UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SUSPENDED-SEDIMENT TRANSPORT IN THE BIG EAU PLEINE RIVER BASIN, CENTRAL WISCONSIN

Open-File Report 78-313

Prepared in cooperation with the

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CONVERSION FACTORS

For the use of those readers who may prefer to use metric units rather than U.S. customary units, the conversion factors for terms used in this report are listed below:

Multiply U.S. customary units	By	To obtain metric unit
mi^2 (square miles)	2.590	km^2 (square kilometers)
tons	.9073	t (metric tons)
$tons/mi^2$ (tons per square mile)	.3503	t/km^2 (metric tons per square kilometer)
ft^3/s (cubic feet per second)	2.832×10^{-2}	m^3/s (cubic meters per second)

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By S. M. Hindall

ABSTRACT

Suspended-sediment yields in the Big Eau Pleine River basin are low to moderate in comparison with other drainage basins in Wisconsin. Average annual yield in the Big Eau Pleine River near Stratford is 32 tons per square mile, with an annual yield ranging from 1.0 to 64 tons per square mile. Fenwood Creek at Bradley and Freeman Creek at Halder, two smaller tributary basins, have average annual yields of 3.3 and 7.9 tons per square mile, respectively. Suspended-sediment concentrations in the basin ranged from 0 to 960 milligrams per liter, with a median concentration at the Stratford site of 13 milligrams per liter. Ninety percent of the material transported by the streams of the Big Eau Pleine basin is finer than sand and is made up of about equal percentages of silt and clay.

A 13-year average of about 9,400 tons per year of suspended sediment is transported to the Big Eau Pleine Reservoir by streamflow and overland flow, whereas about 2,500 tons per year leaves the reservoir in its outflow. Considering only sediment inflow and outflow by streamflow and overland flow, and assuming the 2,500 tons per year is approximately the long-term average, the reservoir trap efficiency would be greater than 70 percent. The actual trap efficiency of the Big Eau Pleine Reservoir probably is somewhat higher than 70 percent because bedload transport of the streams and sediment inflow from shoreline erosion were not measured.

INTRODUCTION

The Big Eau Pleine River basin is in north-central Wisconsin in the Northern Highland Geographic Province (Martin, 1932). Figure 1 shows its location in the State. The Big Eau Pleine is tributary to the Wisconsin River. Its basin has a highly agricultural land use, with only about 20 percent of the basin forested.

A 7,000-acre (approximately) reservoir, the Big Eau Pleine Reservoir, is located in the lower end of the basin. It has a usable storage capacity of 4,457,000,000 ft^3. Two small streams, Fenwood and Freeman Creeks, flow directly into the reservoir.

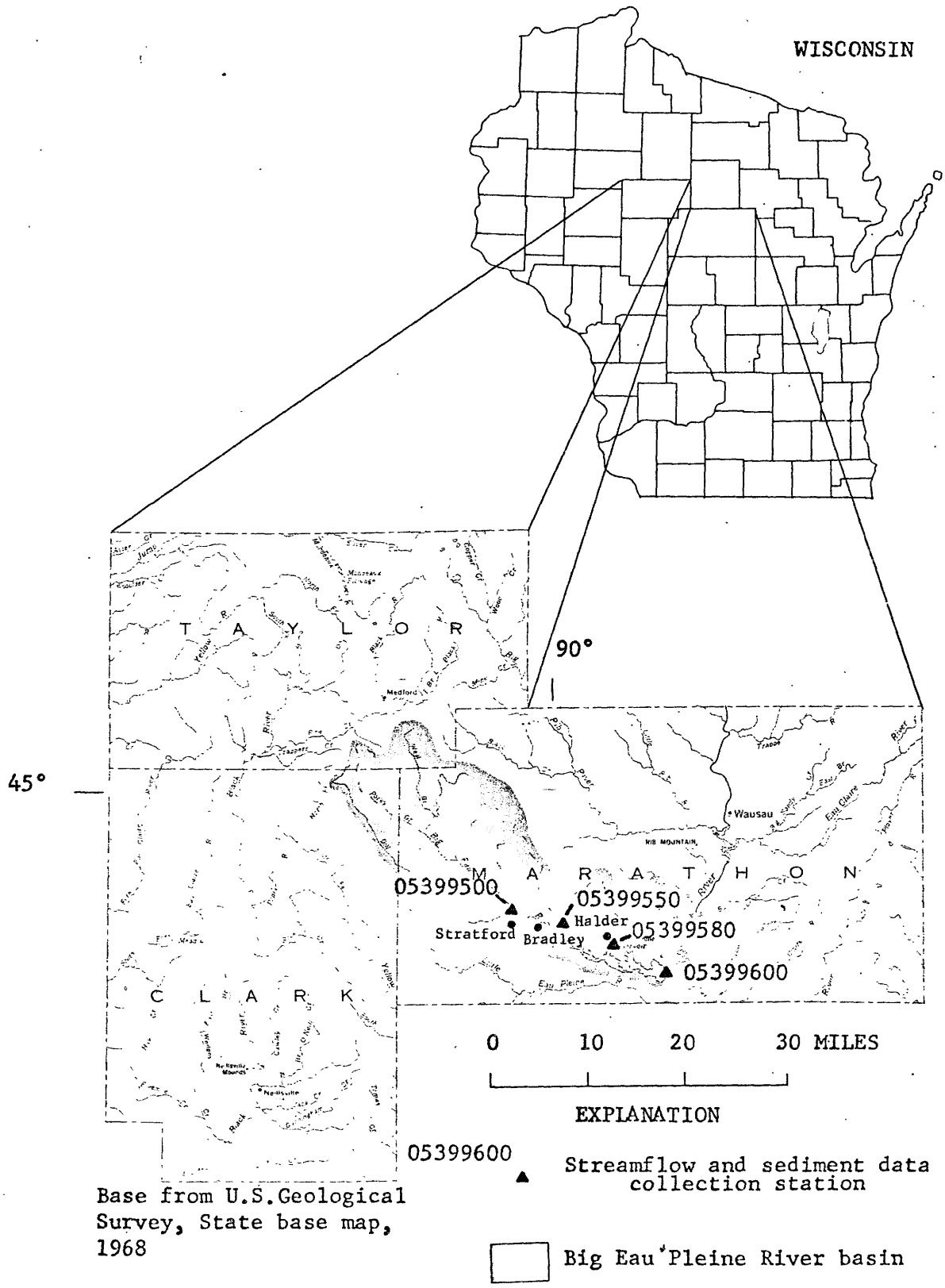

Figure 1. Location of Big Eau Pleine River basin and sediment-monitoring stations.

The Big Eau Pleine near Stratford, Wis., has the longest uninterrupted suspended-sediment record in the State. Suspended sediment was sampled for 13 water years (WY), beginning in October 1964 and ending in September 1977. Suspended-sediment samples were collected at three additional stations in the basin from May 1974 through September 1977. These stations were Fenwood Creek at Bradley, Freeman Creek at Halder, and Big Eau Pleine River near Knowlton below the reservoir. The drainage areas above these monitoring sites are 224 mi^2 above Stratford, 36.9 mi^2 above Bradley, 26.5 mi^2 above Halder, and 363 mi^2 above Knowlton.

The purpose of this report is to discuss the effects of the Big Eau Pleine Reservoir on sediment transport of the river and present sediment-transport data for the river basin.

Before 1974 suspended-sediment data were collected from the Big Eau Pleine River to determine its sediment-yield characteristics. After 1974 determination of the amount of sediment transported to and from the reservoir by the major tributaries became the primary purpose for data collection.

Suspended-sediment-concentration samples were collected intermittently at all four sampling sites. The major emphasis on sampling was during periods of high water because most of the suspended sediment was transported then. The Big Eau Pleine River at Stratford, the largest of the reservoir inflow streams, was sampled about 32 times per year. The two smaller inflow streams at Bradley and Halder were sampled approximately 6 and 7 times per year, respectively. The outflow station at Knowlton was sampled about 46 times per year. A few samples were collected at the Stratford sampling station for determination of suspended-sediment particle size. The data collected through September 1977 were published in the U.S. Geological Survey annual report series, "Water Resources Data for Wisconsin".

The sediment samples were collected using standard techniques (Guy and Norman, 1970) by either USGS personnel or trained local observers. Suspended-sediment-concentration samples were analyzed either by an evaporation or filtration method in a USGS laboratory. Particle size was determined using one or a combination of the following methods: sieving, pipeting, settling in a visual-accumulation tube, or settling in a bottom-withdrawal tube (Guy, 1969). Suspended-sediment loads and yields at the Stratford, Bradley, and Halder stations were calculated using a flow-duration, sediment-rating curving method (Miller, 1951). Sediment loads at the Knowlton station were estimated by averaging the individual suspended-sediment discharge values.

SEDIMENT YIELDS IN THE BIG EAU PLEINE RIVER BASIN

Suspended-sediment yields in the Big Eau Pleine River basin are low to moderate in comparison with yields in other areas of Wisconsin (Hindall, 1975). Table 1 presents the calculated yields for the Big Eau Pleine

Table 1.--Annual suspended-sediment yields and loads in the Big Eau Pleine River basin

Water year	Reservoir inflow						Reservoir outflow	
	Big Eau Pleine River near Stratford, Wis. (05399500)		Fenwood Creek at Bradley, Wis. (05399550)[1]		Freeman Creek at Halder, Wis. (05399580)[1]		Big Eau Pleine River near Knowlton, Wis. (05399600)	
	(tons/mi^2)	(tons)	(tons/mi^2)	(tons)	(tons/mi^2)	(tons)	(tons/mi^2)	(tons)
1965	64	14,400						
1966	59	13,200						
1967	64	14,300						
1968	63	14,200						
1969	40	9,030						
1970	20	4,490						
1971	32	7,160						
1972	35	7,780						
1973	38	8,460						
1974	5.3	1,180	3.3	120	7.9	210	7.7	2,800
1975	7.6	1,690	3.3	120	7.9	210	8.5	3,100
1976	36	8,100	3.3	120	7.9	210	6.6	2,400
1977	1.0	220	3.3	120	7.9	210	5.0	1,800

[1]4-year average.

River near Stratford, Fenwood Creek at Bradley, and Freeman Creek at Halder and the estimated yields for the Big Eau Pleine River near Knowlton.

Suspended-sediment yields from Fenwood Creek at Bradley and Freeman Creek at Halder were typical of yields from basins in the Northern Highland Province of Wisconsin, where yields are generally less than 10 tons/mi^2. The 4-year averages (1974-77 WY) for Fenwood and Freeman Creeks were 3.3 and 7.9 tons/mi^2 per year, respectively.

The 13-year weighted average annual yield for the Big Eau Pleine River near Stratford was 32 tons/mi^2, or considerably higher than yields from most Northern Highland Province basins. Annual yields ranged from 1 ton/mi^2 in WY 1977 to 64 tons/mi^2 in WY 1965 and 1967. Although the yield at Stratford is high for Northern Highland Province basins, it is typical of yields from other agricultural basins in north-central Wisconsin.

During the 13-year data-collection period, the annual suspended-sediment load of the Big Eau Pleine River near Stratford ranged from 220 tons in WY 1977 to 14,400 tons in WY 1965 (table 1). The variation in annual load and water discharge at the Stratford station is shown in figures 2 and 3. Figure 2 is a double mass curve of cumulative annual water discharge versus cumulative annual suspended-sediment load. Changes in the slope of the curve indicate changes in the water discharge-sediment load relation. A steeper-than-average slope curve indicates that the stream had an increase in the rate of sediment transport. A flatter curve indicates a decrease in transport rate. The dry periods of 1974-75 and 1976-77 are evident by a pronounced decrease in slope. The actual variation in annual water and suspended-sediment discharge is shown on figure 3. The illustration indicates a close relation between suspended-sediment load and annual water discharge for the Big Eau Pleine River near Stratford.

A regression analysis of the sediment-yield data gives the following relation:

$$Q_s = 1.27 \times 10^{-4} Q_{aw}^{2.37}$$

where Q_s = annual suspended-sediment yield, in tons per square mile, and

Q_{aw} = annual water discharge, in cubic feet per second.

In the Northern Highland Province suspended-sediment yield varied as the -0.72 power of lake and marsh area (Hindall, 1975). The regression equation is as follows:

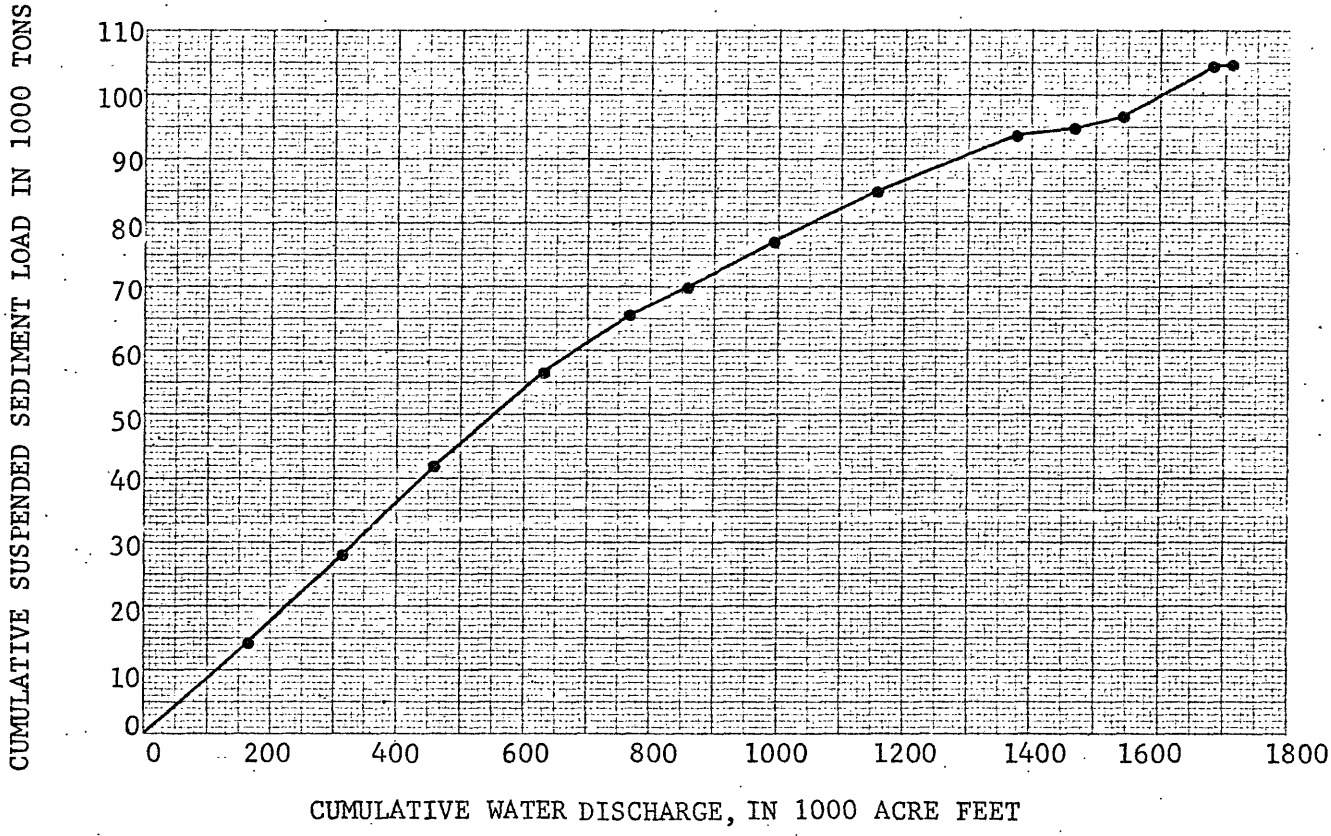

Figure 2. - Cumulative annual water discharge versus cumulative annual suspended-sediment load for the Big Eau Pleine River near Stratford, Wisconsin.

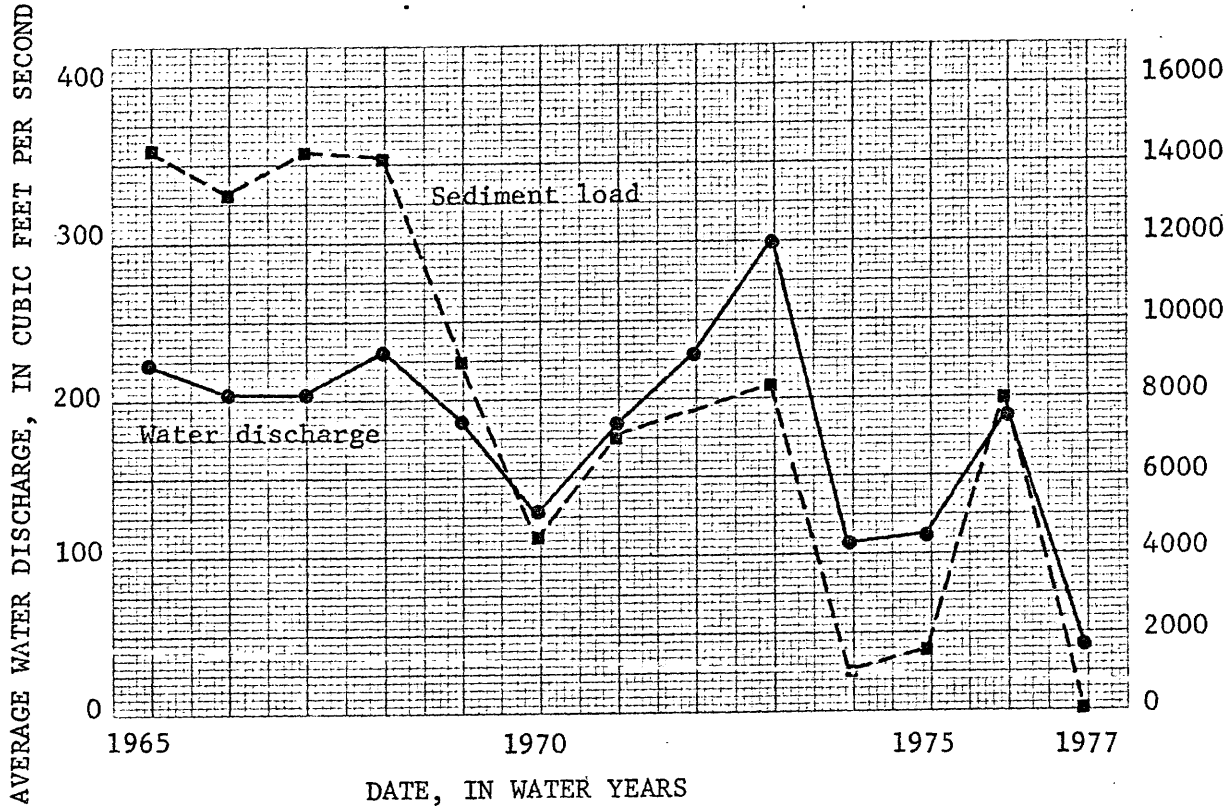

Figure 3. - Annual water and suspended-sediment load for Big Eau Pleine River near Stratford, Wisconsin.

$$Q_s = 51.1\ St^{-0.72}$$

where Q_s is the average annual sediment yield, in tons per square mile, and

St is the percentage of lake and marsh area in the drainage basin.

Measured suspended-sediment concentration in the Big Eau Pleine River basin ranged from 0 to 960 mg/L (milligrams per liter). The maximum range was recorded at the Stratford station; the minimum at the Bradley station. Table 2 lists the maximum, minimum, and median values of suspended-sediment concentration measured at the four monitoring stations in the basin.

Particle-size analyses of three suspended-sediment samples from the Big Eau Pleine River at Stratford indicate that the sediment is about 10 percent sand, 45 percent silt, and 45 percent clay. Figure 4 illustrates a low percentage of sand and about equal percentages of silt and clay.

SUSPENDED-SEDIMENT TRANSPORT TO AND FROM THE BIG EAU PLEINE RESERVOIR

The Big Eau Pleine Reservoir is a large sediment trap that allows passage of only part of the sediment inflow. Sediment eroded from stream channels and upland areas is carried into the reservoir by streamflow and overland flow. Sediment from shoreline erosion, caused by wave action, also enters the reservoir. The only way sediment leaves the reservoir is in the water discharge at the Big Eau Pleine Dam. Calculations of suspended-sediment inflow were made for the three major streams entering the reservoir, and estimates of sediment outflow were made for the one stream leaving the reservoir. Calculated and estimated loads at all four sites for the periods of sediment-data collection are given in table 1. Measurements or estimates of bedload transport and direct shoreline erosion were beyond the scope of this project.

About 9,400 tons per year of suspended sediment enters the reservoir by streamflow and overland flow, whereas only about 2,500 tons/yr leave by streamflow. The inflow estimate was calculated using a sediment yield of 32 tons/mi^2 for the drainage area above the upstream end of the reservoir and 16 tons/mi^2 for the drainage area directly surrounding the reservoir. The 32 tons/mi2 per year is a measured 13-year average, whereas the 16 tons/mi2 per year is an estimated 13-year average. The 16 tons/mi^2 is based on a comparison of yields at Stratford, Bradley, and Halder for the four below-normal runoff years of data collection to the yields at Stratford for the 13-year period and is strictly an estimate. No estimate was made for shoreline erosion, which could be significant. The 2,500 tons per year leaving the reservoir is an estimate based on 4 years of actual sediment load and streamflow determinations and,

Table 2.--Suspended-sediment concentrations measured in the Big Eau Pleine River basin

Station	Maximum		Minimum		Median	
	Concentration (mg/L)	Date	Concentration (mg/L)	Date	Concentration (mg/L)	Date
Big Eau Pleine River near Stratford, Wis. (05399500)	960	June 6, 1966	0	Several days	13	Several days
Fenwood Creek at Bradley, Wis. (05399550)	50	Feb. 19, 1976	2	do.	5	Do.
Freeman Creek near Halder, Wis. (05399580)	62	Mar. 25, 1976	1	do.	4	Aug. 22, 1975 Feb. 19, 1976
Big Eau Pleine River near Knowlton, Wis. (05399600)	80	Oct. 14, 1974	0	May 27, 1974	8	Several days

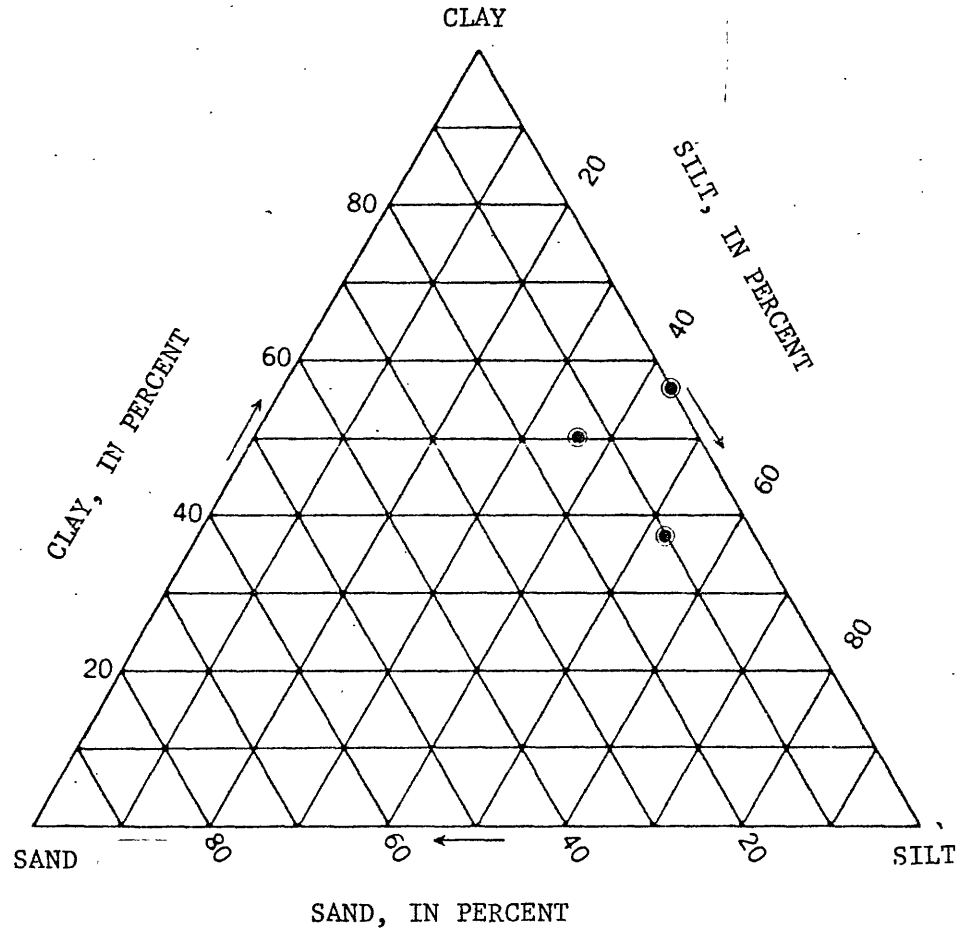

Figure 4. Percentage of sand, silt, and clay in suspended material, Big Eau Pleine River near Stratford, Wisconsin.

because of the reservoir's size, is probably a good estimate of the long-term average. Using the estimated suspended-sediment inflow and outflow, the trap efficiency of the Big Eau Pleine Reservoir is greater than 70 percent. The value probably is lower than the actual trap efficiency because sediment from bedload transport and shoreline erosion was not included.

SUMMARY AND CONCLUSIONS

Annual suspended-sediment yields and loads were calculated or estimated at four different locations in the Big Eau Pleine River basin. Annual yields from 1965 through 1977 for the Big Eau Pleine River near Stratford ranged from 1.0 ton/mi^2 (220 tons) to 64 tons/mi^2 (14,400 tons). At two tributary sites, Fenwood Creek at Bradley and Freeman Creek at Halder, the 1974-77 average annual yields were 3.3 and 7.9 tons/mi^2 (120 and 210 tons), respectively. Estimates of annual suspended-sediment load ranged from 1,800 to 3,100 tons for the river below the reservoir near Knowlton for the 1974-77 water-year period. The maximum recorded suspended-sediment concentration in the basin was 960 mg/L, but the concentrations were generally less than 13 mg/L. Approximately 90 percent of the suspended sediment in the Big Eau Pleine River from 1965-77 was silt and clay, and the remaining 10 percent was sand. Suspended-sediment inflow, not including sediment from shoreline erosion, was about 9,400 tons per year, whereas outflow was about 2,500 tons per year. Trap efficiency for the Big Eau Pleine Reservoir, not including sediment from bedload transport and shoreline erosion, is therefore greater than 70 percent.

The low-to-moderate suspended-sediment yields in the basin cause few problems to the stream channels or the reservoir. The low yields also indicate that upland and stream-channel erosion is not significant, even though there may be local upland areas and stream-channel reaches where erosion is significant.

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