SPATIAL ANALYSIS OF SUSPENDED SEDIMENT CONCENTRATIONS, BUFFALO RIVER WATERSHED, NY

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ABSTRACT: Potential sediment sources for two major tributaries (Cazenovia and Buffalo Creeks) to the Buffalo River were identified through spatial analysis. Sampling for total suspended sediment (TSS) took place at four sites on Cazenovia Creek and three sites on Buffalo Creek between 6/22/92 and 6/7/93. Mean TSS concentrations for the Buffalo Creek sites were similar (28.6-35.8 mg l^{-1}). Mean TSS concentrations for Cazenovia Creek were 42.6 mg l^{-1} for the site furthest downstream and 14.3-18.8 mg l^{-1} for the upstream sites. One site on each creek was located at a U.S. Geological Survey gauge and hourly discharge data were used to develop sediment rating curves. A power function was deemed most appropriate and r^2 values were 59% and 55% for Cazenovia and Buffalo Creeks, respectively. Student's t-tests indicated that the regression slopes were significantly different (α=0.05) from zero. Much of the upper portion of the watershed is characterized by woods and farmland, but prior to joining the Buffalo River the creeks pass through several small communities and receive industrial, commercial, and municipal discharges. To evaluate sediment sources from the rural areas, all farms tracts within 1000 ft of the creeks were considered possible contributors and the centroids of those tracts were digitized using GRASS 4.0 (Geographic Resources Analysis Support System), a personal computer GIS maintained at the Erie County Soil Conservation Service (SCS). A total of 477 tracts in Erie County had edges within 1000 ft of the waterways. An SCS soil erodibility index was used to determine which of the 477 tracts were highly erodible land (HEL). The Buffalo Creek watershed had the largest proportion of HEL in the Buffalo River watershed, at 59% of the total HEL acreage and Cazenovia Creek was 31% HEL. The similar mean TSS concentrations for the Buffalo Creek sites appears to be related to the distribution of highly erodible land. The increase in mean TSS concentrations between the up and downstream sites on Cazenovia Creek indicates that this reach of the creek has an active sediment source.

INTRODUCTION

Suspended sediment in a river system can impact the quality of the river. For example, high concentrations of suspended sediment can negatively impact fish growth and resistance to disease (Herbert and Merkins, 1961; Berg and Northcote, 1985; Redding and Schreck, 1987). Many pollutants preferentially are adsorbed and transported by suspended sediment (Irvine et al., in press; Allen, 1986; and Benes et al., 1985). In addition, upstream sediment input to a harbor or reservoir can result in the need of dredging (Hall, 1955). Therefore, understanding sediment dynamics and sources is essential in developing habitat remediation strategies and landuse management. Sources of suspended sediment in a river may include bed and bank erosion, overland erosion, and discharges from anthropogenic activities (e.g. industrial, municipal discharges, and combined sewer overflows).

The objectives of this paper are to evaluate suspended sediment concentrations for two creeks in the Buffalo River watershed (Buffalo and Cazenovia Creeks) and rural runoff as a sediment source to the creeks. The first objective is met primarily through the development of sediment rating curves and comparisons of suspended sediment concentration means. The second objective is achieved through the use of a Geographic Information System (GIS) available at the Erie County Soil Conservation Service, East Aurora, NY.

METHODS

Sample Area and Field Methods

The Buffalo River basin has a total drainage area of 1,244 km^2 and is fed by three major tributaries: Buffalo Creek; Cazenovia Creek; and Cayuga Creek (Figure 1). Landuse within the watershed varies. Much of the upper portion of the watershed is characterized by woods and farmland, but prior to joining the Buffalo River, the creeks also pass through several small communities and receive industrial, commercial, institutional, residential and municipal discharges.

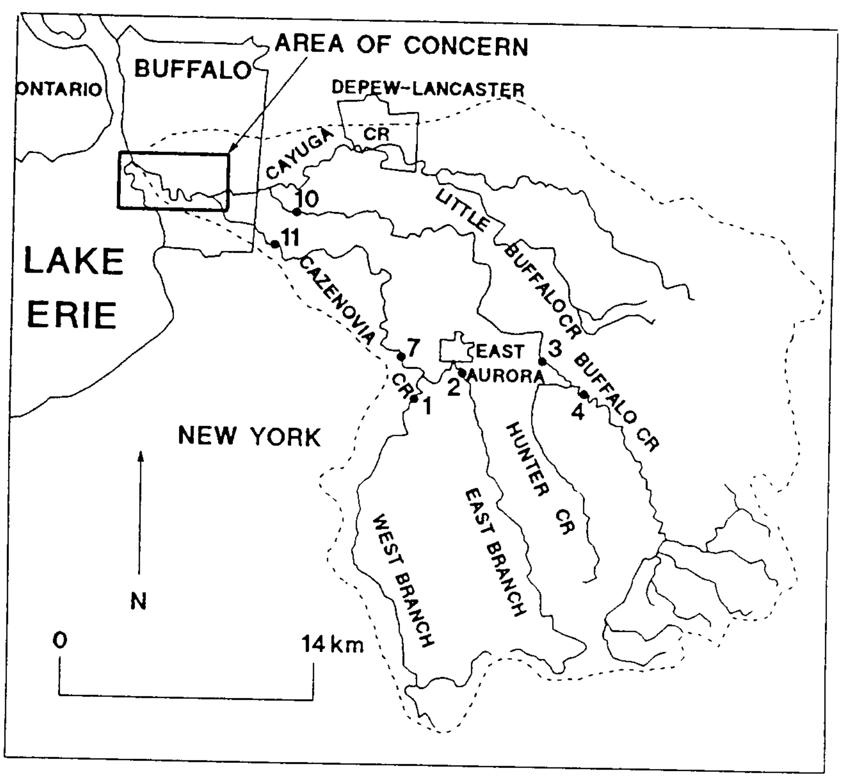

Figure 1 Buffalo River watershed and suspended sediment sample locations.

SPATIAL ANALYSIS OF SUSPENDED SEDIMENTS

Sampling was done at U.S. Geological Survey (USGS) gauge stations for Buffalo and Cazenovia Creeks (sites 10 and 11, respectively) (Figure 1). In addition, there were two upstream sites on Buffalo Creek (sites 3 and 4), and three upstream sites on Cazenovia Creek (sites 7,1, and 2) (Figure 1). Sampling for suspended sediment routinely occurred on a weekly basis at all sites and additional storm event sampling took place at the gauged sites, 10 and 11.

For each site, two 1000 ml bottles were filled at mid channel, 0.6 of the total depth below the surface. During low flow periods, the samples were inserted into the water by hand and uncapped at the appropriate depth. A Wheaton Sub Surface Grab Sampler II, with an 18 ft extension was used to collect samples during high flow periods.

Laboratory Analysis

Determination of suspended sediment concentrations took place in the Soils Laboratory at Buffalo State College. Samples were passed through 0.45µm Millipore filters (Millipore HAWP 047) to determine suspended sediment concentrations. The general filtration procedure followed that described under Standard Method 209 C (Water Pollution Control Federation, 1985).

Development of Rating Curves

Hourly discharge values were available from the USGS for sites 10 and 11 and these were used with the observed suspended sediment concentrations to develop sediment rating curves through least squares regression. The simple least squares regression was done using the Minitab software package (release 8) on a personal computer.

Potential Sediment Loading Inventory

As a first approximation, to evaluate sediment sources from the rural areas, all farm tracts that had a field edge within 1,000 ft of the creeks were considered possible contributors of sediment. The centroids of those tracts were identified on aerial photographs (scale, 1:7,920) housed at the Erie County Soil Conservation Service (SCS). The tract centroids subsequently were plotted on USGS topographic maps (scale, 1:24,000). The GRASS 4.0 (Geographical Resources Analysis Support System), a personal computer GIS maintained at the Erie County SCS , was used to digitize the centroids from the USGS topographic maps. A UNIX version of CAMPS (Computer Aided Management and Planning System) ultimately was linked to GRASS. It then was used to develop an inventory of physical and operational characteristics of the farm tracts, including information on: field acreage; soil type; presence and size of a grass buffer between the tract edge and the receiving water body; and a Highly Erodible Land (HEL) classification which considers slope steepness, slope length, soil type, and crop type.

RESULTS

The mean and range of sampled values for total suspended sediment (TSS) are summarized in Table 1.

Table 1 Summary of total suspended sediment concentrations for Cazenovia and Buffalo Creeks

	Site	Mean TSS, mg l^{-1}	Range TSS, mg l^{-1}	n*
Cazenovia Creek	1	16.0	0.20-194	24
	2	14.3	0.20-119	22
	7	18.8	0.30-212	23
	11	42.6	0.50-408	24
Buffalo Creek	3	35.9	0.50-414	23
	4	28.6	1.70-238	22
	10	35.8	0.42-453	24

* For comparison purposes, additional storm event data for sites 10 and 11 that were used in regression analysis were not included in the calculation of the means.

Results of the suspended sediment sampling indicate that there is a large range of suspended sediment concentrations. Low concentrations occurred during low-flow, steady state conditions, while high concentrations occurred during periods of high discharge.

The mean suspended sediment concentrations appear to be increasing from the up to downstream site on Cazenovia Creek and as a first step, a probability plot correlation coefficient test (Filliben, 1975) was used to evaluate the normality of the TSS concentration distributions. The distributions could not be considered normally-distributed (α=0.05), but a logarithmic transformation of the data and subsequent retesting indicated the data were log-normally distributed (α=0.05). Application of Student's t-test, strictly speaking, assumes the data are normally-distributed. However, Mendenhall (1979) noted that the t-test is not sensitive to this assumption, provided the data have a "mound" shape, which is true of a log-normal distribution. F-tests indicated that the standard deviations were significantly different (α=0.05), as a result, unpooled t-tests were used to evaluate differences between mean TSS concentrations the different sites.

The differences of the upstream sites (1,2,7) and downstream site (11) mean concentrations for Cazenovia Creek were significant at the 0.2 or 0.3 significance level. By comparison, the concentrations for Buffalo Creek were different at the 0.7 or higher significance level. As the mean TSS concentrations suggest (Table 1), there is no difference between concentrations for Buffalo Creek.

Sediment Rating Curves

Sediment rating curves were developed for sites 10 and 11 using least squares regression. A logarithmic form of the regression equation was deemed most appropriate for two reasons. First, the non-logarithmic regression equations predicted negative sediment concentrations at low discharge values and this is not physically possible. Second, residual analysis indicated that the non-logarithmic equations this is not physically possible. Second, residual analysis indicated that the non-logarithmic equations violated some assumptions of regression (i.e. normal distribution and homoscedastic) (Draper and Smith, 1981). Hydrologic systems often are non-linear and logarithmic transformations frequently are used to linearize the equations even though backtransformation of estimates may be biased (Jansson, 1985; Koch and Smillie, 1986 Ferguson, 1987; Irvine and Drake, 1987). The final form of the regression equation was expressed as a power function:

$$C=aQ^b$$

where C is estimated sediment concentration (mg l^{-1}), Q is discharge (cfs), and a and b are constants. The r^2 values for Buffalo and Cazenovia Creeks were 59% and 55%, respectively, which indicated that a large amount of variance was explained by discharge. The rating curves for Buffalo and Cazenovia creeks are shown in Figures 2 and 3, respectively. Student's t-tests indicated that the regression slopes were significantly different (α=0.05) from zero.

Potential Sediment Loading Inventory

A total of 477 tracts were identified that had a field edge within 1,000 ft of a waterway. As stated previously, the GRASS GIS was used to digitize the centroids of the 477 tracts (Figure 4). Through the use of the GRASS GIS and CAMPS, it was calculated that 105 (22%) of the 477 tracts were classified as HEL and some type of conservation practice is utilized on all of these farm tracts. Conservation practices are not used or listed for 372 of the 477 tracts. The total HEL acreage within the 477 tracts is approximately 5,242 acres, which likely is a 5-10% underestimate since data are not listed for some tracts (J. Whitney, SCS, pers. comm.). Fifty-one of the 477 tracts (11%) have poor grass buffers (<20 ft) between field edges and waterways, while 426 of the 477 tracts have medium to very good grass buffers (20-100 ft) between field edges and waterways. The Buffalo Creek watershed (upstream of site 10) had the largest proportion of HEL, at 59% of the total HEL acreage, followed by the Cazenovia Creek watershed (upstream of site 11) with 31% of the total HEL acreage and the Cayuga Creek watershed had 10% of the total HEL acreage.

DISCUSSION AND CONCLUSIONS

Buffalo Creek was part of an SCS bank stabilization program which began in 1953, through which 19 miles of the 21 mile creek were stabilized in some manner (e.g. sloping banks faced with stone). The SCS inspects the bank stabilization measures yearly to maintain and repair them when necessary (J. Whitney, SCS, pers. comm.). Based on their sampling, Parsons et al. (1963) attributed a 40% reduction in TSS concentrations from 1953 to 1961 in the Buffalo Creek to the bank stabilization. On the other hand, only 9 of the 30 miles of Cazenovia Creek have had any bank stabilization implemented. This suggests that the current TSS concentrations for Buffalo Creek, especially during storm events, primarily are from rural runoff, rather than bank erosion.

It appears that the Buffalo Creek watershed is more "erodible" than the Cazenovia Creek watershed. The TSS concentrations at sites 3, 4, and 10 are similar (Figure 1 and Table 1), but concentrations at sites 3 and 4 are higher than the upstream sites 1, 2, and 7 on Cazenovia Creek. The higher erodibility associated with the Buffalo Creek watershed may, in part, be a function of the higher proportion of HEL within 1,000 ft of the waterways, particularly, as noted above, since much of the Buffalo Creek has been stabilized. This suggests that bank material is not a source of TSS. In addition,

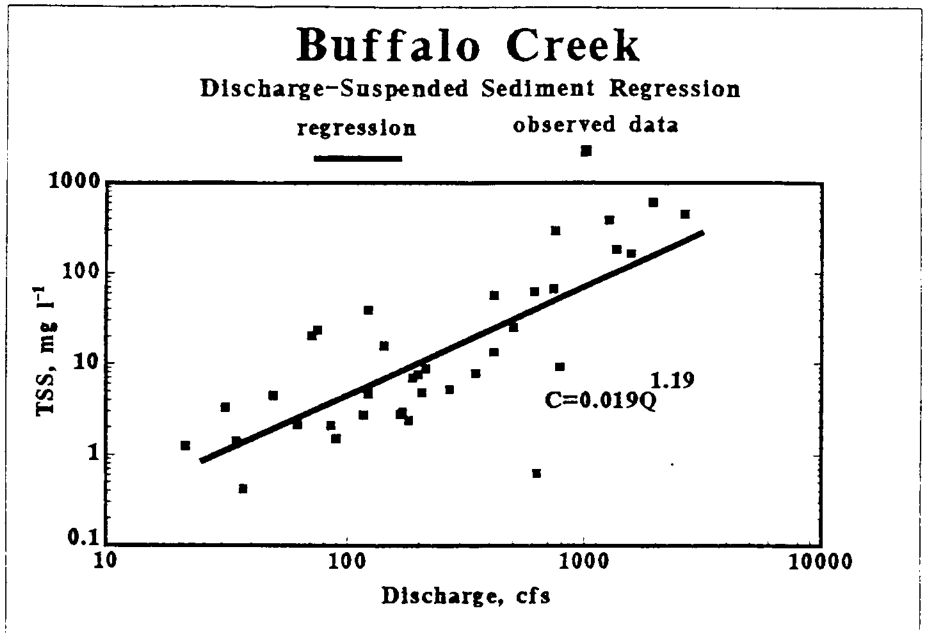

Figure 2 Suspended sediment rating curve for Buffalo Creek. Additional storm event data was included in regression analysis (n=43).

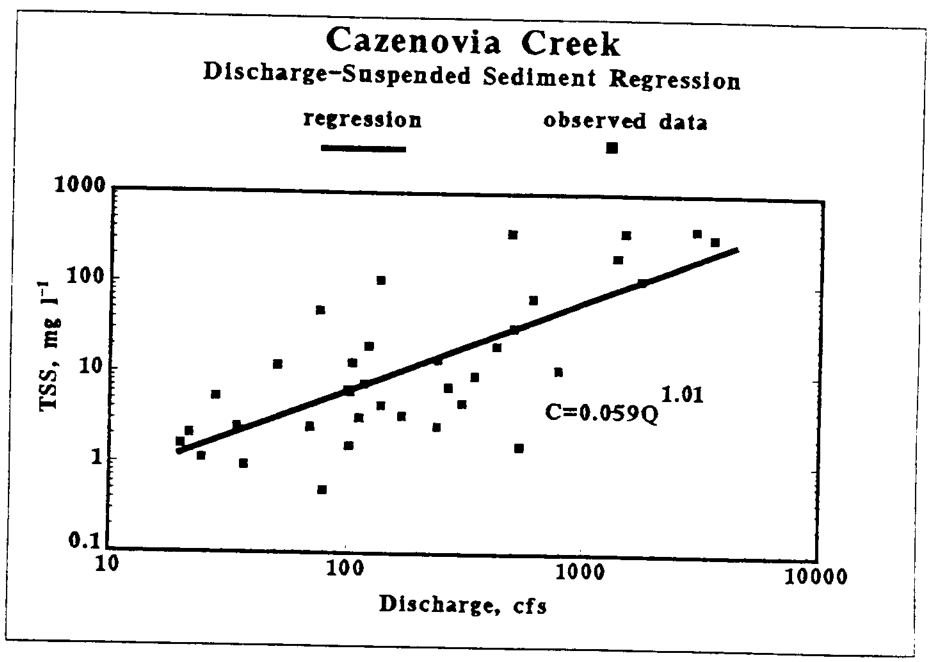

Figure 3 Suspended sediment rating curve for Cazenovia Creek. Additional storm event data was included in regression analysis (n=43)

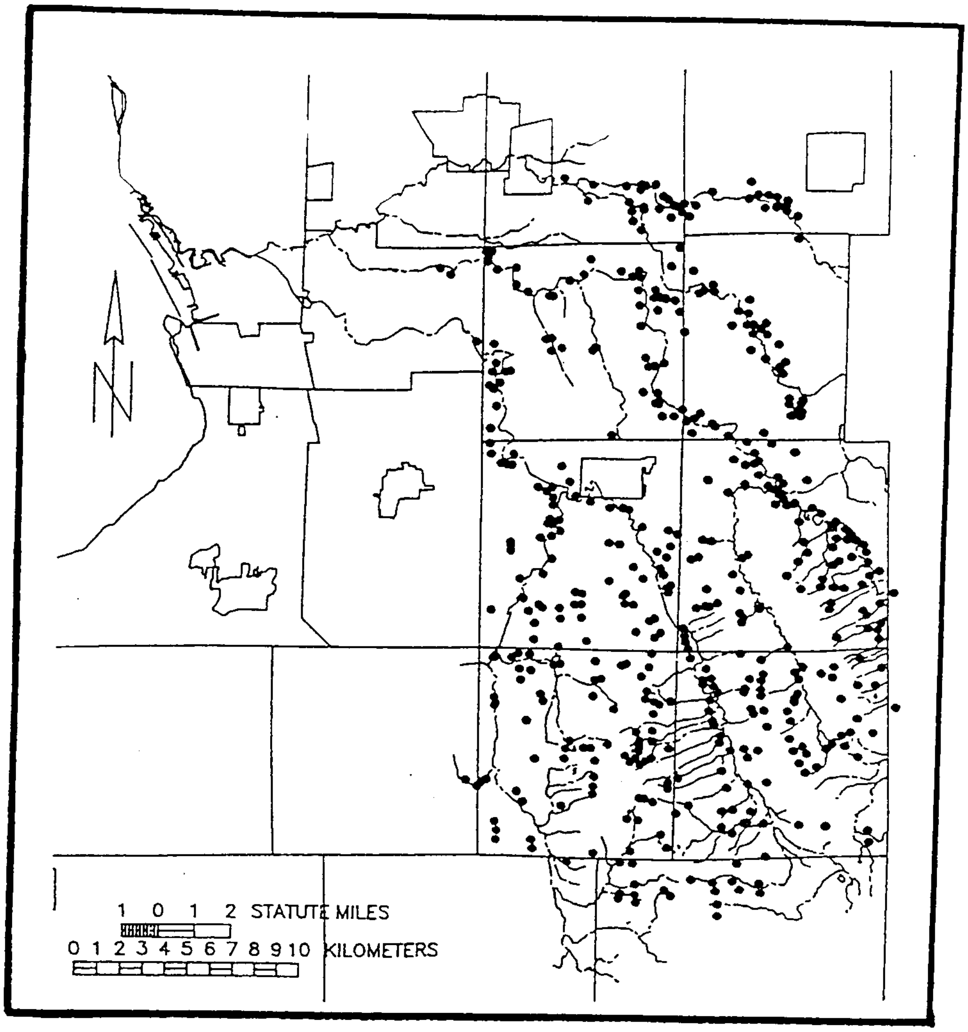

Figure 4 Location of farm tracts in Erie County having a field edge boundary within 1,000 ft of a waterway (•).

much of the creek bed area in the tributaries is bedrock (Sargent, 1975 and Pettibone and Irvine, 1994) and would provide limited contribution of TSS. Finally, the exponent of the regression equation is greater for Buffalo Creek (Figures 2 and 3) indicating that the same increase in discharge for both creeks would result in a higher TSS concentration for Buffalo Creek. The regression results are consistent with the suggestion that the HEL may account for a large proportion of the TSS entering Buffalo Creek.

The results of this study may be used to encourage additional bank stabilization and conservation tillage in targeted areas. Due to the fact that the Buffalo River and harbor are dredged for navigational purposes, a reduction in dredging costs may occur if TSS concentrations decreased in the tributaries of the river. The variability associated with TSS concentrations within the Buffalo River watershed may impact fish growth. For example, largemouth bass are resident to the river and their optimal TSS range is between 5 and 25 mg l^{-1} with levels less than 5 mg l^{-1} resulting in low productivity (Twomey et al., 1984). As a result, low-flow, steady state conditions, as well as high discharge TSS concentrations may not be suitable for largemouth bass. In conclusion, the quality of a river can be impacted by TSS concentrations and landuse management may be used to help control concentrations.

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