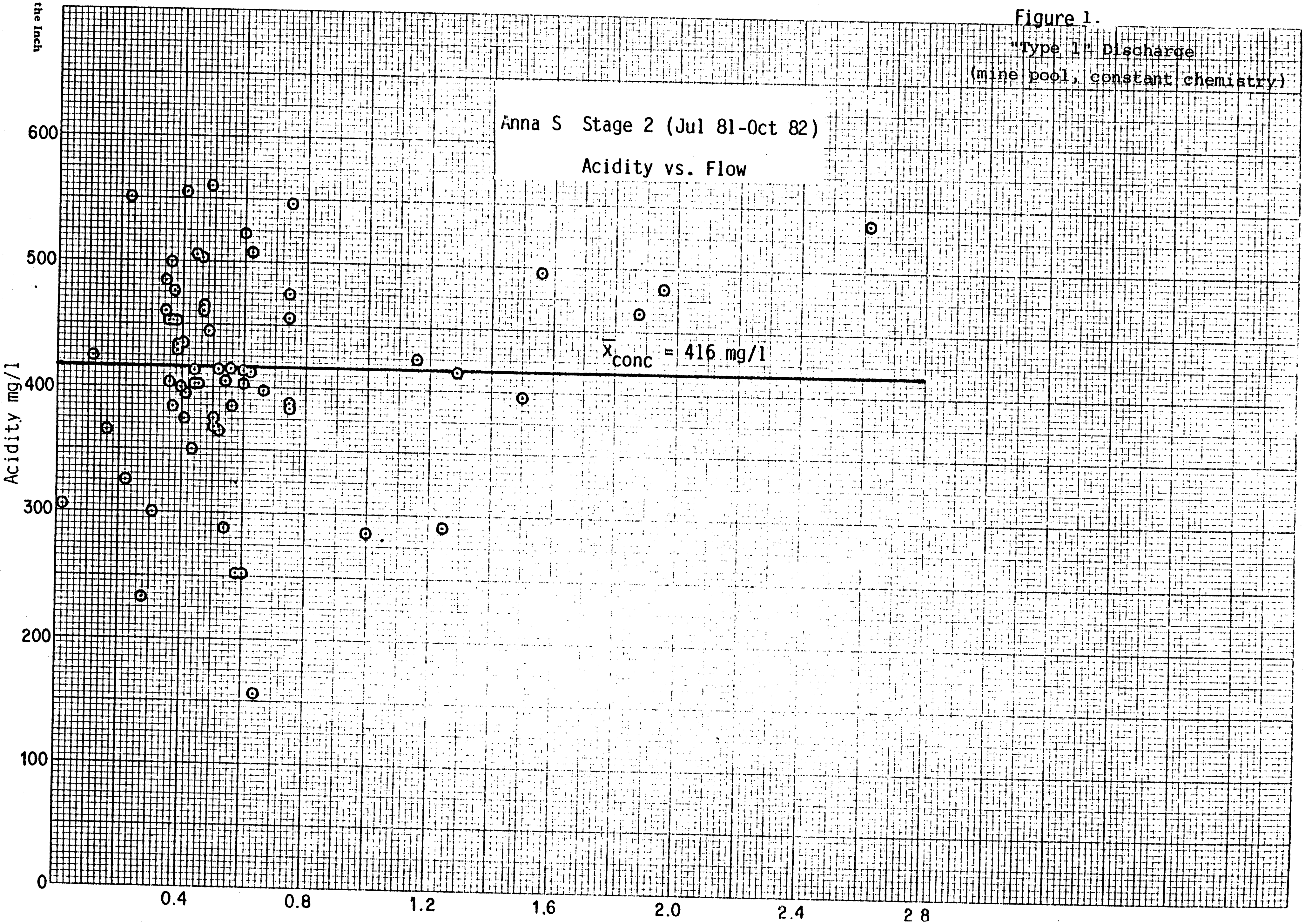
The last type of analysis we performed was to check for relationships between acid concentrations and corresponding flows. This can be a useful technique for distinguishing different "episodes" of mining history. We have seen that some discharges from deep mines with large mine pools and long detention times show little to no correlation between acid concentration and flow. We classify such discharges as "Type 1," and find that acid concentrations tend to vary uniformly about the mean over the full range in flows. See example in Figure 1. Discharges from deep mines without a mine pool, where travel time is faster and flow response to precipitation is rapid, frequently show acid concentration (C) to be inversely proportional to the logarithm of flows (Q), or $C = f(1/\log Q)$. For such "Type 2" discharges we have been able to identify the equations of the curves which describe the relationships of concentration and flow (Figure 2). Once the curve for a particular time period is defined, one can predict concentrations for various flows and compare different episodes of mining.

<u>Interpretations of Analyses</u>

Aside from graphical plots of trends and histograms, which may or may not be clear in their significance, we have relied on statistical tests to provide valid comparisons of sample groups to identify changes in water quality. An understanding of the nature of the <u>distribution</u> of the various sample populations is critical.

With rare exception, stream <u>flows</u> are <u>log</u> <u>normal</u> in their distribution because of the wide range (one to two orders of magnitude) in discharge values related to extreme high flood flows and very low drought flows. Such

Figure 1.
"Type 1" Discharge
(mine pool, constant chemistry)



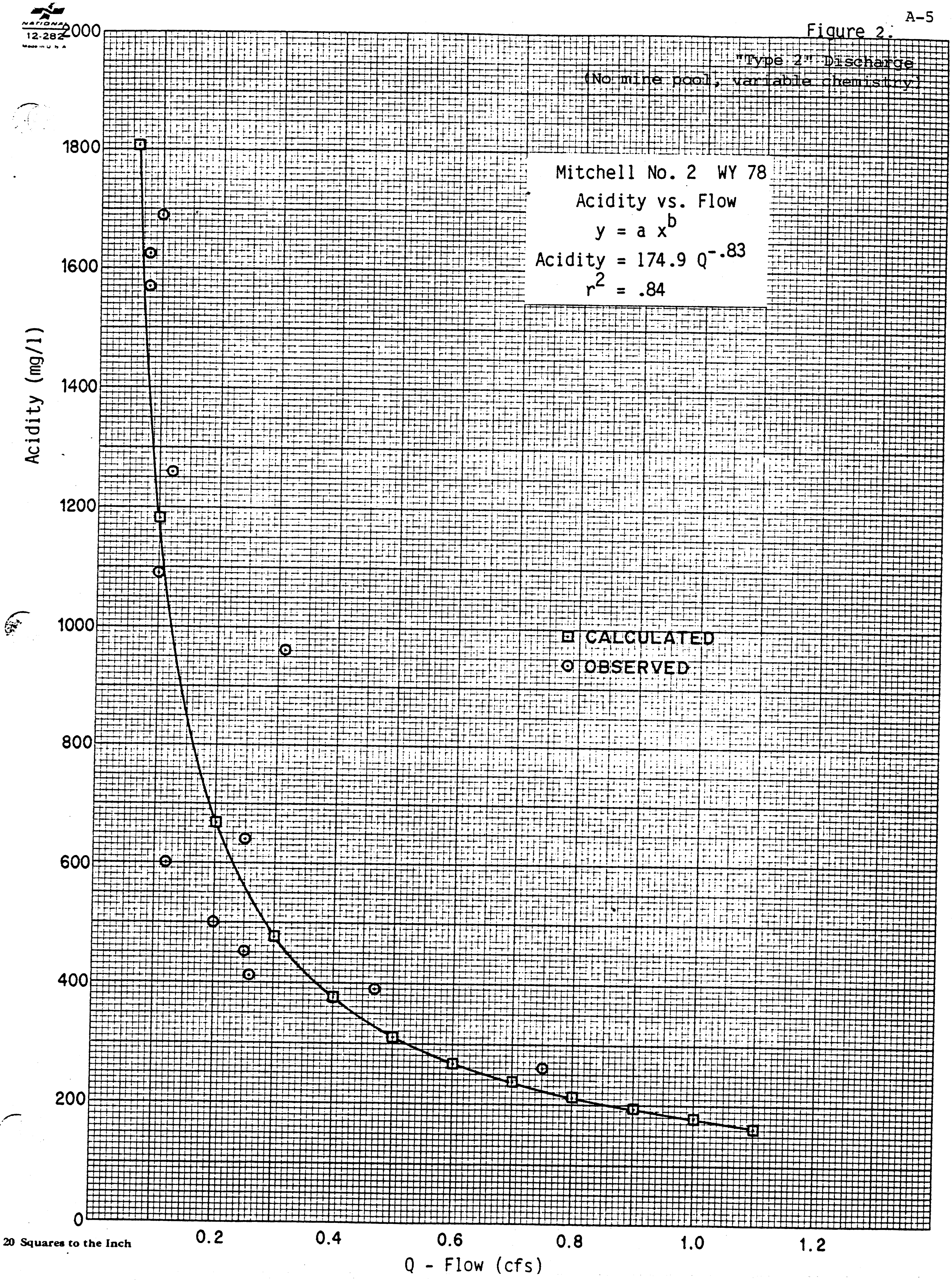


Figure 2.
"Type 2" Discharge
(No mine pool, variable chemistry)
Mitchell No. 2 WY 78
Acidity vs. Flow
y = a x^b
Acidity = 174.9 Q^-.83
r^2 = .84
CALCULATED
OBSERVED
Acidity (mg/l)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0.2
0.4
0.6
0.8
1.0
1.2
Q - Flow (cfs)
NATIONAL
12-282
20 Squares to the Inch

distributions are characteristically skewed, and require log transformation to produce normal distributions for valid statistical comparison.

Concentrations of acidity, iron and sulfate in mine drainage most frequently show a normal distribution centered uniformly about the mean, especially in "Type 1" discharges (mine pool, constant chemistry). Because concentration is a function of the log of flows in "Type 2" discharges (no mine pool, varied chemistry), then concentrations are simply log-transformed flows and must therefore be normally distributed.

Loads calculated as the products of concentration and flow inherit the log normal distribution of the flows; logarithmic transformation of the load data is therefore necessary for valid statistical analysis. This point is extremely important for comparison of average loads which are often the "bottom line" indicators in mine drainage. A graphical comparison of histograms of load data with log-transformed loads quickly proves the log normal nature of load distributions. The highly varying means and enormous standard deviations calculated for chemical load data further confirms the need for log transformation of loads.