SUSPENDED SEDIMENT IN RUNOFF FROM MISSISSIPPI DELTA MSEA PROJECT WATERSHEDS, 1996-99

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INTRODUCTION

One of the most intensive agricultural areas of the United States is located in northwestern Mississippi, a 7,000-square-mile area locally referred to as the Delta. The fertile soils of the Mississippi Delta produce a variety of crops such as cotton, soybeans, corn, and rice. Similar to other areas of the Nation where agriculture is intense, water resources in the Mississippi Delta are vulnerable to potential adverse environmental effects caused by excessive sediment, nutrients, and pesticides transported from agricultural fields.

Suspended sediment—and turbid conditions caused by suspended sediment—is considered one of the primary water-quality concerns in the Mississippi Delta (State of Mississippi 1999). Soil erosion and sedimentation have been well documented as causing declines in fisheries in Delta streams and oxbow lakes by limiting light penetration necessary for photosynthesis in aquatic plants (Cooper and Knight 1978; Knight et al. 1994). The high erosion rates and off-field sediment movement could be linked to farming practices such as conventional tillage (Meyer and Harmon 1978) where soil is disturbed frequently throughout the year, especially during winter and spring when rainfall is greatest. In addition, other contaminants such as nutrients and pesticides can attach to sediment and be transported during runoff events.

The Mississippi Delta Management Systems Evaluation Areas (MDMSEA) project began in 1995 to study agricultural nonpoint-source pollution of oxbow lake watersheds. Specifically. the two purposes of the MDMSEA project were to assess the effects of agriculture on water quality and to evaluate best management practices (BMP's) designed to improve water quality. As part of the MDMSEA project, the U.S. Geological Survey (USGS) began operating an automated streamflow and waterquality sampling network in April 1996 to assess the effects of an untreated system and BMP systems on edge-of-field runoff quality (Rebich 1997). This paper presents selected suspended-sediment concentration and load data for runoff samples collected from nine sites for the MDMSEA project from 1996 through 1999. The paper also presents comparisons of suspended-sediment data from runoff of an untreated field to BMP-treated fields.

SITE LOCATIONS AND FIELD TREATMENTS

The three MDMSEA oxbow lake watersheds are located in Sunflower and Leflore Counties in northwestern Mississippi. Nine USGS streamflow and water-quality sampling sites were established in the MDMSEA watersheds to characterize runoff from untreated and BMP-treated fields (streamflow and water-quality sampling sites are hereafter referred to as runoff sites). The watersheds and runoff sites are described in the following sections; however, due to space limitations, the locations of the watersheds in Mississippi and the runoff sites within each watershed are not shown.

A. Thighman Lake watershed (Sunflower County) - The total drainage area of this watershed, the largest of the three, is about 3,700 acres. Soils in the watershed vary from a loam to a very heavy clay. The Thighman watershed was selected as the control watershed with no BMP's planned by the MDMSEA project. Runoff quality in the Thighman watershed was expected to be the poorest of the three watersheds because conventional tillage was predominant at the beginning of the study. The primary row crops grown in 1995-96 at Thighman were cotton and soybeans, but producers grew a large amount of corn from 1997 to 1999 as a result of market changes (Gwin 2001). In addition, producers in the upper Thighman drainage area began to utilize conservation tillage starting about 1997, possibly in an effort to reduce overhead costs and increase profit. Two runoff sites are located in the Thighman watershed:

- TL2 is on the primary inlet tributary of Thighman Lake and drains about 1,470 acres. Data collected from this site were used to document chemical and sediment loads entering the lake during runoff events.

- TL3 is an edge-of-field site located downstream of a cotton field that was in conventional tillage without BMP's for the entire study period. TL3 drains about 14 acres, and data collected at this untreated site were compared to data collected from the BMP sites.

B. Beasley Lake watershed (Sunflower County) - The total drainage area of this watershed is about 2,100 acres. Soils are generally a loam, and the primary crops include cotton and soybeans with some corn and rice. A large riparian area (about 800 acres) adjacent to the eastern side of the lake, in effect, serves as a natural filter. The Beasley watershed differs from the other two MDMSEA watersheds in that the difference in elevation from the top of the watershed boundary to the lake is about 18 feet (compared to differences of about 5 feet in the other two watersheds). BMP's used in the Beasley watershed were primarily edge-of-field treatments and were either structural, such as slotted-board risers and slotted inlet pipes, or vegetative, such as grassed filter strips. These BMP's were considered to be more economical than other BMP's considered for the MDMSEA project. Although slotted-board risers have proven effective in reducing sediment-laden waters from entering receiving waters such as lakes (State of Mississippi 1999), the BMP's used at Beasley were not expected to produce the highest level of improvement to runoff quality. Five runoff sites were installed in the Beasley watershed:

- BL1 drains about 100 acres of conventional-tillage cotton and is located in a grassed open-channel ditch. Filter strips and slotted-board risers were installed at strategic locations within the BL1 drainage area, but not directly upstream of the sampling point. Data from BL1 were used to evaluate the combined effectiveness of the grassed drainage ditch, slotted-board risers, and filter strips as a system of BMP's.

- BL3 drains about 18 acres of conventionally tilled crops. Cotton was grown every year at this site, except 1998 when corn was grown. A slotted-board riser was installed at the drainage outlet for this sub-watershed directly upstream of the sampling point. No other BMP's were used at this site, and the effectiveness of the slotted-board riser was evaluated individually. Typically, boards were placed in the riser in the fall shortly after harvest (late October) and then removed about one month before planting in the spring (late March) each year. However, boards were installed for only about 1 month in the fall of 1997 (no runoff events) at the request of the landowner in order to prepare fields prior to planting corn in the spring of 1998. Boards were not reinstalled at BL3 until October 1998.

- BL4, BL4A, and BL4B are located within the natural riparian area located directly east of Beasley Lake. Data from these three sites were used to assess the effects of the riparian area on runoff quality. BL4A and BL4B drain about 380 and 170 acres, respectively, and are located at separate inlet channels to the undisturbed riparian area. Fields upstream (not directly) of BL4A and BL4B were primarily in conventional tillage. BL4 drains about 840 acres and is located at the outlet of the riparian area upstream of the lake entrance.

C. Unnamed Lake watershed (Leflore County) – This lake is not named on the USGS topographic map, but is locally and hereafter referred to as Deep Hollow Lake. The total drainage area of this watershed, the smallest of the three, is about 500 acres. Most of the watershed has loam soils that support cotton production (about two-thirds of the watershed), but heavier, clay soils also are present where soybeans are grown. This watershed received the most extensive BMP treatments and was expected to have the greatest improvements to runoff quality of the three watersheds. The same structural and vegetative edge-of-field treatments used in the Beasley watershed also were used in the Deep Hollow Lake watershed. In addition, residue-management practices, such as conservation tillage and winter cover, and new technologies, such as hooded sprayers with weed sensors, were used in this watershed. Two runoff sites were installed in the Deep Hollow Lake watershed:

- UL1 drains about 42 acres where cotton and soybeans were grown throughout the study period. Conservation-tillage cotton was grown in the upper elevations of the UL1 drainage area farthest from the sampling point, and no-till soybeans were grown in the lower elevations nearest the sampling point. Winter wheat was grown on the entire cropped area in the fall of each year with cover lasting from about late fall through late winter. This cover crop was chemically "burned down" or poisoned each year prior to planting in the early spring. In addition, a slotted-board riser was installed on the culvert entrance directly upstream of the sampling point at UL1.
- UL2 drains about 25 acres where cotton and soybeans were grown throughout the study period. Similar to UL1, conservation-tillage cotton was grown in the upper elevations and no-till soybeans were grown in the lower elevations of the UL2 drainage area. Winter wheat was grown on the entire cropped area in the fall of each year and burned down at UL2 at the same time each year as at UL1.

MATERIALS AND METHODS

Continuous streamflow records (or total-runoff volume) were collected at six of the nine runoff sites; the exception was the Beasley riparian area sites. Water-quality samples were collected at each runoff site. The samples were analyzed to determine suspended-sediment concentrations, which were then used to calculate loads. The following sections describe sample-collection procedures and load calculations.

Sample Collection

Water samples were collected from automated samplers installed at each site. About 2,300 samples were analyzed for suspended-sediment concentration by the USGS sediment laboratory in Baton Rouge, LA. Streamflow was measured at six sites by using flumes, weirs, or acoustic Doppler instrumentation (Rebich 1997). Streamflow was not measured at the riparian sites, BL4, BL4A, and BL4B, in the Beasley watershed.

Automated samplers were activated during runoff events when the water level in a flume or weir exceeded a specified elevation. Once activated, the samplers pumped runoff into sample bottles after a specified volume of water flowed past the sampling point. For example, at the UL2 site, after each 4,000-cubic-foot (ft^3) increment of water flowed past the sampling point, the sampler pumped runoff into a sample bottle. This technique is referred to as flow-proportional sampling.

Composite and discrete flow-proportional samples were collected. For composite sampling, each sample of runoff was pumped into a single sample bottle. For example, at the UL2 site, after each 4,000-ft^3 increment of water flowed past the sampling point, 100 milliliters (mL) of water was pumped into the single sample bottle. Therefore, at the end of a storm that produced 40,000 ft^3 of runoff, a single sample bottle would contain 1,000 mL, or 1 liter (L), of runoff. Water from this single container would then be analyzed for suspended-sediment concentration. A composite sample represents a "storm-averaged" concentration of suspended-sediment in the runoff. All nine runoff sites were equipped with a sampler dedicated to composite sampling.

In contrast to composite sampling, each sample of runoff was pumped to a separate sample bottle for discrete sampling. For example, at UL2, after each 8,000-ft^3 increment of water flowed past the sampling point, 1 L of runoff water was pumped into an individual sample bottle. Therefore, if a storm produced 80,000 ft^3 of runoff, ten 1-L containers were available and analyzed individually. Discrete samples were used to determine variation of suspended-sediment concentration over time during each runoff event and to produce more accurate estimates of load. Three sites (TL3, BL3, and UL2) were equipped with samplers dedicated to discrete sampling.

Load Calculations

For this paper, flow data were available for only TL3, BL3, and UL2; therefore, load calculations were made only for those three sites. Loads were calculated by using discrete data where available and procedures described by Porterfield (1972). Loads also were calculated by using composite data for runoff events where discrete data were not available. Some loads were estimated by using regression techniques described by Porterfield (1972) for storms where neither discrete nor composite data were available. Finally, loads were normalized by dividing each individual storm load by the drainage basin size and were expressed as tons (or pounds) per acre.

RESULTS AND DISCUSSION

Concentration (composite samples) and load data from the untreated site, TL3, are presented in the first section of this paper to establish a baseline of information for agricultural practices where no BMP's were used. Concentration and load data from the BMP sites are then compared to data from TL3 in the second section of this paper to document potential improvements to runoff quality.

Suspended sediment in runoff from the untreated site

In 1996, all three oxbow lakes were stressed due to sediment (Knight et al. 2001). Much of the effect of sediment on the lakes was likely the result of conventional tillage, which was predominant among all of the watersheds at the beginning of the study. In some watershed locations, fields were plowed nearly to the edges of the lakes. As previously noted, TL3 remained in conventional tillage without BMP's throughout the study period. The distribution of suspended-sediment concentrations for TL3 is presented in figure 1. The median suspended-sediment concentration was about 1,350 milligrams per liter (mg/L), and concentrations exceeded 4,000 mg/L in 10 percent of the samples. Although no aquatic health standards currently exist for suspended-sediment concentrations for lakes, Cooper and Bacon (1980) stated that primary productivity (phytoplankton) was adversely affected when suspended-sediment concentrations exceeded 100 mg/L. All concentrations of suspended sediment in the runoff from TL3 exceeded 100 mg/L.

The average annual suspended-sediment load at TL3 was 4.9 tons per acre per year (t/ac/yr) (table 1). This sediment load was the highest of any of the MDMSEA runoff sites, but it was below load values reported in the literature for conventional tillage operations in other locations in the Mississippi Delta (9.3 t/ac/yr from 1973 to 1978 near Clarksdale, MS) and in upland areas of Mississippi (8.6 t/ac/yr from 1990 to 1993) (McDowell et al. 1988; Cullum et al. 1992).

Suspended sediment in runoff from BMP sites

As noted previously, soils, crops, drainage basin size, and farming practices varied substantially among the runoff sites in the three MDMSEA watersheds. These variations could limit data interpretation, especially when comparing suspended-sediment data from the untreated site, TL3, to data from the BMP sites. Although selected mathematical differences are cited in the following sections, these differences do not account for the site-to-site variations, and the reader is cautioned against over-interpretation of the results.

Statistical tests for significance were used to compare suspended-sediment concentrations from the eight BMP sites to concentrations from TL3, and to compare loads from BL3 and UL2 to loads from TL3 (Kruskal-Wallis test, Helsel and Hirsch 1992). The entire data set of concentrations and loads for the study period from each site was used in the tests. Results of the tests indicated whether differences in data sets from the BMP sites were statistically significant when compared to data sets from TL3. Selected results from these tests are presented in the following sections, but the data are not shown.

All of the median suspended-sediment concentrations at the eight BMP sites exceeded 100 mg/L (fig. 1). Although most of the suspended-sediment concentrations at the BMP sites were above this "threshold" concentration, there were some fairly substantial differences between suspended-sediment concentrations (and loads) at selected BMP sites compared to concentrations (and loads) at TL3. These differences, along with dilution in the lakes, could lower the concentrations of sediment in the lakes to acceptable levels to sustain primary productivity.

- The differences in suspended-sediment concentrations were statistically significant when comparing concentrations at TL2 to concentrations at TL3. The median suspended-sediment concentration was about 72 percent lower at TL2 than at TL3 (fig. 1). These low concentrations at TL2 could reflect changes in farming practice from conventional tillage to more conservation tillage which began in 1997 in the Thighman watershed. In addition, the lower portion of the TL2 drainage area is considered to be a wetlands/riparian area historically affected by periodic backwater conditions from beaver dams, damaged culverts, and high lake levels. As runoff drains from the fields through the long channel, backwater conditions could cause the velocity of the water to slow and allow sediment to settle.

- The differences in suspended-sediment concentrations were not statistically significant when comparing concentrations at BL3 and BL1 to concentrations at TL3. The median suspended-sediment concentration was slightly lower at BL3 and was slightly higher at BL1 compared to TL3 (fig. 1). These data indicate that the edge-of-field structural and vegetative treatments were ineffective in reducing suspended-sediment concentrations for oxbow lake watersheds such as Beasley where elevation differences from the upper part of the watershed to the lake are large.

- The differences in suspended-sediment loads were not statistically significant when comparing loads at BL3 to TL3, although the average annual suspended-sediment load was 16 percent lower at BL3 than at TL3 (table 1). When suspended-sediment loads were analyzed individually at BL3 (and normalized for flow), however, suspended-sediment load was reduced about 30 percent with boards in place (data not shown).

    - Suspended-sediment loads at BL3 sharply declined starting in 1998 and continuing through 1999 (fig. 2). If concentrations of sediment at BL3 were not statistically different from concentrations at TL3, then the lower loads at BL3 were due to less runoff in 1998 and 1999 (table 1). Although slotted-board risers were designed to reduce runoff, the lower amounts of runoff at BL3 were not due to the slotted-board riser. A field road that bisects the BL3 drainage was altered substantially in 1998 when corn was planted. After the field road was altered, runoff drained only to the sampling site during large runoff events. Therefore, less runoff was observed at BL3 from 1998 to 1999 due to the drainage basin alterations rather than due to the slotted-board riser.

    - Differences in suspended-sediment concentrations were statistically significant when comparing concentrations at BL4A, BL4B, and BL4 to concentrations at TL3. Median suspended-sediment concentrations were 70, 88, and 84 percent lower at BL4A, BL4B, and BL4, respectively, than at TL3 (fig. 1). The low concentrations at these sites reflected the ability of the undisturbed riparian area at Beasley to filter sediment from runoff.

    - Differences in suspended-sediment concentrations were statistically significant when comparing concentrations at UL2 and UL1 to concentrations at TL3. Median suspended-sediment concentrations at UL2 and UL1 were 62 and 48 percent lower, respectively, than concentrations at TL3 (fig. 1).

    - Differences in suspended-sediment loads were statistically significant when comparing loads at UL2 to loads at TL3. The average annual suspended-sediment load was 1.5 t/ac/yr at UL2, which is 70 percent lower than the average annual load at TL3. The average annual sediment load at UL2 was higher than the average annual sediment load for a 5.3-acre no-tillage soybean field in the upland areas of Mississippi, which was 0.22 t/ac/yr (Cullum et al. 1992).

SUMMARY

The highest suspended-sediment concentrations and loads were in runoff samples from TL3. The median suspended-sediment concentration was about 1,350 mg/L, and concentrations exceeded 4,000 mg/L in 10 percent of the samples. The average annual suspended-sediment load at TL3 was 4.9 t/ac/yr. This sediment load was the highest for any of the MDMSEA runoff sites, but it was below load values reported in the literature for conventional tillage operations in other locations in the Mississippi Delta and in upland areas of Mississippi.

Median concentrations of suspended sediment at BL1 and BL3 were nearly equal or actually greater than concentrations at TL3. In addition, the differences in suspended-sediment loads were not statistically significant when comparing loads at BL3 to loads at TL3. When suspended-sediment loads at BL3 were analyzed individually (and normalized for flow), however, the suspended-sediment loads were reduced about 30 percent with boards in place. These data indicate that the edge-of-field structural and vegetative treatments were ineffective in reducing suspended sediment for oxbow lake watersheds such as Beasley where elevation differences from the upper part of the watershed to the lake are large.

Suspended-sediment concentrations and loads were significantly lower where cultural practices such as conservation tillage with winter cover were utilized (UL1 and UL2). Median suspended-sediment concentrations were about 48 and 62 percent lower at UL1 and UL2, respectively, than at TL3. The average annual suspended-sediment load was 70 percent lower at UL2 than at TL3.

Data from the Beasley riparian area sites characterized the efficiency of an undisturbed riparian area for removal of sediment. Median concentrations of suspended sediment were 70, 88, and 84 percent lower at BL4A, BL4B, and BL4, respectively, than at TL3 and were among the lowest median concentrations for any of the other runoff sites.

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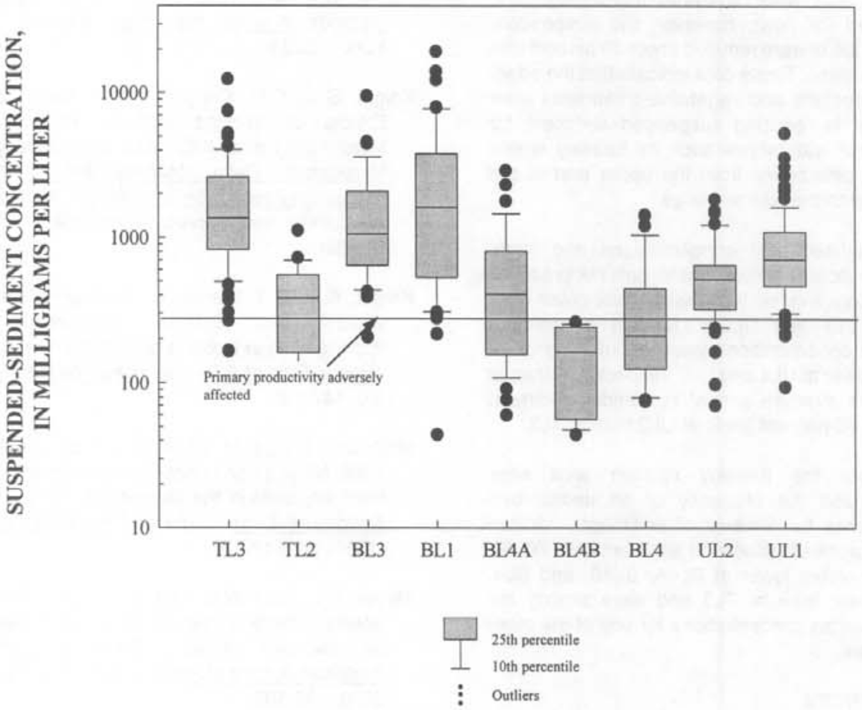

Figure 1. Distribution of suspended-sediment concentrations from composite samples collected at MDMSEA runoff sites, 1996-99.

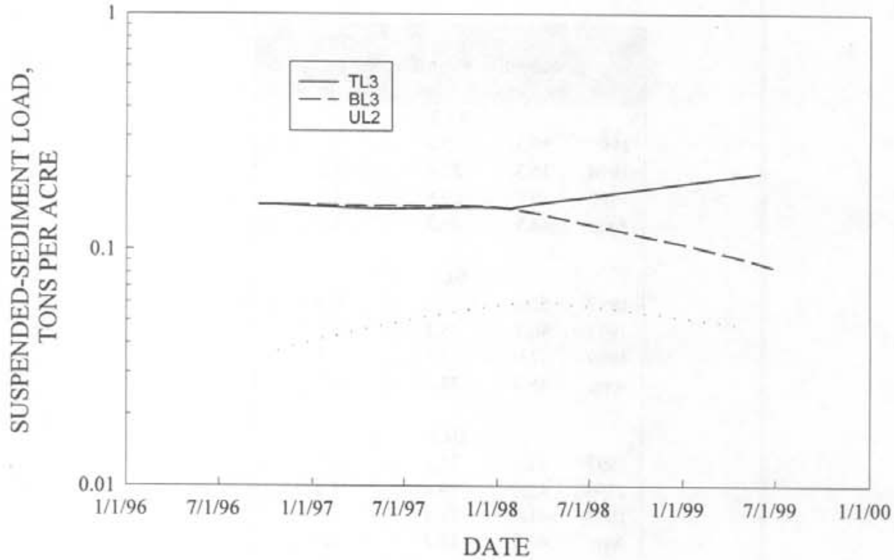

Figure 2. Locally-weighted scatterplot smoothes (LOWESS) for individual suspended-sedimentloads for three MDMSEA runoff sites, 1996-99.

Table 1. Annual suspended-sediment loads for three MDMSEA runoff sites, 1997-99

Year	Rainfall (inches)	Runoff (inches)	Suspended-sediment load (tons per acre)
		TL3	
1997	59.3	39.6	6.4
1998	35.3	25.4	3.8
1999	40.1	22.6	4.6
Avg.	**44.9**	**29.2**	**4.9**
		BL3	
1997	52.0	36.6	6.5
1998	40.3	15.1	3.5
1999	47.0	15.3	2.3
Avg.	**46.4**	**22.3**	**4.1**
		UL2	
1997	53.1	24.1	1.7
1998	45.8	19.4	1.6
1999	41.6	23.4	1.2
Avg.	**46.8**	**22.3**	**1.5**