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Relative magnitudes and sources of sediment in benchmark watersheds of the Conservation Effects Assessment Project

A. Simon and L. Klimetz

Abstract: Sediment is one of the principal pollutants of surface waters of the United States. Efforts by the USDA to quantify and control sediment erosion have historically focused on fields and upland areas. There is a growing body of evidence in agricultural areas, however, that the locus of sediment erosion has shifted from fields and uplands to channels. This is a critical issue in the Conservation Effects Assessment Project that evaluates the effectiveness of controls on sediment erosion. Rapid geomorphic assessments indicate that channel contributions are significant sources of sediment in the studied watersheds. The relative importance of channel processes are obtained by comparing "reference" yields for the ecoregion with the respective watershed yields. Annual suspended sediment yields for the Conservation Effects Assessment Project watersheds exceed the median value for stable streams by 243% in Iowa, 290% in New York, 630% in Mississippi, and between 2,120% and 7,410% in Oklahoma. Erosion from streambanks is an important process that must be addressed in management strategies aimed at controlling sediment production and delivery.

Key words: Conservation Effects Assessment Project (CEAP)—reference conditions—sediment yields—streambank erosion

Sediment is one of the principal pollutants of surface waters of the United States and has been positively correlated with negative impacts on aquatic ecosystems (Newcombe and MacDonald 1991; Newcombe and Jensen 1996). Efforts by the USDA to quantify and control sediment erosion have historically focused on fields and upland areas. There is a growing body of evidence in agricultural areas of the midcontinent, however, that the locus of sediment erosion has shifted from fields and uplands to edge of field gullies and channels (Trimble 1983; Simon and Rinaldi 2000). This is due in part to successful conservation efforts (Trimble and Lund 1983) and the natural attenuation of erosion processes with time. Evaluating the success of conservation efforts is a critical issue in the Conservation Effects Assessment Project (CEAP) as the agency evaluates the effectiveness of controls on sediment erosion.

Following major land-clearing activities in the midcontinent and elsewhere, sediment eroded from fields and uplands was deposited in valley bottoms, filled channels, and accumulated on floodplains, causing severe drainage problems. To convey floodwaters and alleviate flooding problems, channels throughout the midcontinent were dredged and straightened, resulting in destabilization of entire river systems and dramatic increases in erosion rates. This rejuvenation of channel systems results in a systematic series of processes and channel forms that can be identified as *stages of channel evolution* (Schumm et al. 1984; Simon and Hupp 1986; Simon 1989; figure 1). Stages I and VI represent stable or "reference" conditions where the delivery of sediment from upstream is balanced by the stream's ability to transport the sediment through the reach without incising, filling, widening, or narrowing. Stage I represents pre-modified conditions such as existed prior to European settlement and the clearing of forests and grasslands for agriculture that started in the mid-19th century. It is unrealistic to assume that channels will adjust to this state given the change in rainfall-runoff relations commensurate with the change in vegetative cover and land use. For this reason and given the lack of stage I channels in many regions, stage VI is used as the stable, "reference" condition.

A reconnaissance study of about 2,500 km (1,533 mi) of streams in western Iowa showed that 80% of the observed stream reaches were experiencing streambank failures (Hadish 1994). Similar studies in southeastern Nebraska and western Tennessee showed that about 75% and 60% of stream reaches had unstable streambanks, respectively (Simon and Rinaldi 2000; Bryan et al. 1995). Today, these channel erosion processes, which include streambank failures, are still active and contribute a large proportion of sediment to the suspended load in streams (table 1; Simon and Rinaldi 2006).

Erosion of sediment from uplands, fields, and channels contribute to the suspended sediment load of streams. Unstable channel systems and/or watersheds with severe sheet, rill, and gully erosion have higher sediment loads per unit of watershed area (suspended sediment yield) than watersheds without these erosion problems. Thus, systems characterized by these conditions will have higher suspended sediment yields than stable systems within the same general physiographic and climatic setting. Recent research has shown that suspended sediment yields vary by ecoregion (Omernik 1995) and can be distinguished by ecoregion for stable ("reference" conditions) and unstable streams differentiated by stage of channel evolution (figure 1; Simon et al. 2002a, 2002b, 2004a). This methodology provides a framework and an

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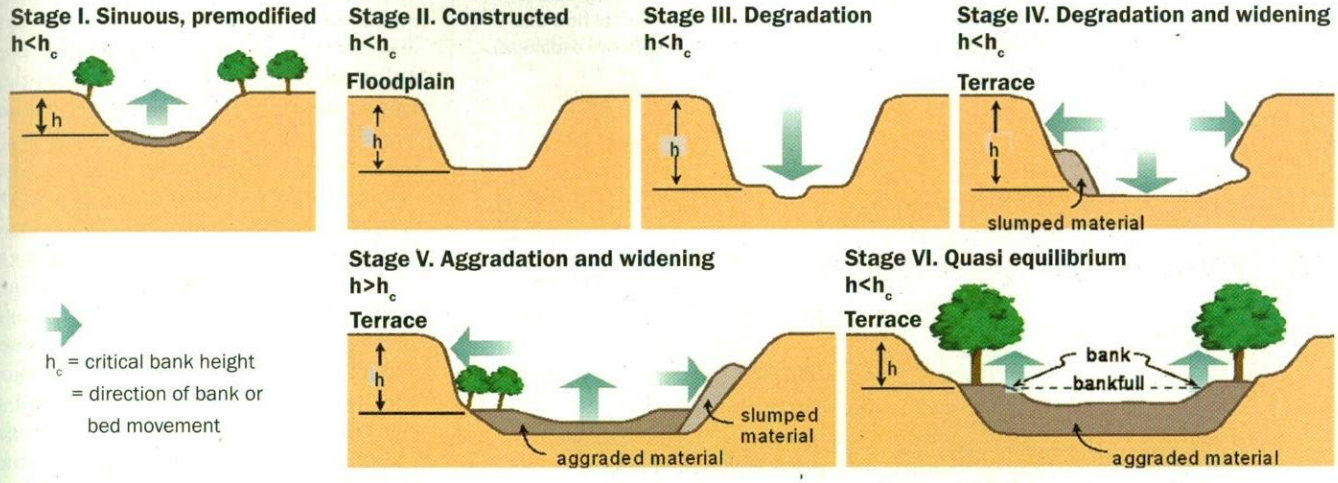
Figure 1
Six stages of channel evolution (from Simon and Hupp 1986; Simon 1989).



Note: Stages I and VI represent stable "reference" conditions because bank heights are less than the critical height for instability and rates of aggradation on the bed are low.

Table 1
Contributions of streambank erosion to total sediment load in incised channels in the southeastern United States.

Stream	Ecoregion	Bed material	Contribution from banks
James Creek, MS (Simon et al. 2002a)	Southeastern Plains	Sand/clay	78%
Shades Creek, AL (Simon et al. 2004b)	Ridge and Valley	Gravel	71% to 82%
Goodwin Creek, MS (E. Langendoen, personal communication, 2006)	Mississippi Valley Loess Plains	Sand/gravel	64%
Yalobusha River, MS (Simon and Thomas 2002)	Southeastern Plains	Clay/sand	90%*
Obion Forked Deer River, TN (Simon and Hupp 1992)	Mississippi Valley Loess Plains	Sand	81%*

* Contribution from banks relative to all channel sources.

important first step for differentiating between those systems within a given ecoregion that have accelerated rates of erosion and sediment delivery, representing water-quality impacts due to sediment. The research further provides a unifying set of measurements and analyses by which to compare sediment transport rates across watersheds being studied as part of CEAP.

The purpose of this investigation, therefore, was to determine the relative magnitudes and sources of sediment transported in CEAP benchmark watersheds relative to stable streams in the same ecoregion. Once impacts due to sediment are identified, understanding the roles of different processes in the delivery of sediment to suspended sediment loads will provide valuable information for evaluating the effectiveness of best management practices (BMPs). The ability to quantitatively differentiate fine-sediment contributed from different source areas is an important second step in evaluating conservation techniques in a given watershed. Each source of sediment must have a unique chemical signature relative to the others to properly differentiate it from other sources and to quantify its contribution to the suspended load. This research, using ^{7}Be and ^{210}Pb as tracers by establishing unique relationships between the two radionuclides for streambank and terrestrial sediment, is being conducted at the National Sedimentation Laboratory, USDA Agricultural Research Service, as a parallel effort to the one described in this paper (Wilson and Kuhnle 2006).

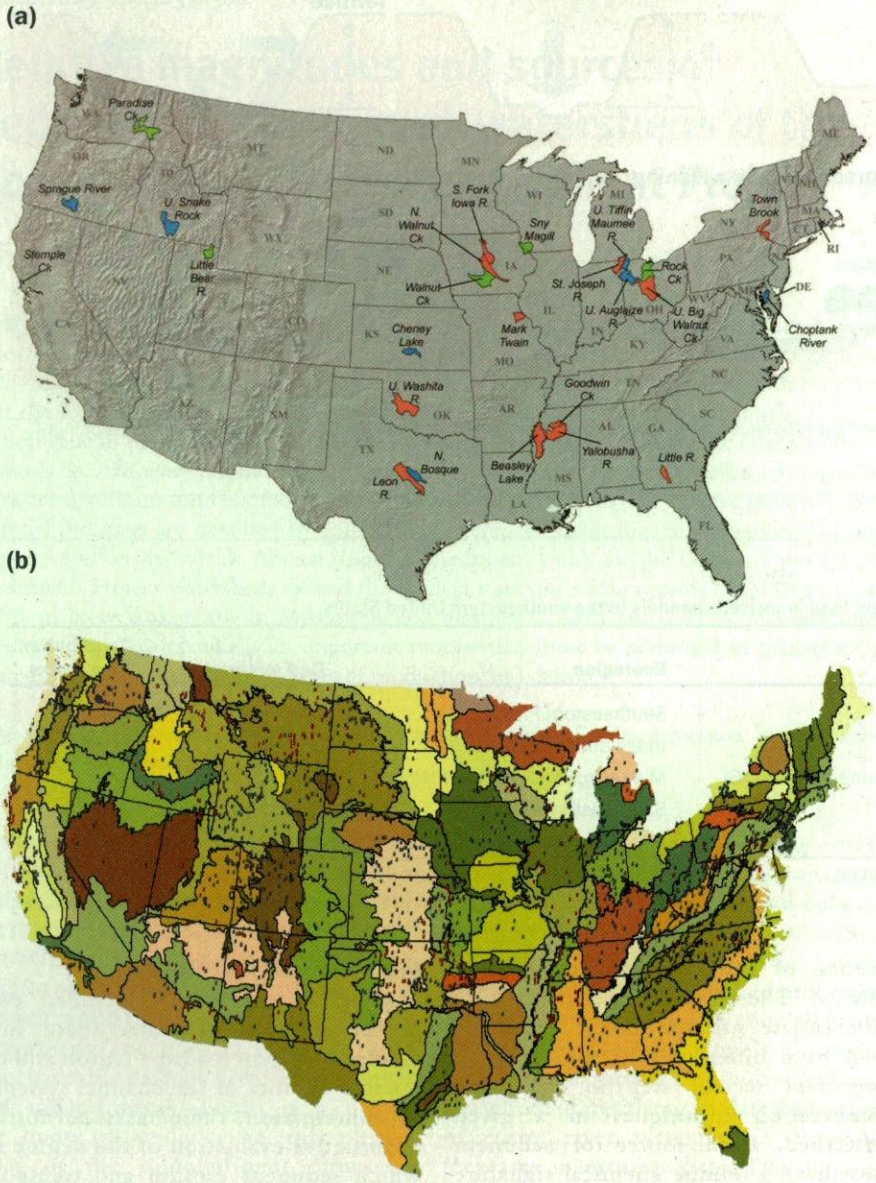
Methods and Materials

The research approach included two phases of work to differentiate suspended sediment loads by region and by relative stability of the channel systems. In combination, these tasks permitted quantitative evaluation of the degree to which sediment erosion and transport represents a water-quality issue in the basin, as well as providing a qualitative evaluation of the role of channel erosion in sediment transport rates.

The first phase involved conducting rapid geomorphic assessments (RGAs) of trunk stream and major tributary channels in the CEAP benchmark watersheds as well as at locations in the ecoregion with historical flow and sediment transport data (US Geological Survey [USGS] stream gauges) to determine relative channel stability and stage

Figure 2

(a) Map with Conservation Effects Assessment Project benchmark watersheds shown in red and other Conservation Effects Assessment Project watersheds shown in blue and green. (b) Level III ecoregions of the continental United States showing locations of historical flow and suspended sediment data (red dots denote sites listed by states as impaired due to sediment).



of channel evolution (figure 2). The second phase focused on analyzing sediment transport and flow data from the CEAP watershed and the associated level III ecoregion (figure 2) to compare rates of sediment transport between the watershed, and stable and unstable streams in the ecoregion.

Rapid Geomorphic Assessments. Relative channel stability and stage of evolution (figure 1) were determined by aerial and ground reconnaissance of main stem and tributary channels using diagnostic criteria of channel form to determine dominant channel processes. Rapid geomorphic assessments were conducted throughout the channel network and included a survey of channel gradient, bed-material sampling, photographs, and an evaluation of attributes of channel erosion and deposition. A reach of 6 to 20 channel widths was evaluated in the vicinity of the site with sites selected so that they represented conditions throughout the channel network. A semiquantitative index of channel stability was calculated by summing values of objectively ranked criteria such as type of bed material, degree of incision, existence and type of bank erosion, extent of reach experiencing streambank failures, prevalence of edge of field gullies, extent of bank and bar deposition, woody-vegetative cover, and stage of channel evolution. Channel-stability index, stage of channel evolution, and stability conditions were mapped to provide a means of determining the relative magnitude and areal extent of channel instabilities and erosion sources.

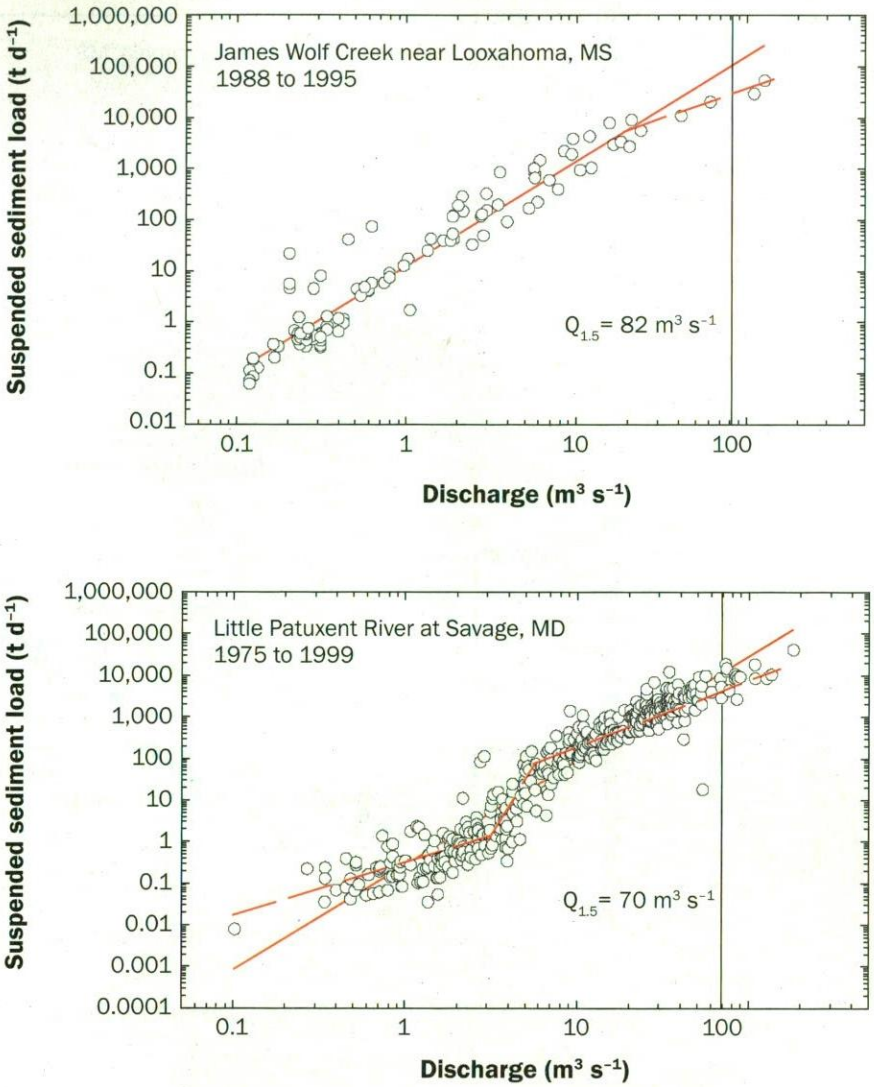
Actual and Reference Sediment Transport Rates. Suspended sediment concentration and associated water discharge data were obtained for more than 2,900 sites from the USGS (figure 2b). To be included in the data set, each site had a minimum of 30 matching samples of concentration and instantaneous discharge. To compare transport rates for sites of different size drainage areas and across ecoregions, a single flow rate known as the "effective discharge" was initially selected. The effective discharge is defined as the flow, or range of flows that transports the greatest proportion of the annual suspended sediment load over the long term (Wolman and Miller 1960; Andrews 1980) and represents the product of the flow frequency and sediment transport relations. The effective discharge has often been ascribed to also represent the bankfull discharge, but this is often not the case. It was decided, therefore, to use a flow of a constant recurrence interval for comparison of transport rates from one region to another. Based on the annual maximum flow series, the recurrence interval of the bankfull discharge often approximates the 1.5-year flow event (Dury et al. 1963; Leopold et al. 1964; Hickin 1968; Dunne and Leopold 1978; Williams 1978; Harman et al. 1999; Odem et al. 1999; Castro and Jackson 2001), although substantial variations around this average value have been noted (Williams 1978). The flow frequency of the effective discharge for diverse ecoregions of the

United States was found by Simon et al. (2004a) to approximate the 1.5-year recurrence interval flow ($Q_{1.5}$). The $Q_{1.5}$ was calculated for the historically gaged sites and sites in the CEAP benchmark watersheds using a log-Pearson III distribution with data obtained from the USGS. Mean daily flow data for the period of record for each gage were also downloaded from the USGS for the purpose of calculating annual suspended sediment loads.

Sediment transport relations were developed for each site, an example of which is shown in figure 3. Once the flow frequency distribution was fit, the 1.5-year flow was obtained from the distribution (i.e., figure 4a). The discharge of the $Q_{1.5}$ was then applied to the sediment transport relation to obtain the loading (t d^{-1}) at the $Q_{1.5}$ (figure 4b). The mean daily discharge for each day of record was also applied to the sediment transport relation to obtain daily loadings. The daily values were summed for each year, providing an annual suspended sediment load and then averaged over the period of record to obtain an average, annual suspended sediment load for each site. To be able to compare watersheds of different size, loadings data were divided by basin area to obtain suspended sediment yields at the $Q_{1.5}$ (t d^{-1} km^{-2}) and on an annual basis (t y^{-1} km^{-2}). These data then provided the foundation for comparing sites characterized by different degrees of instability.

USGS discharge measurement data combined with RGAs at sites in the associated ecoregions were used to distinguish between stable and unstable conditions during the period of sediment sampling. If the period of suspended sediment sampling ceased prior to 1996, an analysis of gauging stations records was conducted to determine whether the channel maintained a stable geometry during the sampling period. Ranges of suspended sediment yields for stable ("reference") and unstable sites were then determined by sorting the data by stage of channel evolution. Flow and sediment transport data available from CEAP watershed gages were used to calculate "actual" sediment transport rates and compared with reference values to determine whether the CEAP watershed streams had been impacted by sediment. Median values were used for this purpose because they best describe the central tendency of these non-normal distributions. The distribution of median suspended sediment yields for ecoregions across the United States is shown in figure 5.

Figure 3
Example of suspended sediment transport relation derived from historical data (note the use of two- and three-stage relations to minimize error at high flows).



Scope of Work. Work on relative magnitudes of sediment transport in the CEAP benchmark watersheds and their associated ecoregions began in 2005. This paper reports on work completed at the time of writing and encompasses field work conducted in the CEAP watersheds in Oklahoma, New York, Georgia, Mississippi, and Iowa.

Results of the research provide a quantitative evaluation of the role of channel processes in the CEAP benchmark watersheds. Table 1 provides a list of the CEAP benchmark watersheds and information regarding data from their respective ecoregions. For those watersheds shown in table 2, suspended sediment yields for stable sites in the associated ecoregion have been used to determine the relative magnitude of erosion-related sediment problems in the CEAP watersheds.

Figure 4

(a) Example of determining of the $Q_{1.5}$ from peak flow data and (b) application to the transport relation for that site.

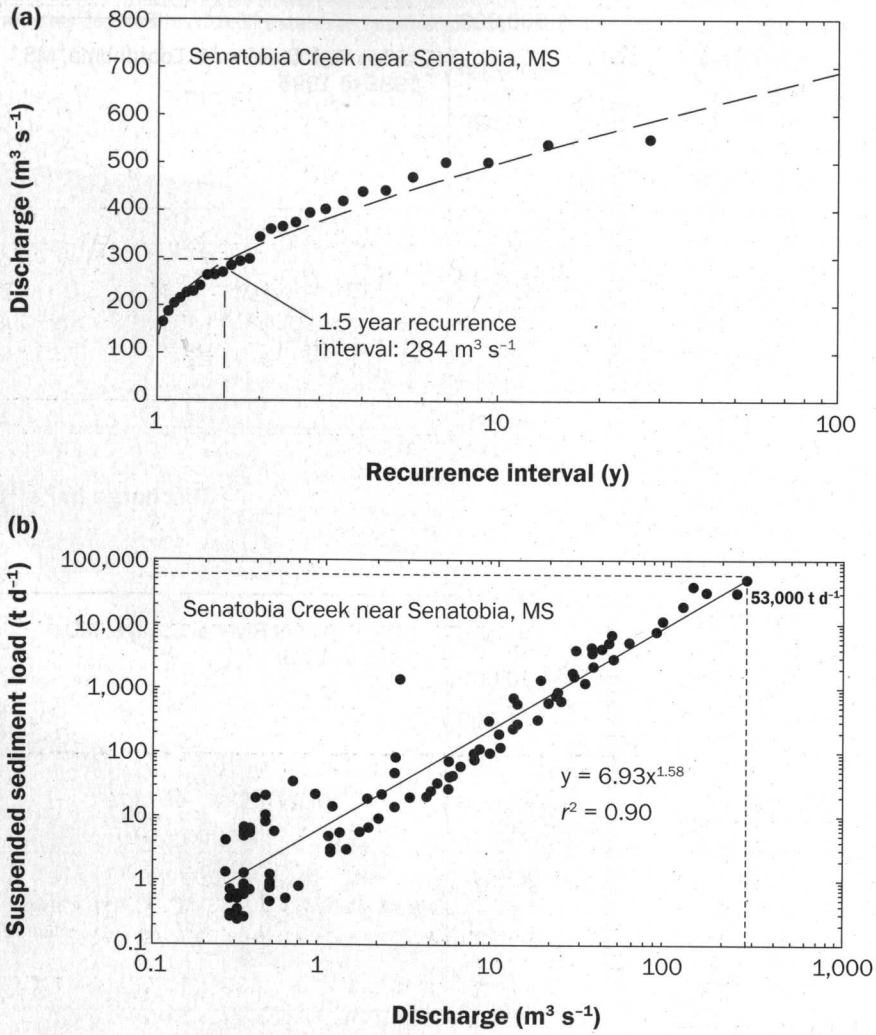


Figure 5
Median suspended sediment yields at the $Q_{1.5}$ for level III ecoregions of the continental United States (from Simon et al. 2004b).

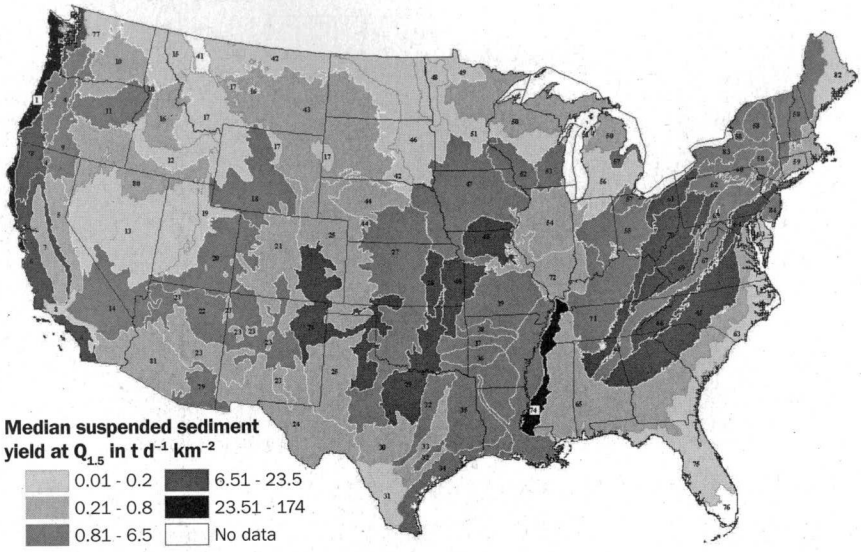


Table 2
Conservation Effects Assessment Project benchmark watersheds and median suspended sediment yields for associated level III ecoregions.

Watershed	Ecoregion	Number of sites	Number of stable sites	Median suspended sediment yield t d^{-1} km^{-2}	Median suspended sediment yield t y^{-1} km^{-2}
Upper Washita River, OK	27	124	38	5.57	64.5
Fort Cobb, OK	27	124	38	5.57	64.5
Town Brook, NY	58	35	21	0.55	7.72
Little River, GA	65	142	51	0.42	12.1
Goodwin Creek, MS	74	27	4	84.6	401
South Fork Iowa River, IA	47	42	20	1.57	50.6

Note: Yield values from Simon et al. (2004a).

Results and Discussion

Little Washita River and Fort Cobb Watersheds, Oklahoma. The Little Washita River and Fort Cobb watersheds of central Oklahoma are located in ecoregion 27, the Central Great Plains (figure 6). A wealth of historical flow and suspended sediment data exist for this ecoregion. Aerial reconnaissance of the two CEAP benchmark watersheds provided an excellent overview of the generally unstable channel conditions in these watersheds characterized by past incision and pervasive streambank instability (figure 7). Most of the channel reaches can be characterized as stage V, with active aggradation and bank failures (figures 7 and 8).

Flow and suspended sediment transport data for ecoregion 27 were analyzed to calculate transport rates at the $Q_{1.5}$ and as average, annual values. Separating these data into stable and unstable sites provided a mechanism to determine the relative magnitude of sediment transport rates in the two CEAP watersheds (figure 9) by comparing the median values of transport rates for stable streams with those calculated for sites within the CEAP watersheds. Suspended sediment yields from sites in both watersheds represent some of the highest in the ecoregion, 1 to 3 orders of magnitude greater than "reference" values (figure 9). For example, at the $Q_{1.5}$, suspended sediment yields for Cobb Creek (pre-dam) and for the Little Washita River near Ninnekah, Oklahoma, are 638 and 184 t d^{-1} km^{-2} (1,653 and 525 tn day^{-1} mi^{-2}), respectively, compared to a median value for stable streams of 1.1 t d^{-1} km^{-2} (3.1 tn day^{-1} mi^{-2}; figure 9). Clearly then, the CEAP watersheds are significantly impacted by sediment with the channels making an important but unknown contribution to suspended sediment loadings. Thus, efforts to reduce loadings and to evaluate the effects of conservation practices should not neglect the potentially significant contribution from channels within these systems.

Figure 6

Location map of Little Washita River and Fort Cobb watersheds showing distribution of sites (circles) with historical flow and sediment transport data in ecoregion 27.

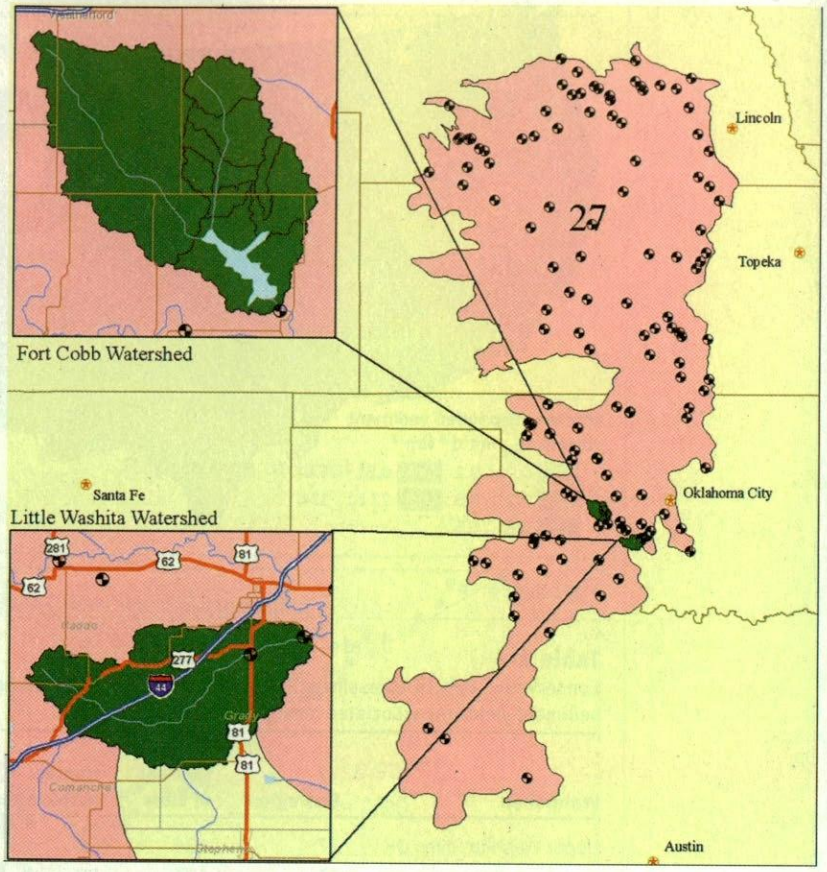


Figure 7

Distribution of stages of channel evolution in the two Conservation Effects Assessment Project watersheds in Oklahoma.

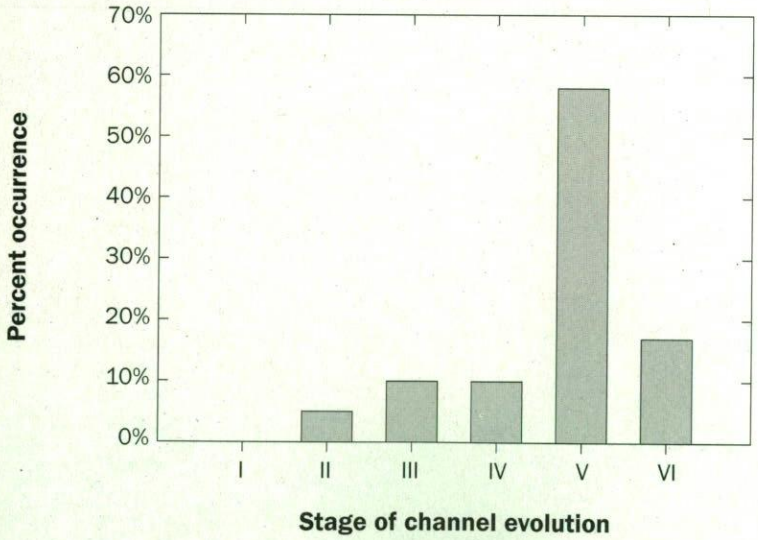
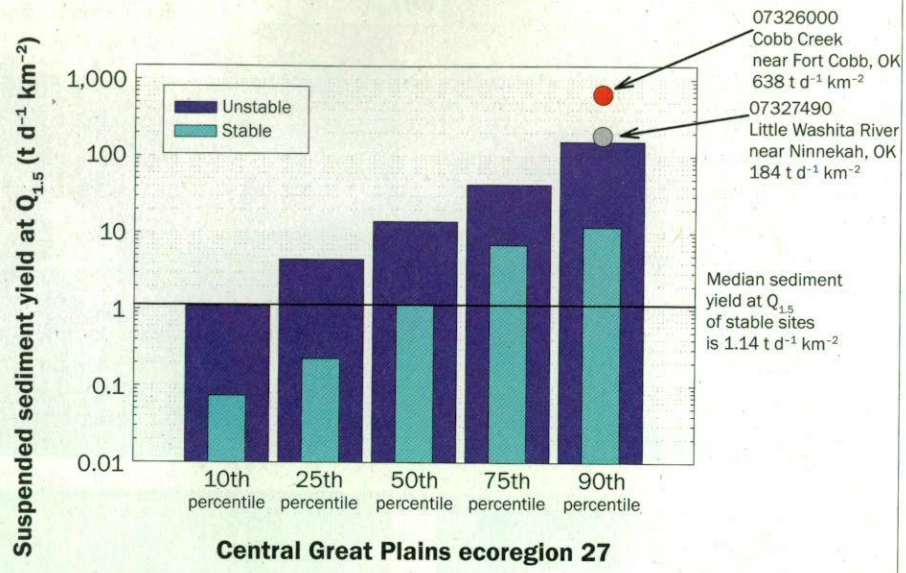
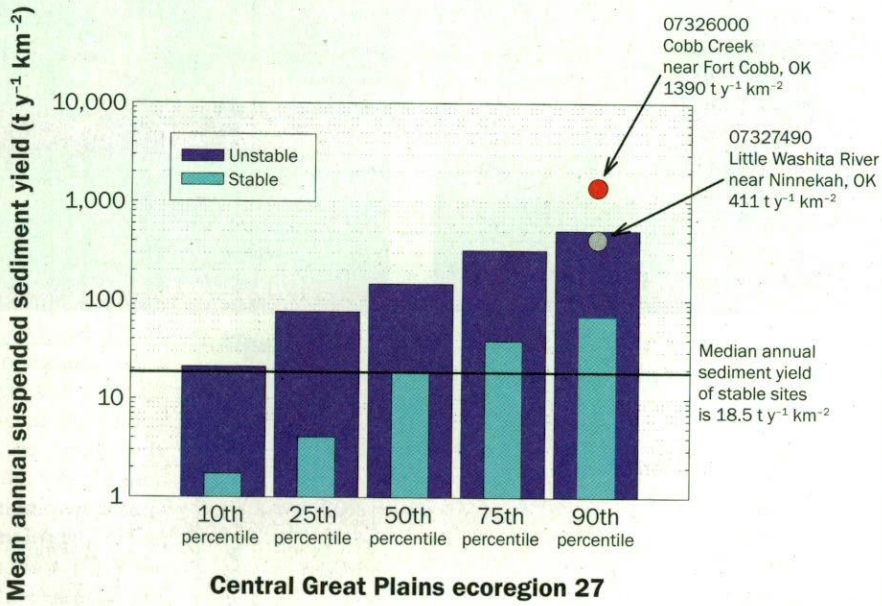


Figure 8
Typical views of (a) and (b) stage IV channels in the Fort Cobb watershed and (c) and (d) stage V channels in the Little Washita River watershed.

Figure 9

Distribution of suspended sediment yields for stable and unstable streams in ecoregion 27 (Central Great Plains) at the $Q_{1.5}$ and for average, annual values.





Note: Yields from sites within the Conservation Effects Assessment Project watersheds are shown as circles.

Town Brook and West Branch Delaware River Watersheds, New York. Town Brook is a tributary to the West Branch Delaware River in New York and is contained within ecoregion 58, the Northeastern Highlands (figure 10). Results of RGA work conducted along Town Brook showed numerous locations of streambank instability but only moderate incision (figure 11). Some of the middle reaches showed evidence of renewed stability (stage VI). Aerial reconnaissance of the West Branch Delaware River identified much of the channel above Cannonsville Reservoir to be in stage V, with active deposition on point bars, bank erosion on the outside of meander bends, and some channel migration.

Analysis of available sediment transport data from these watersheds and ecoregion 58 showed that suspended sediment yields from Town Brook are among the highest in the ecoregion, being 1 to 2 orders of magnitude greater than the median value for stable sites (figure 12). At the $Q_{1.5}$, suspended sediment yield from Town Brook is 18.4 t d^{-1} km^{-2} (52.5 tn day^{-1} mi^{-2}) compared to a "reference" value of 0.45 t d^{-1} km^{-2} (1.3 tn day^{-1} mi^{-2}). Differences in annual values are in the same general range, with Town Brook and stable streams having values of 26.3 t y^{-1} km^{-2} (75.1 tn yr^{-1} mi^{-2}) and 6.7 t y^{-1} km^{-2} (19.1 tn yr^{-1} mi^{-2}), respectively. Although not quite as high, analysis of data received for the West Branch Delaware from

Figure 10
Location map of Town Brook and West Branch Delaware River watersheds showing distribution of sites (circles) with historical flow and sediment transport data in ecoregion 58.

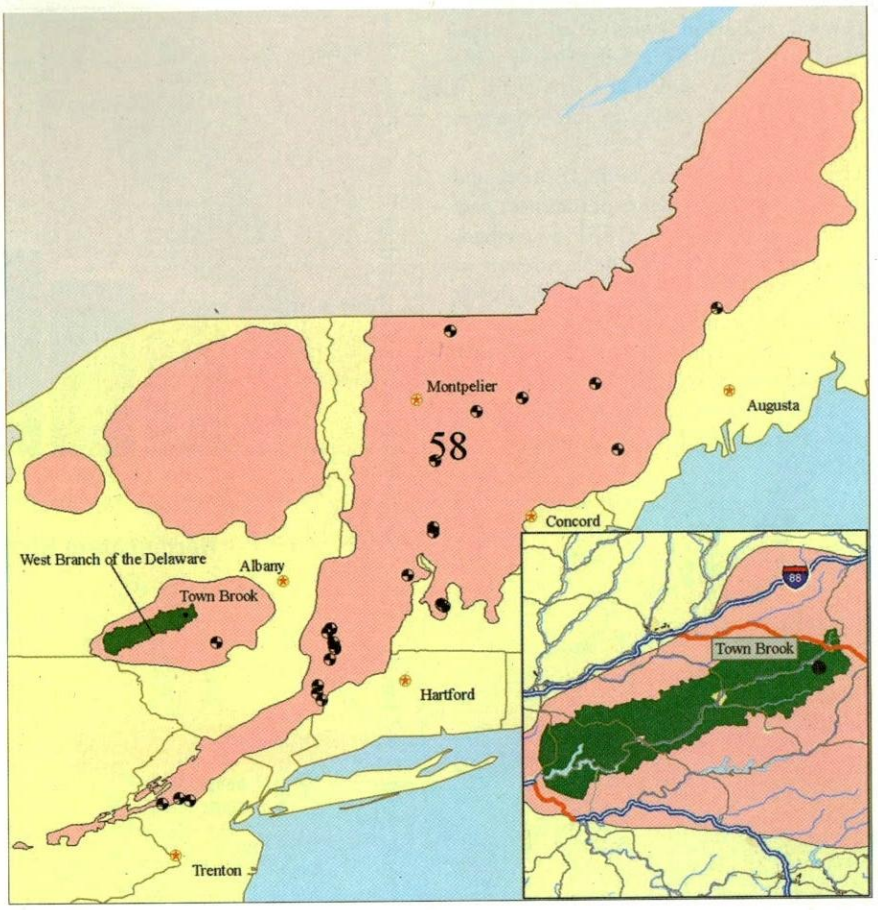
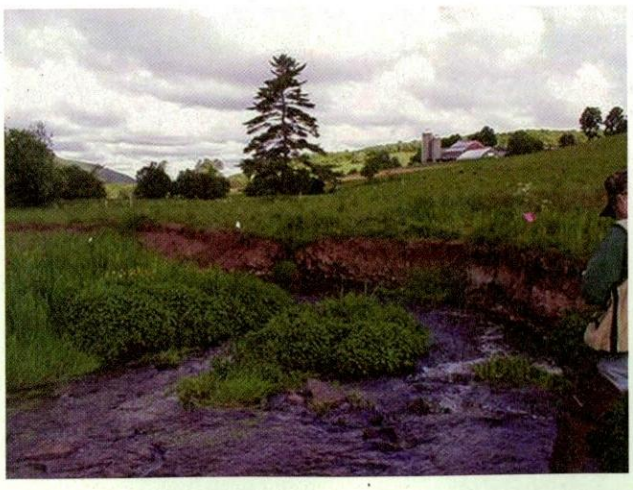
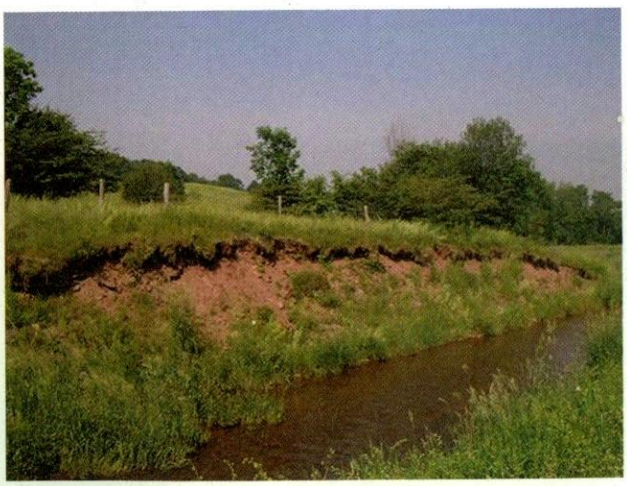


Figure 11
Unstable streambanks along Town Brook, New York (stage V).

(a)



(b)

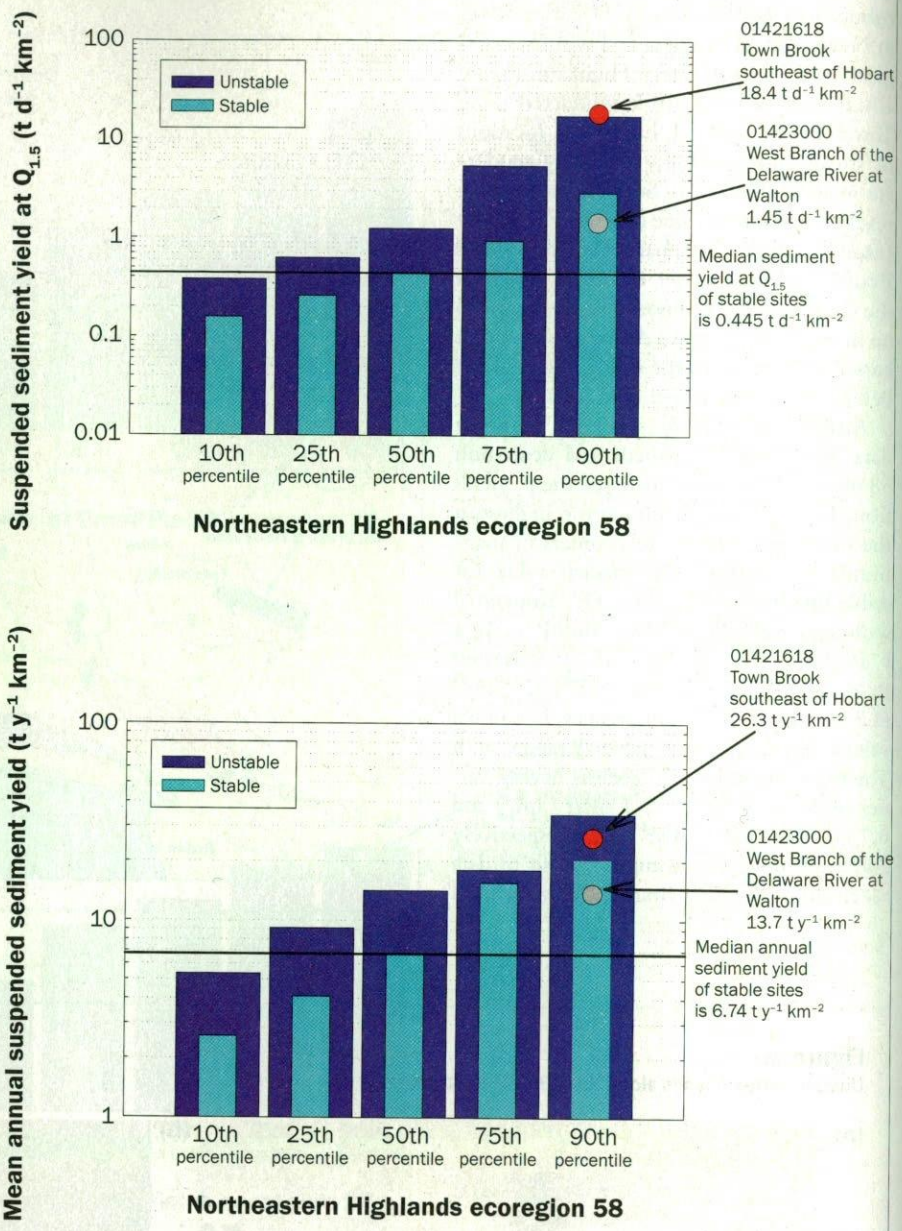


P. Bishop, New York City Department of Environmental Protection (2006), showed suspended sediment yields 2 to 3 times higher (1.5 t d^{-1} km^{-2} [4.3 tn day^{-1} mi^{-2}] at the $Q_{1.5}$; and 13.7 t y^{-1} km^2 [39.1 tn yr^{-1} mi^{-2}]) than median, stable values in the ecoregion (figure 12).

The conclusions from the RGA work and analysis of suspended sediment transport data are that yields from the CEAP watersheds are in excess of those for stable streams in ecoregion 58, particularly from Town Brook where channel contributions are probably an important contributor of sediment. Results of the associated sediment tracking work should elucidate the relative role of channel erosion in the two CEAP watersheds.

Figure 12

Distribution of suspended sediment yields for stable and unstable streams in ecoregion 58 (Northeastern Highlands) at the $Q_{1.5}$ and for average, annual values.



Note: Yields from sites within the Conservation Effects Assessment Project watersheds are shown as circles.

Little River Watershed, Georgia. The Little River watershed is located in ecoregion 65, Southeastern Plains (figure 13). Only limited RGA work has been completed along the channels of the Little River and this was done as part of a previous study. These evaluations, however, took place at two sites with historical flow and sediment transport data, thereby providing a means of comparing suspended sediment yields at these sites with those from the rest of the ecoregion. Inspection of these two sites showed characteristics of restabilized channels (stage VI) with almost 100% vegetative cover, vegetation extending down the bank to low-flow levels, stable banks, and deposited sand on bars and low-bank surfaces (figure 14).

Suspended sediment yields at the $Q_{1.5}$ for the two sites in the Little River watershed are similar to, or less than, the median value (0.23 t d^{-1} km^{-2} [0.83 tn day^{-1} mi^{-2}]) for stable sites in the ecoregion. This was expected, given the relatively stable conditions of the channels evaluated along the Little River. Median, annual suspended sediment yields for the two sites approximate the median (8.64 t y^{-1} km^{-2} [22.4 tn yr^{-1} mi^{-2}]) and 25th percentile values for stable streams (figure 15). Erosion from channel contributions is, therefore, probably not a major sediment source in this watershed. These results, along with the previously reported data for other ecoregions, support the use of this methodology to differentiate sediment loadings and relative channel contributions from the CEAP benchmark watersheds.

Figure 13
Location map of Little River watershed showing distribution of sites (circles) with historical flow and sediment transport data in ecoregion 65.

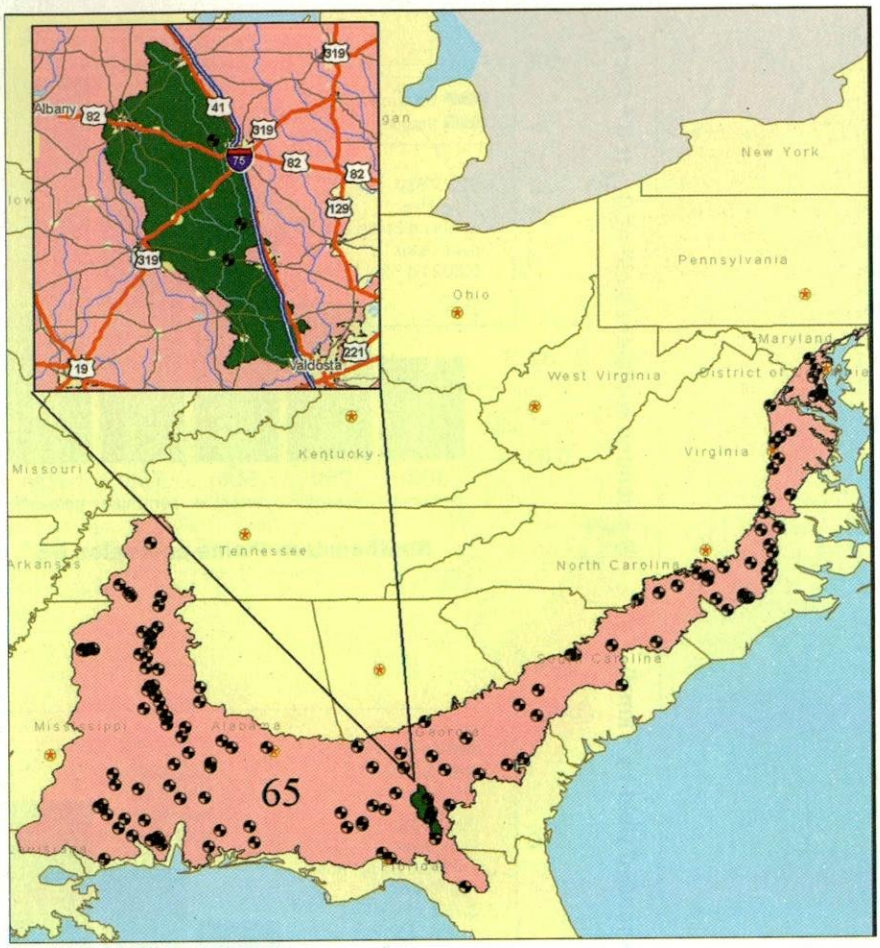
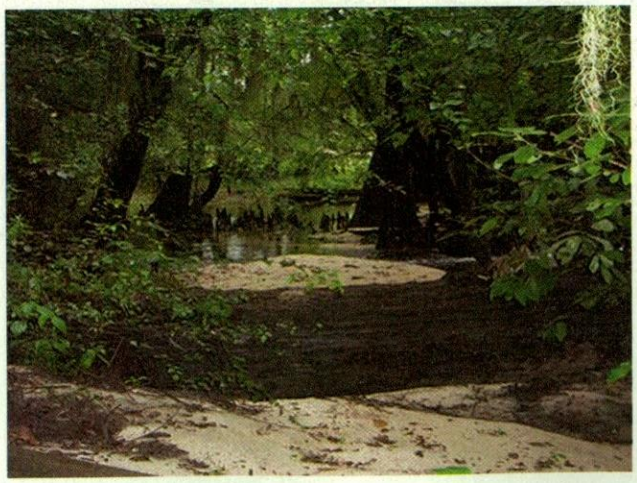


Figure 14
Stable (stage VI) conditions at two sites along the Little River, Georgia.

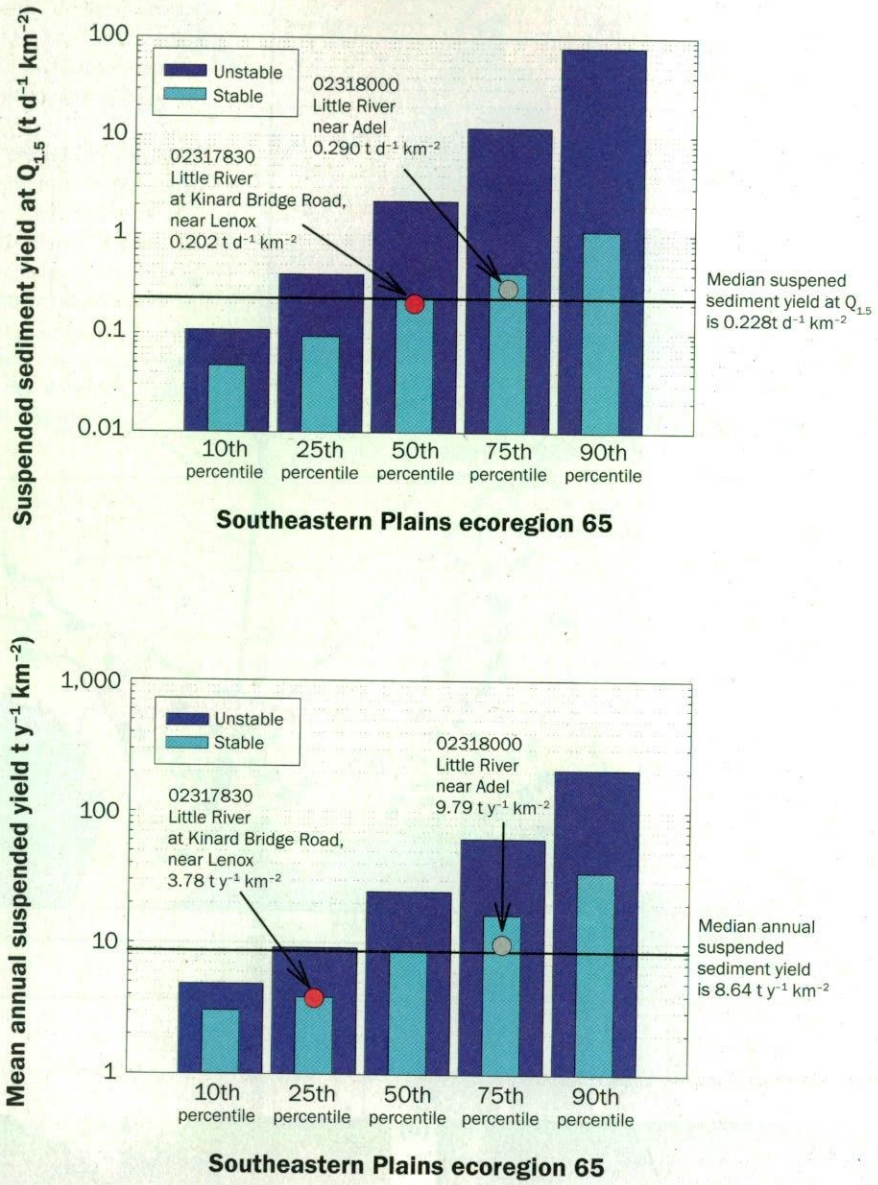
(a)



(b)

Figure 15

Distribution of suspended sediment yields for stable and unstable streams in ecoregion 65 (Southeastern Plains) at the $Q_{1.5}$ and for average, annual values.



Note: Yields from sites within the Little River, Georgia, watershed are shown as circles.

Goodwin Creek Watershed, Mississippi. Goodwin Creek is located in north-central Mississippi within ecoregion 74, the Mississippi Valley Loess Plains (figure 16). The channels of Goodwin Creek are typical of disturbed streams in the region that have undergone incision and subsequent widening by streambank failures (figure 17). Downstream reaches are regaining stability, at least in part due to grade control and bank-stabilization measures.

Suspended sediment yields in ecoregion 74 are the highest in the continental United States owing to the highly erodible soils and stream systems disturbed by channelization (Simon et al. 2004a). Annual suspended sediment yields of fine sediment (<0.063 mm [<0.0025 in]) from Goodwin Creek are about an order of magnitude greater (575 t y^{-1} km^{-2} [1,642 tn yr^{-1} mi^{-2}]) than total suspended sediment yields for stable sites in the ecoregion (78.7 t y^{-1} km^{-2} [225 tn yr^{-1} mi^{-2}]; figure 18), indicating that sediment is an important water-quality issue in this watershed. Given the general channel instabilities characteristic of Goodwin Creek, streambank erosion is probably an important contributor to sediment loadings in the watershed. CEAP activities, therefore, will need to address erosion control within the channel system.

Figure 16
Location map of Goodwin Creek watershed showing distribution of sites (circles) with historical flow and sediment transport data in ecoregion 74.

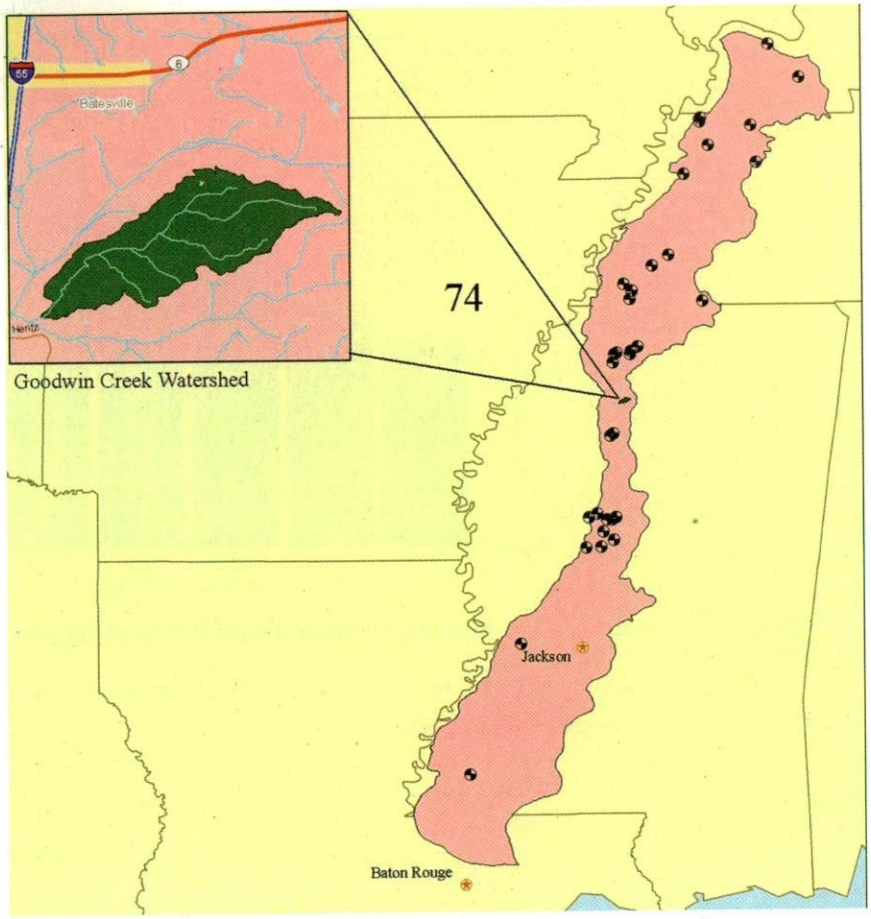
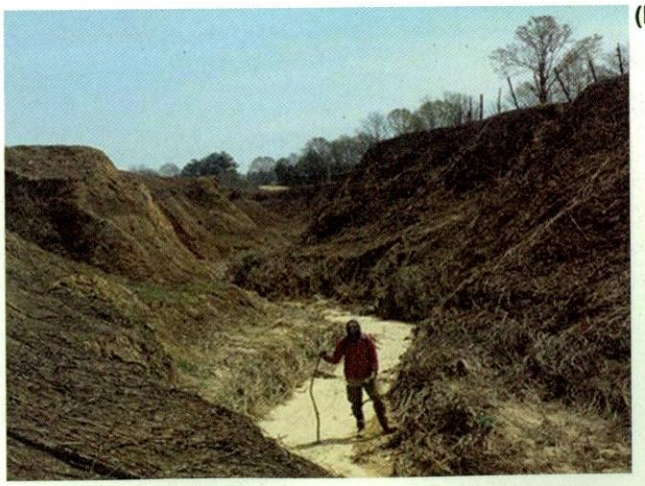


Figure 17
Typical views of unstable channels along Goodwin Creek, Mississippi, showing deep incision and unstable streambanks: (a) stage IV and (b) stage V.

(a)



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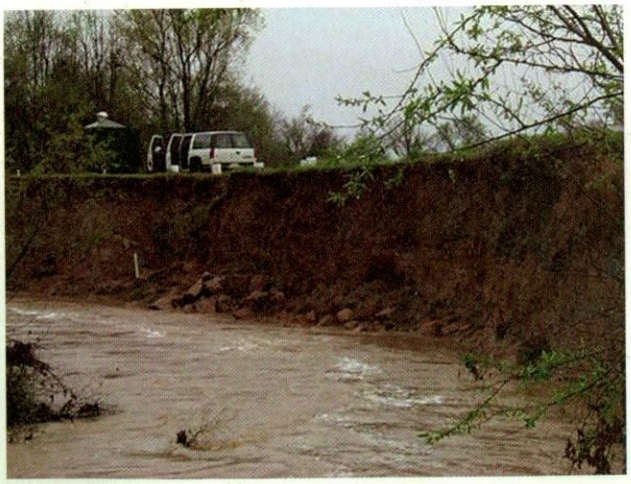
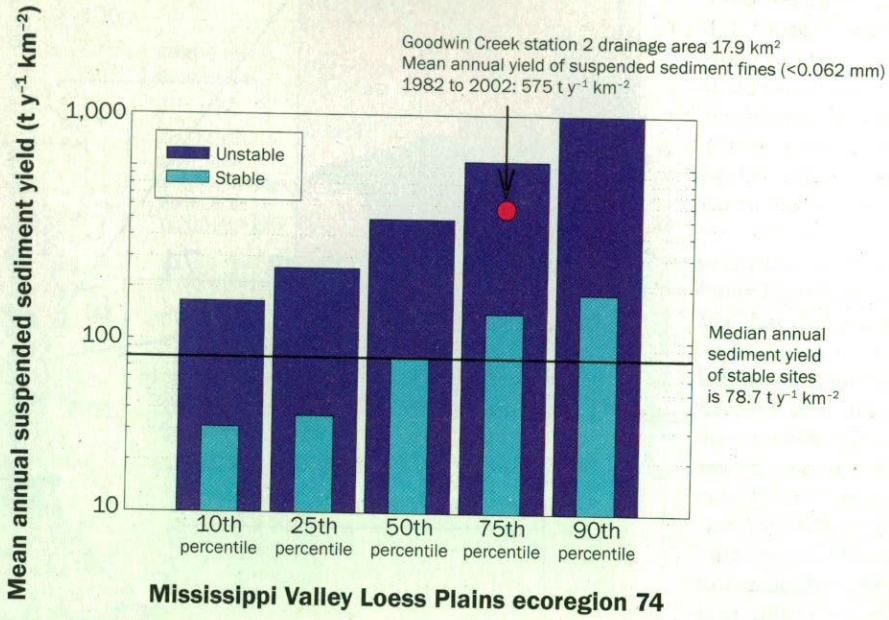


Figure 18

Distribution of average, annual suspended sediment yields for stable and unstable streams in ecoregion 74 (Mississippi Valley Loess Plains).



Note: Yield from station 2 in the Goodwin Creek, Mississippi, watershed is shown as a circle.

South Fork Iowa River Watershed, Iowa. The South Fork of the Iowa River is located in north-central Iowa within ecoregion 47, the Western Corn Belt Plains (figure 19). It is a largely agricultural area representative of tile-drained lands in the region typified by row cropping and livestock production. Upstream reaches of the main stem channel and tributary streams have been channelized into ditches while downstream reaches are sinuous. Much of the channels exhibit late-stage instability (late stage V) characterized by active meander migration, the development of cutoffs through severe erosion on the outside of meander bends, and deposition on inside bends (figure 20). Almost every outside bend along the main stem and major tributaries was actively eroding, indicating that about 50% of the streambanks contribute sediment.

Suspended sediment transport data from the South Fork Iowa River watershed were available for the main stem for the period 1995 to 2005. Suspended sediment yield at the $Q_{1.5}$ ([5.29 t d^{-1} km^{-2} [15.1 tn day^{-1} mi^{-2}]) was two orders of magnitude greater than the median reference value of 0.48 t d^{-1} km^{-2} (1.4 tn day^{-1} mi^{-2}) for ecoregion 47 (figure 21). Median annual suspended sediment yield for the South Fork Iowa River (69.7 t y^{-1} km^{-2} [199.1 tn yr^{-1} mi^{-2}]) was 243% greater than the median annual reference yield of 20.3 t y^{-1} km^{-2} (58.0 tn yr^{-1} mi^{-2}).

Figure 19
Location map of South Fork Iowa River watershed showing distribution of sites (circles) with historical flow and sediment transport data in ecoregion 47.

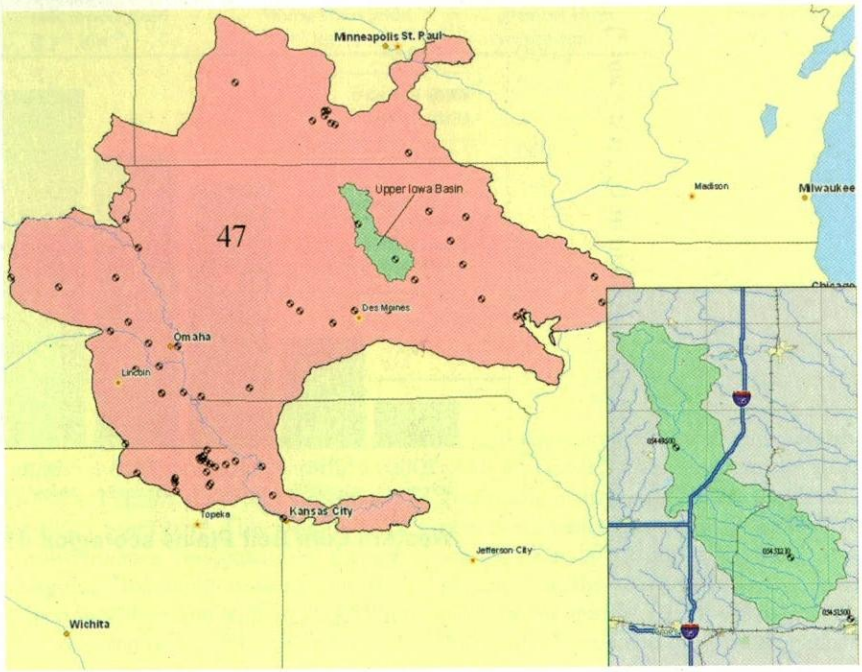


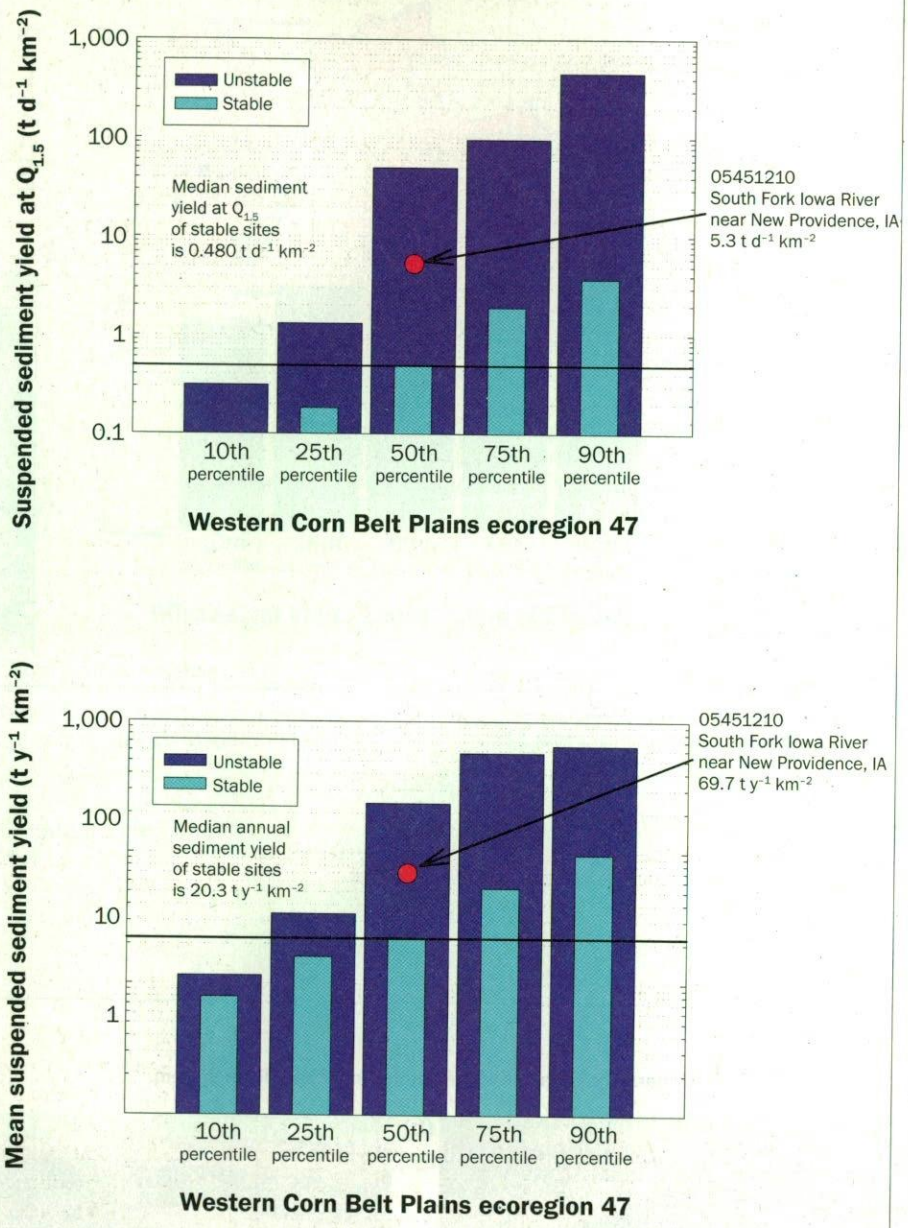
Figure 20
Typical views of stage V, unstable outside banks along the channels of the South Fork of Iowa River system.

(a)

(b)

Figure 21

Distribution of suspended sediment yields for stable and unstable streams in ecoregion 47 (Western Corn Belt Plains) at the $Q_{1.5}$ and for average, annual values.



Note: Yields from the site within the South Fork Iowa River, Iowa, watershed are shown as circles.

Table 3
Comparison of ecoregion annual, suspended sediment reference yields with yields from Conservation Effects Assessment Project benchmark watersheds.

Watershed	Ecoregion	Annual reference yield ($t\ y^{-1}\ km^{-2}$)	Watershed yield ($t\ y^{-1}\ km^{-2}$)	Percent greater than reference	Channel erosion important?
Little Washita, OK	27	18.5	411	2,120%	Yes
Fort Cobb, OK	27	18.5	1,390*	7,410%	Yes
Town Brook, NY	58	6.7	26.3	290%	Yes
West Branch Delaware River, NY	58	6.7	13.7	105%	Yes
Little River, GA	65	8.64	3.8 to 9.8	-56% to 13%	No
Goodwin Creek, MS	74	78.7	575†	630%	Yes
South Fork Iowa River, IA	47	20.3	69.7	243%	Yes

*Pre-dam data.

† Only includes material finer than 0.063 mm.

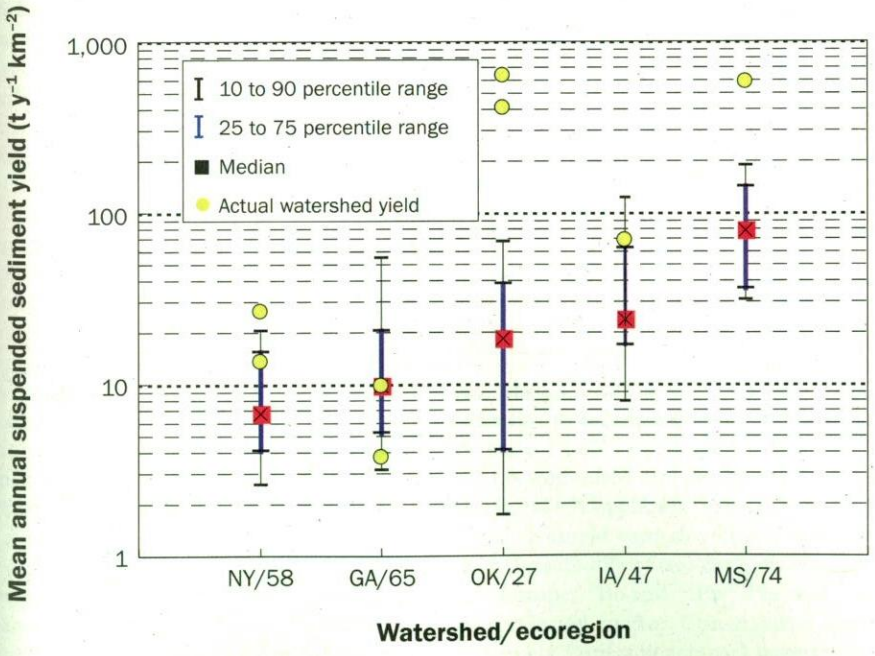
Summary and Conclusions

The methodologies developed for this study to determine the relative impact of sediment erosion in the CEAP benchmark watersheds have proved successful in differentiating sediment production between stable and unstable channel systems. All but one (Little River, Georgia) of the CEAP benchmark watersheds investigated produce appreciably more suspended sediment than stable systems within the same ecoregion (table 2). Rapid geomorphic assessments indicate that channel contributions, particularly streambanks, are probably a significant source of sediment in the other watersheds. The magnitude of this contribution is best quantified through the ongoing sediment tracking research (described in Wilson and Kuhnle 2006). The relative importance of channel processes, however, can probably be obtained from table 3 given the generally unstable nature of the fluvial systems and where a direct comparison between "reference" and watershed yields is provided. These data are also shown graphically in figure 22, where the distribution of suspended sediment yields for stable sites in each of the studied ecoregions are plotted with the actual suspended sediment yield for the specific CEAP watersheds. Still, the method provides only relative magnitudes and does not explicitly account for other sources of sediment such as gullies.

The relative importance of channel processes can be obtained by comparing "reference" yields for the ecoregion and the respective watershed yields. Annual suspended sediment yields for the CEAP benchmark watersheds exceed the median value for stable streams by 243% in Iowa, 290% in New York, 630% in Mississippi, and between 2,120% and 7,410% in Oklahoma.

Assuming that the CEAP benchmark watersheds are representative of agricultural systems in these five ecoregions, results indicate that erosion from channel sources, particularly streambanks, is a critically important process that must be addressed in management strategies aimed at controlling sediment production and delivery in these regions. Whether agencies are evaluating conservation techniques as part of the CEAP program or whether they are involved in developing mitigation strategies in response to sediment total maximum daily loads, the results reported here show that in-channel erosion control will be essential for improving downstream water quality.

Figure 22
Relative sediment impact in Conservation Effects Assessment Project benchmark watersheds as determined from suspended sediment yields for stable sites in the associated level III ecoregion.



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