RESEARCH

Riparian Vegetation and Channel Morphology Impact on Spatial Patterns of Water Quality in Agricultural Watersheds

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ABSTRACT / A model based on the *KLS* factors of the Universal Soil Loss Equation (USLE) accurately predicted temporal dynamics and relative peak levels of suspended solids, turbidity, and phosphorus in an agricultural watershed with well-protected streambanks and cultivation to the stream edge. Fine suspended solids derived from surface runoff appeared to be a major component of the suspended solids in this stream. The model did not predict the same parameters in a watershed with unstable channel substrates, exposed streambanks, and heterogeneity in riparian vegetation and channel morphology. The rate of increase in concentration of the water quality parameters was higher than predicted in areas without riparian vegetation and with unstable substrates. Peak levels were higher than predicted where unstable channel substrates occurred, and potential energy of the stream was high because of stream alterations (removal of near-stream vegetation and creation of a uniform, straight channel). Timing of the peak levels of suspended solids, turbidity, and phosphorus in these areas seemed related to major flushes of discharge due to delayed inputs from the surface or subsurface or both or to rapid urban drainage. Higher suspended solids concentration in this stream seemed to involve larger quantities of large particles.

Thus, the USLE may not adequately predict relative water quality conditions within a watershed when variation in channel morphology and riparian vegetation exists. We make the following recommendations:

1. Models to predict water quality effects of management programs should combine a terrestrial phase (which details hydrologic and erosion processes associated with surface runoff) with an aquatic phase (which details hydrologic processes of scour and sediment transport in channels). The impact of near-channel areas on these hydrologic processes should receive special attention.
2. Sampling schemes should be designed to account for the impact on water quality of both watershed land surface and in- and near-channel processes. In order to help distinguish sources of suspended solids, researchers should emphasize analysis of size distribution of particles transported.
3. Best management systems for improving the broadest range of water resources in agricultural watersheds need to be based on an expanded "critical area" approach, which includes identification of critical erosive and depositional areas in both terrestrial and aquatic environments.

A major societal focus of the last decade in the United States was to decrease nonpoint pollution from agricultural watersheds. Most efforts in this area concentrated on determining gross soil erosion from a watershed using the universal soil loss equation (USLE). Identification of critical erosive areas and treatment with traditional soil conservation practices has commonly been the major objective (Soil Conservation Society of America 1977; Lake and Morrison 1977; Miller et al. 1979).

However, the USLE provides an indication of gross soil loss and not net contributions to the stream. Many, but not all, proponents of the USLE approach recognize this (Wischmeier 1976; Miller et al. 1979). They state that a better understanding of erosion and deposition processes as runoff moves to the stream and through the channel is required to make predictions about water quality. Only when such information is combined with knowledge of gross erosion can effective models be developed for use as regulatory tools to improve water quality (Haith and Loehr 1979).

For example, conflicting results are available concerning the impact of in- and near-stream areas on erosion and deposition processes and water quality. The Illinois Agricultural Task Force (1978) estimates 86% of gross soil erosion comes from agricultural land and 4% from streambanks. Similarly, only 6% of the sediment reaching the Maumee River from Black Creek in Allen County, Indiana originates in stream channels (Mildner 1976). In contrast, 23 to 57% of the total sediment load is derived from streambed and streambank erosion in selected Illinois streams (Evans and Schnepper 1977; Leedy 1979). Widely applicable and successful models

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for predicting water quality must, therefore, be based on a better integration of physical processes in terrestrial, riparian, and aquatic portions of watersheds under all flow conditions (Karr and Schlosser 1978; Leytham and Johanson 1979).

Our purpose in this paper is not to show quantitatively how much riparian vegetation and channel morphology affect water quality. Rather, we seek to illustrate the problems encountered in predicting spatial patterns of water quality with the USLE where riparian vegetation and channel morphology vary spatially. We also discuss approaches to improve monitoring and modelling efforts for the enhancement of water resources in agricultural watersheds.

Methods and Materials

Erosion Modelling

The use of models to identify major source areas of sediment and related pollutants is necessary because of the large area involved and the high costs of land treatment programs. Most commonly used models are directly or indirectly based on the USLE (e.g., Miller et al. 1979). The equation is used to predict average soil loss in tons per acre per year (A) and is of the following form:

$$A = R\,K\,L\,S\,C\,P$$

The rainfall factor R measures erosive force of rain falling within a geographic area. Soil erodibility (K) reflects the susceptibility of a particular soil to erosion. Slope length (L) and slope gradient (S) account for the impact of slope on erosion. The cropping management factor (C) is the ratio of soil loss from land cropped under specified conditions to losses from tilled, continuously fallow land. The erosion control practice factor (P) reflects the soil loss with a specific conservation practice relative to soil loss with straight row farming. With this equation, one can predict long-term average annual losses under specific cropping conditions and how the losses are reduced by alternate erosion control plans.

We use a reduced form of the USLE to calculate erosion potential in subareas of two watersheds. The rainfall erosion index (R) is constant in the watersheds (Wischmeier and Smith 1965). Both watersheds are intensively farmed, with greater than 80–90% of their area in continuous tillage corn and soybeans. Since conservation practices other than isolated grass waterways are uncommon, CP is also assumed to be constant. Therefore, we use KLS as an indication of erosive potential of a given soil type with a specific gradient and slope length.

Erosive potential (EP) as measured by the KLS factor was determined for two study watersheds. Soil maps of the watersheds were taken from soil surveys for Champaign and Vermilion Counties, Illinois published by the Soil Conservation Service, U.S. Department of Agriculture. Soil erodibility values (K) were obtained from Technical Guide Section II-A prepared by the Soil Conservation Service (1977). Slope length (L) and gradient (S) were calculated from topographic maps of the watersheds, where (L) was the field slope length in feet and (S) was the gradient expressed as slope percent. Slopes were determined in each region of the watersheds and LS measured several times along the width of each slope. Where little slope was present, LS values were measured at irregular intervals on slopes nearest the stream. An LS factor was calculated according to the equation presented in Wischmeier and Smith (1965). The LS factor was the expected ratio of soil loss per unit area on a field slope to corresponding losses from the basic 9% slope, 22.1 meters long.

KLS values were used to classify segments of each watershed into five erosion potential (EP) categories: very low, low, moderate, high, and very high. These categories were based on the range of KLS values observed in the watersheds. At this level of discrimination, the procedure identified relative erosive potential for areas of each watershed, rather than field- or plot-specific erosion rates. This allowed us to illustrate the difficulty involved in segregating the impact of riparian vegetation, channel morphology, and erosion potential of the land surface on water quality.

Collection and Analysis of Water Samples

Sample sites could not be automated nor discharge continually measured because of budget limitations and the extensive sampling protocol. Instead, weather radar on a cable television station was monitored to assess the movement of frontal systems into the study watersheds. Sampling was initiated within one hour of the start of rainfall. Samples were collected hourly during the first 6–7 hours. Limited sampling was done during the receding hydrograph. Precipitation records from the nearest weather station were used to estimate amounts of rainfall.

All water samples were collected by attaching a one-liter bottle to a metal pole and lowering it at a uniform rate to the center of the stream bottom. The bottle was reversed on contact with the bottom and raised at a

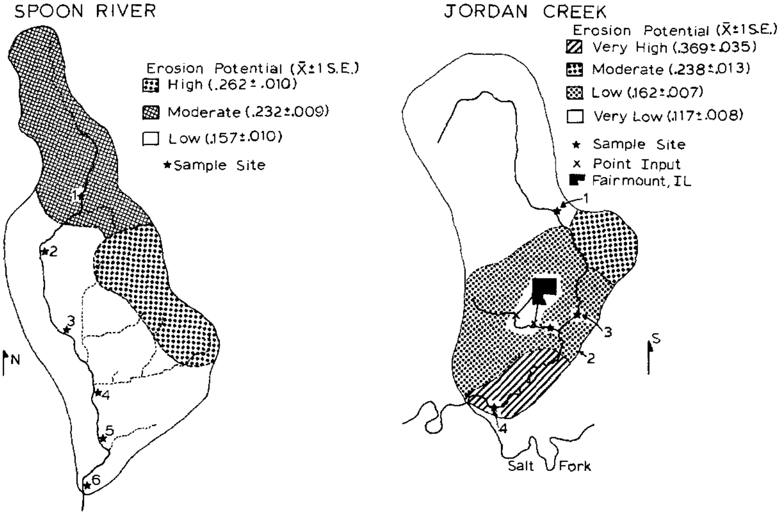

Figure 1. Erosion potential and sample site locations in the Spoon River and Jordan Creek watersheds.

uniform rate. This followed standard United States Geological Survey procedures for sampling throughout the water column (Evans and Schnepper 1977). Samples were analyzed by the Illinois Natural History Survey Laboratory following standard methods (American Public Health Association 1976).

Study Areas

Two watersheds were sampled that differed in channel morphology, type of riparian vegetation, and spatial pattern of erosive potential. Both are in Champaign and Vermilion Counties within 50 km of Champaign-Urbana, Illinois, in the midwestern United States.

Spoon River

Spoon River (30–40 km^2) is located 19 km northeast of Champaign, Illinois in the Salt Fork drainage (Fig. 1). Soil types are predominantly the Elliott-Varna association in rolling areas and Drummer-Brenton-Elburn in level areas.

Estimates of erosion potential (EP) indicate the upper portion of the watershed has a moderate EP, while the lower portion has low EP. The area with greatest EP, in the east-central portion of the watershed, is drained by two man-made channels, which transport runoff to the main stream. Six sample stations are located in the watershed (Fig. 1). Station 1 is in an area with moderate EP, while 2 and 3 are downstream in areas with low EP. Station 4 is located in an area of low EP but below the channels transporting runoff from the high EP area. Stations 5 and 6 are downstream of 4 in a low EP area.

General characteristics of the stream channel (Table 1, Fig. 2) indicate riparian vegetation and channel morphology are similar throughout the watershed. Other than a decrease in downstream gradient, the channel is relatively homogeneous with minimal pool-riffle development, cultivation to the stream edge, primarily sand and gravel substrates, and channel banks well protected by sod.

Jordan Creek

The Jordan Creek watershed (25–35 km^2) is located 50 km east of Champaign-Urbana in the Salt Fork, Vermilion River drainage (Fig. 1). Soils are the Drummer-Flanagan association, except in rolling areas near the Salt Fork where Fincastle-Russel dominates. Channel morphology and riparian vegetation vary along the stream.

Four areas are distinguished in the watershed based on EP (Fig. 1) and channel characteristics (Table 1). One sample station is below each area. Station 1 is characterized by intensively tiled, flat topography of very low EP (Fig. 1) with cultivation to the stream edge and no riparian vegetation. The low-gradient, channelized stream is uniform with no pools or riffles and with

Table 1. Channel characteristics in the vicinity of the six sampling stations on Spoon River and four stations on Jordan Creek

Stream and station	Near-stream vegetation	Channel gradient (m/km)	Channel width (m)	Channel morphology	Substrate
Spoon River					
1	Cultivation to stream edge	2.00	3.0	Poorly developed pools and riffles	Sand-gravel
2	Cultivation to stream edge	1.51	4.4	Poorly developed pools and riffles	Sand-gravel
3	Cultivation to stream edge	1.18	4.8	Uniform: no pools or riffles	Sand-gravel
4	Cultivation to stream edge	0.75	5.1	Uniform: no pools or riffles	Sand-gravel
5	Cultivation to stream edge	0.75	5.8	Uniform: no pools or riffles	Sand-gravel
6	Cultivation to stream edge	0.73	5.5	Uniform: no pools or riffles	Sand-gravel
Jordan Creek					
1	Cultivation to stream edge	0.65	4.4	Uniform: no pools or riffles	Silt-sand
2	Cultivation to stream edge	0.76	2.2	Uniform: no pools or riffles	Silt-sand
3	8–10-meter strip of riparian vegetation	0.72	5.1	Poorly developed pool-riffles	Sand-gravel
4	10–400-meter strip of mature forest and pasture	4.00	8.0	Well-developed pools and riffles	Sand-gravel-rock

Figure 2. Typical channel and riparian conditions throughout Spoon River.

unstable silt-sand substrates (Table 1). Station 2 has low EP (Fig. 1) with no riparian vegetation. The channel at this station is uniform and low gradient, with unstable silt-sand substrates (Table 1). Station 3 is characterized by moderately rolling topography with low-to-moderate EP (Fig. 1). A strip of mixed woody and herbaceous vegetation 8–10 meters wide borders the stream. The vegetation is composed of maple (*Acer* spp.), willow (*Salix* spp.), box elder (*Acer negundo*), hackberry (*Celtis occidentalis*), ash (*Fraxinus* spp.), black cherry (*Prunus serotina*), elm (*Ulmus* spp.), osage orange (*Maclura pomifera*), and multiflora rose (*Rosa multiflora*). The low-gradient channel at Station 3 has poorly developed pools and riffles with stable sand and gravel substrates (Table 1). Station 4 has a rolling topography, highly erodible soils, and very high EP (Fig. 1). Mature forest 10–400 meters wide borders the stream. Vegetation is dominated by maple, oak (*Quercus* spp.), cottonwood (*Populus deltoides*), sycamore (*Plantanus occidentalis*), and ironwood (*Carpinus caoliniana*). The rolling nature of the watershed of Station 4, in combination with intensive agriculture, resulted in major gullies through the riparian vegetation. The channel at Station 4 is high gradient (Table 1) with well-developed pools and riffles and exposed channel banks. Channel substrates are dominated by sand, gravel, and rock. In contrast to the variable riparian vegetation and channel morphology at the stations, all of the watershed has greater than 80% of its area in corn and soybeans. Channel and riparian conditions for each station in Jordan Creek are shown in Fig. 3.

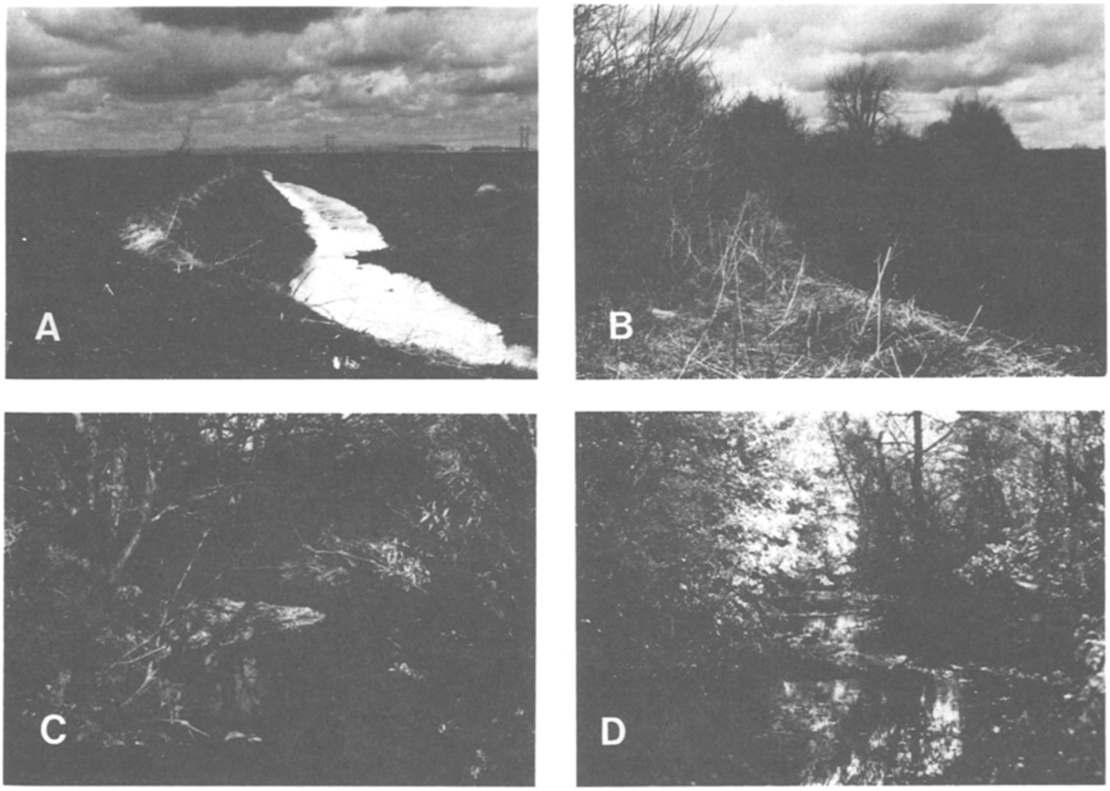

Figure 3. Typical channel and riparian conditions in the vicinity of Stations 1 and 2 of Jordan Creek **(A)**. Riparian vegetation **(B)** and channel conditions **(C)** in the vicinity of Station 3 of Jordan Creek. Riparian vegetation and channel conditions in the vicinity of Station 4 of Jordan Creek **(D)**.

In summary, the watersheds differed extensively in riparian vegetation and channel morphology. In Spoon River, riparian vegetation is absent throughout the watershed, channel morphology is relatively homogeneous, and channel banks are well protected by sod. In Jordan Creek, riparian vegetation and channel morphology vary along the stream.

Results

Although several runoff events were sampled in each watershed, we present results of only one event. Results from other runoff events and another watershed, which are consistent with the conclusions presented here, are described in Schlosser and Karr (1980).

Since the purpose of this research was to illustrate that water quality, as indicated by concentrations of pollutants, varied as a function of interactions between upland erosion potential, riparian vegetation, and channel morphology, discharge was not measured nor loadings calculated. Calculations of loadings would be more appropriate from the perspective of downstream areas, particularly receiving waters such as lakes or reservoirs. Temporal changes in pollutant concentrations are more important from a biological perspective. Both loadings and concentrations should be determined if resources and manpower permit. If not, the relative emphasis on the two should vary depending on the water resource problem under investigation (Karr and Dudley, in press).

Further, we recognize that variables other than erosion potential, stream morphology, and bank vegetation affect spatial patterns of water quality within a watershed. Spatial variation in antecedent moisture conditions and rainfall intensity and duration are especially important. We partially controlled variation in antecedent moisture conditions by restricting our comparisons to relatively small, well-drained watersheds. Controlling for spatial variations in intensity and duration of rainfall is difficult without large expenditures for automatic rain gauges. The similarity of spatial patterns of water quality within the watersheds during runoff events of similar intensity (Schlosser and Karr 1980) suggests that these variables do not account for the patterns described here.

Lastly, many water quality parameters might be discussed. We concentrate on suspended solids, turbidity, and particulate phosphorus since sediment and associated pollutant losses are predicted by the USLE. Patterns for other parameters are described in Schlosser and Karr (1980). It might be argued that these parameters are repetitive, since it is widely assumed they can be predicted from each other. However, there is substantial as yet unexplained variability in the relationship between sediment and associated water quality parameters (Zison 1980). The results presented here indicate hydrologic processes mediated by riparian vegetation and channel morphology have substantial effects on these relationships.

Spoon River

Rainfall on July 30, 1979 in the Spoon River watershed produced approximately 7.5 cm of rain in two events over a 3-hour period. Incipient soil conditions were moist as a result of 5 cm of rain within the previous 7 days. Rate of increase in suspended solids, turbidity, and particulate P was a function of the distance between the sample site and erosive areas (Fig. 4). Close proximity (Station 1) resulted in immediate increases. Sample sites more distantly located from critically erosive areas (Station 4) had a delayed increase in the water quality parameters. Stations near highly erosive areas (4 and 5) experienced the highest levels of suspended solids, phosphorus, and turbidity (Fig. 4). Moderate EP areas (Station 1) also experienced lowered water quality. These parameters peaked at lower levels in areas with lower EP (Stations 2, 3, and 6). In high EP areas, high concentrations of suspended solids and phosphorus are apparently diluted as they pass into the less erosive portions of the watershed. Dual peaks in curves at stations nearest highly erosive areas resulted from two bursts of rainfall initiating two pulses of runoff. Thus, temporal dynamics and peak levels of water quality parameters in Spoon River were a function of local erosion processes in the terrestrial environment.

This conclusion was supported by the temporal variation in sizes of particles transported in Spoon River. A change in the ratio of suspended solids/turbidity provided an index of a change in the relative size composition of particles in suspension because large particles scatter less light than an equal concentration of small particles (Grassy 1943). This ratio was called the coefficient of coarseness (CC). An increase in CC suggested larger particles composed a greater portion of the suspended load.

The ratio showed consistent patterns during large increases in levels of suspended solids in Spoon River and Jordan Creek, even when different stations within a watershed were compared. One should use caution, however, when comparing the ratio during large decreases in levels of suspended solids or during storms of different intensities. We restrict our interpretations to periods of surface runoff when the levels of suspended solids were either increasing or remaining relatively stable.

CC values in Spoon River decreased during periods of increasing levels of suspended solids (Fig. 4). Turbidity increased faster than suspended solids during the rising hydrograph, resulting in a decrease in CC with flushes of suspended solids (Fig. 5). However, at stations in close proximity to critical erosive areas (1, 4, and 5), CC values were significantly larger ($p = 0.05$; Mann Whitney U, one-tailed test) at peak levels of suspended solids.

Turbidity normally increases more slowly than suspended solids during the rising hydrograph (Grassy 1943) because of the increased competence of the stream to transport large particles in the streambed or streambank as velocity increases. Large particles are in limited supply in Spoon River because of stable substrates in the streambed and well-protected streambanks. In this situation, flushes of fine suspended solids derived from surface runoff were associated with increasing discharge, and CC values decreased.

Thus, EP in the watershed was an accurate predictor of the temporal patterns and peak levels of suspended solids in a watershed with no riparian vegetation but with stable substrates and channel banks. Fine suspended solids from surface runoff appeared to be the major component of the suspended load. Increased particle size was associated with critically erosive areas in the terrestrial environment. Turbidity and particulate phos-

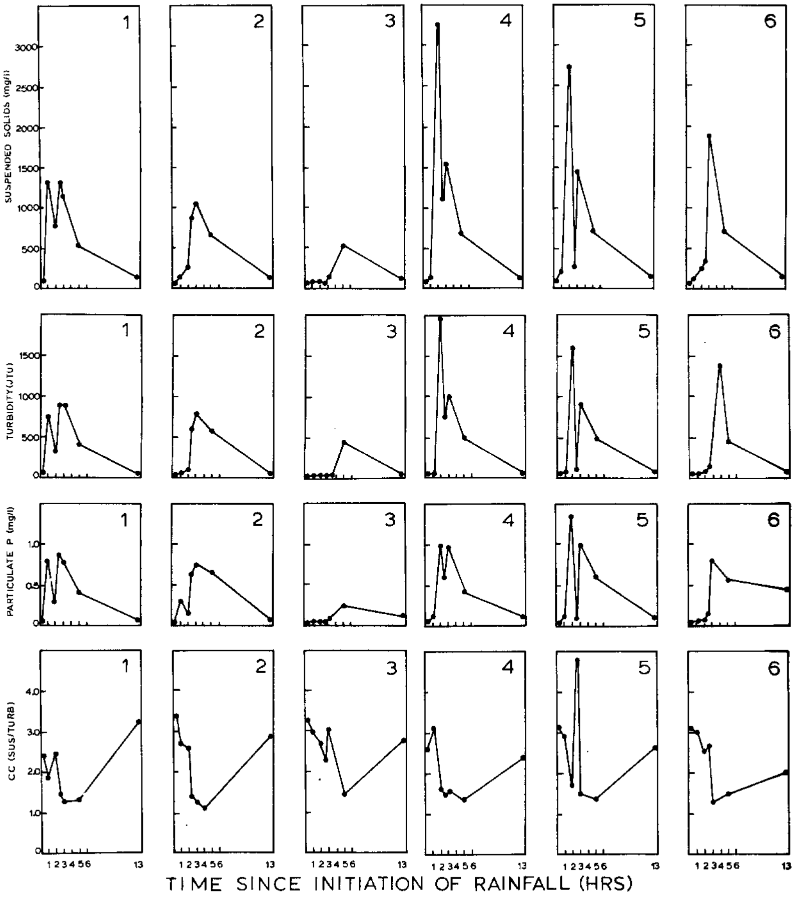

Figure 4. Suspended solids, turbidity, particulate phosphorus and coefficient of coarseness (CC), for six Spoon River sample stations, July 30, 1979.

phorus were consistently related to concentrations of suspended solids.

Jordan Creek

The heterogeneity of riparian vegetation and channel morphology in Jordan Creek provided a circumstance for testing the impact of these factors on the relationship between EP and water quality. On March 3, 1979 a storm dropped 2.5 cm of rain within a 2-hour period on saturated ground.

Levels of suspended solids increased abruptly (Fig. 6) where riparian vegetation was absent and unstable substrates were present (Stations 1 and 2). The absence of riparian vegetation allowed rapid transport of runoff from agricultural areas to the stream. The sharp rise at Station 2 was due to stormwater input from a small urban area (Fairmount, Illinois) and surface runoff from agricultural fields. Station 4, with rolling topography and gully formation, experienced faster increases in suspended solids than Station 3, where riparian vegetation resulted in slower release of runoff to the stream and substrates were relatively stable.

In summary, the rate of increase in suspended solids in Jordan Creek was not solely a function of EP in the watershed but involved two additional factors: (1) the rate of transport of runoff to the stream, which was

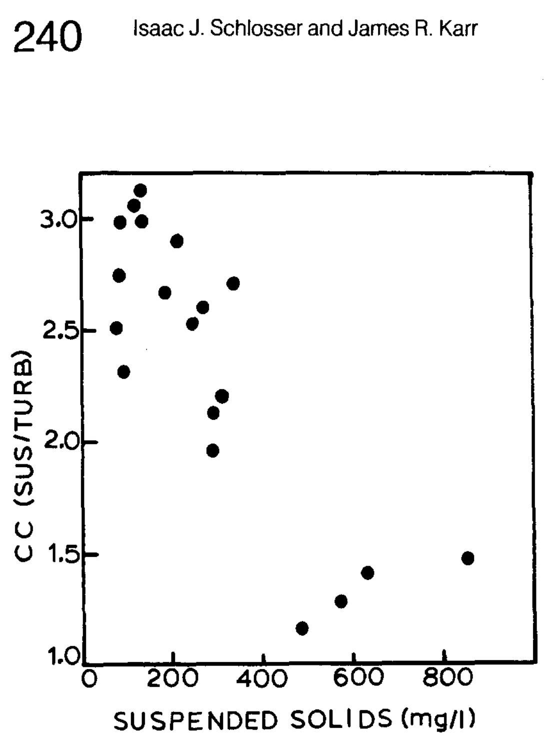

Figure 5. Relationship between suspended solids and coefficient of coarseness (CC) during periods of increasing suspended solids during two runoff events of similar intensity in Spoon River.

decreased by the presence of riparian vegetation, and (2) the stability of substrates in the channel; more stable substrates resulted in slower increases in suspended solids with increasing discharge.

Peak levels of suspended solids varied in magnitude and timing among the four stations and appeared to be a function of potential energy of the stream to transport sediment rather than EP in the watershed. The peak level of suspended solids was highest (928 ppm) for the high-gradient stream (Station 4; Fig. 6). Intermediate levels occurred in the low-gradient, channelized areas; stations 1 and 2 peaked at 879 and 809 ppm, respectively. Station 2 peaked early in the event during the most intense period of urban runoff. Station 1 peaked later during a delayed increase in stream discharge (I. J. Schlosser, personal observation) due to slower surface inputs from this flat region of the watershed or subsurface inputs from the intensive drainage system or both. The lowest level (784 ppm) occurred where the stream had a low-gradient, meandering channel and was bordered by riparian vegetation (Station 3; Fig. 6). The riparian vegetation increased the roughness of the channel (Chow 1959) and reduced the velocity and potential energy of the stream to scour its bed and banks during elevated discharge. Thus, peak levels of suspended solids in Jordan Creek appeared to be a function of localized, in-channel erosive processes, rather than EP in the watershed.

This conclusion was supported by the temporal variation in particle sizes transported in Jordan Creek. Particulate material was readily available for transport in the unstable streambed (Stations 1 and 2) and exposed streambank (Stations 3 and 4). Levels of suspended solids increased faster than turbidity (Fig. 6) because of the entrainment of large particles as velocity increased. CC values increased at all stations with flushes of suspended solids (Fig. 7). Variation in the size of particles transported at the four stations appeared to be a function of the potential energy of the stream. CC values were highest for the high-gradient stream (Station 4) and were lower in the low-gradient, channelized areas (Stations 1 and 2, Fig. 6). Lowest values occurred in the low-gradient, unchannelized area bordered by riparian vegetation (Station 3). This ranking of CC values was in agreement with the ranking of peak levels of suspended solids.

The impact of variation in particle size on attached pollutants was illustrated by the particulate phosphorus data (Fig. 6). Concentrations of particulate phosphorus for Stations 1, 2, and 3 were directly related to levels of suspended solids. Station 4 had the highest level of suspended solids; however, its particulate phosphorus concentrations were substantially lower (Fig. 6). This was probably attributable to the greater proportion of large particles, with smaller surface areas for ion attachment (Stottenberg and White 1953), in the suspended solids at this station (Fig. 6).

In summary, EP in the watershed was not an accurate predictor of spatial and temporal variations in water quality in a complex system like Jordan Creek, with an unstable streambed and streambank and variation in channel morphology and riparian vegetation. Rate of increase of all water quality parameters was faster in areas without riparian vegetation and with unstable substrates, regardless of EP. Peak levels were greater than predicted by EP where unstable substrates occurred and potential energy of the stream was high as a result of stream alterations (removal of near-stream vegetation and creation of a uniform straight channel). Increases in levels of suspended solids were associated with an increase in particle size. Variation in potential energy of the stream and the size of particles transported reduced the level of correlation between suspended solids and other water quality parameters.

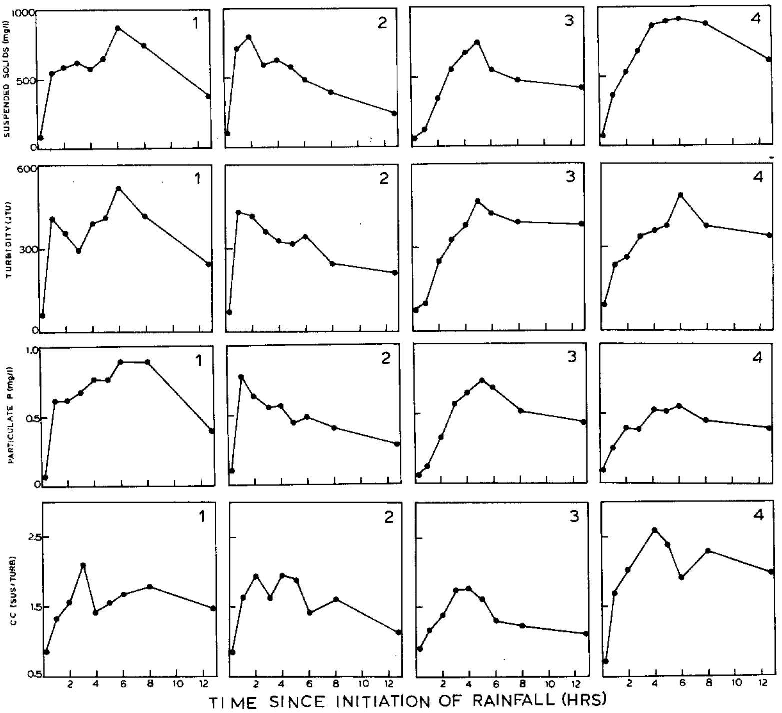

Figure 6. Suspended solids, turbidity, particulate phosphorus, and coefficient of coarseness (CC) in Jordan Creek, March 3, 1979.

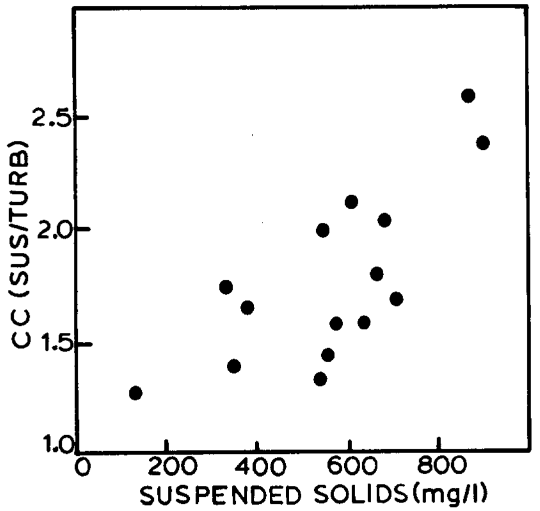

Figure 7. Relationship between suspended solids and coefficient of coarseness (CC) during periods of increasing suspended solids in Jordan Creek.

Discussion

Gross soil erosion on the land surface is not consistently and directly related to water quality. This conclusion is unavoidable, since the relative influence of land surface and channel erosion varies among watersheds and even among regions within the same watershed (Mildner 1976; Dudley and Karr 1977; Evans and Schnepper 1977; Illinois Agriculture Task Force 1978; Leedy 1979; and this study).

Part of this variation is due to interactions between availability of sediment for transport and the hydrologic impact of riparian vegetation and channel morphology. Runoff is rapidly transported to the channel where riparian vegetation is absent. The streambed and streambanks appear to be minor sources of sediment when the streambed is stable and the streambank is well protected. With channel and bank stability, and absence of riparian vegetation, it is relatively easy to predict temporal dynamics and relative peak levels of water quality from knowledge of EP of the land surface.

Where riparian vegetation is present, runoff is released more slowly to the channel and some sediment deposition occurs. The streambed and streambanks contribute significantly to levels of suspended solids where bottom substrates are unstable or bank erosion is actively occurring. In this situation, EP of the land surface does not predict spatial and temporal dynamics of pollutants. Instead, the potential energy of the stream to transport sediment is of primary importance.

These patterns must be considered during efforts to model water quality in agricultural watersheds. Streams like Jordan Creek, with highly modified, unstable channels in upstream areas are quite common throughout the midwestern United States. Installation of soil conservation practices in these watersheds, with the release of relatively clean water into the stream, will not necessarily improve water quality. Particulate material within the channel will still be transported if discharge peaks are not significantly attenuated.

For modelling and enhancement of water resources in agricultural watersheds to be widely applicable and successful, resource managers need to use a perspective encompassing both the terrestrial and aquatic phases of sediment transport (Karr and Schlosser 1978). This conceptual approach, which we have qualitatively illustrated here, needs to be expanded upon in a more detailed quantitative manner in the context of sediment routing models. If properly developed, these models would provide a more accurate picture of sediment movement and sources. This would allow resource managers to relate the sediment to its source in a more quantitative manner than we do in this paper. Development of such quantitative models is still in a primitive state (Leytham and Johanson 1979). Special attention must be directed toward quantifying (1) the impact of riparian vegetation on sediment deposition, hydrography dynamics, and availability of sediment for transport; (2) the impact of channel morphology on sediment availability and potential energy of the stream to transport sediment; and (3) the impact of shifts in the source of sediment from the watershed to the stream on particle size distributions and transport of adsorbed pollutants. Calibration of these models and monitoring by regulatory agencies require careful selection of sample sites and water quality parameters to evaluate the impact of both terrestrial and aquatic processes (Daniel et al. 1978).

Such models will improve prediction of critical erosive and deposition areas in both terrestrial and aquatic environments. Identification of critical erosive areas will assist in improving water quality. Locating critical deposition areas will be especially significant for evaluating the potential impact of alternative management strategies on aquatic biota. Critical erosive areas in terrestrial environments can be treated with a variety of "best management practices" (Haith and Loehr 1979). Treatment of erosive areas in aquatic regions has substantial potential for degrading water quality during base flow (Schlosser and Karr 1981) and biological integrity in streams (Karr and Schlosser 1978; Karr and Dudley, in press) because of alterations of the natural aquatic habitat or riparian vegetation. Constant interaction and cooperation among agriculturalists, hydrologists, geomorphologists, and stream biologists will be necessary to design successful best management systems for improving water resources within the perspective linking terrestrial and aquatic systems.

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