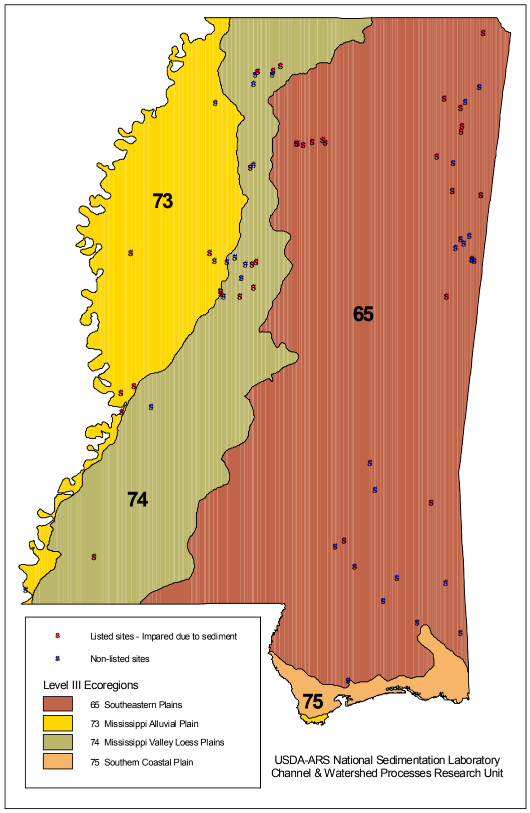
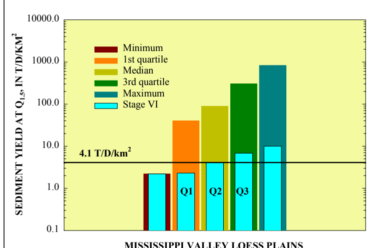
“Reference” and “Impacted” Rates of Suspended-Sediment Transport for Use in Developing Clean-Sediment TMDL’s: Mississippi and the Southeastern United States





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Channel and Watershed Processes Research Unit

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EXECUTIVE SUMMARY

Flow and sediment-concentration data for 239 sites in the three ecoregions of the southeastern United States were acquired and analyzed to develop a methodology by which TMDL practitioners could develop water-quality targets for sediment. The three ecoregions are: Mississippi Alluvial Plain (MAP), Mississippi Valley Loess Plains (MVLP) and Southeastern Plains (SEP). The MAP ecoregion includes the Mississippi Delta. Particular attention was given to Mississippi where sediment-transport relations and associated field evaluations have been completed for all sites that have historical flow and sediment-transport data.

To identify those sediment-transport conditions that represent impacted or impaired conditions, it is essential to first be able to define a non-disturbed, stable, or "reference" condition for the particular stream reach. A process-based conceptual model of channel evolution was found to be superior to a more traditional form-based classification for establishing "reference" conditions. Stages I and VI of the channel evolution model represent stable channel conditions and can, therefore, be used to establish background rates of sediment transport. Stages of channel evolution and rapid geomorphic assessments were conducted at 72 sites in Mississippi and 134 region wide.

Sediment-transport rates at the effective discharge (i.e., that discharge that transports the most sediment over the long term) were used as a measure of sediment production and delivery for the southeastern ecoregions. Sediment yields, expressed in tonnes/day/km^2, ranged from about 0.01 to more than 6,000. Median values for the MAP, MVLP, and SEP are 0.88, 89.0, and 0.50 respectively.

Considering only sites in Mississippi, the median values are considerably higher for the MAP, MVLP, and SEP; 1.7, 262, and 3.9 T/d/km^2, respectively. Median values for stable, "reference" conditions were established for each ecoregion in Mississippi using suspended-sediment yield values for those sites that were identified as Stage I or Stage VI. These sites generally have stability ranking of near 10 or less. Preliminary "reference/target" values for Mississippi sites in the MAP, MVLP, and SEP ecoregions are 1.4, 5.8, and 1.3 T/d/km^2, respectively. These values represent minimal reductions in sediment yield for the MAP or Delta region of Mississippi and substantial reductions in the Loess Hills area.

Appendices I, II, and III of this report contain printouts of transport relations and associated photographs of the sites located in Mississippi, organized by ecoregion. The raw flow, concentration, and sediment-transport data for Mississippi locations is available from Dr. Simon (**asimon@ars.usda.gov**) in CD media.

ACKNOWLEDGMENTS

The authors would like to express their appreciation to the following agencies and individuals for support on this project. The USDA-Agricultural Research Service and U.S. Environmental Protection Agency (Office of Water and Region IV) provided funding for this work. Much of the flow and sediment-concentration data that was downloaded by ARS staff came from U.S. Geological Survey web sites. We would also like to thank Dr. Scott Knight, ARS-National Sedimentation Laboratory for the use of Figure 6 and. Drs Carlos Alonso, Sean Bennett, and Andrew Collison for providing critical reviews of an earlier version of the manuscript.

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INTRODUCTION

Sediment is listed as one of the principal pollutants of surface waters in the United States, both in terms of sediment quantity ("clean sediment") and sediment quality due to adsorbed constituents and contaminants. We can view sediment-transport rates and amounts as (1) "natural" or background, resulting from generally stable channel systems, (2) "impacted", with greater transport rates and amounts, reflecting a disturbance of some magnitude and more pervasive erosion, and (3) "impaired", where erosion and sediment transport rates and amounts are so great that biologic communities and other designated stream uses are adversely effected. Impairment of designated stream uses by clean sediment (neglecting adsorbed constituents) may occur through processes that occur on the channel bed or by processes that take place in the water column. Fully mobile streambeds, and deposition of fines amidst interstitial streambed sands and gravels can pose hazards to fish and benthic macro-invertebrate communities by disrupting habitats, degrading spawning habitat, and reducing the flow of oxygen through gravel beds. Although lethal or sub-lethal thresholds are unknown at this time, high concentrations of suspended sediment, perhaps over certain durations can adversely affect those aquatic species that filter and ingest water. It is critical, therefore, to clearly identify the functional relation between an impact due to sediment and the sediment-transport process so that appropriate parameters are analyzed.

Although clean sediment can adversely affect habitat and other designated uses in a variety of ways, this paper will be limited to discussions and analysis of methods and techniques for analyzing impacts due to suspended sediment. The USDA-Agricultural Research Service, National Sedimentation Laboratory (ARS), is conducting analytic research on suspended-sediment transport and clean-sediment TMDL development throughout the United States. This paper, however, focuses on work conducted in the southeastern United States, predominantly in Mississippi where field efforts have been initially focused. The work described in this paper was made possible by USDA-Agricultural Research Service discretionary research funds and a cooperative project with the U.S. Environmental Protection Agency's Office of Water and Region IV.

SOME CRITICAL ISSUES

Availability of Data

Analysis of the impacts of suspended sediment requires a database of suspended-sediment concentrations with associated instantaneous water discharge. Data of this type permits analysis of sediment-transport characteristics and the development of rating relations (Porterfield, 1972). Collection of suspended-sediment data is time consuming and expensive in that it must take place over a broad range of flows to accurately evaluate the sediment-transport regime at a site. However, the U.S. Geological Survey (USGS) has identified more than 2,900 sites nationwide where at least 30 matching samples of suspended sediment and instantaneous flow discharge have been collected (Turcios and Gray, 2001). More than 400 of these sites coincide with locations that have been listed by States as being impaired in one way or another by sediment. Table 1 provides a list of the general causes of impairment due to sediment as interpreted by the States (U.S. EPA, 2001, written communication) At many of the more than 2,900 sites, data on the particle-size distribution of suspended- and bed-material sediment are also available. Kuhnle and Simon (2000) identified additional sites containing data collected by the USGS and other agencies such as the ARS at their experimental watersheds. This massive historical database serves as the foundation for analyzing sediment-transport characteristics over the entire range of physiographic conditions that exist in the United States, including Hawaii and Puerto Rico.

Table 1 – Causes of impairment due to clean sediment listed by States, Territories and Tribes.

Accumulated sediment	16
Erosion	2
Fine sediment	9
Sediment	1021
Sedimentation	144
Sedimentation/ siltation	98
Siltation	2972
Siltation /turbidity	21
Sludge/sediment	1
Solids	3
Stream bottom deposits	99
Suspended sediment	99
Suspended solids	1128
TSS	31
TTS	1
Turbidity	709
TOTAL	**6354**

Data from U.S. EPA Office of Water, February 2001.

To be useful for TMDL practitioners in States, Territories and Tribes, sediment-transport relations derived from this existing database must be placed within a conceptual and analytic framework such that they can be used to address sediment related problems at sites where no such data exists. To accomplish this, sediment-transport characteristics and relations need to be regionalized according to attributes of channels and drainage basins that are directly related to sediment production, transport, and potential impairment. In a general way, these attributes include among others, physiography, climate and ecology, differentiated collectively as an ecoregion (Omernik, 1995), and dominant stream-channel processes (channel stability), differentiated as stage of channel evolution (Simon and Hupp, 1986; Simon, 1989a). Figure 1 shows the nationwide locations of the existing historical suspended-sediment data by Level III ecoregion. We found that Level II ecoregions (covering broader areas than Level III) over generalized regional characteristics and that the smaller Level IV ecoregions divisions would not provide a sufficient number of sites in each to make regional distinctions.

Sites in three Level III ecoregions containing 239 sites were analyzed for this study (Figure 2). They are:

1. Mississippi Alluvial Plain, incorporating parts of Arkansas, Louisiana, Mississippi, and Tennessee (60 sites);
2. Mississippi Valley Loess Plains, incorporating parts of Kentucky, Mississippi, and Tennessee (33 sites); and
3. Southeastern Plains, incorporating parts of Alabama, Florida, Georgia, Maryland, Mississippi, North Carolina, South Carolina, Tennessee, and Virginia (146 sites).

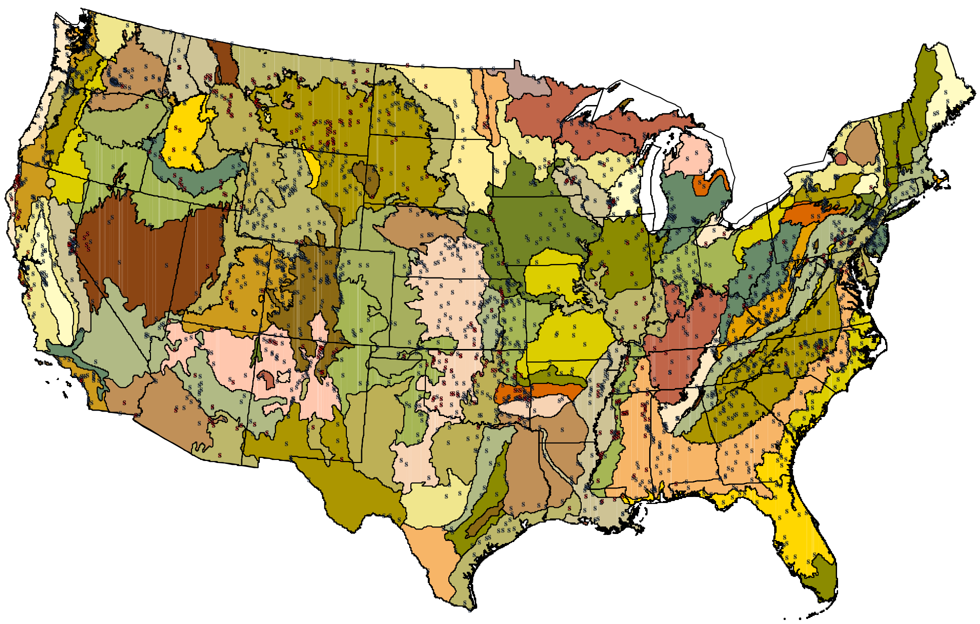

Figure 1 – Level III ecoregions of the continental United States showing locations of sites with at least 30 samples of suspended sediment and associated flow discharge (72 sites are in Mississippi; See Figures 2 and 3).

Field evaluations of channel characteristics have been performed in Mississippi (72 sites), West Tennessee, Georgia and Alabama (Figure 2). A location map of sites in Mississippi and the associated ecoregions is shown in Figure 3. Photographs of the Mississippi sites are contained in the attached appendices, organized by ecoregion.

"Reference" Conditions

Rates and concentrations of suspended-sediment transport vary over time and space due to factors such as precipitation and discharge, geology, relief, land use and channel stability, among others. There is no reason to assume that "natural" or background rates of sediment transport will be consistent from one region to another. Within the context of clean-sediment TMDLs, it follows that there is no reason to assume then that "target" values should be consistent on a nationwide basis. Similarly, there is no reason to assume that channels within a given region will have consistent rates of sediment transport. For example, unstable channel systems or those draining disturbed watersheds will produce and transport more sediment than stable channel systems in the

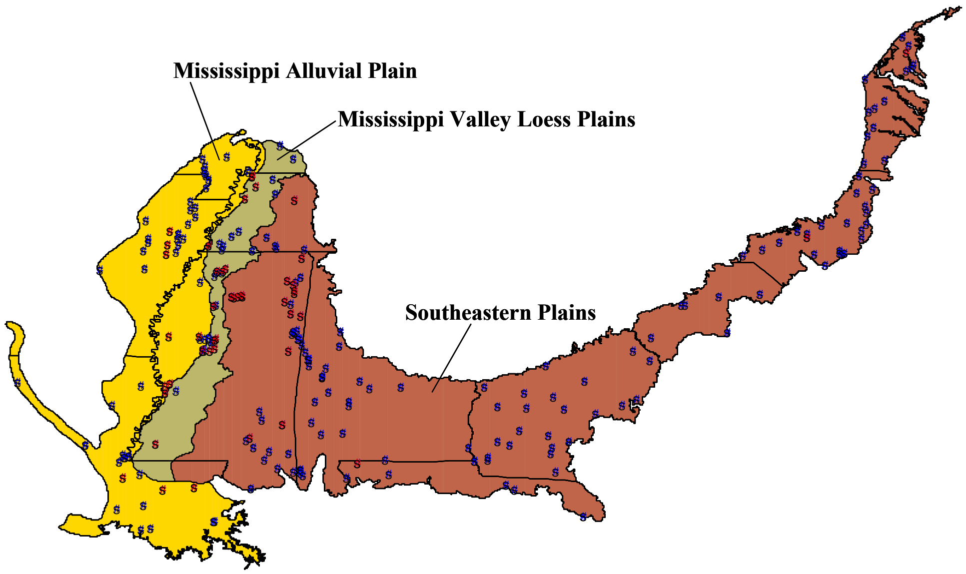

Figure 2 – Map of the Level III ecoregions analyzed in this study.

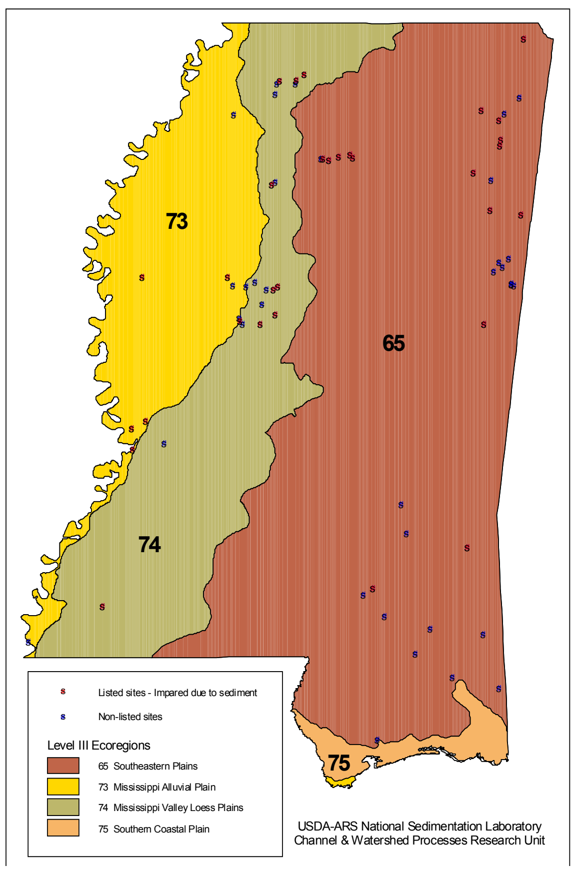

Figure 3 – Map of Level III ecoregions and sites in Mississippi.

same region. This reflects differences in the magnitude and perhaps type of erosion processes that dominate a sub-watershed or stream reach.

In order to identify those sediment-transport conditions that represent impacted or impaired conditions, it is essential to first be able to define a non-disturbed, stable, or "reference" condition for the particular stream reach. In some schemes the "reference" condition simply means "representative" of a given category of classified channel forms or morphologies (Rosgen, 1985) and as such, may not be analogous with a "stable", "undisturbed", or "background" rate of sediment production and transport.

As an alternative scheme for TMDL practitioners, the channel evolution framework set out by Simon and Hupp (1986) is proposed (Figure 4). With stages of channel evolution tied to discrete channel processes and not strictly to specific channel shapes, they have been successfully used to describe systematic channel-stability processes over time and space in diverse environments subject to various disturbances such as stream response to: channelization in the Southeast US Coastal Plain (Simon, 1994) and the Midwestern United States (Simon and Rinaldi, 2000); volcanic eruptions in the Cascade Mountains (Simon, 1992); and dams in Tuscany, Italy (Rinaldi and Simon, 1998). Because the stages of channel evolution represent shifts in dominant channel processes, they are systematically related to suspended-sediment and bed-material discharge (Simon, 1989b; Kuhnle and Simon, 2000; Figure 5a and 5b), fish-community structure (Figure 6), rates of channel widening (Simon and Hupp, 1992), and the density and distribution of woody-riparian vegetation (Hupp, 1992).

An advantage of a process based channel evolution scheme for use in TMDL development is that Stages I and VI represent two true "reference" conditions. In some cases, such as in the Midwestern United States where land-clearing activities and channelization near the turn of the 20th century caused massive changes in rainfall-runoff relations and land use, channels are unlikely to recover to Stage I, pre-modified

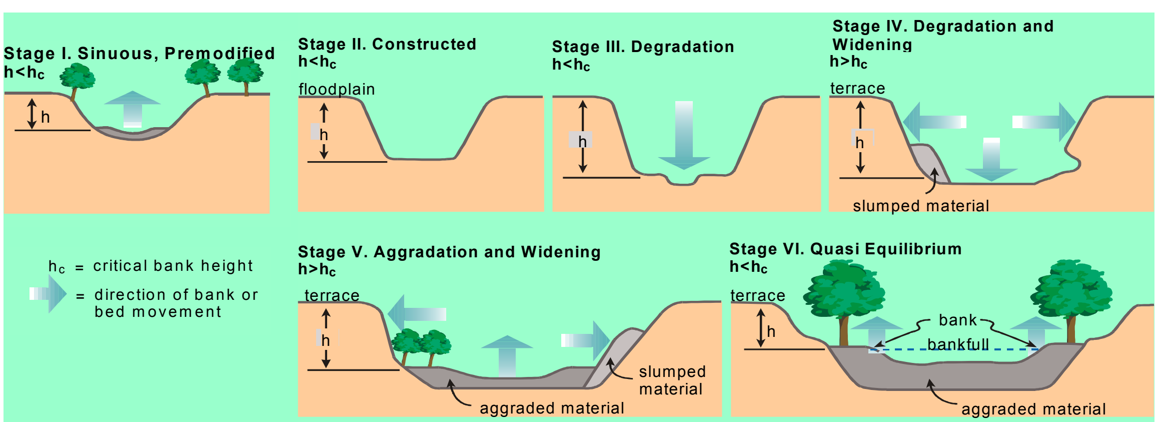

Figure 4 – Six stages of channel evolution from Simon and Hupp (1986) and Simon (1989a) identifying Stages I and VI as "reference" conditions.

conditions. Stage VI, re-stabilized conditions are a more likely target under the present regional land use and altered hydrologic regimes (Simon and Rinaldi, 2000) and can be used as a realistic "reference" condition. However, in pristine areas where disturbances have not occurred or where disturbances have been far less severe, Stage I conditions can be used as a "reference"/target.

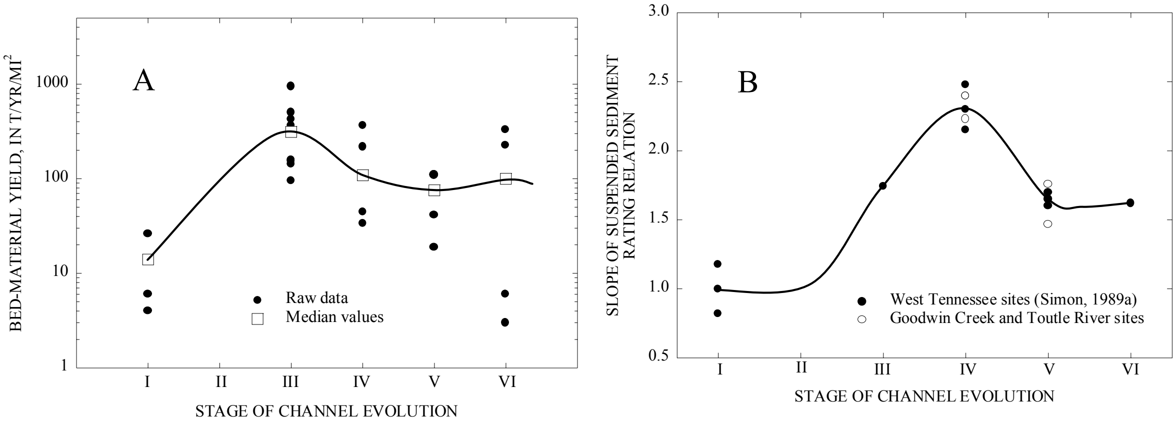

Figure 5 – Relation between stages of channel evolution and (A) bed-material discharge, and (B) suspended-sediment transport rate (Simon 1989b; Kuhnle and Simon, 2000).

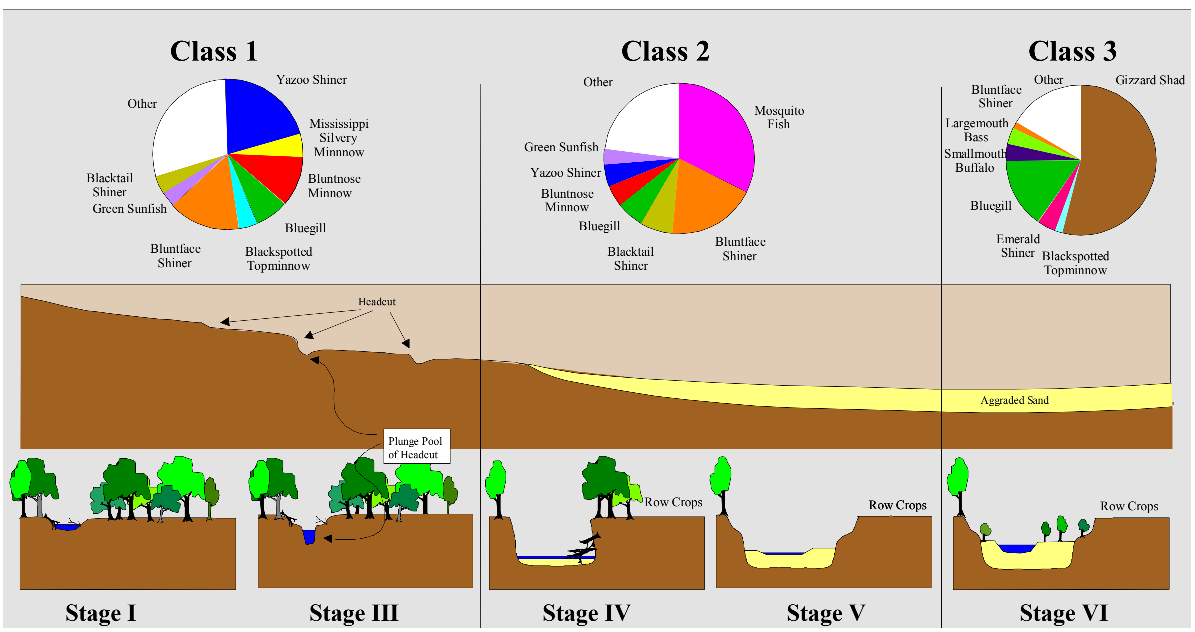

Figure 6 – Fish community structure related to stages of channel evolution in Mississippi.

Stage of channel evolution and other diagnostic criteria of channel processes used to derive a channel-stability index were obtained by field evaluations. Because of the great number of sites that ultimately will be evaluated, a Rapid Geomorphic Assessment (RGA) scheme is used based on those described in Simon and Downs (1995) and Kuhnle and Simon (2000). About 1.0 to 1.5 hours are required to perform the evaluation with this modified technique and including the surveying of channel slope and the taking of bed-material samples. A copy of the field form is shown in Table 2. The channel stability index is calculated by summing the values for each item in Table 2. Appendices I, II, and III contain tables of the summed values, organized by ecoregion. The greater the value, the more unstable the site is. In general, the highest index values occur during Stage IV when both bed erosion and bank failures are the dominant channel processes.

ANALYSIS OF SUSPENDED-SEDIMENT DATA

Analysis of suspended-sediment transport data involves establishing some type of relation between flow and sediment concentration or load. Instantaneous-concentration data combined with either an instantaneous flow value or flow data representing the value obtained from the stage-discharge relation at 15-minute intervals are best. Mean-daily values of both flow and sediment loads, which are readily available from the USGS, tend to be biased towards low-flow conditions, particularly in flashy basins. For establishing sediment-transport rating relations, instantaneous concentration and 15-minute flow data were used from USGS and ARS gauging station records. The resulting relation can be evaluated in several ways:

1. Slope of the rating relation (rate of increase in concentration/load and indicative of sediment availability in the watershed and channel system with increasing flow (Simon, 1989b; Kuhnle and Simon, 2000);
2. Coefficient of the rating relation (concentration/load at a low/base flow and indicative of background levels from the channel system);
3. Frequency and duration of suspended-sediment transport for given concentrations/loads that may represent threshold, sub-lethal or lethal levels for organisms (Kuhnle and Simon, 2000); and
4. Concentration/load at the “effective” discharge.

The “effective discharge” is defined as that water discharge or range of discharges that shape channels and perform the most geomorphic work (erosion and transport of sediment) over the long term. As such, sediment concentrations or loads at the effective discharge can serve as useful indicators of regional suspended-sediment transport conditions for “reference” and impacted sites. In many parts of the United States, the effective discharge is approximately equal to the peak flow that occurs on average, about every 1.5 years ($Q_{1.5}$; for example, Andrews, 1980; Andrews and Nankervis, 1995) and may be analogous to the bankfull discharge in stable streams. Using data from 55 streams, Nash (1994) questioned the validity of the effective discharge occurring on about 1-year intervals based on concerns of transport variability and the difficulty of

Table 2 – Field form for rapid geomorphic evaluations.

CHANNEL-STABILITY RANKING SCHEME

Station #__________________ **Station Description**___________________________________

Date _____________ **Crew** _______________ **Samples Taken**_________________________

Pictures (circle) upstream downstream cross section **Slope**__________

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 protected	2 banks	
	0	1		2	3	____

3. Degree of incision (Relative ele. 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 ripirian 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	2	1.5	1	0.5	0	____
Right	2	1.5	1	0.5	0	____

9. Stage of channel evolution

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

TOTAL ____

describing the relation between suspended-sediment concentration and water discharge with a power function. The recurrence interval for the effective discharge in this study was calculated for 10 streams in Mississippi.

Calculating Effective Discharge ($Q_{1.5}$)

Calculating the effective discharge is a matter of integrating a flow-frequency curve with a sediment-transport rating to obtain the discharge (range of discharges) that transports the most sediment. This was accomplished at the 10 sites where we could readily obtain the complete 15-minute flow record. The 15-minute flow data for the period of record was initially ranked in ascending order, the data separated into 25-33 logarithmic classes, and the percentage of time that flows of each class occurred was calculated. The next step was to develop a first approximation suspended-sediment transport rating function (Porterfield, 1972; Simon, 1989b) by plotting discharge versus concentration in log-log space and obtaining a power function by regression (Figure 7a). Trends of these data (in log-log space) often increase linearly and then break off and increase more slowly at high discharges. Preliminary analyses of the studied streams show that although sand concentrations continue to increase with discharge, the silt-clay fraction attenuates, causing the transport relation to flatten. A simple transport rating developed with a single power function and with this kind of data trend commonly over-estimates concentrations at high flow rates, leading to significant errors in calculating annual loads and the effective discharge. To alleviate this problem, a second linear (in log-log space) segment is often developed with the upper end of data set (Figure 7b). This adjustment to the upper end of the rating directly addresses one of Nash's (1994) concerns regarding the use of a single power function to describe the relation between flow and sediment discharge over the entire range of flows.

Following calculation of a second sediment-rating function to define sediment transport at high discharges, the concentration at the midpoint of each discharge class is then calculated from the rating relation and multiplied by the discharge and its percent

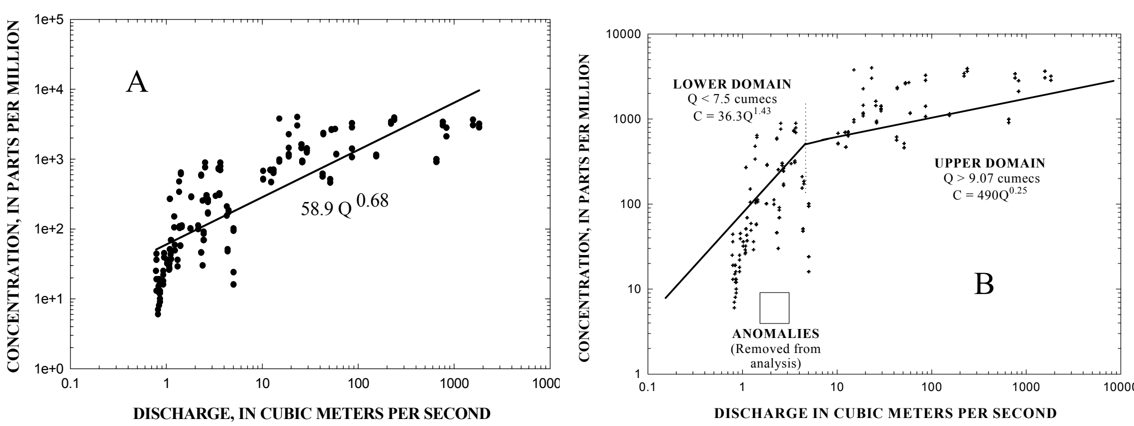

Figure 7 – Example of adjusting upper end of sediment-transport rating to reduce error in estimating the effective discharge.

occurrence. The sum of these values represents the average annual suspended-sediment load, and the discharge class containing the highest value is, by definition, the effective discharge. For the 10 streams analyzed here for the effective discharge, the $Q_{1.5}$ is again, on average, a good approximation (Table 3) and was used, therefore, as a measure of establishing the effective discharge at the remaining study sites.

Table 3 – Comparison of $Q_{1.5}$ and effective discharge for 10 Mississippi streams showing close agreement.

Site	Effective load class m^3/s	Q 1.5 m^3/s	Q1.5/Qeff
Abiaca21-Cr	45.1	72.0	1.596
Abiaca6-SP	67.1	114	1.699
Batupan	332	272	0.820
Fannegusha	235	171	0.729
Harland	146	156	1.068
Hickahala	228	235	1.031
Hotophia	264	97	0.367
Long	250	333	1.332
Otoucalofa	85.7	152	1.779
Senatobia	196	284	1.449
AVERAGE			1.187
MEDIAN			1.200

Using the annual-maximum peak-flow series for each of the 239 sites in the southeastern ecoregions with available data, the effective discharge ($Q_{1.5}$) was then calculated from the log-Pearson Type III distribution (Figure 8a). Where peak-flow data were not available, the $Q_{1.5}$ was calculated from regional relations based on drainage area obtained from the U.S. Geological Survey (1993) and calculated in this study.

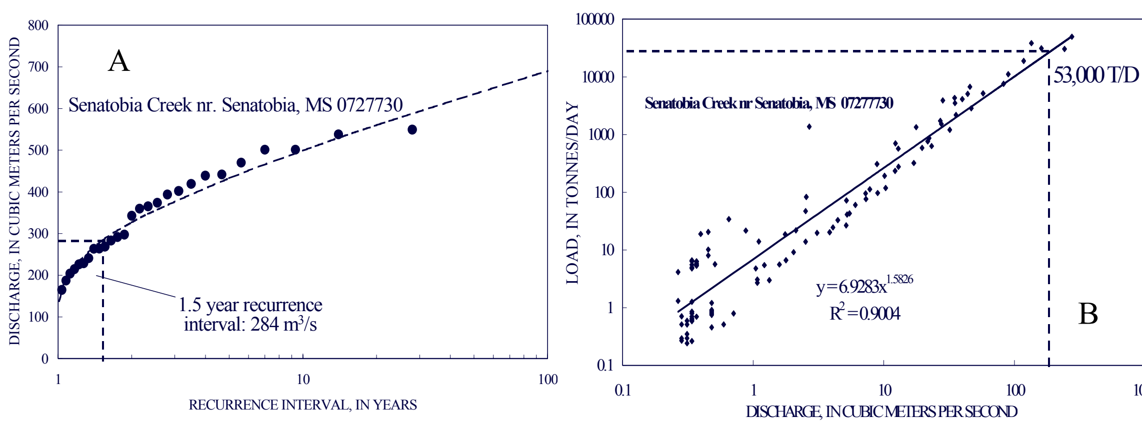

Figure 8 – (A) Obtaining the Q1.5 (effective discharge) from the log-Pearson Type III distribution, and (B) suspended-sediment load at the effective discharge for the Mississippi site 0727730.

SEDIMENT YIELD AT THE EFFECTIVE DISCHARGE

Once the effective discharge ($Q_{1.5}$) was determined at all sites, that discharge was applied to the transport relation for each site (Appendices I, II, and III) to obtain the sediment load at the effective discharge (Figures 8b). To normalize the data for differences in basin size, the sediment load was then divided by the site's drainage area to obtain the sediment yield at the effective discharge (in tonnes/day/km^2). Before the calculated sediment yield was accepted as reliable, particularly where values exceeded 1,000 t/d/km^2, the rating relation was checked to be sure that the upper end was accurately defined and that the $Q_{1.5}$ was within the measured bounds of the data set. If the $Q_{1.5}$ was more than one-half of an order of magnitude greater than the maximum sampled discharge, the calculated effective sediment yield was not included. A summary of these results for all Mississippi sites including regression coefficients for both concentration- and load-transport relations are shown in Table 4. Plots of all calculated transport relations in Mississippi are included in the Appendices. Regression coefficients and exponents shown in Table 4 for concentration are in ft^3/s and mg/l units while the coefficients and exponents for load are in m^3/s and tonnes/d units. Finally, the data were then sorted by ecoregion to establish the range and distribution of sediment yields that could be used as a relative measure of sediment production, transport, and degree of impairment.

For the 239 study sites (Figure 2) in the three ecoregions investigated in the southeastern United States, suspended-sediment yield values ranged over about five orders of magnitude, from 0.01 T/d/km^2 in the Mississippi Alluvial Plain (MAP) to about 6,300 t/d/km^2 in both the Mississippi Valley Loess Plains (MVLP) and the Southeastern Plains (SEP). Without adjustment of the upper end of many of the transport-rating relations (Figure 7b), erroneous estimates of sediment yield as great as tens of thousands of t/d/km^2 would have been reported.

Quartile measures are used in Figure 9 to define the distribution of sediment-yield values because the data are non-normally distributed. The minimum and maximum values actually represent the mean of the five lowest and highest values, respectively and provide a realistic range of values for a given ecoregion. The inter-quartile range (between the 1st and 3rd quartiles), however, provides a more meaningful range of conditions, representing the central 50% of the distribution. All Q1 – Q3 ranges fall within a single order of magnitude yet may vary by more than an order of magnitude between ecoregions (Figure 9), indicating that the sediment yield at the effective discharge may be a reasonably robust parameter to describe sediment-transport characteristics within individual ecoregions. Individual graphs of the suspended-sediment yield quartile measures are provided in the Appendices. Median sediment-yield values for the MAP, MVLP, and SEP ecoregions are 0.88, 89.0, and 0.50 T/d/km^2, respectively.

Table 4 – Suspended-sediment transport data for Mississippi sites showing regression coefficients, sediment yield at the effective discharge and ecoregion.

Ecoregion	Station ID	Concentration		Load		Q1.5	LOAD @ 1.5 RI	Max. sampled Q (m3/s)	Area (km2)	Yield @ 1.5 RI
		Coefficient	Exponent	Coefficient	Exponent					Load/Area
Southeastern Plains	02430000	9.57	0.370	3.09	1.37	49.6	**650**	96	**173**	**3.8**
Southeastern Plains	02430500	15.9	0.238	3.22	1.238	232.0	**2731**	22	**798**	**3.4**
Southeastern Plains	02430680	6.86	0.523	3.83	1.523	291.0	**21662**	71	**339**	**63.9**
Southeastern Plains	02430690	17.0	0.288	4.11	1.288	177.8	**8877**	51	**388**	**8.4**
Southeastern Plains	02431000	4.64	0.529	2.65	1.529	378.0	**19000**	1385	**1585**	**12.0**
Southeastern Plains	02431410	6.37	0.684	6.31	1.684	169.0	**35628**	225	**173**	**205.5**
Southeastern Plains	02433500	1.01	0.582	0.693	1.582	584.0	**16489**	1943	**3175**	**5.2**
Southeastern Plains	02436500	4.11	0.630	3.36	1.63	650.0	**129237**	719	**1606**	**80.5**
Southeastern Plains	02437500	0.395	0.644	0.339	1.644	614.0	**13000**	3200	**5623**	**2.3**
Southeastern Plains	02439400	6.78	0.229	1.32	1.229	476.0	**2578**	294	**2067**	**1.2**
Southeastern Plains	02441498	0.001	1.28	0.011	2.28	#VALUE!	#VALUE!	519	**-**	-
Southeastern Plains	02443500	3.50	0.279	0.819	1.279	376.0	**1610**	340	**1852**	**0.9**
Southeastern Plains	02448000	19.1	0.222	3.64	1.222	266.0	**1300**	422	1989	**0.7**
Southeastern Plains	02472373	0.875	0.578	0.593	1.578	501.9	**153723**	292	**2696**	**4.0**
Southeastern Plains	02472880	0.076	0.936	0.186	1.936	375.0	**284249**	125	**1564**	**11.4**
Southeastern Plains	02473260	0.137	0.783	0.193	1.783	674.7	**676765**	619	**4685**	**4.6**
Southeastern Plains	02473460	23.8	0.154	3.57	1.154	126.0	**947**	51	**264**	**3.6**
Southeastern Plains	02473490	21.7	0.157	3.28	1.157	208.1	**4563**	51	**521**	**3.0**
Southeastern Plains	02474740	0.617	0.539	0.365	1.539	845.0	**11661**	1832	**7798**	**1.5**
Southeastern Plains	02477492	2.42	0.444	1.02	1.444	641.8	**178092**	508	**4268**	**2.7**
Southeastern Plains	02478500	0.861	0.534	0.500	1.534	533.0	**7617**	983	**6967**	**1.1**
Southeastern Plains	02479020	0.810	0.465	0.367	1.465	1357.9	**593477**	3304	**17300**	**0.8**
Southeastern Plains	02479155	1.23	0.685	1.22	1.685	74.0	**1722**	105	**136**	**12.6**
Southeastern Plains	02479560	0.064	0.831	0.107	1.831	228.0	**2222**	170	**1455**	**1.5**
Southeastern Plains	02481510	1.75	0.498	0.894	1.498	247.0	**3432**	343	**798**	**4.3**
Southeastern Plains	03592800	7.36	0.451	3.17	1.451	101.0	**2566**	165	**370**	**6.9**
Southeastern Plains	07274235	22.3	0.382	7.52	1.382	37.7	**520**	20	**21**	**52.9**
Southeastern Plains	07274237	20.7	0.323	5.66	1.323	62.1	**1121**	18	**54**	**24.5**
Southeastern Plains	07274245	4.07	0.748	5.06	1.748	95.1	**21974**	62	**121**	**120.4**
Southeastern Plains	07274247	2.59	0.868	4.94	1.868	121.9	**20000**	118	**192**	**104.2**
Southeastern Plains	07274251	3.90	1.17	21.5	2.17	20.0	**5000**	15	**6**	**833.3**
Southeastern Plains	07274252	1.14	0.927	2.68	1.927	154.0	**35000**	461	**251**	**139.4**
Southeastern Plains	07277000									
Southeastern Plains	07282000									
Southeastern Plains	07282100									
Southeastern Plains	332030088212200	8.00E-08	2.00	8.00E-06	3.00	700.4	2748	2526	14199	0.2
Southeastern Plains	332100088224500	82.4	0.172	13.2	1.172	700.4	28530	444	14199	2.0
Southeastern Plains	332112088223500	3.00E-07	1.90	2.00E-05	2.90	700.2	3567	2804	14195	0.3
Southeastern Plains	332751088261000	0.000006	1.643	0.0002	2.643	631.4	5039	1932	11958	0.4
Southeastern Plains	332929088273300	7.00E-06	1.58	0.0002	2.58	631.0	3351	2393	11945	0.3
Mississippi Alluvial Plain	07279937	172	0.101	21.3	1.101	73.0	**2398**	7	**73**	-
Mississippi Alluvial Plain	07287120	48.5	0.171	7.71	1.171	1460.1	**829403**	866	**19812**	**2.0**
Mississippi Alluvial Plain	07287160	1.06	1.09	4.44	2.09	72.0	**12000**	62	**248**	**48.4**
Mississippi Alluvial Plain	07287355	0.089	1.01	2.79	2.01	792.3	1872278	61	**277**	-
Mississippi Alluvial Plain	07287405	2.21	0.801	3.32	1.801	194.8	**44125**	56	**460**	**-**
Mississippi Alluvial Plain	07288650	53.7	0.243	11.0	1.243	163.0	**6182**	207	**1253**	**4.9**
Mississippi Alluvial Plain	07288800	7.96	0.310	2.08	1.31	1907.5	**1702457**	1471	**32640**	**1.3**
Mississippi Alluvial Plain	07288955	4.98	0.383	1.69	1.383	1679.0	**48768**	1659	**34587**	**1.4**
Mississippi Alluvial Plain	07289000	1.10	0.400	0.397	1.40	35680.0	**937962**	54680	**2953720**	**0.3**
Mississippi Alluvial Plain	07295100	4.3134	0.3074	1.1164	1.3074	nd	**#VALUE!**	40812	**-**	**-**
Mississippi Valley Loess Plains	07273100									
Mississippi Valley Loess Plains	07275530									
Mississippi Valley Loess Plains	07277520	3.13	0.999	9.51	1.999	69	**22000**	147	**66**	**333.3**
Mississippi Valley Loess Plains	07277530	0.742	1.16	4.03	2.16	93	**25000**	128	**116**	**215.5**
Mississippi Valley Loess Plains	07277548	3.20	1.05	11.7	2.05	82	**25000**	125	**91**	**274.7**
Mississippi Valley Loess Plains	07277700	2.91	0.756	3.72	1.756	235	**54217**	453	**313**	**173.0**
Mississippi Valley Loess Plains	07277715	2.53	1.10	11.0	2.10	61	**16000**	84	**53**	**301.9**
Mississippi Valley Loess Plains	07277730	10.0	0.583	6.93	1.583	282	**53007**	275	**212**	**249.6**
Mississippi Valley Loess Plains	07280270	21.9	0.624	17.6	1.624	124	**29000**	186	**96**	**302.1**
Mississippi Valley Loess Plains	07280340	17.3	0.616	13.5	1.616	143	**41054**	283	**140**	**294.1**
Mississippi Valley Loess Plains	07285400									
Mississippi Valley Loess Plains	07287141	18.1	1.19	111	2.19	31	**39418**	1	**15**	-
Mississippi Valley Loess Plains	07287142	17.0	0.708	18.3	1.708	43	**5327**	0	**28**	-
Mississippi Valley Loess Plains	07287144	2.83	1.21	18.0	2.21	69	**194217**	4	**67**	-
Mississippi Valley Loess Plains	07287147	0.399	1.46	6.35	2.46	87	**569037**	5	**103**	-
Mississippi Valley Loess Plains	07287150	1.04	1.11	4.68	2.11	107	**17000**	91	**247**	**68.8**
Mississippi Valley Loess Plains	07287330	3.63	1.00	11.2	2.00	87	**118821**	29	**103**	**830.5**
Mississippi Valley Loess Plains	07287375	5.27	0.868	10.1	1.868	73	**30550**	8	**73**	**-**
Mississippi Valley Loess Plains	07287400	0.194	1.53	3.87	2.53	162	**1505858**	25	**228**	**-**
Mississippi Valley Loess Plains	07287404	3.67	1.03	12.6	2.03	156	**60000**	117	**161**	**372.7**
Mississippi Valley Loess Plains	07290000	12.9	0.321	3.50	1.321	552	**16332**	1373	**7283**	**2.2**
Mississippi Valley Loess Plains	07292500	1.05	0.695	1.08	1.695	1209	**181191**	680	**2038**	**88.9**

(orange)	Insuficient high flow samples
(yellow)	Upper end of transport curve modified
(grey)	Drainage area not available, yield cannot be calculated
100	Load @ 1.5 RI, Yield @ 1.5 RI based on peak flow analysis
100	Load @ 1.5 RI, Yield @ 1.5 RI based on regression between Q1.5 and area

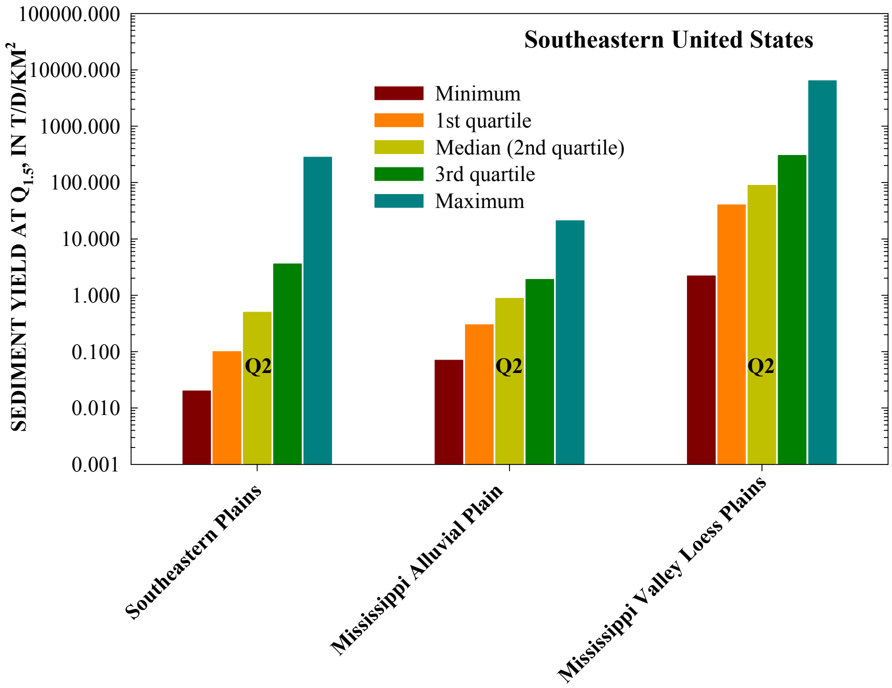

Figure 9 – Quartile measures of suspended-sediment yields at the effective discharge ($Q_{1.5}$) for 239 sites in the southeastern United States.

The MVLP ecoregion clearly produces the greatest amount of sediment in the region (Figure 9), and in fact has the highest sediment yield (at the effective discharge) than any ecoregion in the United States. This is in part due to: (1) the highly erodible nature of the silt-sized sediment that dominates the region, and (2) the extensive channel dredging and straightening that has taken place in the region over the past century in response to land clearing and subsequent channel filling.

To make the use of sediment yields at the effective (channel forming) discharge a useful parameter for establishing target values and developing TMDLs, "reference", "impacted", and "impaired" conditions must be defined in terms of relative channel stability. To accomplish this we use stages of channel evolution (Simon and Hupp, 1986; Simon, 1989a).

"Reference" or "Target" Sediment Yields

The working hypothesis for determining "reference" and "target" values for suspended sediment in this study is that stable channel conditions can be represented by channel evolution Stages I and VI. It follows, therefore, that effective-discharge sediment yields for Stages I and VI in a given ecoregion represent background or "natural" transport rates. To date, evaluation of stage of channel evolution in the MAP, MVLP and SEP ecoregions using the form in Table 2 has been completed at 134 sites with 72 of those in Mississippi. The number of sites evaluated in Mississippi represents all locations where historical flow and sediment-transport data exist. A summary of the results of the Mississippi field evaluations is shown in Table 5. An example of how index values vary with stage of channel evolution is given for the Southeastern Plains (Ecoregion 65) in Figure 10. It is hoped that after further analysis that relations between sediment-transport variables and the channel stability index will be possible, making estimates of sediment-transport rates at ungauged sites possible.

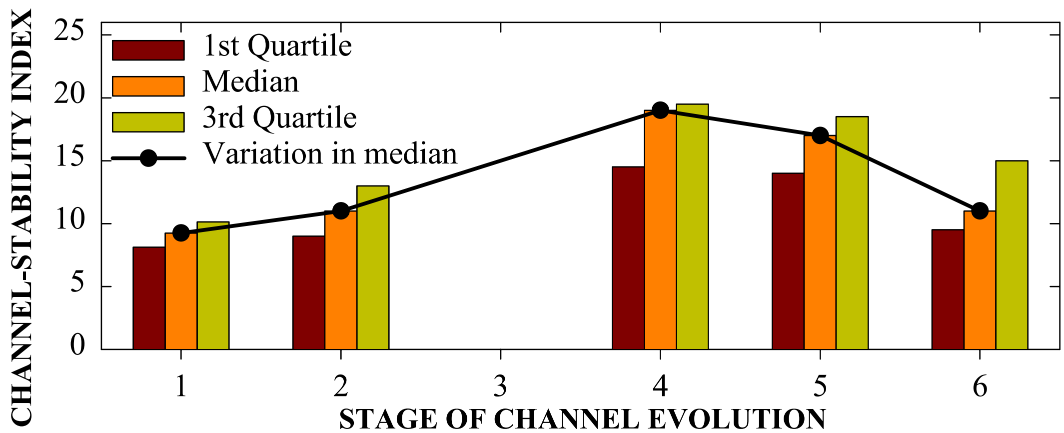

Figure 10 – Distribution of channel-stability index values for the Southeastern Plains.

Preliminary "Reference/Target" Values for Mississippi

Quartile measures for Stage VI conditions occurring at Mississippi sites are shown overlaying data from all Mississippi sites in those ecoregions in Figure 11a. As expected, Stage VI sediment-yield values are considerably lower for each quartile measure in each of the ecoregions. If we assume that the median value for suspended-sediment yield at the $Q_{1.5}$ is an appropriate measure, preliminary "reference/target" values for the MAP, MVLP and SEP are 1.4, 5.8, and 1.25 T/d/km^2, respectively. Table 6, considering only Mississippi data, provides a summary of the median suspended-sediment yield values for each ecoregion along with the "reference/target" value. Note that on average suspended-sediment yields from the MAP ("Delta" region) are closer to the values identified as preliminary "reference/target" values than the other ecoregions. The great disparity between "impacted" suspended-sediment yields for Mississippi sites in the MVLP and those of the "reference/target" is probably due to the severe instabilities in those channels during the period of sediment sampling (1970's and 1980's). In all likelihood suspended-sediment yields have reduced through the 1990's and into the 21st century as channels passed from the severely unstable Stage IV to Stage V, indicating that the reduction in yields will not be as severe as indicated in Table 6.

A "reference/target" value of about 4.1 T/d/km^2 is obtained for the MVLP if we were to consider data from surrounding states as well (Figure 11b). These results should be considered preliminary as more sites in each of the ecoregions are being evaluated for stage of channel evolution, and additional Stage VI sites are identified in other states. This is particularly important in this part of the southeastern United States because

Table 5 – Summary of geomorphic data collected at Mississippi sites.

STATION ID	Station Name	Latitude	Longitude	Stage	Slope (m/m)	Channel Stability Index
02430000	MACKEYS CREEK NR DENNIS, MS	34.5261	-88.3228	**6**	**-**	**16.5**
02430500	TOMBIGBEE RIVER NR MARIETTA, MS	34.4267	-88.4214	**1**	**0.00010**	**10**
02430680	TWENTYMILE CREEK NR GUNTOWN, MS	34.4525	-88.5772	**5**	**-**	**17.5**
02430690	TWENTYMILE CREEK NR MANTACHIE, MS	34.3861	-88.4611	**5**	**0.00005**	**17**
02431000	TOMBIGBEE RIVER NR FULTON, MS	34.2650	-88.4453	**5**	**0.00015**	**20.5**
02431410	MANTACHIE CREEK BL DORSEY, MS	34.2281	-88.4522	**5**	**0.00090**	**21.5**
02433500	TOMBIGBEE RIVER AT BIGBEE, MS	34.0111	-88.5139	**5**	**0.00024**	**15**
02436500	TOWN CREEK NR NETTLETON, MS	34.0589	-88.6278	**5**	**0.00020**	**22**
02437500	TOMBIGBEE RIVER AT ABERDEEN, MS	33.8206	-88.5186	**6**	**-**	**16.5**
02439400	BUTTAHATCHEE RIVER NR ABERDEEN, MS	33.7900	-88.3147	**?**	**-**	**?**
02441498	TOMBIGBEE R.IN COLUMBUS BENDWAY AT COLUMBUS,MS.	33.4350	-88.4939	**6**	**-**	**16.5**
02443500	LUXAPALLILA CREEK NR COLUMBUS, MS	33.5139	-88.3950	**5**	**-**	**11**
02448000	NOXUBEE RIVER AT MACON, MS	33.1022	-88.5611	**6**	**0.00037**	**12**
02472373	LEAF RIVER AT EASTABUCHIE, MS.	31.4389	-89.3000	**5**	**-**	**18**
02472880	BOUIE RIVER NR GLENDALE, MS	31.3956	-89.3656	**5**	**0.00030**	**27**
02473260	LEAF RIVER NR PALMER, MS.	31.2611	-89.2264	**5**	**-**	**20.5**
02473460	TALLAHALA CREEK AT WALDRUP, MS	31.9661	-89.1153	**5**	**BW**	**15**
02473490	TALLAHALA CREEK NR SANDERSVILLE, MS.	31.7853	-89.0758	**5**	**0.00010**	**17**
02474740	LEAF RIVER AT BEAUMONT, MS.	31.1822	-88.9189	**5**	**0.00061**	**16.5**
02477492	CHICKASAWHAY RIVER AT WOODWARDS, MS.	31.6953	-88.6700	**5**	**-**	**12**
02478500	CHICKASAWHAY RIVER AT LEAKESVILLE, MS	31.1483	-88.5644	**6**	**-**	**11.5**
02479020	PASCAGOULA RIVER NR BENNDALE, MS	30.8783	-88.7722	**6**	**-**	**12.5**
02479155	CYPRESS CR NR JANICE MS	31.0250	-89.0167	**6**	**0.00080**	**11.5**
02479560	ESCATAWPA RIVER NEAR AGRICOLA MS	30.8033	-88.4586	**5**	**0.00020**	**23**
02481510	WOLF RIVER NR LANDON, MS	30.4836	-89.2719	**6**	**0.00078**	**11**
03592800	YELLOW CREEK NR DOSKIE, MS	34.9006	-88.2931	**6**	**-**	**17.5**
07273100	HOTOPHIA NEAR BATESVILLE	34.3639	-89.8783	**5**	**0.00043**	**18.5**
07274235	OTOUCALOFA CREEK NR PARIS, MS	34.1489	-89.4389	**5**	**0.00124**	**22**
07274237	OTOUCALOFA CREEK AT PARIS, MS	34.1697	-89.4567	**5**	**0.00376**	**20**
07274245	OTOUCALOFA CREEK EAST OF WATER VALLEY, MS	34.1583	-89.5328	**5**	**0.00105**	**22.5**
07274247	OTOUCALOFA CREEK CANAL E-SE OF WATER VALLEY, MS	34.1303	-89.5933	**5**	**0.00058**	**19**
07274251	TOWN CREEK AT WATER VALLEY, MS	34.1472	-89.6339	**2**	**0.00084**	**23**
07274252	OTOUCALOFA CREEK CANAL NR WATER VALLEY, MS	34.1433	-89.6497	**5**	**0.00042**	**23**
07275530	LONG/PETERS CREEK NEAR POPE	34.2139	-89.9817	**5**	**0.00053**	**20.5**
07277000	PIGEON ROOST NEAR LEWISBURG	34 49.54	89 49.38	**5**	**0.00049**	**23**
07277520	HICKAHALA CREEK NR INDEPENDENCE, MS	34.6750	-89.7575	**5**	**0.00032**	**26**
07277530	HICKAHALA CREEK NR LOOXAHOMA, MS	34.6414	-89.8108	**5**	**0.00091**	**21.5**
07277548	JAMES WOLF CREEK NR LOOXAHOMA, MS	34.6167	-89.8214	**5**	**0.00046**	**26**
07277700	HICKAHALA CREEK NR SENATOBIA, MS	34.6317	-89.9250	**5**	**0.00007**	**25**
07277715	SENATOBIA CREEK NR COMO, MS	34.5503	-89.9567	**5**	**0.00140**	**17.5**
07277730	SENATOBIA CREEK NR SENATOBIA, MS	34.6172	-89.9417	**5**	**0.00043**	**17**
07279937	DAVID BAYOU NR SLEDGE, MS	34.4206	-90.2339	**5**	**-**	**23**
07280270	TILLATOBA CREEK BL OAKLAND, MS	33.9944	-89.9533	**5**	**0.00100**	**25**
07280340	SOUTH FORK TILLATOBA CREEK NR CHARLESTON, MS	33.9783	-89.9792	**5**	**0.00080**	**18**
07282000	YALOBUSHA NEAR CALHOUN CITY	33 50.31	89.937	**5**	**0.00080**	**14.5**
07282100	TOPASHAW NEAR CALHOUN CITY	33 48.89	0.00080	**5**	**-**	**19**
07285400	BATUPAN BOGUE AT GRENADA	33.7739	-89.7875	**5**	**0.00009**	**18**
07287120	YAZOO RIVER NR SHELL BLUFF, MS	33.3967	-90.2719	**5**	**0.00022**	**18.5**
07287141	ABIACA CREEK NR COILA, MS	33.3406	-89.9361	**6**	**0.00098**	**11.5**
07287142	ABIACA CREEK NR BLACK HAWK, MS	33.3181	-89.9667	**5**	**0.00095**	**26.5**
07287144	ABIACA CREEK AT BLACK HAWK, MS	33.3181	-90.0108	**5**	**0.00079**	**19**
07287147	COILA CREEK AT SEVEN PINES, MS	33.3689	-90.0889	**6**	**0.00043**	**8.5**
07287150	ABIACA CREEK NR SEVEN PINES, MS	33.3400	-90.1511	**5**	**0.00127**	**14**
07287160	ABIACA CREEK AT CRUGER, MS	33.3414	-90.2369	**5**	**0.00105**	**16.5**
07287330	FANNEGUSHA CREEK NR ITUMA, MS	33.2264	-90.0417	**5**	**0.00159**	**22.5**
07287355	FANNEGUSHA CREEK NR HOWARD, MS	33.1381	-90.1961	**5**	**0.00138**	**21**
07287375	BLACK CREEK AT BOWLING GREEN, MS	33.1603	-89.9567	**5**	**0.00128**	**21**
07287400	BLACK CREEK AT LEXINGTON, MS	33.1053	-90.0536	**5**	**0.00072**	**19**
07287404	HARLAND CREEK NR HOWARD, MS	33.1014	-90.1731	**5**	**0.00053**	**15**
07287405	BLACK CREEK AT HOWARD, MS	33.1197	-90.1911	**5**	**-**	**21.5**
07288650	BOGUE PHALIA NR LELAND, MS	33.3964	-90.8464	**6**	**0.00018**	**12.5**
07288800	YAZOO RIVER AT REDWOOD, MS	32.4872	-90.8172	**5**	**-**	**18**
07288955	YAZOO RIVER BL STEELE BAYOU NR LONG LAKE, MS	32.4431	-90.9142	**6**	**-**	**6.5**
07289000	MISSISSIPPI RIVER AT VICKSBURG, MS	32.3125	-90.9069	**6**	**-**	**7.5**
07290000	BIG BLACK RIVER NR BOVINA, MS	32.3475	-90.6967	**5**	**0.00011**	**22**
07292500	HOMOCHITTO RIVER AT ROSETTA, MS	31.3228	-91.1075	**5**	**0.00089**	**21**
07295100	MISSISSIPPI RIVER AT TARBERT LANDING, MS	29.8600	-89.9800	**6**	**-**	**-**
3320300882122	TOMBIGBEE R. HAIRSTON BEND IN CUT NR.COLUMBUS,MS	33.3417	-88.3561	**6**	**-**	**-**
332100088224500	TOMBIGBEE R. OLD CHANNEL AT HAIRSTON BEND BL COLUM	33.3500	-88.3792	**6**	**-**	**-**
332112088223500	TOMBIGBEE R. AB.CUT AT HAIRSTON BEND BL.COLUMBUS,M	33.3533	-88.3764	**6**	**-**	**-**
332751088261000	(N) TOMBIGBEE R. IN COLUMBUS CUT NR. COLUMBUS,MS	33.4642	-88.4361	**6**	**-**	**-**
332929088273300	TOMBIGBEE RIVER ABOVE CUT NEAR COLUMBUS, MS.	33.4914	-88.4592	**6**	**-**	**-**

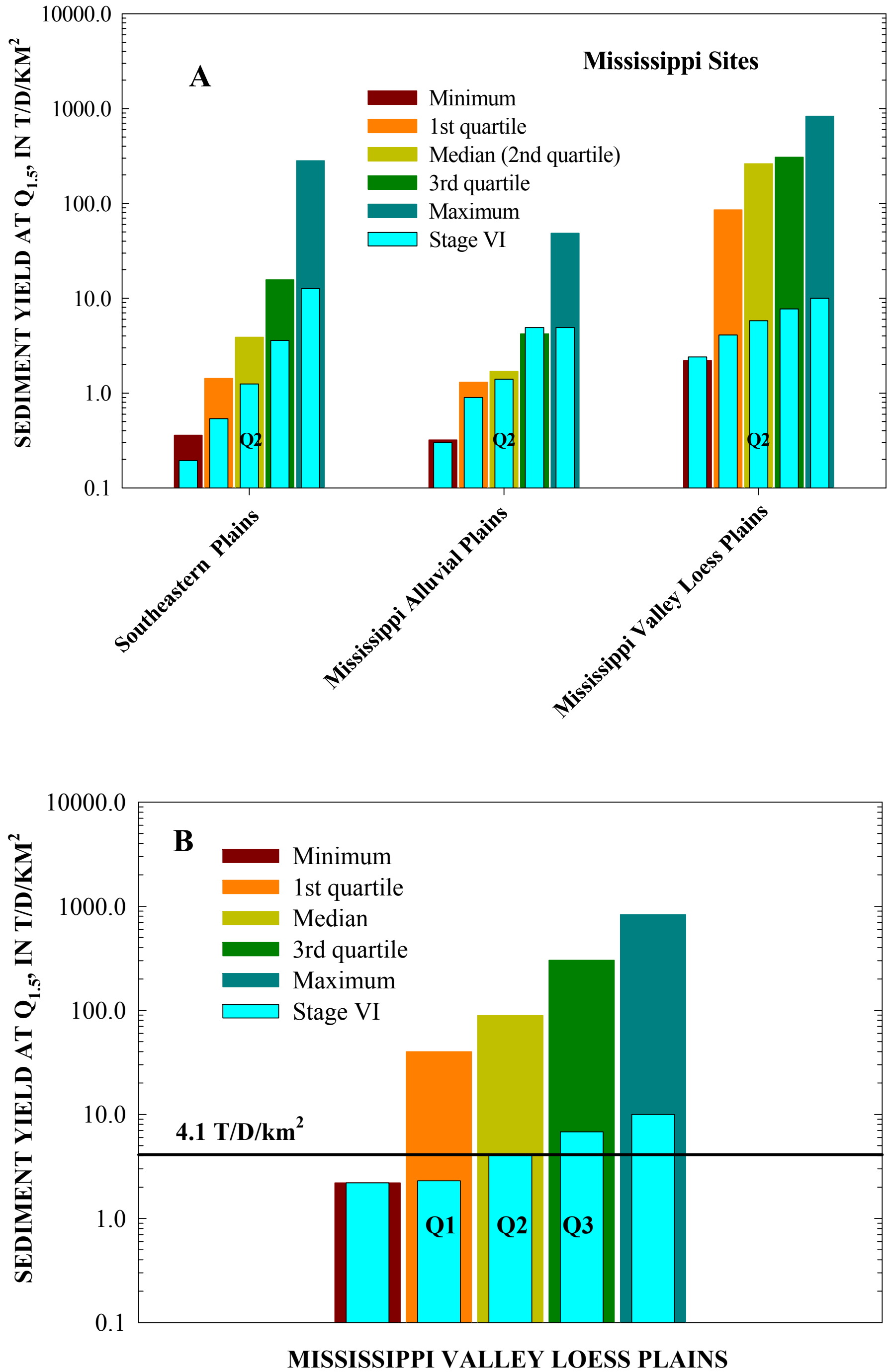

Figure 11 – Quartile measures for Stage VI "reference/target" conditions for (A) Mississippi data in the three ecoregions; and (B) Mississippi Valley Loess Plains for all states evaluated. The black line represents the preliminary target yield.

suspended-sediment yields in both the MAP and SEP ecoregions in Mississippi are considerably higher (about an order of magnitude) than in the rest of the states comprising these ecoregions. The greater sediment yields for these ecoregions in Mississippi, as compared to the other states, is probably due to the close proximity of the highly erodible and unstable stream systems of the MVLP. Figure 12 displays this difference for the SEP ecoregion.

Table 6 – Median values of suspended-sediment yield (in T/d/km^2) for all Mississippi sites and for stable (Stage VI) sites by ecoregion.

Ecoregion	Median (all sites)	Median (Stage VI)	Reduction
Mississippi Alluvial Plain	1.7	1.4	18%
Mississippi Valley Loess Plains	262/89*	5.8	93 - 98%
Southeast US Plains	3.9	1.3	67%

* 262 T/d/km^2 is median for Mississippi sites, 89 T/d/km^2 is for all sites in MVLP

Listed versus Non-Listed

Finally, it needs to be pointed out that for some states, quartile measures of suspended-sediment yields at the effective discharge are greater (on average) for non-listed streams than for listed streams. This can be attributed to several factors including:

1. States, Territories and Tribes use different criteria to list streams;
2. Sites may be listed for a clean-sediment issue other than lethal or sub-lethal levels of suspended-sediment concentration; and
3. Sites were listed in 1998 whereas the period of historical data may not encompass the conditions represented by the current listing.

Still, it seems likely that it will be shown that many sites listed as impaired due to sediment in fact have relatively low suspended-sediment yields for their ecoregion. The methods shown in this paper will provide a simple tool for identifying those streams and, therefore, aid in potentially de-listing streams that would otherwise require the development of a TMDL for clean sediment.

Functional Relations with Aquatic Organisms

Ultimately, target values for sediment will need to be linked to aquatic health and integrity. To do this, sediment data will need to be in a form that can be linked to biologic function. Lethal or sub-lethal levels of suspended-sediment are probably a function not only of the absolute concentration, but also the frequency and duration that a given concentration persists. Perhaps certain aquatic organisms can survive an exceptionally high concentration if it occurs over a very short duration, but become impaired at some lower concentration maintained over a longer time period. Using an assumed threshold concentration of 1,000 mg/l, we calculated for eight sites in the MVLP ecoregion in Mississippi, the duration that the associated flow discharge was equaled or exceeded without falling below this level. This provided the duration that the assumed concentration of 1,000 mg/l was equaled or exceeded for each of the eight sites. These data were compared to the total number of benthic organisms sampled at each of the sites. The results show a non-linear decrease in total benthic population with increasing duration (Figure 13), indicating that this may be a valid approach for the "aquatic life support" designated use. It is these types of relations that should prove useful in establishing functionally-related TMDL's for suspended sediment once true threshold conditions can be determined for various organisms in different environments.

Availability of Historical Data and Sediment Transport Relations

The USDA-ARS National Sedimentation Laboratory, Channel and Watershed Processes Research Unit has acquired all available sediment concentration, peak flow, bed material particle size, and bed load data from the U.S. Geological Survey national data base. These data have been used to establish suspended-sediment transport relations for more than 2,900 sites nationwide. All transport relations and site photographs for Mississippi sites are shown in the attached appendices. The raw data, transport relations, and peak-flow files can be obtained from Dr. Simon (asimon@ars.usda.gov) on CD media.

SUMMARY

"Reference" or "target" sediment-yield values at the Q 1.5 are indicated in Figures 11a and 11b are shown for instructional purposes, and at this point do not represent statistically significant values due to a lack of field evaluations of stable sites that also have adequate historical data on sediment transport. Yields from the Mississippi Valley Loess Plains are the highest in the United States. Those from the Mississippi Alluvial Plain (Delta Region) are relatively low and would require only a mild reduction to approach median "reference" conditions. Furthermore, more detailed analysis of channel conditions during the actual period of sediment sampling needs to be completed to evaluate channel-stability conditions during the sediment-sampling period. Additional field evaluations throughout the region are ongoing (January 2002) and will provide the necessary data to establish "reference" conditions for each of the three ecoregions studied. Further analysis of this and similar data sets from other states and ecoregions is also ongoing and will prove useful in determining "reference", impacted, and impaired conditions across the United States. These data are to be combined with ongoing efforts to determine lethal and sub-lethal levels of suspended-sediment concentrations, and characterization of the magnitude, frequency, and duration of suspended-sediment concentrations nationwide to establish scientifically defensible TMDL's for suspended sediment. The approach described here for suspended-sediment in the southeastern United States will also be applied in Mississippi, the southeastern United States and nationwide to bed-material transport by comparing "reference" magnitude, frequency, and durations of bed-material movement with those parameter values at all other sites.

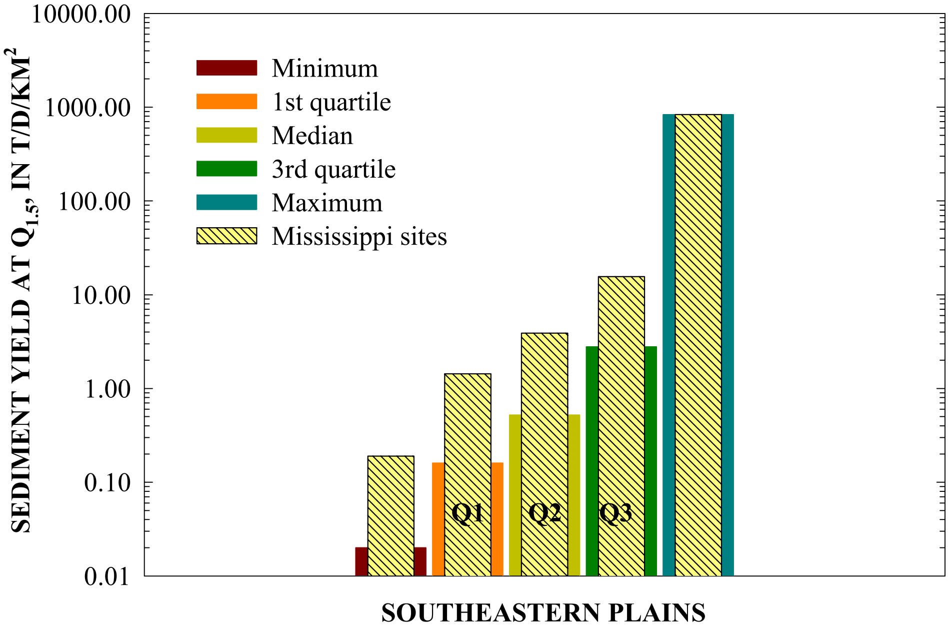

Figure 12 – Suspended-sediment yields at the effective discharge (Q1.5) are significantly higher than those in the other parts of the Southeastern Plains Ecoregion.

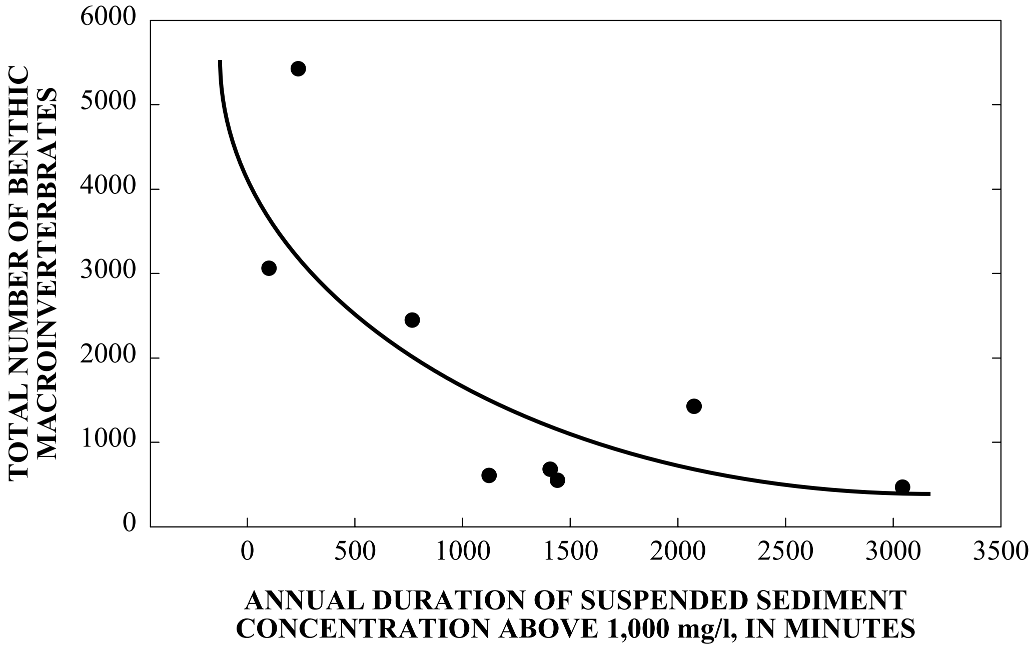

Figure 13 – Relation between annual duration of suspended-sediment concentration greater than 1,000 mg/l and number of benthic organisms (Kuhnle *et al*., 2001).

REFERENCES

Andrews, E.D., 1980, Effective and bankfull discharge of streams in the Yampa River Basin, Colorado and Wyoming. Journal of Hydrology, 46, 311-330.

Andrews, E.D., and Nankervis, J.M., 1995, Effective discharge and the design of channel maintenance flow for gravel-bed rivers. In, Costa, J.E., Miller, A.J., Potter, and Wilcock, P. R., (Eds.), Natural and Anthropogenic Influences in Fluvial Geomorphology, Geophysical Monograph 89, p. 151-164. American Geophysical Union.

Hupp, C.R., 1992, Riparian vegetation recovery patterns following stream channelization: A geomorphic perspective. Ecology 73(4):1209-1226.

Kuhnle R., and Simon, A., 2000, Evaluation of Sediment Transport Data for Clean Sediment TMDL's. National Sedimentation Laboratory Report 17, Ox ford, Mississippi, 65 p.

Nash, D.B., 1994, Effective sediment discharge from magnitude-frequency analysis. Journal of Geology, 102, 79-95.

Omernik, J.M., 1995, Ecoregions: A framework for environmental management, In, Davic, W., and Simon, T., (Eds.), Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making, Lewis Publishers, Chelsea, Michigan.

Porterfield, G., 1972, Computation of fluvial sediment discharge. U.S. Geological Survey, Techniques in Water Resources Investigations, Book 3, Chapter C3, 66 p.

Rinaldi, M., and Simon, A., 1998, Adjustments of the Arno River, Central Italy, Geomorphology, 22, 57-71.

Rosgen, D.L., 1985, A classification of natural rivers. Catena, 22, 169-199.

Simon, A., 1994, Gradation processes and channel evolution in modified West Tennessee streams: Process, response and form. U.S. Geological Surbey Professional Paper 1470, 84 p.

Simon, A., 1989a, A model of channel response in disturbed alluvial channels. Earth Surface Processes and Landforms, 14(1): 11-26.

Simon, A., 1989b, The discharge of sediment in channelized alluvial streams, Water Resources Bulletin, v. 25, no. 6, 1177-1188.

Simon, A., and Downs, P.W., 1995, An interdisciplinary approach to evaluation of potential instability in alluvial channels, Geomorphology, v. 12, 215-232.

Simon, A., and Hupp, C. R., 1986, Channel evolution in modified Tennessee channels, Proceedings of the Fourth Interagency Sedimentation Conference, March 1986, Las Vegas, Nevada, v. 2, Section 5, 5-71 to 5-82
.

Simon, A., and Hupp, C. R., 1992, Geomorphic and vegetative recovery processes along modified stream channels of West Tennessee. U. S. Geological Survey Open-file Report 91-502, 142 p.

Simon A., and Rinaldi, M., 2000, Channel instability in the loess area of the Midwestern United States Journal of American Water Resources Association, 36(1): 133-150.

Turcios, L.M., and Gray, J.R., 2000, U.S. Geological Survey sediment and ancillary data on the world wide web.7th Federal Interagency Sedimentation Conference, vol. 1, Poster 31, Reno Nevada.

U.S. Geological Survey, 1993, Nationwide summary of U.S. Geological Survey regional regression equations for estimating magnitude and frequency of floods for ungaged sites. Compiled by M.E. Jennings, W.O. Thomas, Jr., and H.C. Riggs, U.S. Geological Survey Water-Resources Investigations Report 94-4002.

APPENDIX I - Ecoregion 65

APPENDIX II - Ecoregion 73

APPENDIX III - Ecoregion 74