To the Graduate Council:

I am submitting herewith a thesis written by Lawrence M. Brede entitled "Characterization and Analysis of Selected Water Quality Parameters of the Clinch and Powell River Basins in Northeast Tennessee". I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Environmental Engineering.

P.E.

Dr. Bruce A. Tschantz, Major Professor

We have read this thesis and recommend its acceptance:

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Accepted for the Council:

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CHARACTERIZATION AND ANALYSIS OF
SELECTED WATER QUALITY PARAMETERS
OF THE
CLINCH AND POWELL RIVER BASINS
IN
NORTHEAST TENNESSEE

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Lawrence M. Brede

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Dedicated to the "Oh the Monkey" Choir

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I would like to thank my wife, Sarah, for the unconditional support she has given to me during the course of this research. She always has a reassuring word, a great attitude, and a cold beer when the stress level rises.

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ABSTRACT

The United States Geological Survey, in cooperation with the Tennessee State Planning Office, conducted a four year water quality study in the Clinch and Powell River basins in northeast Tennessee. An intermittent sampling program was conducted from June 1989 through May 1993. Water quality constituents were determined for two sites on each river, an upstream site near the Tennessee/Virginia state line and a downstream site prior to entering the backwater of Norris Lake.

Fecal bacteria were above the regulatory limits on both upstream sites for 13 out of 37 samples. These bacteria counts were reduced through dilution and short life expectancy prior to reaching the downstream sites, which only exceeded regulatory limits for 2 out of 32 samples.

Individual nutrient measurements of nitrogen and phosphorus compounds were found consistent with natural surface water levels throughout the entire study period. Nutrient loads were attempted to fit a regression function of water discharge and seasonal effects. However, the error obtained with this method was excessively large (82% error on average), and the technique was determined to be unacceptable.

Sediment discharge was found to be a function of water discharge, a rainfall factor, and seasonal effects at the four study sites. Annual sediment loads were estimated for each

river as 105 tons/mi^2/year on the Clinch River and 175 tons/mi^2/year on the Powell River. These estimates contain an average 17.5 percent range of error.

The major ionic composition of the rivers (calcium, magnesium, sodium, potassium, sulfate, chloride, silica, and fluoride) is an indication of the geology under the basin. All levels of these ionic species determined in the study were found to be consistent with a carbonate system. No values were measured in excess of regulatory limits.

During the study period, measured concentrations of 2 trace constituents exceeded regulatory limits at the upstream sites. Total iron concentrations exceeded the aquatic life standard for 18 of 23 samples at the Clinch River near Looney's Gap, for 36 of 38 samples at the Powell River at Alanthus Hill, for 2 of 3 samples at the Clinch River above Tazewell, and for 1 of 2 samples at the Powell River above Arthur. Total manganese concentrations exceeded the aquatic life standard for 16 of 23 samples at the Clinch River near Looney's Gap, for 35 of 38 samples at the Powell River at Alanthus Hill, for 2 of 3 samples at the Clinch River above Tazewell, and 1 of 2 samples at the Powell River above Arthur. Total copper concentration exceeded aquatic life standards for 1 of 2 samples at Powell River above Arthur.

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CONVERSION TABLE

For readers who prefer the International System (metric) to inch-pound units, the following conversion factors are provided:

Multiply these units	By	To obtain
inch (in)	25.4	millimeter
foot (ft)	.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
cubic feet (ft^3)	.0283	cubic meter
gallon (gal)	3.785	liter
pound (lb)	.4536	kilogram

Temperature conversion between fahrenheit and centigrade is calculated utilizing the following conversion:

$$^{\circ}C = (^{\circ}F - 32)/1.8$$

$$^{\circ}F = 9/5(^{\circ}C) + 32$$

CHAPTER 1

INTRODUCTION

A. General

From June 1989 through December 1993 the U.S. Geological Survey (USGS), in cooperation with the Tennessee State Planning Office, conducted a water quality study in the Clinch and Powell River Basins. Sampling was done at two stations near the Tennessee-Virginia state line and at two stations upstream from Norris Lake backwater. This report presents a summary of the water quality data and potential water quality problems, estimates of annual loads for selected constituents, and a comparison of land use and water quality.

B. Purpose and Scope

The purpose of the study included identification of potential water quality problems and estimation of selected annual loadings on both study rivers in northeast Tennessee. To accomplish this task four sites were activated, two located in each basin. The Clinch River basin sites included the Clinch River near Looney's Gap, Tennessee near the Tennessee-Virginia state line and the Clinch River above Tazewell, Tennessee at a point prior to the backwater of Norris Lake. The Powell River basin sites included the Powell River at Alanthus Hill, Tennessee near the Tennessee-Virginia state line and the Powell River above Arthur, Tennessee upstream of the backwater of Norris Lake (fig. 1, table 1).

Sampled water quality parameters included bacteria, nutrients, sediment, major ionic composition, and selected trace constituents. Sampling intensity varied over the study period due to differing annual study requirements. Both storm flow, defined as flow sampled over a storm hydrograph, and low/medium flow, defined as flow sampled more than 72 hours after a precipitation event, were measured (table 2).

Study objectives included development of easily applied equations to predict storm loading of both suspended sediment and nutrients, and development of relationships between easily measured parameters and other constituents for quick estimation. Also, definition of land use impacts and seasonal effects on water quality was desired as well as annual sediment and nutrient loading estimates.

The study involved four years of sampling, from June 1989 through February 1994, with varying levels of intermittent and intensive sampling. Numerous flow conditions from the 99 percent chance flow duration through the 0.5 percent chance flow duration were sampled.

C. Analysis Background

The techniques used to analyze the data in this report are standard procedures used by the United States Geological Survey for water quality analysis in surface waters. However, these procedures have not been previously applied to either

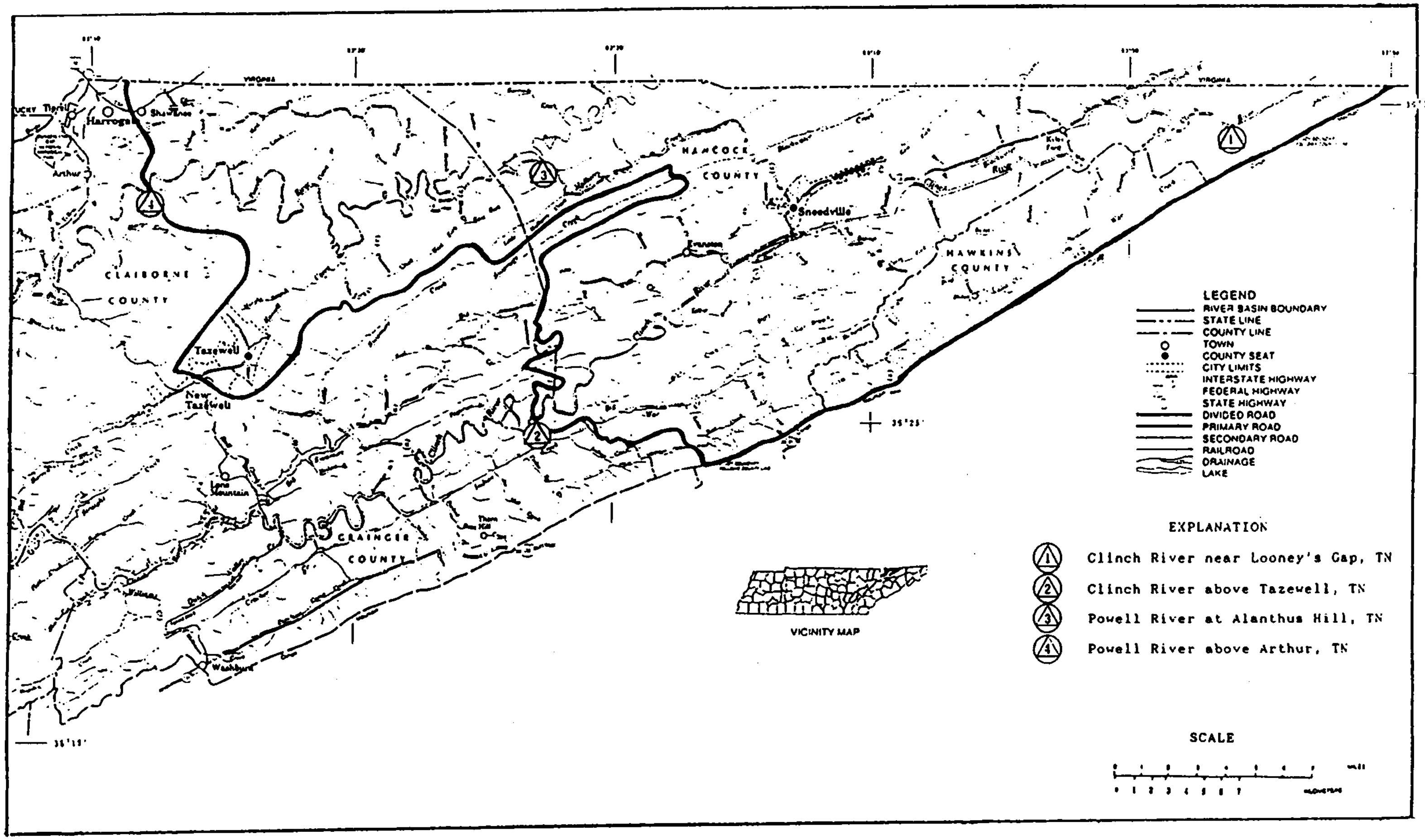

Figure 1.--Location of surface water stations in Tennessee portion of Clinch River and Powell River Basins

Table 1.--Station location details of the four water quality sampling sites located in the Tennessee part of the Clinch River and Powell River Basins

Station number	Latitude	Longitude	Drainage area in square miles	Site name
03527220	36°34'22"	82°56'20"	1,154	Clinch River nearLooney's Gap, Tennessee
03528000	36°25'30"	83°23'54"	1,474	Clinch River above Tazewell, Tennessee
03531680	36°33'23"	83°22'47"	510	Powell River at Alanthus Hill, Tennessee
03532000	36°32'30"	83°37'49"	685	Powell River aboveArthur, Tennessee

Table 2.--Water quality sampling by type and date for the four sites in the Clinch River and Powell River basins

Clinch River near Looney's Gap, Tennessee

Storm Samples:	16-18 September 1989
	10-12 February 1990
	19-20 December 1990
	14-15 February 1991
	29 March - 2 April 1991
	19-21 May 1993
Low/Medium Flow Samples:	17 June 1989
	18 July 1989
	22 August 1989
	22 September 1989
	16 October 1989
	15 November 1989
	04 December 1989
	10 January 1990
	28 February 1990
	03 December 1990
	26 June 1991
	22 October 1991
	17 December 1991

Powell River at Alanthus Hill, Tennessee

Storm Samples:	16-18 September 1989
	10-13 February 1990
	05-07 May 1990
	07-09 January 1991
	18-22 February 1991
	22-24 November 1991
	01-06 December 1991
Low/Medium Flow Samples:	19 July 1989
	24 August 1989
	29 September 1989
	17 October 1989
	16 November 1989
	06 December 1989
	07 January 1990
	11 January 1990
	01 March 1990
	25 June 1991
	23 October 1991
	18 December 1991

Clinch River above Tazewell, Tennessee

Storm Samples:	17-19 June 1989
	18-19 September 1989
	10-13 February 1990
	05-07 May 1990
Low/Medium Flow Samples:	08 June 1989
	21 July 1989
	23 August 1989
	14 September 1989
	27 September 1989
	04 October 1989
	18 October 1989
	07 November 1989
	14 November 1989
	07 December 1989
	12 January 1990
	23 January 1990
	27 February 1990
	23 May 1990
	27 July 1990
	08 November 1990
	07 March 1991
	13 November 1991
	04 August 1992
	15 September 1992
	08 October 1992

Powell River above Arthur, Tennessee

Storm Samples:	07-08 June 1989
	15-19 June 1989
	17-19 September 1989
	16-18 November 1989
	10-13 February 1990
	05-07 May 1990
Low/Medium Flow Samples:	20 July 1989
	25 August 1989
	28 September 1989
	19 October 1989
	13 November 1989
	05 December 1989
	09 January 1990
	23 February 1990

the Clinch River Basin or the Powell River Basin.

Additionally, the use of a rainfall factor in determining river suspended sediment load is a unique approach to this research. While the concept has been applied to other techniques in the past, the inclusion into the Geological Survey's technique is new.

CHAPTER 2

LITERATURE REVIEW

A. History of Clinch and Powell River Basin Research

The importance of the Clinch and Powell River Basins as a source of numerous beneficial resources has been understood for many years. The first study aimed at specifically determining the extent and value of these resources was conducted by the Tennessee State Planning Office as part of a statewide research project in 1934 (Lucas, 1936). However, this report was very broad-based and gave only general overviews of the types of problems which existed in the basins. No in-depth research was conducted.

The Clinch and Powell River Association was chartered in 1960 with three objectives: (1) To plan, promote, and sustain a program for full development of the land and water resources of the Clinch River, its valleys, and tributaries; (2) to achieve interest and support of public development of water and energy resources throughout Tennessee Valley; and (3) to engage in investigation, studies, planning, reporting, dissemination of information about the Association's program (Tennessee Valley Authority, 1963). With this council came the first intensive study of the study basins. However, while this study intensely analyzed the mineral and water resources in the basins, it did not focus on the potential pollution caused by the interaction of the two resources (Tennessee

Valley Authority, 1963). Pollution was not considered a harmful problem during this time when resources were considered more limitless.

In 1974 the United States Congress mandated national goals of "swimmable and fishable waters" by 1983, thereby forcing the State of Tennessee to develop a management plan. The Statewide 208 Water Quality Management Plan was enacted in 1976, and the Clinch River Basin was a primary study area (Tennessee Department of Public Health, 1978). The published Water Quality Management Plan was the first analysis of the water quality in the river basin as well as the land use impacts on the water quality. Though these impacts were not modeled, definable limits were set for both water in the river and discharges into the river.

The impacts of coal mining in the entire region were studied and summarized in 1980. The Clinch and Powell River Basins in the study area were a part of this project and were analyzed closely at this time (Hufschmidt, 1981). Water quality problems were identified and attributed to most probable causes including coal-mining and agricultural effects.

Recent years have seen a focus on land use impacts in the basins with emphasis on nonpoint source pollution problems (Sagona, 1991 and U.S. Department of Agriculture, 1992). These studies have all focused on total annual load estimation without consideration of individual storm loading. Impacts are defined by generalized overall estimations.

B. Related Studies

The methodology of utilizing regression analysis for describing basin flow is common in the United States Geological Survey (USGS). The initial study using regression in an area similar to the Clinch and Powell River Basins was conducted in the New River and Clear Fork Basins in a water quality study published in 1980 (Parker and Carey, 1980). Though limited in scope, the study provided the first real application of the methodology in this geographic region.

However, one of the seven initial study sites of the USGS' National Water Quality Assessment (NAWQA) is the Kentucky River Basin, which contains very similar conditions as the study basin (Smoot and others, 1991). Numerous trace constituents and nutrients were found to relate to discharge, season of the year, and a trend factor accounting for the time each constituent was sampled during the study. The regression model was determined to be a legitimate approach to defining these relationships.

C. Water Quality Trend Determination

Water quality of separate constituents can be estimated using a number of techniques. These constituents include all facets of water quality parameters including ions, metals, bacteria, and sediment.

1. Scatterplots

Scatterplots are a simple tool utilized to visually depict the relationship between two variables. Trends are graphically displayed and easily understood from a two-dimensional representation. Additionally, extreme values, intervariable dependency, and long term changes can be depicted (Schlotzhauer, 1991).

Noise in a scatter plot is defined as the variability between points. Different techniques are utilized to smooth this variation into a single trend. The most common is the average, or mean, method. This technique assumes variability is due to a smooth component (trend) plus a random error (Ott, 1993). Smoothing the scatterplot identifies this trend component by damping out the random error.

Another method used to dampen error and identify the trend in a scatterplot is Locally Weighted Scatterplot Smoothing (LOWESS). This method uses a weighted regression which minimizes effects by limited outliers. It fits the center distribution without predetermined bias towards shape of the distribution (Crawford, 1983).

2. Boxplots

The boxplot is a simple method which visually displays a distribution's symmetry, skew, median, and outliers (Tukey, 1977). A normal distribution is represented with a perfectly symmetrical boxplot, while a distribution with more inherent skew is represented with a more uneven boxplot. A boxplot is an effective method of showing the body of the distribution without giving special weight to outliers. The positive identification of outliers may reveal points that require special attention.

Because boxplots show the distribution of a single variable, they are an effective means of comparing the variation in that variable between different sites. They are an accurate method of comparing sites even when the amount of data between sites varies greatly (Tukey, 1977).

3. Piper Diagram

A Piper diagram is a trilinear diagram which represents percentages of cations and anions as a single point (Freeze and Cherry, 1979). Therefore waters which contain completely different total ionic composition concentrations can be visually inspected and compared with an easily read diagram. Similar types of waters are easily discernable from those less similar, and an individual graph can accommodate a large number of data (Hem, 1992).

4. t-Test

A common method of comparing two independent samples is the two-sample t-test. The t-test checks the hypothesis that either the means for the two groups are equal (H_0, null) or they are not equal (H_1, alternate). There are three assumptions in this test: (1) the observations are independent, (2) the observations are representative of a normally distributed group, and (3) the variances of the groups are equal (Schlotzhauer, 1991).

The test statistic is defined as:

$$t = (y_1 - y_2)/[s_p/(1/n_1 + 1/n_2)]$$

where: t = test statistic

y_1 = mean of group 1

y_2 = mean of group 2

s_p = average of the two sampling standard deviations

n_1 = population of group 1

n_2 = population of group 2

and s_p is derived from:

$$s_p^2 = [(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2]/(n_1 + n_2 - 2)$$

where: s_p^2 = pooled variance

s_1^2 = variance of group 1

s_2^2 = variance of group 2

(n_1+n_2-2)= degrees of freedom

The two-sample t-test can be utilized when comparing two groups with similar, non-skewed distributions or two groups with equal sample sizes. In a regression model, this t-test can be used to determine if an individual independent variable is a significant contributing variable to the dependent variable (Younger, 1993).

5. f-Test

The f-test statistic checks that either the model explains no variation in the dependent variable (H_0, null hypothesis) or that the model explains some variation in the dependent variable (H_1, alternate hypothesis). Therefore, the larger the f value, the stronger the evidence to reject H_0.

The f-test statistic is defined (Ott, 1991) as:

$$f = MS_{lack}/MS_{exp}$$

where: f = test statistic

MS_{lack} = mean squares due to lack of fit

MS_{exp} = mean squares due to pure experimental error

The f-test statistic can be utilized to determine if a regression model accurately describes a system (Younger, 1993 and Schlotzhauer, 1991).

6. Linear Regression

Linear regression is the relationship between a dependent variable and independent variable for time series data (Ott, 1991). This method is a deterministic model because there is only a single predicted value for the dependent variable for any one given independent variable. After the predicted line is fit to the data set, a p-value is calculated to determine if the slope is significant.

Additionally, the variance in the dependent variable that is described by the independent variable is called the coefficient of determination, or R^2. A "perfect" fit between two variables would result in an R^2 of 1.00, while two completely unrelated variables would have a coefficient of determination approaching zero.

7. Multiple Regression

Multiple regression utilizes the same theory as linear regression except the dependent variable is described with two or more independent variables. The system therefore becomes multi-dimensional (Ott, 1991).

However, the tests described previously can still be utilized to understand the interrelationship of the variables. A t-test on each individual independent variable checks the relevance of that variable to the dependent variable while an f-test on the whole system describes the fit of the model (Younger, 1993 and Schlotzhauer, 1991).

The use of multiple regression to describe water quality constituent activity has greatly increased since the initiation of the National Water Quality Assessment Program by the U.S. Geological Survey in 1986. Constituents are typically related to discharge, season, and a trend factor (Smoot and others, 1991).

8. Seasonal Kendall Analysis

The seasonal Kendall analysis is a statistical technique capable of analyzing time-series data for upward or downward trend while accounting for seasonal variation effects (Zipper, 1992). The null hypothesis in this test is that the probability distribution of the random variable does not change over time. The test compares all possible pairs of data. If a temporally later value is higher than the first value, a plus is recorded, if the later value is lower a minus is recorded. If there is no trend in the data the number of pluses should approximately equal the number of minuses. However, if the number of pluses greatly exceeds the number of minuses, an upward trend is indicated. Likewise, if the number of minuses greatly exceeds the number of pluses, a downward trend is indicated (Crawford, 1983).

The seasonal Kendall slope estimator is used to measure the magnitude of the trend. This method has a greater precision than regression if the data are log-normally distributed, but a lesser precision if the data are normal. This analysis helps verify that the trends are the result of changes in the variables rather than just variation in the sequence of how these variables are presented (Hirsch, 1981).

9. General Suspended Sediment Formulas

Techniques to define suspended sediment loading in natural waters originated with Dupuit's physical model in 1865 (Graf, 1984). Currently there are four primary formulas utilized to determine these loads. The formulas are described as follows as the Einstein Method, the Lane Method, the Toffaletti Method, and the Hydrologic Engineering Center Scour and Deposition in Rivers and Reservoirs computer program (HEC-6).

a. Einstein Method

The Einstein method is the most intensive and difficult method to apply to suspended sediment estimation. The baseline equation (Einstein, 1950) is:

$$g_{ss} = 11.6C_a u'_* a[2.303\log(30.2D/\triangle)I_1 + I_2]$$

where g_{ss} = suspended sediment load per unit time per unit width

C_a = reference concentration

u'_* = turbulent shear factor

a = particle radius

D = flow depth

$\triangle$ = corrective value

I_1 = integral value (figure 2)

I_2 = integral value (figure 3)

The primary benefit of Einstein's application is the in-depth accounting for the numerous characteristics of the site including width and depth of the stream, particle characteristics, and flow characteristics. The disadvantages of the process lie in the accurate estimation of the parameters, properly reading and interpreting table values for these constituents (such as the I values), and problems associated with applying a difficult equation to find a solution such as potential for calculation error and misuse of the formula.

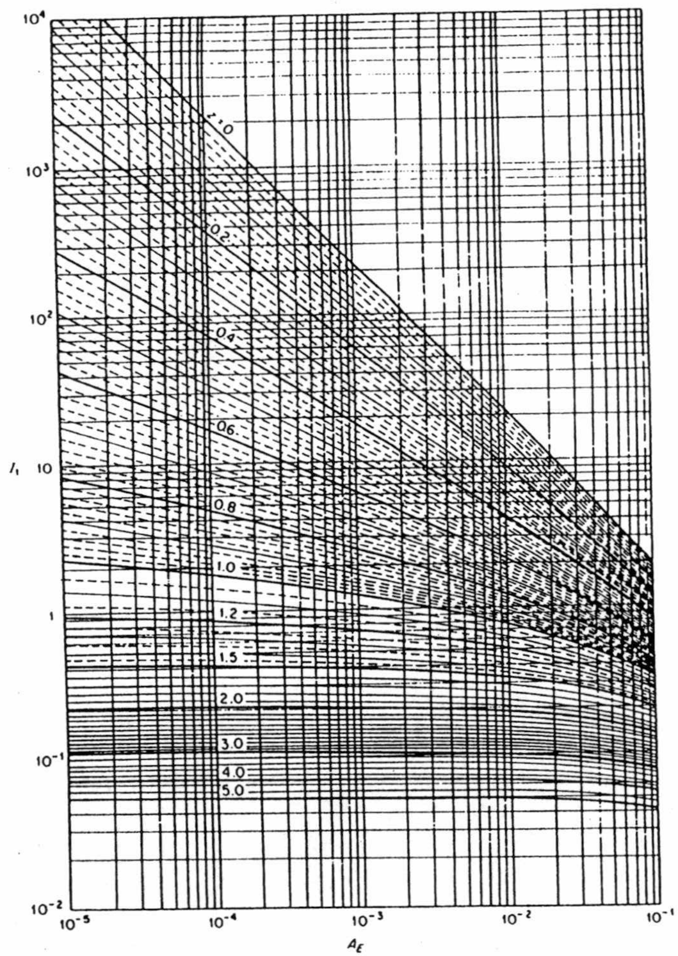

Figure 2.--Function I_1 in terms of A_E for values of z

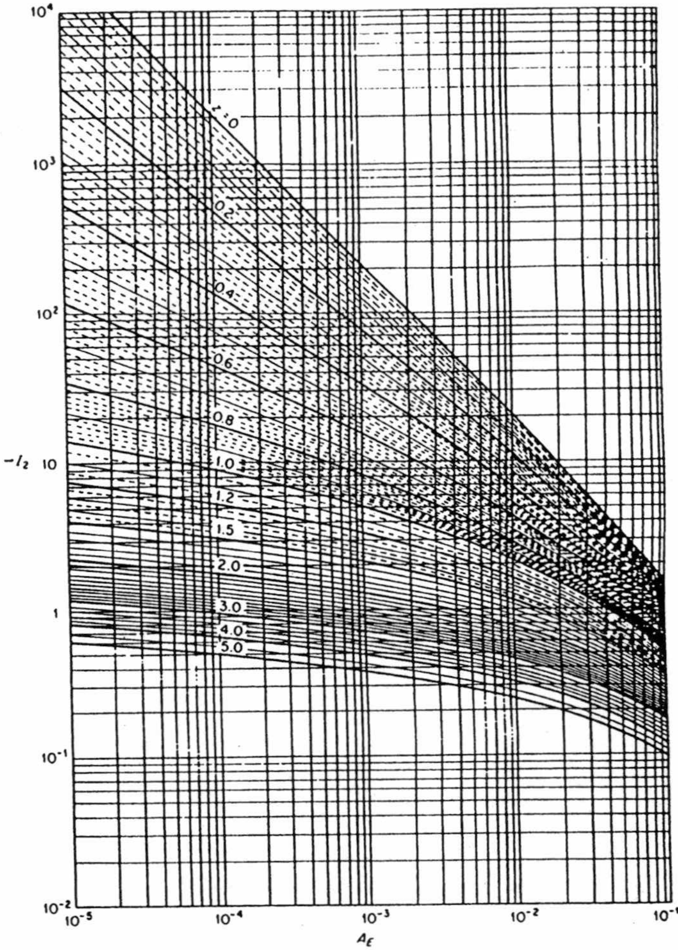

Figure 3.--Function I_2 in terms of A_E for values of z

b. Lane Method

The Lane solution is slightly easier to apply. The general form of the equation (Lane, 1949) is:

$$g_{ss} = qC_aP_Le^{(15Vssa)/(Du*)}$$

where g_{ss} = suspended sediment load per unit time per unit width

q = discharge in volume per unit time per unit width

C_a = reference concentration

P_L = function of V_{ss}/u_* (fig. 4)

V_{ss} = settling velocity of particle

a = particle radius

D = depth of flow

u_* = shear velocity

Like the Einstein equation, the Lane method accounts for streamflow characteristics, particle characteristics, and site characteristics. The disadvantages fall along the same areas as well, including estimation of numerous values, graph interpretation, and potential difficulties in solution application.

c. Toffaletti Method

The Toffaletti method is a set of empirical formulas that assumes sediment is carried in four zones in the stream (American Society of Civil Engineers, 1984). The zones are divided into three which carry the suspended load, the upper, middle, and lower, and the bed zone which carries the bed load.

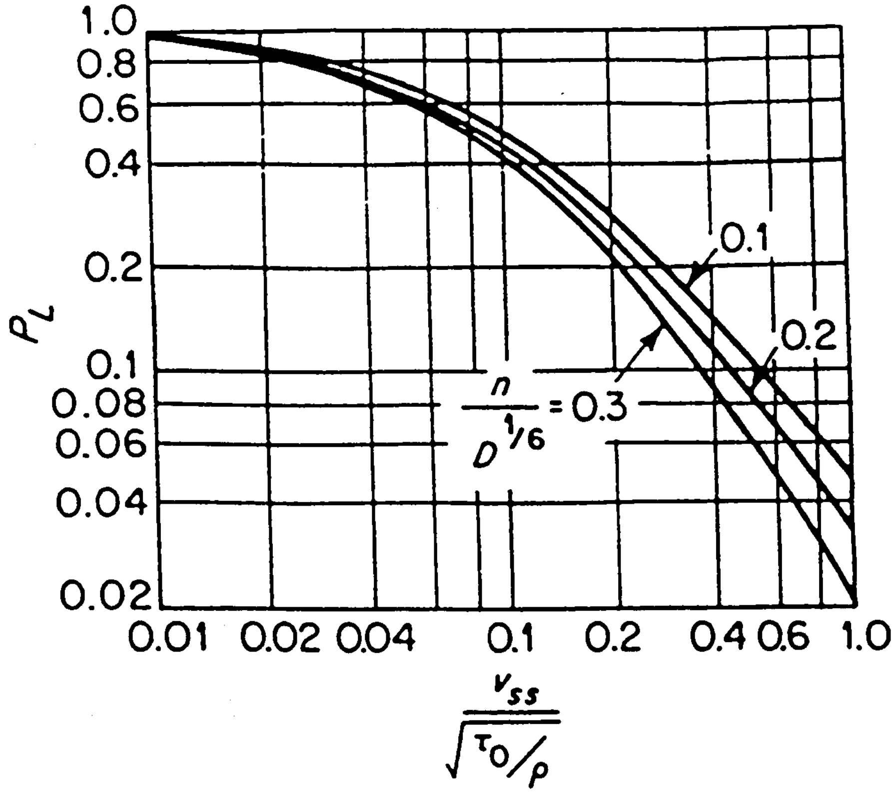

Figure 4.--Lane's relationship of the factor P_L

The suspended load can be solved through manipulation of the following series of equations:

$$g_{ssi} = g_{ssLi} + g_{ssMi} + g_{ssUi}$$

$$g_{ssli} = \frac{0.6p_i}{(T_T A k_4/V^2)^{5/3}(d_{si}/0.00058)^{5/3}} \text{ (tons/day/ft)}$$

$$T_T = 1.10(0.051 + 0.00009T)$$

$$g_{ssli} = M_i \frac{(r/11.24)^{1+nv-0.758zi} - (2d_{si})^{1+nv-0.756zi}}{1 + n_v - 0.756z_i}$$

$$g_{ssmi} = M_i \frac{(r/11.24)^{0.244zi}[(r/2.5)^{1+nv-zi} - (r/11.24)^{1+nv-zi}]}{1 + n_v - z_i}$$

$$g_{ssui} = M_i \frac{(r/11.24)^{0.244zi}(r/2.5)^{0.5zi}[r^{1+nv-1.5zi} - (r/2.5)^{1+nv-1.5zi}]}{1 + n_v - 1.5z_i}$$

$$M_i = 43.2p_i C_{Li}(1 + n_v)Vr^{0.758zi-nv}$$

$$n_v = 0.1198 + 0.00048T$$

$$z_i = (w_i V/c_z rS)$$

$$c_z = 260.67 - 0.667T$$

$$A = \text{function of } (10^5 v)^{1/3}/10U'.$$

$$C_i = C_{Li}(y/r)^{-0.756zi}$$

$$C_i = C_{Mi}(y/r)^{-zi}$$

$$C_i = C_{Ui}(y/r)^{-1.5zi}$$

where:

- g_{ssi} = suspended load, in tons/day/foot width
- g_{ssli} = suspended load in lower zone, in tons/day/foot
- p_i = sediment weight fraction
- T_T = adjusted water temperature
- A = a value that is a function of the equation as listed on the preceding page in units such that suspended load is given in tons/day/foot
- k_4 = correction factor from figure 5

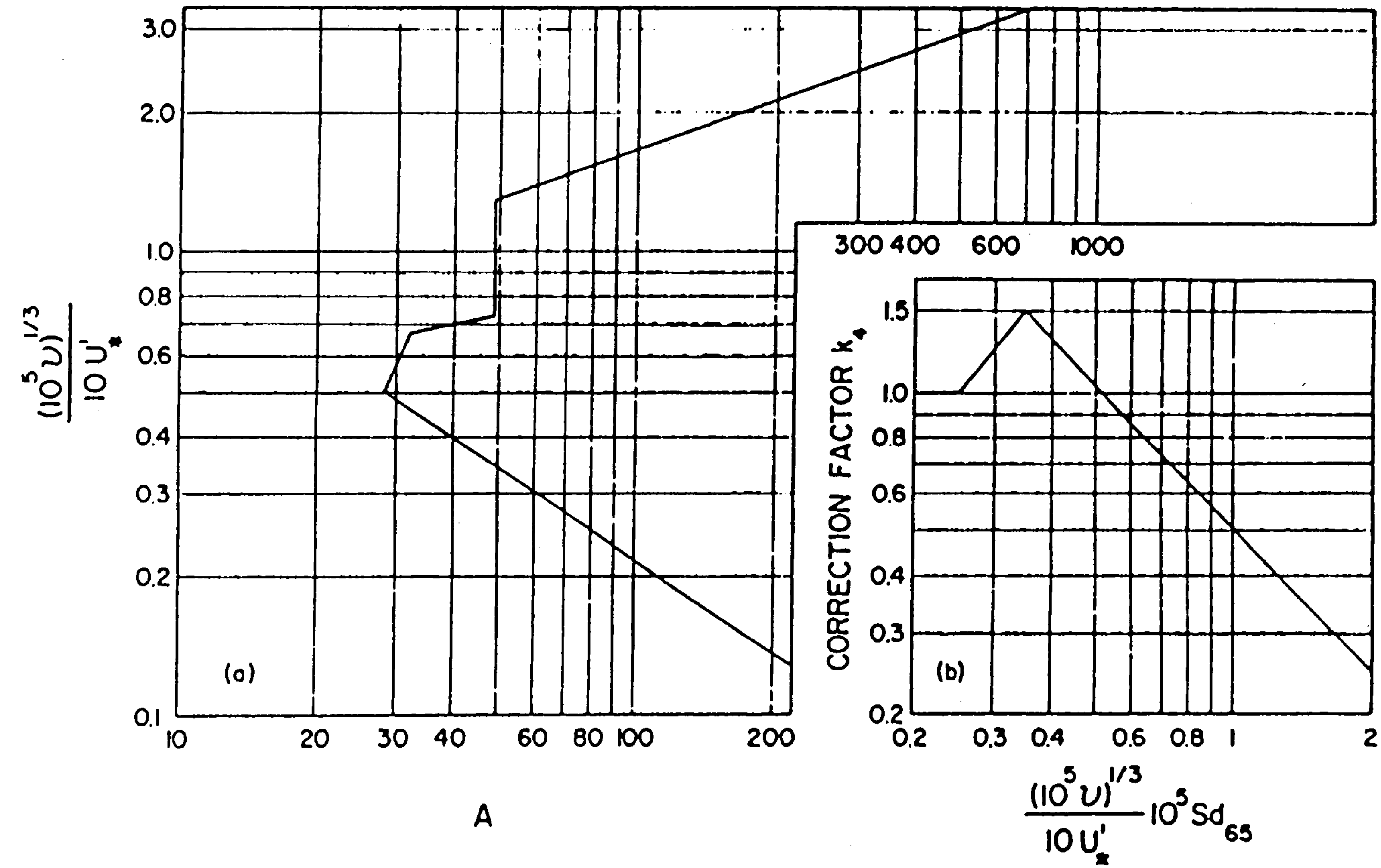

Figure 5.--Factors in Toffaletti relations: (a) Factor A; (b) correction factor k_4

V = mean velocity in the real stream

d_{si} = geometric mean of particle sizes in zone

T = water temperature, in degrees Fahrenheit

M_i = empirical value

r = hydraulic radius of real stream, in feet

n_v = empirical exponent

z_i = empirical exponent

g_{ssmi} = suspended load in middle zone, in tons/day/foot

g_{ssui} = suspended load in upper zone, in tons/day/foot

C_{Li} = suspended sediment concentration in lower zone, in pounds per cubic foot

C_{Mi} = suspended sediment concentration in middle zone, in pounds per cubic foot

C_{Ui} = suspended sediment concentration in upper zone, in pounds per cubic foot

C_i = average suspended sediment concentration in stream, in pounds per cubic foot

w_i = fall velocity of the sediment of size d_{si} in water of temperature T, in feet per second

c_z = empirical value

S = slope of the real stream

v = kinematic viscosity of the water, in square feet per second

U'_* = shear velocity, in feet per second

y = depth ratio factor for zone determination where:
the lower zone extends from $y/r = 2d_{si}/r$ to $y/r = 1/11.24$
the middle zone extends from $y/r = 1/11.24$ to $y/r = 1/2.5$
the upper zone extends from $y/r = 1/2.5$ to the surface

The Toffaletti method is easily applied to different streams, and has some distinct advantages. It is based on numerous data and is recognized by the American Society of Civil Engineers as an accurate method. The load is broken down into the separate component parts for a more complete analysis of how the flow is actually carrying the sediment. However, a detailed analysis of numerous characteristics of the sediment and stream is required to utilize this method.

d. HEC-6

The United States Army Corps of Engineers Hydrologic Engineering Center has developed a widely used program to predict sediment loads called HEC-6 (U.S. Army Corps of Engineers, 1993). The model is a one-dimensional numerical model that simulates the interaction between flow hydraulics and the sediment transport rate. It is based on the ability of a stream to transport sediment based on Einstein's theory as previously discussed.

The program requires a knowledge of the cross-sectional geometry of the study reach, grain size classification of the sediment particles in the reach, reach length, Manning's n for the channel, structures in the channel, bed properties, and flow properties. Output available from the program includes suspended and bed sediment loads, areas of scour and deposition, and equilibrium conditions for each specified flow.

If the data is available to apply the HEC-6 model, it offers the ability to manually enter numerous channel variations and observe the effect of each.

10. Sediment-Rating Curves

Sediment load predictions may be calculated by combining the sediment-rating curve of flow versus sediment discharge and flow duration curves for stream sites (Miller, 1951). Sediment-rating curves may not appear to correlate if taken in bulk, so time period separation must be applied by comparing the different flow-duration curves to the corresponding sediment-rating curve. A change in the flow-duration curve may occur due to seasonal effects, extreme high flow events, and timing of peaks (Glysson, 1987). However, an accurate accounting of the flow-duration curve applied to sediment rating curves reduces this inherent bias.

Transport curves typically appear linear on logarithmic paper (Trimble, 1984) and can be described with the following log-linear equation:

$$Q_s = aQ_w^b$$

where Q_s = suspended-sediment discharge, in tons/day

a = a coefficient that is an indicator of relative erodibility

Q_w = water discharge, in cubic feet per second

b = an exponent representing the slope of the transport curve

These curves are then often a linear regression function as discussed earlier when converted to the logarithmic format (i.e. $\log Q_s = \log a + b\log Q_w$).

Utilization of a log-log estimate in a sediment rating curve can induce an upwards shift in estimation of up to 50% in high flows (Ferguson, 1987). However, this overprediction can be reduced with a correction factor based on known concentrations. Ferguson (1987) determined the correction factor to relate directly to standard error of the estimate, s, where the simple correction factor $2.65s^2$ removes most of the bias. Stated simply, the correction factor increases with s, so as the underprediction increases with higher loads, the factor increases as well.

11. Universal Soil Loss Equation "R-factor"

One method of describing rainfall contribution to soil loss during an individual storm event is a variation of the rainfall and runoff factor, R, from the universal soil loss equation (Wischmeier, 1978 and Barfield, 1981). This rainfall factor is defined as:

$$R = EI_{30}$$

$$E = 916 + 331\log I_{60}$$

where R = rainfall index

E = total storm energy, in hundreds of foot-tons per acre

I_{30} = maximum thirty minute storm intensity, in inches per hour

I_{60} = average hourly storm intensity, in inches per hour

This term accounts for a storm's total energy as well as the maximum intensity of the storm. For example, a light storm with a long, slow duration may have the same energy as a storm with a heavy intensity but short duration. The more intense storm is more likely to dislodge soil particles from the land, which in turn are more likely to become surface water sediment, so it has a higher R-value. A maximum I-value is set at 3 inches per hour because the median dropsize does not continue to increase when intensities exceed 3 inches per hour (Hudson, 1971).

The I-factor is typically designated as the maximum storm thirty minute intensity. However, this factor has been modified for specific applications as data was available (Wischmeier, 1978).

12. METCMP

The United States Geological Survey (USGS) has designed a statistical rainfall package which reduces hourly rainfall intensities into ten-minute interval intensities (Ormsby, 1990). This program, called METCMP, bases total storm rainfall on a normal unit hydrograph for each storm. Maximum intensity can therefore be accurately estimated without previous knowledge of the actual storm pattern.

Though the program is currently available in UNIX format in conjunction with the USGS ANNIE interface package, no documentation has been printed. Documentation for the program is being written by the USGS for future publication.

D. On-going Basin Studies

Currently three studies are in progress in the Clinch and Powell River Basins upstream of the study area. The Water Resources Division of the Tennessee Valley Authority is conducting an analysis of annual sediment loading into Norris Lake. This study is utilizing land use, contributing area, and daily flows to make the estimate.

The Water Resources Planning Leader of the Soil Conservation Service in Nashville, Tennessee is conducting a land use inventory of the basins in the Tennessee portion of the study area. The study is based on aerial and satellite imagery with an expected accuracy of 0.2 percent. Finally, the Clemson University Department of Environmental Toxicology, Institute of Wildlife and Environmental Toxicology, is conducting research on the water quality effects on mussel fauna in the study basins and the effects of varying flow conditions on the toxicity to early life stage responses of these freshwater mussels.

CHAPTER 3

BASIN DESCRIPTION

A. General

The Clinch and Powell River Basins in the study area are situated upstream of the backwater of Norris Lake. The basins are adjacent to each other and flow from the northeast to the southwest with the Clinch River Basin to the east and the Powell River Basin to the west. Though all four sampling sites are located in Tennessee, most of the drainage area for these basins is located in southwest Virginia.

B. Physiography and Topography

The Clinch River and Powell River Basins are located in northeast Tennessee in the Appalachian Plateau and Valley and Ridge physiographic provinces (fig. 6). The Valley and Ridge physiographic province is characterized by parallel southwest to northeast valleys and ridges, with valleys having an average width of forty-five miles. The valleys within the basin have slopes between 0.0001 foot per foot (ft/ft) and 0.0025 ft/ft at altitudes varying from 1,200 to 1,600 feet. The ridges bounding these valleys have altitudes near 2200 feet.

In the study area, the northwest portion of the Powell River basin contains a part of the Cumberland Plateau region of the Appalachian Plateau physiographic province. A portion

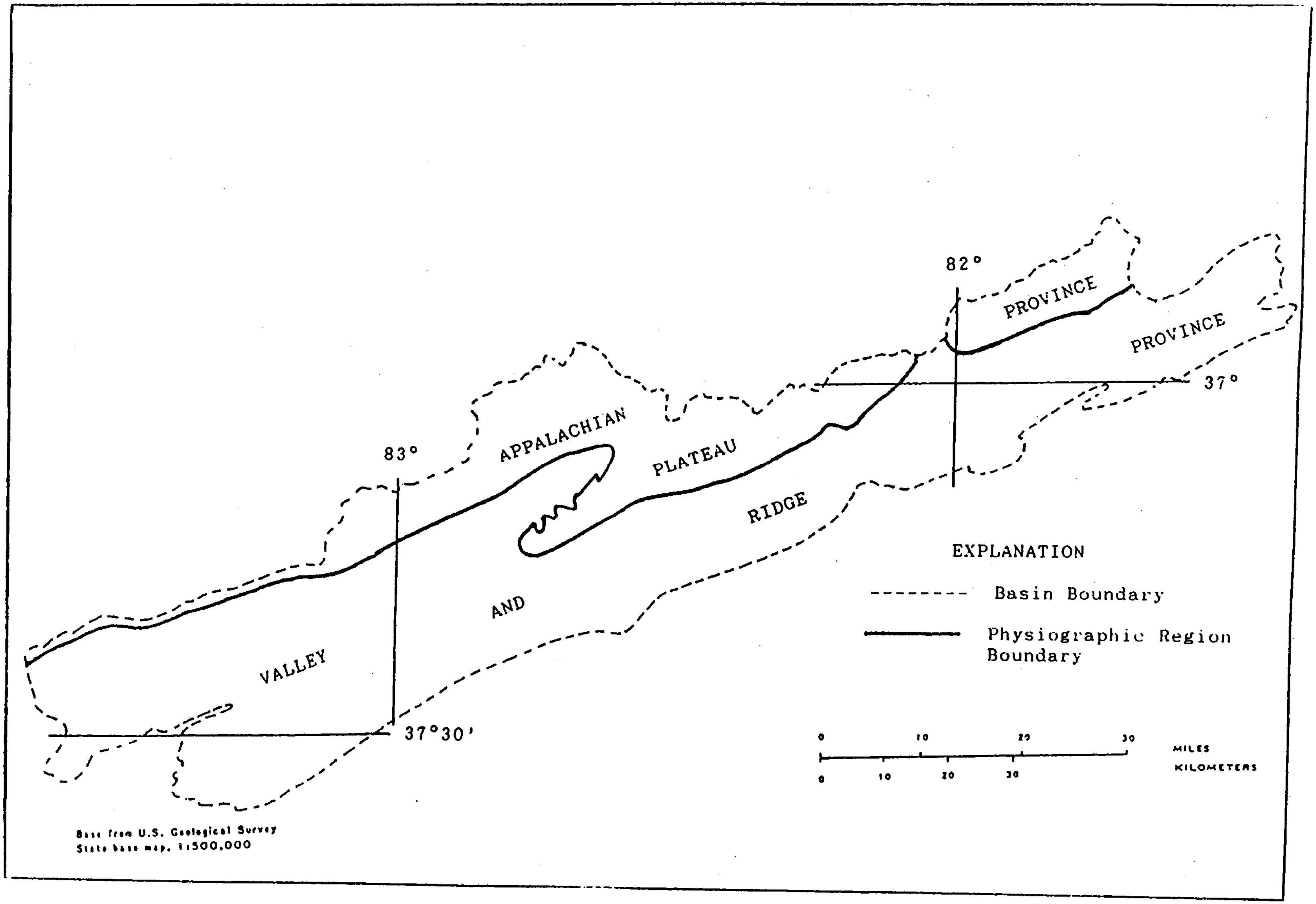

Figure 6.—Diagram of the combined Clinch River and Powell River Basins with physiographic provinces identified (from Hufschmidt, 1981)

of the province's eastern border drains into the Clinch-Powell basin. It is marked by a prominent escarpment of cliffs one thousand feet higher than the Valley and Ridge Province.

C. Surface Geology

The study area lies in a folded and extensively faulted region underlain by rock formations consisting mostly of the Pennsylvanian, Cambrian, and Ordovician Ages (fig. 7). The folds and faults formed from strong horizontal compression caused by sea floor expansion acting on the region since late Paleozoic time (Hufschmidt, 1981). The differential erosion of these folded and faulted belts has given rise to the valleys (underlain by soft or less resistant rock) and ridges (underlain by hard or more resistant rock) characteristic of the basin (Floyd, 1978).

While the surface geology of the two basins is similar, one significant difference exists. The Powell River basin is underlain primarily with Pennsylvanian and Cambrian age rock. Pennsylvanian age formations are sedimentary and consist of sandstones and shale with coal beds. These coal beds are the greatest variance between basin geologies. Cambrian age formations are sedimentary and metamorphic and consist of limestones, dolomites, and shale. The Clinch River basin is underlain primarily with Cambrian and Ordovician age formations. Ordovician age formations are sedimentary and consist of limestones and dolomites. Small areas of the

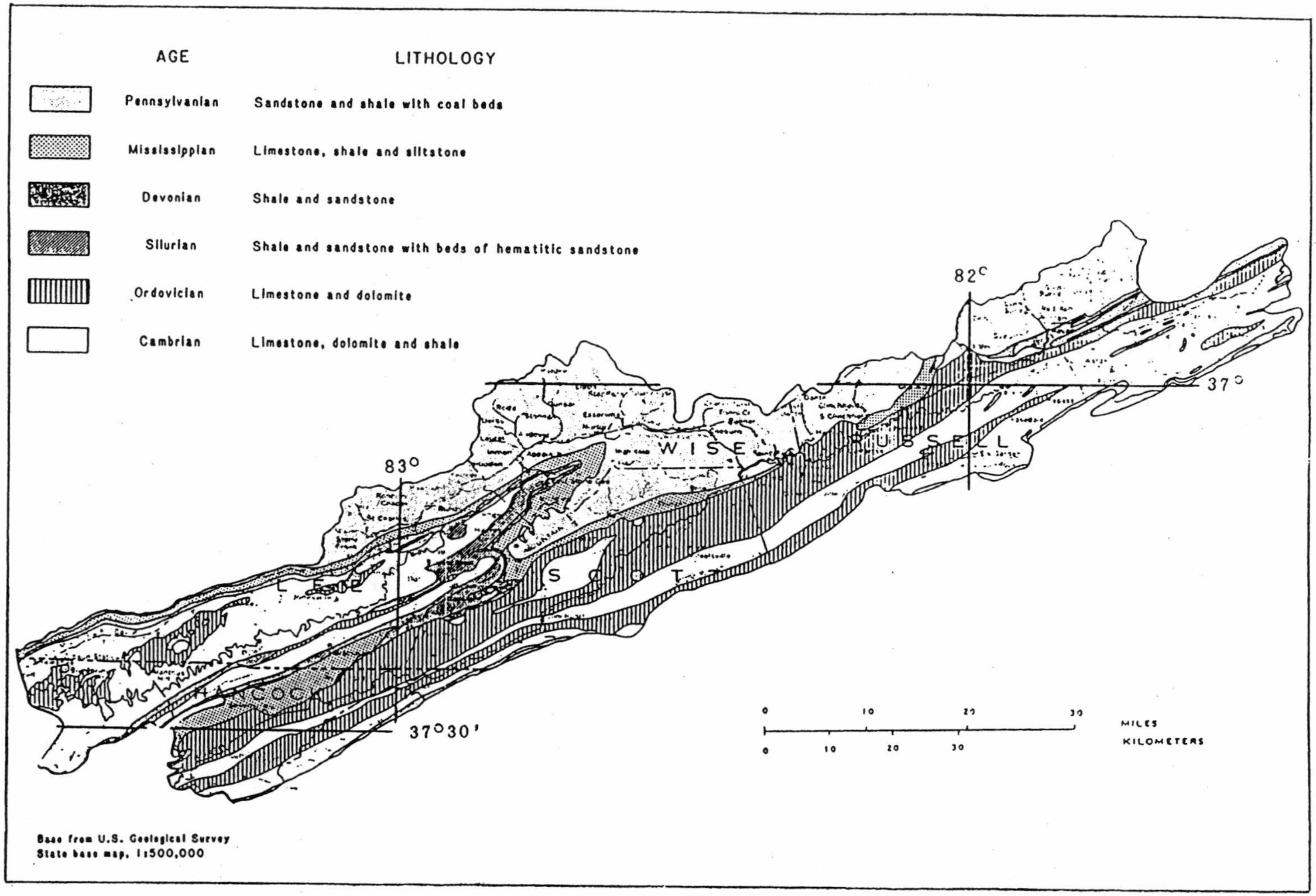

Figure 7.--Diagram of surface geology of the combined Clinch River and Powell River Basins (from Hufschmidt, 1981)

combined basin system are underlain with Mississippian, Devonian, and Silurian age formations. These formations are also sedimentary which is consistent with the primary basin geology.

D. Climate

The study area has a mean annual temperature of 58 degrees fahrenheit. The coldest months are December and January with daily minimum temperatures of 30 degrees fahrenheit, and the hottest months are July and August with daily maximum temperatures of 87 degrees fahrenheit (National Oceanic and Atmospheric Administration, 1982).

Average annual precipitation is 49 inches with 23 inches occurring during the April through September growing season. Average annual snowfall varies from 8 inches in the southwest portion of the watershed to 12 inches on the highland area of the Cumberland Plateau. The highest volume precipitation occurs from December through March caused by frontal activity and from July through August caused by late day convective storms (Hufschmidt, 1981).

E. Land Use

The Clinch River Basin drains 1,154 square miles in southwest Virginia upstream of Looney's Gap, Tennessee and 320 square miles in northeast Tennessee for a total contributing study area of 1,474 square miles north of Tazewell, Tennessee (table 3). The Powell River basin drains 510 square miles in southwest Virginia upstream of Alanthus Hill, Tennessee and 175 square miles in northeast Tennessee upstream of Arthur, Tennessee for a total contributing study area of 685 square miles (table 3).

Well over half of each basin is forested. The majority of forest land in both the Clinch River Basin and the Powell River Basin is of the oak-hickory type. The Clinch River Basin also contains loblolly-shortleaf pine, maple-beech-birch, oak-pine, and elm-ash- cottonwood forest types which occupy less than 10 percent of the forested area. The Powell River Basin contains small areas of eastern red cedar and maple-beech-birch forest types (Soil Conservation Service, 1992).

The primary crops in this region include tobacco, corn, and small grains in addition to numerous haylands. Livestock in both basins includes mostly beef cattle, horses, and sheep, followed by dairy animals and hogs, and then poultry animals (Soil Conservation Service, 1992).

The region bears strata which contains bituminous coal. Both deep and surface mining of bituminous coal occurs in both basins. The Clinch River Basin contains 14,401 acres of mined and mine associated (land directly impacted by mine runoff) lands in the study area. The Powell River basin contains 11,299 acres of mined and mine associated lands in the study area. Most of the mining impacts occur in Virginia. Mined or

Table 3.--Land uses of the Clinch River and Powell River basins separated by percentage makeup of each subbasin

Station	Basin Area in square miles	Land use as percentage of basin area			
		Forest	Cropland	Pasture	Mined and Urban
Clinch River					
near Looney's Gap	1,154	56.0	14.0	23.0	7.0
Looney's Gap to Tazewell	320	77.7	6.1	14.4	1.8
above Tazewell	1,474	60.8	13.0	21.1	5.1
Powell River					
at Alanthus Hill	510	61.0	16.0	14.0	9.0
Alanthus Hill to Arthur	175	62.4	16.0	18.6	3.0
above Arthur	685	61.4	16.0	15.2	7.4

mine affected area includes 12,969 acres (90.1% of total) in the Clinch River basin in Virginia and 9,308 acres (82.4% of total) in the Powell River basin in Virginia (Soil Conservation Service, 1992)

F. Flood Frequency Curves

Flood probability values, or flood frequency curves, were generated by two methods because of lack of data. The flood frequency curve for the Clinch River near Looney's Gap, Tennessee (fig. 8A) was calculated using Method B from Weaver and Gambel (1993) for ungaged sites in rural basins of Tennessee. The flood frequency curve for the Clinch River above Tazewell, Tennessee (fig. 8B) was defined by Weaver and Gambel (1993). The flood frequency curve for the Powell River at Alanthus Hill (fig. 8C) was also calculated using Method B, and the Powell River above Arthur, Tennessee (fig. 8D) was also defined by Weaver and Gambel (1993).

G. Flow Duration Curves

Sufficient record existed to develop flow duration curves for the downstream sites, Clinch River above Tazewell, Tennessee and Powell River above Arthur, Tennessee (fig. 9). The flow duration curve for the Clinch River above Tazewell is based on 74 years of record (1919 through 1993). The curve for the Powell River above Arthur is based on 61 years of record (1920 through 1981) (Bingham, 1985). The fairly steep,

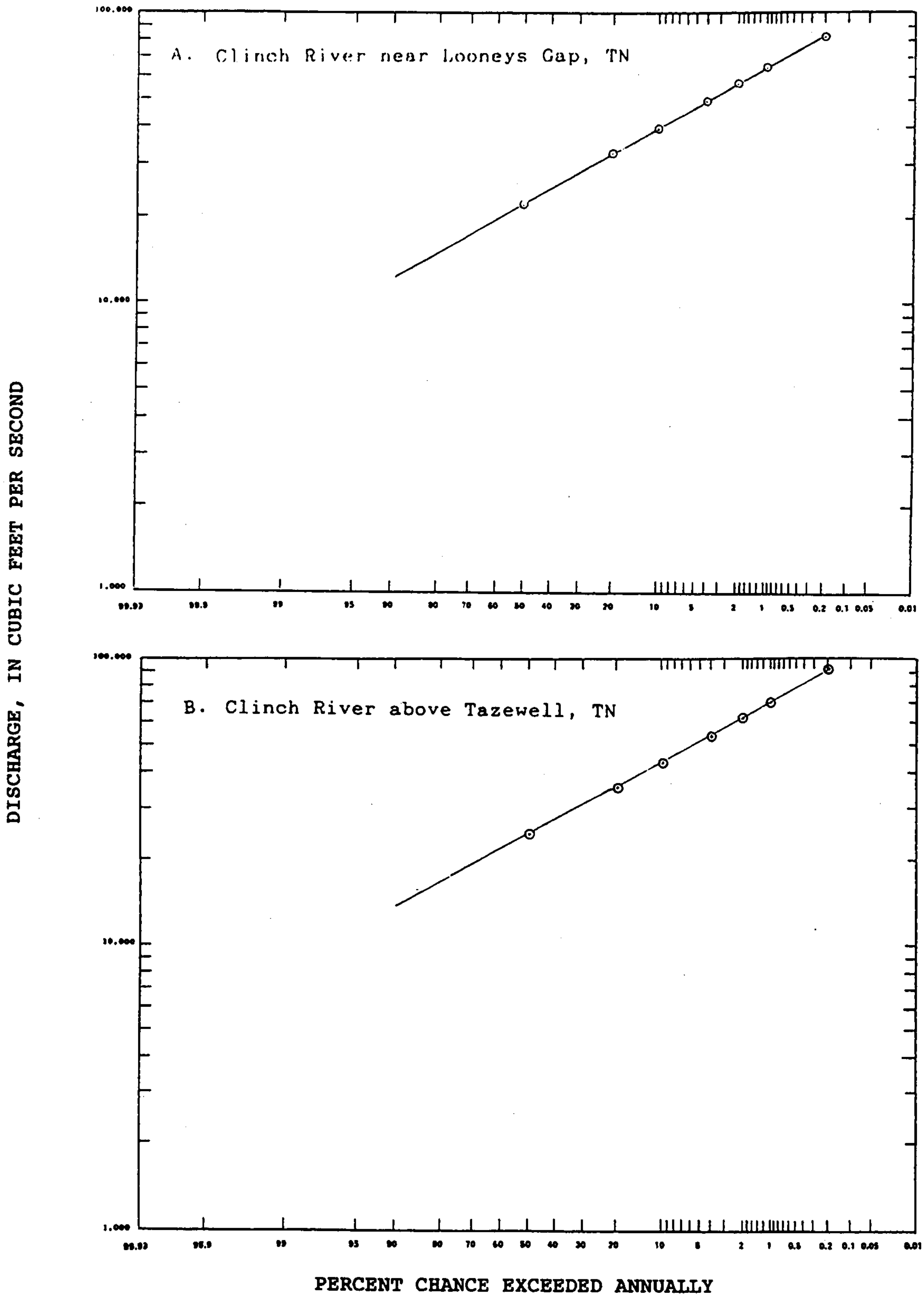

Figure 8.--Flood flow frequency curves for sampling sites in study area

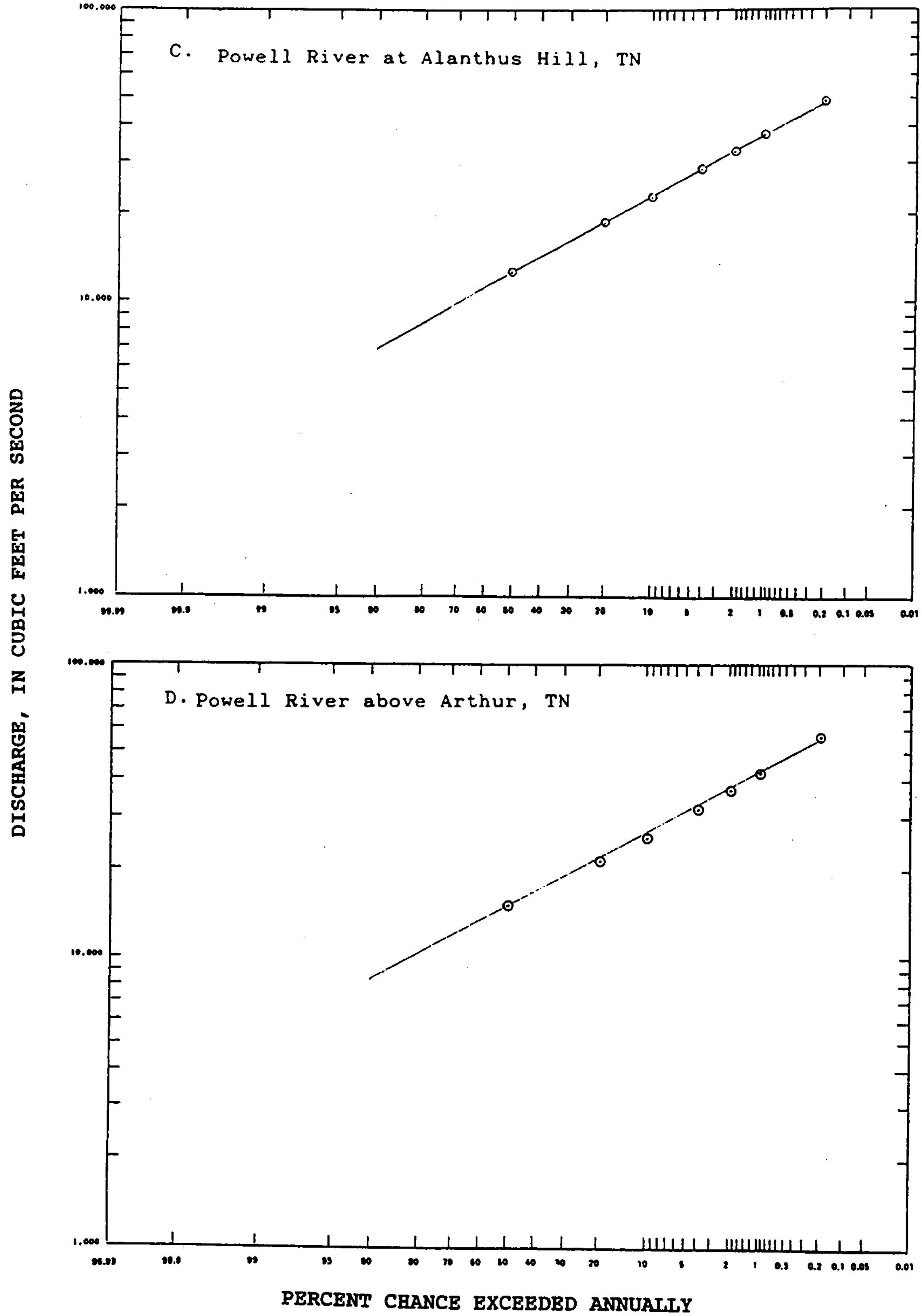

Figure 8.--Flood flow frequency curves for sampling sites in study area (continued)

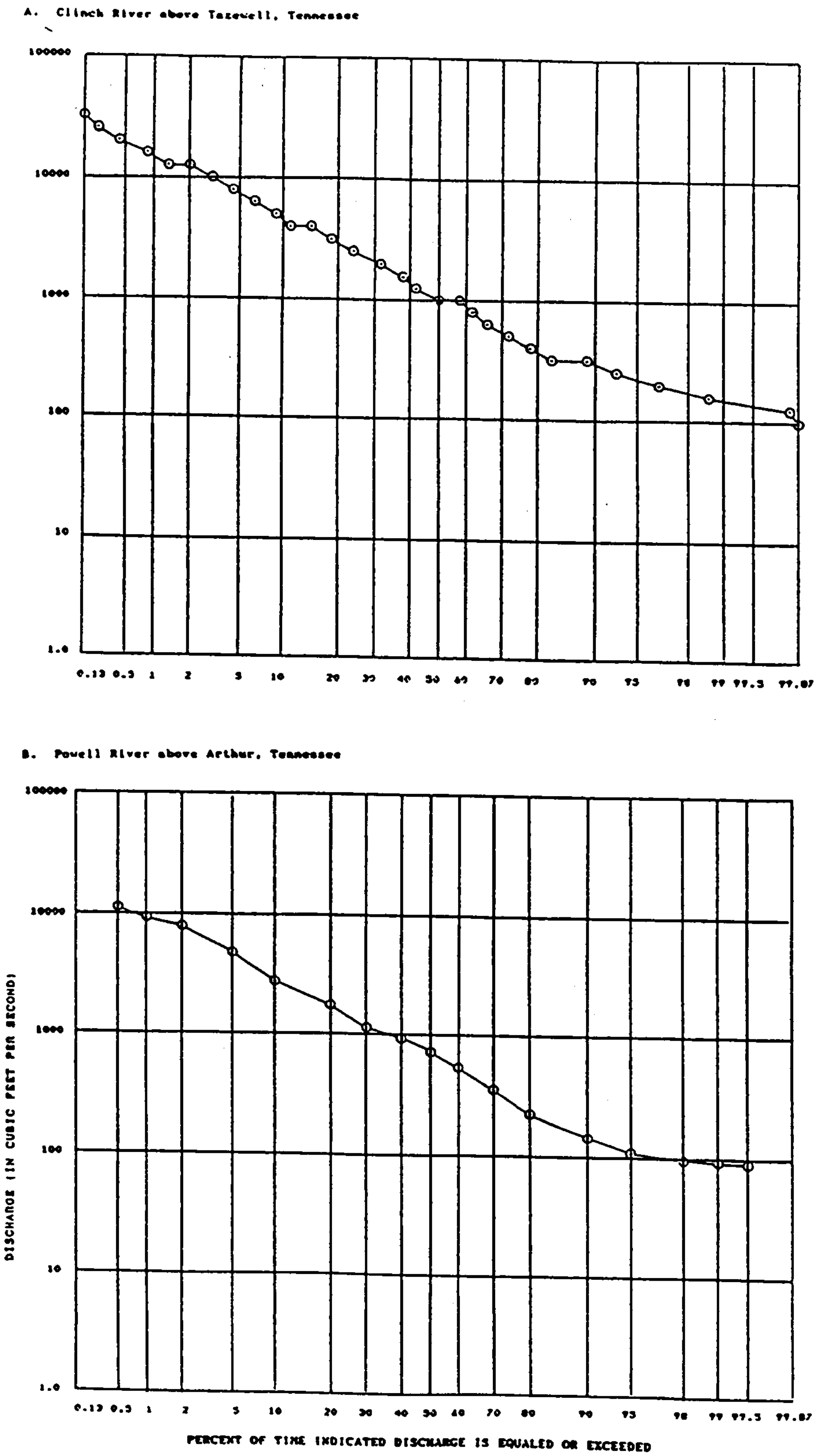

Figure 9.--Flow duration curves for downstream stations in study area

constant slopes of the flow duration curves are characteristic of highly variable streamflow with most flow a direct result of precipitation runoff.

CHAPTER 4

METHODS

A. Boxplots

Boxplots were used to compare variations in specific chemical constituents between the four sites. Boxplots are used to visually depict the symmetry of a distribution, its median value, and any samples detected significantly outside the majority of values. The Tukey boxplot method was used in this study (fig. 10). The Tukey boxplot consists of a box drawn from the 25th percentile up to the 75th percentile of the data; this box is described as the inner quartile range. A horizontal line is drawn across the box at the 50th percentile to designate the median. Lines, or whiskers, extend from the ends of the box to the greatest value outside the box but within 1.5 times the inner quartile range (upper or lower adjacent values). These whiskers are used to describe the quartile skewness of the data distribution (fig. 10). Additionally, values near the ends of the distribution are also depicted (fig. 10). Outside values are defined as values which lie between 1.5 times the inner quartile range and 3.0 times the inner quartile range, and are displayed graphically with asterisks. Far outside values are defined as values which are greater than 3.0 times the inner quartile range, and are graphically displayed as circles. These ranges also have a probability of occurrence which is considered in

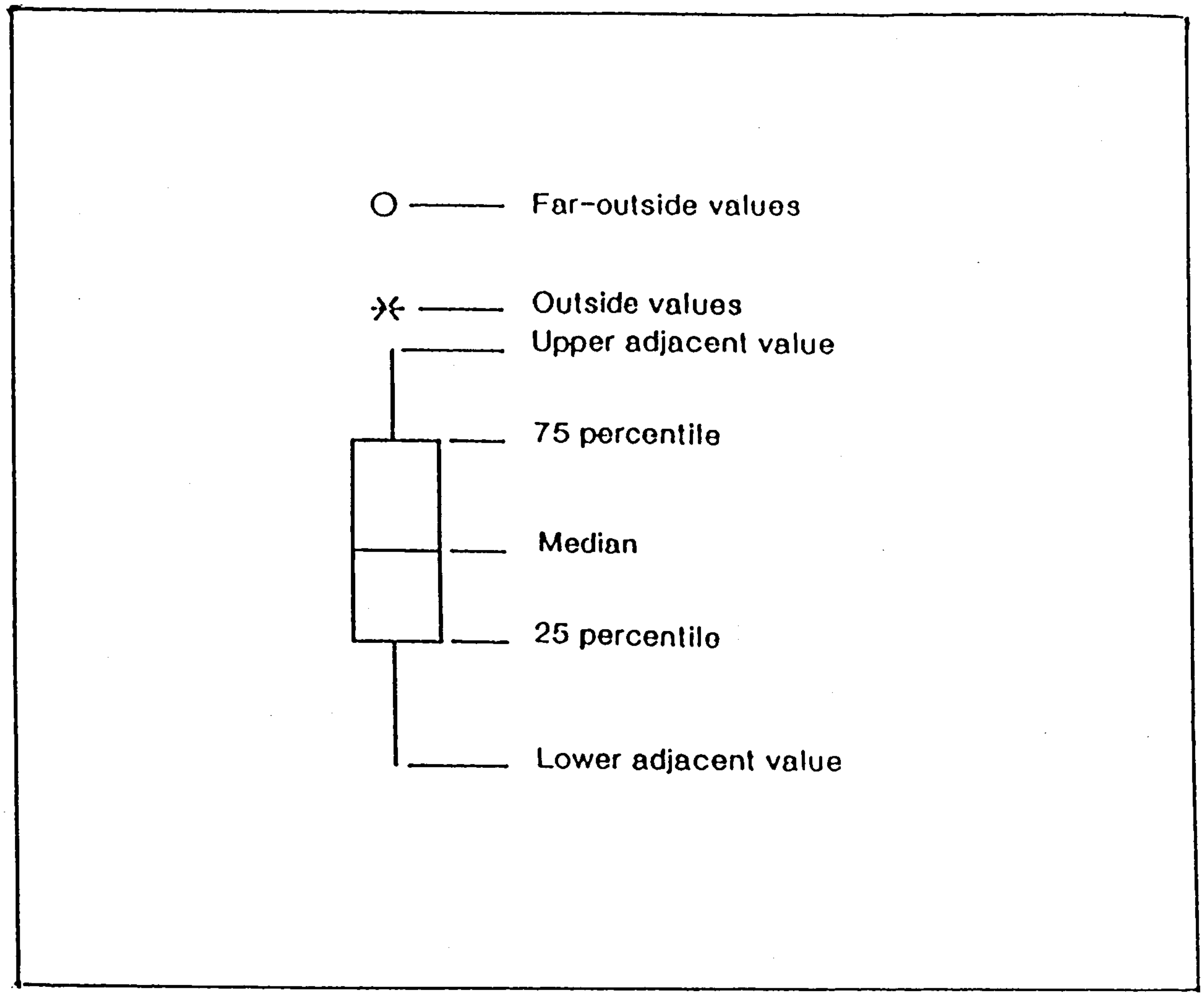

Figure 10.--Pictorial description of Tukey boxplot

data analysis.

B. Piper Diagrams

Piper diagrams were utilized to compare the overall chemical characteristics of water between the four sites. Piper diagrams are chemical constituent descriptors that permit cation and anion compositions of many samples to be displayed on a single graph (fig. 11). Visual inspection can therefore yield a quick comparison of major groupings or trends in the data. Compositional categories can be defined from distinct zones described by cation and anion concentration. The Piper diagram shows concentrations as percentages. This means that waters with completely different total concentrations can have the same descriptive point on the diagram if the percentages are equal (Freeze and Cherry, 1979). A Piper diagram can accommodate numerous analyses on a single plot so each station in the study has a single Piper diagram representing all of the data collected at that location.

C. Regression

Because of the discrete sampling pattern used in this project, linear regression was utilized to determine the relation between suspended sediment and discharge, season, and a rainfall factor. Regression analysis relates a dependent variable with independent variables. One method used to

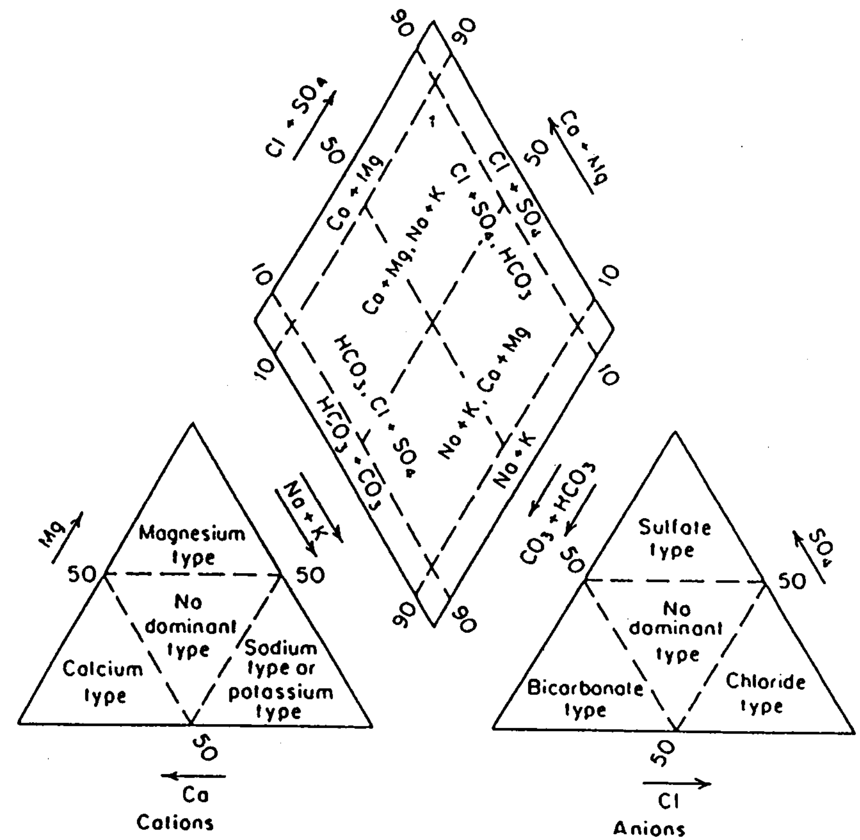

Figure 11.--Water type designation from Piper diagram determination

describe the fit of these independent variables to the dependent variable is the R-squared coefficient (R^2). A perfect system has an R^2 value equal to 1.0; a system that does not relate well between variables contains an R^2 that approaches zero. Additionally, a standard error of each regression can be utilized to predict the range of probable values for each regression.

D. Data Collection

Hydrographs for sampled storm flow events were taken from continuous recording stations, if available, or constructed by connecting actual discharge measurements made over the course of the hydrograph (fig. 12). The accuracy of hydrograph delineation for each storm flow event varied largely, and therefore a linear estimate between samples was used to form all hydrographs.

Rainfall data was supplied by the Tennessee Valley Authority Data Management Section and taken from the National Weather Service monthly published rainfall data for Tennessee (table 4). This data was utilized in a Thiessen weighted calculation to determine a basin rainfall factor in calculating storm loads.

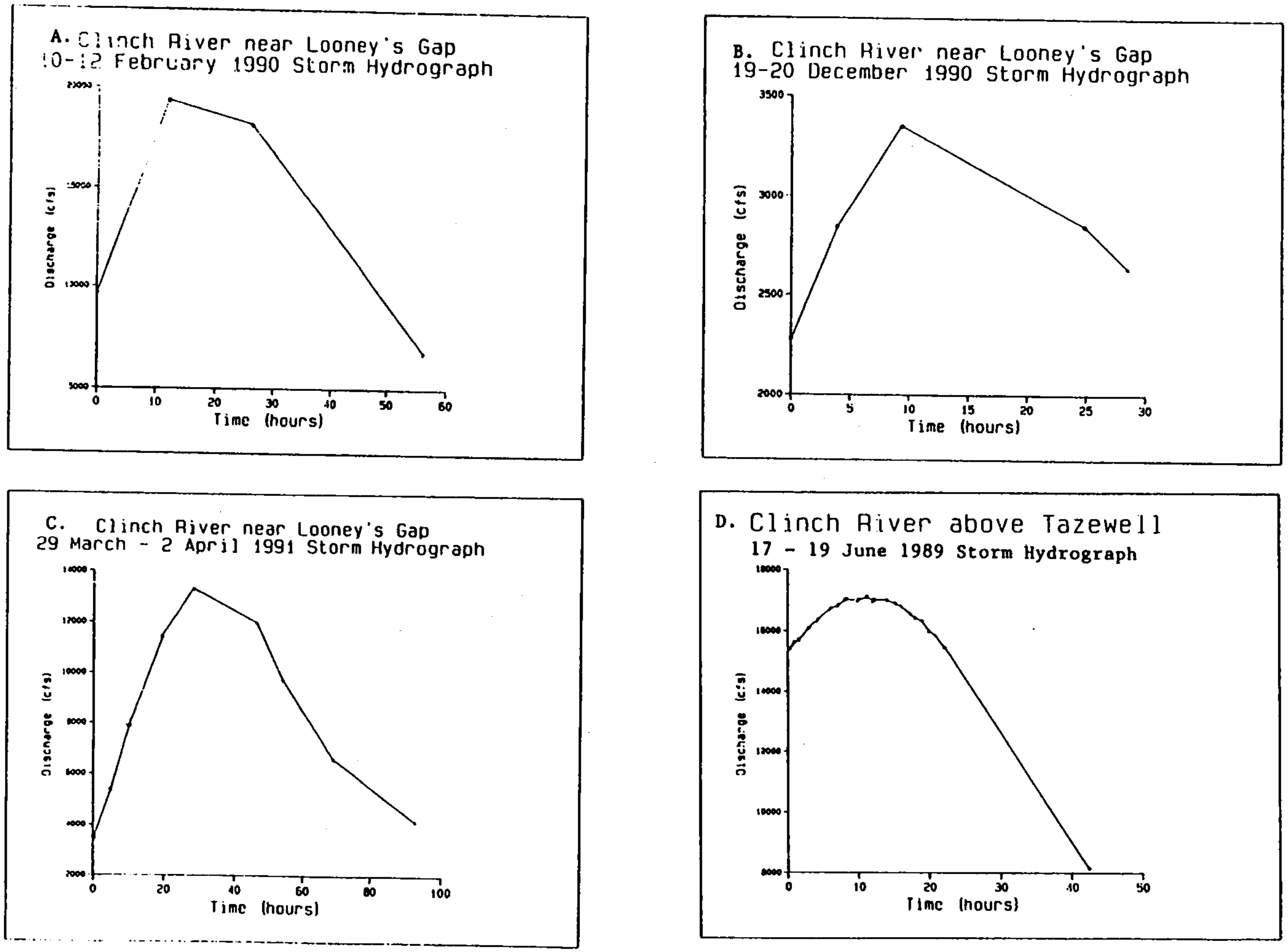

Figure 12.--Approximate storm hydrographs for study period listed by site and date of occurrence

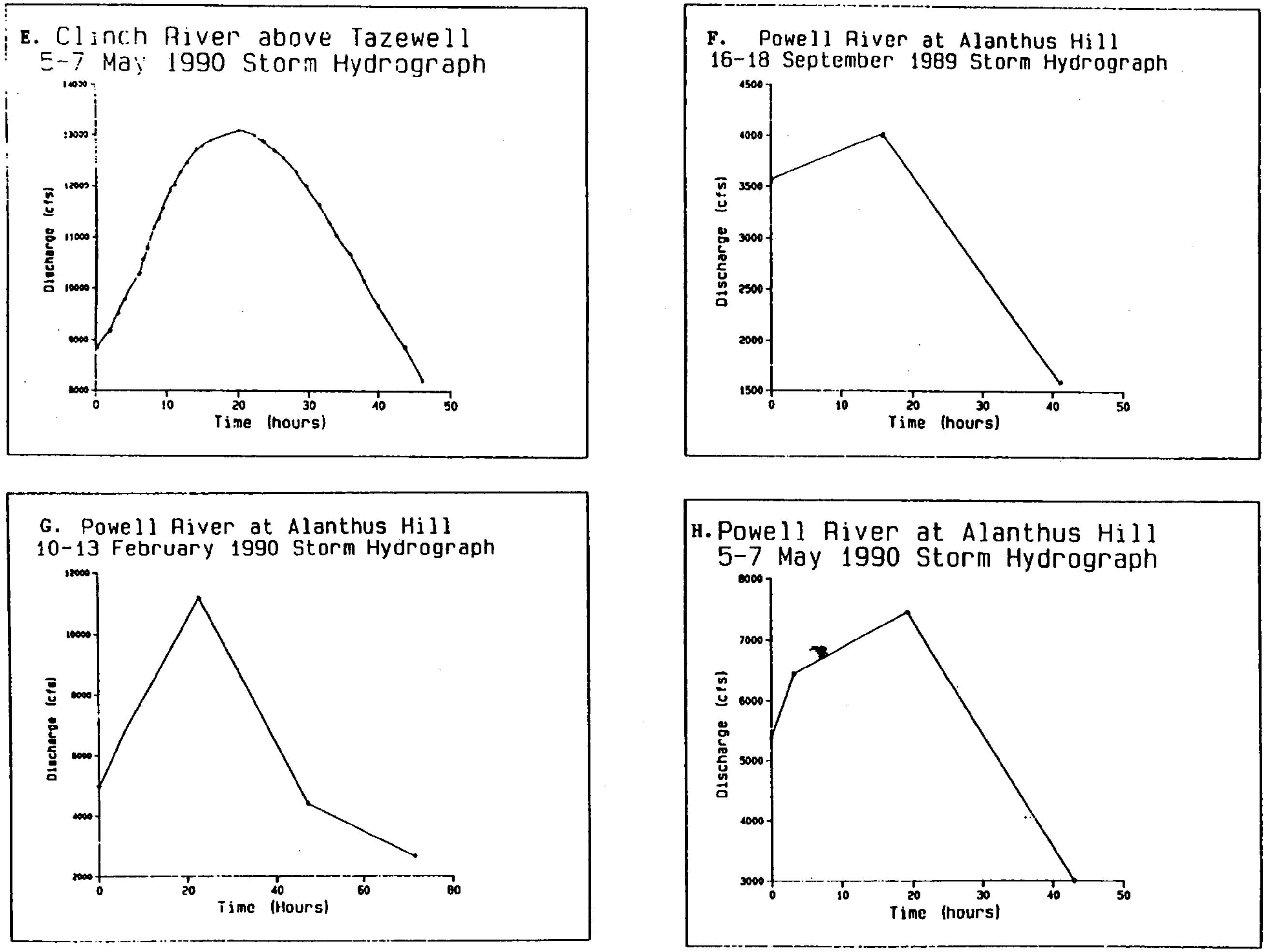

Figure 12.--Approximate storm hydrographs for study period listed by site and date of occurrence (continued)

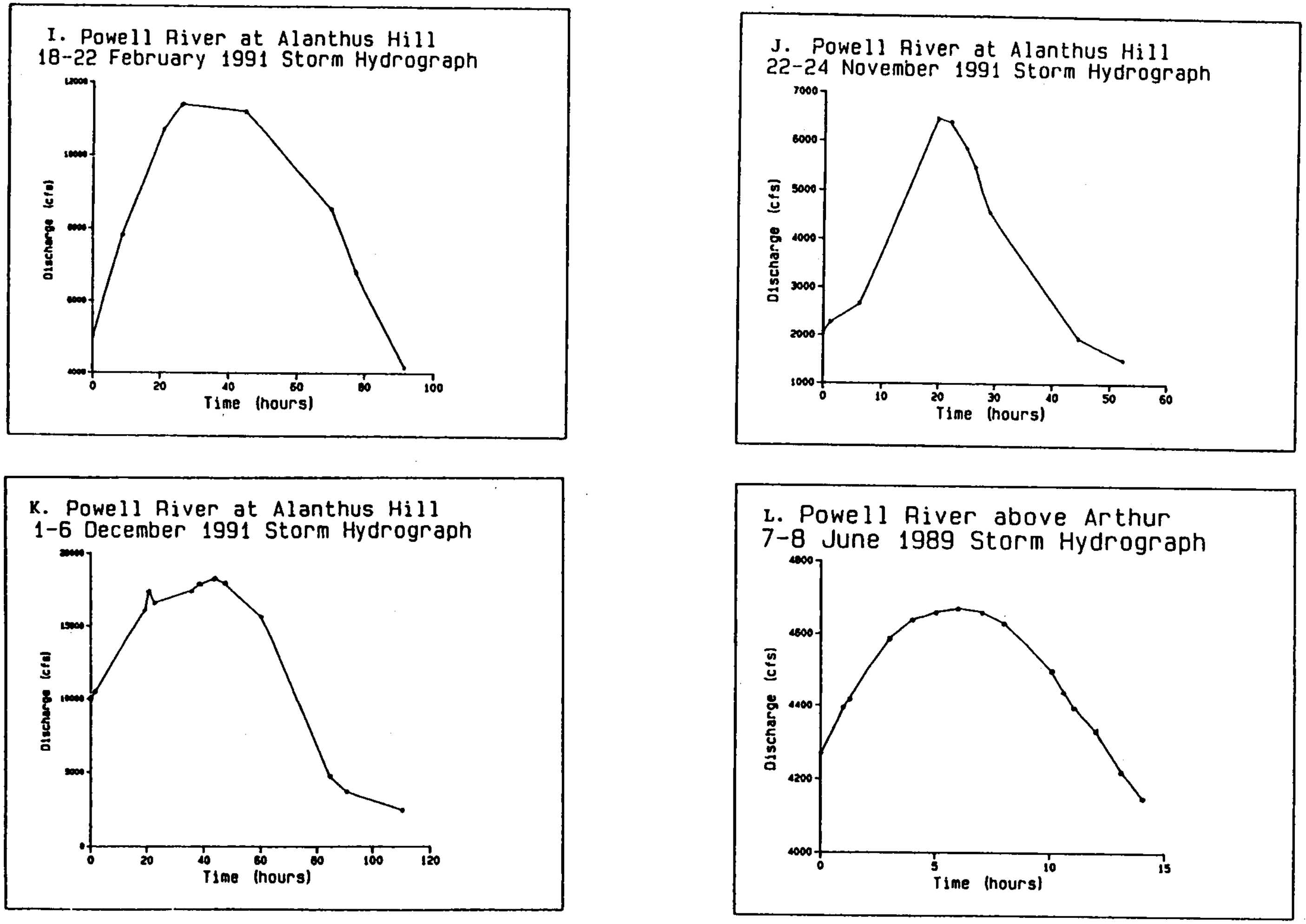

Figure 12.--Approximate storm hydrographs for study period listed by site and date of occurrence (continued)

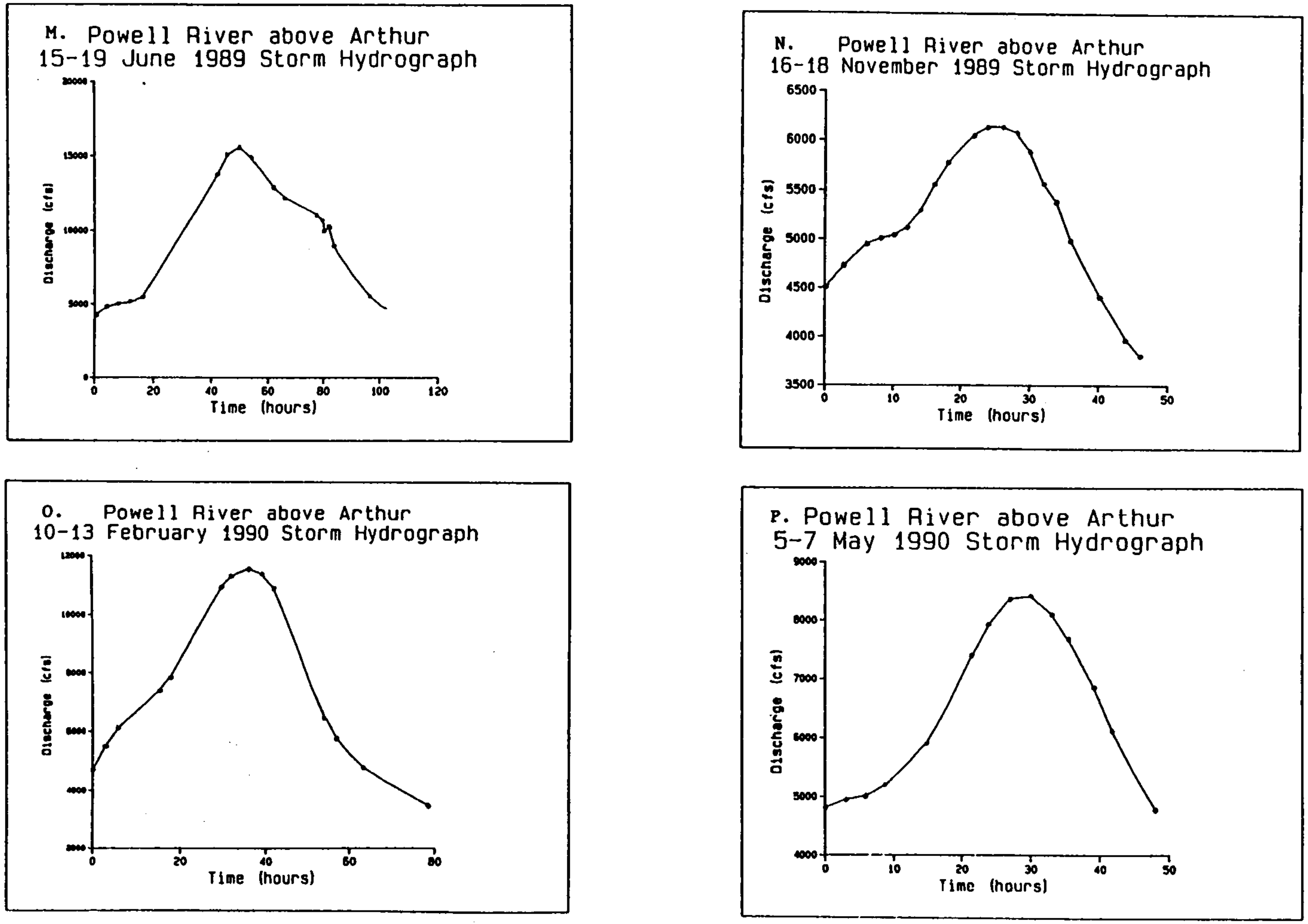

Figure 12.--Approximate storm hydrographs for study period listed by site and date of occurrence (continued)

Table 4.--Station locations for fourteen rain gages used in Thiessen diagram/rainfall factor determination

Station name	Latitude	Longitude	Data type	Thiessen Weight
Wise, Virginia	36°58'00"	82°34'00"	hourly	6.25
Rogersville, Tennessee	36°25'00"	82°59'00"	hourly	.78
Arthur, Tennessee	36°32'32"	83°37'49"	2-hour	4.69
Speedwell, Tennessee	36°27'27"	83°53'04"	6-hour	4.69
Fitts Gap, Tennessee	36°35'20"	83°13'40"	6-hour	4.69
Church Hill, Tennessee	36°31'16"	82°44'15"	6-hour	.78
Duffield, Virginia	36°42'44"	82°47'47"	6-hour	12.5
Pennington Gap, Virginia	36°44'48"	83°02'20"	6-hour	12.5
Appalachia, Virginia	36°53'54"	82°47'18"	6-hour	12.5
Tazewell, Virginia	37°07'33"	81°33'29"	6-hour	6.25
Coeburn, Virginia	36°55'44"	82°28'53"	6-hour	6.25
Lebanon, Virginia	36°54'33"	83°03'39"	6-hour	9.37
Richlands, Virginia	37°05'46"	81°50'09"	6-hour	9.37
Hilton, Virginia	36°38'44"	82°29'15"	6-hour	9.37

CHAPTER 5

RESULTS SUMMARY

A. General

Results for the study include the total summary of all sampled water quality constituents and relationships which were determined through various methods discussed in detail as reported.

B. Statistical Data Summary

Table 5 statistically summarizes selected water quality constituents for each of the four sampling sites. The summary includes the maximum value of the constituent determined at the site, the minimum value of the constituent determined at the site, the mean and median of all constituents at the site, and the values of constituent levels at which 25% (P25) and 75% (P75) of the measured levels were greater than that measured value. The median, P25, and P75 are used in defining the limits of the Tukey boxplot as previously discussed (figure 10).

Additionally, the number of samples taken for each constituent at each site, and the number of samples taken which were measured below detection limits are listed for each site. The detection limit for any constituent which falls in the latter category is defined in the "Minimum" column.

Table 5.--Statistical summary of water quality in study area by site and constituent

[P75, the value of the 75th percentile sample; P25, the value of the 25th percentile sample; Number not detected, the number of samples with measured values lower than detectable levels; mg/l, milligrams per liter (parts per million); us/cm, microsiemens per centimeter; mL, milliliter; <, less than; dis, dissolved concentration; tot, total concentration; %, percent; mm, millimeter; NTU, nephelometric turbidity unit; ug/l, micrograms per liter (parts per billion)]

Parameter	Units	Maximum	Minimum	Mean	Median	P75	P25	Number of samples	Number not detected
	Station Number 03527220			Clinch River near Looney's Gap, Tennessee					
pH .	standard	8.6	7.2	8.16	8.2	8.25	8.1	41	0
Acidity	mg/l	9.9	5	5.61	5			8	0
Alkalinity	mg/l	149	92	120	119			8	0
Specific conductance	us/cm	445	220	281	273	309	240	40	0
Dissolved oxygen	mg/l	14.1	7.6	10.1	10.4	11	8.9	38	0
Fecal coliform	colonies/ 100 ml	6700	5	1755	490	2450	93.5	19	0
Fecal strep-tococci	colonies/ 100 ml	20000	22	4093	2250	5800	76	18	0
Nitrogen:									
NO2	mg/l	.04	< .01		< .01	< .01	< .01	35	31
NO3	mg/l	.96	.68	.808	.795			4	0
NO2 + NO3	mg/l	1.1	< .05		.73	.82	.6	35	1
NH4 (dis)	mg/l	.05	< .01		.02	.03	.01	40	5
NH4 (tot)	mg/l	.05	< .01		.02	.04	.01	35	2
Total organic nitrogen	mg/l	1.5	.15	.62	.58	.68	.43	27	0

***note: mean pH is the simple mean of all measured sample pH's**

Table 5.--Statistical summary of water quality in study area by site and constituent (continued)

Parameter	Units	Maximum	Minimum	Mean	Median	P75	P25	Number of samples	Number not detected
Station Number 03527220 Clinch River near Looney's Gap, Tennessee									
Phosphorus:									
Dissolved	mg/l	.03	< .01		.01	.02	< .01	40	19
Total	mg/l	.23	< .01		.07	.1	.03	40	[illegible]
Ortho-phophorus	mg/l	.03	< .01		.01	.01	< .01	40	26
Total organic carbon	mg/l	10	1	4.55	4	5.6	2.7	33	0
Sediment:									
Concentration	mg/l	450	2	110.5	95.5	127.5	56.5	42	0
% < .062mm	percent	100	69	89.1	89	95	84	42	0
Turbidity	NTU	60	.7	22	16			6	0
Total dissolved solids	mg/l	232	145	172	163			6	0
Major ions									
Calcium	mg/l	45	31	37.2	37			6	0
Magnesium	mg/l	14	8.3	10.2	9.15			6	0
Sodium	mg/l	21	4.8	8.75	6.55			6	0
Chloride	mg/l	5.8	3.7	4.67	4.6			6	0
Potassium	mg/l	2.6	1.4	1.78	1.55			6	0
Sulfate	mg/l	59	23	33.8	31.5			6	0
Fluoride	mg/l	.2	< .1		.1			6	1
Silica	mg/l	6.9	.94	4.84	5.9			6	0
Hardness	mg/l	170	110	133	130			6	0

Table 5.--Statistical summary of water quality in study area by site and constituent (continued)

Parameter	Units	Maximum	Minimum	Mean	Median	P75	P25	Number of samples	Number not detected
Station Number 03527220 Clinch River near Looney's Gap, Tennessee									
Aluminum:									
Dissolved	ug/l	50	< 10		20	30	20	16	1
Total	ug/l	3300	50	1420	1350	2300	330	23	0
Arsenic:									
Dissolved	ug/l	< 1			1			4	0
Total	ug/l	1	< 1		< 1			6	1
Barium:									
Dissolved	ug/l	43	29	38.7	40			6	0
Total	ug/l	< 100			< 100			6	6
Beryllium:									
Dissolved	ug/l	< .5			.5			4	4
Total	ug/l	< 10			10			6	6
Cadmium:									
Dissolved	ug/l	< 1			< 1			4	4
Total	ug/l	< 1			< 1			6	6
Chromium:									
Dissolved	ug/l	1	< 1		< 1			4	3
Total	ug/l	2	< 1		< 1			6	5
Cobalt:									
Dissolved	ug/l	< 3			< 3			6	6
Total	ug/l	4	< 1		1			6	3

Table 5.--Statistical summary of water quality in study area by site and constituent (continued)

Parameter	Units	Maximum	Minimum	Mean	Median	P75	P25	Number of samples	Number not detected
	Station Number 03527220			Clinch River near Looney's Gap, Tennessee					
Copper:									
Dissolved	ug/l	4	1		2			4	1
Total	ug/l	11	6		7			5	0
Iron:									
Dissolved	ug/l	60	6		16	25	8	23	1
Total	ug/l	5000	170	2300	2300	3400	1200	23	0
Lead:									
Dissolved	ug/l	9	< 1		1			4	1
Total	ug/l	10	2	5.5	4.5			6	0
Lithium:									
Dissolved	ug/l	17	8	10.5	8.5			6	0
Total	ug/l	20	< 10		15			6	2
Manganese:									
Dissolved	ug/l	11	1	5.7	5.5			6	0
Total	ug/l	350	8	166	190	230	80	23	0
Mercury:									
Dissolved	ug/l	.2	< .1		.1			4	2
Total	ug/l	.1	< .1		< .1			6	5
Molybdenum:									
Dissolved	ug/l	< 10			< 10			6	6
Total	ug/l	1	< 1		< 1			6	5

Table 5.--Statistical summary of water quality in study area by site and constituent (continued)

Parameter	Units	Maximum	Minimum	Mean	Median	P75	P25	Number of samples	Number not detected
	Station Number 03527220		Clinch River near Looney's Gap, Tennessee						
Nickel:									
Dissolved	ug/l	1	< 1		1			6	1
Total	ug/l	7	2	3.5	2			6	0
Selenium:									
Dissolved	ug/l	< 1			< 1			6	6
Total	ug/l	< 1			< 1			6	6
Silver:									
Dissolved	ug/l	< 1			< 1			6	6
Total	ug/l	< 1			< 1			6	6
Strontium:									
Dissolved	ug/l	300	84	134	105			6	0
Total	ug/l	290	50	107	70			6	0
Vanadium:									
Dissolved	ug/l	< 6			< 6			6	6
Zinc:									
Dissolved	ug/l	35	7	16.8	12.5			4	0
Total	ug/l	150	< 10		20			6	0

Table 5.--Statistical summary of water quality in study area by site and constituent (continued)

Parameter	Units	Maximum	Minimum	Mean	Median	P75	P25	Number of samples	Number not detected
	Station Number 03528000		Clinch River above Tazewell, Tennessee						
pH	standard	8.8	8.1	8.31	8.3	8.35	8.2	14	0
Acidity	mg/l							0	0
Alkalinity	mg/l	146	100	124	123			9	0
Specific conductance	us/cm	460	99	308	303	340	280	34	0
Dissolved oxygen	mg/l	13.2	8.1	10	9.8	10.7	8.7	14	0
Fecal coliform	colonies/ 100 ml	6000	61	1010	380	720	90	13	0
Fecal streptococci	colonies/ 100 ml	3300	11	873	470	1050	135	11	0
Nitrogen:									
NO2	mg/l	.03	< .01		< .01	< .01	< .01	14	12
NO3	mg/l	.93	.83					2	0
NO2 + NO3	mg/l	1	.49	.77	.79	.94	.6	14	0
NH4 (dis)	mg/l	.04	< .01		.01	.03	< .01	14	0
NH4 (tot)	mg/l	.07	< .01		.02	.03	.01	14	0
Total organic nitrogen	mg/l	1.6	.15	.46	.29	.39	.28	9	0
Phosphorus:									
Dissolved	mg/l	.04	< .01		.01	.02	< .01	14	5
Total	mg/l	.13	.01	.47	.03	.07	.02	14	0
Ortho-phosphorus	mg/l	.04	< .01		.01	.02	< .01	14	0

*note: mean pH is the simple mean of all measured sample pH's

Table 5.--Statistical summary of water quality in study area by site and constituent (continued)

Parameter	Units	Maximum	Minimum	Mean	Median	P75	P25	Number of samples	Number not detected
	Station Number 03528000			Clinch River above Tazewell, Tennessee					
Total organic carbon	mg/l	6.8	1.1	3.41	3.3	4.4	1.85	12	0
Sediment:									
Concentration	mg/l	717	3	250.6	300.5	423.5	66	78	0
% < .062mm	percent	99	45	86.9	87	96	81	74	0
Turbidity	NTU	32	1	18	21			3	0
Total dissolved solids	mg/l	175	141	163	173			3	0
Major ions									
Calcium	mg/l	42	34	38	38			3	0
Magnesium	mg/l	12	7.8	9.9	9.9			3	0
Sodium	mg/l	7.4	3.5	6	7.1			3	0
Chloride	mg/l	4.3	3	3.76	4			3	0
Potassium	mg/l	1.8	1.4	1.56	1.5			3	0
Sulfate	mg/l	30	22	25.3	24			3	0
Fluoride	mg/l	.1	.1	.1	.1			3	0
Silica	mg/l	7.4	2.4	5.67	7.2			3	0
Hardness	mg/l	150	120	137	140			3	0

Table 5.--Statistical summary of water quality in study area by site and constituent (continued)

Parameter	Units	Maximum	Minimum	Mean	Median	P75	P25	Number of samples	Number not detected
Station Number 03528000 Clinch River above Tazewell, Tennessee									
Aluminum:									
Dissolved	ug/l	30	10	20	20			3	0
Total	ug/l	8140	1260	4717	4750			3	0
Arsenic:									
Dissolved	ug/l	< .01			.01			3	3
Total	ug/l	< .01			.01			3	3
Barium:									
Dissolved	ug/l	38	34	35.3	34			3	0
Total	ug/l	< 100			< 100			3	3
Beryllium:									
Dissolved	ug/l	< .5			< .5			3	3
Total	ug/l	< 10			< 10			3	3
Cadmium:									
Dissolved	ug/l	< 1			< 1			3	3
Total	ug/l	1	< 1		< 1			3	2
Chromium:									
Dissolved	ug/l	< 1			< 1			3	3
Total	ug/l	< 1			< 1			3	3
Cobalt:									
Dissolved	ug/l	< 3			< 3			3	3
Total	ug/l	2	< 1		1			3	3

Table 5.--Statistical summary of water quality in study area by site and constituent (continued)

Parameter	Units	Maximum	Minimum	Mean	Median	P75	P25	Number of samples	Number not detected
Station Number 03528000 Clinch River above Tazewell, Tennessee									
Copper:									
Dissolved	ug/l	7	2	3.67	2			3	0
Total	ug/l	10	8	9.33	10			3	0
Iron:									
Dissolved	ug/l	23	7	13.7	11			3	0
Total	ug/l	2700	190	1730	2300			3	0
Lead:									
Dissolved	ug/l	2	< 1		1			3	1
Total	ug/l	8	7	7.33	7			3	0
Lithium:									
Dissolved	ug/l	15	7	10.3	9			3	0
Total	ug/l	20	< 10		10			3	1
Manganese:									
Dissolved	ug/l	8	2	4	2			3	0
Total	ug/l	150	30	107	140			3	0
Mercury:									
Dissolved	ug/l	.1	< .1		< .1			3	2
Total	ug/l	.1	< .1		< .1			3	2
Molybdenum:									
Dissolved	ug/l	< 10			< 10			3	3
Total	ug/l	< 1			< 1			3	3

Table 5.--Statistical summary of water quality in study area by site and constituent (continued)

Parameter	Units	Maximum	Minimum	Mean	Median	P75	P25	Number of samples	Number not detected
		Station Number 03528000		Clinch River above Tazewell, Tennessee					
Nickel:									
Dissolved	ug/l	1	< 1		1			3	1
Total	ug/l	6	< 1		3			3	1
Selenium:									
Dissolved	ug/l	< 1			1			3	3
Total	ug/l	< 1			< 1			3	3
Silver:									
Dissolved	ug/l	< 1			< 1			3	3
Total	ug/l	< 1			< 1			3	3
Strontium:									
Dissolved	ug/l	120	82	101	100			3	0
Total	ug/l	100	80	90	90			3	0
Vanadium:									
Dissolved	ug/l	< 6			< 6			3	3
Zinc:									
Dissolved	ug/l	140	4	51.3	10			3	0
Total	ug/l	50	< 10		20			3	1

Table 5.--Statistical summary of water quality in study area by site and constituent (continued)

Parameter	Units	Maximum	Minimum	Mean	Median	P75	P25	Number of samples	Number not detected
	Station Number 03531680			Powell River at Alanthus Hill, Tennessee					
pH	standard	8.3	7.7	8	8	8.1	7.9	55	0
Acidity	mg/l	25	5	9.8	9.9	9.9	5	29	0
Alkalinity	mg/l	157	62	96	91	122	77	28	0
Specific conductance	us/cm	402	165	247	233	278	201	58	0
Dissolved oxygen	mg/l	13.8	6.6	10.2	10.1	11.1	9.2	41	0
Fecal coliform	colonies/ 100 ml	7300	14	2020	760	3600	140	18	0
Fecal strep-tococci	colonies/ 100 ml	15000	3	3590	2150	5700	180	18	0
Nitrogen:									
NO2	mg/l	.01	< .01		< .01	< .01	< .01	56	51
NO3	mg/l	.93	.51	.78	.83			5	0
NO2 + NO3	mg/l	1.1	.23	.77	.76	.85	.69	56	0
NH4 (dis)	mg/l	.04	< .01		.01	.02	< .01	56	26
NH4 (tot)	mg/l	.07	< .01		.02	.03	.01	56	8
Total organic nitrogen	mg/l	1.4	.17	.57	.47	.81	.29	44	0
Phosphorus:									
Dissolved	mg/l	.04	< .01		.01	.02	.01	56	12
Total	mg/l	.41	.02	.11	.09	.15	.04	56	0
Ortho-phosphorus	mg/l	.03	< .01		.01	.01	< .01	56	27

*note: mean pH is the simple mean of all measured sample pH's

Table 5.--Statistical summary of water quality in study area by site and constituent (continued)

Parameter	Units	Maximum	Minimum	Mean	Median	P75	P25	Number of samples	Number not detected
		Station Number 03531680		Powell River at Alanthus Hill, Tennessee					
Total organic carbon	mg/l	19	1.1	6	4.9	8.8	3.1	48	0
Sediment:									
Concentration	mg/l	1040	2	229.6	192.5	313.5	82	72	0
% < .062mm	percent	96	13	77.6	83	89	78	74	0
Turbidity	NTU	140	.6	(1) biased with storm data				23	0
Total dissolved solids	mg/l	255	98	146	144	160	113	23	0
Major ions									
Calcium	mg/l	49	22	30.8	30	34	25	22	0
Magnesium	mg/l	12	4.7	6.96	6.55	8	5.2	22	0
Sodium	mg/l	13	2.2	5.6	4.6	7.3	2.8	22	0
Chloride	mg/l	4.2	1	2.71	2.5	3.1	2.4	22	0
Potassium	mg/l	2.7	1.3	1.9	1.7	2.1	1.7	22	0
Sulfate	mg/l	43	16	27.3	27	34	20	22	0
Fluoride	mg/l	.2	< .01		< .01	.01	< .01	22	12
Silica	mg/l	6.5	2.8	5.27	5.2	6	4.9	22	0
Hardness	mg/l	160	74	105	100	120	83	22	0

Table 5.--Statistical summary of water quality in study area by site and constituent (continued)

Parameter	Units	Maximum	Minimum	Mean	Median	P75	P25	Number of samples	Number not detected
Station Number 03531680 Powell River at Alanthus Hill, Tennessee									
Aluminum:									
Dissolved	ug/l	70	10	35.8	35	50	30	38	0
Total	ug/l	8400	50	2980	2600	4800	1600	37	0
Arsenic:									
Dissolved	ug/l	< .01			< .01			3	3
Total	ug/l	2	< .01		< .01	< .01	< .01	22	17
Barium:									
Dissolved	ug/l	49	24	35.9	37	39	33	22	0
Total	ug/l	100	< 100		< 100	< 100	< 100	22	19
Beryllium:									
Dissolved	ug/l	< .5			< .5			3	3
Total	ug/l	< 10			< 10			22	22
Cadmium:									
Dissolved	ug/l	< 1			< 1			3	3
Total	ug/l	2	< 1		< 1			22	21
Chromium:									
Dissolved	ug/l	2	< 1		< 1			3	2
Total	ug/l	16	< 1		3.5	9	2	22	3
Cobalt:									
Dissolved	ug/l	< 3			< 3			22	22
Total	ug/l	10	< 1		4	8	2	22	2

Table 5.--Statistical summary of water quality in study area by site and constituent (continued)

Parameter	Units	Maximum	Minimum	Mean	Median	P75	P25	Number of samples	Number not detected
Station Number 03531680 Powell River at Alanthus Hill, Tennessee									
Copper:									
Dissolved	ug/l	< 3			3			22	22
Total	ug/l	6	< 1		3.5			8	3
Iron:									
Dissolved	ug/l	810	9	58.3	38.5	56	20	38	0
Total	ug/l	16000	140	5570	4750	9500	2700	38	0
Lead:									
Dissolved	ug/l	1	< 1					3	1
Total	ug/l	80	3	20.3	14.5	27	10	22	0
Lithium:									
Dissolved	ug/l	5	< 4		< 4	< 4	< 4	22	17
Total	ug/l	20	< 10		< 10	< 10	< 10	22	17
Manganese:									
Dissolved	ug/l	11	< 10		4	6	< 10	38	16
Total	ug/l	890	< 10		295	500	170	38	1
Mercury:									
Dissolved	ug/l	< .1			< .1			3	3
Total	ug/l	.1	< .1		< .1	< .1	< .1	22	21
Molybdenum:									
Dissolved	ug/l	< 10			10			22	22
Total	ug/l	2	< 1		< 1	< 1	< 1	19	16

Table 5.--Statistical summary of water quality in study area by site and constituent (continued)

Parameter	Units	Maximum	Minimum	Mean	Median	P75	P25	Number of samples	Number not detected
Station Number 03531680 Powell River at Alanthus Hill, Tennessee									
Nickel:									
Dissolved	ug/l	2	< 1		1	1	1	23	16
Total	ug/l	23	1	10.3	9.5	16	5	22	0
Selenium:									
Dissolved	ug/l	< 1			1			22	22
Total	ug/l	< 1			< 1			22	22
Silver:									
Dissolved	ug/l	< 1			< 1			22	22
Total	ug/l	< 1			< 1			22	22
Strontium:									
Dissolved	ug/l	210	78	134	140	170	90	22	0
Total	ug/l	180	70	119	110	150	90	22	0
Vanadium:									
Dissolved	ug/l	< 6			< 6			22	22
Zinc:									
Dissolved	ug/l	12	< 3		7			3	1
Total	ug/l	140	< 10		65	90	30	22	1

Table 5.--Statistical summary of water quality in study area by site and constituent (continued)

Parameter	Units	Maximum	Minimum	Mean	Median	P75	P25	Number of samples	Number not detected
	Station Number 03532000			Powell River above Arthur, Tennessee					
pH	standard	8.4	8	8.2	8.3	8.3	8.1	15	0
Acidity	mg/l	5	5					2	0
Alkalinity	mg/l	154	104	122	120			7	0
Specific conductance	us/cm	410	190	284	285	320	232	15	0
Dissolved oxygen	mg/l	13	7.5	10	9.9	10.4	9.45	15	0
Fecal coliform	colonies/ 100 ml	730	20	270	160			9	0
Fecal streptococci	colonies/ 100 ml	2100	34	520	160			9	0
Nitrogen:									
NO2	mg/l	.02	< .01		< .01	< .01	< .01	15	13
NO3	mg/l	.92	.73					2	0
NO2 + NO3	mg/l	1.2	.54	.78	.73	.87	.69	17	0
NH4 (dis)	mg/l	.04	< .01		.02	.03	.01	17	4
NH4 (tot)	mg/l	.13	< .01		.02	.02	.01	17	3
Total organic nitrogen	mg/l	1.4	.28	.61	.47	.76	.28	10	0
Phosphorus:									
Dissolved	mg/l	.07	< .01		< .01	.01	< .01	17	12
Total	mg/l	.18	.01	.054	.03	.06	.02	17	0
Ortho-phosphorus	mg/l	.05	< .01		< .01	.02	< .01	17	10

*note: mean pH is the simple mean of all measured sample pH's

Table 5.--Statistical summary of water quality in study area by site and constituent (continued)

Parameter	Units	Maximum	Minimum	Mean	Median	P75	P25	Number of samples	Number not detected
Station Number 03532000 Powell River above Arthur, Tennessee									
Total organic carbon	mg/l	17	1	4.6	3.1	5	1.4	13	0
Sediment:									
Concentration	mg/l	871	1	335.8	333	448	211.5	120	0
% < .062mm	percent	98	50	83	86	89	82	103	0
Turbidity	NTU	31	.6					2	0
Total dissolved solids	mg/l	181	161					2	0
Major ions									
Calcium	mg/l	40	39					2	0
Magnesium	mg/l	12	8.6					2	0
Sodium	mg/l	9.2	7.8					2	0
Chloride	mg/l	2.9	2.7					2	0
Potassium	mg/l	1.5	1.4					2	0
Sulfate	mg/l	33	30					2	0
Fluoride	mg/l	.1	.1					2	0
Silica	mg/l	6.5	5					2	0
Hardness	mg/l	150	130					2	0

Table 5.--Statistical summary of water quality in study area by site and constituent (continued)

Parameter	Units	Maximum	Minimum	Mean	Median	P75	P25	Number of samples	Number not detected
Station Number 03532000 Powell River above Arthur, Tennessee									
Aluminum:									
Dissolved	ug/l	30	10					2	0
Total	ug/l	3400	50					2	0
Arsenic:									
Dissolved	ug/l	< 1						2	2
Total	ug/l	1	< 1					2	1
Barium:									
Dissolved	ug/l	39	37					2	0
Total	ug/l	< 100						2	2
Beryllium:									
Dissolved	ug/l	< .5						2	2
Total	ug/l	< 10						2	2
Cadmium:									
Dissolved	ug/l	< 1						2	2
Total	ug/l	< 1						2	2
Chromium:									
Dissolved	ug/l	1	< 1					2	1
Total	ug/l	3	1					2	0
Cobalt:									
Dissolved	ug/l	< 3						2	2
Total	ug/l	5	< 1					2	1

Table 5.--Statistical summary of water quality in study area by site and constituent (continued)

Parameter	Units	Maximum	Minimum	Mean	Median	P75	P25	Number of samples	Number not detected
Station Number 03532000 Powell River above Arthur, Tennessee									
Copper:									
Dissolved	ug/l	2	1					2	0
Total	ug/l	43	11					2	0
Iron:									
Dissolved	ug/l	20	6					2	0
Total	ug/l	5900	130					2	0
Lead:									
Dissolved	ug/l	1	< 1					2	1
Total	ug/l	12	4					2	0
Lithium:									
Dissolved	ug/l	5	5					2	0
Total	ug/l	< 10						2	2
Manganese:									
Dissolved	ug/l	< 10	1					2	1
Total	ug/l	420	7					2	0
Mercury:									
Dissolved	ug/l	.1						1	0
Total	ug/l	< .1						2	2
Molybdenum:									
Dissolved	ug/l	< 10						2	2
Total	ug/l	1	< 1					2	1

Table 5.--Statistical summary of water quality in study area by site and constituent (continued)

Parameter	Units	Maximum	Minimum	Mean	Median	P75	P25	Number of samples	Number not detected
	Station Number 03532000			Powell River above Arthur, Tennessee					
Nickel:									
Dissolved	ug/l	1	1					2	0
Total	ug/l	9	3					2	0
Selenium:									
Dissolved	ug/l	< 1						2	2
Total	ug/l	< 1						2	2
Silver:									
Dissolved	ug/l	< 1						2	2
Total	ug/l	< 1						2	2
Strontium:									
Dissolved	ug/l	170	160					2	0
Total	ug/l	150	100					2	0
Vanadium:									
Dissolved	ug/l	< 6						2	2
Zinc:									
Dissolved	ug/l	16	11					2	0
Total	ug/l	40	10					2	0

C. Specific Conductance

Sufficient data existed at the upstream sites in each basin to relate specific conductance with five water quality parameters: calcium, magnesium, sodium, total hardness, and total dissolved solids (table 6). The relationships can only be assumed valid at these sites, Clinch River near Looney's Gap, Tennessee and Powell River at Alanthus Hill, Tennessee.

D. Sediment Relationships

Suspended sediment was found to relate to seasonal effects, discharge, and a rainfall factor (table 7). The seasonal effects are described by the radian year (θ), where April 27th is defined as $\theta = 0$. Discharge effects are defined by the instantaneous discharge. The rainfall effects are defined with a modified R-factor where R is a product of total rainfall in inches and six-hour intensity in inches per hour (in/hr). All independent variables listed were found significant at the .95 level through t-test analysis.

E. Trace Constituent Equations

Total concentrations of numerous trace constituents were found to relate extremely closely with season, discharge, and the six-hour rainfall factor. Though these relationships apparently exist, insufficient data was collected to confidently include a numerical analysis of them.

Table 6.--Relation between selected parameters and specific conductance at upstream sites in study area

[where [parameter] is parameter concentration in milligrams per liter; (specific conductance) is specific conductance in microsiemens per centimeter]

[parameter] = A + B(specific conductance)

Parameter	A	B	R^2	Number of sample points
		CLINCH RIVER NEAR LOONEY'S GAP		
Calcium	11.47395	.084701	.821351	6
Magnesium	-1.57561	.038765	.914048	6
Silica	16.45	-.038280	.835286	6
Sodium	-22.26180	.102236	.897113	6
Sulfate	-26.14970	.197746	.762525	6
Total hardness	17.56874	.381641	.859158	6
Total dissolved solids	5.21274	.548749	.880619	6
		POWELL RIVER AT ALANTHUS HILL		
Calcium	6.32483	.102571	.897278	23
Chloride	-1.64722	.018935	.676922	23
Magnesium	-3.49252	.044677	.909487	23
Sodium	-7.68959	.056223	.925887	23
Sulfate	-9.86947	.159486	.744546	23
Total hardness	-1.53528	.451028	.980570	23
Total dissolved solids	12.35206	.544053	.940798	23

Table 7.--Regression relationship between suspended sediment and selected independant variables for the four sites in the study area

$$\log[S.S.] = C + B(t) + D(\sin\theta) + E(\log Q) + F(R)$$

[where [S.S.] is instantaneous suspended sediment concentration in milligrams per liter; t is a trend factor where January 1, 1989 is t=0; θ is the radian year with April 27 as θ=0; Q is instantaneous discharge in cubic feet per second; R is a rainfall factor defined by the weighted product of total precipitation and six-hour rainfall intensity; S.E. is standard error of the regression estimate; N is the number of samples used in regression analysis; C, B, D, E, and F are regression coefficients]

Station	C	B	D	E	F	R^2	Percent Error	N
Clinch River								
Looney's Gap	-4.608	.0019	.3333	1.6033	-.0002	.941	14.5	42
Tazewell	13.968		-3.1304	.3081	-.1422	.878	15.4	78
Powell River								
Alanthus Hill	-4.144		.1901	1.5602	.0072	.937	9.2	72
Arthur	-.433	.0008	.1442	.6229	.0038	.611	14.0	120

CHAPTER 6

DISCUSSION

A. Samples

Manual samples were collected at the four study sites over the hydrograph during individual storms to capture the rise, peak, and recession of the event (table 2). Samples were taken with a depth integrating sampler. Additionally, samples were collected during low and medium flow conditions (table 2), defined as samples taken when the basin had not received significant rain effects within 72 hours prior to sampling.

B. Field Measurements

Specific parameters were measured in the field. These include pH, specific conductance, dissolved oxygen, fecal coliform, fecal streptococcal, discharge, and water temperature. The remainder of the sampled chemical constituents were measured by USGS laboratory analysis. A mussel analysis was conducted by Clemson University, and settleable solids determination was conducted by International Technology Corporation.

Quality assurance and quality control was ensured by the standard methods utilized to collect these data (Guy and Norman, 1976). Additionally, standard USGS techniques are used and a secondary laboratory analysis of field measured constituents is conducted upon receipt of each sample to verify accuracy.

1. pH

A major factor effecting the pH of natural waters is the carbonate system. The Clinch River and Powell River Basins are located on sedimentary formations consisting of highly carbonated sandstones and limestones which act as pH controls. The pH of a natural system buffered in this manner typically ranges from 6.0 to 9.0 (Snoeyink and Jenkins, 1980). Between all sites the pH of the waters ranged from 7.2 to 8.8, and lowered during storm flow (table 8). Though storm flow pH averages were less than low and medium flow averages, the values were never measured below the natural range.

The median pH in the Clinch River, including all flows and all events, is approximately 8.22, and the median in the Powell River is approximately 8.10 (fig.13, table 5). The data indicates a lower average pH in the Powell River in both normal and storm flow events than the average pH of the Clinch River. A potential source of this variance is the higher percent of mined land in the Powell River basin. The greater mined area contributes a larger acid runoff, and therefore the pH will decrease. Additionally, more percent mined area exists in the upstream sites, the results of which are notable in the boxplots. It is noted that throughout the study period no measured pH value was outside the 6.0 - 9.0 range for a

Table 8.--Comparison of pH during low and storm flow

Station	Range	Low flow average	Storm flow average
Clinch River			
near Looney's Gap	7.2-8.6	8.23	8.12
above Tazewell	8.1-8.8	8.34	8.22
Powell River			
at Alanthus Hill	7.7-8.3	8.18	7.96
above Arthur	7.8-8.4	8.30	8.04

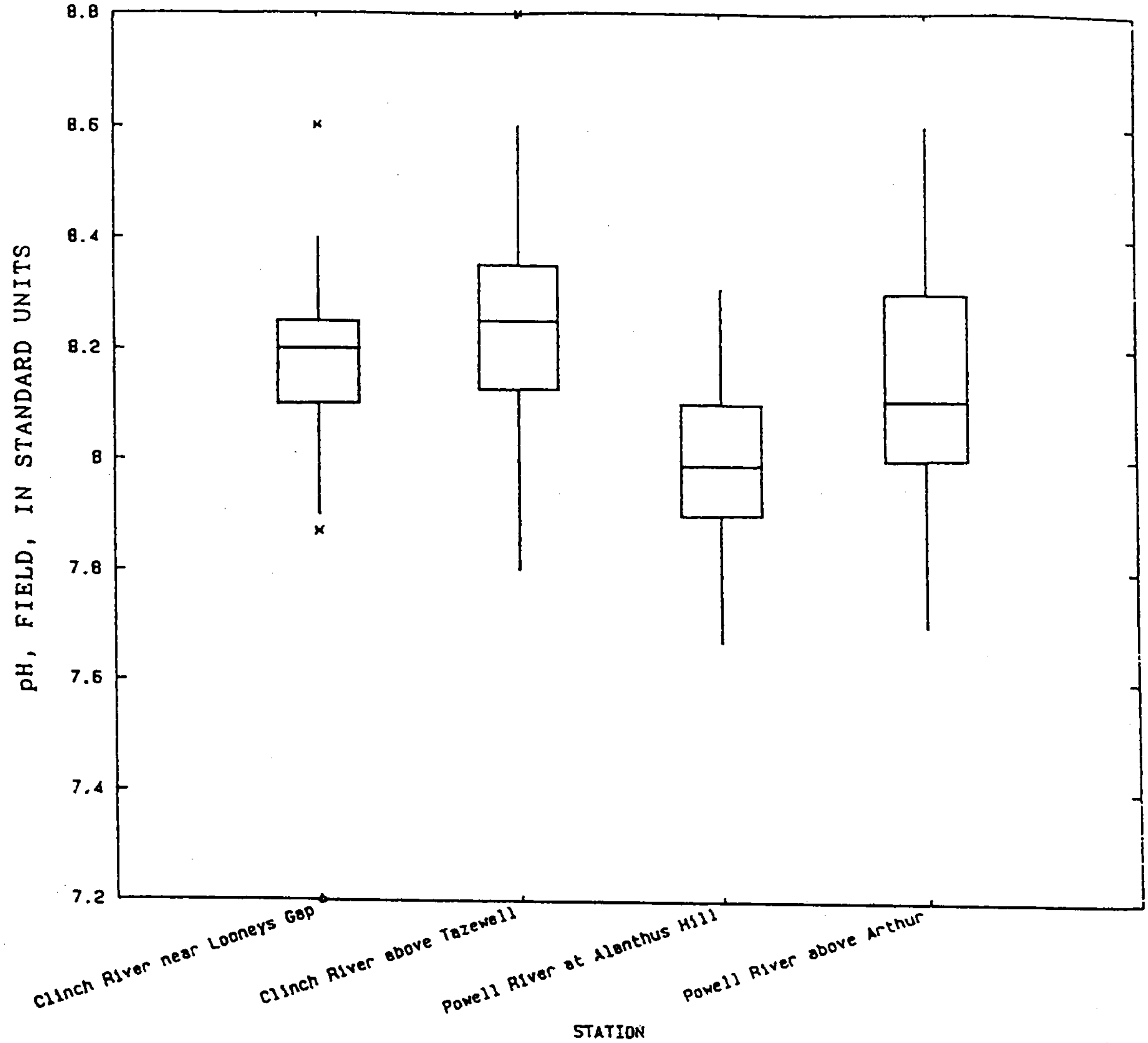

Figure 13.--Boxplots comparing pH variation by site

natural system, and therefore pH variance is not considered a problem.

2. Acidity and Alkalinity

Acidity and alkalinity are defined as the capacity of the river water to neutralize a strong base or a strong acid respectively. In natural waters these capabilities are derived from several different solute species and are evaluated through acid-base titration to a specific end point (Hem, 1992).

a. Acidity

There are a number of potential sources of acidity in the study area. The most probable is from the oxidation of sulfide minerals exposed to the air by the 6,513 acres of surface mining in the Clinch River basin (Clinch River Basin, 1992) and the 5,347 acres of surface mining in the Powell River basin (Powell River Basin, 1992) in Virginia.

In this study acidity was tested at three of the four sites (table 5) with measurements ranging from 5.0 milligrams per liter as calcium carbonate to 25 milligrams per liter as calcium carbonate (table 5). The higher acidity measurements occurred in winter months at higher discharges. These periods respond to the double effects of higher flow (a response to higher precipitation) and less ground cover to inhibit overland flow and sediment transportation. This indicates that increased capacity for runoff is probably moving the mining pollutants more efficiently into the waters and therefore increasing the acidity readings.

b. Alkalinity

Alkalinity resides in natural waters in many different species, the most common being the carbonate family. Over the pH range of the study, 7.2 to 8.8, the majority of the carbonate species in the system exists as bicarbonate. In waters with the characteristics of the study area, the alkalinity can be completely attributed to dissolved bicarbonate and carbonate without significant error (Hem, 1992).

Alkalinity varied at each site from lows near 92 milligrams per liter as calcium carbonate on the Clinch River near Looney's Gap and the Powell River at Alanthus Hill, to highs over 150 milligrams per liter as calcium carbonate on the Clinch River at Looney's Gap and the Powell River above Arthur (table 5). However, the median for all four sites only varies between 119 and 123 milligrams per liter as calcium carbonate (fig. 14). The alkalinity also increases at the downstream sites. These data indicate a validation of the pH data and once again reflect the larger percent mining impacts at the upstream sites.

3. Specific Conductance

Specific conductance is a measurement of the ability of

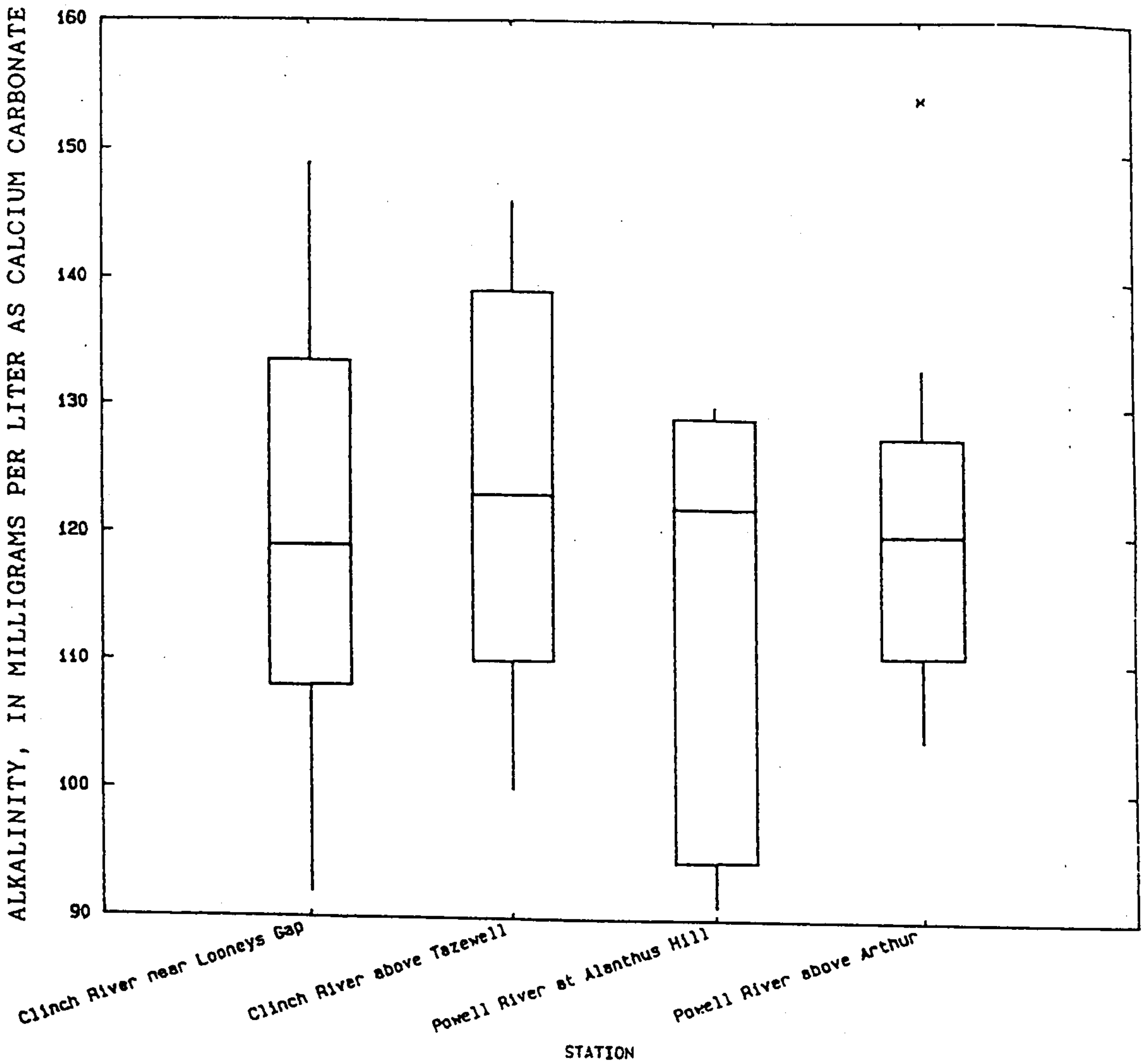

Figure 14.--Boxplots describing alkalinity variation by site

solution do conduct an electrical current and is related to the concentration of charged ions; therefore, pure water has a low conductance and a higher conductance indicates a higher ion concentration (Hem, 1992). Ranges of specific conductance in the study varied from a low of 100 microsiemens per centimeter to a high of 460 microsiemens per centimeter. The median values for the four sites ranged from 230 to 300 microsiemens per centimeter (fig. 15, table 5). These values indicate that the water in the study basin contains minimal dissolved ions in solution.

4. Dissolved Oxygen

Dissolved oxygen is the primary requirement for aerobic systems and therefore is necessary for many types of aquatic life. Dissolved oxygen did not vary significantly and was never measured below acceptable levels at any of the four sites (table 5). However, no measurements were taken during low flow periods in the early morning hours when dissolved oxygen is typically at its lowest level. Though there is no indication of low levels, additional samples are required to verify these results.

5. Fecal Indicator Bacteria

Fecal bacteria are indicators of stream contamination from warm blooded animal wastes. Although these bacteria may not themselves be harmful to contact, they indicate the

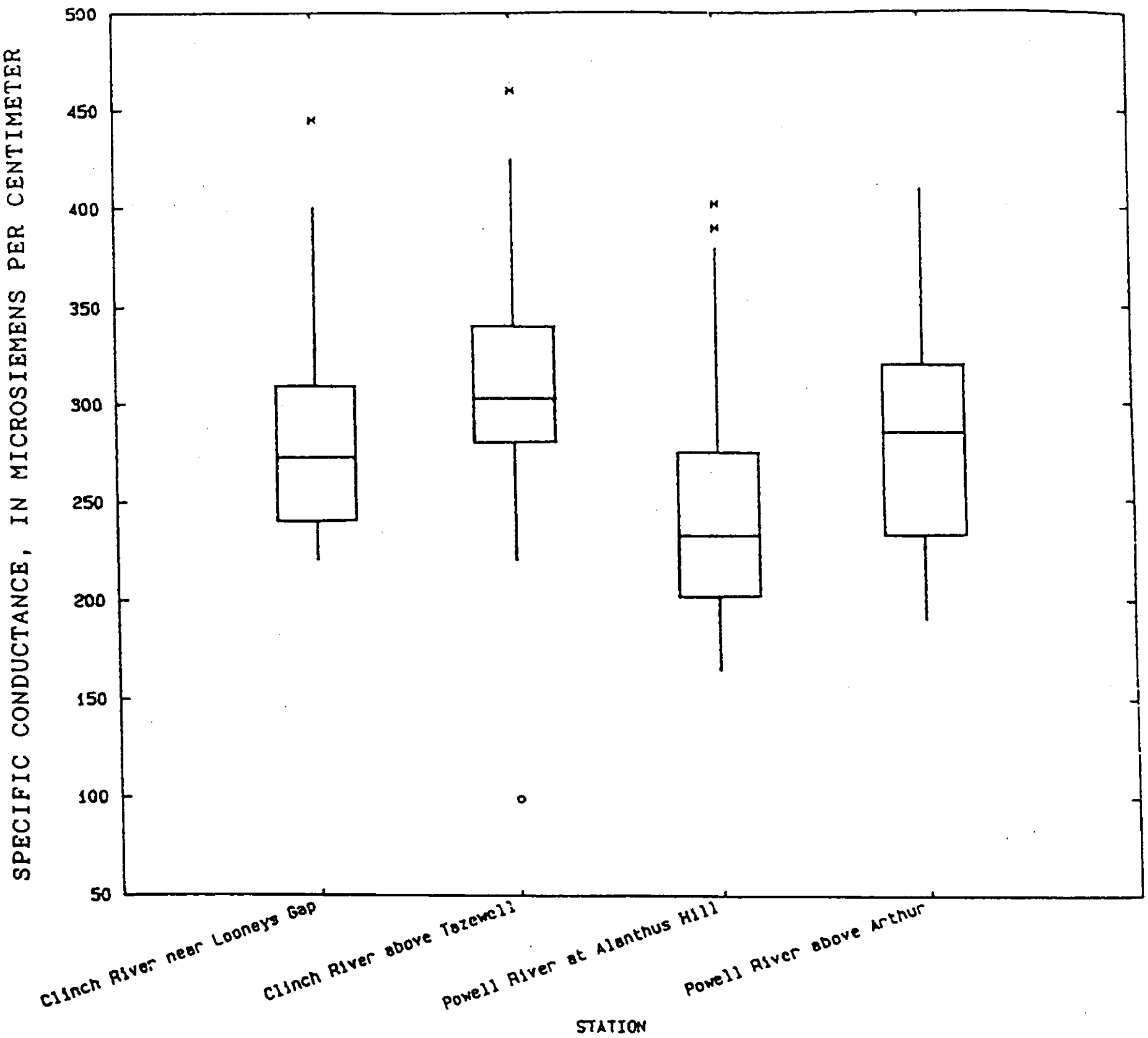

Figure 15.--Boxplots describing specific conductance variation by site

potential that more dangerous animal pathogens may be present in the water. These pathogens can be bacteria, virus, or protozoa and can have to potential to spread disease to humans. Both fecal coliform and fecal streptococci are measured in colonies per 100 milliliters of sampled water.

Fecal coliform and fecal streptococci have different characteristics which act in combination to help analyze pollutant sources and the extent of pollution. For example, the ratio of fecal coliform to fecal streptococci (FC/FS) helps determine the origin of pollution (table 9) (Clesceri, 1989).

A comparison of the ratios for the four sites (table 10) indicates that the pollutant source is potentially a mix of human waste discharge and runoff from livestock operations. No relation between discharge and the FC/FS ratio could be determined with the study data.

Two potential problems for this determination exist in the fecal streptococci count. Fecal streptococci have relatively short lives, so the sampling for determination of the concentration is only effective 24 hours downstream of the source. Also, their usefulness in determining the FC/FS ratio is not effective when the count is lower than 100 colonies per 100 milliliters (Clesceri, 1989). Therefore, without an accurate knowledge of contributing sources, the pollutant loads are presumed to be non-human.

Table 9.--Ratio of fecal coliform to fecal streptococcal for typical waste sources

Waste Source	Fecal coliform/fecal streptococcal ratio
Human	4.4
Duck	0.6
Sheep	0.4
Chicken	0.4
Pig	0.4
Cow	0.2
Turkey	0.1

Table 10.--Ratio of fecal coliform to fecal streptococcal for sites in study area

[FC/FS is fecal coliform to fecal streptococcal ratio]

Station	High FC/FS ratio	Low FC/FS ratio	Average ratio
Clinch River			
near Looney's Gap	1.71	0.10	0.63
above Tazewell	2.09	.22	.98
Powell River			
at Alanthus Hill	5.05	.07	1.02
above Arthur	1.87	.13	.89

a. Fecal Coliform

Fecal coliform colonies ranged from a low count of 5 colonies per 100 milliliters to a high of 7,500 colonies per 100 milliliters (table 5). The upstream sites, Clinch River near Looney's Gap and Powell River at Alanthus Hill, showed a greater range of readings, higher medians, and greater outliers than the downstream sites, Clinch River above Tazewell and Powell River above Arthur (fig. 16). This result indicates that the upstream sites are receiving greater pollution loading than the downstream sites.

The upstream sites exceeded the single sample regulatory limits (table 11) for recreation for 6 of 19 samples at the Clinch River near Looney's Gap and for 7 of 18 samples at the Powell River at Alanthus Hill. Additionally, the aquatic life criteria was exceeded for 4 samples at the Clinch River near Looney's Gap and for 3 samples at the Powell River at Alanthus Hill. The frequent exceedence of the recreation limits prohibits the upstream portion of the stream from being used for this purpose. Additionally, the fish and aquatic life limit was exceeded frequently enough to require concern for potential use. The downstream sites, especially on the Powell River, are within the required safety limits. These results indicate a lower pollution loading in the Tennessee portion of the basin and some dilutional effect being included at the downstream sites.

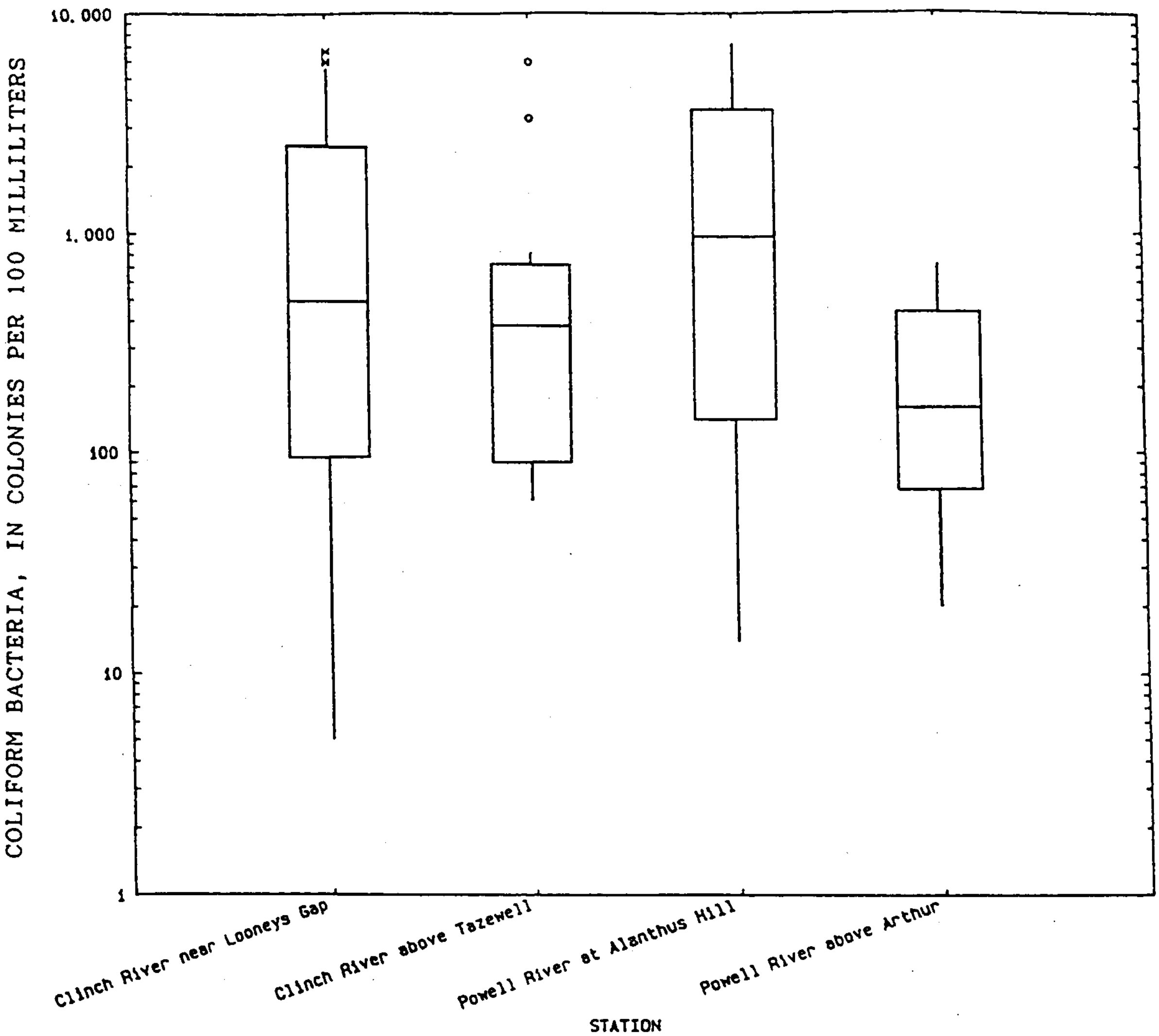

Figure 16.--Comparison boxplots of fecal coliform bacteria for each of the four sampling sites

Table 11.--Regulatory water quality constituent limits listed by use (from Tennessee Department of Environment and Conservation, 1991)

[°C, degrees centigrade; mg/l, milligrams per liter (parts per million); >, greater than; ml, milliliters; ug/l, micrograms per liter (parts per billion); N, nitrogen]

Constituent	Domestic water supply	Industrial water supply	Fish and aquatic life	Recreation	Irrigation	Wildlife and livestock watering	Federal or State regulated
pH	6.0-9.0	6.0-9.0	6.5-8.5	6.0-9.0	6.0-9.0	6.0-9.0	State
Temperature	30.5 °C	30.5 °C	30.5 °C	30.5 °C			State
Alkalinity			20 mg/l				Federal
Dissolved oxygen			> 5 mg/l				State
Fecal coliform	5000 colonies per 100 ml		5000 colonies per 100 ml	1000 colonies per 100 ml			State
Nitrates	10 mg/l						Federal
Ammonia			16.5 ug/l as N				Federal
Phosporus			.1 ug/l				Federal
Turbidity		No measureable limits defined in regulations					
Total dissolved solids	500 mg/l	500 mg/l					State
Chloride			10 ug/l				Federal
Hardness		No measureable limits defined in regulations					State

Table 11.--Regulatory water quality constituent limits listed by use (continued)

[°C, degrees centigrade; mg/l, milligrams per liter (parts per million); >, greater than; ml, milliliters; ug/l, micrograms per liter (parts per billion); N, nitrogen]

Constituent	Domestic water supply	Industrial water supply	Fish and aquatic life	Recreation	Irrigation	Wildlife and livestock watering	Federal or State regulated
Arsenic	50 ug/l		360 ug/l		100 ug/l		Both
Barium	1 mg/l						Federal
Beryllium			1100 ug/l	1.3 ug/l	100 ug/l		Both
Cadmium	10 ug/l		9 ug/l				State
Chromium	50 ug/l		16 ug/l	670 mg/l			State
Copper	1 mg/l		34 ug/l				Both
Iron	300 ug/l		1 mg/l				Federal
Lead	50 ug/l		198 ug/l				State
Manganese	50 ug/l		100 ug/l				Federal
Mercury	2 ug/l		2.4 ug/l	.15 ug/l			State
Nickel			2594 ug/l	4.6 mg/l			State
Selenium	10 ug/l		20 mg/l				State
Silver	50 ug/l		13 ug/l				State
Zinc	5 mg/l		210 ug/l				Both

b. Fecal Streptococci

Fecal streptococci ranged from a low of 3 colonies per 100 milliliters to a high of 20,000 colonies per 100 milliliters (table 5). The stations on the Tennessee and Virginia state line (Clinch River near Looney's Gap and Powell River at Alanthus Hill) showed wider ranges, higher medians, and higher overall values than the downstream stations (Clinch River above Tazewell and Powell River above Arthur) (fig. 17). This data seems to indicate a greater pollution source in the basin above the upstream sites. Though these data indicate higher pollutant loading at the upstream sites, there are no regulatory limits for fecal streptococci.

C. Laboratory Analysis

The remaining constituent samples were taken from the field and analyzed at the USGS Water Quality Laboratories in Ocala, Florida. The results of each constituent are described in this section.

Quality assurance/quality control was ensured by standard USGS guidelines and laboratory practice (Fishman and Friedman, 1989). These practices are tested by the USGS laboratory to maintain their own accuracy and results are returned immediately to the sampling USGS District.

1. Nutrients

Nutrients are frequently found at elevated concentrations

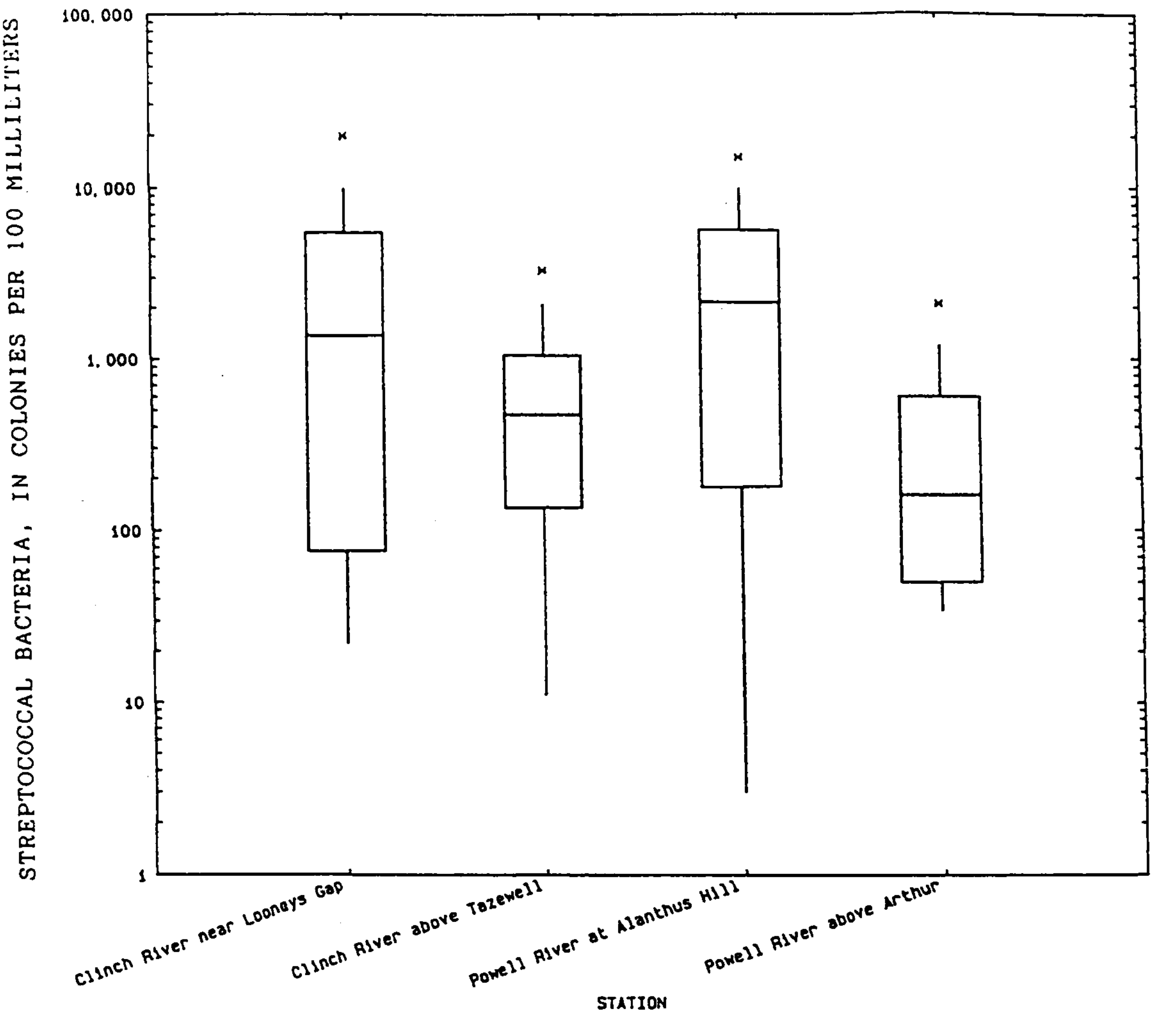

Figure 17.--Comparison boxplots of fecal streptococcal bacteria for each of the four sampling sites

in surface waters near agricultural lands because of the high concentrations of nitrogen and phosphorus in fertilizers. Additionally, grazed pasture land contributes nutrients from animal waste.

Nutrient loads were attempted to directly relate to discharge and season. The relation to time of year is due to the growing cycle, highly fertilized when initially growing, no fertilizer during winter months. The discharge term accounts for storm flows or periods of low flows. Annual loads were estimated based on these relationships. However, the error associated with this technique is too large to be utilized as an accurate estimation method.

a. Nitrogen

Many sources, natural and man-made, contribute to the nitrogen content of surface waters. Natural sources include precipitation, runoff, and erosion of fertile land. Biological nitrogen fixation by microorganisms, such as blue-green algae, also contribute nitrogen to surface waters. Man-made sources of nitrogen include agricultural, domestic (septic), and industrial waste-water discharge. Neither the levels of total nitrogen nor any of its components were found to be excessive for natural waters in any of the study samples (table 5, table 11).

b. Phosphorus

The occurrence of phosphorus in surface waters can be attributed to many natural processes as well as human activity. Weathering of phosphorus bearing rock, erosion or fertile sediments, and plant decay can contribute phosphorus to surface waters. Human contributions include domestic and industrial sewage effluent, synthetic detergents, and some fertilizers as three of the more common sources of phosphorus. Over the pH range in the study (table 8), phosphorus typically exists as H_2PO_4 and HPO_4 (Hem, 1992). For the four study sites the majority of phosphorus is in the HPO_4 state because of the average Ph levels of the rivers. Over the entire sampling data only an average of ten percent of phosphorus exists in the dissolved state. Values of phosphorus in the study were found to be consistent with natural waters (table 5, table 11).

2. Suspended Sediment

Suspended sediment can have numerous effects on water quality. Suspended sediment particles can adsorb some pesticides, nutrients, organic matter, and metals and more readily transport these compounds downstream. High sediment loads settle and have a direct adverse effect on the biological and aquatic communities by covering substrate and habitat. Finally, high sediment loads make surface waters unsuitable for recreation by destroying the aesthetic quality.

a. Concentration

Suspended sediment ranged from a low concentration of 1 milligram per liter to a high of 1,040 milligrams per liter (table 5). Annual loads were determined using relations determined in the study (table 12).

Sediment concentration varied between sites by upstream and downstream location, study trend, season, discharge, and rainfall. Between the four sites, the downstream locations (Clinch River above Tazewell and Powell River above Arthur) had higher mean concentrations, higher concentrations in the upper quartile, and greater standard deviations (table 5).

A regression over the total data set for each individual site revealed that a good relation exists between suspended sediment concentration and these factors at three sites. The Powell River above Arthur did not correlate well due to a single event of low discharge carrying extremely high sediment loads (table 7).

A trend factor, measuring the time during the study the sample was taken, is the first regression independent variable. To separate the data seasonally, each calendar year was divided into radians where April 27th is $\theta=0$, and the discharge was related to the sine of the radian date. A modified rainfall factor was determined based on a Theissen diagram for the rain gages involved in the study. A product of total rainfall and 6-hour intensity, readily available from

Table 12.--Estimated annual sediment loads for the Clinch River and Powell River Basins

[where (tons/mi^2) is tons per square mile]

Station	Total Annual Load (tons)	Annual Load Per Basin Area (tons/mi^2)	Percent Error
Clinch River			
near Looney's Gap	143,000	124	19
above Tazewell	143,000	97.0	13
Powell River			
at Alanthus Hill	110,000	216	25
above Arthur	126,000	184	11

the National Oceanic and Atmospheric Administration, weighted by the Thiessen diagram (table 4) was used to derive this factor. Instantaneous discharge measurements taken during the sampling event were the final regression factor.

The date used as 0=0 was optimized through regression to maximize the coefficient of determination. The rainfall factor was maximized using different approaches including the USLE "R", the intensity adjusted with the METCMP program, and six-hour intensity. A t-test analysis was conducted on each independent variable in the regression, and only factors significant to 95 percent were included in the final results.

b. Finer Suspended Sediment Fraction

The average percent of suspended sediment finer than 0.062 millimeters in diameter, the break point between sand and silt, varied between 85 and 89 percent. No correlation existed between discharge and percent finer than 0.062 millimeters. These percentages indicate that the majority of the sediment transported by both rivers consists of silts and clays. Each river appears to have a similar content of sand versus silt between sites, with the Clinch River made up of a slightly larger silt/clay component than the Powell River (fig. 18).

c. Turbidity

No regulatory limit is defined for turbidity, however typical drinking water after treatment typically contains less

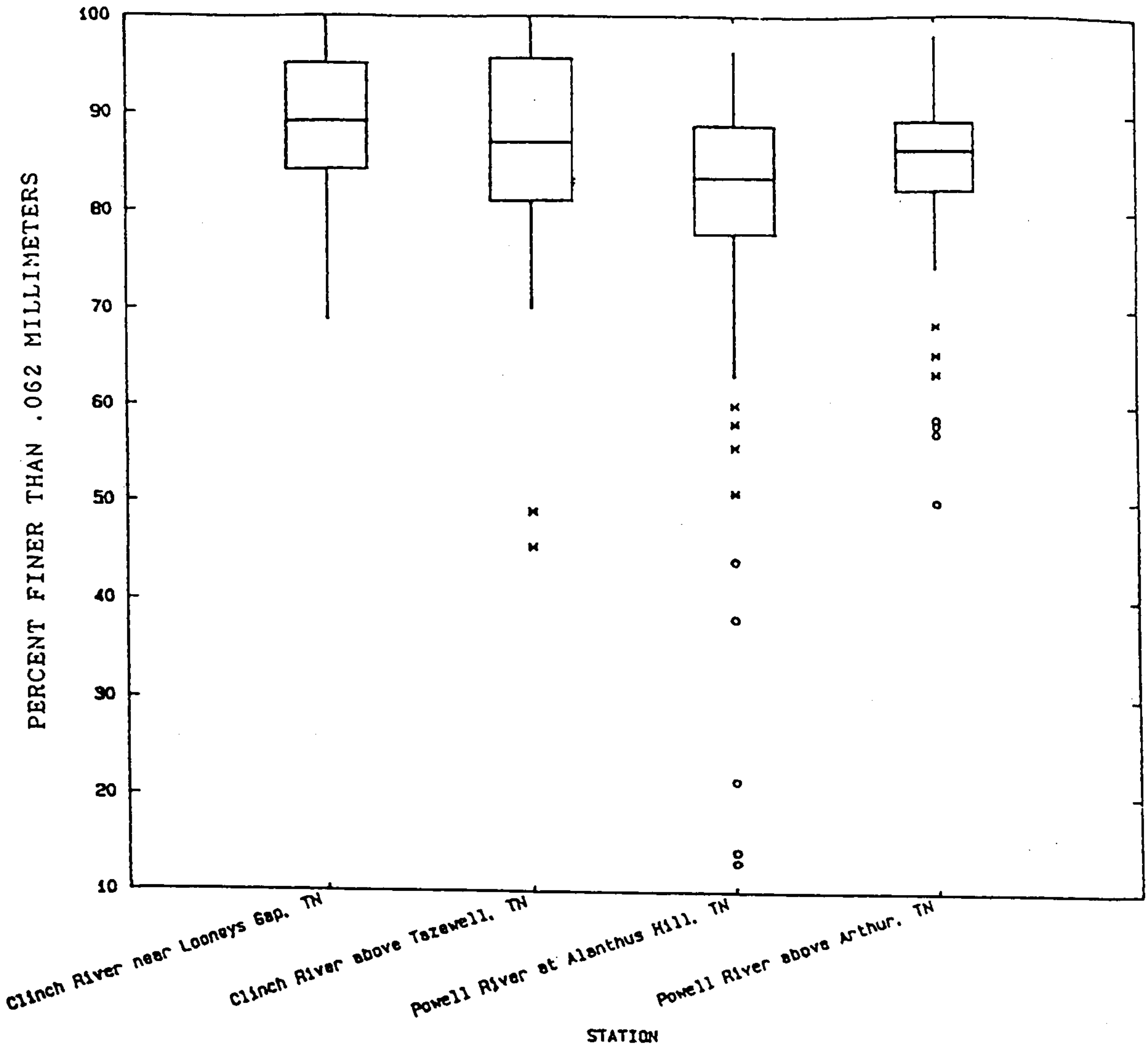

Figure 18.--Boxplots describing percent of sediment with diameter less than 0.062 millimeters listed by site

than one nephelometric turbidity unit (NTU). An NTU is a standard measurement that is based on an intensity of light scattered by a sample compared with a reference solution. High turbidity indicates a high content of suspended material which may contain adsorbed contaminants. Because of the relatively low turbidity values sampled in this study (table 5), turbidity is not considered a problem at the sampling sites.

d. Total Dissolved Solids

Total dissolved solids (TDS) consist of inorganic salts, some organic matter, and dissolved constituents. Throughout the study period the TDS levels remained well below the Tennessee regulated limit of 500 milligrams per liter for domestic and industrial water supply (table 11).

Total dissolved solids are directly related to specific conductance levels measured in the water. The relation between specific conductance and total dissolved solids is especially accurate at the stations on the Tennessee and Virginia state line (table 6).

3. Major Ions

The major ions determined in the study act as "fingerprints" for the type of water which is being sampled. Major ion determination included calcium, magnesium, sodium, potassium, sulfate, chloride, silica, and fluoride as well as total hardness, which is expressed in milligrams per liter as calcium carbonate (table 5).

By plotting these constituents on a Piper diagram (fig. 11) the sites can be compared for differences or similarities in ion content. The study measurements reveal that these sites are all predominantly of the calcium-bicarbonate type (fig. 11, fig. 19). These results are consistent with the surface geology of the basin.

Additionally, sufficient data existed at the upstream stations on both rivers to develop regression relationships between specific conductance and selected ion concentrations (table 6). These relationships can be used to make quick estimates of ionic composition from field measurements of specific conductance.

4. Trace Constituents

Twenty trace constituents were measured (table 5), and their levels were compared on an individual basis with the most stringent State of Tennessee or Federal regulatory standard (table 11). This revealed that of the trace constituents, copper, iron, lead, manganese, and zinc exceeded regulated limits.

At all four sites iron and manganese concentrations exceeded both the drinking water standards and the aquatic life standards frequently. Zinc concentrations exceeded the

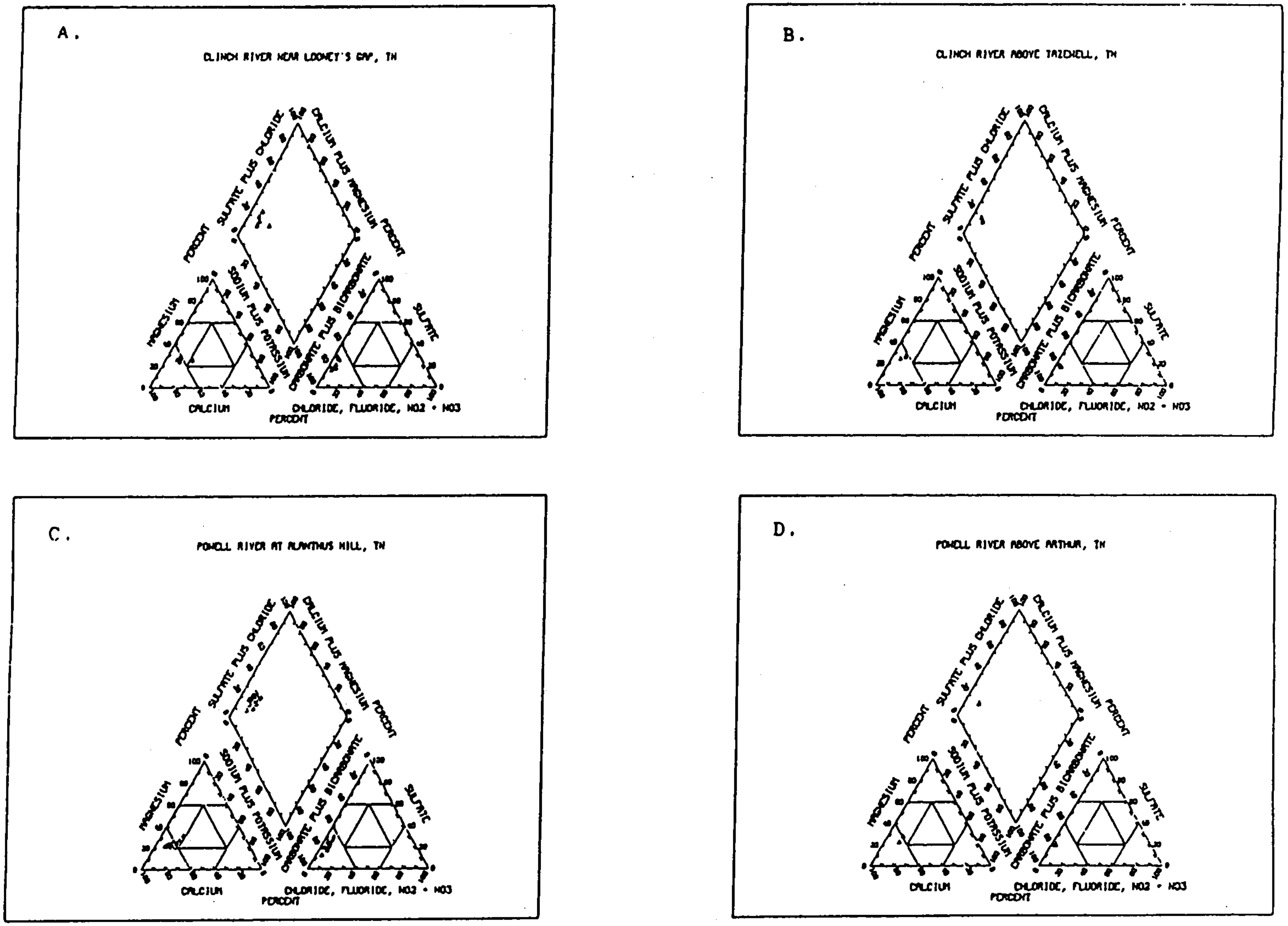

Figure 19.—Comparison Piper diagrams for the four surface water sites from study period data

aquatic life standard in one of six samples from the Clinch River at Looney's Gap, Tennessee and three of seven samples from the Powell River at Alanthus Hill, Tennessee. Copper concentrations exceeded the aquatic life standard in one of two samples from the Powell River above Arthur, Tennessee. Finally, lead concentrations exceeded drinking water standards in one of twenty samples from the Powell River at Alanthus Hill, Tennessee. Therefore, the majority of the exceeded standards occurred at the upstream sites and appear to dilute below regulated levels prior to reaching the downstream sites (table 5, table 11).

Additionally, total concentrations of trace constituents related to discharge, sediment concentration, season, and rainfall factor. Insufficient data was sampled to report the results in this document. However, excellent correlations between these factors and the total amounts of each trace constituent may warrant further investigation. The dissolved constituents did not correlate with these same variables.

The constituents which were measurable in the study revealed that for most constituents only a small fraction exists in the dissolved phase (figure 20). These trends are the same at all four sites. Strontium is the only element with dissolved concentrations higher than total concentrations. The reason for this difference again relates to the geology of the site. When carbonate areas form,

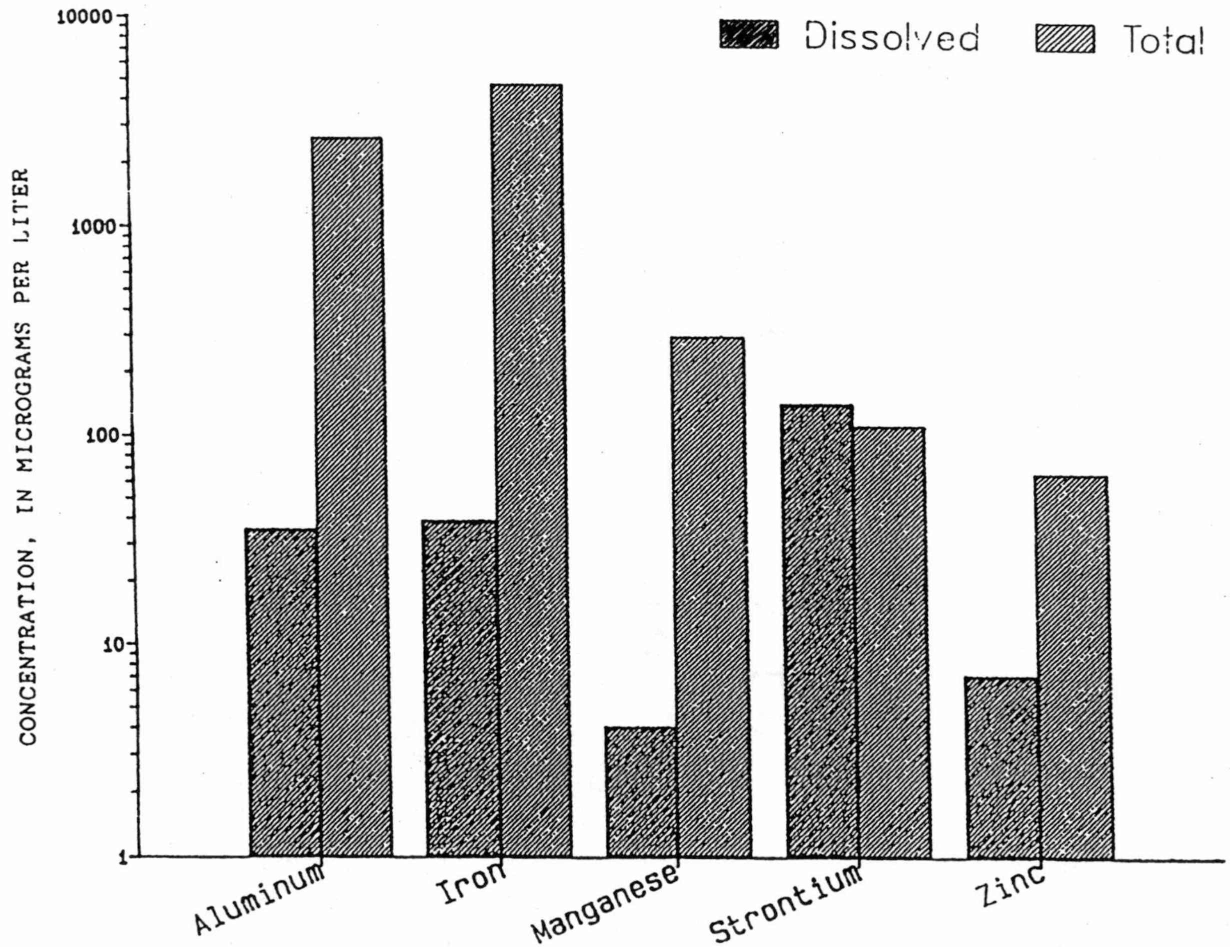

Figure 20.--Bar charts comparing dissolved and total concentrations of selected constituents for the Powell River at Alanthus Hill, Tennessee

strontium tends to accumulate in the lattice. As the carbonate species dissolves into fresh waters flowing over its geology the strontium dissolves out of the matrix as well. Therefore, in carbonate areas such as the study area, strontium concentrations can be expected to contain large dissolved components.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

This report analyzes the water quality at two points each on the Clinch River and Powell River in northeast Tennessee. The variation in land use is minimal and because the basins are so large the varying impacts were not detectable.

Basic water quality parameter concentrations of the river systems were not considered a problem. The pH levels at all four study sites were measured at levels consistent with sites in a carbonate geology and within regulatory levels. All dissolved oxygen levels were measured above the regulatory minimum criteria at all four sites, but should be remeasured at times typically critical to confirm these results.

Fecal bacteria were measured in exceedence of regulated criteria, primarily at the upstream sites. Bacteria levels at the downstream sites indicate some dilutional effects between the upstream and downstream sites on both rivers. This result indicates a higher animal waste component affecting the upstream sites.

Nutrient equations used to predict annual loads were found to inaccurately estimate the real loads with the independent variables used and should not be applied to the Clinch River and Powell River basins. However, regression analysis shows that sediment concentration relates well to a trend factor, season, rainfall, and discharge, and can be applied in the study area. In making these predictions it is noted that only three years of discrete sampling were used in determining the relationships between constituents. As more data becomes available these relationships may change.

Though mining operations occur in the headwaters of the study area, the water quality impacts further downstream are apparently minimal. Parameters measured with greater than regulatory limits in the study were copper, iron, lead, manganese, and zinc. These exceedence values are typically found at the upstream sites. Therefore, the downstream sites are being diluted with a greater undeveloped area of the watershed and the values are reduced.

B. Recommendations for Future Study

The seasonality effects were described with a minimal variety of sampling over the annual cycle. Future study should more fully cover the entire year and the equations modified as necessary to more accurately define these effects. To more accurately define the seasonal effects, the regression analysis should include a factor allowing the seasonal start date to vary. This task can be accomplished by including another constant in the seasonal independent variable such $\sin(\theta + \text{constant})$, and allowing the constant to solve itself for each individual site.

More sampling of total concentrations of trace constituents should be taken. The relationship between these constituents and season, discharge, and rainfall appears to be an accurate fit, but insufficient data was taken to report the findings in this study.

The rainfall factor may be more accurately described with a known 30-minute intensity. Future inclusion of this technique in research should base the rainfall on actual 30-minute intensity and compared to the variation with 6-hour intensity.

Finally, this data should be utilized as a planning tool for the more data intensive and detailed analysis that the NAWQA program will bring to the region when the Upper Tennessee River Basin project initiates in 1995. The findings of this report can be expanded as the data base in both the Clinch River Basin and the Powell River Basin increases over the course of the three year data collection period.

BIBLIOGRAPHY

BIBLIOGRAPHY

American Society of Civil Engineers, 1984, ASCE Manual 54: American Society of Civil Engineers, 63 p.

Barfield, B.J., R.C. Warner, and C.T. Haan, 1981, Applied Hydrology and Sedimentology for Disturbed Areas: Oklahoma Technical Press, 603 p.

Bingham, R.H., 1985, Low Flows and Flow Duration of Tennessee Streams Through 1981: U.S. Geological Survey Water Resources Investigations Report 84-4347, 325 p.

Clarke, C.D., and P.G. Waldo, 1988, Sediment Yield From Small Watersheds: Soil Conservation Service, 23 p.

Clesceri, Lenore S., Arnold E. Greenberg, and R. Rhodes Trussel, 1989, Standard Methods for the Examination of Water and Wastewater: American Public Health Association, 1193 p.

Clinch and Powell River Valley Association, 1963, Clinch-Powell Valley, Summary of Resources with Inventory Supplements: Tennessee Valley Authority, 263 p.

Clinch River Basin, 1992, Land and Water Resources Study for Hydrologic Units: U.S. Department of Agriculture, Soil Conservation Service, 58 p.

Crawford, Charles D., James R. Slack, and Robert M. Hirsch, 1983, Nonparametric Tests for Trends in Water-Quality Data Using the Statistical Analysis System: U.S. Geological Survey Open-File Report 83-550, 102 p.

Curtis, Neville, 1980, Prediction of the Concentration of Fine Sediment in Channels From Single Storm Events: U.S. Department of Agriculture, Soil Conservation Service, Geology Note 2, 7p.

Dotson, Donald L., 1993, Land Use/Land Cover of the Clinch River and Powell River Basins in Northeast Tennessee (unpublished): U.S. Department of Agriculture, Soil Conservation Service, 2 p.

Einstein, H.A., 1950, The Bed-Load Function for Sediment Transport in Open Channel Flow: U.S. Department of Agriculture Technical Bulletin No. 1026.

Evaldi, R.D., and J.G. Lewis, 1986, Water-Quality Appraisal of Nasqan Stations Below Impoundments, Eastern Tennessee: U.S. Geological Survey Water resources Investigations Report 85-4171, 50 p.

Fenneman, Nevin M., 1938, Physiography of the Eastern United States: McGraw-Hill Book Company, 714 p.

Ferguson, R.I., 1986, River Loads Underestimated by Rating Curves: Water Resources Research, Volume 22, Number 1, 3 p.

Fishman, Marvin J., and Linda C. Friedman, 1989, Methods for Determination of Inorganic Substances in Water and Fluvial Sediments: Techniques of Water-Resources Investigations of the United States Geological Survey, 545 p.

Floyd, Robert J., 1965, Tennessee Rock and Mineral Resources: Tennessee Division of Geology Bulletin 66, 119 p.

Freeze, R. Allan, and John A. Cherry, 1979, Groundwater: Prentice-Hall Books, 604 p.

Glysson, G. Douglas, 1987, Sediment-Transport Curves: U.S. Geological Survey Open-File Report 87-218, 47 p.

Graf, W.H., 1984, Hydraulics of Sediment Transport: Water Resources Publications, 513 p.

Guy, Harold P., 1970, Fluvial Sediment Concepts: Techniques of Water-Resources Investigations of the United States Geological Survey, 55 p.

Guy, Harold P., and Vernon W. Norman, 1976, Field Methods for Measurement of Fluvial Sediment: Techniques of Water -Resources Investigations of the United States Geological Survey, 59 p.

Hem, John D., 1985, Study and Interpretation of the Chemical Characteristics of Natural Water: U.S. Geological Survey Water Supply Paper 2254, 263 p.

Hirsch, Robert M., 1981, Techniques of Trend Analysis for Monthly Water-Quality Data: U.S. Geological Survey Open-File Report 81-488, 30 p.

Hudson, N.W., 1971, Raindrop Size: Soil Conservation, 56 p.

Hufschmidt, Peter W., and others, 1981, Hydrology of Area 16 Eastern Coal Province, Virginia and Tennessee: U.S. Geological Survey Open-file Report 81-204, 68 p.

Jenkinson, John J., and Steven A. Ahlstedt, 1988, Quantitative Reassessment of the Freshwater Mussel Fauna in the Powell River, Tennessee and Virginia: Tennessee Valley Authority, River Basin Operations, Water Resources, 28 p.

Jenkinson, John J., and John H. Heuer, 1986, Cumberlandian Mollusk Conservation Program: Tennessee Valley Authority, Office of Natural Resources and Economic Development, Division of Air and Water Resources, 120 p.

Lane, E.W., E.J. Carlson, and O.S. Hanson, 1949, Low Temperature Increases Sediment Transportation in Colorado River: American Society of Civil Engineers, Civil Engineering Volume 16.

Larson, J.D., 1985, Selected Hydrologic Data for the Powell River Basin in Wise County, Virginia: U.S. Geological Survey Open-File Report 85-186, 22 p.

Lucas, Broder F., and E.P. Callahan, 1936, Major Rural Land Use Problems in Tennessee: Tennessee State Planning Commission, 23 p.

Luther, Edward T., 1977, Our Restless Earth: The Geological Regions of Tennessee: University of Tennessee Press, 94 p.

Miller, Carl R., 1951, Analysis of Flow-Duration, Sediment -Rating Curve Method of Computing Sediment Yield: U.S. Department of Interior, Bureau of Reclamation, 55 p.

Miller, Robert A., 1974, The Geological History of Tennessee: Tennessee Division of Geology Bulletin 74, 63 p.

National Oceanic and Atmospheric Administration, 1974, Climates of the States, Volume 1 - Eastern States: Water Information Center, 480 p.

National Oceanic and Atmospheric Administration, 1988-1993 (monthly), Climatological Data for Tennessee: National Climatic Data Center, 24 p.

Ormsby, Lindell, 1990, METCMP Statistical Rainfall Analysis Package: United States Geological Survey Computer Program.

Ott, R. Lyman, 1993, An Introduction to Statistical Methods and Data Analysis: Duxbury Press, 1049 p.

Porterfield, George, 1972, Computation of Fluvial-Sediment Discharge: U.S. Geological Survey Techniques of Water Resources Investigations, Book 3, Chapter C3, 66 p.

Powell River Basin, 1992, Land Use and Water Resources Study for Hydrologic Units: U.S. Department of Agriculture, Soil Conservation Service, 51 p.

Rantz, Saul E., 1968, A Note on Relating Sediment Discharge to Stream Discharge: U.S. Geological Survey Water Resources Division Bulletin, July-September 1968, 2 p.

Sagona, Frank J., and Tammy L. Carrol, 1991, Aerial Inventory of Land Uses and Nonpoint Pollution Sources - Powell and Upper Clinch River Watersheds: Tennessee Valley Authority, Water Quality Department, 71 p.

Schlotzhauer, Sandra D., and Ramon C. Littell, 1991, SAS System for Elementary Statistical Analysis: SAS Institute Inc., 417 p.

Smoot, J.L., T.D. Liebermann, R.D. Evaldi, and K.D. White, 1991, Surface Water Quality Assessment of the Kentucky River Basin, Kentucky: Analysis of Available Water-Quality Data Through 1986: U.S. Geological Survey Open-File Report 90-360, 209 p.

Snoeyink, Vernon L., and David Jenkins, 1980, Water Chemistry: John Wiley and Sons, 463 p.

Stevens, Herbert H., and Chih Ted Yang, 1989, Summary and Use of Selected Fluvial Sediment-Discharge Formulas: U.S. Geological Survey Open-File Report 89-4026, 97 p.

Tennessee Department of Environment and Conservation, 1991, State of Tennessee Water Quality Standards: Tennessee Department of Environment and Conservation, Bureau of Environment, Division of Water Pollution Control, Chapters 1200-4-3 and 1200-4-4, 45 p.

Tennessee Department of Public Health, 1978, Water Quality Management Plan for the Clinch River Basin: Tennessee Department of Public Health, Division of Water Quality Control, 62 p.

Tennessee/Virginia Joint Task Force, 1990, Conserving the Unique Values of the Clinch and Powell Rivers: A Report to the Governors of Virginia and Tennessee, 23 p.

Trimble, Stanley W., and William P. Carey, 1984, Sediment Characteristics of Tennessee Streams and Reservoirs: U.S. Geological Survey Open-File Report 84-749, 32 p.

Tukey, J.W., 1977, Exploratory Data Analysis: Addison-Wesley Publishing Company.

U.S. Department of Agriculture, 1966, Procedure for Determining Rates of Land Damage, Land Depreciation, and Volume of Sediment Produced by Gully Erosion: USDA Soil Conservation Service, Technical Release No. 32, 18 p.

U.S. Geological Survey, 1986, Annie User Interface Package: Computer Program Written in UNIX Format.

U.S. Geological Survey, 1991, METCMP Statistical Rainfall Analysis Package: Computer Program Written in UNIX Format.

Waldo, Peter G., 1985, Sediment Yields From Large Watersheds: Soil Conservation Service, 23 p.

Weaver, Jess D., and Charles R. Gambel, 1993, Flood Frequency of Streams in Rural Basins of Tennessee: U.S. Geological Survey Water-Resources Investigations Report 92-4165, 38 p.

Williams, Laurie A., and S.J. Klaine, 1993, In Situ Juvenile Mussel Bioassays Conducted in the Clinch and Powell Rivers: Clemson University, 9 p.

Williams, Laurie A., and S.J. Klaine, 1993, Juvenile Mussel Laboratory Bioassays with Stormwater Runoff Samples from the Clinch River (Looney's Gap, TN): Clemson University, 9 p.

Williams, Laurie A., and S.J. Klaine, 1993, Juvenile Mussel Laboratory Bioassays with Stormwater Runoff Samples from the Powell River (Alanthus, TN): Clemson University, 10 p.

Wischmeier, W.H., and D.D. Smith, 1978, Agriculture Handbook No. 537: U.S. Department of Agriculture, 58 p.

Younger, Mary Sue, 1993, Survey of Statistical Methods Parts 1 and 2: Statistics 531 Class Notes, 290 p.

Zipper, Carl E., Golde I. Holtzman, Sungsue Rheem, and Gregory K. Evanylo, 1992, Surface Water Quality Trends in Southwestern Virginia, 1970-1989: I. Seasonal Kendall Analysis: Virginia Water Resources Research Center, Virginia Polytechnic Institute and State University, 99 p.

VITA

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Larry graduated from The Kamehameha Schools in May 1984 and began his studies at the United States Military Academy at West Point. He graduated from USMA in May 1988 and served the next four years as an infantry officer with the 101st Airborne Division, including combat operations in Desert Shield and Desert Storm.

He returned to graduate school at the University of Tennessee in June 1992, and began working at the United States Geological Survey in Knoxville, Tennessee in November of that year. Upon graduation, he will begin employment with Bechtel Environmental in Oak Ridge, Tennessee.