PRELIMINARY SEDIMENT ANALYSIS FOR THE BROAD RIVER

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Abstract. Sediment Total Maximum Daily Loads (TMDLs) have been proposed for segments of the North, Middle, and South Forks of the Broad River. Our objectives are to present the sediment data that is available for the Broad River and to use HSPF to make a preliminary analysis of sediment sources. Total suspended solids (TSS) was measured at the USGS gaging station on the Broad River near Bell from 1958 to 1979 and the mean TSS concentration was a relatively high value of 75 mg/L. HSPF was used to predict TSS during the period 1971 to 1979. Land use data was from 1983. Only small adjustments to default discharge parameters were required to calibrate HSPF to the observed discharge at Bell. To calibrate the model for TSS, bed sediment parameters had to be adjusted including reducing the critical shear stresses for deposition and scouring and increasing the initial silt content and depth of bed sediments. These results may indicate that the source of the high suspended sediment levels in the Broad River is *legacy* sediment.

INTRODUCTION

Sediment Total Maximum Daily Loads (TMDLs) have been proposed for segments of the North, Middle, and South Forks of the Broad River (U.S. EPA, 2001c). The TMDL's were developed due to biological and habitat impairment, which was attributed to sediment. However, sediment measurements were not used in developing the TMDLs due to the scarcity of data for this basin. The draft TMDL documents recommended further analysis of the sediment loadings and revision of the TMDL as necessary.

One of the methods recommended by EPA for determining the acceptable maximum daily load of a contaminant is through the use of reference streams (U.S. EPA, 1999). These are streams that drain watersheds with relatively little disturbance and can be expected to represent natural or background levels. Rating curves (concentration of contaminant vs. discharge) can be used to account for different rates of flow.

Another method for determining the acceptable load is through the use of watershed-scale models such as those contained in the EPA BASINS software (U.S. EPA, 1999). BASINS includes GIS databases, meteorological data, and several watershed scale models including the Hydrological Simulation Program - Fortran (HSPF) (U.S. EPA, 2001b).

Our objectives are to present the sediment data that are available for the Broad River and to use HSPF to make a preliminary analysis of sediment sources.

METHODS

The most extensive data on sediment in the Broad River basin has been collected at the USGS gaging station near Bell, Georgia where state highway 17 crosses the river. This site is close to the confluence with the Savannah River and includes most of the Broad River basin with a drainage area of 1,430 mi^2.

We divided the watershed into six subwatersheds (North/Middle Fork, Hudson, South Fork, Long Creek, Upper Broad, and Lower Broad) that ranged in size from 150 to 305 mi^2. Landuse categories were agricultural, barren, forest, and urban or built-up lands. The soil layer was from the STATSGO database.

We compared HSPF predictions of discharge and total suspended sediment (TSS) to those measured at the U.S. Geological Survey (USGS) station near Bell. Daily gage data were available for the years from 1937 to 1998 (USGS. 2001). There were 377 measurements of TSS made between 1958 and 1979 (Pearlman, 1985). The nearest weather station in the BASINS database was located at Athens and it covered the period from 1970 to 1995. Landuse data in BASINS was from 1983. As a result, we chose to use gage data from 1979 through

1989 to calibrate HSPF for water flow and TSS data from 1970 through 1979 to calibrate for TSS.

RESULTS

The rating curve for the measured TSS vs discharge data from the USGS station near Bell is shown in Figure 1. Discharge (Q) was normalized by dividing by the average discharge (Q_o) of 1,818 cfs. The equation of the regression line was TSS = $75.3\ (Q/Q_o)^{1.08}$ indicating a TSS of 75.3 mg/L at the mean discharge rate. By comparison, the same analysis produced a corresponding value for the Chattooga River near Clayton of 10.7 mg/L (data not shown), indicating that TSS has been relatively high in the Broad River.

BASINS includes a default file that contains values for all of the HSPF parameters. The values that we used for selected parameters related to flow and sediment are shown in Table 1. Our approach was to adjust as many parameters as possible based on known relationships with soil or landuse characteristics and to calibrate the remaining parameters. HSPF divides the soil profile into an upper zone where evaporation and transpiration occur readily, a lower zone where transpiration occurs, and a groundwater zone. We used the water table depth and available water (in/in) from the soil layer in each subwatershed to calculate the total available water in the upper (UZSN) and lower (LZSN) zones, assuming a 6-in thick upper zone. BASINS Draft Technical Note 6 provides guidance in selecting water flow parameters (U.S.

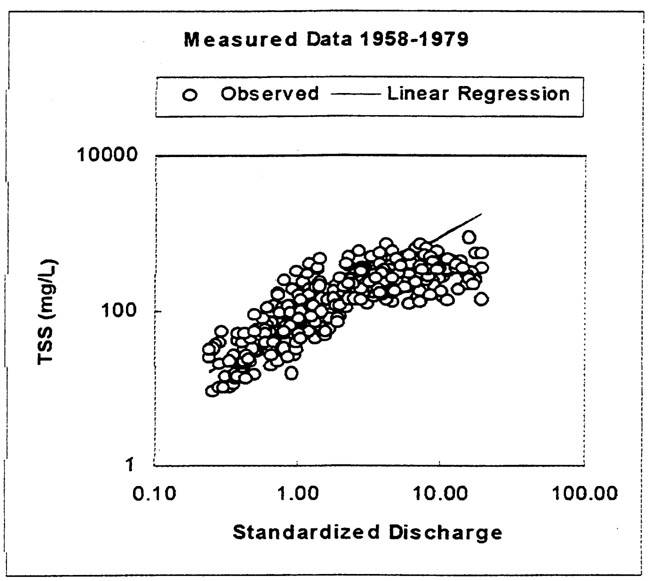

Figure 1. TSS vs. standardized discharge for USGS station near Bell, GA, 1958-1979.

EPA, 2001a). It suggests that the infiltration capacity parameter (INFILT) can be calculated by assuming that the soil field saturated hydraulic conductivity (permeability) is equal to twice the product of INFILT and the interflow parameter (INTFW). We used permeability from the soil layer in each subwatershed to calculate INFILT in this manner. Technical Note 6 also provides guidance on adjusting the monthly lower zone transpiration index (MON-LZETP) based on cover and we followed these recommendations. It also provides guidance on adjusting the vegetation interception storage capacity based on cover and we did that as well. We used the default values for impervious land percentages: 50% of the urban or built-up land was impervious and all other landuses were 100% pervious. The landuse layer in BASINS does not distinguish between cultivated and pasture agricultural land. We assumed that the agricultural land was 50% cultivated and 50% pasture. Since the USGS gage data was average daily values, we used a time step of one day for HSPF in calibrating dishcarge.

With these adjustments to the water flow parameters and before calibrating, the total predicted discharge for 1980 to 1989 was 5.449 million cu ft, compared to the observed 5.554 million cu ft. Generally, base flow was slightly over predicted and the hydrographs were over predicted early and under predicted late. We made small adjustments to the groundwater recession rate (AGWRC), the fraction of water lost to deep groundwater (DEEPFR), INTFW, and the interflow recession rate (IRC) to calibrate water flow (Table 1). The predicted discharge for 1980 to 1989 after these adjustments was 5.507 million cu ft. The storm hydrographs were reasonably well predicted, although there was still a tendency to under predict the peaks and over predict the recession limb, although base flow was well predicted (data not shown).

In regard to the erosion parameters, we assumed that the soil detachment coefficient (KRER) was equal to the USLE soil erodibility factor in the soil layer (assuming a practice factor of unity), as suggested by Donigian et al. (1978). We also adjusted monthly cover (MON-COVER) and rate of sediment attachment (AFFIX) to reflect landuse differences based on six HSPF simulations for the Piedmont region in Virginia (Donigian et al., 1999) (Table1). In regard to bed sediment parameters, we adjusted the effective diameter of the bed sand sediment based on the Piedmont smulations in Donigian et al. (1999), as well as the silt and clay fall velocities.

Since the USGS sediment data represented instantaneous values, we used the minimum time step of

Table 1. HSPF Parameters Adjusted to Account for Soil Properties or Landuse and those Calibrated

Parameter	Description	Default Value	Adjusted Value	Calibrated Value
UZSN	upper zone nominal storage (in)	1.13	0.54-0.72[1]	
LZSN	lower zone nominal storage (in)	14.1	3.99-7.51[1]	
INFILT	index to soil infiltration capacity (in/hr)	0.16	0.32-0.72[1]	
MON-LZETP	monthly lower zone ET parameter	0.2-0.4	0.2-0.7[2]	
CEPSC	interception storage capacity (in)	0.10	0.10-0.25[2]	
AGWRC	groundwater recession rate	0.98		0.97
DEEPFR	fraction of groundwater lost to deep flow	0.10		0.09
INTFW	interflow in flow	0.75		1.0
IRC	interflow recession	0.50		0.30
MON-COVER	monthly cover by vegetation or mulch	0.88	0.10-0.95[3]	
AFFIX	daily decrease in sediment attachment rate	0.030	0.002-0.010[3]	
KRER	soil detachment coefficient	0.01	0.26-0.29[1]	
KGER	scour coefficient for gully erosion	0.01		0.02
SAND-D	effective diameter of transported bed sand (in)	0.04	0.005[3]	
SAND-RHO	density of transported bed sand (g/cm^3)	4.0	2.65[3]	
SILT-W	fall velocity in still water for bed silt (in/sec)	0.05	0.005[3]	
CLAY-W	fall velocity in still water for bed clay (in/sec)	0.05	0.0001[3]	
M	bed sediment erodibility coefficient	0.90	0.40[3]	
SILT-TAUCD	critical bed shear stress for deposition (lb/ft^2)	0.10		0.05
CLAY-TAUCD	critical bed shear stress for deposition (lb/ft^2)	0.12		0.01
SILT-TAUCS	critical bed shear for scouring (lb/ft^2)	0.30		0.10
CLAY-TAUCS	critical bed shear for scouring (lb/ft^2)	0.34		0.01
SAND-INIT	initial bed sand fraction	0.60		0.40
SILT-INIT	initial bed silt fraction	0.20		0.40
BEDDEP	initial total depth of bed (ft)	1.5		5.0

[1]Different values depending on soils.
[2]Different values depending on landuse as suggested in US EPA (2001a).
[3]Similar to values used for Piedmont studies in Donigian et al. (1999).

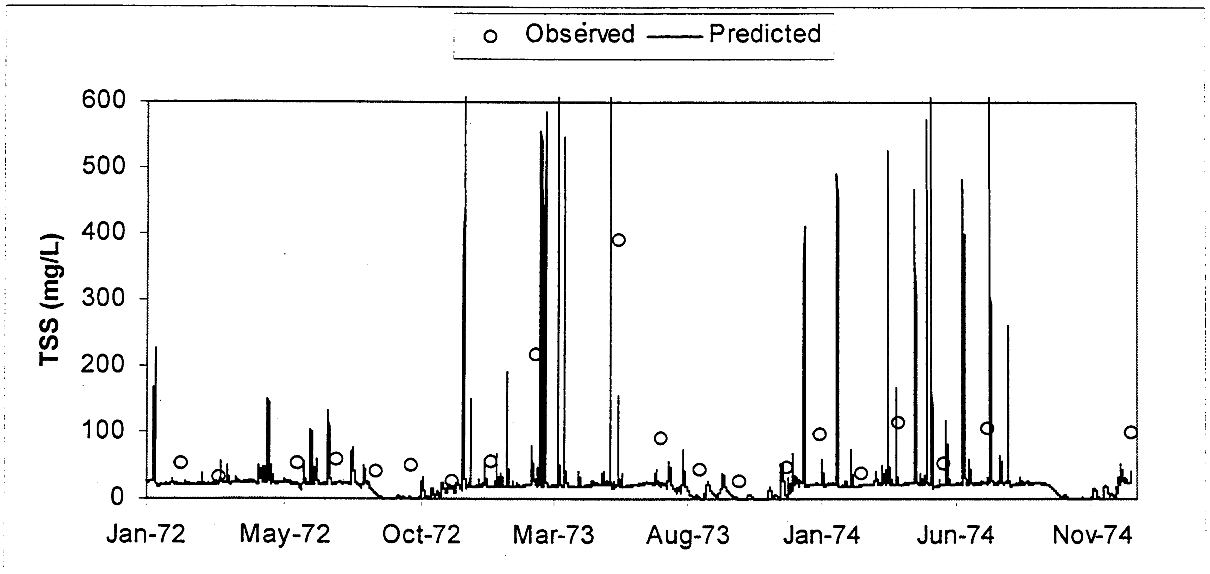

Figure 2. Predicted and observed TSS near Bell, GA, January 1972 to December 1974.

one hour for HSPF in calibrating TSS. Without any calibration of the erosion and sediment parameters, the model generally predicted less than the observed TSS Measurements of TSS were never more frequent than monthly so for a large storm, only a single observed value of TSS was usually available. As such, the observed TSS pollutographs for large storms were ill-defined. In contrast, many of the measurements of TSS occurred under baseflow conditions or after small storms so this value was well defined by the the observed data. As such, we focused on calibrating to the baseflow TSS.

To get baseflow TSS to increase without causing extremely large storm TSS, we reduced the critical shear stresses for bed sediment deposition and scouring and increased the initial silt content and depth of bed sediments (Fig. 2). Most of these parameters were found to be sensitive HSPF parameters in a sediment study by Fontaine, and Jacomino (1997). The maximum annual erosion rate from upland areas for all landuses varied between 1.7 and 3.3 ton/acre, which are generally low rates. These results may indicate that the source of the high suspended sediment levels in the Broad River is *legacy* sediment from the first half of the 20th century when most of the tillable land was in cotton production.

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