A SEDIMENT BUDGET FOR TOWN CREEK WATERSHED: SUSPENDED SEDIMENT TRANSPORT RATES ANALYSIS.

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Abstract The Town Creek watershed is located in the Southeastern Plains Ecoregion in Mississippi. Its total area covers 1,769 km^2 and represents approximately 50% of the upper Tombigbee River basin area contributing to the Aberdeen Pool on the Tennessee-Tombigbee Waterway. The sediment yield from the watershed attributes to the estimated 320,000 T yr^{-1} of deposition in Aberdeen pool, where annual dredging averages 310,000 T yr^{-1}. To produce remedial measures and future BMPs in Town Creek watershed for reducing water quality impairment and dredging costs (expressed in terms of a percent reduction of sediment loads), it is necessary to know the current sediment sources and loads transported within the watershed. A sediment budget for a partial sub-basin (1606 km^2) within the watershed is under development by means of flow, streambank, streambed, and suspended sediment monitoring, GIS applications and modeling methods. In order to identify suspended sediment transport trends and to start identifying possible general conditions driving sediment supply and exportation within and from Town Creek watershed, the present paper presents results from a study which adapts Tiers 1 and 2 steps from Sharp's sediment budget template. A suspended sediment transport curve was determined using 1,401 records of suspended sediment concentrations and flow discharges at the USGS station 02436500 (Town Creek near Nettleton, MS) between 1981 and 1995 and between May 2008 and April 2009. Average suspended sediment loads at the USGS station of Town Creek over a 29-yr period were about 1,000.000 T yr^{-1}. Estimated suspended sediment yield at the effective flow ($Q_{1.5}$) was 80 T d^{-1} km^2. Suspended sediment yield at the last studied year 2008-2009 was about 40 T d^{-1} km^2. Suspended sediment loads and yields for Town Creek estimated by regional relations were significantly lower than estimations obtained by the local expression. Temporal analysis of suspended sediment transport relations from 1981 to 2009 showed a reduction in the amount of suspended sediment loads contributed by Town Creek watershed at a specific instantaneous flow. Analysis in time of suspended sediment transport curves parameters (slope and intercept) showed active geomorphic processes and differences in stages of channel evolution caused by changes in channel gradient and channel morphology in different sections along the Town Creek. Tier 2 integration of the suspended sediment rating curve overestimated annual suspended sediment loads from years with low annual average daily flow. The reduction of suspended sediment loads should be focused on the attenuation of geomorphic processes and stabilization of reaches and agricultural lands near streambanks at the northern 320 km^2 of Town Creek watershed. Analysis of bed material transport by incorporating Tier 3 of the analysis proposed by Sharp (2007) will result in a more comprehensive understanding about the discharge of sediments from Town Creek watershed, its sediment budget, and the stage of channel evolution in the different subareas of the watershed.

INTRODUCTION

Sediment budgets are important in defining the dynamic behavior of a stream (Sharp, 2007). Knowledge of stream and watershed characteristics is important for understanding natural processes and problems associated with watershed management and stream restoration. Sediment production and deposition have been linked to variations in fluvial sediment transport. In many lowland rivers, a major part of sediment is transported in suspension. Sharp (2007) generated and presented tools that are easy to use and understand in order to create an example sediment budget template (SBT) for the Mobile River Basin and the Mobile Bay watershed. His study produced an intermediate tool to relate more comprehensive numerical models to theory. The Tier 1 and Tier 2 analyses proposed by Sharp (2007) implement basic principles to create a conceptual sediment budget by determining a suspended sediment transport relation, suspended sediment loads and yields at the effective discharge ($Q_{1.5}$).

Suspended sediment ratings, included in Tier 1 and Tier 2 analyses, represent the relationship between suspended sediment load and water discharge in a stream. The most commonly used sediment rating curve is a power function:

$$Q_s = aQ^b \tag{1}$$

where Q_s is suspended sediment load (T d^{-1}), Q is water discharge (m^3s^{-1}), and a and b are regression coefficients. This expression incorporates the effect of stream power at increased discharge and the availability of new sources of sediment in weather conditions that cause high discharge. Asselman (2000) did not find physical meaning for the regression coefficients in the sediment rating curve. Morgan (2006) considered the intercept parameter (a) as an erosion index in streams. Large values of the slope parameter (b), taken to depict an index of the erosive power of the river, are considered indicative of streams with a strong increase in entrainment and transport with increasing flow discharge (Yang et al., 2006). Simon et al (2002) related changes in the levels of b with the different stages of channel evolution. Due to the inverse correlation between a and b, a suggested combination of this pair of parameters is proposed by some authors (Thomas, 1988; Yang et al., 2006) as a measure of soil erodibility and erosivity. All of these studies concluded that parameters from a suspended sediment relation are associated with river or stream channel morphology.

Background and scope The waterbodies located in the hydrologic unit (HUC) 03160102 of the Tombigbee River Basin are on the Mississippi 2004 Section 303(d) list of waterbodies as impaired due to sediment (MDEQ, 2004). Water Quality criteria for the State of Mississippi do not contain a numerical target for sediment but are in narrative form "Waters shall be free from materials… in such degree as to create nuisance, render the waters injurious to public health, recreation or aquatic life and wildlife… or impair the water for any designated uses" (Simon et al., 2002).

A research which overall goal is to determine sediment and nutrient sources within Town Creek watershed, northeast Mississippi, is currently performed. This paper presents preliminary results to determine a sediment budget for this watershed. Current field reconnaissance, monitoring and research, performed by the Civil and Environmental Engineering Department, Mississippi State University (CEE-MSU), have evidenced streambank erosion processes at incised unstable streambanks and edge-of-field gully erosion processes near streambanks with limited riparian vegetation in the northern headwaters area of the Town Creek watershed (Ramirez-Avila et al., 2009). Headwaters, urban areas and other zones in development (e.g. the building of the Toyota Plant at Blue Springs, MS) in the northern area of the watershed were the most significant contributors of suspended sediment loads during storm flow events. Those contributions represented up to 70% of the suspended sediment yield for the entire watershed, while the northern headwaters represent no more than 20% of the Town Creek watershed area (Ramirez-Avila et al. 2009a). Significant reductions of suspended sediment concentration and loads along the middle 20 km and the meandering last 10 km of the principal channel located in the other 80% of the studied watershed area were observed during the CEE-MSU research study.

The Town Creek watershed is located in the Southeastern Ecoregion Plains in Mississippi. Its total area covers 1,769 km^2 and represents approximately 50% of the upper Tombigbee River basin area contributing to the Aberdeen Pool on the Tennessee-Tombigbee Waterway (Figure 1). The sediment yield from the watershed attributes to the estimated 320,000 T yr^{-1} of deposition in the Aberdeen pool, where annual dredging averages 310,000 T yr^{-1}. To produce remedial measures and future BMP's in Town Creek watershed for reducing water quality impairment and dredging costs (expressed in terms of a percent reduction of sediment loads), it is necessary to know the sediment sources and loads currently transported within the watershed. A sediment budget for a partial sub-basin within the watershed is under development by means of flow, streambank, streambed and suspended sediment monitoring, GIS applications and modeling methods. In order to identify suspended sediment transport trends and to start identifying possible general conditions driving sediment supply and exportation within and from Town Creek watershed, the present study adapts Tiers 1 and 2 from Sharp's methodology. The study's objective is to determine suspended sediment loads and yields at Town Creek near Nettleton, MS (USGS station 02436500), which is the closest accessible point to the watershed outlet. Temporal variation in suspended sediment relations, loads, and yields are determined and evaluated. A relation between the sediment rating parameters, suspended sediment load trends, and watershed characteristics are also analyzed.

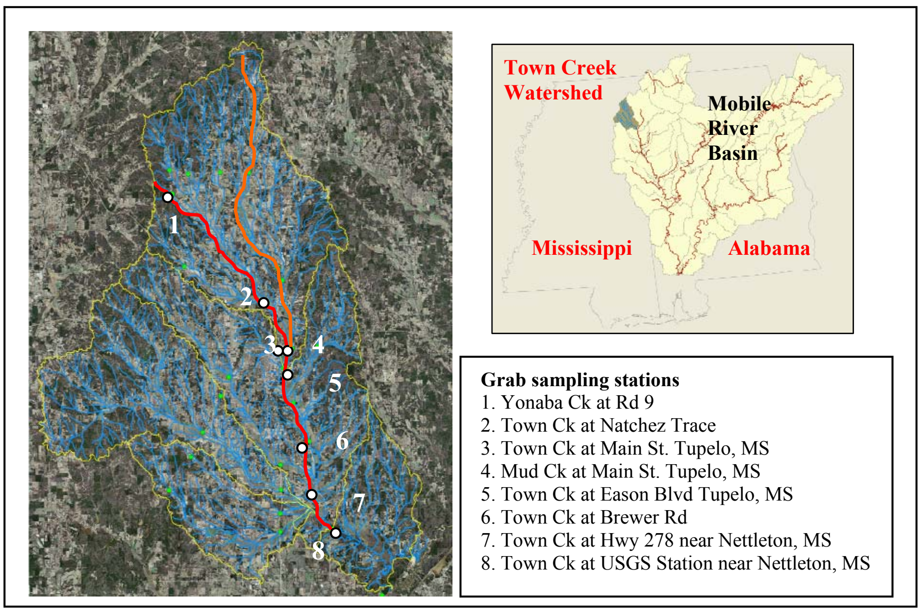

Figure 1 Location of the Town Creek watershed and the USGS station 02436500 (Town Creek near Nettleton, MS).

METHODS

This study used two of the three-tier sediment budget system proposed by Sharp (2007) to determine sediment yield and a sediment budget. Initially, using a VBA/Excel program, a suspended-sediment transport rating relation of flow discharge versus sediment load for Town Creek watershed was obtained by plotting in log-log space and regressing with a power function. Instantaneous suspended sediment concentration data combined with instantaneous flow data, representing the value obtained from the stage discharge relation at 15-min intervals, were used to determine the suspended sediment load. The flow and suspended sediment dataset comprised 1273 USGS gauging station records from 1980 to 1995 at the USGS station 02436500 (Town Creek near Nettleton, MS). Additionally, 128 more records from May 2008 to April 2009 were obtained from a suspended sediment data collection using an automatic sampler (ISCO Model 6712) at the same location where the USGS real time flow station was located.

Suspended sediment load at the effective discharge was used as an indicator of suspended sediment transport conditions for Town Creek watershed (Tier 1). The effective discharge in the present study was assumed to be the flow with a return period of 1.5 yr ($Q_{1.5}$), which can also be considered the bankfull discharge (Julien, 2002). The effective discharge was determined by using the Log Pearson Type III method found in the Bulletin 17-B (USDI, 1981) through the application of the model PeakFQ Win 5.2 (USGS, Reston, VA). A standard WATSTORE format Peak Flow data was obtained from the USGS station 02436500 web page as an input database to run the model. Suspended sediment yield was determined as the estimated suspended sediment load divided by the 1606 km^2 of drainage area at the site of study. The second tier analysis estimated the annual suspended sediment load and suspended sediment yield by summarizing calculated daily sediment loads using the average daily flow data of the USGS station 02436500. The daily average flow dataset ranged from January 1, 1981 to December 31, 2007, and May 1, 2008 to April 30, 2009. The determined suspended sediment transport rating relation parameters (slope and intercept), the suspended sediment load, and the suspended sediment yield estimated by Tier 1 and Tier 2 routines were compared (Confidence intervals at α=0.05) with parameters and results generated by suspended sediment transport relations from Simon et al. (2002) and Sharp (2007).

Tier 1 and Tier 2 routines were also used to derive an annual suspended sediment transport rating relation, suspended sediment load and suspended sediment yield amounts for each year with recorded data at the USGS station 02436500. Estimations from the annual relations were compared with annual estimations obtained by integrating the suspended sediment rating curve based on the full data set for each year with recorded data at the studied site (Tier 2 analysis). Trend, significant correlation (α=0.05) and a power regression (if correlation was significant) between annual rate of increase in load (slopes) and annual load at low or base flow conditions (intercepts) were evaluated.

To determine the correlation between annual average instantaneous flow and the rate of increase in load, a clustering procedure was used. Three clusters grouped into five consecutive years (1981 to 1985, 1986 to 1990, and 1991 to 1995) were determined. The last cluster also included the year of the CEE-MSU research between May 1, 2008 and April 30, 2009. Significant correlation (α=0.05) and power regressions were obtained for each cluster. A final analysis was performed to determine if suspended sediment loads from Town Creek watershed have changed over time. Initially, the records from May 1, 2008 to April 30, 2009 were excluded from the third cluster and analyzed as an individual group. A new transport curve was determined for each cluster. The confidence interval (α=0.05) for the slope and the coefficient obtained from each regression in each cluster were used as indicators of possible time changes in sedimentation processes within the studied area.

ANALYSIS AND RESULTS

A transport curve was developed for Town Creek near Nettleton, MS encompassing a continuous 16-yr period of records from the USGS 02436500 gauging station and 1-yr of automatic sampling at the same location (Figure 2). Equation 2 represents the obtained expression (R^2=0.93),

$$Q_s = 2.968Q^{1.6536} \tag{2}$$

where Q_s is the suspended sediment load (T d^{-1}), Q is the flow discharge (m^3s^{-1}), the coefficient represents the load at a low flow or base flow and is indicative of background levels from the channel system (Simon et al., 2002), and the exponent represents the rate of increase in load and is indicative of sediment availability in the watershed and channel system with increasing flow (Kunhle and Simon, 2000). The obtained slope coefficient is representative for a Stage III channel or channel in degradation, according to the categories of stage of channel evolution suggested by Simon (1989). Suspended load contributions

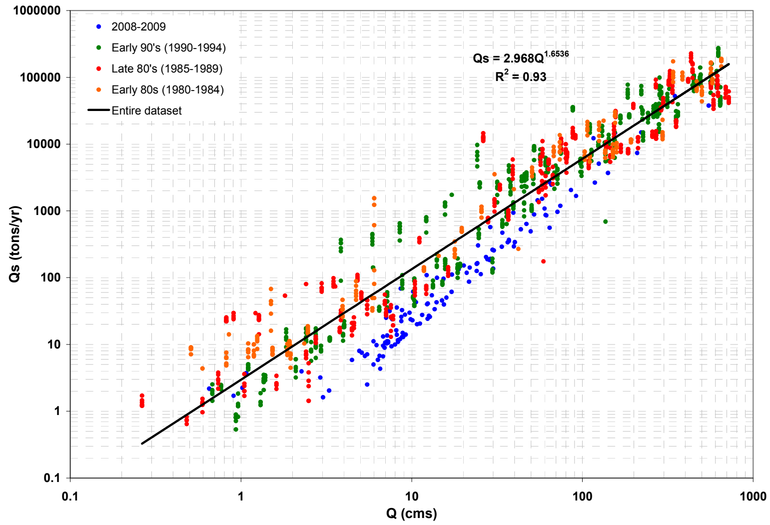

Figure 2 Relation between sediment load (Q_s) and instantaneous flow (Q) for 1401 gauging station records at the USGS 02436500 gauging station (Town Creek near Nettleton, MS).

could come from agricultural lands near streambanks, degrading tributaries and streambank failures. Those sources represent different agents of erosion that could be present during this phase. Dominant channel processes are illustrated by basal erosion and pop-out failures on streambanks, and riparian vegetation may lean towards the channel. It is expected that Stage III reaches manifest greatest bed-material discharges because this is the stage when maximum rates of bed degradation occur.

Using the estimated effective discharge $Q_{1.5}$ = 636 m^3s^{-1} for the 1606 km^2 of drainage area at the site of study, an average annual suspended sediment load and annual suspended sediment yield of 127,728 T d^{-1} and 80 T d^{-1} km^2 were calculated respectively. Table 1 shows the comparison among suspended sediment transport relations generated by previous studies at the same location and the present study results. A significant difference (α=0.05) was not observed between the slopes and coefficients included in the expression proposed by Simon et al. (2002) and obtained in the present analysis. The estimated suspended sediment load and suspended sediment yield calculated under both expressions were very similar. That condition was expected although in the present analysis a new dataset of 128 records was included. The regional model proposed by Sharp (2007) underestimated the suspended sediment load and suspended sediment yield for Town Creek using our expression by about six times. Sharp's regional suspended sediment rating curve is based on all gauging stations within the Tombigbee River Basin, and suspended sediment load rates for a similar flow discharge can vary up to 4 orders of magnitude. The reference yield for Southeastern Plain Ecoregion watersheds including Town Creek at the $Q_{1.5}$ was determined by Simon et al. (2002) as 3.9 T d^{-1} km^2. For the drainage area at the USGS station location, a suspended sediment load of 6270 T yr^{-1} was then estimated. The estimated suspended sediment yield from Town Creek for the analyzed period was about 20 times (one order of magnitude) greater than the reference condition at the effective discharge (see Table 1). An annual suspended sediment load of 1,073,433 T yr^{-1} and annual suspended sediment yield of 668 T yr^{-1} km^2 were obtained after integrating the suspended sediment rating curve using average daily flows for Town Creek near Nettleton, MS (Tier 2 procedure). The regional model in this case underestimated the amounts calculated by the estimated transport model and the previous NSL model by about 4 times.

Table 1 Comparison of suspended sediment transport relations at the USGS 02436500 gauging station (Town Creek near Nettleton, MS) determined by different authors showing calculated load and yield estimated at $Q_{1.5}$=636 m^3s^{-1} and drainage area A=1606 km^2.

Model	Rating curve coefficient a	Rating curve exponent b	R^2	Tier 1 Effective flow ($Q_{1.5}$)		Tier 2 Daily Flow	
				Load (T d^{-1})	Yield (T d^{-1} km^2)	Load** (T yr^{-1})	Yield (T yr^{-1} km^2)
Entire dataset (1401 records)	2.968	1.653	0.93	127,728	80	1,073,433	668
Regional model (Sharp, 2007)	6.485	1.259	0.84	21,923	14	257,051	160
NSL (Simon et al., 2002)	3.360	1.630	*	124,731	77	1,054,556	657

*Not reported by authors

**Average annual value for continuous estimation from January 1 1981 to March 30 2008 and May 1 2008 to April 30 2009.

Table 2 Annual suspended sediment transport relations at the USGS 02436500 gauging station (Town Creek near Nettleton, MS) showing estimated load and yield at the determined $Q_{1.5}$=636 m^3s^{-1} and drainage area A=1606 km^2.

Year	Rating curve coefficient a	Rating curve exponent b	R^2	Tier 1 Effective Flow ($Q_{1.5}$)		Tier 2 Daily Flow	
				Load (T d^{-1})	Yield (T d^{-1} km^2)	Load (T yr^{-1})	Yield (T yr^{-1} km^2)
1981*	7.389	1.633	0.98	280,022	174	358,644	223
1982	4.639	1.592	0.95	135,085	84	2,102,374	1,310
1983	11.320	1.423	0.96	110,096	69	2,649,102	1,650
1984	5.102	1.568	0.96	126,696	79	752,797	469
1985	7.818	1.532	0.92	154,464	96	600,461	374
1986	3.182	1.676	0.94	158,869	99	702,953	438
1987	2.635	1.807	0.96	307,005	191	791,831	493
1988**	4.920	1.018	0.82	3,508	2	24,852	16
1989	3.776	1.509	0.93	64,356	40	733,129	456
1990	3.052	1.686	0.96	162,440	101	1,785,102	1,112
1991	3.405	1.609	0.92	110,366	69	3,549,304	2,210
1992	2.730	1.853	0.88	426,665	266	1,065,833	664
1993	1.041	1.898	0.99	218,301	136	419,663	261
1994	2.804	1.690	0.87	152,842	95	1,094,037	681
1995	1.678	1.748	0.96	133,694	83	759,359	473
2008 - 2009	0.408	1.864	0.94	68,597	40	262,405	163

* Instantaneous flow for suspended sediment records always lower than 26 m^3s^{-1}.

** Instantaneous flow for suspended sediment records always lower than 12 m^3s^{-1}.

Annual suspended sediment transport relations, suspended sediment loads and suspended sediment yield for the USGS station 02436500 are shown in Table 2. The average daily suspended sediment load and sediment yield at $Q_{1.5}$ determined from each annual expression were 166,684 T d^{-1} and 104 T d^{-1} km^2, respectively. Estimated suspended sediment load and yield at effective flow for 1988 were the lowest for the period of analysis. The lowest values observed could be caused by significant low flow conditions observed during that entire year and because of the low range of instantaneous flow (< 12 m^3s^{-1}) and suspended sediment loads (67 T d^{-1}) recorded in the database. These conditions generated the estimation of the lowest slope (close to 1) (but not the highest intercept) of the determined annual suspended sediment transport curves for this year. The observed slope could be considered an indication of low sediment availability in the watershed and channel system with increasing flow. For that specific year, the suspended sediment load and suspended sediment yield at the effective discharge were lower than the "reference" rate of suspended sediment transport suggested by Simon et al. (2002) (Figure 3).

The annual suspended sediment loads varied between 24,852 T yr^{-1} and 3,549,304 T yr^{-1} when determined by the Tier 2 analysis. Also in this analysis the lowest load and yield occurred in 1988.

Figure 3 compares the annual suspended sediment loads calculated by integrating the suspended sediment rating curve based on (1) the entire period of record (Eq. 2) and (2) annual records. The annual suspended sediment loads using the general transport curve (Eq. 2) are similar to those estimated by using each annual transport curve. For years with a reduced amount of cumulative annual flow the general transport equation underestimated the suspended sediment transport rates in a range between 60% and 90% the estimated loads obtained by using the respective annual transport curve.

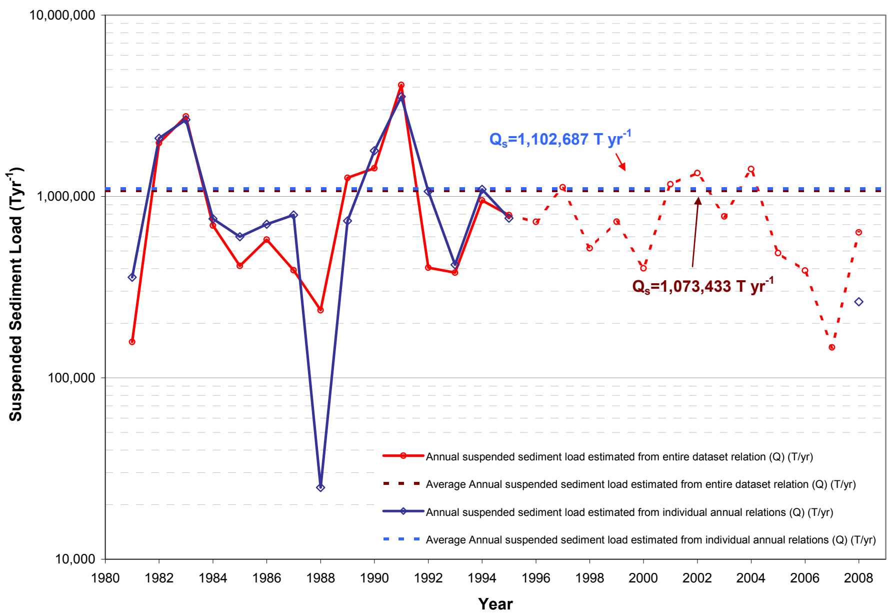

Figure 3 Annual suspended sediment loads at USGS station 02436500 (Town Creek near Nettleton, MS) determined by integrating two different suspended sediment rating curves (Tier 2 analysis): (i) suspended sediment rating curve based on the entire period of record (Equation 2), and (ii) annual suspended sediment rating curves.

The values for the slope and the intercept obtained for each annual suspended sediment transport relation at the USGS 02436500 (Town Creek near Nettleton, MS) are shown in the Figure 4. An increasing trend in the rate of increase in load was observed while a trend towards reduction in the load at low or base flow conditions occurred during the study period. The increase in the rate of increase in load categorized Town Creek with transitional channels that followed Stage III toward the Stage IV. This condition indicates streambank erosion and bed instability processes that result from changes in channel gradient and channel morphology. Incised channels (V-shaped) are observed upstream and transitionally change to broad U-shaped channels.

A significant correlation (α=0.05) and an exponential expression with a negative slope were determined between the suspended sediment load at low or base flow and the rate of increase in load (Figure 5). A similar condition was found by Asselman (2000). The pair of parameters for the year 1988 was determined as an outlier and was not included in the determination of the correlation. The correlation between annual average instantaneous flow and the rate of increase in load was only observed with cluster analysis. For each individual cluster, as the magnitude of the annual average instantaneous flow (Q) increased, the rate of increase in load (b) was reduced. At the same annual average instantaneous flow, the relative efficiency of the stream to transport increasing amounts of suspended sediment with increasing flow rates increased in time. Although the cluster including the later records had a higher reduction rate of b with increasing Q (slope), this parameter did not show significant difference (α=0.05) among clusters (Figure 6).

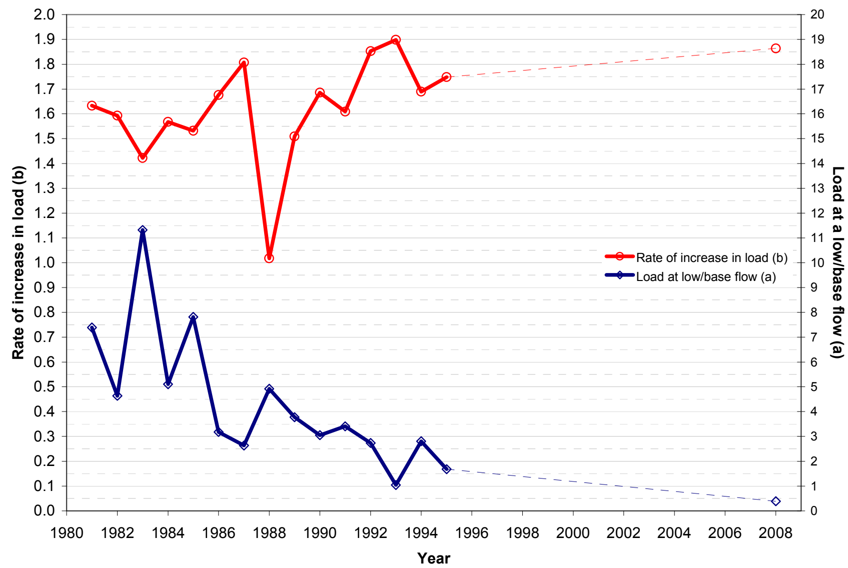

Figure 4 Rate of increase in load (slope) and loads at low/base flow (intercept) obtained for each year with recorded data at the USGS station 02436500 (Town Creek near Nettleton, MS).

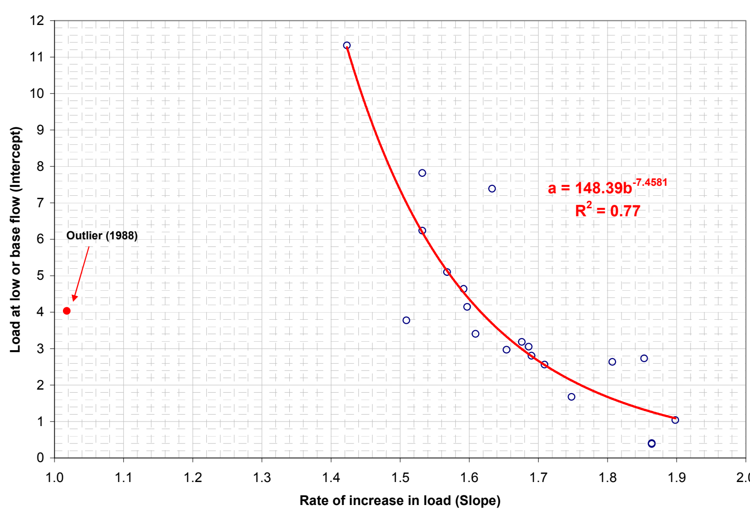

Figure 5 Relation between the annual suspended sediment load at low or base flow and the annual rate of increase in load at USGS station 02436500 (Town Creek near Nettleton, MS).

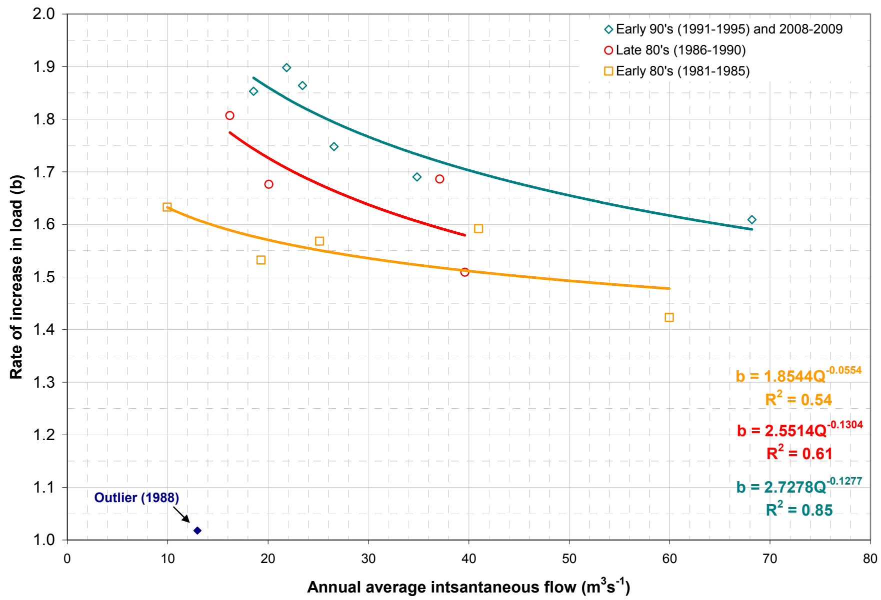

Figure 6 Clustered relation between annual average instantaneous flow (m^3s^{-1}) and the rate of increase in load obtained for each year with recorded data at the USGS station 02436500 (Town Creek near Nettleton, MS).

Because there is a lack of data on suspended sediment loads from Town Creek watershed for the last 14 years, it is difficult to make a statement about suspended sediment yield trends. The estimation of suspended sediment loads using Eq. 2 showed a trend toward reducing the annual loads. Transport curves determined for each of the four clusters used in the determination of change in time of suspended sediment loads from Town Creek watershed are shown in Figure 7. The comparison of slopes among clusters (α=0.05) confirmed that a significant increase in the rate of increase in load for Town Creek watershed occurred over the time (Table 3). This behavior would suggest an increase in time of the sediment availability, transport capacity and probable suspended sediment loads in the watershed and channel system with increasing flow. However, at the same time the suspended sediment load amount under low or base flow was reduced. Both conditions can be explained by the difference in stages of channel evolution presented in different sections along the Town Creek. The rising relative efficiency of the stream to transport increasing amounts of suspended sediment with increasing flow rates within Town Creek could be attributed to the increased contribution of significant amounts of suspended sediment loads (up to 70%) from agricultural lands, with high gully erosion and streambank erosion activities from the incised unstable (Stage III and IV) channels in the northern headwaters. The middle 20 km and the last meandering 10 km along the wide vegetated stable principal reach favor stream energy reduction, suspended sediment deposition on streambanks during and after storm flow events, seasonal streambed mobility, and suspended sediment concentration reduction (by increase in flow). The described condition could be a factor to explain the temporal reduction of suspended sediment loads at low flow conditions. A trend toward the reduction of the annual average instantaneous flow was observed from the analysis of those records (not shown). That should be considered another factor affecting the significant reduction of suspended sediment contribution at a specific flow rate of up to one order of magnitude in time from 1981 to 2009 from Town Creek watershed. The observed relation between the magnitude of the suspended sediment transport curve parameters and the trend toward reducing suspended sediment loads was similarly observed by Yang et al. (2007).

Table 3 Suspended sediment transport relations at USGS station 02436500 (Town Creek near Nettleton, MS) determined for different periods between 1981 and 1995 and May 2008 to April 2009, showing calculated load and yield at the $Q_{1.5}$=636 m^3s^{-1} and drainage area A=1606 km^2.

Model	Rating curve coefficient a	Rating curve exponent b	R^2	Tier 1 Effective Flow ($Q_{1.5}$)		Tier 2 Daily Flow	
				Load (T d^{-1})	Yield (T d^{-1} km^2)	Load* (T yr^{-1})	Yield (T yr^{-1} km^2)
Early 80's (1981-1985)	6.375	1.545	0.97	106,433	66	1,360,106	847
Late 80's (1986-1980)	3.543	1.597	0.93	136,274	85	682,922	425
Early 90's (1991-1995)	2.563	1.709	0.94	158,336	99	1,612,386	1004
May 2008-April 2009	0.408	1.864	0.94	68,597	40	262,405	163
Entire dataset (1401 records)	2.968	1.654	0.93	127,728	80	1,073,433**	668

*Average annual value for the years in the cluster.

**Average annual value for continuous estimation from January 1 1981 to March 30 2008 and May 1 2008 to April 30 2009.

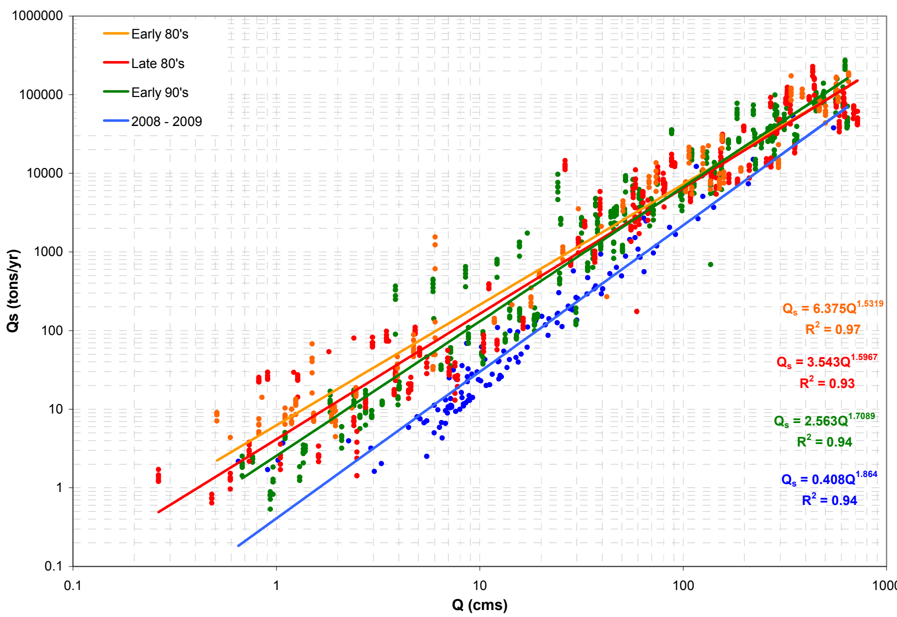

Figure 7 Relations between suspended sediment load (Q_s) and instantaneous flow (Q) for different time periods (clusters) at USGS station 02436500 (Town Creek near Nettleton, MS).

CONCLUSIONS

Annual suspended sediment loads near the outlet of Town Creek watershed, Mississippi, between 1981 and 2009 are trending downward. Average suspended sediment loads at the USGS station 02436500 (Town Creek near Nettleton, MS) of Town Creek over this 29-yr period are about 1,000.000 T yr^{-1}. Estimated suspended sediment yield at the effective flow ($Q_{1.5}$) is 80 T d^{-1} km^2. Suspended sediment yield at the last studied year 2008-2009 is reduced to about 40 T d^{-1} km^2.

Regional models based on data from Southeastern Plain Ecoregion watersheds can significantly underestimate suspended sediment loads and suspended sediment yields. Annual suspended sediment transport relations are significantly affected by the occurrence of low flow periods. The relative efficiency of Town Creek to transport increasing amounts of suspended sediment with increasing flow rates has increased in time. However, relative efficiency reduces with increasing instantaneous flow.

Temporal analysis of suspended sediment transport relations from 1981 to 2009 show a reduction in the amount of suspended sediment loads contributed by Town Creek watershed at a specific instantaneous flow. The reduction is higher under low flow conditions (< 10 m^3s^{-1}). Rising relative efficiency of Town Creek to transport increasing amounts of suspended sediment with increasing flow rates show the high erosion potential of important geomorphic processes in a specific area of the watershed. This condition can be inferred from considering that suspended sediment loads at low flow or base flow conditions has decreased, and considerably less sediment at a given discharge was transported in the last decade than in earlier years. Current relative efficiency of the Town Creek to transport increasing amounts of suspended sediment with increasing flow rates is attributed to active geomorphic processes at the northern 320 km^2 of the watershed. Temporal reduction in suspended sediment loads at low flow or base flow conditions in Town Creek are attributed to the presence of wide stable vegetated channels and the significant increase in flow (suspended sediment dilution) along the middle and lower areas of the watershed.

Over continuous periods of time (exceeding two decades), differences up to one order of magnitude can be achieved using a single suspended sediment transport relation based on the entire period of record instead of annual suspended sediment transport relations. Larger differences occur under low average annual instantaneous or daily flow conditions.

Current and historic suspended sediment transport curve parameters for Town Creek watershed can be compared using annual average instantaneous or daily flow. The parameter estimation allows the establishment of a correlation between annual average instantaneous flow and the rate of increase in load and a correlation between the suspended sediment transport curve parameters.

A joint analysis of field reconnaissance, suspended sediment transport relation parameters, flow and suspended sediment loads trend and changes in time can be used to determine different stages of channel evolution of reaches or areas inside a watershed.

Analysis of bed material transport by incorporating Tier 3 of the analysis proposed by Sharp (2007) is needed for a more comprehensive understanding of the sediment discharge , the sediment budget, and the stage of channel evolution in the different subareas within the Town Creek watershed.

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