TOTAL MAXIMUM DAILY LOAD (TMDL)

For

Siltation, Turbidity, and Habitat Alteration

In Shades Creek

Jefferson County, Alabama

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October 2004

TMDL SUMMARY / SIGNATURE SHEET

Siltation, Turbidity, and Habitat Alteration / Shades Creek
Jefferson County, Alabama
HUC 03150202

The TMDL for Shades Creek satisfies the 1998 consent decree obligation established in the matter of Edwards W. Mudd, II et al. v. John Hankinson et al. (Civil Action Number CV-97-S-0714-M) and Alabama Rivers Alliance, Inc. v. John Hankinson et al. (Civil Action Number CV 97-S-2518-M), requiring TMDLs be developed in accordance with a specified schedule. The TMDL schedule is based on Alabama's 1996 §303(d) List. This TMDL addresses impairment due to siltation, turbidity, and habitat alteration. Turbidity refers to excessive amounts of fine-grained materials being transported in the water column. Impairment due to siltation implies that deposition of fine-grained materials on the channel bed has hampered oxygenation of coarser bed materials (gravels and cobbles), creating poor habitat for aquatic organisms. By controlling sediment loadings in Shades Creek, water quality standards for siltation, turbidity and habitat alteration should be achieved.

The data used to develop the TMDL is based on an extensive field and modeling study conducted by staff from the Channel and Watershed Processes Research Unit (CWP) of the U.S. Department of Agriculture (USDA), Agricultural Research Service, National Sedimentation Laboratory during the winter and spring of 2003. The overall objective of the CWP study was to determine sediment yields in the Shades Creek watershed and to compare these to "reference" sediment yields for stable streams in the Ridge and Valley Ecoregion. Sediment loading emanating from various channel and upland sources in the Shades Creek watershed were simulated using AnnAGNPS and the channel-evolution model CONCEPTS. The purpose of the modeling effort was to evaluate the change in simulated runoff, suspended sediment loads, reach-average widening, and bed elevation change resulting from landuse change and instream bank protection. Watershed reconnaissance, channel surveys, sampling and testing of streambed and bank sediments, and rapid geomorphic assessments were conducted along the entire length of Shades Creek to support the modeling effort. Model results were compared to runoff and sediment loadings at the USGS flow gage on Shades Creek near Greenwood, AL and suspended sediment data collected by Storm Water Management Authority (SWMA).

In the absence of a numerical target, suspended-sediment loads and bed-material characteristics along Shades Creek are compared to stable streams in the Ridge and Valley ecoregion. Sediment conditions in stable streams are termed "reference" streams or reaches as these streams exhibit "expected" conditions that integrate all naturally occurring processes. By reducing suspended-sediment loads in Shades Creek to conditions expected in reference streams in the ecoregion, water quality standards for siltation, turbidity and habitat alteration should be achieved. A hypothesis of this TMDL is a stable stream would support healthy biota. In the time since EPA proposed this TMDL, SWMA and CWP staff have been working to confirm this hypothesis.

In the Shades Creek watershed, sediment entrained from channel bank failures and sediment from overland runoff are blamed as a contributor to fine-grained sediment deposition on channel beds. Model results using 2001 land cover data indicate that about 19,700 metric Tonnes per year (T/yr) are transported in Shades Creek. When comparing the simulated loads using 1991 and 2001 landuse data, loadings of sands emanating from uplands and streambanks have increased by 1,680 T/yr (181%) and 1,240 T/yr (29.1%), respectively. Streambank contributions of fines have decreased about 12 percent with respect to the 1991 landuse scenario due to channel adjustments between 1978 and 2001. The model was used to simulate the effects of instream best management practices (BMPs) on sediment loadings using 2001 landuse data. Results of this scenario indicate about a 40% reduction of fines eroded from the streambanks.

In the southwest portion of the Shades Creek watershed, two NPDES facilities are permitted to discharge sediment to Mud Creek, a tributary to Shades Creek. The contribution of suspended-sediment load from these facilities is negligible compared to sediment from non-point sources. Shades Creek is in the Birmingham/Jefferson County Municipal Separate Storm Sewer System (MS4) area. The NPDES program permits construction activities greater than one acre in size. The impact of improperly designed and constructed BMPs can contribute lasting effects on habitat alteration. SWMA routinely collects water quality data in Shades Creek and has documented the effectiveness of BMPs to reduce sediment loadings to the stream. SWMA provided much of the water quality data used in the TMDL.

Sediment impairment is considered a long-term process; therefore, the TMDL is expressed in terms of median annual yield in metric units of Tonne per year per square kilometer (T/yr/km^2). Based on available sediment transport data, the median annual suspended-sediment yield for Shades Creek is 52.6 T/yr/km^2. As a comparison, the median annual suspended-sediment yield for "reference" streams in the Ridge and Valley Ecoregion is 24.7 T yr/km^2. This yield represents a Total Suspended Solids (TSS) concentration of 45.1 mg/L. A 53 percent reduction in suspended-sediment yield is necessary to reduce sediment yields in Shades Creek to conditions in stable streams in the ecoregion.

During the public comment period, EPA received numerous comments regarding expressing the TMDL as an average annual load. Embeddedness (i.e., sediment finer than 2 mm) is used in the TMDL to address the siltation impairment. A "reference" bed-material composition is presented for streambeds dominated by coarse-grained materials (i.e., gravels). An analysis of bed materials addresses those reaches identified during the field study as impaired due to siltation by evaluating the percentage of fine-grained materials (sands and fines) embedded in gravel or gravel/cobble dominated streambeds. Coarse-grained reaches are identified because streams designated as impaired due to siltation impact spawning habitats and other biological life functions by clogging interstitial spaces in gravel/cobble beds. Embeddedness values collected in stable coarse-grained reaches ranged from 0 to 13.4 percent fine sediment. Targeting the percent of sand, silt, and clay particles in coarse-grained reaches to be within the range observed in stable segments of Shades Creek should promote healthy habitat.

Under the authority of Section 303(d) of the Clean Water Act, 33 U.S. Code §1251 et seq., as amended by the Water Quality Act of 1987 (PL 100-4), the U.S. Environmental Protection Agency is herby establishing a TMDL for sediment in Shades Creek. The TMDL requires limits for point sources, including continuous discharge facilities, MS4s areas, and NPDES regulated construction activities. Waters originating from nonpoint sources shall not exhibit sediment loadings above the limits set herein.

The establishment of these TMDLs is subject to the completion of consultation under Section 7(d) of the Endangered Species Act (ESA). EPA initiated consultation with the Fish and Wildlife Service on the Agency's CWA Section 303(d) establishment of these TMDLs under Section 7(a)(2) of the ESA. As part of the consultation, EPA completed a biological evaluation which concluded that the establishment of the TMDLs is not likely to adversely affect Federally listed endangered and threatened species or their critical habitat. Section 7(a)(2) requires federal agencies, in consultation with the Service, to ensure that their actions are not likely to jeopardize the continued existence of federally listed species or result in the destruction or adverse modification of designated critical habitat of such species. EPA's establishment of these TMDLs does not foreclose either the formulation by the Service, or the implementation by EPA, of any alternatives that might be determined in the consultation to be needed to comply with Section 7(a)(2). By establishing these TMDLs subject to the consultation under ESA Section 7, EPA has explicitly stated that it retains its discretion to take appropriate action if the consultation identifies deficiencies in the TMDLs requiring remedial action by EPA.

___________/s/_______________ _____11/1/04___
James D. Giattina, Director Date
Water Management Division

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1. Introduction

Total Maximum Daily Loads (TMDLs) are required for impaired waters on a State's Section 303(d) list as required by the Federal Clean Water Act Section 303(d) and implementing regulation 40 CFR 130. A TMDL establishes the maximum amount of a pollutant a waterbody can assimilate without exceeding the applicable water quality standard. The TMDL then allocates the total allowable load to individual sources or categories of sources through wasteload allocations (WLAs) for point sources, and through load allocations (LAs) for non-point sources. In the TMDL, the WLAs and LAs provide a basis for states to reduce pollution from both point and non-point source activities that will lead to the attainment of water quality standards and protection of the designated use.

The TMDL for Shades Creek satisfies the 1998 consent decree obligation established in the matter of Edwards W. Mudd, II et al. v. John Hankinson et al. (Civil Action Number CV-97-S-0714-M) and Alabama Rivers Alliance, Inc. v. John Hankinson et al. (Civil Action Number CV 97-S-2518-M), requiring TMDLs be developed in accordance with a specified schedule. The TMDL schedule is based on Alabama's 1996 §303(d) List. Fifty-five miles of Shades Creek, from its source to the Cahaba River, is non-supporting of the Fish and Wildlife (F&W) designated use, therefore, was placed on the State of Alabama's 303(d) list. The TMDL for Shades Creek addresses impairment due to siltation, turbidity, and habitat alteration. By controlling sediment loadings in Shades Creek, water quality standards for siltation, turbidity and habitat alteration should be achieved.

The Shades Creek TMDL is based on an extensive study conducted during the winter and spring of 2003 by the Channel and Watershed Processes Unit (CWP) of the U.S. Department of Agriculture (USDA), Agricultural Research Service (ARS), National Sedimentation Laboratory in Oxford, MS. The Storm Water Management Authority (SWMA) of Birmingham provided suspended-sediment data collected on Shades Creek and personnel to assist with the field study. The first component of the CWP study was conducted in the field with overall objective to determine sediment yields in the Shades Creek watershed and to compare these to "reference" sediment yields for unimpaired streams in the Ridge and Valley Ecoregion.

A second component of CWP study was the development of numerical models to quantify sediment sources from both upland areas and instream processes. Water and sediment contributions from uplands areas can be obtained with the ANNualized AGricultural Non-Point Source (AnnAGNPS) modeling system (Bingner and Theurer, 2001). This information is also supplied as the boundary conditions used to determine the channel contributions from main channel streambeds and banks using the CONsevational Channel Evolution Pollutant Transport System (CONCEPTS) model (Langendoen, 2000). These models were selected as they have the capabilities of simulating the fate and transport of sediment from both overland and instream sources. Results of the AnnAGNPS and CONCEPTS models are presented in the TMDL; a modeling report prepared by CWP is included as an attachment to this TMDL (Simon, et. al, 2004).

2. Watershed Characterization

2.1 General Information

Shades Creek is a subwatershed comprising approximately 357 square kilometers (138 square miles) within the upper portion of the Cahaba River Basin. From its headwaters in northeastern Jefferson County, Alabama, Shades Creek flows through urban and residential areas south of Birmingham to its confluence with the Cahaba River near the Shelby and Bibb County lines (see Figure 1).

The upper portions of the Shades Creek watershed lie within the Ridge and Valley ecoregion designated as Southern Limestone/Dolomite Valleys (67f), while the lower portion lies within the Southern Shale Valleys ecoregion (67g). Ecoregion 67f is composed of mixed and deciduous forests, pasture and croplands and a physiography characterized by undulating to rolling valleys with rounded hills and some steep ridges. Ecoregion 67g is composed of mixed and deciduous forests with some pasture and cropland and a physiography characterized by undulating to rolling valleys, and some low, rounded hills and knobs. Streams in ecoregion 67f and 67g are moderate to low gradient with bedrock, cobble, gravel, and sandy substrates.

Elevations within the Shades Creek watershed are based on Digit Elevation Models (DEMs) derived from USGS 7.5 minute quad maps. Elevations in the watershed ranged from 110 meters (m) above sea level (asl) at the downstream end to 378m (asl) at the headwaters. Land slopes ranged from nearly flat along the floodplains of Shades Creek to step slopes, up to 25 percent, along the ridges. The average land slope for the entire watershed is about 9 percent.

Dominant soils along the Shades Creek channel are Sullivan silty and Holston loamy soils. Along the steeper sections of the watershed along the ridges are Bodine and Motevallo silty soils and Lessburg sandy loams. The spatial variation of soils within the Shades Creek watershed is provided in Figure 4-2 of the CWP modeling report. Streambed and bank material composition and geotechnical properties were obtained at select intervals along Shades Creek to support numerical modeling efforts. Stream bank materials have an average silt/clay content of 15%, and average sand content of 81%, and average gravel content of 4%. Bank-toe materials have an average silt/clay content of 13%, average sand content of 67%, average gravel content of 5%, and an average boulder/cobble content of 15%. The streambed materials have an average silty/clay content of 1%, average sand content of 24%, average gravel content of 28%, and an average boulder/cobble content of 47%.

Two periods of landuse information were used in the TMDL: one describing the landuse during 1991 and the other during 2001. The 1991 landuse layer was used to validate the numerical model during the simulation period 1964-2001. For 1991, the watershed was comprised of land areas representing 74% forest, 14% pasture, 9% urban, and 3% water. Lands classified as pasture included the categories barren, transitional, agriculture, shrubland, and grassland. The wetlands and water categories were grouped as a single water category. The 2001 landuse was comprised of land areas representing 70% forest, 16% pasture, 11% urban, and 3% water. Analysis of digital topographic maps and on-site inspections were used to verify the 2001 landuse especially in areas that were classified as urban in 1991 and have become forest in 2001. This could have resulted from increased trees or wooded areas within urban areas that have grown during 1991 to 2001 being classified as forest areas in 2001. The 2001 landuse was used in the model for running predictive scenarios. Land use distribution in the Shades Creek watershed for the two time periods are shown in Figures 4-3 and 4-4 of the CWP modeling report.

2.2 Rapid Geomorphic Assessments

As part of the CWP field study, Rapid Geomorphic Assessments (RGAs) were conducted at 105 sites over 76.4 km of Shades Creek from the headwaters to approximately 10 km above the confluence with the Cahaba River. The cross section locations coincided with locations surveyed in 1978 as part of a flood-hazard study. At each cross section, RGAs were conducted and samples of bed, bank, and bank-toe materials were collected and tested. The purpose of the RGAs was to determine relative channel stability and stage of channel evolution (see Appendix A). The RGA procedure consists of four steps: photographing upstream, downstream, and across the reach; sampling bed material, observing channel conditions and diagnostic criteria listed on the channel stability ranking scheme (example form included in Appendix A); and survey channel gradient, or water-surface slope if channel is too deep to wade. Results of the RGAs are shown in Figure 2. In terms of channel stability, values of 20 or greater are indicative of instability; values below 10 are indicative of stability. The mean index for Shades Creek was about 14, indicative of low to moderate instabilities. Bank failures are relatively common with about one third of all banks failing (see Figure 2).

A conceptual model of channel evolution was used on Shades Creek to characterize varying stages of channel modification through time (Simon and Hupp, 1986; Simon, 1986b). Stage I, undisturbed conditions, is followed by the construction phase (Stage II) where vegetation is removed and/or the channel is modified significantly. Degradation (Stage III) follows and is characterized by channel incision which leads to an increase in bank heights and angles until critical conditions of the bank material are exceeded, and the banks fail by mass-wasting processes (Stage IV). Sediments eroded from upstream degrading reaches and tributary streams are deposited along low gradient downstream reaches. This process is termed aggradation and begins in Stage V, which continues until stability is achieved through a reduction in bank heights and bank angles. Stage VI (restabilization) is characterized by the relative migration of bank stability upslope (as determined by establishing woody-riparian species), point-bar development, and incipient meandering. Stages I and VI represent two true “reference” conditions.

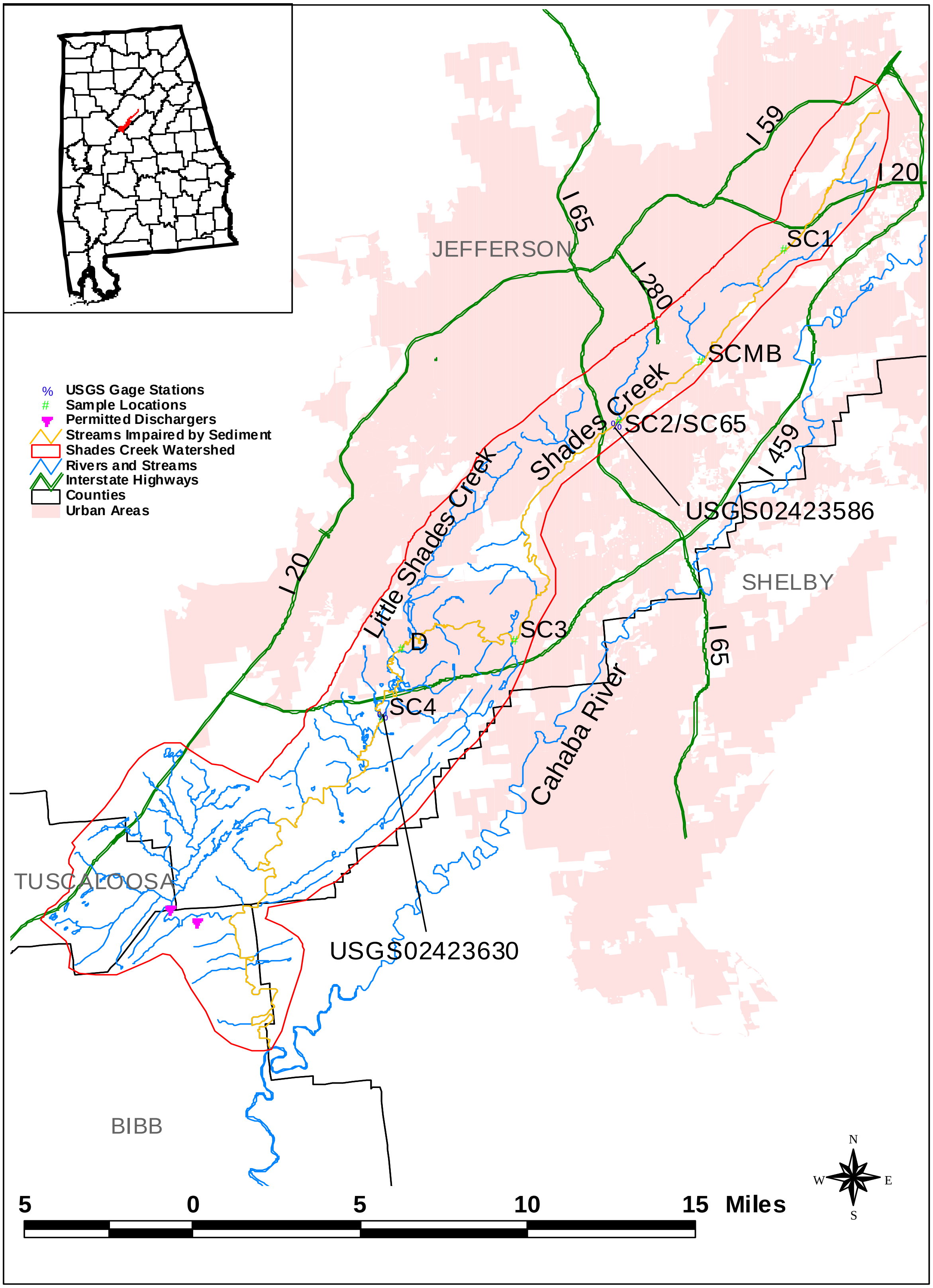

Figure 1. Shades Creek watershed

Results of the RGAs in Shades Creek identified 41 of the 105 cross sections as stable based on channel evolution and relative channel stability. Of the 41 stable sections, 19 stage I sites were identified, mostly along the downstream-most reaches and coincide with beds composed of bedrock. In addition, 22 stage VI sites were identified and are indicative of where Shades Creek has recovered from disturbances.

In Shades Creek *in situ* bank-toe materials are composed of a wide range of materials ranging from silts and clays to bedrock. To measure streambank stability *in situ* devices such as the borehole shear test and the submerged jet-test device were utilized in the field. The advantage of using *in situ* devices is that the test can be carried out on undisturbed soils and at various depths to locate weak strata. In cases where bank-toe material is fine-grained alluvium a submerged jet-test device was used to measure the critical shear stress (i.e., stress where there is no erosion) and erodibility coefficient. In cases where bank-toe material is composed of coarse-grained materials, samples were collected and published values for the critical shear stress were assigned (Julien, 1995). The shear strength of the bank materials was determined at various depths using the borehole shear device. Results of the bank stability measurements were used to represent the cross section for input to the CONCEPTS model.

In addition to characterizing the streams using RGA techniques, bulk samples of bed materials were collected to determine the degree of fine-sediment deposition where beds were dominated by gravels and/or cobbles. Deposition of fine-grained sediment (silts, clays and sands) is one of the main concerns along Shades Creek because of the potential filling of interstitial spaces in gravel and cobble beds. This condition is described as embeddedness, and is generally represented by the percentage of material finer than 2mm within a coarser matrix of gravels and/or cobbles. The frequency of bed material types found on Shades Creek is shown in Figure 3. Of the 102 sites sampled for bed material along Shades Creek, 53 are considered coarse-grained (dominated by gravel or larger clasts), 30 bedrock, and 19 fine grained (dominated by sand or finer clasts). In terms of overall stream lengths, 32% of the reach contains bedrock beds, about 41% has coarse-grained beds, and 27% has fine-grained beds.

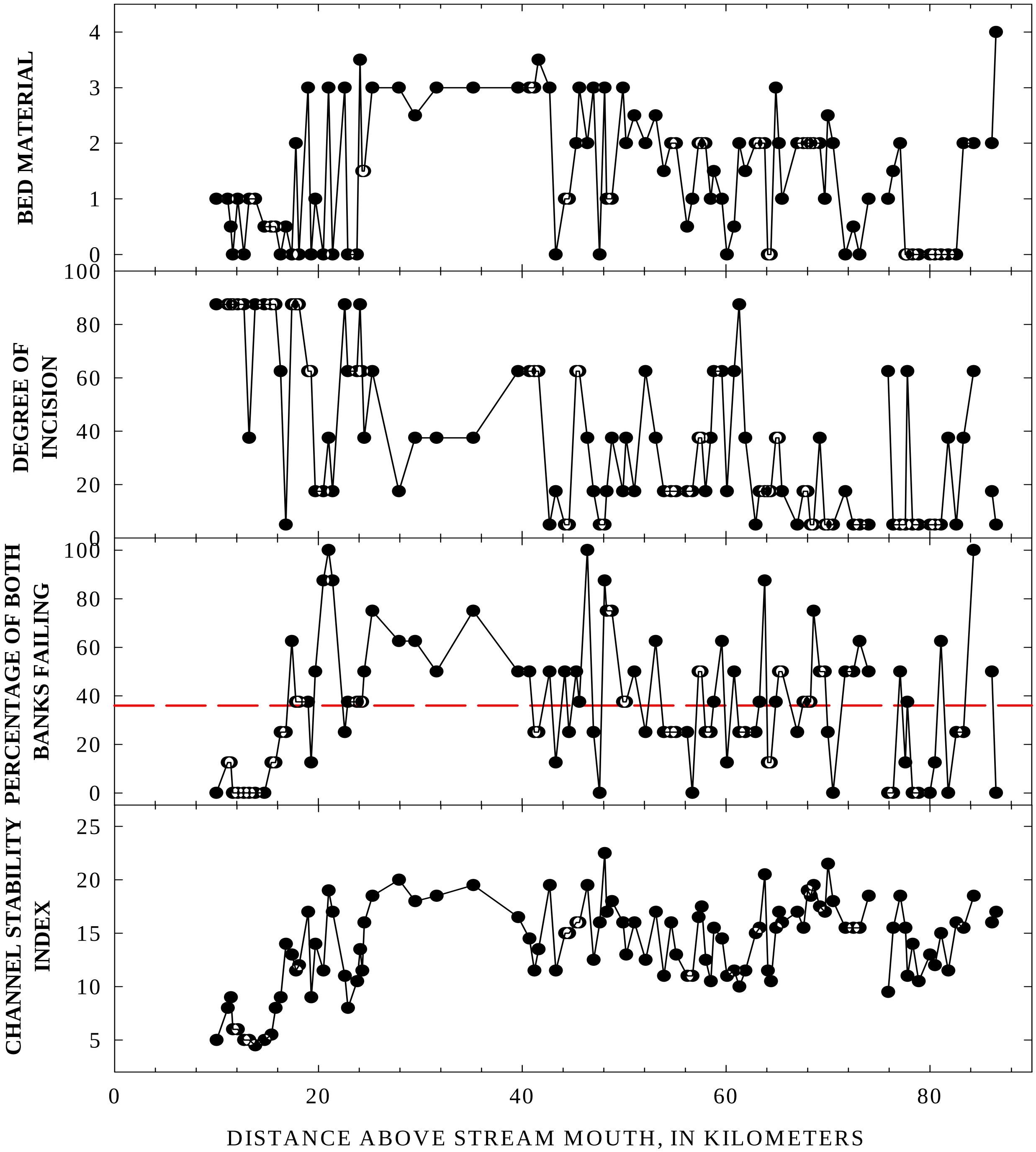

Figure 2. Longitudinal trends from RGAs in Shades Creek. Ordinate values on plots refer to RGA ranking scheme. Dotted line indicated average length of observed banks that are failing (36%).

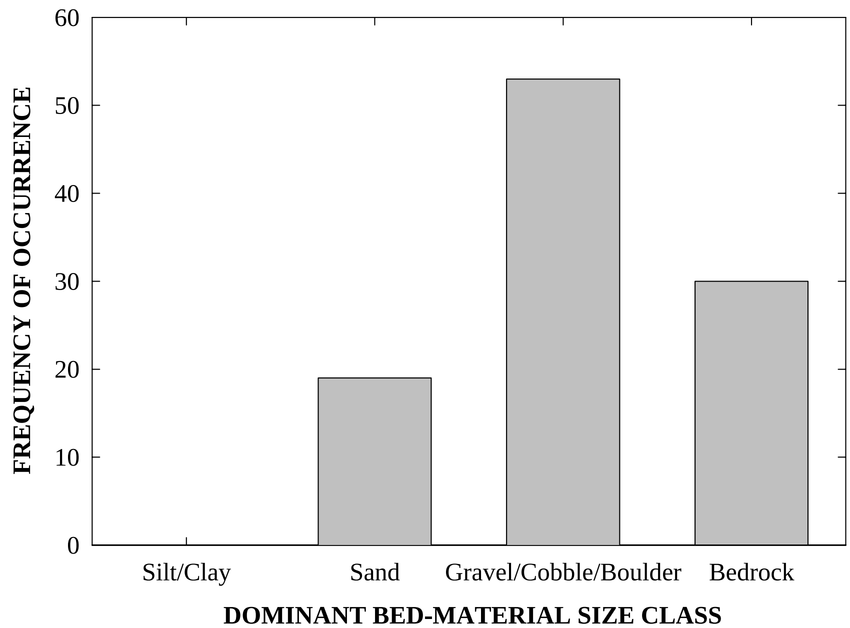

Figure 3. Frequency of bed material types in Shades Creek

3. Water Quality Assessment

Data collected in 1994 by the Geological Survey of Alabama (GSA) supported the decision made by EPA to include Shades Creek on the Alabama 1996 303(d) list as being impaired and not fully supporting water quality use classification (GSA, 1997). Since 1997, EPA biologist from the Ecological Assessment Branch of the Science and Ecosystem Support Division (SESD) conducted three habitat studies in the Shades Creek watershed to support TMDL development (USEPA, 1997, 2000, and 2002). The results of these independent studies concluded that Shades Creek is being negatively impacted by the increase of water volumes and velocity within the channel, which is attributable to nonpoint source runoff from existing development. Addressing sediment loadings from the watershed, habitat and water quality should improve in Shades Creek and be reflected in the biological community.

The studies described in this section were conducted according to EPA approved Standard Methods protocols. A summary of sampling stations from the various habitat and water quality studies conducted in the Shades Creek watershed is shown in Table 1. The original site designations from the studies were maintained, but for clarity were assigned a river-mile for orientation within the watershed. Definitions of the various metrics used in biological assessments of fish and macroinvertebrates are included in Appendix B.

Table 1. Summary of sampling stations in Shades Creek watershed

Station	Agency	Location	River Mile	Notes
SC1	SWMA	Elder Street	6	
SC-MB	UAB	Mountain Brook Pkwy	10	at Southwood Rd.
SH-02	SESD	Hwy 280	11	
SC2	SWMA	Lakeshore Drive	14	near Columbiana Rd
SC-65	UAB	Lakeshore Drive	14	at W. Rue Maison
SC-42	GSA	CR 42	16	Oxmoor Rd
SH-03	SESD	CR 42	16	**Same as SC-42**
SHD-10	ADEM	CR 95	18	Wood Waste Facility
SH-04	SESD	SR 150	24	
SH1	ADEM	SR 150	24	**Same as SH-04**
SH1a	ADEM	SR 150	25	Downstream SH1
SC3	SWMA	SR 150	25	near Galleria
SHD-11	ADEM	SR 150	26	near Parkwood
SH-05	SESD	Morgan Rd	31	
SC-55	GSA	CR 55	35	Dickey Springs Rd (Greenwood)
SC4	SWMA	CR 55	35	**Same as SC-55**
SH-06	SESD	SR 53	39	McClendon Chapel Rd
SH-07	SESD	Mitchell Ford	46	War Eagle Drive
SC-12	GSA	CR 12	50	Bibb Co.
SC-1	SESD	CR 12, Grey Hill Rd	53	Confluence with Cahaba R.
HTHS	*UAB*	*Cahaba River at Hewitt – Trussville High School*	*5*	*Reference: Cahaba River*
SHD-12	*ADEM*	*AL Hwy 150, Muscoda*	*8*	*Tributary: Little Shades Creek*

3.1 Water Quality Criteria

The Alabama 303(d) List identifies Shades Creek as having impaired conditions to support Fish and Wildlife (F&W) designated use due to turbidity, siltation and habitat alteration. Impairment due to turbidity refers to excessive amounts of fine-grained materials being transported in the water column. Impairment due to siltation implies that deposition of fine-grained materials on the channel bed has hampered oxygenation of coarser bed material (gravels and cobbles), creating poor habitat for aquatic organisms. Water quality criteria for the fish and wildlife use classification are described in ADEM Admin. Code R. 335-6-10-.09(5)(9). The criteria does not contain a numerical target for sediment but is in narrative form for turbidity:

> "*there shall be no turbidity other than natural origin that will cause substantial visible contrast with the natural appearance of waters or interfere with any beneficial uses which they serve. Furthermore, in no case shall turbidity exceed 50 Nephelometric units above background. Background will be interpreted as the natural condition of the receiving waters, without the influence of man-made or man-induced causes. Turbidity levels caused by natural runoff will be included in establishing background levels*".

The State of Alabama does not have numerical limits for siltation or habitat alteration. Water quality criteria applicable to all state waters are defined in ADEM Admin. Code R. 335-6-10-.06(c):

> *"State waters shall be free from substances attributable to sewage, industrial wastes, or there wastes in concentrations or combinations which are toxic or harmful to human, animal or aquatic life to the extent commensurate with the designated usage of such waters".*

3.2 Biological Assessments with Fish

3.2.1 Geological Survey of Alabama (GSA)

In the GSA study, the conditions of the fish community generally correlated with habitat parameters described by a scoring system that evaluates local site conditions for stability and diversity. Biological assessments were conducted at three locations: Shades Creek at Bibb County Highway 12 (furthest downstream station); Shades Creek at Greenwood; and Shades Creek at Oxmoor (upstream station). As shown in Table 2, the habitat scores at the Greenwood station were the lowest due to riparian and bank structure depreciation, while the site downstream in Bibb County was more stable.

The GSA study defined biotic integrity as the ability to support and maintain a balanced, integrated, adaptive community of organisms having a species composition comparable to that of natural habitat of the region. This can be quantified with an Index of Biotic Integrity (IBI) score for sample sites and utilized for correlating with other variables, whether physical or chemical. The IBI measures 12 attributes of the fish community, also known as metrics, which are scored 1 (worst), 3, or 5 (best) compared to values expected from an undisturbed fish community in similar-sized streams of the same region. The sum of the scores for the 12 metrics (total IBI) varies from 12 to 60. Based on the IBI score, fish communities are assigned to one of five classes: excellent (57 to 60), good (48 to 52), fair (39-44), poor (28-35), and very poor (12-23). The index of biotic integrity (IBI) score at the upstream station was in the poor range while the downstream portion was rated fair. At the upstream station, the fish community status demonstrated impairment with only 5 species producing 542 g of biomass in a sample. Of note, collections within that site coincided with elevated turbidity and TSS concentrations (see Table 2).

Table 2. Water Quality and Fish Collection Data (GSA, 1997)

Station	Date	Turbidity (JTU)	TSS (mg/L)	Habitat Score Max=135	# Species	Biomass (g)	IBI Score
SC-42	4/19-6/29/94	18-120	19-223	97.5 (good)	5	542	34 (poor)
SC-55	4/19-6/29/94	16-205	20-490	83.5	Data not collected		
SC-12	4/19-6/29/94	13-48	13-47	105 (good)	18	935	40 (fair)

3.2.2 University of Alabama at Birmingham

Biological assessments were made by the Biology Department of the University of Alabama during for 2000 through 2003 for select seasons as part of their ongoing research in local water quality. Using the Rapid Bioassessment Protocol (RBP) II (USEPA, 1999), biological collections of fish and benthic macroinvertebrates were performed, as well as evaluations of water quality parameters and habitat conditions. It is beneficial to sample fish communities as they provide supplemental ecological information differing from that of benthic macroinvertebrate communities because they are longer-lived and consequently integrate environmental contaminants over a longer period of time. A summary of the selected metrics at the UAB sites is provided in Table 3. Results indicate fish IBI scores were poor overall through the years at the Shades Creek sites and correlated with lower habitat scores. Conversely, collections at the reference site of the Cahaba River at Hewitt-Trussville High School, had higher habitat ratings with higher IBI scores and representation by crevice spawners. Collections did not reveal any of the sedimentation-sensitive crevice spawners at the Shades Creek stations. Local crevice spawners are the Alabama shiner, *Cyprinella callistia*, and the tricolor shiner, C. *trichroistia* (Drs. R. Angus and Dr. K. Marion unpublished data).

Table 3. Summary of IBI scores at select locations in Shades Creek and Cahaba River (UAB, 2004)

Station	Sample Date	Habitat Score Max=200	IBI score	Condition	% Crevice Spawners
SCMB	6/4/2002	132	36	Poor	0.0
	10/10/2002	130	28	Poor	0.0
SC65	4/17/2000	125	40	Fair	0.0
	9/22/2000	123	34	Poor	0.0
	4/20/2001	131	34	Poor	0.0
	9/26/2001	117	32	Poor	0.0
	4/19/2002	117	38	Fair	0.0
	11/1/2002	134	36	Poor	0.0
HTHS	5/3/2000	172	52	Good	35.4
	10/27/2002	180	50	Good	26.7
	10/4/2001	178	50	Good	21.1
	6/6/2002	180	46	Fair	21.0
	10/23/2002	180	50	Good	35.2
	4/30/2003		52	Good	28.0

3.3 Biological Assessments with Macroinvertebrates

3.3.1 EPA Science and Ecosystem Support (SESD)

In January 1997, EPA conducted a Rapid Bioassessment Protocol II (RBP II) at two locations within the Shades Creek watershed using a multi-habitat approach (USEPA Region 4, 2002). In the multi-habitat approach samples are collected in pools, snags/woody debris, leaf packs, streambanks, bottom substrate and riffles. The RBP II consists of three components: (1) a family taxonomic level biosurvey of the benthic macroinvertebrates, (2) a habitat evaluation, and (3) in-situ water quality measurements including water temperature, dissolved oxygen, pH, and conductivity. The purpose of the study was to identify possible impacts to the benthic macroinvertebrate fauna associated with construction activities, land clearing, and excavation for University Park, a development near Samford University. Results of the study indicate all three components of the RBP II did not identify any marked differences in the water quality or biology downstream of the University Park development. It was noted that Shades Creek is impacted by sedimentation from nonpoint source runoff from development and impervious area both upstream and downstream of University Park. The integrity of the stream riparian zone has been compromised throughout the study area; channelization has also eliminated quality stream habitat.

In October 2000, EPA Region 4 SESD working with ADEM, GSA, and the Alabama Rivers Alliance acquired biological community and habitat information at various locations in Shades Creek streams in the Cahaba River basin (USEPA, 2001). A multi-habitat RBP III was used to sample the benthic macroinvertebrates and included sampling both ripples and banks. Benthic macroinvertebrate data were used to calculate five metrics for evaluating habitat. Table 4 provides a summary of select metrics calculated for this study. Benthic macroinvertebrate data indicate the greatest impairment at the stations in the upper portion of the watershed (i.e., Stations Sh-02 and SH-03) where land cover is dominated by urban areas. Habitat evaluations indicate degradation with regards to epifaunal substrate, sediment deposition, and bank stability at all stations with the exception of SH-03 and SH-07.

Table 4. Summary of Metric and Habitat Evaluation Results (SESD, 2001)

Station	**Sorenson's QS**	**Habitat Score (max= 200)**	**Taxa Richness**	**EPT Index**	**% Dominant Taxa**	**Multi-metric Score (max=30)**
SH-02	0.24	107	35	5	16.78	18
SH-03	0.37	129	27	1	13.07	20
SH-04	0.25	89	39	11	18.21	24
SH-05	0.31	85	39	10	14.21	24
SH-06	0.48	95	30	9	24.12	24
SH-07	0.38	130	42	11	26.67	22

In 2002, SESD conducted biological and water quality studies of the Cahaba River and associated tributaries (USEPA, 2002). The studies focused on the causes of nutrient impairment in the Cahaba River. A multi-habitat approach was used to collect benthic macroinvertebrate samples in Shades Creek at station SC-1 in July 2002 during a time of low water levels. Station SC-1 is located at County Road 12 near the confluence with the Cahaba River (see Figure 1). Metrics exhibiting sensitivity to stress that aided in identifying perturbation relative to the benthic macroinvertebrate community are shown in Table 5. Results indicate this station supporting good ecological health. This is to be expected as the stream is well connected to the floodplain and has wide riparian buffers. Little to no development has occurred in the lower portion of the watershed.

Table 5. Summary of Select Metric and Habitat Evaluations, July 2002 (SESD, 2002)

Station	EPT Index	% EPT	Taxa Richness	% Dominant Taxa	Habitat Score	% Ephemeroptera	IAI
SC-1	13	58	27	23	169	47	2.04

3.3.2 University of Alabama at Birmingham (UAB)

Benthic macroinvertebrate samples were collected simultaneous to the fish collections in the UAB research project. Macroinvertebrate community structures serve a different purpose as indicators of water quality than the fish, as they will reflect impacts rather quickly in terms of their presence/absence, dominance by particular species or a dramatic change in feeding regimes. Long-term biological sampling of riffles was carried out at three locations during spring, summer and fall seasons also using the RBP II for biota collections, habitat assessments and in-situ water quality measurements. Taxa richness numbers are different when samples are collected in only riffles as compared to the numbers from a multi-habitat sampling approach.

The Cahaba River at Hewitt-Trussville High School (HTHS) was identified as supporting a healthy biological community and is considered an appropriate reference site for comparison in biological assessments, habitat and water quality evaluations for Shades Creek. A summary of select metrics (Appendix 1) computed at these stations is shown in Table 6 and provides further indication that Shades Creek is impaired by sedimentation. For example the percent intolerant taxa are missing relative to the HTHS reference site at all of the Shades Creek stations. The percentage of the orders Ephemeroptera, Plecoptera and Trichoptera (EPT), has traditionally been used as an indicator of water quality; however, research is determining that the removal of the tolerant Ephemeroptera family, Baetidae, and the Trichoptera hydropsychids shows a more realistic depiction of the truly sensitive EPTs remaining. Beck's Biotic Index displays a trend of low scores for sites known to be impaired by sedimentation while the reference site has scores that range much higher, indicating good water quality. In addition, habitat scores are lower at the Shades Creek sites and sediment depths in pools at the Shades Creek sites are higher relative to the HTHS reference site.

Table 6. Summary of select metrics at long-term biological monitoring sites

Station	Season /Year	Sediment Depth (cm)	Habitat Score max=200	% EPT	% EPT modified	Beck Biotic Index	% Intolerant Taxa	IAI
SCMB	Sp 2002	3.7	132	45.2	1.0	1	0.0	0.16
	Su 2002			44.4	2.9	1	0.0	0.09
	Fa 2002	3.2	130	29.2	1.0	1	1.0	0.17
SC65	Sp 2000	5.6	125	1.5	0	0	0.0	0.13
	Su 2000			45.4	1.02	0	0.0	0.04
	Fa 2000	4.6	123	21.2	4.0	0	0.0	0.09
	Sp 2001	4.4	131	6.9	0	1	0.0	0.06
	Su 2001			22.6	1.4	0	0.0	0.01
	Fa 2001	2.7	117	11.7	0.98	0	0.0	0.01

Station	Season /Year	Sediment Depth (cm)	Habitat Score max=200	% EPT	% EPT modified	Beck Biotic Index	% Intolerant Taxa	IAI
	Sp 2002	4.5	117	62.2	0	0	0.0	0.12
	Su 2002			50.7	1.5	1	0.0	0.09
	Fa 2002	4.1	134	31.4	2.4	1	2.4	0.21
HTHS	Sp 2000	1.4	172	27.9	10.9	9	4	0.29
	Fa 2000	1.5	174	77.4	31.7	1	0.0	0.49
	Sp 2001	1.3	178	56	25.5	10	3	0.47
	Fa 2001	0.8	180	26.4	13.2	5	4	0.11
	Sp 2002	1.6	180	62.3	48.1	8	5	1.48
	Su 2002			58.3	47.7	8	5	0.50
	Fa 2002	1.8	180	55.5	48.5	6	3	0.90

3.4 Water Chemistry Data

3.4.1 Alabama Department of Environmental Management (ADEM)

ADEM has an ambient monitoring station on Shades Creek near Hwy 150, identified as SH1, which was moved slightly downstream of the bridge and relabeled as SH1A (see Figure 1). Water quality samples are collected monthly and analyzed for turbidity, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), and other conventional parameters. Data collected between 1994 and 2002 are summarized in Table 7. In addition, ADEM conducted an intensive survey in 1997 at 13 locations along Shades Creek. The stations showing the highest turbidity and TSS results were located near station SH1 and Little Shades Creek.

Table 7. Summary of Ambient Monitoring Data (1994-2002) collected by ADEM

Station	Sample Period	Parameter	# Samples	Min.	Max.	Mean
SH-1	1/4/94 – 10/16/96	Turbidity (NTU)	33	2.4	590	44.46
SH-1A, SHD-11	11/13/96 – 8/6/02	“	27	0.07	85.7	19.48
SHD-10	6/4/97 – 9/16/97	“	5	5.9	53.8	24.54
SHD-12	6/4/97 – 9/16/97	“	5	7.2	34	14.72
SH-1	1/4/94 – 10/16/96	TSS (mg/L)	32	1	605	51.03
SH-1A, SHD-11	11/13/96 – 8/6/02	“	27	1	53	13.81
SHD-10	6/4/97 – 9/16/97	“	5	5	29	13.8
SHD-12	6/4/97 – 9/16/97	“	5	2	5	3.4
SH-1	1/4/94 – 10/16/96	TDS (mg/L)	32	80	264	158.97
SH-1A, SHD-11	11/13/96 – 8/6/02	“	27	108	424	166.30
SHD-10	6/4/97 – 9/16/97	“	5	111	213	153.6
SHD-12	6/4/97 – 9/16/97	“	5	165	210	191.6

3.4.2 Stormwater Management Authority, Inc. (SWMA)

Shades Creek is located geographically within the Birmingham/Jefferson County MS4 permit area for the Stormwater Management Authority, Inc. (SWMA). SWMA is a public corporation representing Jefferson County and 23 cities and is responsible for administering the Phase I MS4 permit. SWMA oversees a water quality data collection effort for streams, screening points, and characterization sites as required in the NPDES permit. In accordance with permit requirements, SWMA collects water quality samples quarterly at four locations in Shades Creek during both rain events and dry weather. The MS4 permit requires monitoring for numerous parameters including TSS and TDS, but monitoring turbidity is not a permit requirement. All samples were collected and analyzed as per the Quality Assurance/Quality Control (QA/QC) mandates of the NPDES permit. A summary of available TSS and TDS measurements collected between 1999 and 2003 is shown in Table 8. The data shown in Table 8 was used to calibrate the AnnAGNPS and CONCEPTS models.

Table 8. Summary of Water Quality Data Collected by SWMA (1999-2003)

Station	Samples Collected	Total Dissolved Solids (mg/L)			Total Suspended Solids (mg/L)		
		Min	Max	Median	Min	Max	Median
Dry Weather							
SC1	11	135	250	194	1	171	5
SC2	11	128	266	191	1	9	5
SC3	11	120	246	189	1	15	6
SC4	4	132	139	132	1	14	12
Rain Events							
SC1	11	60	218	131	5	56	12
SC2	11	98	199	140	5	136	36
SC3	11	90	254	145	5	621	43
SC4	3	137	167	154	6	41	14

3.5 Suspended Sediment Data

Suspended-sediment data were available for Shades Creek near Greenwood, AL (USGS station 02423630) from the USGS and from SWMA (see Table 8). When used in conjunction with the instantaneous discharge at the time of sample collection, sample data was used to compute suspended-sediment transport rates. Integration with continuous flow records allows annual suspended-sediment loads to be calculated.

In the Ridge and Valley, 74 sites in seven states have at least 30 matching samples of suspended sediment and instantaneous flow discharge. Of the 74 sites, 56 gauging stations had sufficient mean-daily flow data to calculate annual suspended-sediment loads. Flow data were downloaded from the USGS web site and discharge values were converted from ft^3/s to m^3/s. Daily loads were calculated for each gage by applying the appropriate rating equation to the mean discharge for each day, giving a suspended-sediment load in metric units of T/d. Daily-load values were summed by calendar year and divided by drainage area to obtain the annual suspended-sediment yield (in metric units of $T/y/km^2$) for each year of flow record. Mean annual suspended-sediment yields were calculated by dividing by the number of years of complete flow record. An annual concentration (in mg/l) was calculated for each station-year of record by dividing the suspended-sediment load by the total volume of water during the year. Summing the annual concentrations and then dividing these values by the number of years in the complete flow record obtained mean-annual concentrations.

3.5.1 Suspended Sediment Transport Rating

Mean-daily flow values from USGS gaging station records were used to calculate annual loads and yields. A daily load was calculated for each suspended sediment sample using the following formula:

$$L = 0.0864\, C\, Q \qquad (1)$$

where: L = load in T/d;
C = instantaneous concentration, in mg/l; and
Q = instantaneous discharge, in m^3/s.
The value 0.0864 is to convert from seconds to days and from milligrams to tonnes.
Linear regression in log-log space results in power function describing the relation between instantaneous discharge and load as:

$$L = a\, Q^{b} \qquad (2)$$

where a and b are regression coefficients.

3.5.2 "Existing" Sediment Transport Conditions on Shades Creek

A suspended-sediment rating relation was developed for the gauge near Greenwood based on data obtained from the USGS and, more recently, from data collected by SWMA (see Figure 4). Note that both the 95% confidence limits of the regression and the 95% prediction limits are shown in Figure 4, highlighting the relative uncertainty inherent in predicting a suspended-sediment load at a given discharge. In terms of average annual values, the suspended sediment load at the Greenwood gage is about 9850 T/yr. Normalizing this load by the drainage area results in an average annual sediment yield of 52.6 T/y/km^2. The median annual suspended-sediment concentration for Shades Creek near Greenwood is 77.6 mg/l.

The AnnAGNPS and CONCEPTS models were used to estimate the sediment contribution from the watershed and instream processes based on current (2001) land use. At the confluence of Shades Creek and the Cahaba River, the total suspended sediment load is about 19,700 T/yr, or in terms of yield, 54 T/yr/km^2. Simulated and measured sediment yield are within 5 percent.

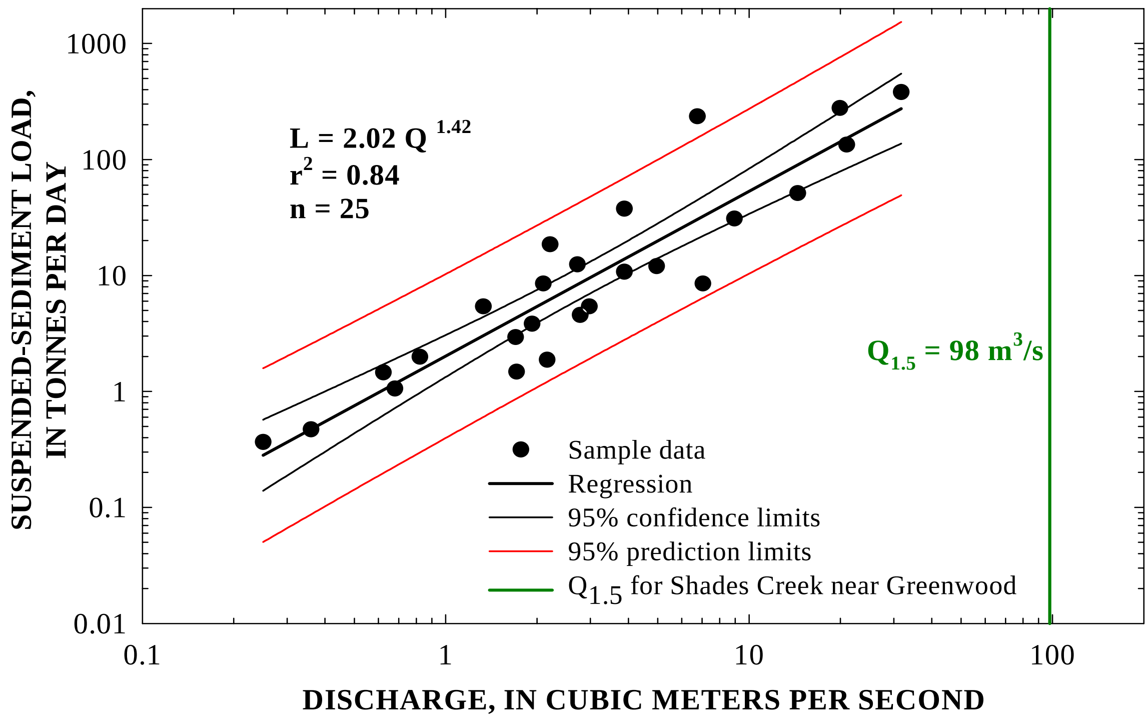

Figure 4. Suspended sediment rating relation for Shades Creek at USGS gage 02423630

4. Technical Approach for Target Identification

In the absence of numerical targets, EPA often compares pollutant loads transported in an impaired stream to those transported in an unimpaired or reference stream. In this TMDL, an unimpaired stream is considered a stable stream as defined by geophysical properties. Future studies in the Shades Creek watershed will correlate habitat quality and geophysical properties. The ecoregion approach bases the TMDL target on suspended sediment loads transported in stable streams. This approach has been used successfully in other Region IV states to develop approvable TMDLs. Because the effects of sedimentation on habitat and water quality are considered a long-term process, the target for the Shades Creek TMDL is represented as the median average annual load carried in stable streams in the ecoregion.

One of the objectives of the CWP study was to determine applicable suspended-sediment “reference” condition and sediment yield for the Ridge and Valley Ecoregion and apply it to conditions along Shades Creek using geomorphic techniques and historical data from U.S. Geological Survey gauging station on Shades Creek near Greenwood, Alabama. Bed material composition measured in Shades Creek was compared to “reference” values in the Ridge and Valley ecoregion. Bed material composition is discussed in this TMDL as it could be used as an indicator of improved habitat conditions. Details on the development of the ecoregion targets are included in the attached CWP report and summarized below. Reference streams can be defined as those streams exhibiting “expected” conditions that integrate all naturally occurring processes.

4.1 Reference Sediment Yields

The Ridge and Valley ecoregion encompasses a geographical area extending from Pennsylvania to Alabama. Seventy-four sites within the Ridge and Valley ecoregion have sufficient flow and suspended sediment data to construct transport-rating curves (see Section 2.6 in the CWP modeling report). At each site, discharge is plotted versus concentration in log-log space and obtaining a power function by regression (Porterfield, 1972; Glysson, 1987; Simon, 1989a). Figure 5 illustrates the development of sediment transport rating relationship for a stable stream in the Ridge and Valley Ecoregion. Preliminary analyses show that although sand concentrations continue to increase with discharge, the silt-clay fraction attenuates, causing the transport relation to flatten. A transport rating developed with a single power function commonly over-estimates concentrations at high flow rates, leading to errors in calculating the effective discharge. To alleviate this problem, a second or third linear (in log-log space) segment is sometimes developed with the upper end of data set (see Figure 5).

Annual suspended-sediment yields were calculated for all sites with available data in the Ridge and Valley using mean-daily flow data and the suspended-sediment transport relations described above. Median annual suspended-sediment yield and concentration for stable/reference sites in the Ridge and Valley is 24.7 T/y/km^2 and 45.1 mg/l, respectively. Calculations of reference conditions at all sites in the Ridge and Valley are included in Simon (2003). A comparison of annual suspended-sediment yields and concentrations for "reference" sites and unstable sites in Shades Creek are shown in Figure 6 and Figure 7.

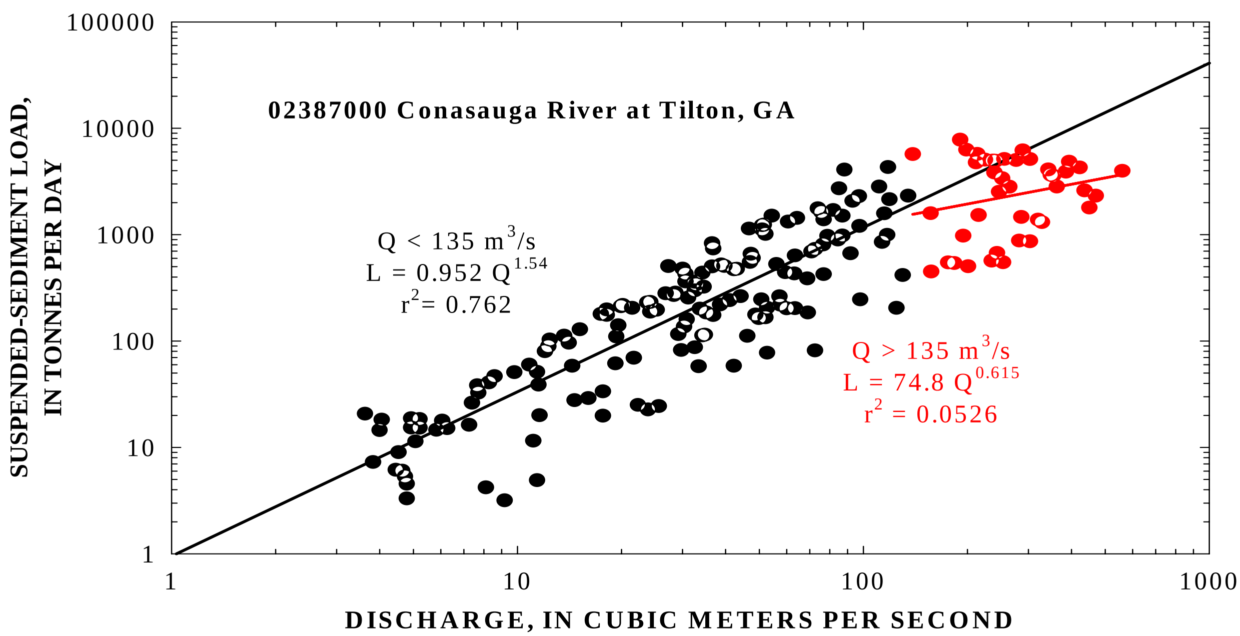

Figure 5. Development of suspended-sediment rating relation in log-log space showing potential error at high discharges without incorporating a second linear segment.

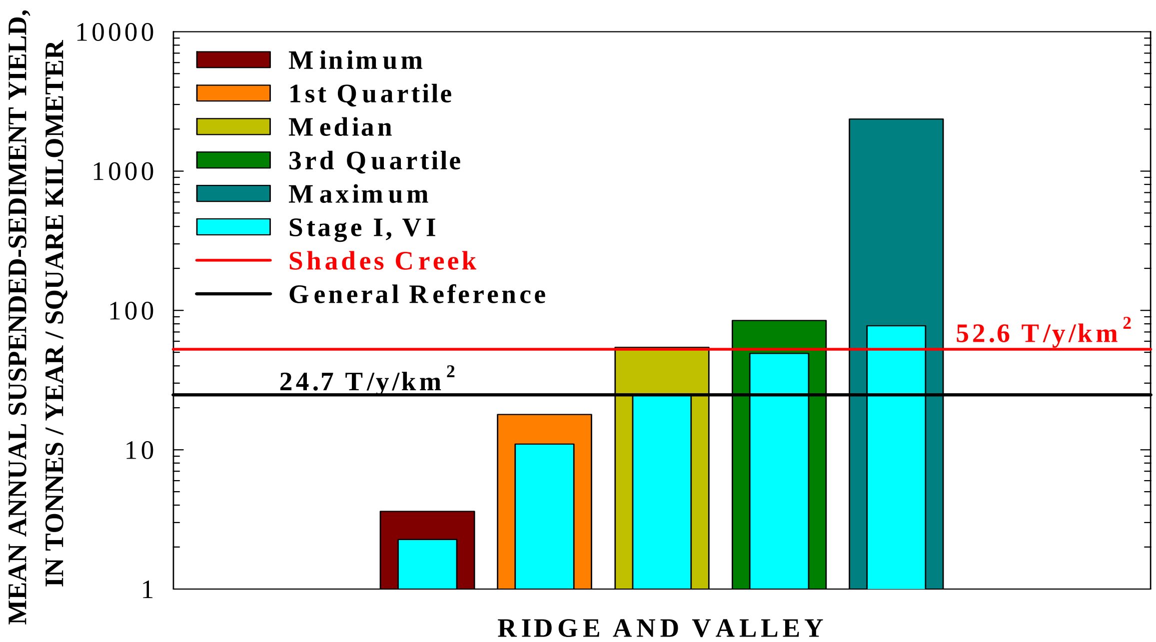

Figure 6. Comparison of mean annual suspended-sediment yield in "reference" streams in the Ridge and Valley and in Shades Creek

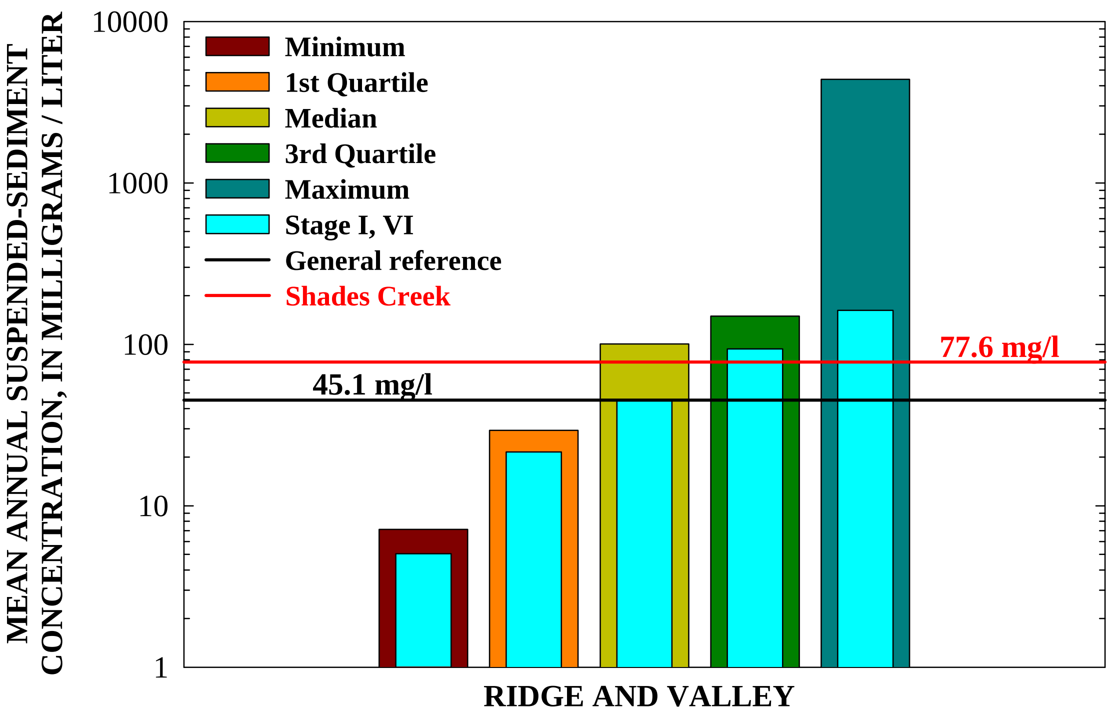

Figure 7. Comparison of mean annual suspended-sediment concentration in "reference" streams in the Ridge and Valley and in Shades Creek

4.2 "Reference" Bed Material Composition

Using the same concept for bed material as was used for suspended sediment, sites from the Ridge and Valley were sorted into stable and unstable sites to determine a reference bed-material composition for coarse-grained reaches. Coarse-grained reaches are singled out because streams designated as impaired due to siltation impact spawning habitats and other biologic life functions by clogging interstitial spaces in gravel-cobble beds. Because a reasonably large number of stable sites were also located on Shades Creek, reference conditions developed for the Ridge and Valley can be directly compared to reference conditions along Shades Creek itself. Reference sites on Shades Creek are designated as being Stage I or Stage VI based on the channel evolution model and are listed in Appendix A. The importance of discussing bed material composition is this could be used as an indicator of achieving the TMDL.

A reference bed-material composition is based on a measure of embeddedness; the percentage of materials finer than 2 mm (sand, silt and clay) in gravel or gravel/cobble-dominated streambeds. Bed-material data from both the Ridge and Valley and Shades Creek were filtered to include only those sites that are dominated by coarse-grained sediment (more than 50% of the streambed composed of materials coarser than 2 mm). Further sorting of the data into stable and unstable sites provided a means of comparing the degree of embeddedness in coarse-grained stream reaches. A reference value of 4%, based on the median percentage of streambed material finer than 2 mm was determined for not only the Ridge and Valley (Figure 8) but for Shades Creek as well (Figure 9).

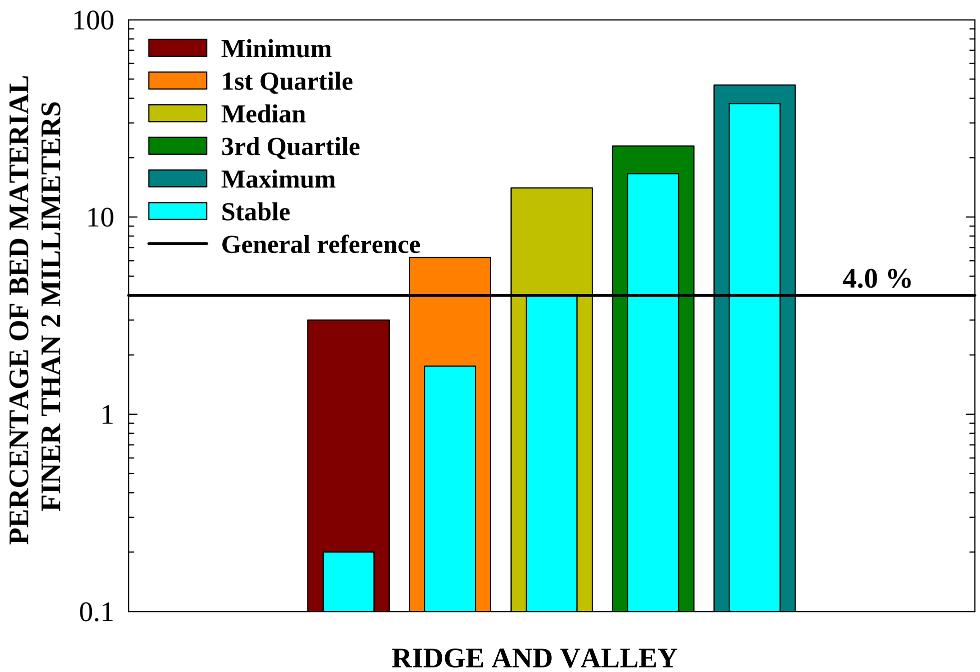

Figure 8. Comparison of percentage of bed material finer than 2 mm (sand) for "reference" and unstable sites in the Ridge and Valley

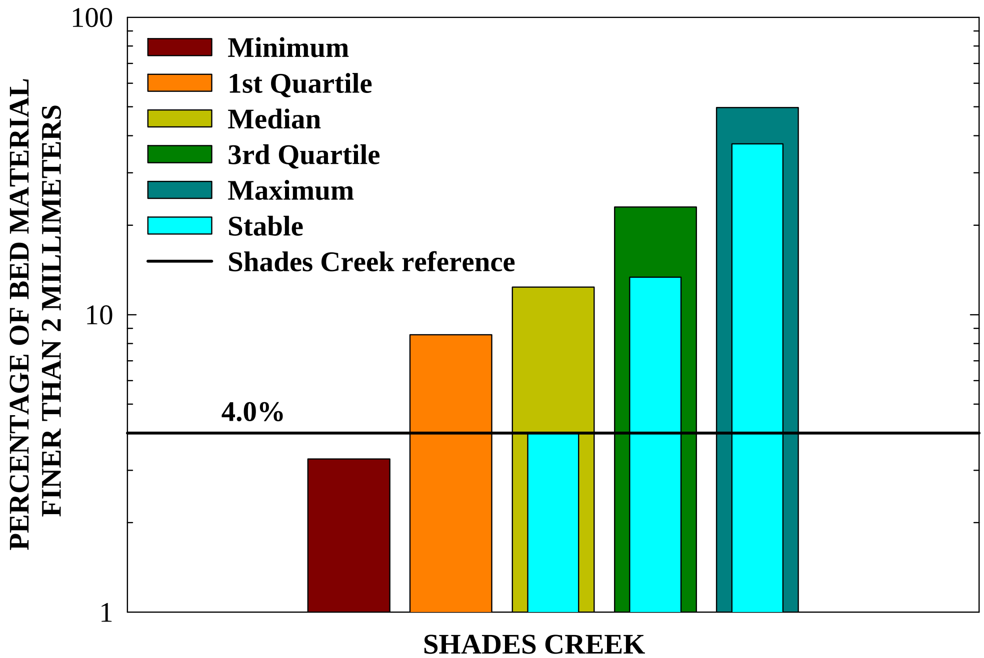

Figure 9. Comparison of percentage of bed material finer than 2 mm (sand) for stable and unstable sites in Shades Creek

A comparison of embeddedness values for "reference" and unstable sites in the Ridge and Valley and Shades Creek is shown in Table 9. It is coincidental that the median values for embeddedness are the same for both Shades Creek and the Ridge and Valley. Achieving the embeddedness values measured in stable segments of Shades Creek should result in attainment of improved habitat quality.

Table 9. Comparison of embeddedness in stable and unstable sites in Shades Creek and Ridge and Valley

Location	1st Quartile	Median	3rd Quartile	Inter-quartile range
Stable/reference sites				
Ridge and Valley	1.8	4.0	16.6	14.8
Shades Creek	0	4.0	13.4	13.4
Unstable sites				
Ridge and Valley	6.2	14.1	22.9	16.4
Shades Creek	8.6	12.4	23.0	14.4

5. Source Assessment

A TMDL evaluation examines the known potential sources of the pollutant in the watershed, including point sources, nonpoint sources, and background levels. For the purpose of these TMDLs, construction activities greater than one acre, MS4s, and continuous discharge facilities under the National Pollutant Discharge Elimination

System (NPDES) Program are considered point sources. The AnnAGNPS and CONCEPTS models were used to characterize nonpoint sources of sediment.

5.1 Continuous Discharge Point Sources

Collection system failures may have been a historical source of turbidity and sediment in the Upper Shades Creek watershed, but is unlikely since the closure of the Shades Valley Waste Water Treatment Plant (WWTP). The 1.8 million linear feet of sewer servicing the Shades Creek basin is connected to the Valley Creek WWTP which discharges to Valley Creek. Leakage from collection lines could contribute to high turbidity levels in the stream.

There are two WWTP located on Mud Creek, a tributary to Shades Creek in the southwest portion of the watershed (see Figure 1). Tannehill State Park Lagoon (NPDES AL0056359) and East Tuscaloosa-West Jefferson STP (NPDES AL0068420) are permitted to discharge municipal waste. In general, sediment loads from point sources are negligible in relation to the nonpoint sources. In addition, sediment from point sources are generally composed of organic material and would provide less direct impact to biological integrity than would direct soil loss to the streams. According to ADEM's database, both facilities have not had any violations for TSS since 2001 (ADEM, 2003). During the month of April 2001, East Tuscaloosa-West Jefferson STP had one TSS violation. During the month of September 2001, Tannehill State Park Lagoon had three TSS violations. Turbidity limits are not required in either permit. Permit information and calculated wasteload allocations (WLA) for NPDES facilities are shown in Table 10.

Table 10. Continuous discharge NPDES facilities in Shades Creek watershed

Facility	NPDES No.	Design Flow (mgd)	TSS Limit (mg/l)	WLA (Tonne/day)
E. Tuscaloosa-W. Jefferson STP	AL0068420	0.8	30	0.09
Tannehill State Park Lagoon	AL0056359	0.08	90	0.03

Note: WLA calculated as follows: flow (mgd) * concentration(mg/l) * 8.345/2204.623 = tonne/day (e.g., 0.8*30*8.345 = 200 lb/day = 0.09 tonne/day)

5.2 Municipal Separate Storm Sewer Systems (MS4s)

Large and medium Municipal Separate Storm Sewer Systems (MS4s) serving populations greater than 100,000 people are required to obtain an NDPES storm water permit. At present, Jefferson County/City of Birmingham and 22 other municipalities are included in one MS4 permit regulated by the NPDES program (ALS000001). In March 2003, EPA initiated Phase II MS4 permits for municipalities of 50,000 people. Currently, Sylvan Springs is the only Phase II municipality to join the SWMA program (personal correspondence with SWMA, 2003).

The upper Shades Creek watershed, from the headwaters to the Jefferson County line, is within the MS4 permit area (personal correspondence with SWMA, 2002). Discharges from MS4s occur in response to storm events. During rain events, sediment originating from construction activities and urban areas is transported to the stream through road drainage systems, curb and gutter systems, ditches, and storm drains. The MS4 permit requires quarterly collection of water quality samples at select locations and times. Samples are analyzed for metals, cyanides, phenols, and conventional pollutants including suspended sediment. As part of the MS4 permit, SWMA has an Erosion and Sediment Control Ordinance to control discharges of storm water and non-storm water discharges to the MS4 from lands on which land-disturbing activities are conducted.

5.3 NPDES Construction Activities

ADEM requires an NPDES permit for construction activities of one acre or greater in size. The permit requires a Construction Best Management Practices Plan (CBMPP) be designed for the site and fully implemented and maintained to minimize pollutant discharges in stormwater runoff to the maximum extent practicable during land disturbance activities. Details of the requirements of ADEM's NPDES construction permit can be found in ADEM Admin. Code 335-6-12.

5.4 Nonpoint Sources

Nonpoint sources of sediment can potentially include roads, bare ground (i.e., non-permitted construction type sites, etc.), and sheet and rill erosion from uplands and agricultural fields, gullies, and streambeds and banks. The highest eroding areas occur in the upper end of the watershed as well as along some of the ridges. One of the principal indicators why these areas produce such high erosion values is the effect of slope and gradient on erosion.

The adjustment of channel width by mass-wasting and related processes represents an important mechanism of channel response to increased streamflow. Sediment entrained from bank failures are blamed as a contributor to fine-grained sediment deposition on the streambed. Stream bank failures occur when erosion of the bank toe and the channel bed adjacent to the bank have increased the height and angle of the bank to the point where gravitational forces exceed the shear strength of the bank material. After failure, bank materials may be delivered directly to the flow and deposited as bed material, or dispersed as wash load, or deposited along the toe of the bank as intact blocks, or as smaller, dispersed aggregates (Simon et al., 1991).

AnnAGNPS and CONCEPTS modeling were conducted to determine the relative contribution of sediment from upland and channel sources. Four modeling scenarios were conducted to investigate a range of past, current and potential, future conditions in the watershed. Past conditions were simulated using 1991 landuse (Validation Scenario). Current and future conditions were simulated using 2001 landuse (2001 LU). A comparison of the relative source contribution of uplands and streambanks to suspended sediment integrated over the study reach between the 1991 and 2001 landuse scenarios is shown in Table 11. When comparing the landuse scenarios, loadings of sands emanating from uplands and streambanks have increased about 1,600 T/yr (170%) and 1,240 T/yr (29%), respectively. Streambank contributions of fines have decreased about 12 percent with respect to the Validation scenario due to channel adjustments between 1978 and 2001. In both scenarios, streambanks are the greatest source of sediments to suspended loads even though the relative contribution has decreased since 1991.

To illustrate the capabilities of AnnAGNPS to identify sources of runoff and sediment, the Little Shades Creek watershed simulation results were extracted from the complete Shades Creek simulation. The average annual runoff at the confluence of Little Shades Creek and Shades Creek was 326 mm/yr for the Validation scenario and 337 mm/yr for the 2001 LU scenario. Sediment eroded within the AnnAGNPS cells, transported to the edge of each cell, and then transported within the channel to the outlet of Little Shades Creek produced 23 T/yr/km^2 of sediment for the Validation scenario. For the 2001 LU scenario, the average annual sediment load from Little Shades Creek was 36 T/yr/km^2. This indicates that increased urbanization within Little Shades Creek watershed between 1991 and 2001 resulted in about a 56% increase in sediment loads entering Shades Creek.

Table 11. Comparison of relative source contributions between 1991 and 2001 landuse scenarios

Sediment Size	**Uplands**		**Streambanks**		**Total[1] (T/yr)**
	%	**Load (T/yr)**	**%**	**Load (T/yr)**	
1991 Landuse Scenario (Validation Scenario)					
Fines	29.2	6044	70.8	14,656	20,700
Sands	17.8	924	82.2	4266	5,190
Total Suspended	26.9	6940	73.1	18,860	25,800
2001 Landuse Scenario (2001 LU)					
Fines	40.3	7536	59.7	1164	18,700
Sands	31.2	2496	68.8	5504	8,000
Total Suspended	37.6	10,040	62.4	16,660	26,700

Notes: Total load represents the amount of sediment entering the modeling reach from streambanks and uplands; however, not all of it makes it to the downstream boundary, as a portion will be deposited along the streambed.

6. Numerical Modeling Results

The watershed model AnnAGNPS and the channel evolution model CONCEPTS were used to validate the ecoregion approach as well as to evaluate the distribution of sediment sources within the Shades Creek watershed using 1991 and 2001 landuse data. The CONCEPTS model was applied only to the main channel of Shades Creek and was used to identify locations in the stream where significant widening has occurred. Weather patterns recorded at the Birmingham airport were used in the AnnAGNPS model. Sediment loadings from tributaries were determined by AnnAGNPS and inputted to the CONCEPTS model at cells representing the confluence of tributaries and the main channel. Stream characteristic used in the CONCEPTS model were initially defined from 1978 Federal Emergency Management Agency (FEMA) channel surveys. Model results indicated structures such as pipe culverts and bridge crossings did not have significant affects on flow hydraulics and were not included in the CONCEPTS model.

The AnnAGNPS and CONCEPTS models were calibrated using 1991 landuse coverage and FEMA channel surveys (Validation Scenario). In the Validation Scenario, annual runoff and sediment loads simulated by AnnAGNPS were compared with data measured at the USGS gage near Greenwood, AL (02423630). The 2001 landuse coverage and channel characteristics defined from CONCEPTS at the end of the Validation Scenario were used as initial conditions for other model scenarios. These scenarios evaluated changes in sediment loads and bed material composition resulting from: 2001 landuse changes (2001 Landuse Scenario), instream BMPs (LURP Scenario), and potential future landuse changes where all forested areas are changed to urban (LUFU Scenario). Details on model calibration of these scenarios can be found in the attached CWP modeling report; a summary of the results is described below.

6.1 Simulated Runoff

An evaluation of the capability of AnnAGNPS to reproduce measured trends in runoff, sediment, and peak rates contributes to the reliability of input parameters used by CONCEPTS. Simulated average annual runoff was 78 percent of the measured as the measured runoff contains base flow that the simulated results do not reflect. The elimination of base flow from measured runoff would have improved the comparison; however, analysis was not available to estimate base flow contributions.

In the validation scenario, a significant amount of runoff occurs towards the upper end of the watershed where urban conditions dominate. In the central portion of the watershed, forest conditions dominate, resulting in lower levels of runoff. In the 2001 landuse scenario, the total average annual runoff at the outlet of the model (i.e., confluence with Cahaba River) was similar to the Validation scenario. Runoff produced from the 2001LUFU scenario shows almost all areas of the watershed producing higher amounts of runoff compared to the other scenarios. This is a result of higher SCS Curve Numbers (CNs) defined for urban areas. The variability of soil characteristics between soils would be another major cause of any variability among the runoff from the AnnAGPNS cells in the 2001 LUFU scenario since the landuse is mainly all forest.

6.2 Sediment Load

In general, annual loads of sediment transported in Shades Creek appear to be correlated with annual runoff. Years with low runoff correspond to years with low annual sediment loads. CONCEPTS model results were calibrated to loads measured at the USGS gage near Greenwood. Between 1978 and 2001, the Greenwood gage had 8 years of measured data. The measured annual sediment load was 9,850 T and the corresponding simulated average-annual load of suspended sediment over the same period was 10,400 T, a 5 percent difference. In terms of yield, the measured average annual load equates to 52.6 $T/yr/km^2$. For the Validation scenario, the simulated average annual yield is 58 $T/yr/km^2$.

During the field investigation segments of Shades Creek were identified as having significant bank failures. The CONCEPTS model was used to simulate the affect instream BMPs would have on sediment loadings at 17 cross sections experiencing widening greater than 1.5 m in the Validation scenario. In this scenario (2001LURP), 8.77 km or 11.5% of the model reach length was protected against erosion. Model results show that protecting streambanks significantly reduced the average widening of the modeling reach. The amount of fines eroded from the streambanks has been greatly reduced (by 10,200 T/y or 40%) because of bank protection.

The major outcomes of the four modeling scenarios regarding simulated runoff, suspended sediment load, reach-average widening, and bed elevation change are shown in Table 12. The simulated sediment load shown in this table are at the confluence of the Cahaba River and are less than what is transported in Shades Creek because of deposition. The largest amount of deposition occurs immediately downstream of the confluence with Little Shades Creek as the bed material alternates between sand and bedrock. The 2001LUFU scenario shows almost all areas producing high runoff and sediment loads, as one would expect from an urban landscape. Protecting those cross sections experiencing the greatest widening had little effect on suspended sediment loads at the lower ends of Shades Creek due to simulated deposition of the eroded streambank materials along other sections of the stream. The sediment load for the Validation scenario equates to a sediment yield of 58 $T/yr/km^2$, which is within 10% of the measured yield at the Greenwood gage. Modeling results support the ecoregion loads and percent reduction required in this TMDL.

Table 12. Simulated average annual model results for the four modeling scenarios

Scenario	Runoff (m/yr)	Sediment Load[1] (T/yr)	Change in Top Width (cm/yr)	Change in Bed Elevation (cm/yr)
Validation	462	21,000	3.37	0.338
2001 Landuse	457	19,700	2.83	0.172
2001 LURP	457	19,500	1.62	0.117
2001 LUFU	702	29,200	4.20	0.276

Notes: Sediment load at the confluence of Shades Creek and Cahaba River

7. Total Maximum Daily Load (TMDL)

A TMDL establishes the total pollutant load a waterbody can assimilate and still achieve water quality standards. The components of a TMDL include a wasteload allocation (WLA) for point sources, a load allocation (LA) for nonpoint sources (including natural background), and a margin of safety (MOS), either implicitly or explicitly, to account for uncertainty in the analysis. Conceptually, a TMDL is defined by the equation:

$$TMDL = \Sigma\ WLA + \Sigma\ LA + MOS$$

The TMDLs for Shades Creek is expressed in terms of median annual sediment yield, in metric units of T/yr/km^2, using data collected from reference streams in the Ridge and Valley ecoregion. It is acceptable for TMDLs to be expressed through other appropriate measures (e.g., sediment yield) other than mass loads per time (40 CFR 130.2). The AnnAGNPS and CONCEPTS model results support the TMDL sediment yield and percent reduction calculated using the ecoregion approach.

7.1 Wasteload and Load Allocations

The WLA component for the TMDL is separated into continuous discharge and wet weather components. The continuous discharge WLA is expressed in metric units of mass loads per time (i.e., tonne/day) and is based on facility design flow (converted to metric units) and permit limits for total suspended solids (see Table 10 for WLA by facility). The wet weather WLA applies to MS4 areas and construction activities regulated under the NPDES program. The wet weather WLA and the LA components are expressed as average annual sediment yield based on reference conditions. The reduction necessary to achieve the TMDL is based on the percent difference between existing loads measured at the Greenwood gage and median annual sediment loads for stable streams in the Ridge and Valley. TMDL components are shown in Table 13.

Table 13. TMDL Components

WLA		LA (T/yr/km^2)	MOS	TMDL[2] (T/yr/km^2)	% Reduction
Continuous (T/day)[3]	Wet Weather[1] (T/yr/km^2)				
0.12	24.7	24.7	Implicit	24.7	53

Notes:

1. Wet weather WLA applies to MS4 areas and NPDES construction activities.
2. TMDL equates to a median annual concentration of 45.1 mg/L and a total load of about 8,820 T/yr (i.e., 24.7 T/yr/km^2 * 357 km = 8820 T/yr).
3. The units for the continuous discharge facilities are expressed in units of days to reflect permit limits. The permit does not have average annual limits for TSS. If the facilities discharged this load of 0.12T/day continuously for 365 days, the annual load would be about 44 T/yr, which is insignificant compared to the total load of 8,820 T/yr (see note 2). The allocation of 0.12 T/day represents the current permit limit; no reductions are required by the TMDL.

7.2 Margin of Safety

A Margin of Safety (MOS) is a required component of a TMDL that accounts for the uncertainty in the relationship between the pollutant leads and the quality of the receiving waterbody. The two types of MOS development are to implicitly incorporate the MOS using conservative model assumptions or to explicit specify a portion of the total TMDL as the MOS. The MOS selected for this TMDL is implicit as conservative assumptions in the ecoregion approach (i.e., calculating sediment yields based on all stable sites regardless of drainage area) and numerical modeling provides a sufficient MOS. Examples of conservative assumptions used in the AnnAGNPS model include: homogeneous landuse within each AnnAGNPS model cell; to simulate runoff, a similar CN values is used for all landuse in each category (i.e., forest, pasture (assumed poor), and urban (includes commercial and business)); and rainfall distribution is based on measurements at the Birmingham airport and assumed to occur uniformly over the watershed.

7.3 Critical Conditions

The average annual watershed load represents the long-term processes of sediment accumulation of sediments in the stream habitat areas that are associated with the potential for habitat alteration.

7.4 Seasonal Variation

Seasonal variation is incorporated in these TMDLs through the use of average annual loads. Average annual loads are based on a 25-year simulation period using the AnnAGNPS model.

8. Conclusions

Alabama has adopted the Basin Approach to Water Quality Management, a plan that divides Alabama's major drainage basins into groups. During each yearlong cycle, resources for water quality monitoring are focused in one of the basin groups. During the next monitoring phase in the Cahaba River Basin, Shades Creek will receive additional monitoring to identify any changes or improvements in water quality. Monitoring is ongoing by SWMA and provides important data during both wet and dry conditions.

In addition to collecting suspended-sediment data, biological data are needed to determine whether the degree of embeddedness as shown for stable sites is in fact a threshold for biologic communities or if the embeddedness for unstable sites is of sufficient magnitude to impair biologic function.

The application of the AnnAGNPS and CONCEPTS models could be used as a land management tool to provide an indication of the quantity of sediment delivered to Shades Creek from upland area and instream processes. Model scenarios could be developed to assist in identifying the best location for BMPs in the watershed. It is anticipated that different types of BMPs would be needed in the highly erodible areas of the watershed (i.e., ridges and Little Shades Creek) as compared to those required in low gradient areas. More stringent the BMPs should be required the closer the land disturbance activities are to Shades Creek. Results of habitat studies indicate stations supporting good ecological health are in locations where the stream is well connected to the floodplain and has wide riparian buffers.

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Appendix A: RGA Results

1. **Primary bed material**

Bedrock	boulder/cobble	gravel	sand	silt/clay
0	1	2	3	4

2. **Bed/bank protection**

Yes	No	(with)	1 bank	2 banks
			Protected	
0	1		2	3

3. **Degree of incision (Relative elev. of "normal" low water; floodplain/terrace @ 100%)**

0 – 10%	11 – 25%	26 – 50%	51 – 75%	76 – 100%
4	3	2	1	0

4. **Degree of constriction (Relative decrease in top-bank width from up to downstream)**

0 – 10%	11 – 25%	26 – 50%	51 – 75%	76 – 100%
0	1	2	3	4

5. **Streambank erosion (Each bank)**

	None	fluvial	mass wasting (failures)
Left	0	1	2
Right	0	1	2

6. **Streambank instability (Percent of each bank failing)**

	0 – 10%	11 – 25%	26 – 50%	51 – 75%	76 – 100%
Left	0	0.5	1	1.5	2
Right	0	0.5	1	1.5	2

7. **Established riparian woody-vegetative cover (Each bank)**

	0 – 10%	11 – 25%	26 – 50%	51 – 75%	76 – 100%
Left	2	1.5	1	0.5	0
Right	2	1.5	1	0.5	0

8. **Occurrence of bank accretion (Percent of each bank with fluvial deposition)**

	0 – 10%	11 – 25%	26 – 50%	51 – 75%	76 – 100%
Left	0	0.5	1	1.5	2
Right	0	0.5	1	1.5	2

9. **Stage of channel evolution**

I	II	III	IV	V	VI
0	1	2	4	3	1.5

Figure A- 1. Channel stability ranking scheme used to conduct rapid geomorphic assessments (RGAs). The channel stability index is the sum of the values obtained for the nine criteria.

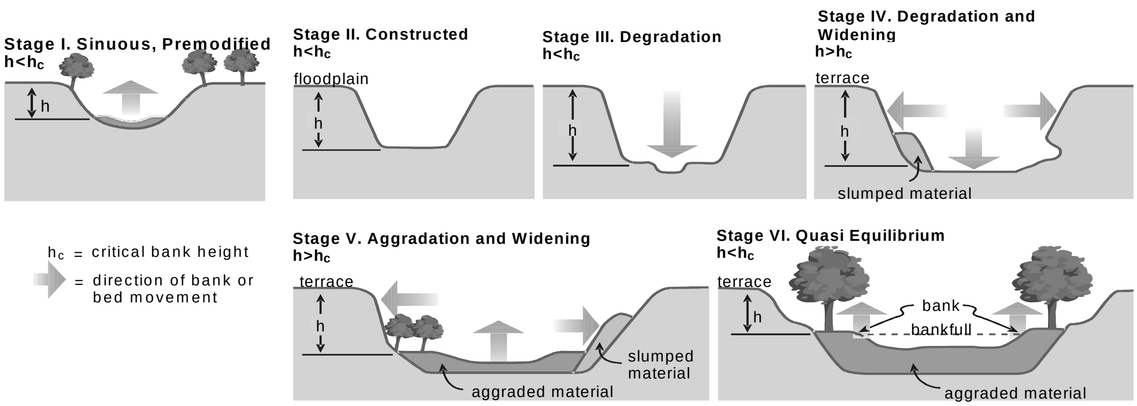

Figure A- 2. Six stages of channel evolution from Simon and Hupp (1986) and Simon (1989b) identifying Stages I and VI as stable, “reference” conditions

Table A- 1. Percentage of fines (embeddedness) for coarse-grained sites along Shades Creek

Dominant bed material type	% Fines	Site	River kilometer
Gravel/Sand	49.7	AZ	51.0
Gravel	36.6	BE	55.1
Boulder/Cobble	35.0	AV	48.3
Boulder/Cobble	33.1	AU	48.1
Gravel	32.4	BX	65.2
Gravel	31.1	DA	84.3
Gravel/Cobble	29.4	CH	70.5
Gravel/Cobble	29.4	CG	70.0
Gravel	23.7	AR	46.4
Gravel	21.0	BT	63.8
Gravel	20.7	O	17.8
Gravel	20.4	BA	52.1
Gravel	16.7	BD	54.6
Gravel	16.0	DC	86.1
Gravel	14.8	BI	57.6
Gravel	14.0	BS	63.3
Gravel	12.9	CO	76.4
Gravel	12.8	BH	57.3
Gravel	12.0	CP	77.1
Gravel	12.0	CD	68.6
Gravel	12.0	BQ	61.9
Boulder/Cobble	12.0	AW	48.8
Gravel	11.8	CE	69.2
Gravel	11.3	AP	45.3
Gravel	10.0	CC	68.3
Gravel	10.0	BZ	67.0
Gravel	9.9	BP	61.3
Gravel/Cobble	9.3	BC	53.9
Gravel	8.1	CF	69.7
Gravel	8.0	CB	68.0
Gravel	6.0	AY	50.2
Gravel	5.0	BY	65.5

Note: Sites exceeding the most stringent reference (4%) are shown in green, while those exceeding the Shades Creek reference (13.4%) are shown in orange and those exceeding the Ridge and Valley reference (16.6%) are shown in yellow.

Table A- 2. Rapid Geomorphic Assessments (RGAs) for Shades Creek

Site	River kilometer	Stage of channel evolution	Bed material	Bed or bank protection	Incision	Constriction	Stream bank erosion		Stream bank instability		Woody vegetative cover		Bank accretion		Channel stability index
							Left	Right	Left	Right	Left	Right	Left	Right	
DD	86.5	III	Clay	No	0-10%	0-10%	Fluvial	Fluvial	0-10%	0-10%	76-100%	76-100%	0-10%	0-10%	17
DC	86.1	V	Gravel	No	11-25%	0-10%	Fluvial	Fluvial	26-50%	26-50%	51-75%	51-75%	26-50%	26-50%	16
DB	85.5	-	-	No	-	-	-	-	-	-	-	-	-	-	-
DA	84.3	V	Gravel	No	51-75%	0-10%	Mass Wasting	Mass Wasting	76-100%	76-100%	76-100%	76-100%	0-10%	11-25%	18.5
CZ	83.3	VI	Gravel	No	26-50%	0-10%	Fluvial	Fluvial	11-25%	11-25%	26-50%	26-50%	0-10%	0-10%	15.5
CY	82.6	V	Bedrock	No	0-10%	0-10%	Fluvial	Fluvial	11-25%	11-25%	51-75%	51-75%	0-10%	0-10%	16
CX	81.8	VI	Bedrock	No	26-50%	0-10%	Fluvial	Fluvial	0-10%	0-10%	51-75%	51-75%	0-10%	0-10%	11.5
CW	81.1	V	Bedrock	No	0-10%	0-10%	Mass Wasting	Fluvial	51-75%	26-50%	76-100%	76-100%	51-75%	26-50%	15
CV	80.5	VI	Bedrock	No	0-10%	0-10%	Fluvial	Fluvial	0-10%	11-25%	76-100%	51-75%	0-10%	51-75%	12
CU	80.0	VI	Bedrock	No	0-10%	0-10%	Fluvial	Fluvial	0-10%	0-10%	76-100%	51-75%	0-10%	0-10%	13
CT	78.9	VI	Bedrock	No	0-10%	0-10%	Fluvial	Fluvial	0-10%	0-10%	76-100%	51-75%	26-50%	51-75%	10.5
CS	78.3	VI	Bedrock	No	0-10%	0-10%	Fluvial	Fluvial	0-10%	0-10%	26-50%	11-25%	11-25%	11-25%	14
CR	77.8	V	Bedrock	No	51-75%	0-10%	Fluvial	Fluvial	26-50%	11-25%	51-75%	76-100%	51-75%	26-50%	11
CQ	77.6	V	Bedrock	No	0-10%	0-10%	Fluvial	Mass Wasting	0-10%	11-25%	51-75%	11-25%	26-50%	26-50%	15.5
CP	77.1	V	Gravel	No	0-10%	0-10%	Mass Wasting	Mass Wasting	26-50%	26-50%	26-50%	11-25%	76-100%	76-100%	18.5
CO	76.4	VI	Cobble/Gravel	No	0-10%	0-10%	Fluvial	Fluvial	0-10%	0-10%	26-50%	76-100%	0-10%	0-10%	15.5
CN	75.9	VI	Boulder/Cobble	No	51-75%	0-10%	Fluvial	Fluvial	0-10%	0-10%	51-75%	76-100%	26-50%	11-25%	9.5
CM	75.2	II	-	Bed and both banks	-	-	-	-	-	-	-	-	-	-	-
CL	74.0	V	Boulder/Cobble	No	0-10%	0-10%	Mass Wasting	Fluvial	51-75%	11-25%	51-75%	26-50%	11-25%	11-25%	18.5
CK	73.1	V	Bedrock	Bed	0-10%	0-10%	Mass Wasting	Fluvial	51-75%	26-50%	26-50%	51-75%	26-50%	51-75%	15.5
CJ	72.5	V	Bedrock/Boulder	Bed	0-10%	0-10%	Fluvial	Mass Wasting	26-50%	26-50%	51-75%	51-75%	26-50%	26-50%	15.5
CI	71.7	V	Bedrock	No	11-25%	0-10%	Fluvial	Mass Wasting	26-50%	26-50%	26-50%	26-50%	26-50%	51-75%	15.5
CH	70.5	II	Gravel	No	0-10%	0-10%	Mass Wasting	Fluvial	0-10%	0-10%	0-10%	0-10%	11-25%	11-25%	18
CG	70.0	V	Gravel/Sand	No	0-10%	11-25%	Mass Wasting	Fluvial	11-25%	11-25%	11-25%	51-75%	0-10%	0-10%	21.5
CF	69.7	V	Boulder/Cobble	No	0-10%	0-10%	None	Mass Wasting	0-10%	76-100%	11-25%	51-75%	76-100%	0-10%	17
CE	69.2	V	Gravel	No	26-50%	0-10%	Mass Wasting	Mass Wasting	26-50%	26-50%	76-100%	76-100%	0-10%	11-25%	17.5
CD	68.6	V	Gravel	No	0-10%	0-10%	Mass Wasting	Fluvial	76-100%	26-50%	76-100%	76-100%	0-10%	11-25%	19.5
CC	68.3	V	Gravel	No	0-10%	0-10%	Fluvial	Mass Wasting	11-25%	26-50%	76-100%	76-100%	0-10%	0-10%	18.5
CB	68.0	V	Gravel	No	11-25%	0-10%	Mass Wasting	Fluvial	26-50%	11-25%	26-50%	51-75%	0-10%	0-10%	19
CA	67.6	V	Gravel	No bed protection, one bank	11-25%	0-10%	Mass Wasting	Fluvial	26-50%	11-25%	51-75%	51-75%	76-100%	76-100%	15.5
BZ	67.0	V	Gravel	No	0-10%	0-10%	Mass Wasting	None	26-50%	0-10%	51-75%	76-100%	11-25%	0-10%	17
BY	65.5	V	Boulder/Cobble	No	11-25%	11-25%	Mass Wasting	Fluvial	51-75%	11-25%	76-100%	26-50%	51-75%	51-75%	16
BX	65.2	V	Gravel	No	26-50%	0-10%	Fluvial	Mass Wasting	11-25%	51-75%	76-100%	51-75%	0-10%	11-25%	17
BW	64.9	V	Sand	No	26-50%	11-25%	Fluvial	Fluvial	11-25%	26-50%	76-100%	76-100%	11-25%	51-75%	15.5
BV	64.4	VI	Bedrock	No	11-25%	0-10%	Fluvial	Fluvial	0-10%	11-25%	51-75%	76-100%	11-25%	51-75%	10.5
BU	64.1	VI	Bedrock	No	11-25%	0-10%	Fluvial	Fluvial	0-10%	11-25%	76-100%	76-100%	0-10%	26-50%	11.5

Site	River kilometer	Stage of channel evolution	Bed material	Bed or bank protection	Incision	Constriction	Stream bank erosion		Stream bank instability		Woody vegetative cover		Bank accretion		Channel stability index
							Left	Right	Left	Right	Left	Right	Left	Right	
BT	63.8	V	Gravel	No	11-25%	0-10%	Mass Wasting	Mass Wasting	76-100%	51-75%	76-100%	76-100%	0-10%	0-10%	20.5
BS	63.3	V	Gravel	No	11-25%	0-10%	Fluvial	Fluvial	11-25%	26-50%	76-100%	76-100%	0-10%	26-50%	15.5
BR	62.9	VI	Gravel	No	0-10%	0-10%	Fluvial	Fluvial	11-25%	11-25%	76-100%	76-100%	11-25%	0-10%	15
BQ	61.9	VI	Cobble/Gravel	No	26-50%	0-10%	Fluvial	Fluvial	11-25%	11-25%	51-75%	76-100%	11-25%	51-75%	11.5
BP	61.3	VI	Gravel	No	76-100%	0-10%	Fluvial	None	26-50%	0-10%	26-50%	51-75%	11-25%	51-75%	10
BO	60.8	VI	Bedrock/Boulder	No	51-75%	0-10%	Fluvial	Fluvial	26-50%	26-50%	26-50%	76-100%	0-10%	26-50%	11.5
BN	60.1	VI	Bedrock	No	11-25%	0-10%	None	Fluvial	0-10%	11-25%	51-75%	76-100%	0-10%	11-25%	11
BM	59.6	V	Boulder/Cobble	No	51-75%	0-10%	None	Mass Wasting	11-25%	76-100%	51-75%	0-10%	76-100%	11-25%	14.5
BL	58.8	V	Cobble/Gravel	No	51-75%	0-10%	Mass Wasting	Fluvial	26-50%	11-25%	26-50%	51-75%	0-10%	11-25%	15.5
BK	58.5	VI	Bedrock/Gravel	No	26-50%	0-10%	None	None	11-25%	11-25%	11-25%	11-25%	51-75%	51-75%	10.5
BJ	58.0	VI	Gravel	No	11-25%	0-10%	Fluvial	Fluvial	11-25%	11-25%	51-75%	51-75%	26-50%	76-100%	12.5
BI	57.6	V	Gravel	No	26-50%	0-10%	Fluvial	Mass Wasting	11-25%	51-75%	51-75%	51-75%	11-25%	11-25%	17.5
BH	57.3	V	Gravel	No	26-50%	0-10%	Fluvial	Fluvial	26-50%	26-50%	51-75%	51-75%	11-25%	11-25%	16.5
BG	56.7	I	Boulder/Cobble	No	11-25%	0-10%	Fluvial	None	0-10%	0-10%	26-50%	11-25%	51-75%	0-10%	11
BF	56.2	I	Bedrock/Boulder	No	11-25%	0-10%	Fluvial	Fluvial	11-25%	11-25%	51-75%	51-75%	51-75%	0-10%	11
BE	55.1	I	Gravel	No	11-25%	0-10%	Fluvial	Fluvial	11-25%	11-25%	51-75%	51-75%	11-25%	11-25%	13
BD	54.6	V	Gravel	No	11-25%	0-10%	Fluvial	Fluvial	11-25%	11-25%	11-25%	51-75%	76-100%	0-10%	16
BC	53.9	II	Cobble/Gravel	No	11-25%	0-10%	Fluvial	Fluvial	11-25%	11-25%	26-50%	51-75%	76-100%	76-100%	11
BB	53.1	V	Gravel/Sand	No	26-50%	0-10%	Fluvial	Mass Wasting	11-25%	76-100%	51-75%	11-25%	76-100%	26-50%	17
BA	52.1	V	Gravel	No	51-75%	0-10%	Fluvial	Fluvial	11-25%	11-25%	76-100%	26-50%	51-75%	26-50%	12.5
AZ	51.0	V	Gravel/Sand	No	11-25%	0-10%	Fluvial	Fluvial	26-50%	26-50%	26-50%	26-50%	76-100%	51-75%	16
AY	50.2	V	Gravel	No	26-50%	0-10%	Fluvial	Fluvial	26-50%	11-25%	51-75%	51-75%	76-100%	51-75%	13
AX	49.9	V	Sand	No	11-25%	0-10%	Fluvial	Fluvial	26-50%	11-25%	51-75%	51-75%	51-75%	26-50%	16
AW	48.8	V	Boulder/Cobble	No	26-50%	0-10%	Mass Wasting	Mass Wasting	51-75%	51-75%	51-75%	51-75%	11-25%	11-25%	18
AV	48.3	V	Boulder/Cobble	No	11-25%	0-10%	Mass Wasting	Mass Wasting	51-75%	51-75%	76-100%	76-100%	26-50%	26-50%	17
AU	48.1	V	Sand	No	0-10%	0-10%	Mass Wasting	Mass Wasting	76-100%	51-75%	26-50%	26-50%	26-50%	26-50%	22.5
AT	47.6	II	Bedrock	Bed and both banks	0-10%	0-10%	None	None	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	16
AS	47.0	VI	Sand	No	11-25%	0-10%	Fluvial	Fluvial	11-25%	11-25%	76-100%	76-100%	51-75%	51-75%	12.5
AR	46.4	V	Gravel	No	26-50%	0-10%	Mass Wasting	Mass Wasting	76-100%	76-100%	11-25%	11-25%	76-100%	51-75%	19.5
AQ	45.6	V	Sand	No	51-75%	0-10%	Fluvial	Fluvial	11-25%	26-50%	51-75%	51-75%	0-10%	11-25%	16
AP	45.3	V	Gravel	No	51-75%	0-10%	Mass Wasting	Fluvial	76-100%	0-10%	11-25%	51-75%	76-100%	0-10%	16
AO	44.6	V	Boulder/Cobble	No	0-10%	0-10%	Fluvial	Fluvial	11-25%	11-25%	76-100%	76-100%	26-50%	0-10%	15
AN	44.2	V	Boulder/Cobble	No	0-10%	0-10%	Fluvial	Fluvial	26-50%	26-50%	76-100%	76-100%	26-50%	26-50%	15
AM	43.3	VI	Bedrock	No	11-25%	0-10%	None	Fluvial	0-10%	11-25%	0-10%	76-100%	0-10%	51-75%	11.5
AL	42.7	V	Sand	No	0-10%	0-10%	Mass Wasting	Mass Wasting	26-50%	26-50%	51-75%	51-75%	26-50%	51-75%	19.5
AK	41.6	V	Sand/Silt Clay	No	51-75%	0-10%	Fluvial	Fluvial	11-25%	11-25%	26-50%	51-75%	51-75%	76-100%	13.5
AJ	41.2	V	Sand	No	51-75%	0-10%	Fluvial	Fluvial	11-25%	11-25%	51-75%	76-100%	76-100%	76-100%	11.5
AI	40.7	V	Sand	No	51-75%	0-10%	Mass Wasting	Fluvial	51-75%	11-25%	26-50%	51-75%	76-100%	76-100%	14.5
AH	39.6	V	Sand	No	51-75%	0-10%	Mass Wasting	Fluvial	51-75%	11-25%	0-10%	11-25%	76-100%	76-100%	16.5
AG	35.2	V	Sand	No	26-50%	0-10%	Mass Wasting	Mass Wasting	26-50%	76-100%	51-75%	51-75%	51-75%	0-10%	19.5

Site	River kilometer	Stage of channel evolution	Bed material	Bed or bank protection	Incision	Constriction	Stream bank erosion		Stream bank instability		Woody vegetative cover		Bank accretion		Channel stability index
							Left	Right	Left	Right	Left	Right	Left	Right	
AF	31.6	V	Sand	No	26-50%	0-10%	Mass Wasting	Mass Wasting	26-50%	26-50%	11-25%	0-10%	76-100%	76-100%	18.5
AE	29.5	V	Gravel/Sand	No	26-50%	26-50%	None	Mass Wasting	11-25%	76-100%	76-100%	11-25%	76-100%	11-25%	18
AD	27.9	V	Sand	No	11-25%	0-10%	Mass Wasting	Mass Wasting	26-50%	51-75%	26-50%	11-25%	51-75%	51-75%	20
AC	25.3	V	Sand	No	51-75%	0-10%	Mass Wasting	Mass Wasting	76-100%	26-50%	11-25%	51-75%	11-25%	76-100%	18.5
AB	24.5	V	Cobble/Gravel	No	26-50%	0-10%	Mass Wasting	Fluvial	51-75%	11-25%	11-25%	26-50%	76-100%	26-50%	16
AA	24.3	V	Cobble/Gravel	No	51-75%	0-10%	None	Mass Wasting	0-10%	51-75%	76-100%	26-50%	76-100%	51-75%	11.5
Z	24.1	V	Sand/Silt Clay	No	76-100%	0-10%	Fluvial	Fluvial	11-25%	26-50%	11-25%	26-50%	76-100%	76-100%	13.5
Y	23.8	V	Bedrock	No	51-75%	0-10%	Mass Wasting	Fluvial	51-75%	0-10%	26-50%	76-100%	76-100%	76-100%	10.5
X	22.9	I	Bedrock	No	51-75%	0-10%	Fluvial	Fluvial	26-50%	11-25%	26-50%	51-75%	51-75%	51-75%	8
W	22.6	VI	Sand	No	76-100%	0-10%	Fluvial	Mass Wasting	0-10%	26-50%	76-100%	51-75%	51-75%	51-75%	11
V	21.4	V	Bedrock	No	11-25%	0-10%	Mass Wasting	Mass Wasting	51-75%	76-100%	51-75%	76-100%	26-50%	26-50%	17
U	21.0	V	Sand	No	26-50%	0-10%	Mass Wasting	Mass Wasting	76-100%	76-100%	76-100%	76-100%	26-50%	26-50%	19
T	20.5	I	Bedrock	No	11-25%	0-10%	Fluvial	Fluvial	76-100%	51-75%	76-100%	26-50%	51-75%	51-75%	11.5
S	19.7	VI	Boulder/Cobble	No	11-25%	0-10%	Fluvial	Fluvial	26-50%	26-50%	76-100%	51-75%	26-50%	0-10%	14
R	19.3	VI	Bedrock	No	51-75%	0-10%	Fluvial	Fluvial	0-10%	11-25%	76-100%	51-75%	11-25%	51-75%	9
Q	19.0	V	Sand	No	51-75%	0-10%	Mass Wasting	None	51-75%	0-10%	51-75%	11-25%	0-10%	11-25%	17
P	18.1	V	Bedrock	No	76-100%	11-25%	Fluvial	Fluvial	26-50%	11-25%	51-75%	76-100%	11-25%	11-25%	12
O	17.8	I	Gravel	No	76-100%	0-10%	Fluvial	Fluvial	26-50%	11-25%	11-25%	76-100%	0-10%	11-25%	11.5
N	17.4	V	Bedrock	No	76-100%	0-10%	Mass Wasting	Fluvial	76-100%	11-25%	51-75%	51-75%	51-75%	0-10%	13
M	16.8	I	Bedrock/Boulder	No	0-10%	0-10%	None	Fluvial	0-10%	26-50%	11-25%	11-25%	0-10%	11-25%	14
L	16.3	I	Bedrock	No	51-75%	0-10%	Fluvial	Fluvial	11-25%	11-25%	51-75%	51-75%	11-25%	11-25%	9
K	15.8	I	Bedrock/Boulder	No	76-100%	0-10%	Fluvial	Fluvial	11-25%	0-10%	76-100%	51-75%	0-10%	11-25%	8
J	15.4	I	Bedrock/Boulder	No	76-100%	0-10%	Fluvial	Fluvial	11-25%	0-10%	76-100%	76-100%	26-50%	51-75%	5.5
I	14.7	I	Bedrock/Boulder	No	76-100%	0-10%	Fluvial	None	0-10%	0-10%	76-100%	76-100%	51-75%	0-10%	5
H	13.8	I	Boulder/Cobble	No	76-100%	0-10%	Fluvial	Fluvial	0-10%	0-10%	76-100%	76-100%	51-75%	76-100%	4.5
G	13.2	I	Boulder/Cobble	No	26-50%	0-10%	None	Fluvial	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	5
F	12.7	I	Bedrock	No	76-100%	0-10%	Fluvial	Fluvial	0-10%	0-10%	76-100%	76-100%	26-50%	26-50%	5
E	12.1	I	Boulder/Cobble	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	0-10%	0-10%	6
D	11.6	I	Bedrock	No	76-100%	0-10%	Fluvial	None	0-10%	0-10%	76-100%	76-100%	0-10%	0-10%	6
C	11.4	I	Bedrock/Boulder	No	76-100%	0-10%	None	Fluvial	0-10%	11-25%	51-75%	26-50%	0-10%	26-50%	9
B	11.1	I	Boulder/Cobble	No	76-100%	0-10%	Fluvial	Fluvial	11-25%	0-10%	76-100%	76-100%	0-10%	11-25%	8
A	10.0	I	Boulder/Cobble	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	26-50%	0-10%	5

Appendix B: Definitions of Metrics for Biological Assessments

Metric Definitions

- Sorenson's Community Similarity Index: Comparison of taxonomic similarity between study and reference site in terms of presence or absence of taxa. Values range from 0 to1.0 with increasing value indicating increasing similarity.

- Taxa Richness: Total number of taxa collected from a site.

- Total number of taxa collected of the generally pollution-sensitive orders Ephemeroptera, Plecoptera and Trichoptera (EPT).

- Percent contribution of dominant taxon.

- % EPT: Percent of sample composed of the generally pollution-sensitive orders Ephemeroptera, Plecoptera and Trichoptera.

- % Ephemeroptera: Sample percent composed of the generally pollution-sensitive order.

- IAI (Indicator Assemblage Index): Comparison of relative abundance of EPT and the pollution-tolerant chironomids and annelids (CA) in comparison to a reference site. Values over 1.0 indicate sample site had less CA than reference site.

- Beck's Biotic Index: Classification system based on organism responses to pollution or habitat-stress. Values 3 or above usually indicate moderate to good water quality.

- % Intolerant Taxa: Percentage of sample whose assigned tolerance value is less than 3 on a scale of 1-10 (Bode 1996).

- IBI: measures 12 attributes of the fish community, also known as metrics, which are scored 1 (worst), 3, or 5 (best) compared to values expected from an undisturbed fish community in similar-sized streams of the same region. The sum of the scores for the 12 metrics (total IBI) varies from 12 to 60. Based on the IBI score, fish communities are assigned to one of five classes: excellent (57 to 60), good (48 to 52), fair (39-44), poor (28-35), and very poor (12-23)

- % Crevice Spawners: sedimentation-sensitive crevice spawners are the Alabama shiner, *Cyprinella callistia,* and the tricolor shiner, C. *trichroistia*

Attachment 1: Suspended-Sediment Modeling Report

(Available as a separate file prepared by USDA-ARS, National Sedimentation Laboratory and entitled: "Suspended-Sediment Transport and Bed-Material Characteristics of Shades Creek, Alabama and Ecoregion 67: Developing Water-Quality Criteria for Sediment", January 2004)