FIELD PERFORMANCE AND EVALUATION OF TWO AUTOMATIC SUSPENDED SEDIMENT PUMPING SAMPLERS 1/

by

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INTRODUCTION

Numerous methods and types of samplers have been used to determine amounts of sediment being transported in flowing streams (3,4).3/ Depth integration of several verticals in a stream cross section is probably the most accurate method of determining the mean suspended sediment concentration, but this method is costly, time consuming and requires numerous personnel when a network of watersheds is being studied. To meet the needs for accurate and extensive measurements of suspended sediments in streamflow, various sampling and monitoring devices have been developed to supplement or replace manual sampling methods.

This report presents the preliminary results of field tests of two types of pumping samplers (US PS-67 and US PS-69) developed by the Federal Inter-Agency Sedimentation Project for automatically collecting suspended sediment samples in flowing streams (1,5,6).

General Sampler Operation

The PS-67 and the PS-69 operate similarly. Both samplers:

1. Are powered by three 12-volt automotive-type batteries.

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3/ Numbers in parentheses refer to Literature Cited.

2. Have an intake with hydraulic conveyance lines of nearly the same diameter throughout to maintain a constant velocity of the sediment-water mixture.

3. Have a backflush reservoir for clearing the lines before the sample is pumped.

4. Have a traversable distributor arm for placing the individual samples in separate storage containers.

5. Have a plug-in logic control box with triggering options (constant interval timer and delta stage switch, both of which are used in conjunction with a river stage float switch).

The similarity ends here because the PS-67 sampler is a smaller semi-portable unit holding 48 pint milk bottles as sample containers. A trap system collects the pumped sample, which is dispensed to the sample containers at the end of the pump cycle. A reversible pump is used for the backflush and pump cycles.

The PS-69 sampler can hold 72 quart sample containers. A flow diverter, similar to that used on the Chickasha Sediment Sampler (2), is used to divert the flow into the sample container during the pump cycle. Separate pumps are used for the backflush and pump cycles.

Both samplers are activated when the water in the stream reaches a preselected stage. The first step in the sampling cycle is to backflush the system to clear the lines of trash and to prime the pump. At the end of the backflush sequence, the sample distributor nozzle positions itself over the appropriate sample container and the pump cycle begins. At or near the end of the pumping period a sample is extracted and dispensed to the sample container. The stage record is marked simultaneously to indicate the time and stage that the sample was collected. The sampler then continues to collect and store samples at selected intervals until all bottles are filled or the stage drops below the preselected level.

Field Installation and Testing Procedure

Both the PS-67 and PS-69 samplers were installed at previously established runoff and sediment discharge gaging stations. The PS-67 sampler was located at gaging station 5, on a 1000-acre agricultural watershed, within the Pigeon Roost Creek Watershed, Marshall County, Mississippi. The PS-69 sampler was located at the gaging station on Toby Tubby (Laboratory) Creek in Oxford, Mississippi. The Laboratory

Creek Watershed contains 1000 acres, of which about 60% is urban. Channel bottom widths are about 12 and 20 feet for station 5 and Laboratory Creek, respectively.

Each pumping sampler installation consists of:

1. A water stage recorder that provides a complete gage height record during storm runoff.

2. A footbridge or working platform across the stream to facilitate collection of depth-integrated samples in several verticals to represent the mean sediment concentration in the stream cross section for comparison with the pumped sample.

3. A waterproof, insulated shelter large enough to house the pumping sampler.

4. An intake located in the channel, positioned 0.5 to 1.0 foot above the channel bed, and designed to shed trash and floating debris.

The sample collected by the pumping sampler represents a point concentration in the stream cross section. The correlation between this point concentration and the stream cross section concentration depends on (a) stream velocity, (b) sediment particle sizes, (c) location of the sampler intake in the cross section, and (d) intake velocity of the pumping sampler (7,8).

For these tests, the intake system was constructed of an 8-foot length of 3-inch structural aluminum channel with a 3/4-inch diameter intake located 2 feet from the downstream end of the channel. The upstream end of the channel was secured in the stream bank approximately 0.75 foot above the channel bed; the downstream end of the channel was at the same height, but out from the streambank. This was deemed necessary to offset the possibility that the momentum of the larger suspended sand particles (D_{50}=0.2 mm) would carry them past the intake.

Pumped samples were compared with cross section samples collected simultaneously. Cross section samples later described represent the mean suspended sediment concentrations of the stream cross section.

RESULTS AND DISCUSSION

Both samplers have performed well mechanically during the 2 years of operation. Two problems, common to both samplers, were encountered during the test period: (a) Low battery power after a short time of operation caused interruptions in the sampling cycle and loss of pumped samples. This was corrected by installing demand-type battery chargers and 24-hour timers to regulate the charging cycle. (b) Frequent clogging of the sample distributor arm nozzle caused a loss of samples. Enlarging the distributor arm nozzle corrected this problem and is recommended where heavy trash loads are anticipated. After these corrections were made, few malfunctions occurred in either sampler.

The sediment sampling performance of the PS-67 and PS-69 samplers will be discussed separately since they were located on different streams.

Pumping Sampler US PS-69

Numerous storms occurred in the Laboratory Creek Watershed during the reported test period. Most storms that produced sufficient runoff to activate the pumping sampler also were sampled manually with a DH-48 sampler. The results of a typical storm which occurred on January 22, 1971, are shown in Figure 1. In general, close agreement was observed for this runoff event between the sediment discharges determined by cross section and by pumped samples.

Several cross section and pumped samples were collected simultaneously during the test period. The samples were wet-sieved through a 0.062-mm sieve to determine the sand (>0.062 mm) and fine sediment (<0.062 mm) concentrations. The relationship between the simultaneous cross section and pump sample concentrations was determined by least squares analyses. No significant difference (95 percent level) was observed between the cross section and corresponding pump samples for fine sediment concentrations (Figure 2). This indicates that the fine sediments were mixed uniformly throughout the cross section. The simultaneous cross section and pump samples of total (sands + fines) sediment concentrations are compared in Figure 3. The slope of the regression line is near unity (1.03), but the cross section sample concentrations are about 590 ppm higher than the pump concentrations. This difference, which is attributed to differences in sand concentrations, illustrates the inability of the pumping sampler point intake to accurately sample the suspended sand load. Similar results were reported by Welch et al. (9).

Relocating the pump sampler intake may not improve the relationship between the total measured cross section and pump sample concentrations. Differences in sand concentrations between simultaneous depth-integrated single vertical samples can be appreciable, as illustrated in Table 1 for the runoff event of July 25, 1971. The coefficients of variation ranged from 7.1 to 29.5 percent for the sand concentrations compared with coefficients of 0.8 to 4.9 percent for the fines concentrations (Table 2). Single vertical samples were collected at intervals of 5 feet in the cross section.

The measured sediment discharge rating curves determined from the cross section samples (247 values) and pump samples (152 values) are compared in Figure 4. There is no significant difference (95 percent level of confidence) in the slopes of comparable cross section and pump sediment discharge rating curves. The discharge rating curves for the fine sediments are in excellent agreement. However, sand discharge measured in the pump samples was about 60 percent less than that determined in the cross section samples. This lower sand discharge is reflected, of course, in the total measured sediment discharge, which is about 23 percent less for the pump samples.

Pumping Sampler US PS-67

Pump samples were collected at Sation 5 in the Pigeon Roost Creek Watershed during 15 runoff events. Only seven of these events were sampled manually for comparison. The time between initial runoff and peak discharge is so short that it is difficult to obtain cross section samples during the ascending stage. In general, the samples collected manually at Station 5 were on the descending stage of the hydrograph. One such storm is shown in Figure 5. Agreement was fair between the sediment discharges determined by cross section and pump samples.

The simultaneous pump and cross section fine concentrations (<0.062 mm) are compared in Figure 6. No significant difference is indicated between the concentrations measured by the two methods. In Figure 7, cross section and pump total (sands + fines) measured sediment concentations are compared. In general, the cross section sample concentrations are higher than the pump sample concentrations. This difference is attributed to differences in sand concentrations as determined by the two methods. Again, this illustrates the inability of the pump sampler to accurately sample the suspended sand load.

The runoff sediment discharge relationship for the fines, sands, and total measured sediment for the cross section (87 values) and pump samples (213 values) are shown in Figure 8. The difference between the cross section and pump fine sediment discharge rating curves is attributed to the lack of cross section samples on the ascending stage of the hydrograph. The runoff-sediment relationship for the pump samples represents the point sediment discharges for both the ascending and descending stages of the runoff hydrograph, whereas the cross section discharges, in general, represent only sediment discharges for the descending stage of the hydrograph. Fine sediment concentrations during the ascending stage of the hydrograph can be three to ten times greater than concentrations during the descending stage, for a given water discharge. Thus, one would not expect as close agreement between the cross section and pump sediment discharge rating curves at Station 5 as was observed on Laboratory Creek, where both ascending and descending stage samples were collected manually.

The pump samples are higher in sand concentrations at the higher water discharges. This is reflected by the difference in slopes between the cross section and pump total measured sediment rating curves. This slope difference may be related to the sampler intake location, but more studies are needed to resolve this problem.

SUMMARY AND CONCLUSIONS

The PS-67 and PS-69 automatic pumping samplers were designed to collect suspended sediment samples from a fixed point in the cross section of a flowing stream. The performances of these samplers were tested on sand bed ephemeral streams, which transport high percentages of sand in suspension. The pump sample sediment concentrations were compared with depth-integrated mean cross section sample concentrations collected manually. No significant difference was observed in the fine (<0.062 mm) sediment concentrations between cross section and pump samples collected simultaneously. The concentration of fine sediments is apparently independent of the pump sampler intake location. Cross section total measured sediment concentrations (sand + fines) were higher than corresponding pump sample concentrations. This difference in the two methods of sampling is attributed to differences in the measured sand concentrations. The pump sample sand concentrations were not representative of the mean cross section sand concentrations. The spatial and partical size distributions of the suspended sand load will obviously influence the accuracy of the point sample concentrations. Since these distributions are related, in part, to the sediment source areas, runoff characteristics, and the channel hydraulics, it is essential that mean cross section samples be collected at each gaging station for comparison. It is equally important that the temporal distribution of the sediment load be defined throughout the hydrograph for accurate comparisons between the cross section and pump sediment discharge relationships.

Although it is necessary to collect cross section samples manually in order to calibrate the pump sampler, both pumping samplers have provided more complete coverage of storm events than samples collected manually, at a great savings in time and labor. The pumping samplers can provide samples at remote locations and on streams that peak rapidly, where few or none would be collected manually.

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Table 1.--Sand Concentrations (> 0.062 mm) of Simultaneous Depth Integrated Single Vertical Samples (Runoff Event of July 25, 1971 on Laboratory Creek).

Time of Sampling

Vertical	0931	0942	1005	1012	1028	1035	1056
	Concentration ppm						
1	2820	3230	3580	3260	2250	2580	1010
2	3960	2540	3010	3290	2590	1980	620
3	3550	2490	2160	2090	2380	1800	630
$\overline{X}$ 1/	3443	2753	2917	2880	2407	2120	753
s 1/	577	414	715	684	172	408	222
C (%) 1/	16.8	15.0	24.5	23.8	7.1	19.2	29.5

1/ Mean, standard deviation, and coefficient of variation, respectively.

Table 2.--Fine Concentrations (< 0.062 mm) of Simultaneous Depth Integrated Single Vertical Samples (Runoff Event of July 25, 1971 on Laboratory Creek).

Vertical	Time of Sampling						
	0931	0942	1005	1012	1028	1035	1056
	Concentration ppm						
1	3300	2810	2415	2210	1750	1650	1360
2	3450	2745	2410	2130	1630	1550	1280
3	3520	2715	2380	2040	1710	1500	1300
$\overline{X}$ 1/	3423	2757	2402	2127	1697	1567	1313
s 1/	112	49	19	85	61	76	42
C (%) 1/	3.3	1.8	0.8	4.0	3.6	4.9	3.2

1/ Mean, standard deviation, and coefficient of variation, respectively.

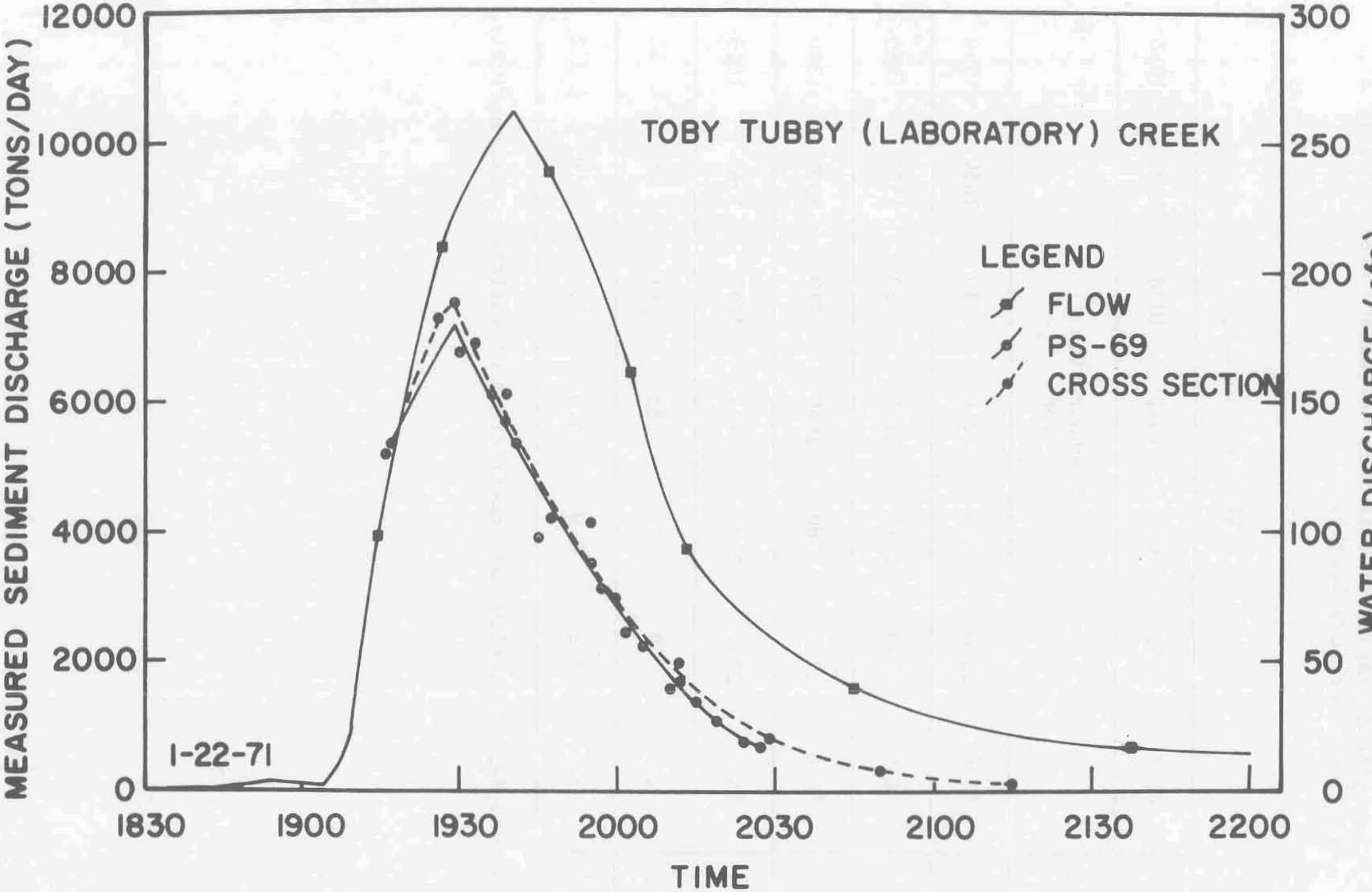

Figure 1.--Comparison of Cross-Section and PS-69 Sediment Discharges for Storm of January 22, 1971.

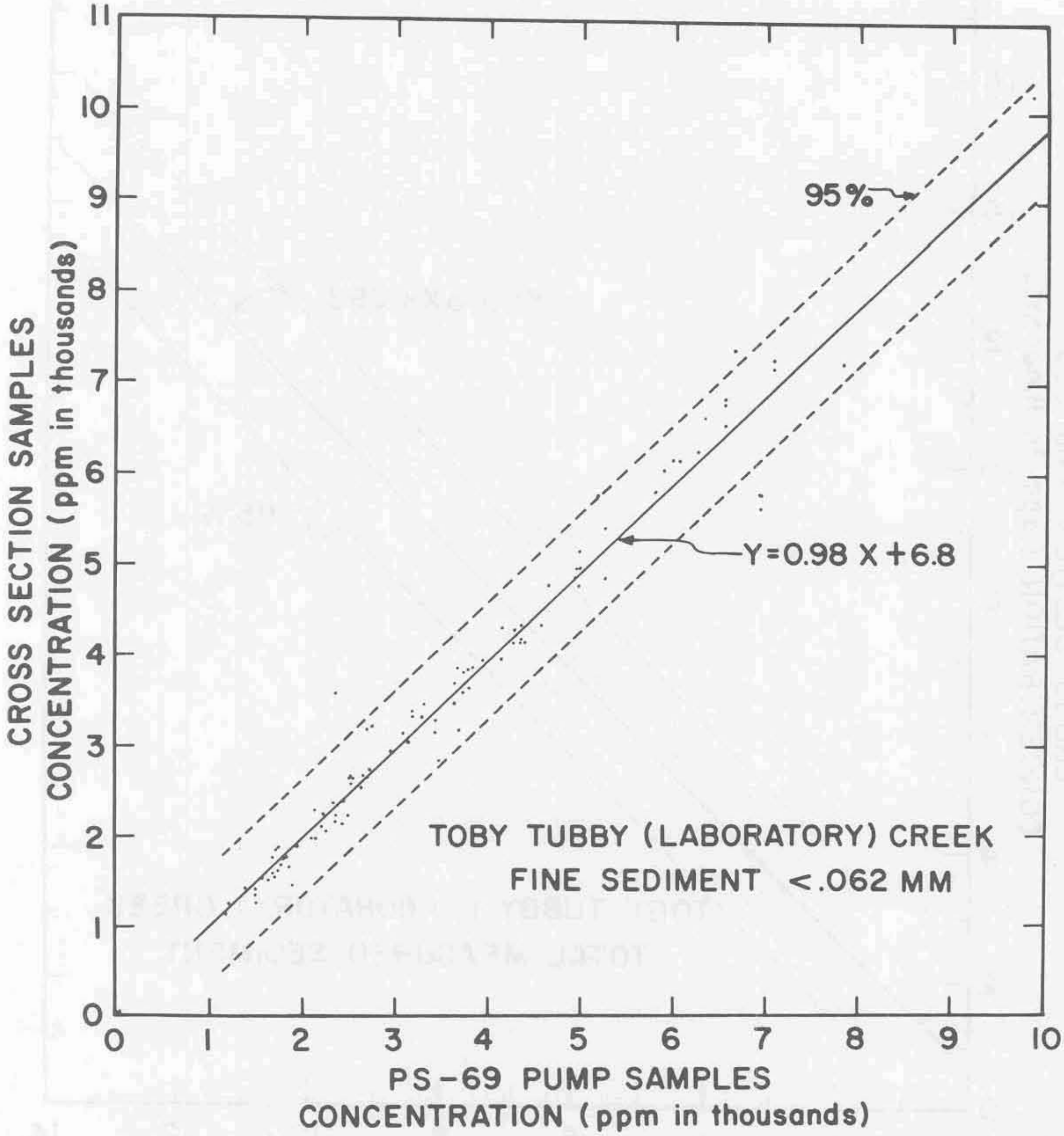

Figure 2.--Relationship Between Cross-Section and PS-69 Fine Sediment Concentrations.

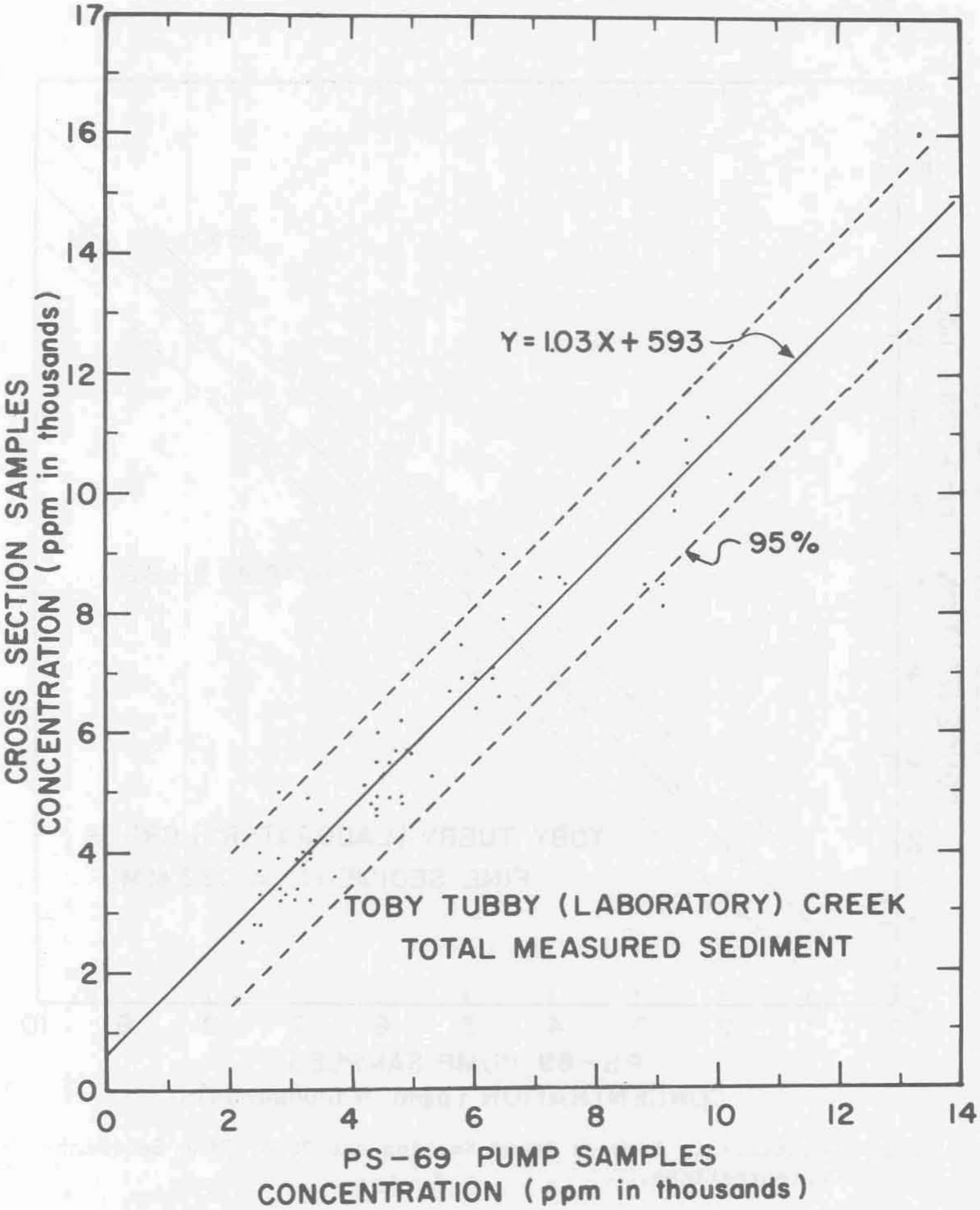

Figure 3.--Relationship Between Cross-Section and PS-69 Total Measured Sediment Concentrations.

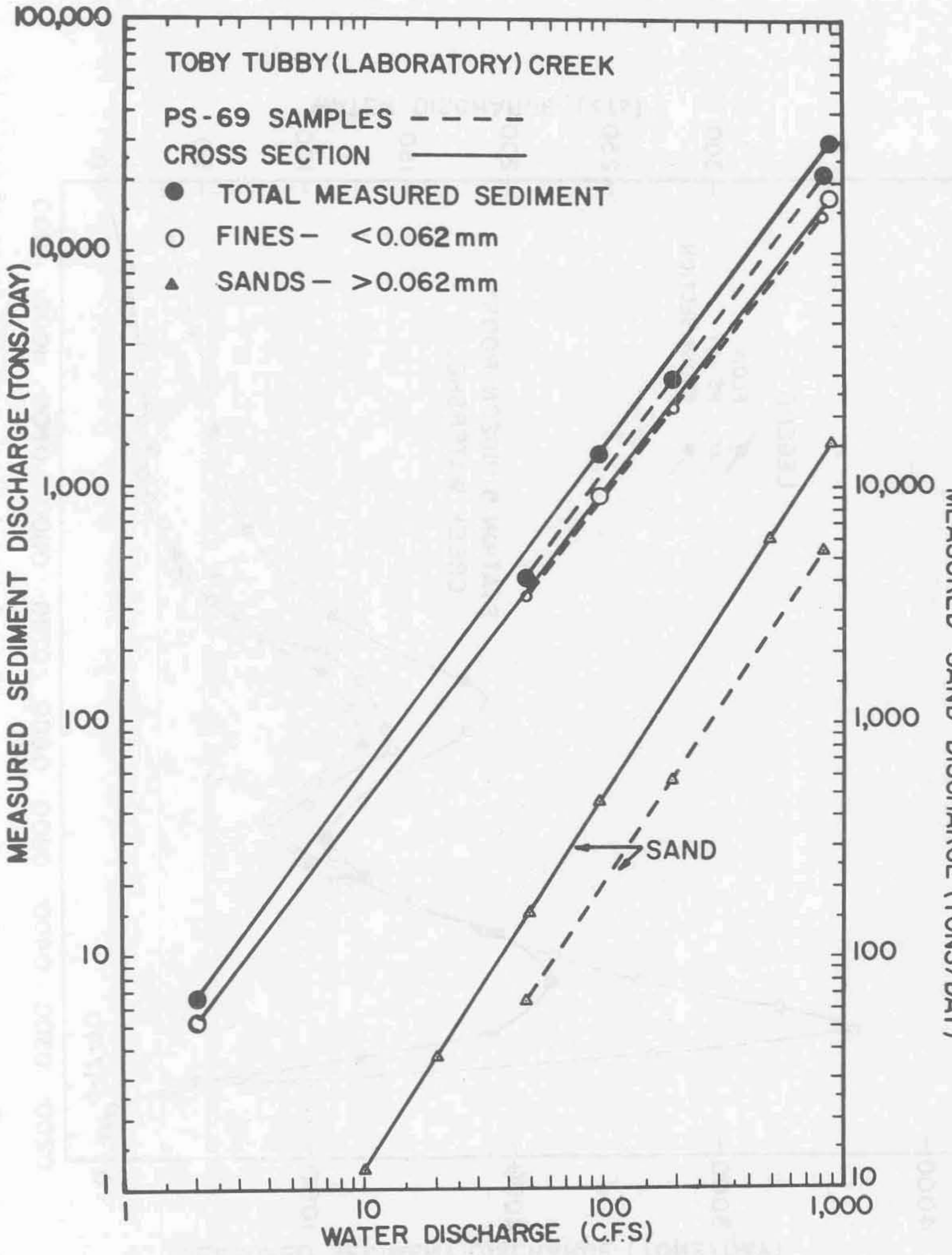

Figure 4.--Sediment Rating Curves for Fine, Sand, and Total Measured Sediment Discharges.

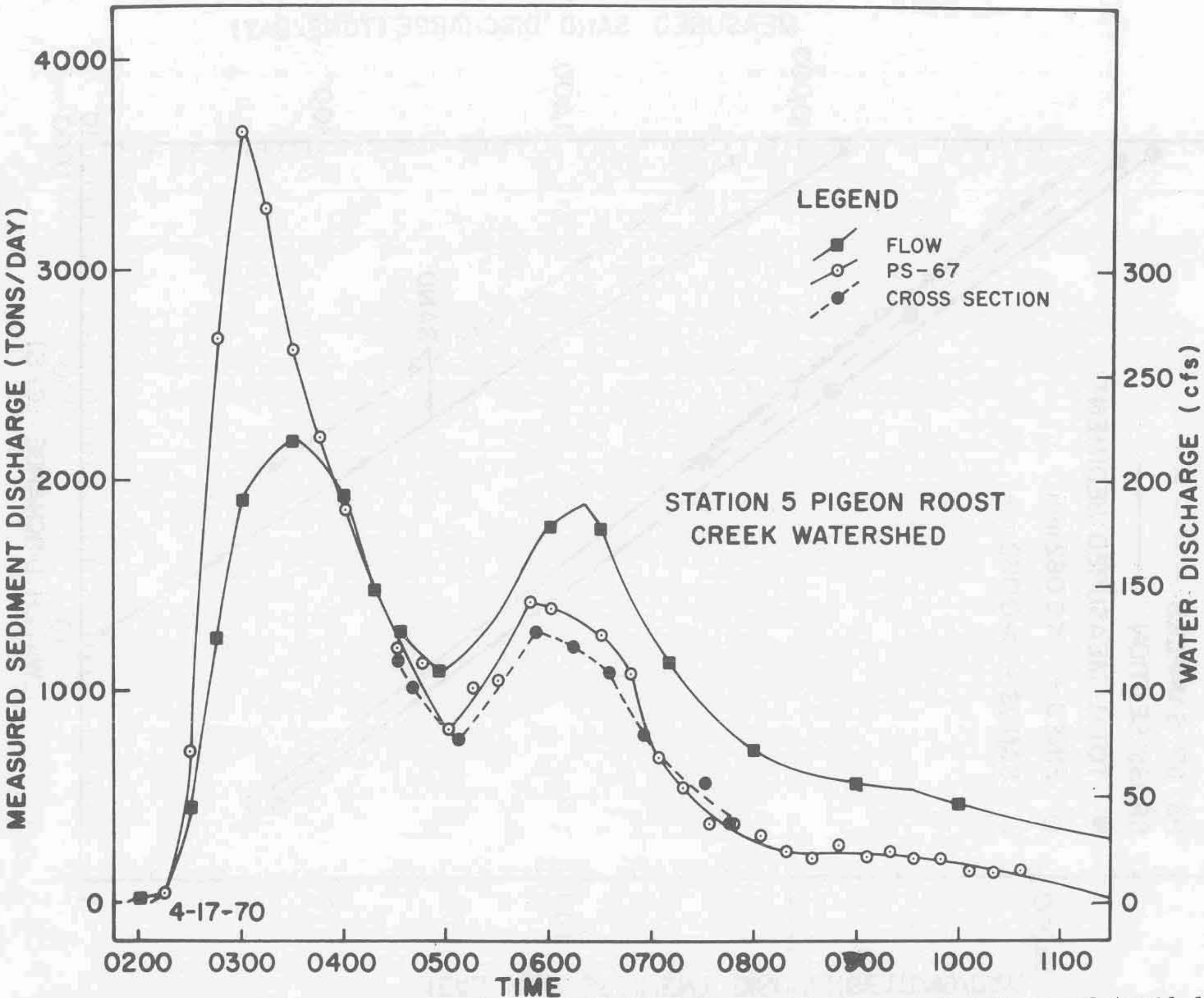

Figure 5.--Comparison of Cross-Section and PS-67 Sediment Discharges for Storm of April 17, 1970.

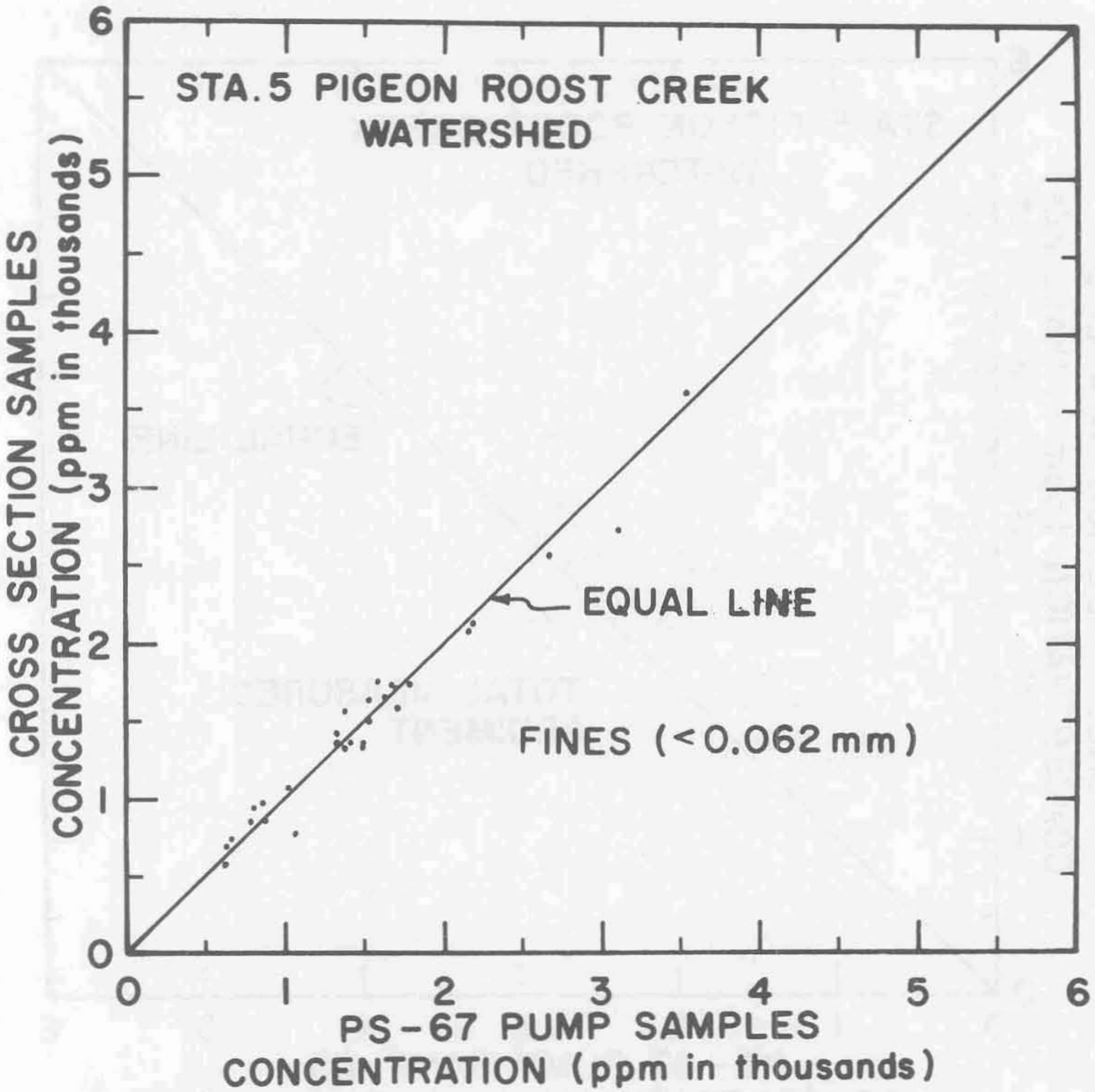

Figure 6.--Comparison of Cross-Section and PS-67 Pump Sampler Fine Sediment Concentrations.

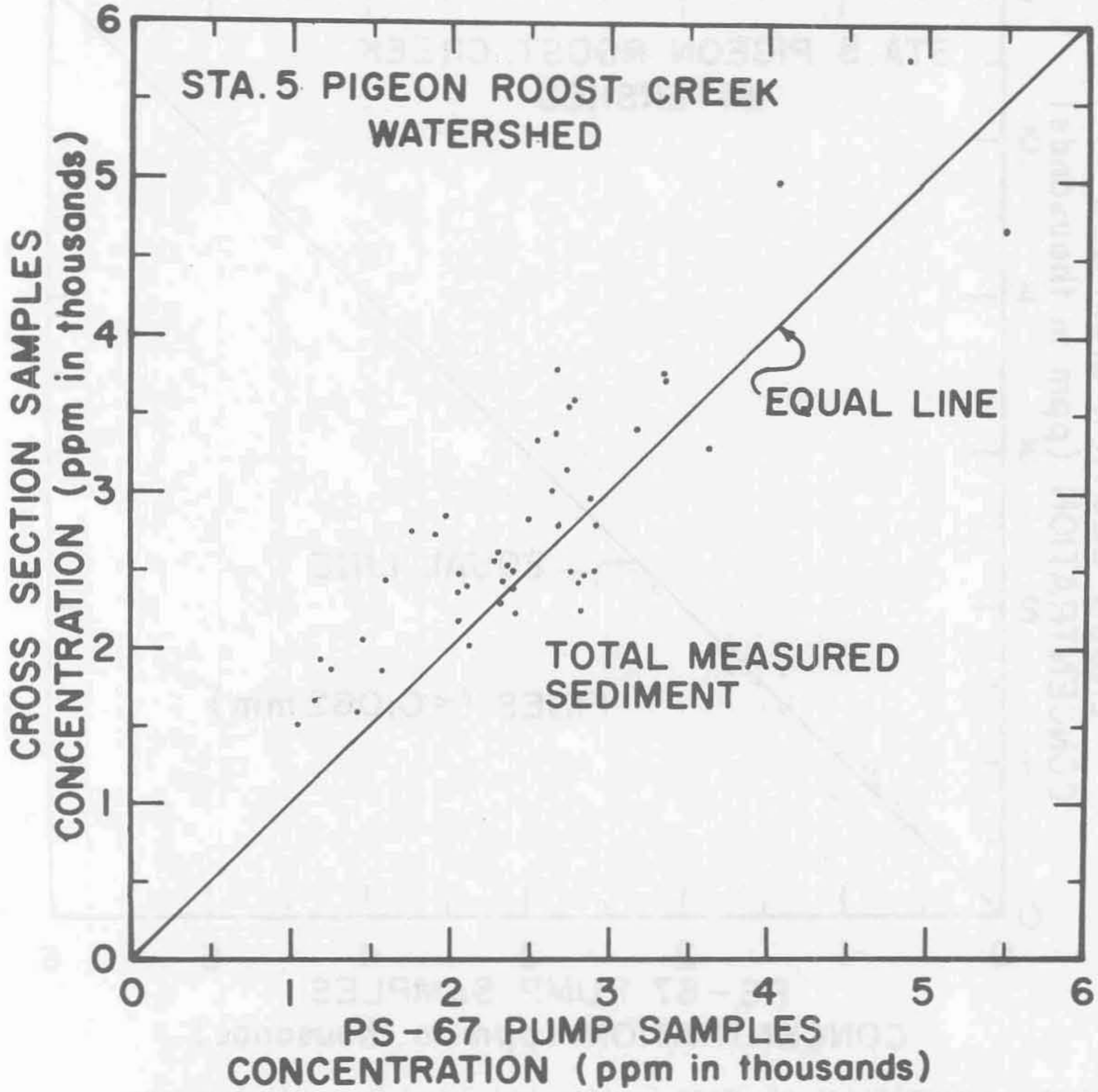

Figure 7.--Comparison of Cross-Section and PS-67 Pump Sampler Total Measured Sediment Concentrations.

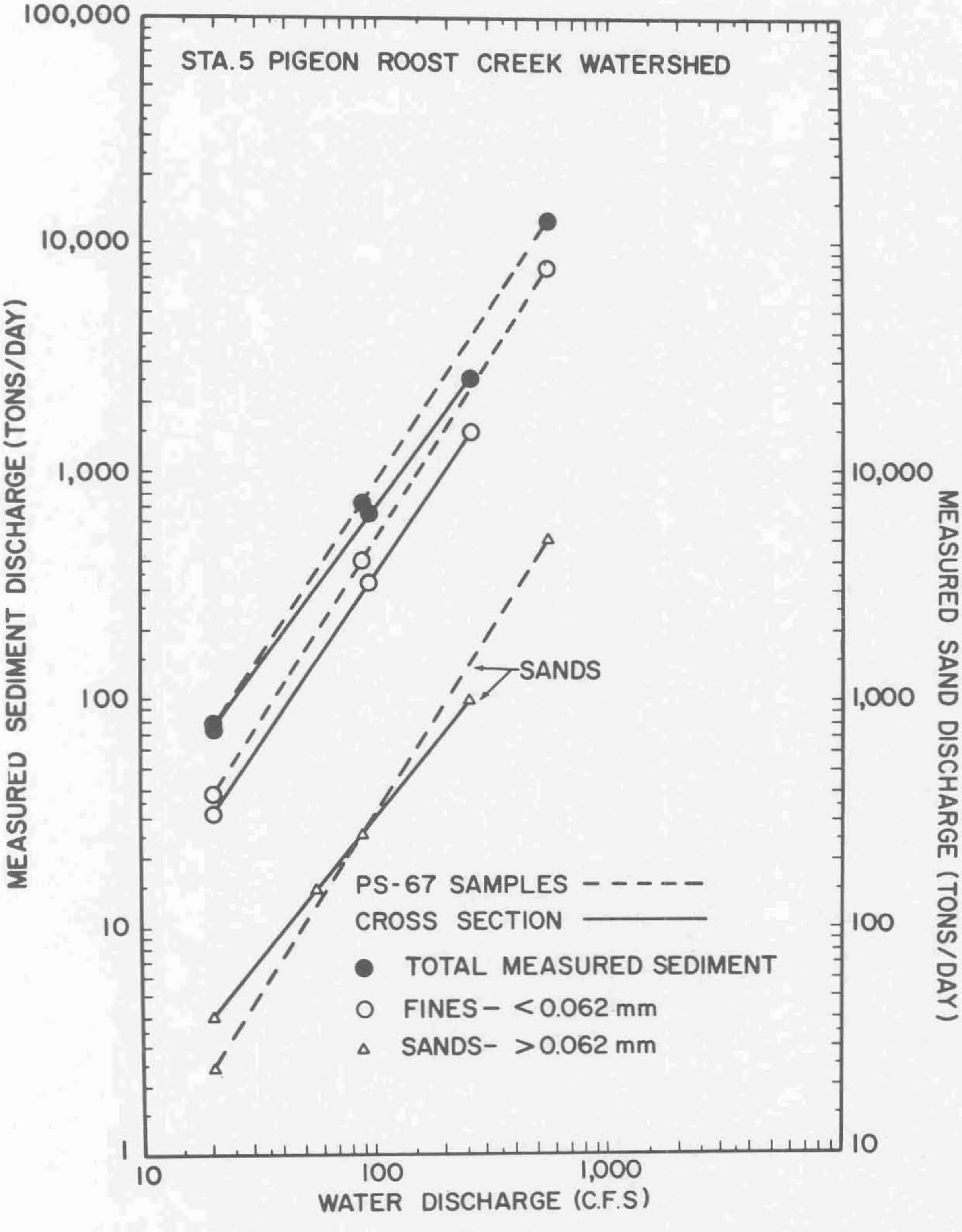

Figure 8.--Sediment Rating Curves for Fine, Sand, and Total Measured Sediment Discharges.