TOTAL MAXIMUM DAILY LOAD (TMDL) DEVELOPMENT

For Sediment in the

Little Shoal Creek Watershed

May 09, 2000

EPA
United States
Environmental Protection
Agency

Region 4
serving the southeast

APPROVAL PAGE

for *Sediment* in Little Shoal Creek Watershed, GA

The Little Shoal Creek was included on the State of Georgia's 1998-303(d) List because of biological and habitat impairment. Sediment was determined to be the pollutant of concern. Due to the restrictive timeframe imposed by the February 2000 Order on Consent in the Georgia TMDL lawsuit to propose and finalize certain TMDLs, this level 1 screening level TMDL was developed that provided estimates of the stream's loading. The Little Shoal Creek TMDL sediment loading capacity is expressed as an equation relating allowable sediment concentration versus stream flow factor and is based on sediment concentrations and flows measured in a biologically unimpacted healthy stream. (USEPA 1999a, Appendix A).

The working hypothesis for the sediment target is that if the Little Shoal Creek maintains sediment concentrations within the 95% confidence levels of the sediment-discharge relationship for a biologically unimpacted healthy stream, then the Little Shoal Creek will remain stable and not be biologically impaired due to sediment. Conversely if the sediment concentrations exceed the unimpacted stream's sediment-discharge relationship, the stream will become unstable and may become biologically impaired. The Little Shoal Creek TMDL is expressed as the following relationship between sediment concentration and a stream flow factor.

$X = 58.3 * (Y)^{1.37}$

Where:

X = natural occurring sediment concentration in the Little Shoal Creek

Y = Little Shoal Creek daily stream flow / Little Shoal Creek mean stream flow

Using this relationship, the Little Shoal Creek watershed loads for the low flow year would be estimated at 4.2 million kg/year and the average annual loading capacity is estimated at 52 million kg/year.

APPROVED BY:

MAY 09 2000

Robert F. McGhee, Director

Date

Water Management Division

EPA-Region 4

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Executive Summary

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Using this relationship, the Little Shoal Creek watershed loads for the low flow year would be estimated at 4.2 million kg/year and the average annual loading capacity is estimated at 52 million kg/year.

Further analysis needs to be completed on this watershed, additional data needs to be collected to better define the sediment loadings and the TMDL needs to be revisited and revised as additional information becomes available. A schedule for completion of the future phases of this TMDL is provided later in this document. It is further recommended that the Little Shoal Creek watershed be considered a high priority for any sediment reduction Best Management Practices (BMPs) for agriculture, forestry, construction, urban development or any other land disturbing activities.

Introduction

Section 303(d) of the Clean Water Act (CWA) as Amended by the Water Quality Act of 1987, Public Law 100-4, and the EPA's Water Quality Planning and Management Regulations [Title 40 of the Code of Federal Regulation (40 CFR), Part 130] require each State to identify those waters within its boundaries not meeting water quality standards applicable to the waters' designated uses. The identified waters are prioritized based on the severity of pollution with respect to designated use classifications. TMDLs for all pollutants violating or causing violation of applicable water quality standards are established for each identified water. Such loads are established at levels necessary to implement the applicable water quality standards with seasonal variations and margins of safety. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a water body, based on the relationship between pollution sources and in-stream water quality conditions, so that states can establish water-quality based controls to reduce pollution from both point and nonpoint sources and restore and maintain the quality of their water resources.

Location:

Little Shoal Creek Tributary to Chattooga River

Reach file number:	03060102 155
HUC:	03060102

River Basin:	Savannah River Basin
County:	Hart
Watershed Size:	6.5 square miles
Map:	Figure 1

Problem Definition

The 303(d) listing cause of impairment was biological and habitat impairment. (EPA 1999a, Appendix B) Field studies confirmed the pollutant of concern to be sediment causing habitat impairment in the stream due to excessive sedimentation. Because of the limited data, the current watershed sediment loading to the river cannot be quantified

Target Identification

Point source(s)

No point sources are located in the watershed

Nonpoint sources (in addition to natural or normal sources):

Due to lack of monitoring data and other information on the watershed, estimates for the nonpoint source sediment contributions cannot be made, at present.

- Agriculture – sediment loads were not quantified
- Forestry - sediment loads were not quantified
- Urban - sediment loads were not quantified
- Roads - sediment loads were not quantified

Stream sediment sources

- Eroding banks – sediment loads were not quantified

- Down-cutting of stream bottom - sediment loads were not quantified
- Lack of riparian buffer zone – sediment loads were not quantified

Background or natural loading

Background loading values were determined from the reference stream flows and sediment concentrations.

Background

Water Quality:	STORET Station GAEPD-01006001
Flow:	USGS Station 02191000
Other Data:	EPA BASINS database (EPA 1998)

Numeric Targets and Sources - Model Development

Narrative Standard

Maintain biological integrity of the waters of the State – Georgia's Water Quality Standard is established in Georgia's Rules and Regulations for Water Quality Control, Chapter 391-3-6, Revised November 23, 1998. Georgia Regulation 391-3-6-.03(2)(a).

Numeric Target

The working hypothesis for the sediment target is that if the Little Shoal Creek maintains sediment concentrations within the 95% confidence levels of the sediment-discharge relationship for a biologically unimpacted healthy stream, then the Little Shoal Creek will remain stable and not be biologically impaired due to sediment. Conversely, if the sediment concentrations exceed the unimpacted stream's sediment-discharge relationship, the stream will become unstable and may become biologically impaired.

The Little Shoal Creek TMDL target is expressed as the following relationship between sediment concentration and a stream flow factor.

$$X = 58.3 * (Y)^{1.37}$$

Where:

X = natural occurring sediment concentration in the Little Shoal Creek

Y = Little Shoal Creek daily stream flow / Little Shoal Creek mean stream flow (See Appendix C)

The flow records from 1970 to 1997 were evaluated and used, in conjunction with the above equation, to determine the daily flows and corresponding daily sediment concentrations. These were then used to calculate the annual average sediment load and the low flow year sediment load.

Total Maximum Daily Load (TMDL)

Critical Condition Determination

The low flow year could be used for evaluating point source impacts. Low flow conditions are used because this is when point sources would be expected to have the most impact. Annual average flow was used for evaluating nonpoint source impacts and instream sediment producing processes. For the next phase of this TMDL, watershed loadings will be developed for 1970 to 1997 and the critical watershed-loading year can be better defined.

Seasonal Variation

Twenty plus years of flow and meteorological records were examined. The low flow year could be used to examine point source impacts and the 25 year average annual flow year was used to examine nonpoint source impacts.

Margin of Safety

The equation fitting the center of the allowable stream sediment concentration was used as a conservative approach. Note that either excess or a lack of sediment in the stream can be a detriment to stream health. The margin of safety can be more appropriately applied to the suggested watershed source reductions during the next phase of the TMDL.

TMDL Determination

Expression of numeric targets and source allocations in terms of time steps different from daily loadings and as functions of other watershed processes are allowable as alternative measures for sediment TMDLs. (EPA 1999b, Appendix D) This TMDL is expressed as a relationship between sediment concentration and a stream flow factor. In the next phase the TMDL will be expressed as a recommended loading or a percent reduction of existing loads.

The TMDL can be expressed as a loading value. The average annual sediment loading capacity for 1970 to 1997 equals 52 million kg/year and the low flow year, where point source impacts would be the greatest, the sediment loading capacity (1986) equals 4.2 million kg/year

Further details on the daily flow and sediment graphs are in Figures 2 and 3.

Allocation of Responsibility and Recommendations

Sources:

No point sources are located in the watershed.

Unknown sources that account for the exceedence of the Loading Capacity may be unpaved roads, lack of riparian buffer zones, instream processes such as eroding stream banks, down-cutting of the stream bottom, agriculture, forestry, etc. Further work and analysis will need to be completed in the watershed to determine the existing loading and the sources of the excess loads.

Schedule for the Next Phase of the TMDL

Waters on the State's 303(d) list that are located in the Savannah Basin will be due for TMDL development again in 2004. According to the 1997 Consent Decree in the Georgia TMDL Lawsuit, TMDLs taking into consideration both point and nonpoint sources must be proposed by State of Georgia on or before June 30, 2004 or by EPA on or before August 30, 2004. Phase 2 of this TMDL that will consider both point and nonpoint sources will, therefore, be developed no later than these dates.

Recommendations:

Due to the restrictive timeframe imposed by the February 2000 Order on Consent to propose and finalize TMDLs, this level 1 screening TMDL was developed that provided estimates of the stream's loading capacity and the relative impact of point source contributions. Further analysis needs to be completed on these watersheds, additional data needs to be collected to better define the sediment loadings, and the TMDL needs to be revisited and revised as additional information becomes available.

It is further recommended that the Little Shoal Creek watershed be considered a high priority for any sediment reduction BMPs. Unknown sources accounting for the exceedence of the Loading Capacity may be watershed processes such as unpaved roads, lack of riparian buffer zones, or instream processes such as eroding stream banks, down-cutting, etc. Further monitoring and analysis will need to be completed in the watershed and in the stream to determine the existing loading and the sources of the excess loads.

The following ongoing work will assist in the development of more refined TMDL and the source loading relationship:

- The NRCS may be able to supply further data to update the agriculture database and the Universal Soil Loss Equation (USLE) loading information.
- The U.S. Forest Service and State Forestry agencies may be able to supply further data to update the forestry database, locations and contributions from roads and the USLE loading information.
- Further sediment loading techniques are being developed as part of the Chattooga Watershed TMDL project. When the sediment loading methodology is refined and the appropriate data collected, further analysis can be completed on these watersheds, sediment loadings better defined and the TMDL revised.

Figure 1. Location of Little Shoal Creek Watershed

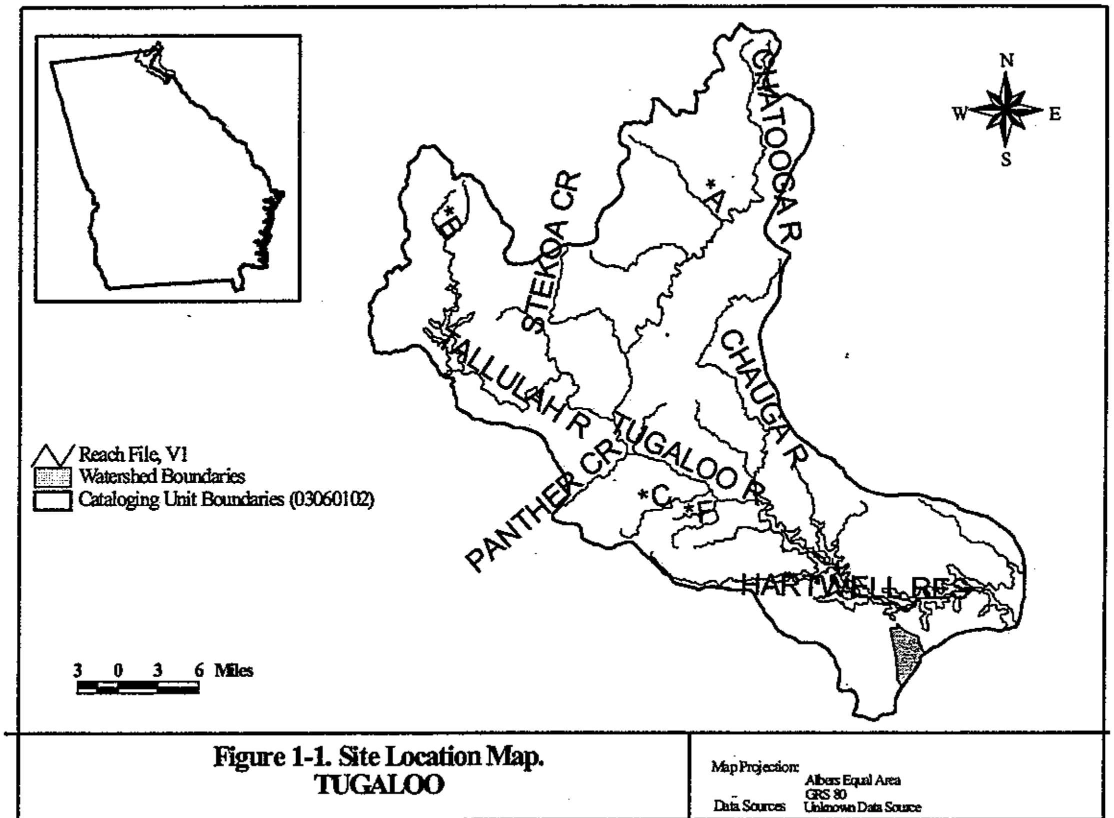

Figure 1-1. Site Location Map.
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Figures 2 and 3. Graphs of estimated flows and sediment concentrations

Figure 2
Little Shoal Creek Estimated Flows 1970 -1995

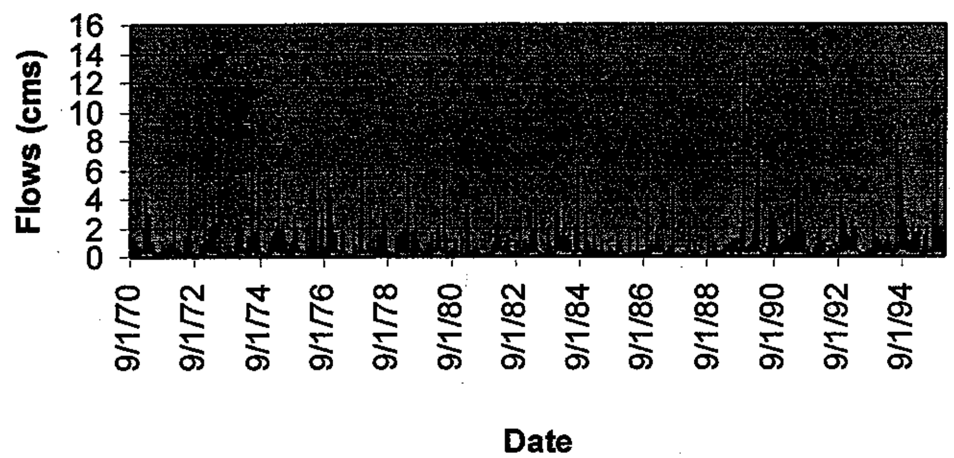
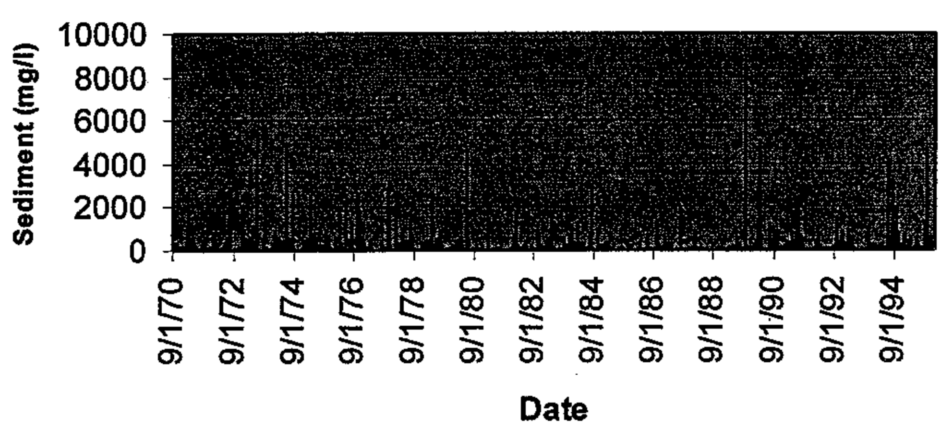


Figure 3
Little Shoal Creek Estimated Sediment
1970 -1995

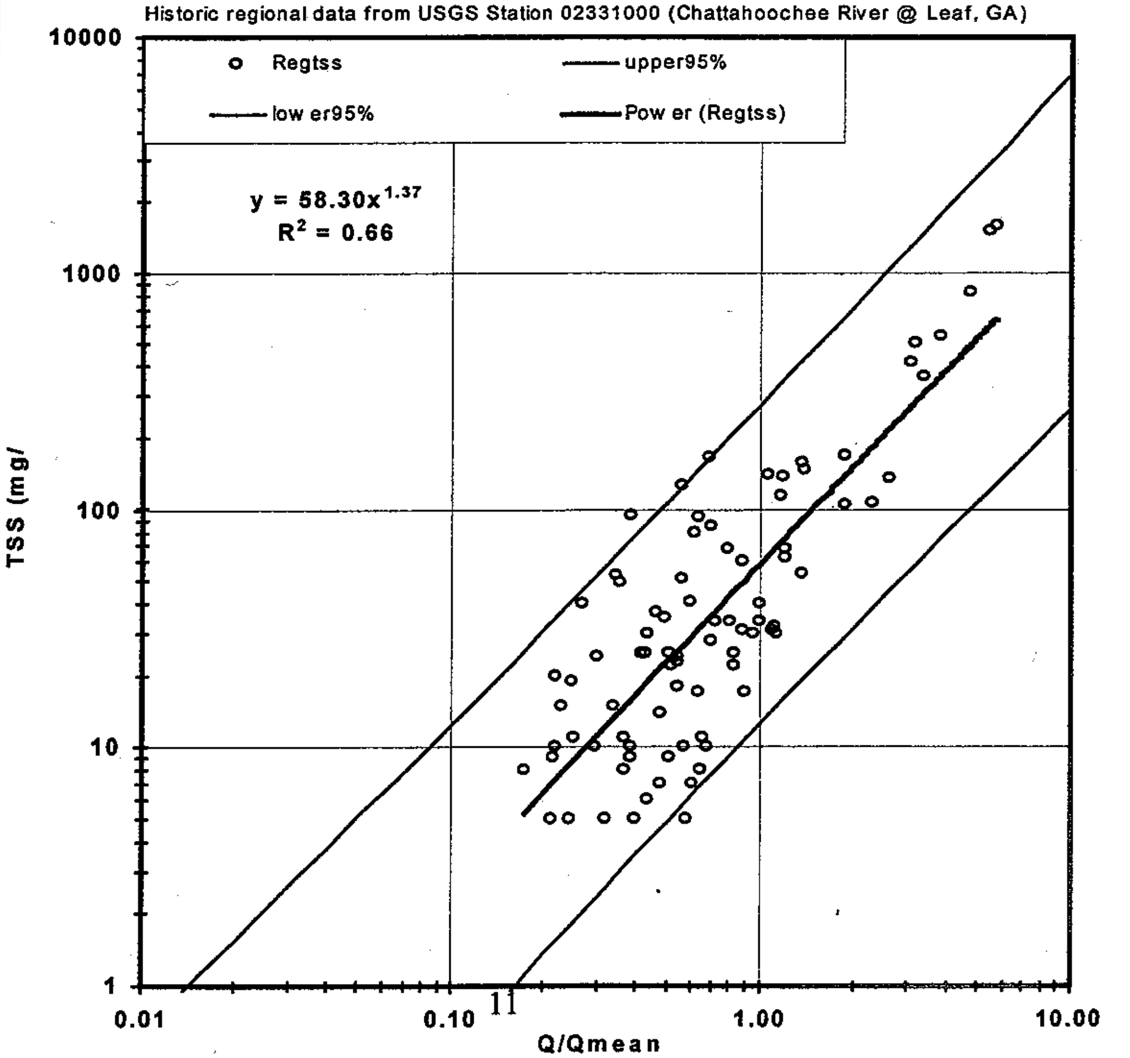


Appendix A: Reference Stream Information and Sediment-Flow Relationship and Chattooga River Watershed Hydrologic / Sedimentation Study

Regional TSS data, compiled from the USGS records (Perlman, 1994), were regressed against discharge normalized to mean discharge (Q/Qmean) (Holmbeck-Pelham and Rasmussen 1997). Reference regional TSS versus flow relationships are developed from historic data from USGS station number 02331000 (Chattahoochee River near Leaf, Georgia). (EPA 1999a)

FIGURE 7 : OBSERVED TSS OVERLAYING COMBINED REGIONAL TSS (Upper Chattooga River TMDL Project)

Historic regional data from USGS Station 02331000 (Chattahoochee River @ Leaf, GA)



CHATTOOGA RIVER WATERSHED

HYDROLOGIC / SEDIMENTATION

STUDY

(Rabun County, Clayton, Georgia)

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April 1999

CHATTOOGA RIVER WATERSHED

HYDROLOGIC / SEDIMENTATION

STUDY

As an integral part of the comprehensive water quality investigation of the Chattooga River Watershed (USEPA-WMD, Draft Report, 1998), a hydrological and sedimentological study was conducted on selected stream reaches within the study area (refer to *Assessment of Water Quality Conditions - Chattooga River Watershed*, USEPA-WMD, Draft Report, 1998). Sedimentation has been reported to be the leading determinant in loss of habitat and reduction in bedform diversity within the study area. The objective of this study was to conduct a sediment yield study and determine if sediment is a primary cause of physical and biological impairment to streams in the Watershed. The results will be correlated with aquatic ecological and fluvial geomorphological data to develop an overall condition of the Watershed.

ACKNOWLEDGMENTS

Dave Melgaard (EPA-WMD) was the project officer on the comprehensive water quality investigation of the Chattooga River Watershed. Bruce Pruitt was the sediment yield leader and author of this report. Morris Flexner and Tony Able provided field assistance during the sediment yield study.

METHODS

Five stream reaches were selected for the study: Stekoa Creek upstream (SC01) and downstream (SC02) of Clayton, Georgia; Warwoman Creek (WW02A); Addie Branch (R2; and Big Creek (WF08). The stream reaches were selected based on the following criteria:

The relative degree of biological impairment as measured using rapid bioassessment protocol; position within the watershed; relative geomorphic condition; and access logistics.

The stormflow study was conducted from March 27 to April 1, 1998. Prior to stormflow sampling, tapedowns were established and appropriate cross-sections for gaging and sediment collection were identified. Baseflow discharge and sediment samples were collected on March 27 and 28, prior to the storm initiation.

Rainfall was measured at the Shoney's Inn swimming pool, and stream stage of Stekoa Creek was measured at the Shoney's Inn bridge, Clayton, Georgia. The gage and tapedown were installed and maintained by Tony Able (USEPA-WMD) and were meant for response planning of sample teams during the stormflow study.

A total of twenty-one observations were made across the five stations during the study. On-site measurements at each station included tapedowns (start and finish), stream discharge, turbidity, and collection of suspended and bedload sediment. The stations were sampled in the following sequence: R2, WF08, WW02, SC01, and SC02 (Figure 1). Sample collection followed the Sediment Yield - Standard Operation Procedure (SESD-EAB, 1998, attached). Stream discharge was gaged simultaneously with sediment collection. Water column samples were collected using a depth integrating suspended hand line sampler (US DH-59). Field turbidity was determined *in-situ* at ambient air conditions using a HACH Model 2100P Turbidimeter. Turbidity was field determined for future use by EPA Region IV and State water quality personnel as a rapid means of identifying potential sediment impaired streams ("red flags"). Consequently, sample temperature was not adjusted prior to measuring turbidity. Laboratory determinant of total suspended solids (TSS) and total dissolved solids (TDS) followed USEPA Methods 160.2 and 160.1, respectively. Bedload sediment samples were collected utilizing a 3-inch cable suspended bedload sampler (US BL-84) or a 3-inch wading type bedload sampler (US BLH-84), transported to the laboratory in 1-liter containers, and processed for particle size determination (PSD) in the laboratory using the EPA-SESD wet sieve method (SESD-EAB Draft SOP, Jan. 99 - method attached). The procedure was followed with the exception of the silt/clay separation step which was not required since the samples were collected in coarse Nitex mesh bags.

Laboratory results of dry-weight, bedload samples (M_b, grams) were converted to bedload transport rate (Q_b, tons/day) by the following equation:

$$Q_b = M_b/(TN)\ W_s \times 1.59e^{-4} \qquad (1)$$

where T = subsample duration (in this case, 5 min.);

N = number of subsamples (2);

W_s = wetted surface (ft)

Regression relationships were tested against ANOVA at a 95% confidence level. Consequently, unless otherwise noted hereafter, significance was determined at $\alpha = 0.05$, based on a t-test using advanced regression.

RESULTS

Precipitation. Rainfall distribution at a subwatershed scale throughout the Chattooga River Watershed is influenced by orographic effect of mountain ranges and watershed orientation to frontal systems. For instance, rainfall recorded at the Shoney's Inn (elevation ~ 2042 ft. above NGVD) began at 10:05 PM on March 29 and continued until April 1 for a total of 2.25 inches (57 mm) (Figure 2). In contrast, rainfall recorded at Black Rock Mountain State Park (elevation ~ 3640 ft. above NGVD) totaled 0.78 inches (20 mm) for the three-day duration. The most intense rainfall occurred on March 30 with an average of 0.16 in/hr between 5:20 AM and 10:16 AM (measured at Shoney's Inn).

Suspended Sediment (Regional). Regional TSS data, compiled from the United States Geologic Survey records (Perlman 1984), were regressed against discharge normalized to mean discharge (Q/meanQ) (Holmbeck-Pelham and Rasmussen 1997). The USGS stream station utilized in development of the regional sediment curve was the Chattahoochee River near Leaf (Station no. 02331000) for the period of record, 1958 - 1984. TSS data from the Soque River station near Cornelia (02331250) and the Chestatee River near Dahlonega (02333500) were not used due to the difference in slope of the regression as compared to the Chattahoochee River station in the former and shift upward in the regression of the latter (Figure 4). In addition, there was an improvement in the regression coefficient from 0.54 to 0.66 and, consequently, confidence in using the regional data set improved as a reference. Regional TSS (from the Chattahoochee River) plotted against Q/meanQ was observed to be significant (R^2=0.66, log transformed), given by (Figure 7):

$$y = 58.3x^{1.37} \qquad (2)$$

Suspended Sediment (Local, this study). TSS, collected by vertical integration of the water column, was regressed against turbidity (NTU) and discharge (Q), (Figures 5 and 6, respectively). The relationship between TSS and NTU was significant (R^2=0.93, log transformed), given by:

$$y = 1.16x^{1.39} \quad (3)$$

Based on the suspended sediment rating curve, TSS vs. Q was significant (R^2=0.77, log transformed), given by:

$$y = 0.02x^{1.67} \quad (4)$$

Local TSS data were compared against regional TSS by overlaying the two and constructing 95% confidence bands (Figure 7). Two stations, Stekoa Creek SC01 and SC02, were observed above the upper 95% confidence band (3 out of the 21 total observations during the stormflow study). In general, data points that plot above the upper 95% confidence band are indicative of higher than "normal" concentrations of TSS for a given discharge to mean discharge. Other stations, R2, WW02A, and WF08 were below or within the normal range of the regional TSS data set. In addition, four out of the 21 total observations were below the lower 95% confidence band. These observations were made at Warwoman Creek (WW02A) and Big Creek (WF08).

Bedload Sediment. Similar to TSS, bedload was regressed against discharge (Figure 8). Even though discharge only accounted for 50% of the variability in total bedload (R^2=0.50, log transformed), similar slopes were observed between the suspended sediment rating curve (equation 4) as compared with the bedload sediment rating curve (equation 5):

$$y = 0.001x^{1.62} \quad (5)$$

Total Sediment. Bedload and TSS loadings were combined into total sediment load and plotted against discharge (Figure 9) resulting in the following regression equation (R^2=0.77, log transformed):

$$y = 0.02x^{1.68} \quad (6)$$

In general at all five stations, TSS loadings accounted for the over twice the bedload contribution to the total sediment load. Consequently, TSS exerted the most influence on the total sediment rating curve as evidenced by nearly identical regression equations (equation 4 compared with equation 6). By far, total sediment observed at Stekoa Creek - upstream (SC01) exceeded all other stations during the study in both total stormflow and maximum observed total load (Figures 10 and 11, normalized to drainage area). The second highest total load was observed at Stekoa Creek - downstream (SC02). Total sediment loads observed at WF08, WW02A, and R2 were dramatically less as compared to SC01 and SC02.

DISCUSSION

Peak total load normalized to drainage area was plotted against drainage density (stream length / drainage area) to determine if the between station variation in total discharge was related to the "normal" variation in stream length (Figure 12). The range of drainage density was 4.1 to 5.1. The two Stekoa Creek stations (SC01 and SC02), which had the highest peak total load, were within the range of drainage density. Consequently, the difference in peak total loads between stations can not be explained by a "normal" difference in drainage density.

Peak total loads were plotted against road density (road length / drainage area), which ranged from zero (R2 - Addie Branch) to 4.6 (SC01 - Stekoa Creek) (Figure 13). Road density represents the net impacts of road construction and maintenance, interception of subsurface interflow, routing of other non-point sources to the stream, and entrainment, mobilization, and transport of sediment to the stream. In contrast to drainage density, a significant increase in peak total loads in response to road density was observed at the two Stekoa Creek stations (SC01 and SC02). A similar relationship was observed when peak total loads were regressed against total density (drainage density + road density) (Figure 14).

CONCLUSIONS

A relationship between TSS and turbidity (NTU) can be developed with a specific hydro-physiography. Turbidity can be used as a surrogate to TSS with the following assumptions and cautions: 1) the relationship between TSS vs. NTU is hydro-physiography specific; 2) turbidity includes inorganic and organic constituents including phyto- and zooplankton; and 3) stream discharge and/or stage should be determined during turbidity measurements and compared against a regional regression curve.

Based on the results of this study and comparison against regional sediment data, Stekoa Creek (SC01 and SC02) exhibits greater than "normal" suspended sediment loads. TSS concentrations from Addie Branch (R2), Warwoman Creek (WW02A), and Big Creek (WF08) were within or below "normal" regional TSS concentrations.

Total stormflow sediment load and peak total sediment loads did not increase with drainage density. However, total loads increased significantly at station SC01 and SC02 with increase in road density and, consequently, total density. Assuming that every road has at least one road ditch, road density nearly doubled the effective drainage density in both Stekoa Creek stations.

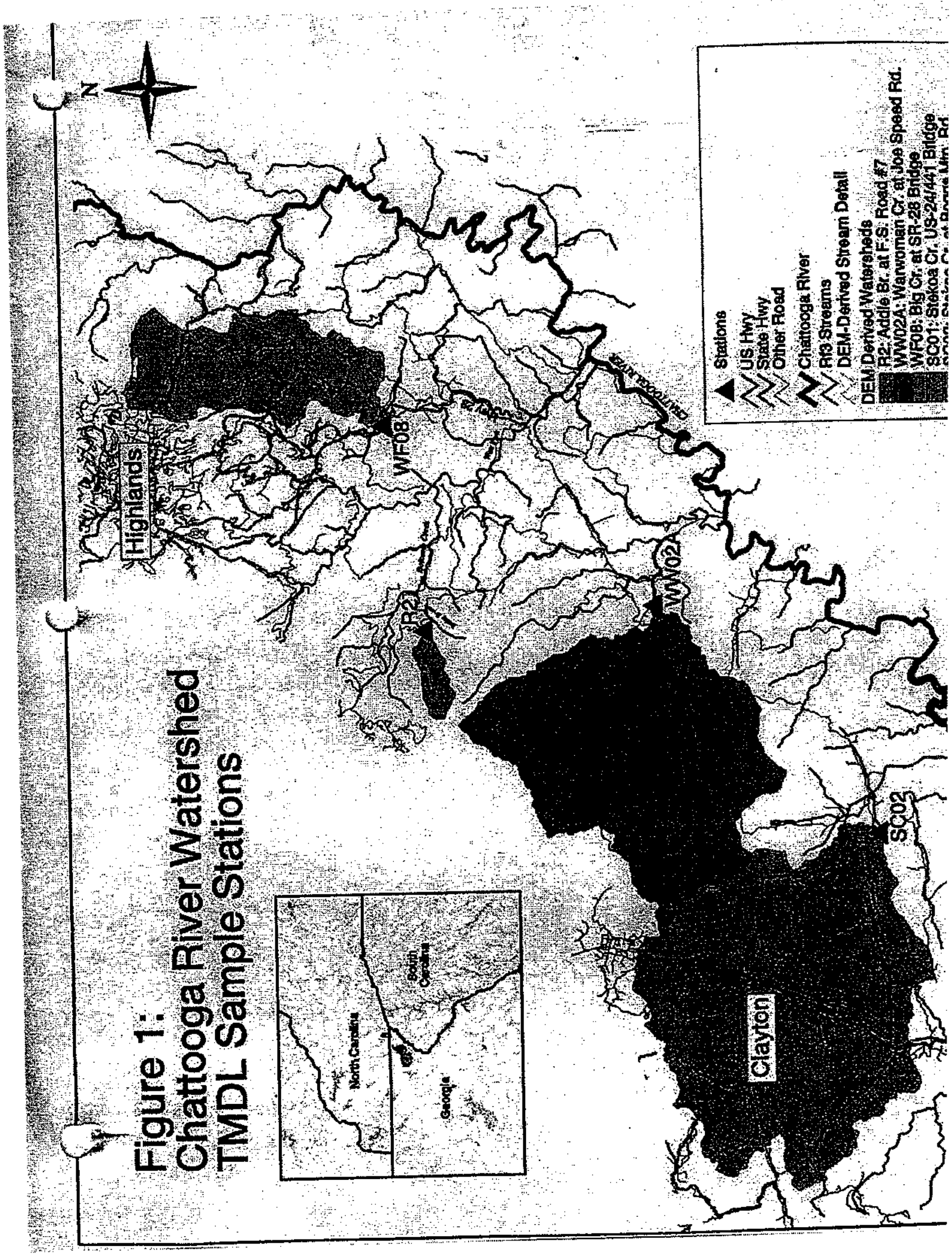


Figure 1:
Chattooga River Watershed
TMDL Sample Stations
N
Highlands
WF08
R2
WW02
SC02
Clayton
North Carolina
South Carolina
Georgia
Stations
US Hwy
State Hwy
Other Road
Chattooga River
Rf3 Streams
DEM-Derived Stream Detail
DEM Derived Watersheds
R2: Addie Br. at F.S. Road #7
WW02A: Warwoman Cr. at Joe Speed Rd.
WF08: Big Cr. at SR-28 Bridge
SC01: Stekoa Cr. US-24/441 Bridge

FIGURE 2: RAINFALL RECORD (UPPER CHATTOOGA RIVER TMDL PROJECT)

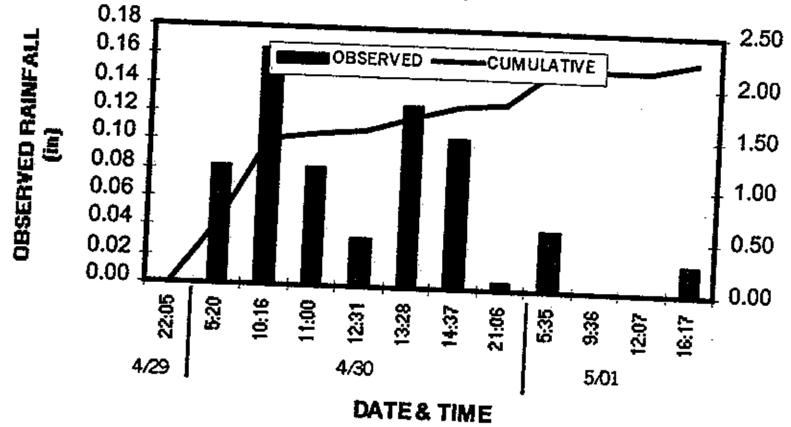


FIGURE 3: RAINFALL RECORD AND GAGE HEIGHT (UPPER CHATTOOGA RIVER TMDL PROJECT)

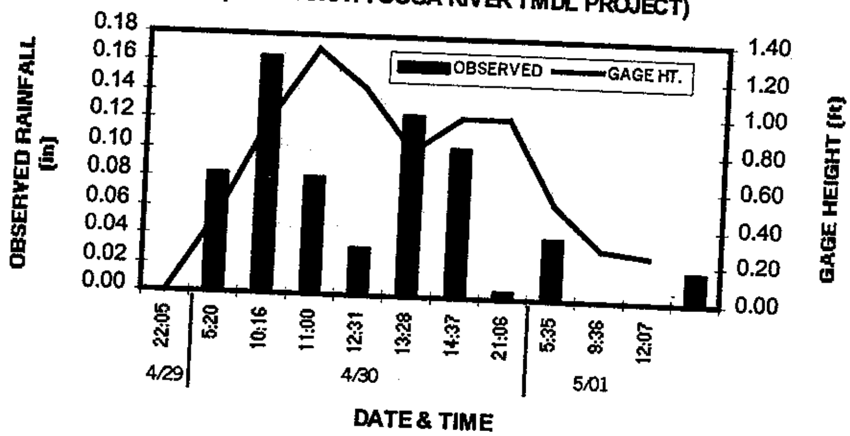


FIGURE 4: REGIONAL TSS DATA (Upper Chattooga River TMDL Project)

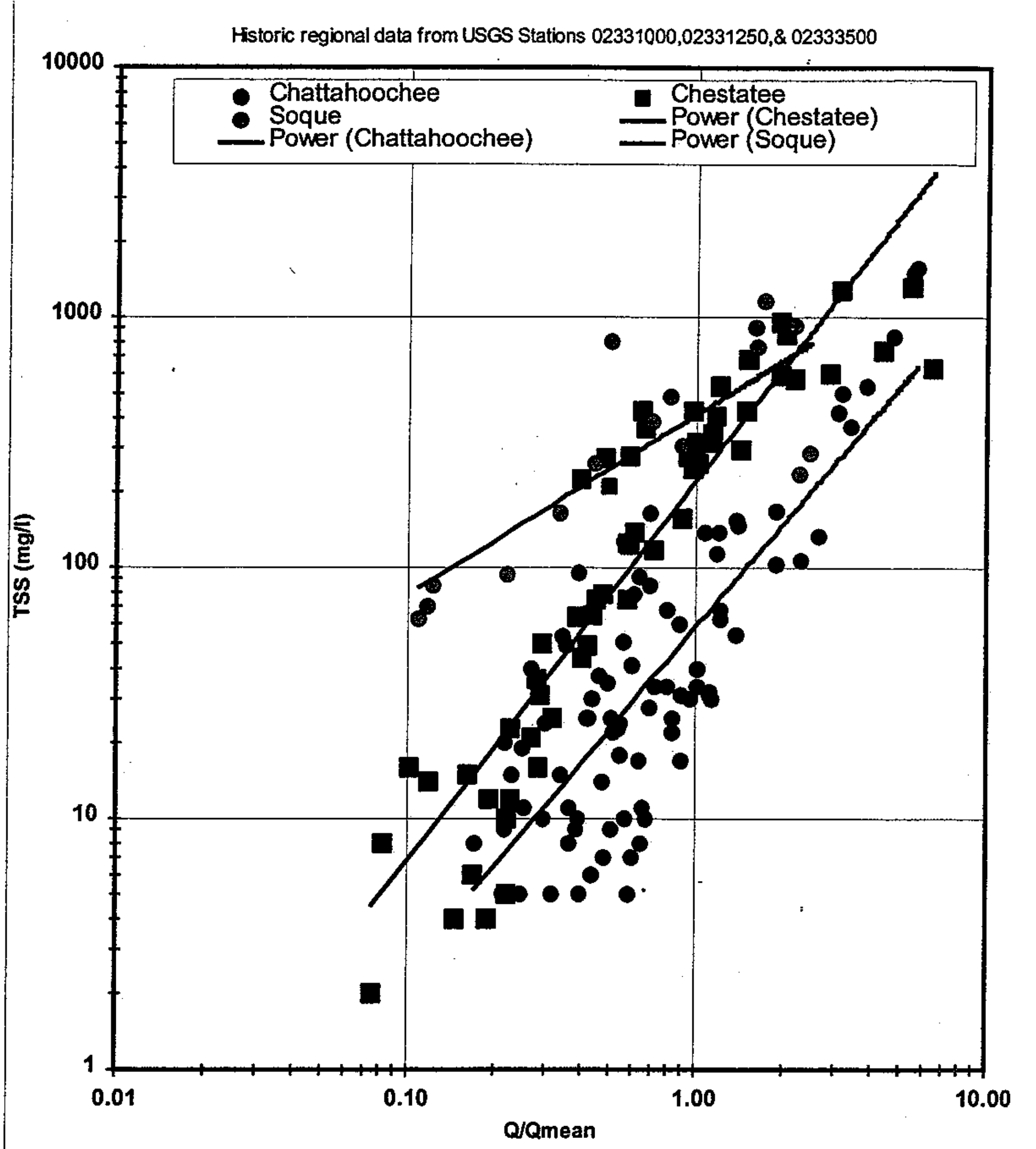


FIGURE 5: Total Suspended Solids (TSS) and Turbidity (NTU) Relationship (Upper Chattooga River TMDL Project)

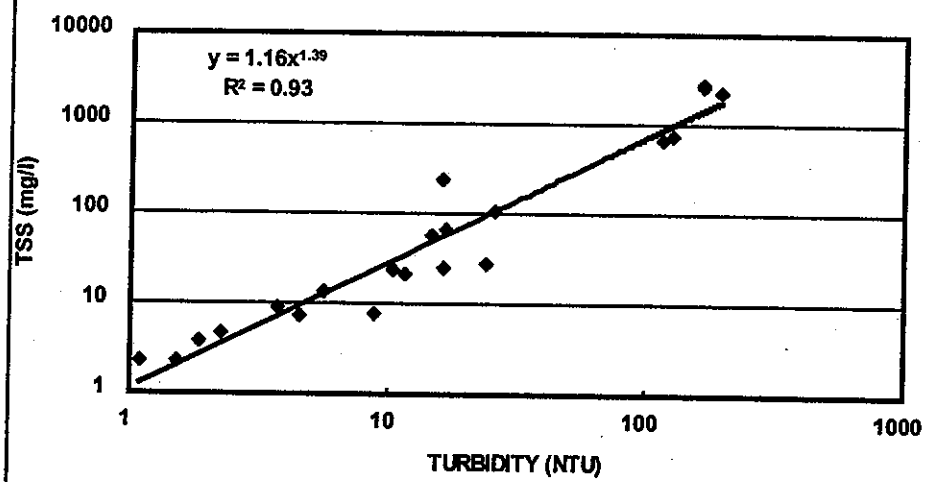


FIGURE 6: TOTAL SUSPENDED SEDIMENT RATING CURVE (Upper Chattooga River TMDL Project)

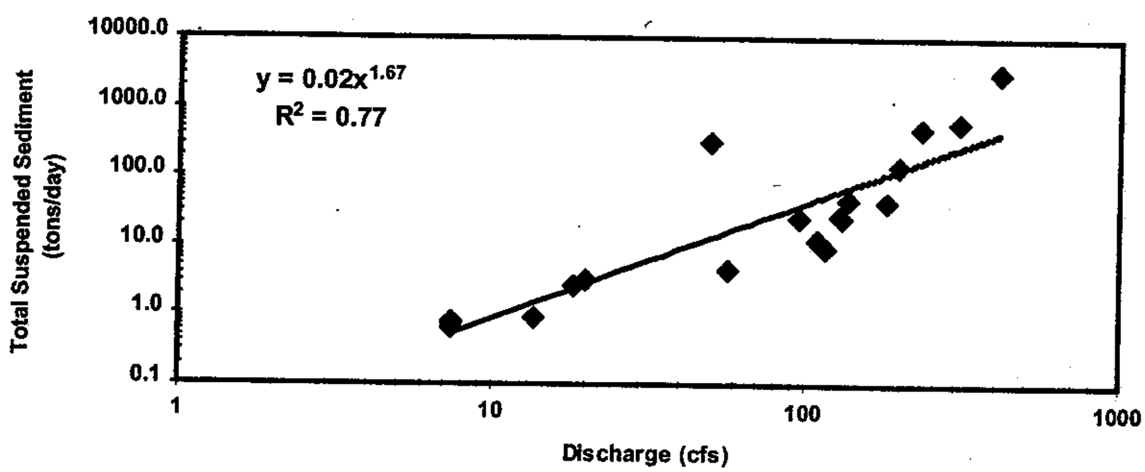


FIGURE 7 : OBSERVED TSS OVERLAYING HISTORIC REGIONAL TSS (Upper Chattooga River TMDL Project)

Historic regional data from USGS Station 02331000 (Chattahoochee R. @ Leaf, GA)

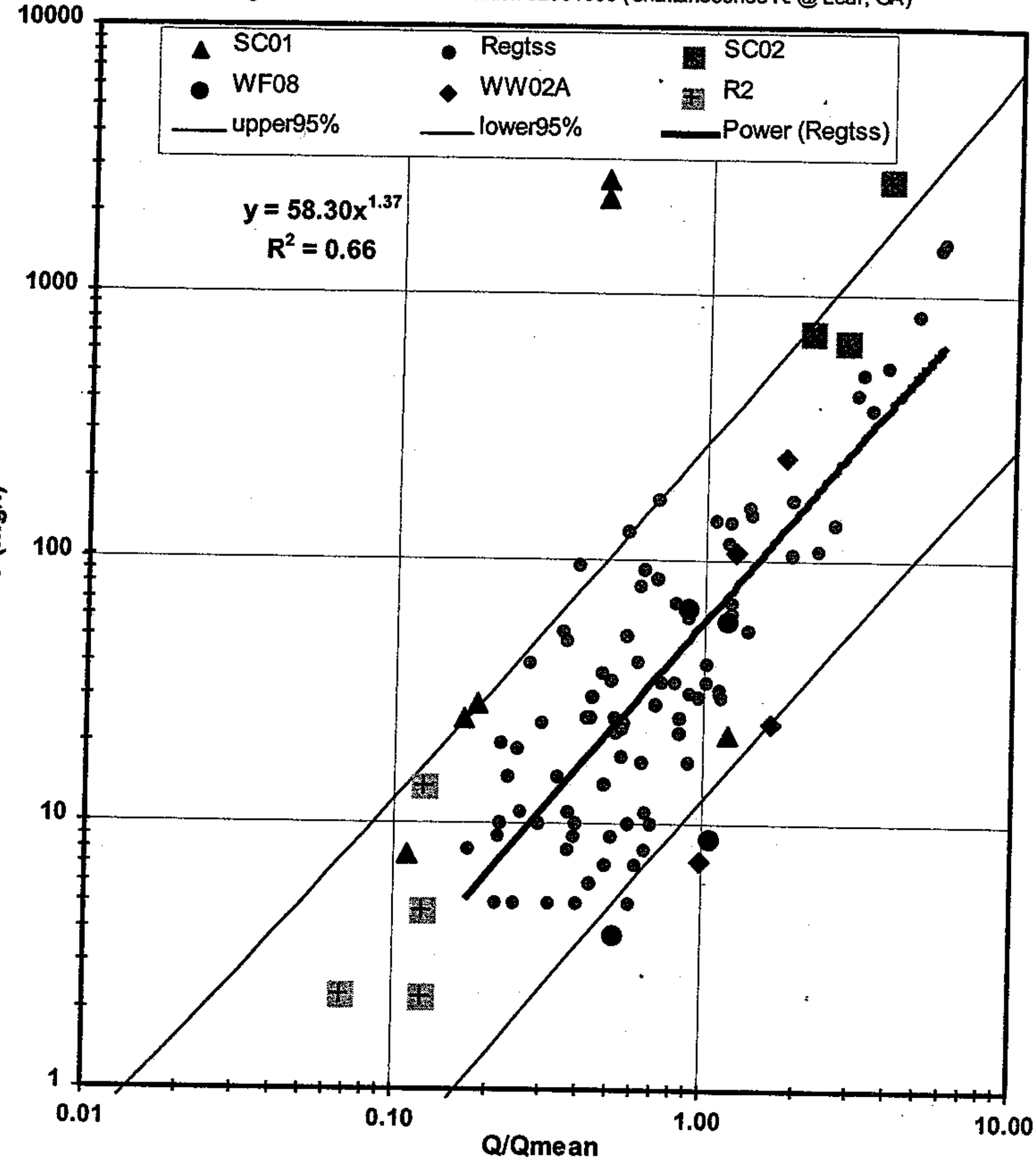


FIGURE 8: TOTAL BEDLOAD SEDIMENT RATING CURVE (Upper Chattooga River TMDL Project)

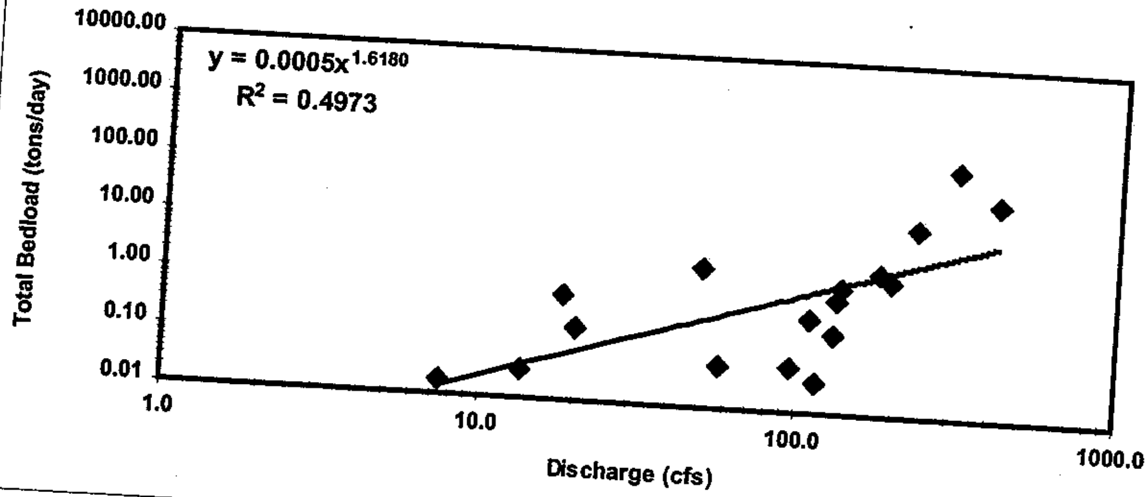


FIGURE 9: TOTAL SEDIMENT RATING CURVE (Upper Chattooga River TMDL Project)

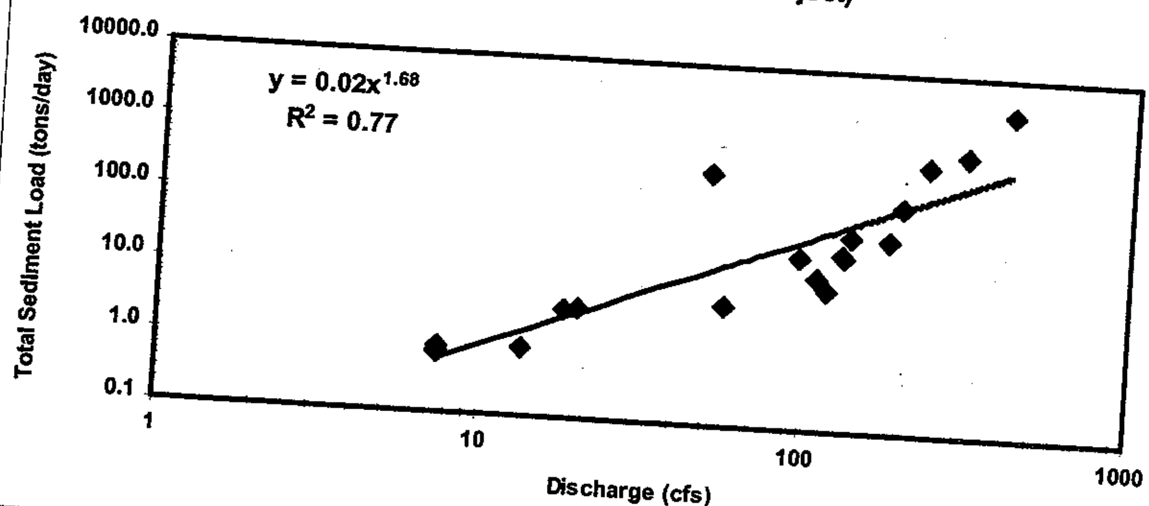


FIGURE 10: TOTAL STORMFLOW SEDIMENT LOAD NORMALIZED TO DRAINAGE AREA
(Upper Chattooga River TMDL Project)

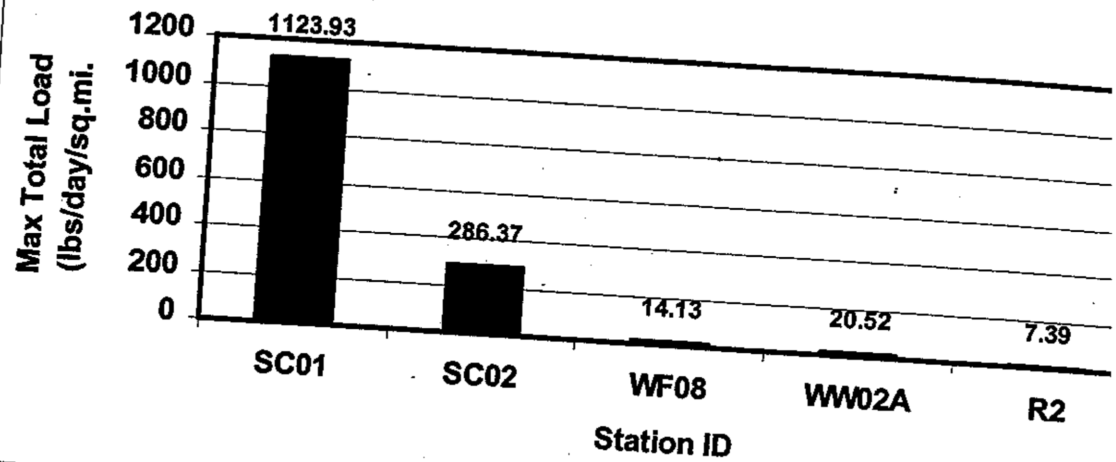


FIGURE 11: PEAK TOTAL SEDIMENT LOAD NORMALIZED TO DRAINAGE AREA
(Upper Chattooga River TMDL Project)

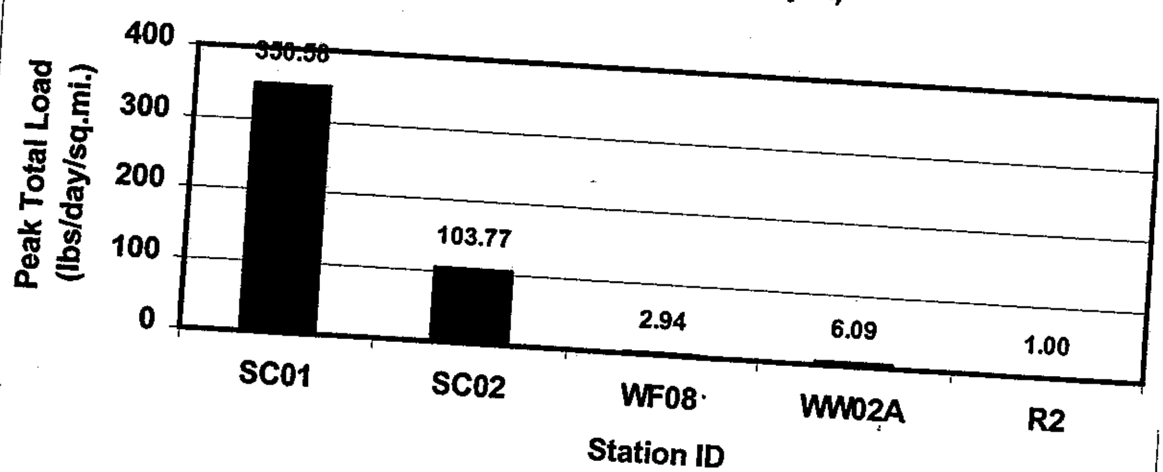


FIGURE 12: PEAK TOTAL SEDIMENT LOAD vs. DRAINAGE DENSITY
(Upper Chattooga River TMDL Project)

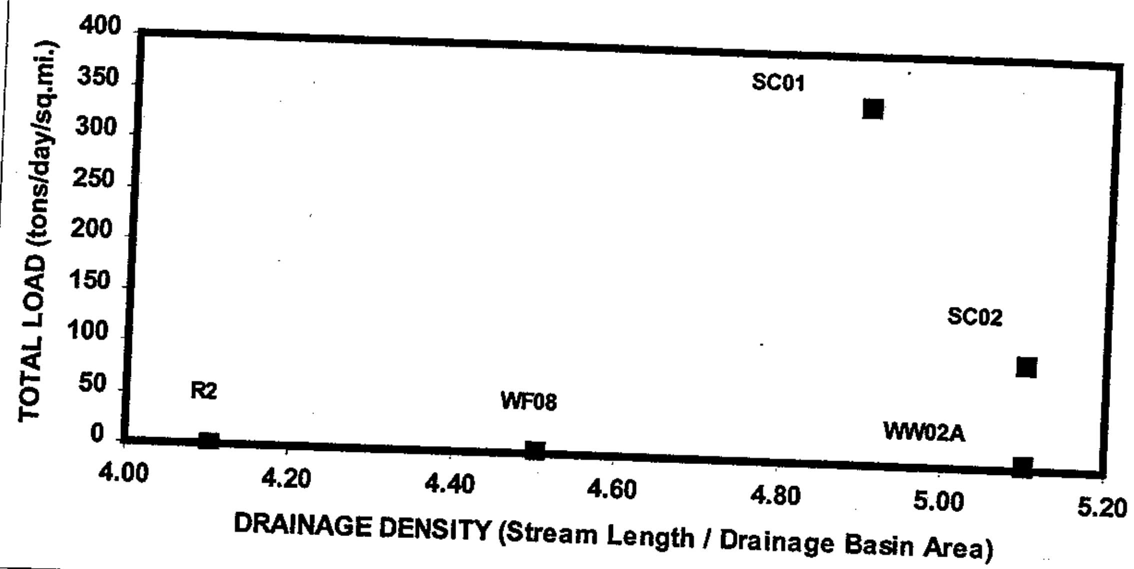


FIGURE 13: PEAK TOTAL SEDIMENT LOAD DURING STORM EVENT
(Upper Chattooga River TMDL Project)

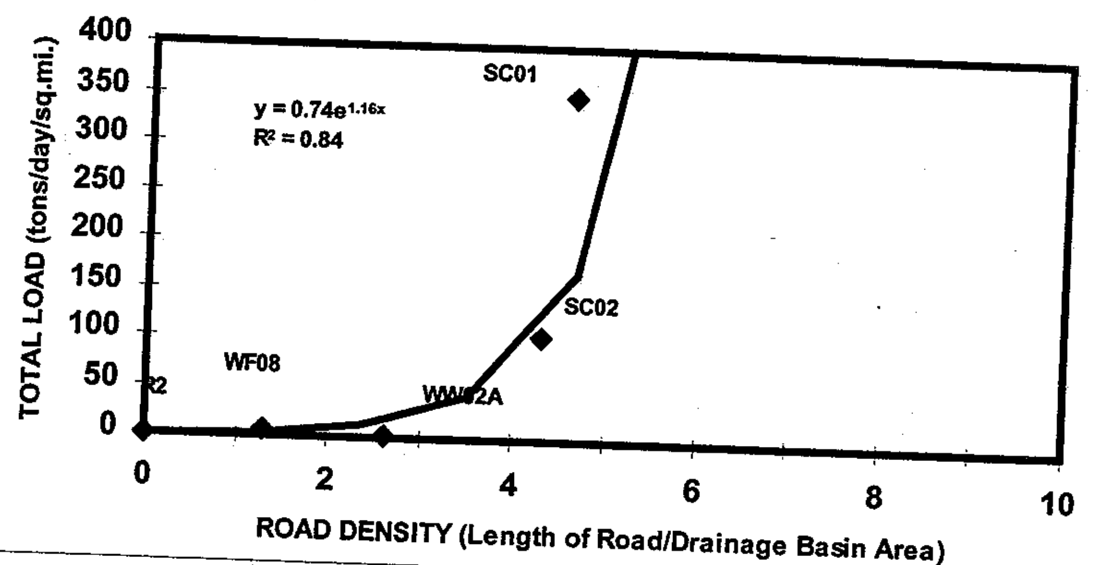
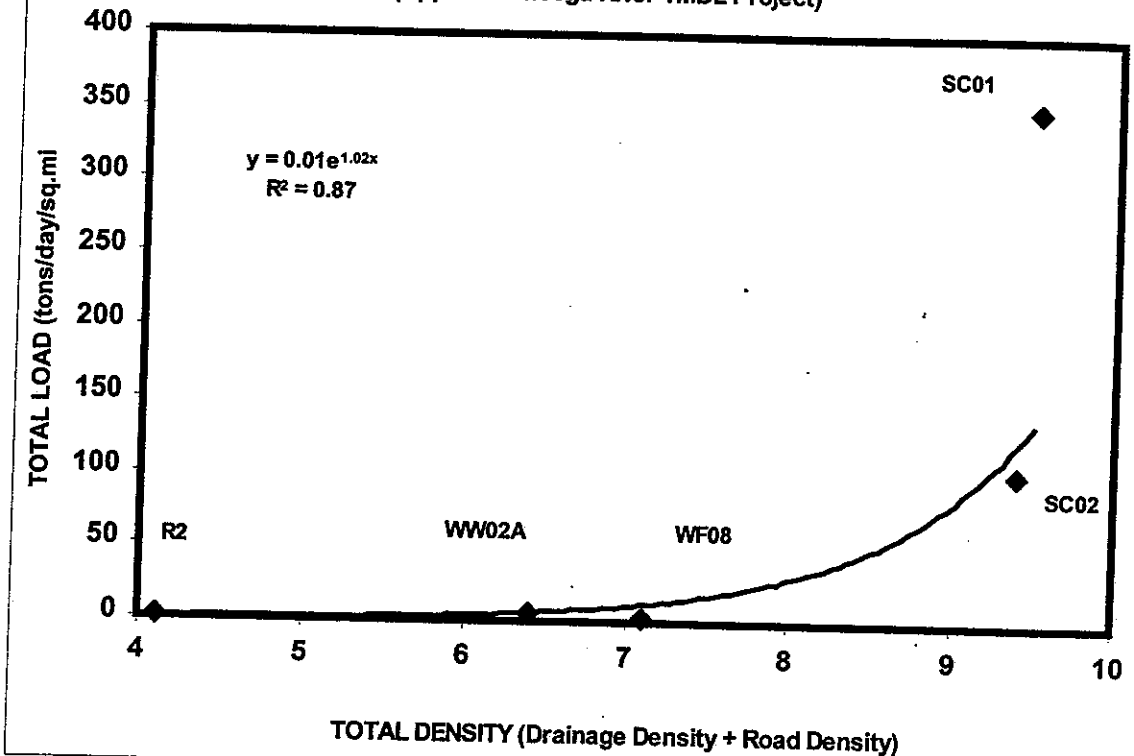


FIGURE 14: PEAK TOTAL SEDIMENT LOAD vs. TOTAL DENSITY
(Upper Chattooga River TMDL Project)



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Appendix B: Biological and Habitat Data and Information

STREAM NAME: Little Shoal Creek

STATION NUMBER/LOCATION: SAV-13 @ Griffin Rd. Br.

BASIN NUMBER: 3060102140

COUNTY: Hart

ECOREGION: 65b (draft)

DATE SAMPLED: 7/15/96

EPT INDEX and RATING: 4 and 0 (Very Poor)

TOTAL TAXA: 16

HABITAT SCORE and RATING: 48 and 0 (Very Poor)

D.O. (Mg/L) and pH: 7.3 and 6.6

TEMP. (Cent.) and CONDUCTIVITY: 22.4 and 43.7

NUTRIENTS: NH_3: 0.09mg/L; NO_3+NO_2: 0.52mg/L; KJL-N: 0.92mg/L;

Total P: 0.37 mg/L : TOC: 5.0mg/L

OVERALL RATING: Very Poor

COMMENTS: Habitat degradation appears to be the cause of the very poor rating. The habitat assessment indicated only 10% stable habitat, 75% embeddededness, and heavy deposits of fine material with 50% of the bottom affected by deposition.

Appendix C: EPA's "Protocol for Developing Sediment TMDLs"

Excerpts from EPA's "Protocol for Developing Sediment TMDLs", October 1999

The traditional approach to TMDL formulation is to identify the total capacity of a waterbody for loading of a specific pollutant while meeting water quality standards. This loading capacity is not to be exceeded by the sum of pollutant loads allocated to individual point sources, nonpoint sources, and natural background. Therefore, TMDLs have often been expressed in terms of maximum allowable mass load per unit of time. However, alternative approaches to sediment TMDL analysis might also be appropriate. In many cases, it is difficult or impossible to relate sediment mass loading levels to designated or existing use impacts or to source contributions. These analytical connections can be difficult to draw for several reasons, including the following: Sediment yields vary radically at different spatial and temporal scales, not only within a watershed, but across the country, making it difficult to derive meaningful "average" sediment conditions. Sediments are a natural part of all waterbody environments, and it can be difficult to determine whether too much or too little mass loading is expected to occur in the future and how sediment loads compare to natural or background conditions. A significant level of uncertainty is associated with sediment delivery, storage, and transport estimates. Fortunately, it is acceptable for TMDLs to be expressed through appropriate measures other than mass loads per time (40 CFR 130.2). It is important to note, however, that some of the limitations associated with mass load approaches, such as high temporal variability, are also present in the alternative approaches and the consequences of these limitations should be assessed and acknowledged. The alternative measures for sediment TMDLs can take several forms, including the following: Expression of numeric targets in terms of substrate or channel condition, aquatic biological indicators, or hillslope indicators such as road stream crossings with diversion potential or road culvert sizing. The hillslope indicators and targets should complement in-stream indicators and targets. Expression of numeric targets and source allocations in terms of time steps different from daily loadings and as functions of other watershed processes such as precipitation or runoff. Expression of allocations in terms other than loads or load reductions (e.g., specific actions shown to be adequate to result in attainment of TMDL numeric targets and water quality standards.

Some erosion occurs in all watersheds, even those which are completely undisturbed. Some watershed types are extremely prone to periodic major sedimentation events. Designated uses located in such settings have often adapted to naturally high sediment conditions. TMDLs need to distinguish sedimentation rates associated with human activities in the study watershed from those associated with naturally occurring (and presumably uncontrollable) sediment sources. Human land management activities can change the magnitude, locations, and timing of land erosion or runoff events as well as the key physical characteristics of receiving waters. Methods sensitive to changes in the driving forces that influence sedimentation (e.g., models like RUSLE, HSPF, and WRENSS) will be useful in comparing natural and anthropogenic sources if data about key processes are available for the TMDL study area and reference watersheds. Methods that estimate sediment loading or yields as a function of sediment concentration and streamflow (e.g., rating curves) are less useful in evaluating how existing sedimentation rates differ from natural sedimentation rates. Where rating curve methods are used, careful comparison to reference watersheds (and the underlying differences in land use or land characteristics) can assist in comparing natural and human-caused sedimentation. A sediment budget is an "accounting of the sources and disposition of sediment as it travels from its point of origin to its eventual exit from a drainage basin" (Reid and Dunne, 1996).

Sediment budget analyses are useful both for the conceptualization of sediment problems and as a tool for estimating sediment loadings. Full-scale sediment budgeting provides an inventory of the sources of sediment in a watershed and estimates sediment production and delivery rates from each source. Component processes are identified, and process rates are usually evaluated independently of one another. All of the relevant processes are quantified, including hillslope delivery processes (creep, mass movement), channel sources (e.g., bank collapse), in-channel storage, bedload and suspended sediment transport capacity, and net sediment yield from the basin. If the effects of particular land use activities on each process are known, the overall influence of a suite of existing or planned land use activities can be estimated.

One method for establishing target values is comparison to reference sites—waterbodies that are representative of the characteristics of the region and subject to minimal human disturbance. Where narrative standards are involved, assessing environmental conditions in receiving waters often depends on comparing observed conditions to expected conditions. This comparison is typically done by comparing data collected from impaired sites to similar data from the same sites collected before impairment and/or from one or more appropriate reference sites where designated uses are in good condition. Conditions at the reference site (e.g., suspended sediment concentrations) can then be interpreted as approximate targets for the indicators at the impaired site. A disadvantage to this approach is that it might not aid in determining an impairment threshold. Reference sites may represent the completely unaffected state, a relatively unaffected state, or increasing degrees of existing impact.

Appendix D: Watershed Characterization

Watershed Information for Little Shoal Creek

State Waterbodies Within the Watershed

		Reach File V1			Reach File V3		
Watershed ID	Watershed Name	Type	No. Segments	Total Length (mi)	Type	No. Segments	Total Length (mi)
3060102 155 0.00	TUGALOO	Stream	0	0	Stream	8	8.7

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Rosgen. 1996. "Applied River Morphology",

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Response to Public Comment on Proposed TMDL