SEDIMENT TRANSPORT RATES
FOR COLES CREEK AND BUFFALO RIVER
NEAR NATCHEZ, MISSISSIPPI - PROGRESS REPORT

by

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INTRODUCTION

Since 1959, work by USDA Sedimentation Laboratory personnel has been underway on Pigeon Roost Creek and its tributaries and in laboratory test channels to investigate procedures for determining the sediment transport rate. Procedures have been used that involve streamflow measurements to define stage-discharge relations for the streams and sediment sampling to determine the suspended sediment concentration in the flow.

The investigation on Coles Creek and Buffalo River is essentially an extension of the Pigeon Roost Creek investigations to larger streams with greater flow discharges and supposedly higher sediment loads. The choice of these two streams for this investigation is based on proposed diversions of these channels by the Corps of Engineers and their request for sediment load information through the Soil Conservation Service. This report primarily describes the methods being used to estimate the sediment transport rates. Preliminary analyses of the data are presented, but these are subject to revision as more data are obtained.

Both of these streams are in the same general climatic area and drain watersheds along the bluff line of the Mississippi River. Coles Creek near Church Hill, Miss., drains a watershed of 257 square miles and Buffalo River at the U. S. Highway 61 bridge near Woodville, Miss., drains 182 square miles. The maximum flood of record for both streams is on the order of 40,000 cfs. and both have rather low base flows (1, 2) 1/.

1/ Numbers in brackets refer to references cited.

In other respects these streams are very different. Buffalo River has a relatively wide channel with an average sand bed width of about 225 feet, and has a watershed of classical drainage pattern with one main channel and much smaller tributaries. Coles Creek has a sand bed width of only about 110 feet and a drainage network with two main forks (North and South Forks) of about equal drainage areas.

Water stage records and flow measurements for Buffalo River have been collected at the U. S. Highway 61 bridge by the U. S. Geological Survey since 1942. These records include well-defined stage-discharge and flow duration curves that are essential to a sediment yield investigation. Records are available for Coles Creek for the period of June 1961 to December 1962 (1). A tenative stage-discharge relationship was developed by USGS from flow measurements made during that period.

OBJECTIVES

Reliable estimates of the sediment yield and transport rates may be crucial in insuring success of river rectification works like those proposed by the Corps of Engineers for Coles Creek and Buffalo River. Numerous transport relationships have been proposed for estimating the bed material transport rates. Each computation method has met with varying degrees of success and failure depending upon the validity of underlying assumptions for a particular application. In addition, the fine sediment load or wash load, which may account for most of the sediment load of a stream, eludes any general computation method based on streamflow variables. Thus, at least a minimum flow measurement and sampling program for each channel in question is required to verify existing procedures or to develop new, more reliable or simpler procedures for estimating the transport quantities.

Included within the overall objective of determining the expected annual yield of sediment by the Buffalo River and Coles Creek watersheds are the following four specific objectives:

1. To investigate the relationships between the pertinent flow variables and the best estimate of the bed material transport rate.

2. To measure the fine sediment concentration during flood flows and attempt to correlate the concentration with flow discharge and season.

3. To determine the average sediment delivery by the channels from load-discharge relationships that will be developed from the data and flow duration information.

4. To compare the best estimates of the sediment transport rates with rates predicted by published computation procedures and flume model tests.

EXPERIMENTAL PROCEDURE

River reaches that include bridge sections to facilitate flow measurement and sampling were chosen for each stream. Since the reach of Buffalo River including the U. S. 61 bridge section is less than ideal because of excessive channel curvature immediately upstream and severe bank erosion, a second more uniform reach was also selected. Surveys of the channel cross section geometry at five ranges along each of the three test reaches have been completed by SCS personnel. These surveys provide the channel geometry information and low water slopes for use in sediment load computations.

Flow information including water stage records is being provided by the USGS gage on the U. S. 61 bridge over Buffalo River and by the Agricultural Research Service recording gage on the county bridge about 0.7 mile below the confluence of the North and South Forks of Coles Creek.

The stage discharge relationship supplied by USGS provides adequate discharge information for Buffalo River, but ARS flow velocity measurements form a vital part of the data collection program on Coles Creek. During periods of significant flow, velocity is measured with a current meter at six to eight points across the channel and these measurements are related to the water stage recorder readings. These measurements will permit the development of a stage-discharge relationship for this channel.

Flood water samples are being collected at the bridge section over each stream. The sampling equipment at each stream includes a 3/4-ton pickup truck on which is mounted a power-driven reel and extendable crane and a 200-pound P-63 sampler used for collecting depth-integrated samples. The samples are collected at several points across the channel. Appropriate identifying information, including stage and time of sampling, is noted on each bottle. They are weighed and returned to the sediment analysis laboratory for concentration and particle size distribution determinations. The concentration data are then related to the flow discharge through the stage-discharge relationships.

During September 1968 about twenty crest gages were installed along each of the surveyed reaches. A new, inexpensive crest gage (Figure 1) was dusted with powdered kaolinite. The bend in the tubing near the top prevents rain from entering and the small holes allow air to escape as the water rises in the tubing. As the flood water rises, the kaolinite film is removed leaving a well-defined crest indication. Redusting the tubing with kaolinite, using a standard garden duster, completely obscures any previous crest indication.

The first inspection of the gages, in January 1969, showed them to be in good working order. Condensation had caused minor streaking of the kaolinite film in the upper part of the tubes, but crest marks from a flood that occurred about four weeks before the inspection were plainly visible and higher flood crests would have been recorded.

OBSERVATIONS AND PRELIMINARY INTERPRETATIONS

One of the first steps in the Coles Creek-Buffalo River project was the sampling and analysis of the material comprising the channel beds. Figure 2 gives the cumulative bed material particle size distributions for the streams. The bed material in Coles Creek appears to be slightly coarser with a wider range of sizes than that in Buffalo River. A few gravel bars were observed along Coles Creek and their contribution of about 3 percent in material coarser than about 2 mm accounts for most of the difference in the size distributions. Median particle diameters of 0.30 and 0.33 mm and geometric standard deviations $\left(\sqrt{\frac{D_{84}}{D_{16}}}\right)$ of 1.46 and 1.69 for Buffalo River and Coles Creek, respectively, characterize the bed materials.

Table 1 lists the discharge measurements that have been obtained from Coles Creek. Each discharge was computed from velocity and depth measurements taken at six to eight points across the channel. Each velocity measurement was taken at a point 0.6 of the local depth from the water surface. Figure 3 shows the depth-discharge relations defined by these measurements and those obtained by USGS during 1961-62. The agreement between the two sets of data suggests a fairly stable relationship for appreciable discharges.

Tables 2 and 3 give the sediment concentration analyses and load computations for each series of sediment samples collected from Coles Creek and Buffalo River, respectively. Each sediment sample was analyzed separately to depict any lateral variation in concentration across the channel. For any series of samples the fine sediment concentration was essentially constant across the channel but the coarse sediment concentrations varied. Some samples exhibited exceedingly high sand concentrations, which indicated that the sampler nozzle was allowed to rest too long near the bed or was buried in a dune face. Such obviously incorrect sand concentrations have been deleted from the average coarse sediment concentration determinations. Accurate samples of the coarse sediment in motion are extremely difficult to obtain over an alluvial bed, but fortunately the fine sediment load is predominant. Errors in the coarse sediment yield determinations will have only a small effect on the total sediment yield.

Figures 4 and 5 show plots of the fine sediment transport rate-discharge data for Coles Creek and Buffalo River. The data points exhibit more scatter than is desirable, but the consistency of the concentrations in samples of each set suggest that this deviation of average concentration is real and not due to sampling errors. This variation in the transport-discharge relation for Coles Creek may be attributable to the dual watershed drainage system (North and South Forks). The concentration may vary depending upon the relative flow contribution from each of these watersheds as well as changes in vegetative cover with season. Even with the scatter unresolved, the data seem to suggest an average relationship which when based on enough data should provide a reliable, long-term sediment yield estimate.

Table 1.--Discharge Measurements for Coles Creek near Church Hill, Mississippi

Date	Width (feet)	Area (sq.ft.)	Mean Velocity (fps.)	Gage height	Discharge (cfs.)	Number meas. sections
8/26/67	113.0	361.8	2.09	5.73	756	7
8/27/67	192.0	2,073.7	7.54	15.39	15,630	6
8/27/67	221.0	2,737.3	7.33	19.20	20,070	8
8/27/67	211.0	2,381.4	6.42	18.20	15,300	8
8/27/67	180.0	1,503.3	4.70	13.95	7,070	8
8/28/67	135.0	523.5	3.89	7.88	2,030	7
9/6/67	153.0	922.7	4.07	10.14	3,759	8
12/15/67	182.0	1,750	5.96	14.30	10,437	8
12/15/67	162.0	1,232	3.80	11.81	4,678	8
12/15/67	132.0	617	2.88	8.06	1,776	7
4/13/68	159.0	1,071	5.94	11.29	6,357	8
4/14/68	127.0	326.5	2.64	6.68	863	6
5/26/68	185	1,477	6.35	15.36	9,388	6
5/26/68	148	636	3.58	9.22	2,276	5
12/1/68	147	810	5.58	10.84	4,516	5
12/21/68	140	877	3.90	10.16	3,421	5

Table 2.--Coles Creek - Transport from Floodwater Samples

Gage Height ft.	Date	Q cfs	Av.* Sediment Concentration ppm		Sed. Transport Rate lb/sec	
			D< .062 mm	D> .062 mm	D< .062 mm	D> .062 mm
6.25	8/26/67	1,280	1,580	142	126	11
19.57	8/27/67	21,900	12,960	2,427	17,680	3,310
10.54	8/27/67	4,750	3,965	574	1,170	170
18.30	8/27/67	18,700	7,600	1,137	8,850	1,320
16.05	8/27/67	13,800	3,450	306	2,970	263
8.36	8/28/67	2,670	2,856	unreliable	475	---
10.78	9/6/67	6,000	5,315	unreliable	1,987	---
13.29	12/15/67	8,400	9,010	1,320	4,715	690
13.67	12/15/67	8,950	4,440	919	2,476	512
8.38	12/15/67	2,680	2,090	816	349	136
11.74	1/9/68	6,250	2,668	945	1,039	368
11.44	4/4/68	5,850	6,034	1,318	2,200	480
9.00	4/13/68	3,210	11,400	2,210	2,280	442
6.83	4/14/68	1,590	4,830	1,752	478	174
16.39	5/26/68	14,000	3,810	1,050	3,323	916
9.64	5/26/68	3,810	2,890	775	686	184
10.30	8/19/68	4,500	10,170	822	2,850	230
11.41	12/1/68	6,700	3,470	980	1,448	409
10.35	12/21/68	5,400	2,830	1,740	952	585

* Average of 5 to 8 samples taken at different points across the stream.

Table 3.--Buffalo River - Transport Data from Floodwater Samples

Gage Height ft.	Date	Q cfs	Av.* Sediment Concentration ppm		Sed. Transport Rate lb/sec	
			D< .062 mm	D> .062 mm	D< .062 mm	D> .062 mm
11.98	5/24/68	10,100	4,870	1,730	3,060	1,090
11.44	5/24/68	8,500	3,840	1,460	2,030	770
9.70	5/25/68	4,430	2,850	1,130	787	312
7.16	6/2/68	1,430	1,160	467	103	42
7.03	6/2/68	1,330	915	317	76	26
6.50	6/6/68	950	3,680	621	218	37
6.36	6/6/68	865	3,060	319	165	17
7.85	12/1/68	2,100	1,530	590	200	77
7.65	12/1/68	1,830	1,330	878	152	100
6.26	12/3/68	802	389	78	19	39
6.42	12/3/68	905	306	114	17	64
6.67	12/3/68	1,060	376	151	25	10.0
6.88	12/3/68	1,210	501	198	38	15
6.88	12/3/68	1,210	478	214	36	16
6.79	12/3/68	1,140	473	153	34	11
6.05	12/13/68	696	721	157	31	6.8
6.23	12/13/68	795	510	196	25	9.7
7.00	12/13/68	1,300	527	360	43	29
7.31	12/13/68	1,550	714	505	69	49
7.38	12/13/68	1,600	724	584	72	58
7.31	12/13/68	1,550	710	378	69	37
7.19	12/13/68	1,450	577	253	52	23
7.04	12/13/68	1,400	511	216	45	19
6.27	12/21/68	808	277	205	14	10

* Average of 4-8 samples taken at different points across the channel.

Table 4 gives the results of coarse sediment transport rate estimates for Coles Creek by the Einstein Bed Load Function (3) and from a Froude model analysis of some tests in the USDA Sedimentation Laboratory 100-ft. flume. Flood crest elevations and low water surveys indicate a slope value for Coles Creek of 0.00050. This slope value and the bed material roughness diameter of 0.41 mm were used in computing the flow velocity for each of the load computations by the Einstein method. The Einstein computations were related to the flow discharge through the computed velocity and an observed velocity discharge curve which was derived from stage-area and stage-discharge (Figure 3) curves. The stage area curve was developed from the SCS channel survey data. Thus the questionable hydraulics computation steps of the Einstein method were replaced with observed channel hydraulic factors.

The Froude model analysis was based on the assumption that the dimensionless sediment transport rate, i.e., the average sediment concentration, is a function of the Froude number. This assumption agrees with the basic concepts of regime theory and is supported by laboratory flume investigations.

The flume tests upon which the model analysis was made were for a coarser bed material (D_m = 0.40 mm) than that found in Coles Creek (D_m = 0.33 mm); however, other tests indicate that the sediment concentration is only slightly affected by median diameter for $0.10 \leq D_m \leq 0.40$ and for the Froude number range encountered in Coles Creek. The flume tests suggest slightly higher transport rates than do the Einstein computations, but lower rates than those determined from the sediment samples. Too much emphasis should not be placed on the coarse sediment concentrations of the flood water samples, since if the bed is firm the sampler will generally fail to sample the higher concentration zone near the bed, or if the bed is fluid the sampler may bury in the bed and the resulting concentrations would be too high. The channel bed is quite irregular and soft, so the fluid bed theory for appreciable flows is probably correct.

SUMMARY AND FUTURE WORK

The data that have been presented are adequate for only preliminary representation of procedures that are being used to estimate the average annual sediment yield. Adequate data should provide reliable average sediment transport-discharge relations, which when routed through flow duration information, will give estimates of the sediment yield. The flow duration relations for these streams have been developed by SCS personnel.

Additional flood crest information to be obtained from the crest gages may give more reliable energy slope values to use in coarse sediment transport computations. Computations by various methods found in the literature will be made and revised as more reliable information is obtained.

Table 4.--Coles Creek - Sediment Load for D> .062mm by Einstein Method and Flume Model Analysis

Velocity fps	Discharge cfs	Sediment Transport by Einstein Method lb/sec	$\frac{V}{\sqrt{gR}}$	Sediment Transport by Flume Tests lb/sec
1.12	88	.0322	.225	0.83
1.45	206	.222	.229	2.0
1.74	980	.717	.177	--
2.23	2,320	2.934	.184	--
3.03	4,500	13.24	.215	41.5
4.54	8,500	105.3	.278	153
5.75	11,500	237	.328	460
6.78	14,700	738	.369	911
7.71	17,900	1,203	.407	1,470
8.57	22,600	1,870	.439	2,210
9.36	27,900	2,764	.465	3,040

REFERENCES

(1) Surface Water Records of Mississippi, U.S. Dept. of the Interior - Geological Survey, Jackson, Mississippi, 1962.

(2) Water Resources Data for Mississippi, U.S. Dept. of the Interior - Geological Survey, Jackson, Mississippi, 1965.

(3) Einstein, H. A., The Bed-Load Function for Sediment Transportation in Open Channel Flows, USDA-SCS Technical Bulletin No. 1026, Washington D.C., Sept. 1950.

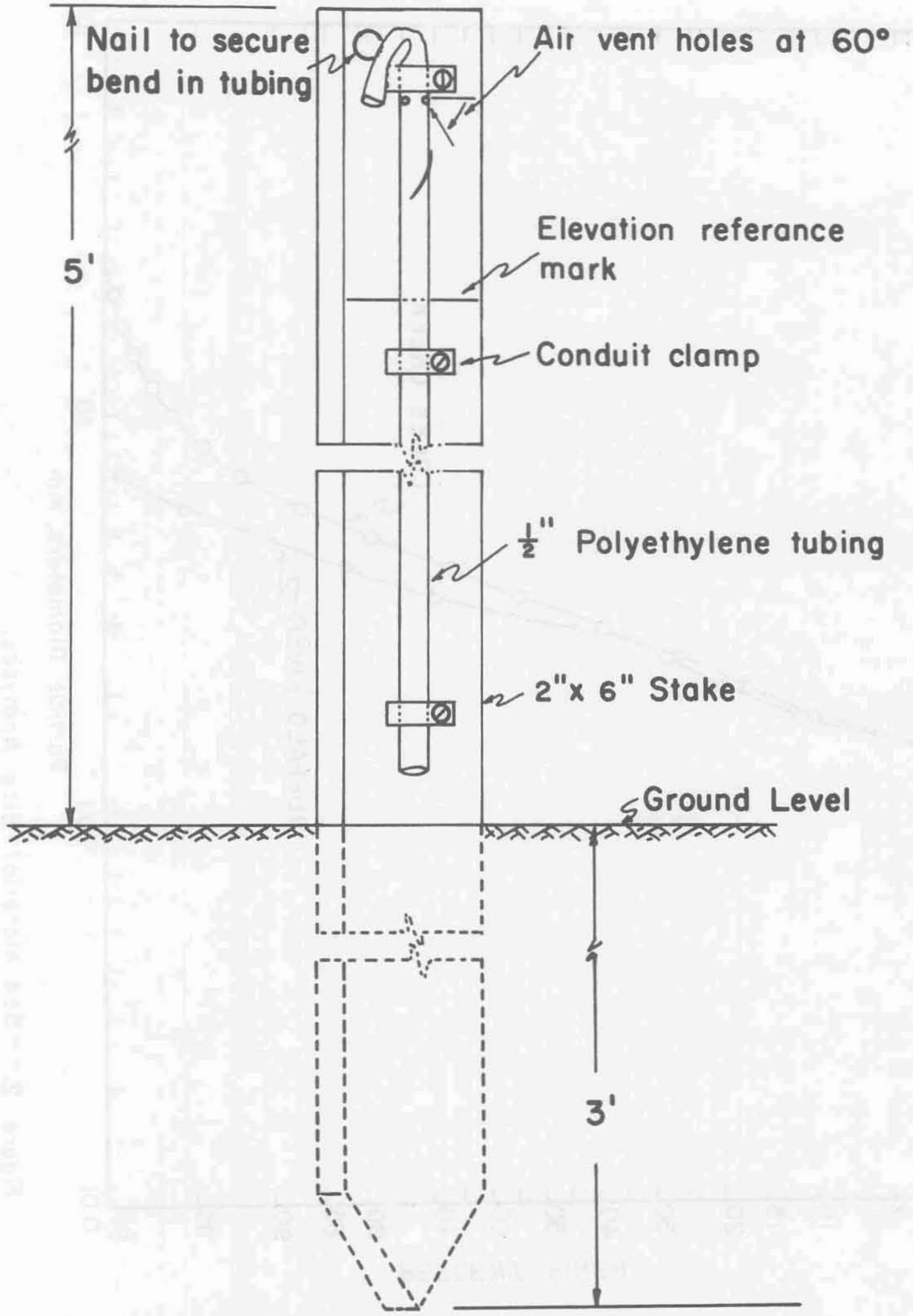

Figure I.--Crest Gage.

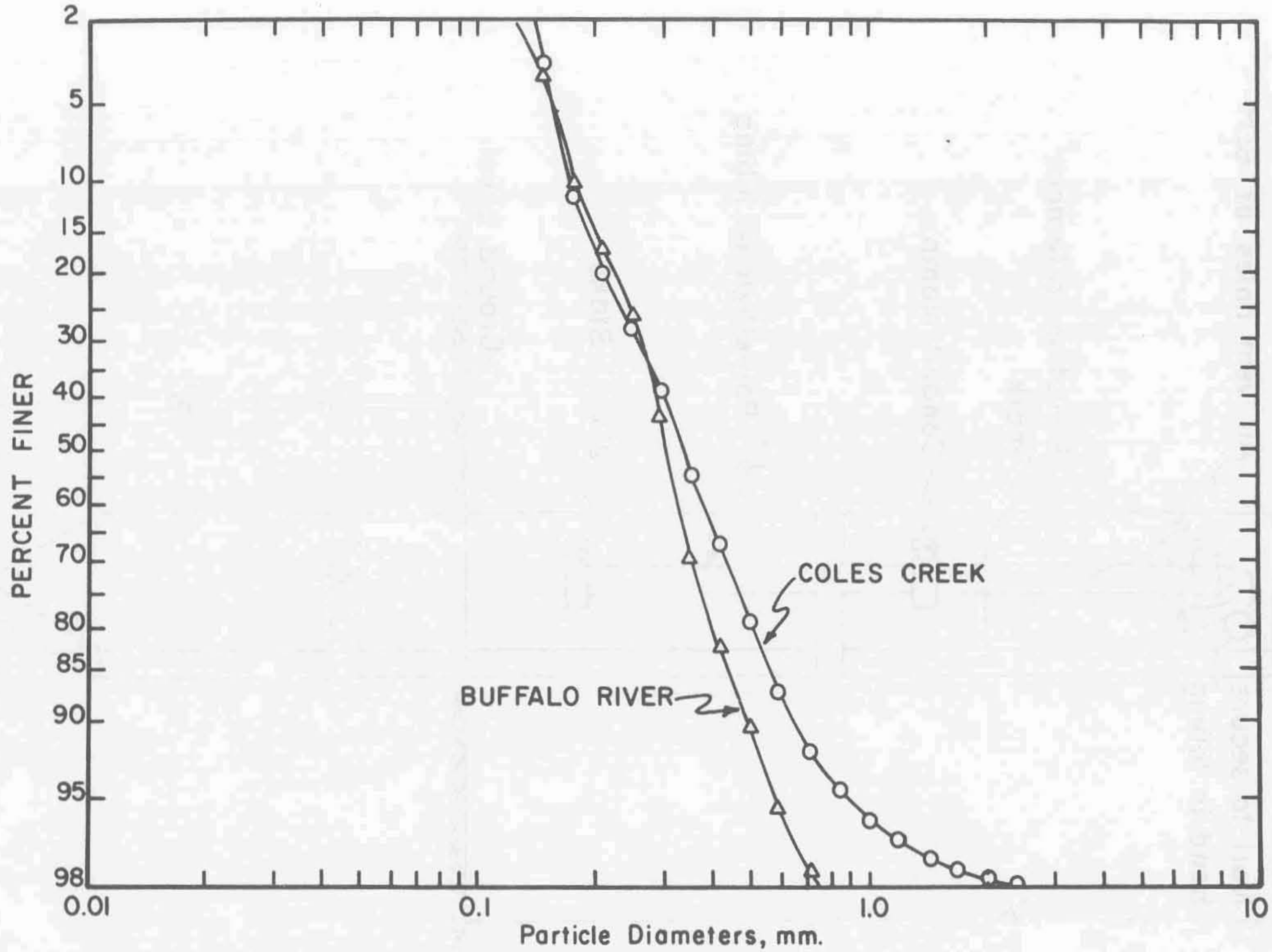

Figure 2.-- Bed Material Size Analyses.

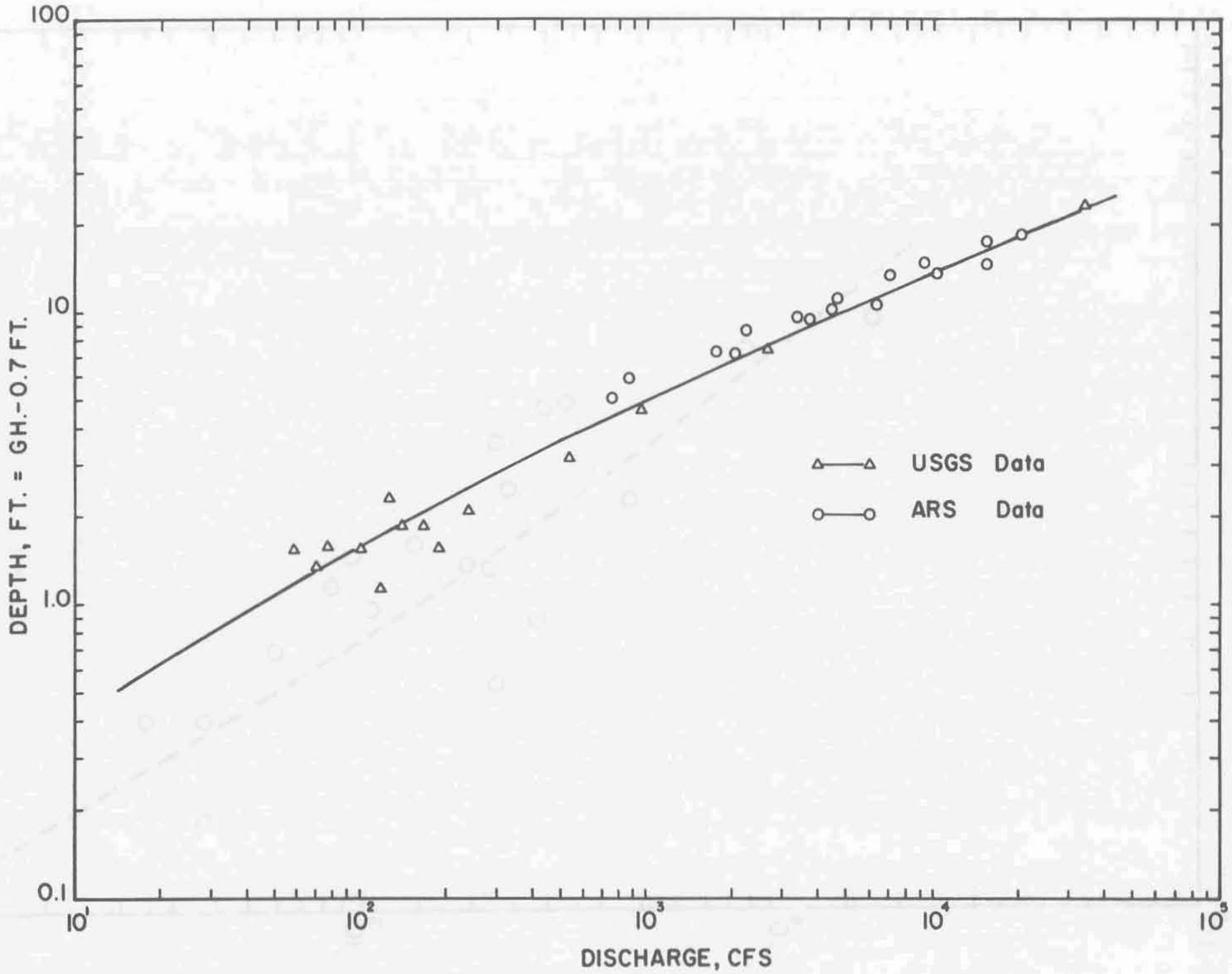

FIGURE 3.--Coles Creek Rating Curve.

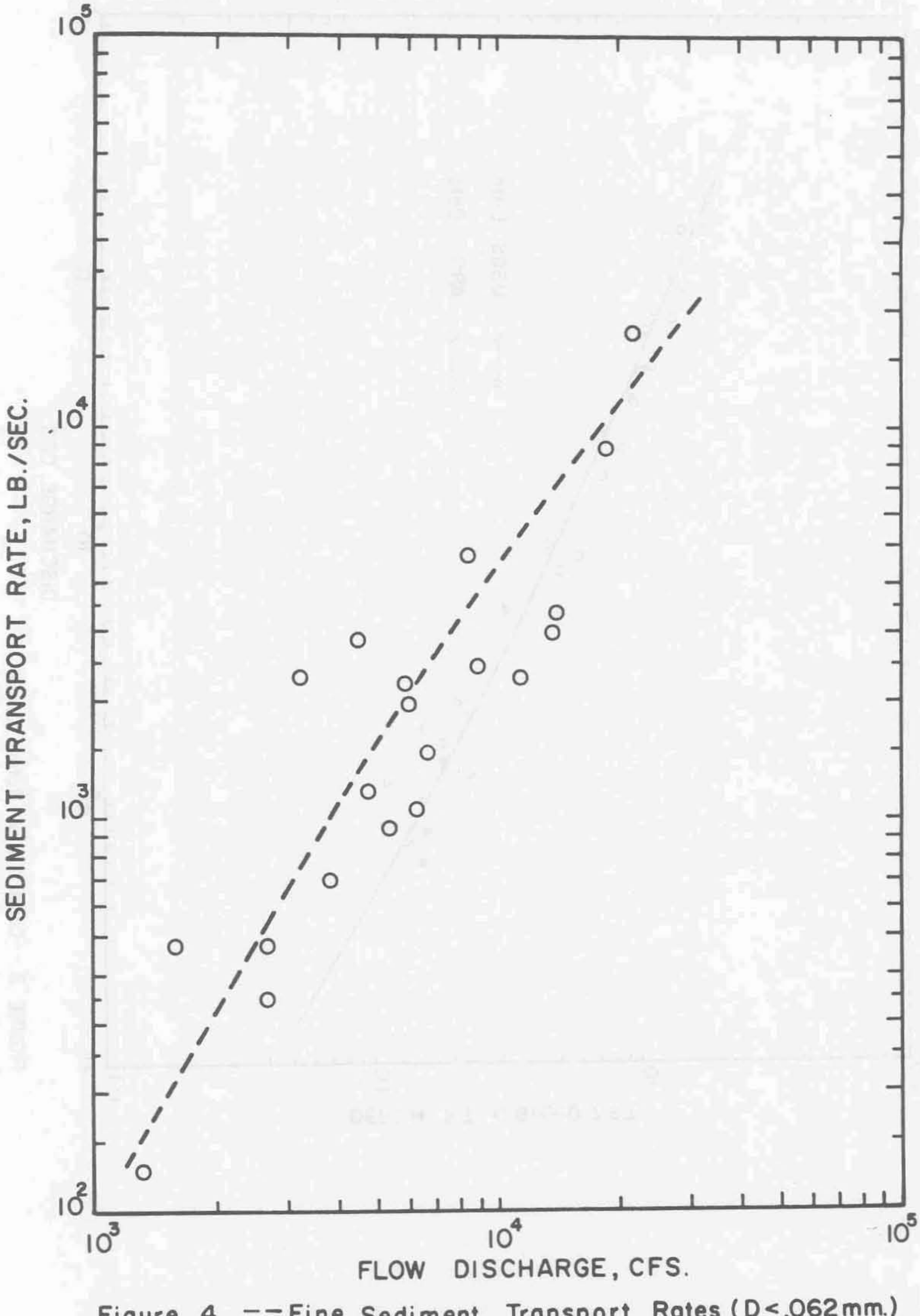

Figure 4. --Fine Sediment Transport Rates (D<.062mm.) Coles Creek near Church Hill, Mississippi

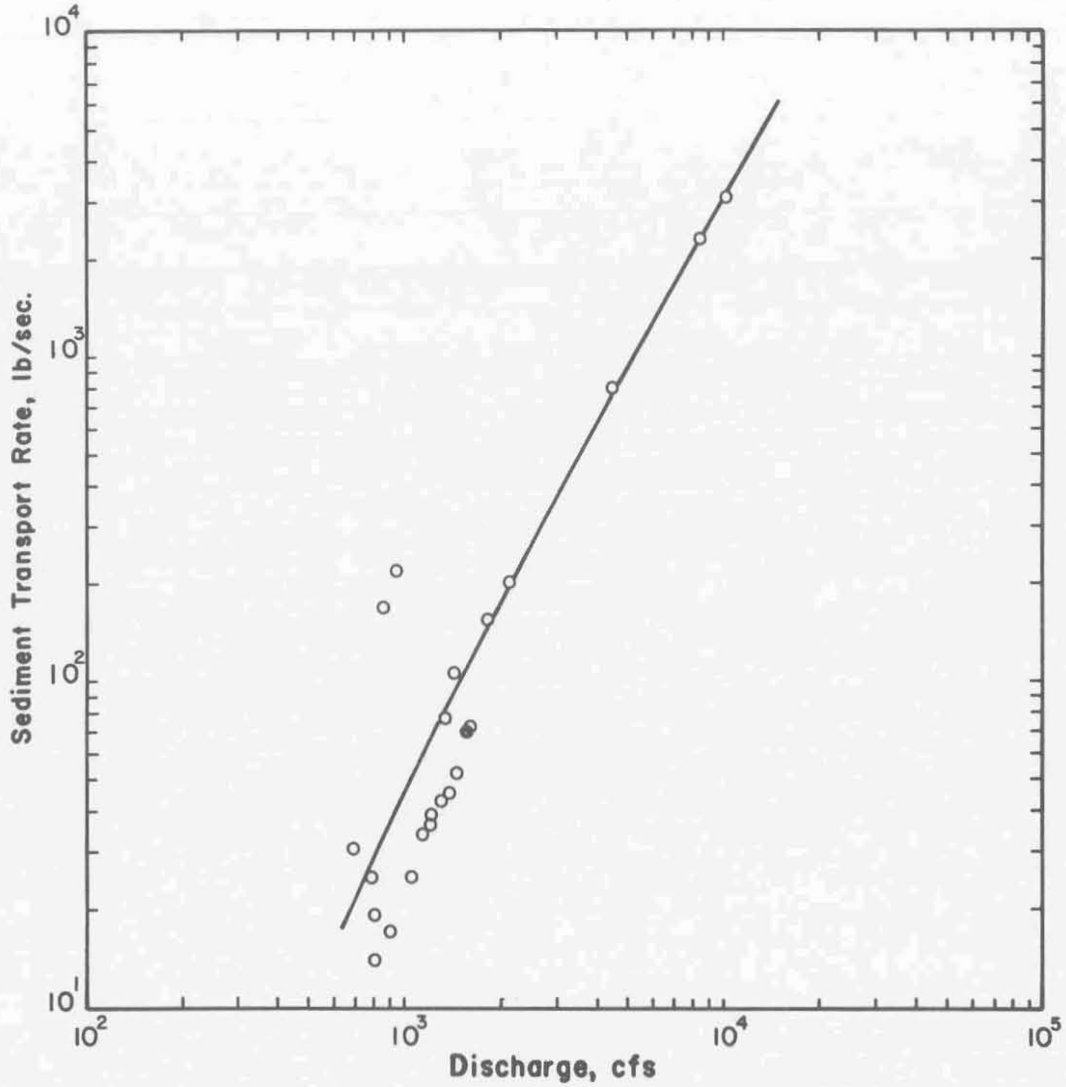

Figure 5.--Fine sediment transport rates for Buffalo River Mississippi at U S Highway 61 Bridge.