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DEEP RIVER VELOCITY AND SEDIMENT PROFILES AND THE SUSPENDED SAN--ETC(U)
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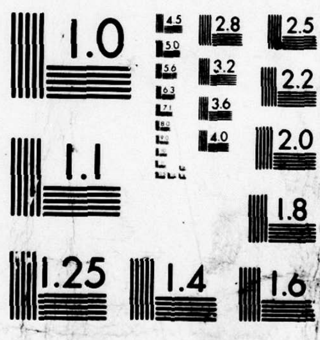
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DEEP RIVER VELOCITY AND SEDIMENT PROFILES AND THE SUSPENDED SAND LOAD

By

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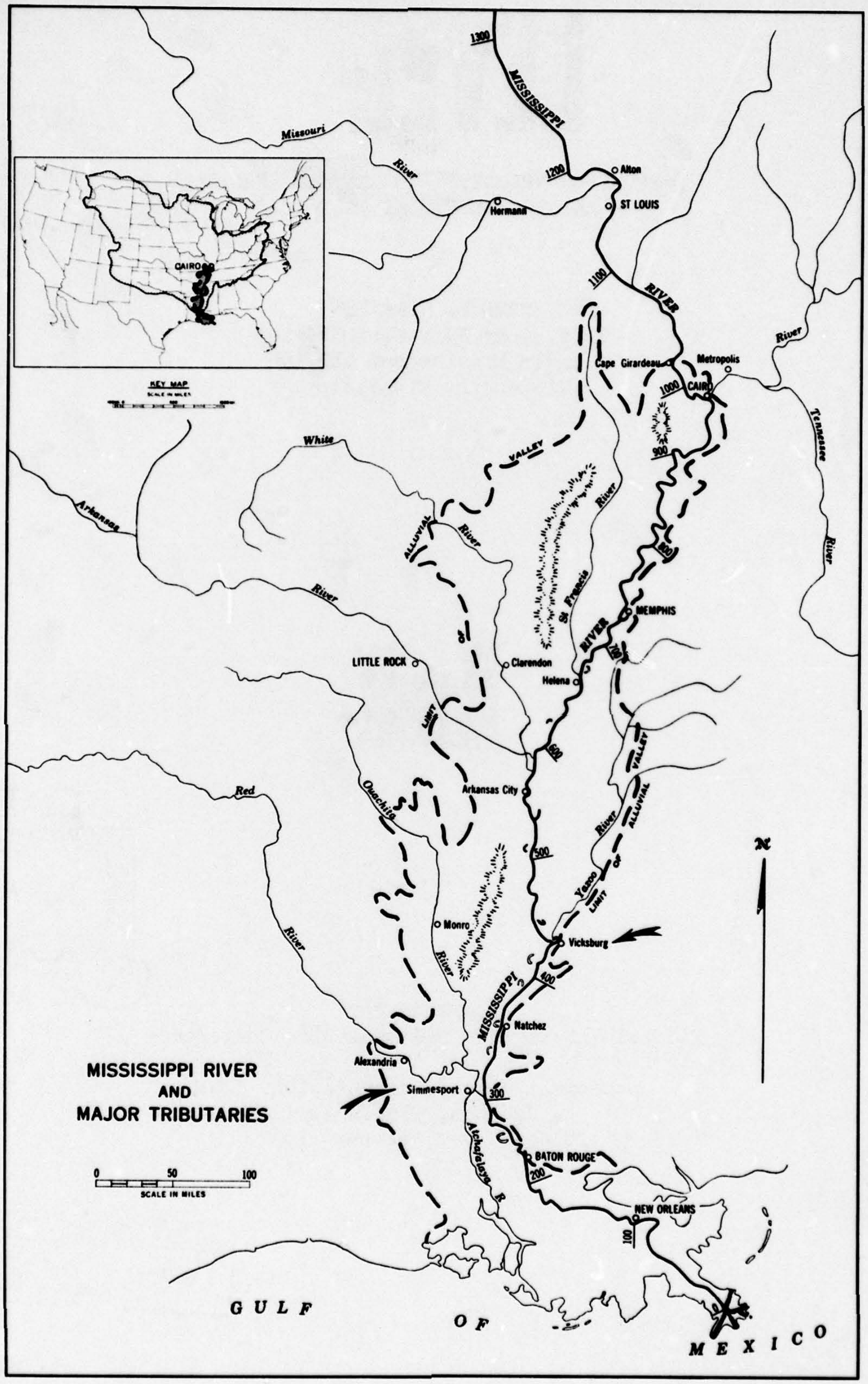

Frontispiece

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Synopsis

A large number of velocity measurements have been made in the Atchafalaya River at Simmesport and in the Mississippi River at Vicksburg to define the vertical velocity distribution. Examination of these data shows the average vertical velocity profile of the two streams to be almost identical at the respective locations. However, a comparison of this measured vertical velocity distribution with that derived by a formula in common usage in analytical sedimentation studies shows these two to be quite different.

Suspended sediment measurements are also made at regular intervals in the Atchafalaya River at Simmesport. Sampling procedure is in accordance with the Luby method for point measurement. An evaluation of the accuracy of this method is made by a study of 11 sets of measurements covering a wide range of flow conditions. The study indicates that the silt and clay portion of the suspended load was satisfactorily measured, but that there was a significant deficiency in measurement of the sand portion. A detailed study of the fine sand fraction of the suspended load in the 11 examples indicated that the Luby sampling procedure gave fine sand loads averaging about 30 percent less than the apparent actual load. In some instances a part of this deficiency is attributable to abnormal or atypical samples, but even so, economic reasons forbid an adequate number of Luby point samples to accurately measure the sand load in large, deep rivers. The procedure used herein for evaluating the accuracy of sediment measurements would be useful in routine analyses for detecting abnormal or apparently erroneous samples and to approximate the quantity of unmeasured load below the lowermost Luby measuring point.

DEEP RIVER VELOCITY AND SEDIMENT PROFILES AND THE SUSPENDED SAND LOAD

Introduction

In recent years a considerable number of velocity and suspended sediment measurements have been made in the Atchafalaya and Lower Mississippi Rivers, two large and deep streams in the Lower Mississippi Valley. This paper presents the results of some of these measurements and a token comparison with theoretical and empirical procedures developed to provide this information analytically.

Vertical Velocity Distribution

In the period 1955 through 1960 several hundred vertical velocity profiles were measured in the Atchafalaya River at the Simmesport discharge range (see frontispiece). Similar measurements were made in the Mississippi River at the Vicksburg discharge range in the period 1949 through 1956. The results of these measurements in terms of velocity coefficients, or the relation of the mean velocity in the vertical to that at any given depth, are shown in Fig. 1 and Table 1. It is to be noted from these data that the average vertical velocity profiles of the two streams are practically identical at the respective locations.

These data were obtained over a period of several years in all seasons and include measurements over a wide range of stage, discharge, and water temperature. A grouping of the data in accordance with conditions of similarity, i.e. season and stage, provided no evidence of distinguishing characteristics attributable to these variables. This approach indicated

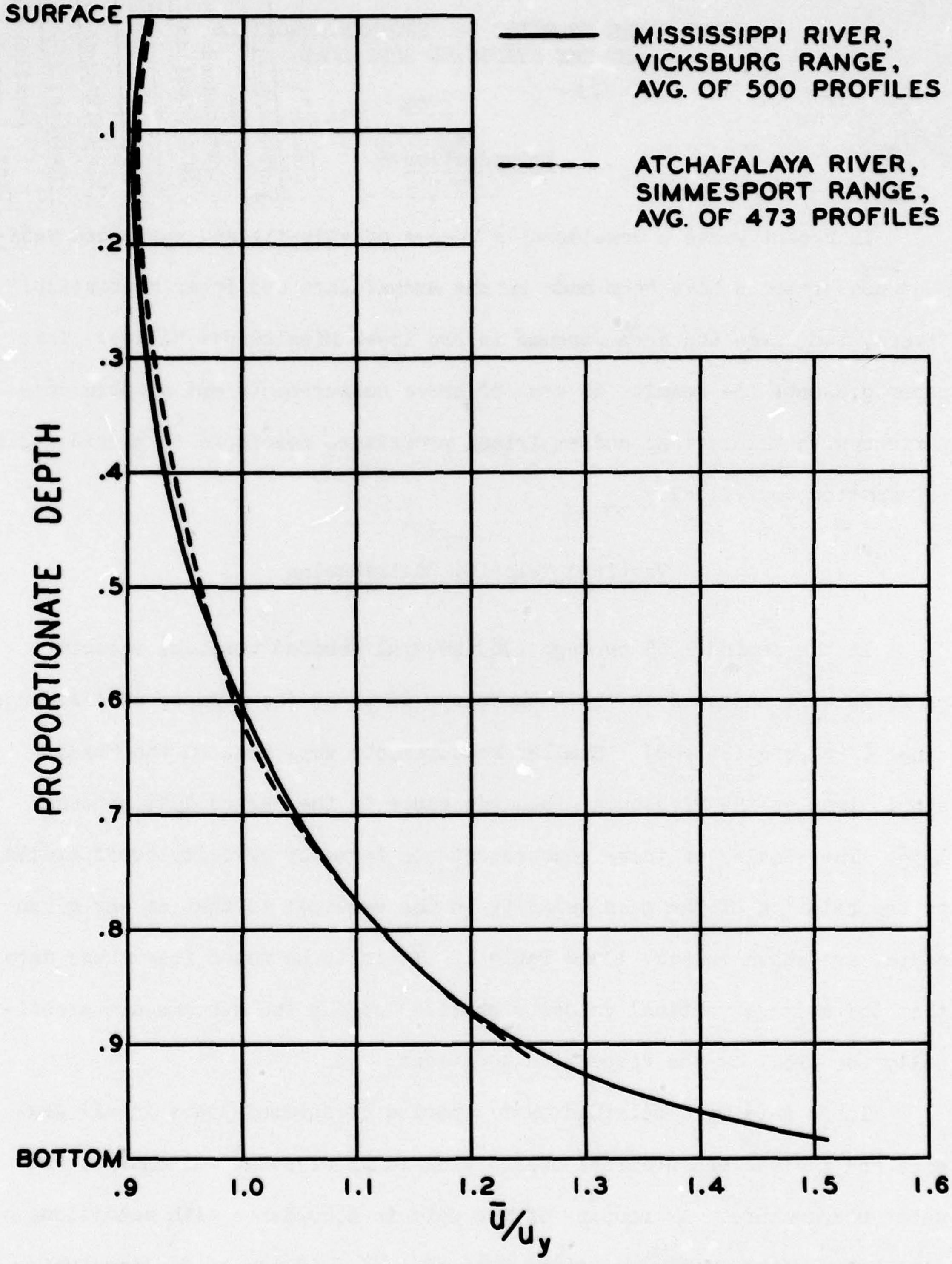


FIG. 1 VELOCITY PROFILES

Table 1

Average Velocity Coefficient $\bar{U}/U_y$

Proportionate Depth	Mississippi River at Vicksburg*	Atchafalaya River at Simmesport**
S†	0.915	0.917
0.1	.902	.906
.2	.905	.912
.3	.914	.922
.4	.931	.938
.5	.957	.960
.6	.994	.991
.7	1.045	1.042
.8	1.121	1.120
.9	1.244	1.233
B††	1.461	---

* Determined from 500 measurements.
** Determined from 473 measurements.
† Surface measurement taken at 0.5-ft depth.
†† Bottom measurement taken at 1.8 ft above bottom.

that the natural scatter or variations due to turbulence obscured the discernment of any seasonal or other effects. Table 2 shows the degree of variation in the 500 sets of Vicksburg measurements by deviations from the average for each tenth of depth. It is of particular interest to note in this tabulation that scatter is more pronounced in the upper and lower regions of flow, particularly the latter. As will be seen later, this greater scatter at the extremities of the velocity profile apparently affects sediment sampling in these areas.

A log-log plot of the velocity coefficients in Table 1 applied to any value of mean velocity gives the reasonably accurate vertical velocity distribution formula

$$U_y = 1.15\,\bar{U}\left(\frac{y}{d}\right)^{0.155} \qquad (1)$$

in which y is distance above the bed, d is the depth of a mean-depth section, $\bar{U}$ is the average velocity of flow in the mean-depth section, and U_y is the point velocity at y distance from the bed. This velocity distribution for any values of $\bar{U}$ and d shows that m, the number of velocity units per cycle of 10 of either y or y/d, can be expressed as

$$m = \frac{\bar{U}}{3.40} \qquad (2)$$

The Von Karman coefficient expressed as $k = \dfrac{2.3\, u_*}{m}$ then becomes

$$k = \frac{44.4 \sqrt{Sd}}{\bar{U}} \qquad (3)$$

in which S is the water-surface slope and u_*, the shear velocity, equals $\sqrt{Sdg}$, g being the acceleration due to gravity.

A comparison of the vertical velocity distribution given by formula 1 above with that from formula 3 in USDA Soil Conservation Service Technical Bulletin No. 1026 shows the two to be quite different. The latter formula gives velocities ranging from about 40 percent higher at the surface to about 100 percent higher near the bed. In this comparison the Technical Bulletin No. 1026 formula 3 was used in the form

$$\frac{\bar{U}_y}{u_*} = 8.50 + 5.75 \log_{10}\left(\frac{y}{\Delta}\right)$$

If this formula is stated as

$$\frac{\bar{U}_y}{u_*} = C + 5.75 \log_{10}\left(\frac{y}{\Delta}\right)$$

it is found that to reproduce the vertical velocity distribution determined by formula 1 would require C to be a negative number. Further, C would not be a constant for the range of y values, bottom to surface.

Although the procedure outlined in SCS Technical Bulletin No. 1026

Table 2

Summary of Deviations from the Average Velocity Coefficient at Each Tenth of Depth for the 500 Measurements in the Mississippi River at Vicksburg

% Deviation from Average	Proportionate Depth S*	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	B**
-20 > -20										4	44
-19											6
-18										2	9
-17	1									1	7
-16											15
-15	2							1	3	3	9
-14	1	2						1		7	11
-13	2		1					1	3	7	11
-12	3								5	18	15
-11	5	2	1				1	5	3	7	13
-10	10	1	1				2	3	6	22	13
-9	14	5	2	2		1		4	8	17	10
-8	18	10	3	2		2	4	8	11	13	16
-7	20	17	4	7	2	4	3	14	15	15	10
-6	26	24	14	6	6	9	10	13	23	26	12
-5	29	41	28	17	12	10	22	13	37	20	15
-4	34	37	38	25	16	18	31	37	29	18	11
-3	36	35	50	49	33	32	30	37	32	23	18
-2	26	44	53	72	60	57	59	39	27	26	16
-1	31	33	52	58	77	80	55	45	41	27	22
0	19	35	48	55	67	77	58	44	29	33	19
+1	29	30	43	53	81	76	76	53	34	29	13
+2	35	38	32	54	61	55	54	54	33	22	14
+3	28	23	26	34	35	33	34	39	37	15	11
+4	17	31	29	28	20	25	23	28	28	19	9
+5	24	20	28	15	12	11	15	24	24	25	16
+6	17	24	17	7	6	4	13	15	24	12	12
+7	18	16	12	8	5	4	4	8	12	12	9
+8	13	12	7	3	2	2		8	10	10	13
+9	7	6	3	2	1		2	1	8	9	11
+10	9	3	4		4		1	2	6	15	5
+11	7	5	2				1		1	12	7
+12	5	2	1	1			1	1	4	6	6
+13	2	1					1			2	10
+14	2	1		2				2	2	3	2
+15	1	1							2	5	6
+16	1										3
+17									2	4	4
+18	2									1	5
+19	1								1		2
+20 > +20	5	1	1							10	40

* Surface measurement taken at 0.5-ft depth.
** Bottom measurement taken at 1.8 ft above bottom.

for determining sediment loads has previously been used in Atchafalaya River studies, the preceding comparison of formulas indicates that use of the vertical velocity distribution formula 3 for sediment studies of either the Atchafalaya or Lower Mississippi River would give loads greatly in excess of measured loads.

Sediment Sampling and the Total Load

Suspended sediment sampling was initiated in 1949 on the Lower Mississippi River at Baton Rouge, and in 1951 on the Atchafalaya River at Simmesport. In 1958 the Baton Rouge operation was transferred to Red River Landing, about 72 miles upstream. Sampling is generally at two-week intervals, more frequent during floods when possible, and less frequent during the low-water season. The Luby method for point sampling was adopted for these stations, with 40 samples taken in Mississippi River cross sections, a sample from five levels in each of eight verticals, and 25 samples in the Atchafalaya River at five levels in five verticals. Bed material samples are also taken at each river station at each vertical of suspended sediment measurement.

Over the period of observations, which included all types of water years, the measured suspended sediment in the Lower Mississippi River averaged 84 percent finer than 62 microns at Baton Rouge and 71 percent at Red River Landing. In the Atchafalaya River at Simmesport the average was 76 percent. Bed material samples from the Baton Rouge and Simmesport stations show the dominant material to be fine and very fine sand, and very little of the sand portion of the measured suspended sediment at these stations exceeded 1/4 mm in size. The characteristics of these suspended sediments, then, are such that the Luby five-point method would be expected to give an overall total-load accuracy within 1 or 2 percent. A summary of the results of observations at the three stations discussed above is shown in Table 3.

Evaluation of Measured Load

The discussion that follows attempts to evaluate the accuracy of suspended sediment measurements and load determinations of the Atchafalaya River at Simmesport.

The laboratory analyses of the suspended sediment samples indicate generally that the material finer than 62 microns is fairly evenly distributed in the vertical, and that a major portion of this fraction of the load is in the size range of very fine silts and clays. As these fine materials comprise about 76 percent of the total load on a long-term basis, it is considered that this major portion of the total load is accurately measured. For an estimate of accuracy of measurement of the suspended sands, the fine sand fraction (1/4 to 1/8 mm) was selected for study. This is generally the dominant bed material and is found in transport at all levels in the channel section except at extremely low flows.

Figs. 2 through 12 present 11 examples of fine sand distribution as determined from analyses of the point samples. These examples cover a wide range of discharge with water depths at the verticals varying from 83 to 46 ft on the deep side of the channel, and from 54 to 26 ft on the shallow side. It is to be noted in the figures that measured data are shown for six levels in the verticals. The five measurements and average thereof on the extreme right in each figure show the results of measurements made at

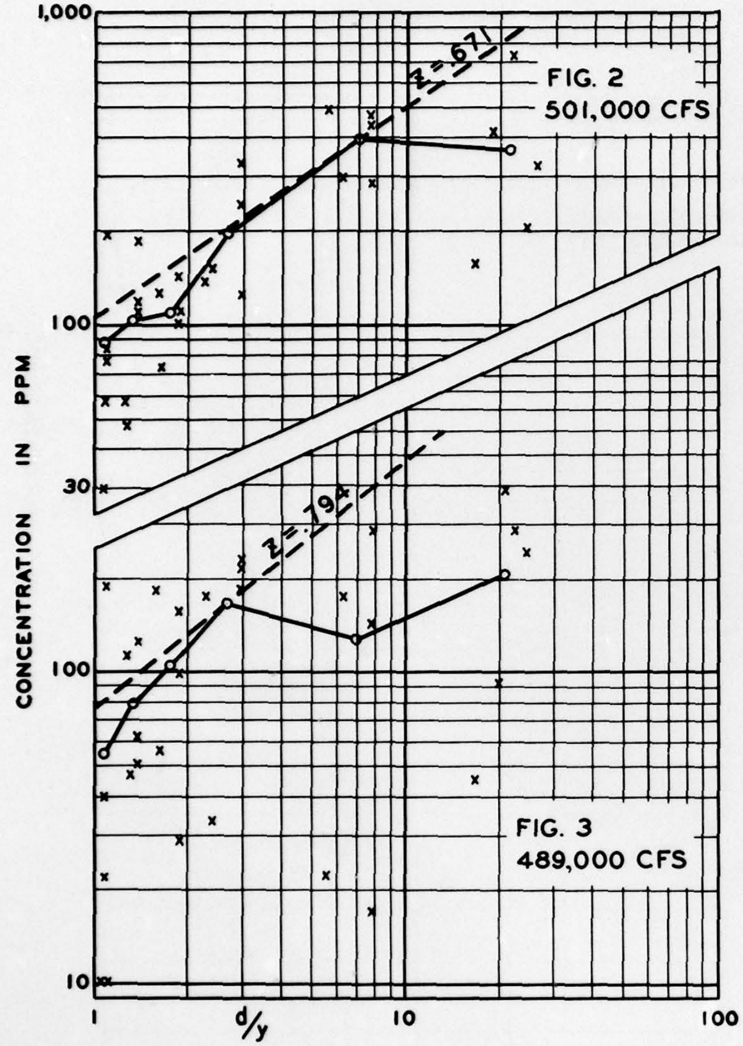
Table 3

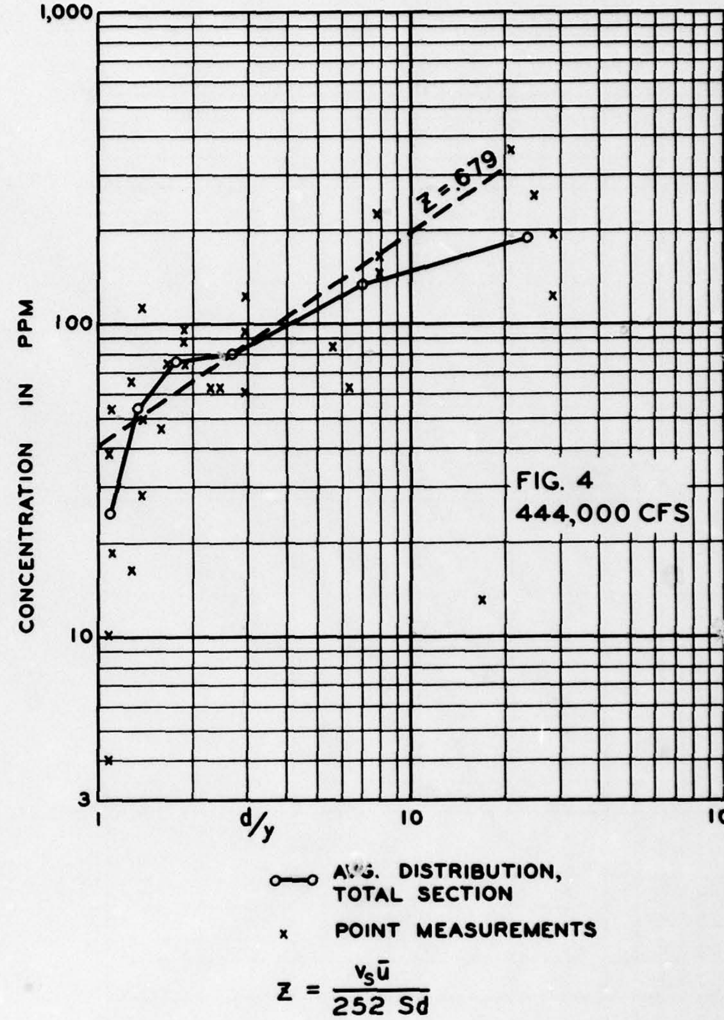
Summary of Measured Suspended Sediment Loads

Water Year (Oct-Sept)	Total Measured Sediment Load (in 1000 tons)	Sand-Silt Ratio: Sand In 1000 tons	Sand %	Silt In 1000 tons	Silt %	Water-Year Discharge (1000 dsf)	Average Sediment Concentration (in ppm)
		Atchafalaya River at Simmesport, Louisiana					
1951-1952	196,460	48,890	25	147.570	75	80,800	900
1952-1953	135,230	28,440	21	106,790	79	56,960	880
1953-1954	54,130	13,110	24	41,020	76	31,980	627
1954-1955	93,360	24,080	26	69,280	74	50,425	686
1955-1956	67,175	15,450	23	51,730	77	49,080	507
1956-1957	225,474	55,700	25	169,774	75	74,059	1126
1957-1958	214,390	48,082	22	166,308	78	89,413	887
1958-1959	83,230	20,944	25	62,286	75	55,729	553
1959-1960	131,878	24,153	18	107,725	82	69,333	704
1960-1961	133,372	40,524	30	92,848	70	76,814	643
		Lower Mississippi River at Baton Rouge and Red River Landing, Louisiana*					
1949-1950	548,330	107,770	20	440,560	80	245,200	828
1950-1951	575,280	67,600	12	507,680	88	224,810	947
1951-1952	408,390	73,820	18	334,570	82	200,660	754
1952-1953	212,580	28,920	14	183,660	86	142,200	552
1953-1954	107,730	14,090	13	93,650	87	88,660	449
1954-1955	211,490	39,930	19	171,550	81	137,460	570
1955-1956	161,220	25,920	16	135,300	84	127,530	468
1956-1957	291,388	53,043	18	238,345	82	172,875	624
1957-1958	325,774	95,203	29	230,571	71	195,653	616
1958-1959	230,504	78,693	34	151,811	66	129,253	660
1959-1960	318,234	77,219	24	241,015	76	163,850	718
1960-1961	231,754	71,471	31	160,283	69	168,133	510

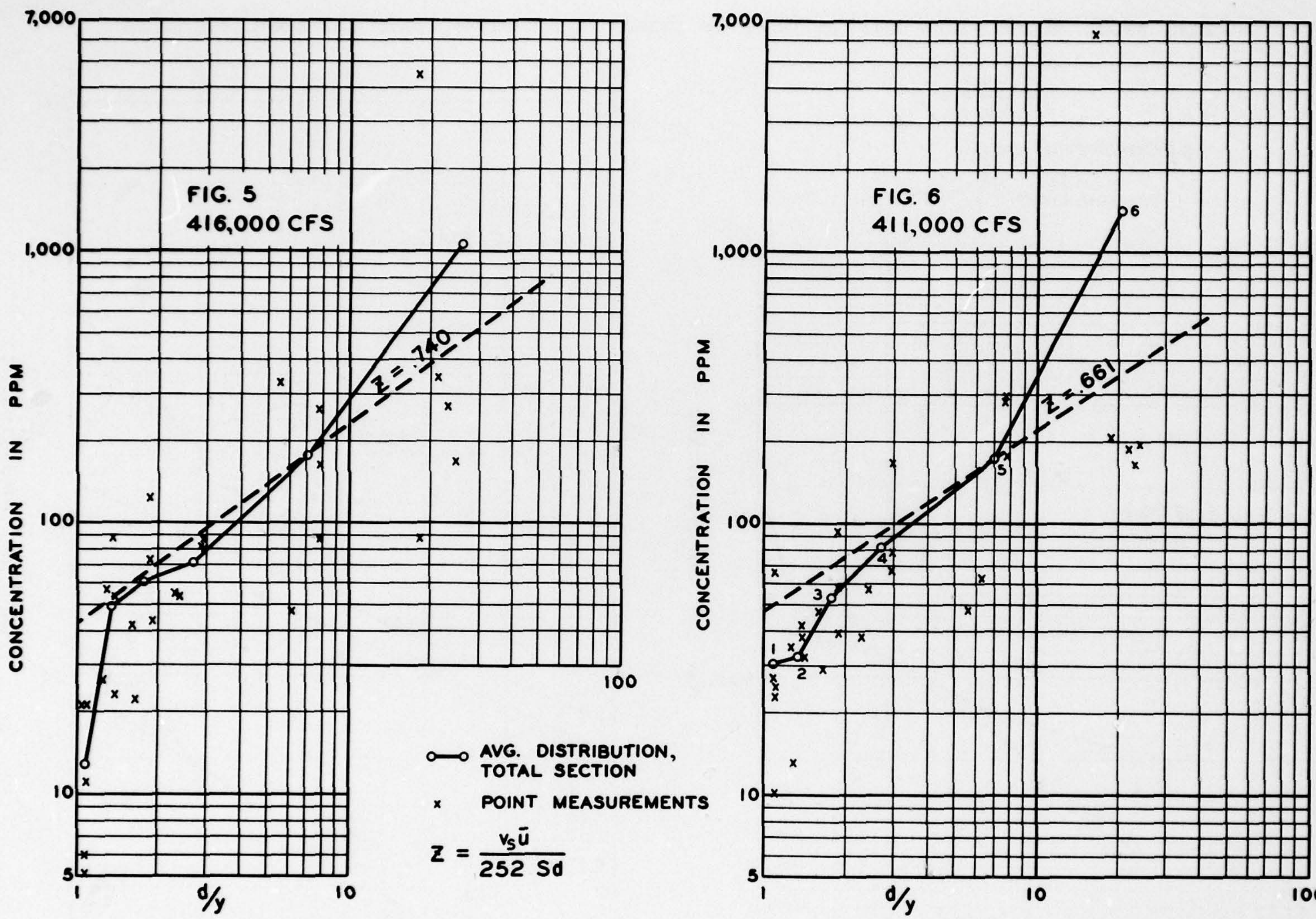
Note: The sand fraction is the material retained on the No. 230 sieve (0.062 mm). The silt fraction includes all of the fine material passing the No. 230 sieve.

* Sampling at Red River Landing after 1 January 1958.





MEASURED SUSPENDED FINE SAND AT SIX LEVELS AT EACH OF FIVE VERTICALS IN CROSS SECTION



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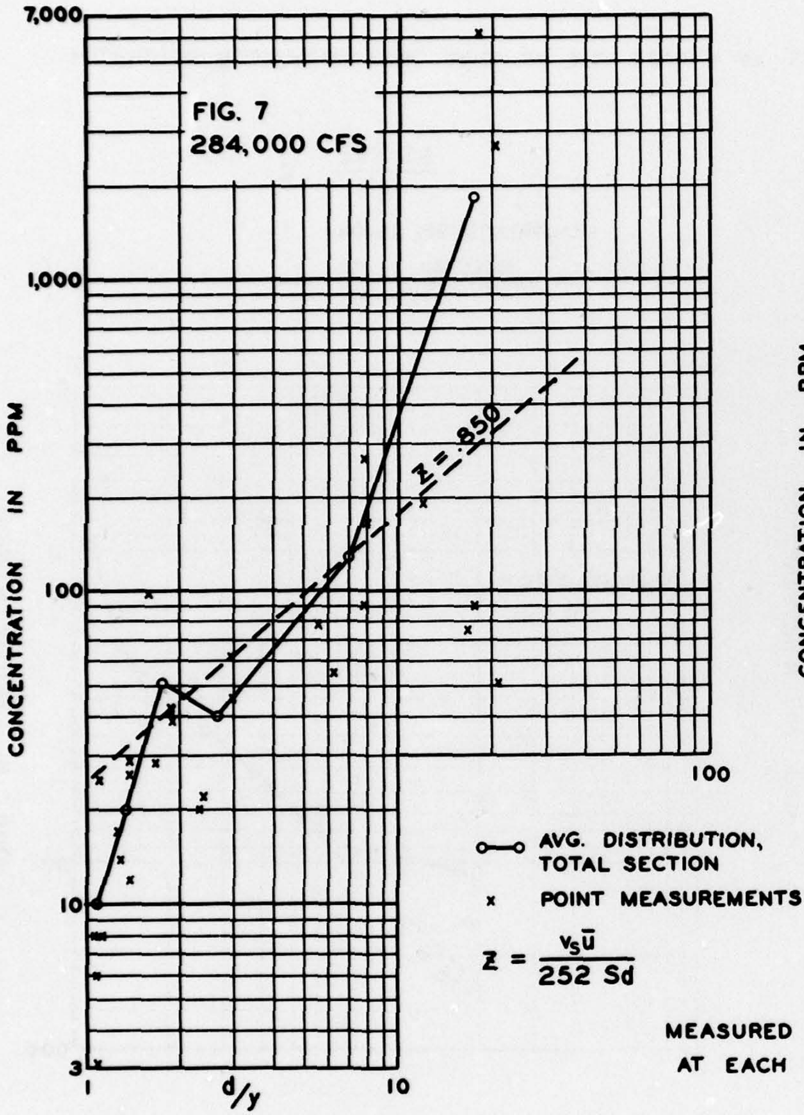
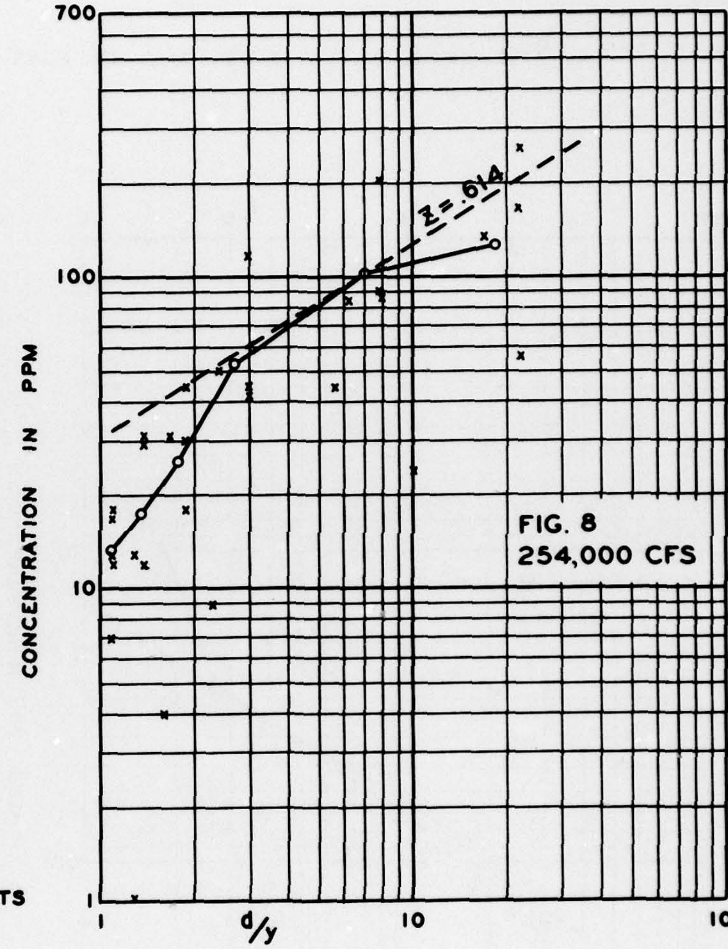




MEASURED SUSPENDED FINE SAND AT SIX LEVELS AT EACH OF FIVE VERTICALS IN CROSS SECTION

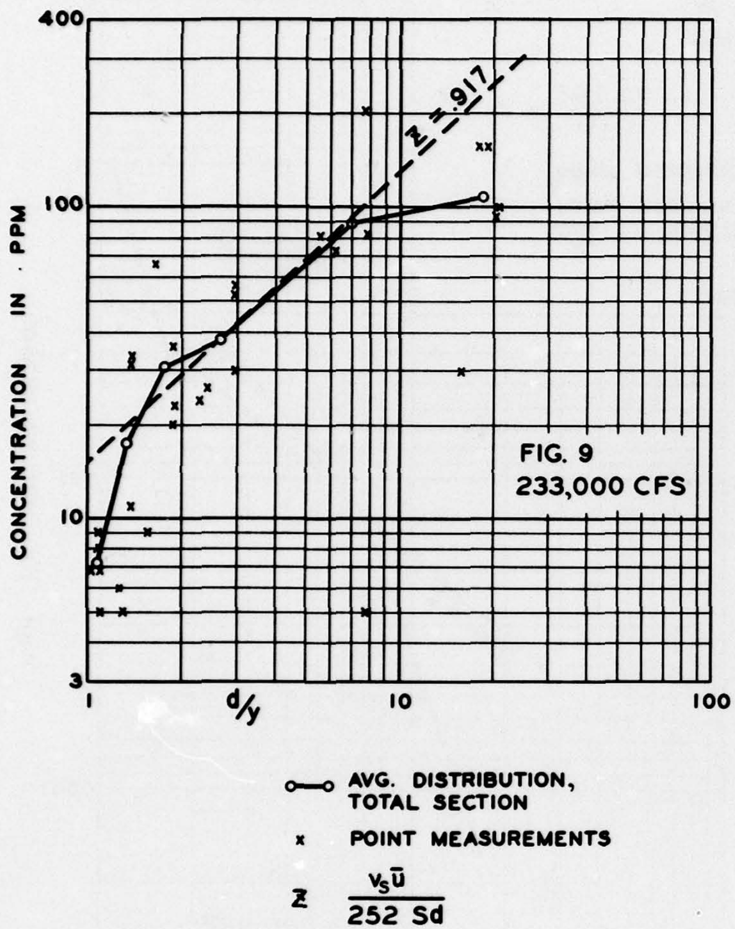


FIG. 9
233,000 CFS

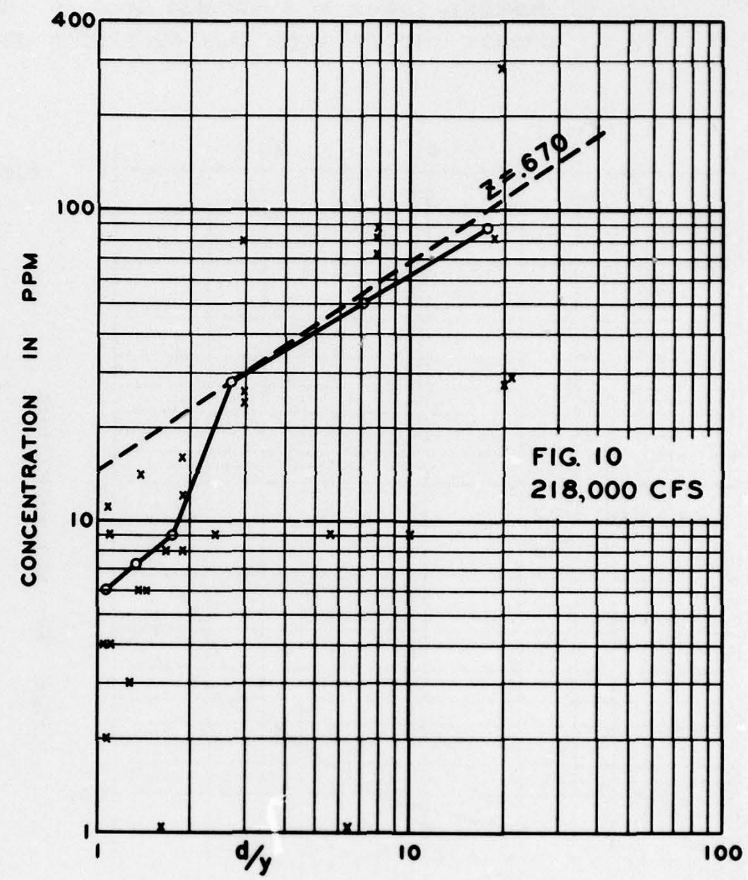
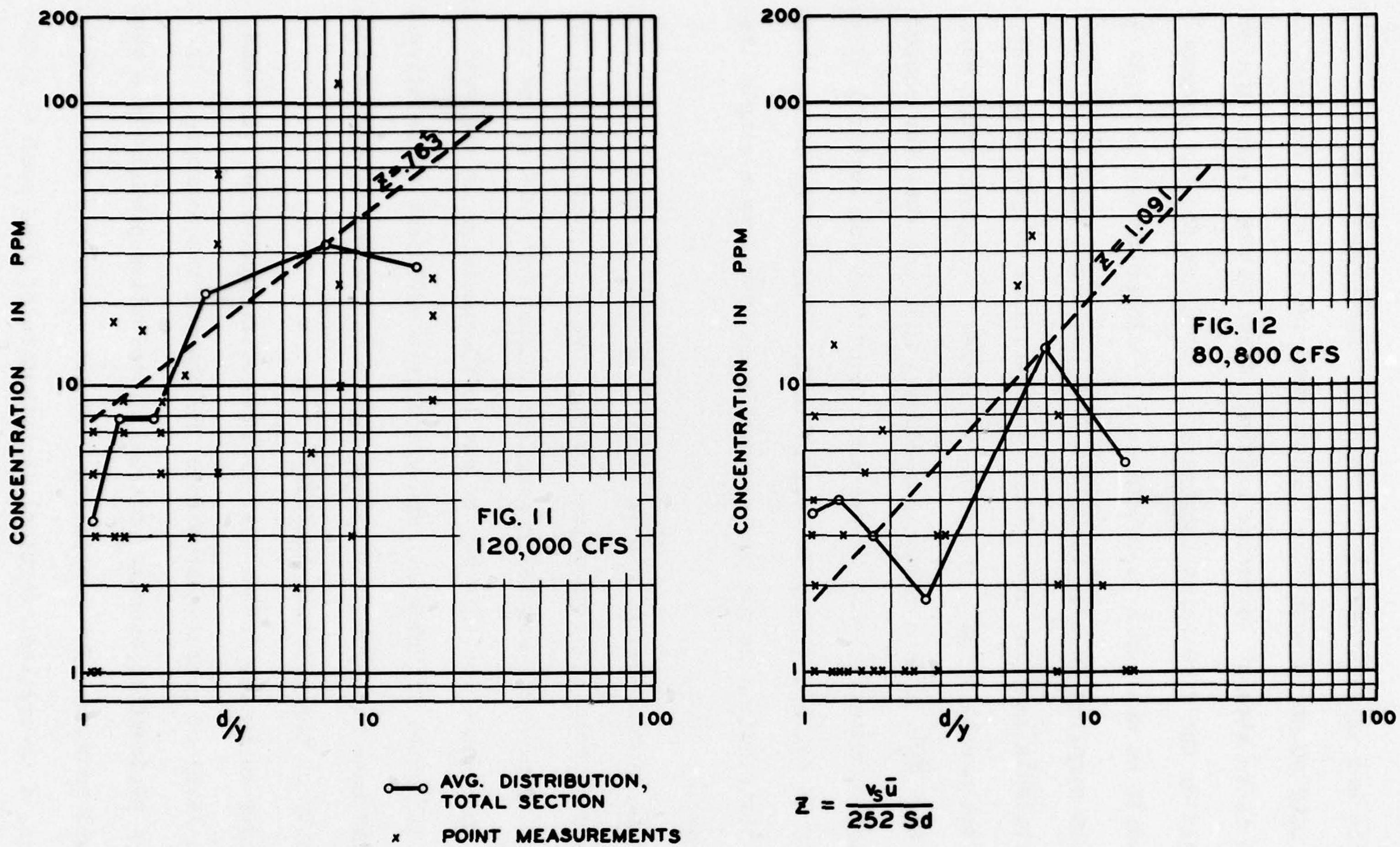


FIG. 10
218,000 CFS

MEASURED SUSPENDED FINE SAND AT SIX LEVELS AT EACH OF FIVE VERTICALS IN CROSS SECTION



$$Z = \frac{v_s \bar{u}}{252\, S d}$$

MEASURED SUSPENDED FINE SAND AT SIX LEVELS AT EACH OF FIVE VERTICALS IN CROSS SECTION

3 ft from the bed in each vertical. This is a measurement somewhat below the lowest Luby point in each case, and is not used in load computation. Its purpose is to attempt to define sediment distribution nearer the bed than dictated by the five-point Luby method. Although for the purpose stated it would be desirable to obtain samples closer to the bed than 3 ft, experience in sampling in deep turbulent flow has shown this to be the lowest practicable sampling level from considerations of possible loss or damage to instruments. The plot in these figures is concentration versus d/y rather than $\frac{d-y}{y}$, a more common procedure. This was done for convenience of load computation, but it was also found that the vertical distribution could be defined by d/y as well or better than by the conventional plot. The distribution is not satisfactorily definable by a single line in either case.

The plot of measured points in Figs. 2 through 12 shows a wide scatter in fine sand concentration values at all levels in each example, but in most of the examples the scatter appears to be somewhat less at and near middepth. The reason for this may be due to fluctuations in the velocity pattern as indicated in Table 2. The velocity coefficient is relatively stable at and near middepth, but fluctuates to an increasing degree toward each extremity of the vertical profile.

In order to better define the vertical distribution of fine sand, each common level of measurement across the channel was averaged. In essence this produced an average vertical distribution profile in a mean depth channel section. For comparison with the measured average vertical distribution, a theoretical vertical distribution of fine sand is indidated by the dashed line in each example. The evaluation of the coefficient Z for this theoretical distribution was determined by the expression

$$Z = \frac{v_s}{ku_*} = \frac{v_s}{k\sqrt{Sdg}}$$

in which v_s is the settling velocity of fine sand grains in feet per second. By substitution for k from formula 3

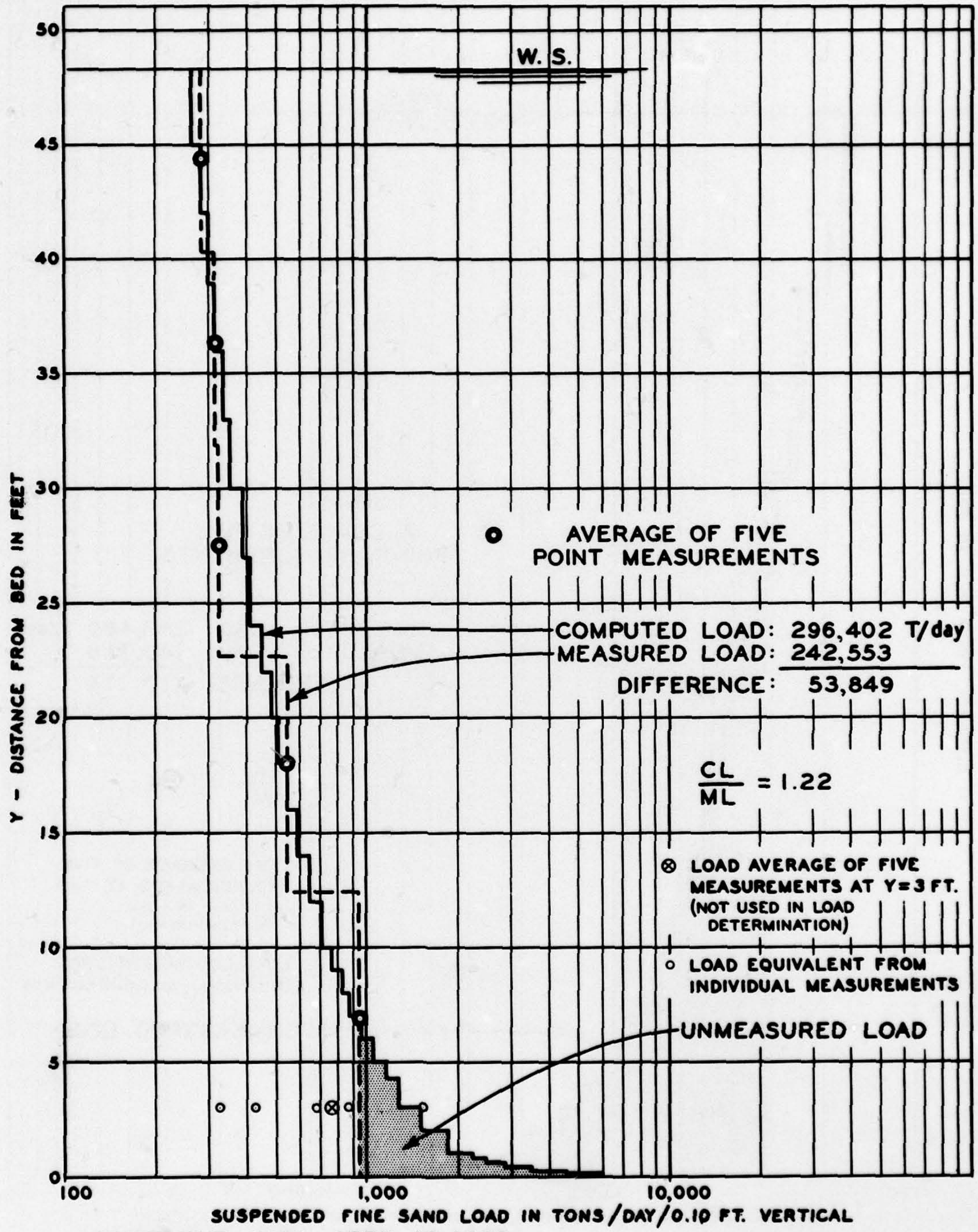
$$Z = \frac{v_s \bar{U}}{252\ Sd} \qquad (4)$$

In about two-thirds of the examples presented the measured data approximate this theoretical distribution from about middepth to 0.85 depth, or about one-third of the total depth. Several of the other examples, especially as shown in Figs. 3 and 12, have apparent sampling errors, or at least the questionable samples are not typical if a logical order of sediment density from surface to bottom is an accepted fact. In this regard it is not readily understood why the concentration at the points 3 ft above the bed should be generally out of line on the low side. In Figs. 5, 6, and 7 the average is high, but in each of these cases the high average is caused by a single sample of very high concentration.

In evaluating the accuracy of the fine sand measurements, the average profiles of Figs. 2 through 12 were each described by three lines. In fitting these lines to the average profiles it was assumed that the profiles approximated the true sediment distribution within the limits of the Luby points, except in cases such as shown in Figs. 3 and 12. One of the lines was fitted to points representing the profile in the approximate upper half of the channel section; another was fitted to profile points from approximate middepth to the level d/y = 11.24; and a third line extended from

$d/y = 11.24$ to near bed at $y = 3.68\ D_{65}$. The slope of the line to near bed was set as the equivalent of that of a $\frac{d-y}{y}$ versus concentration plot of the middle line. Any slope or position of the middle line plotted with d/y values will intersect a $\frac{d-y}{y}$ plot at $d/y = 11.24$. The lower limit of suspended load was assumed to be at the level $y = 3.68\ D_{65}$. For cases such as shown in Figs. 3 and 12, the middle line was assumed to be the dashed line, with extension of this line in the case of Fig. 12 to include all distribution from $d/y = 11.24$ to $d/y = 1$. To illustrate this, in Fig. 6 the sediment distribution in the upper portion of the channel section would be described by a line passing midway between points 1 and 2 and through point 3. Between this line and a point on $d/y = 11.24$ the distribution would be described by a line passing through points 4 and 5. From a point on this line at $d/y = 11.24$, the distribution to the lower limit of suspended material is on a line leaving a slope 0.756 times the slope of the preceding intersecting line. This distribution line near the bed will then be at a slope equivalent to a $\frac{d-y}{y}$ plot of the line passing through points 4 and 5.

The above-described procedure permits each of the sediment distribution lines to be formulated in terms compatible with formula 1 for vertical velocity distribution. It is then a rather simple mathematical process to compute the total fine sand load. The results of these computations and a comparison with the loads determined by the measurements alone are shown in Figs. 13 through 23. These graphs show the respective fine sand load in tons per day per 0.10-ft increments of depth at any level in the vertical over the entire width of a mean depth channel section. This type of plot is of special interest in that indicated loads from abnormal measurements are quite obvious at first glance. Also, it is immediately noticeable that



PERTINENT DATA : APRIL 12, 1962

Q : 501,000 CFS

WIDTH : 1651 FT

$\bar{u}$: 6.28 FPS

d : 48.3 FT

S : 4.92×10^{-5}

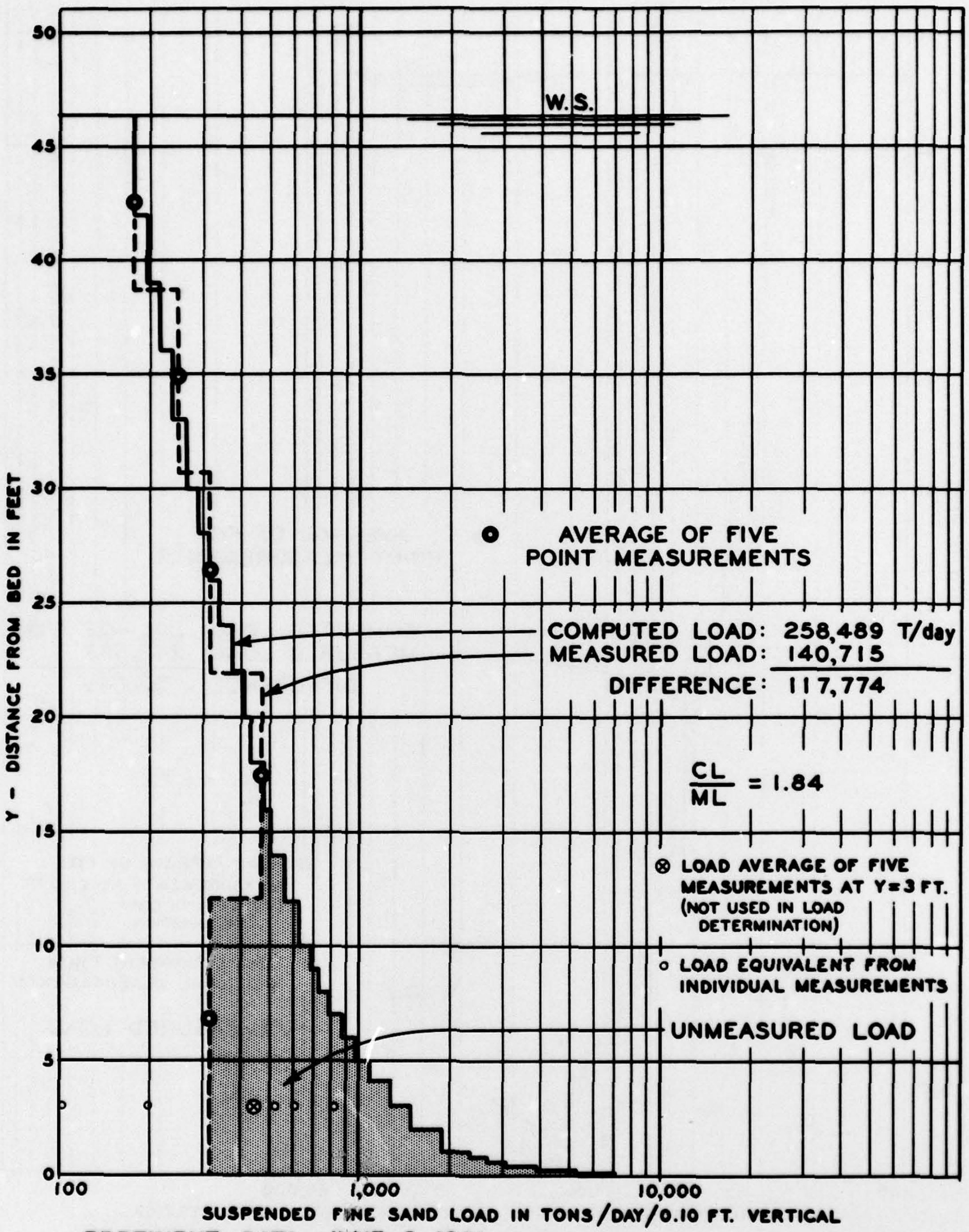
D_{65} : 7.38×10^{-4} FT

WATER TEMP. : 59°F

FINE SAND PORTION OF BED MATERIAL : 71.7 %

ATCHAFALAYA RIVER
SIMMESPORT
SEDIMENT RANGE

FIG. 13



PERTINENT DATA : JUNE 5, 1961

Q : 489,000 CFS S : 5.03×10^{-5}

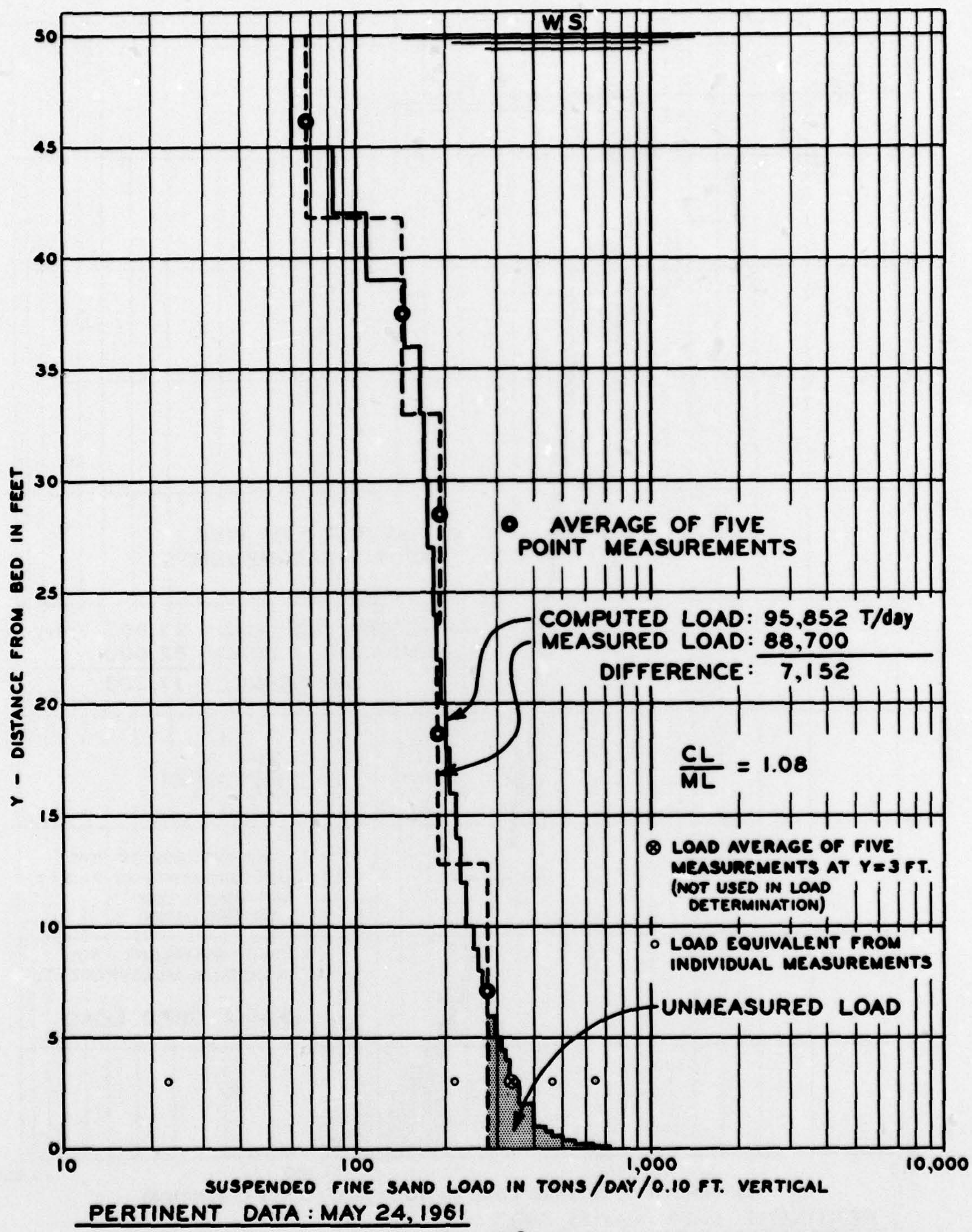
WIDTH : 1587 FT D_{65} : 6.75×10^{-4} FT

$\bar{u}$: 6.66 FPS WATER TEMP. : 70°F

d : 46.3 FT FINE SAND PORTION OF BED MATERIAL : 81.6 %

ATCHAFALAYA RIVER
SIMMESPORT
SEDIMENT RANGE

FIG. 14



PERTINENT DATA : MAY 24, 1961

Q : 444,000 FT S : 4.65×10^{-5}

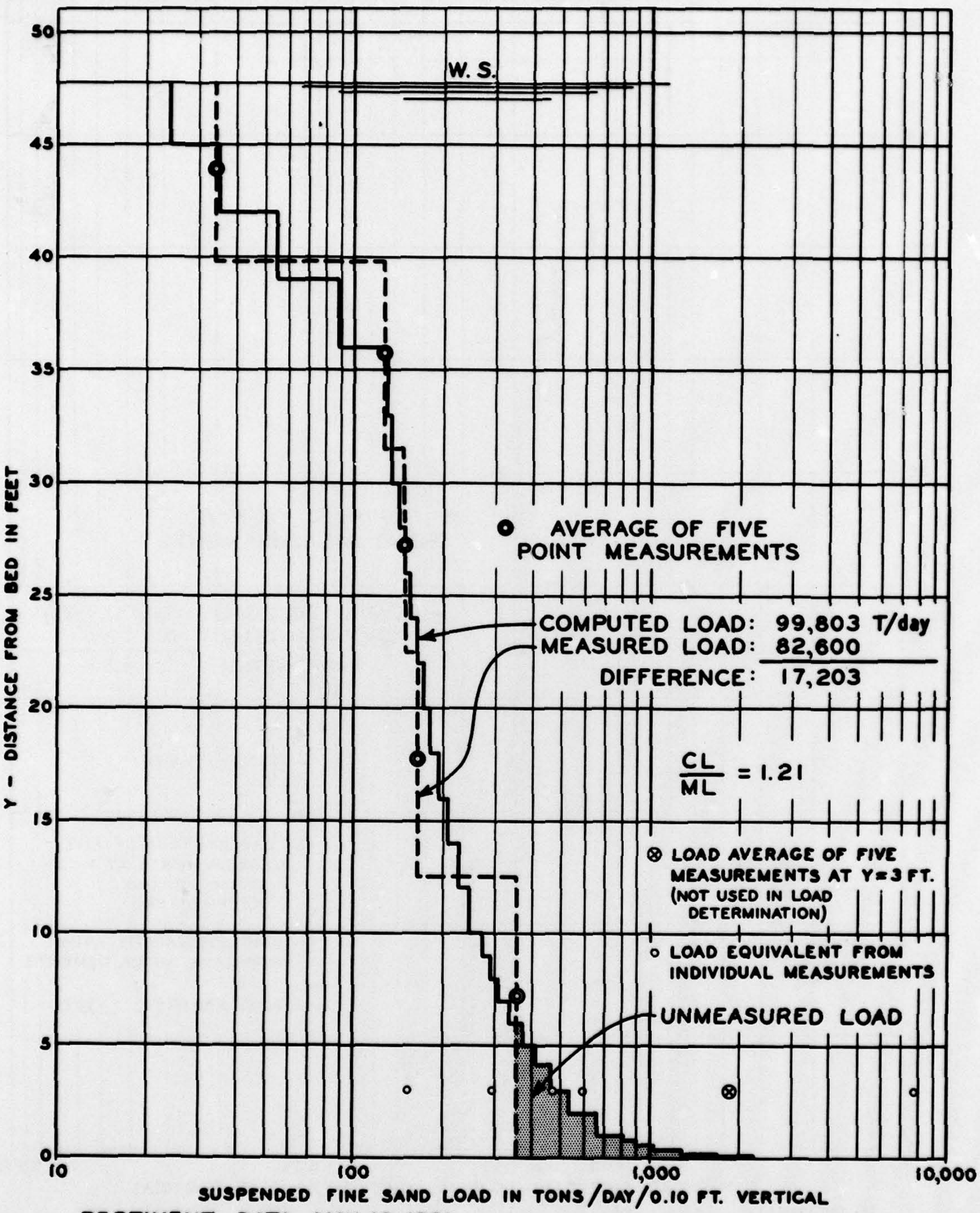
WIDTH : 1562 FT D_{65} : 6.98×10^{-4} FT

ū : 5.68 FPS WATER TEMP. : 70°F

d : 50.0 FT FINE SAND PORTION OF BED MATERIAL : 77.1 %

ATCHAFALAYA RIVER
SIMMESPORT
SEDIMENT RANGE

FIG. 15



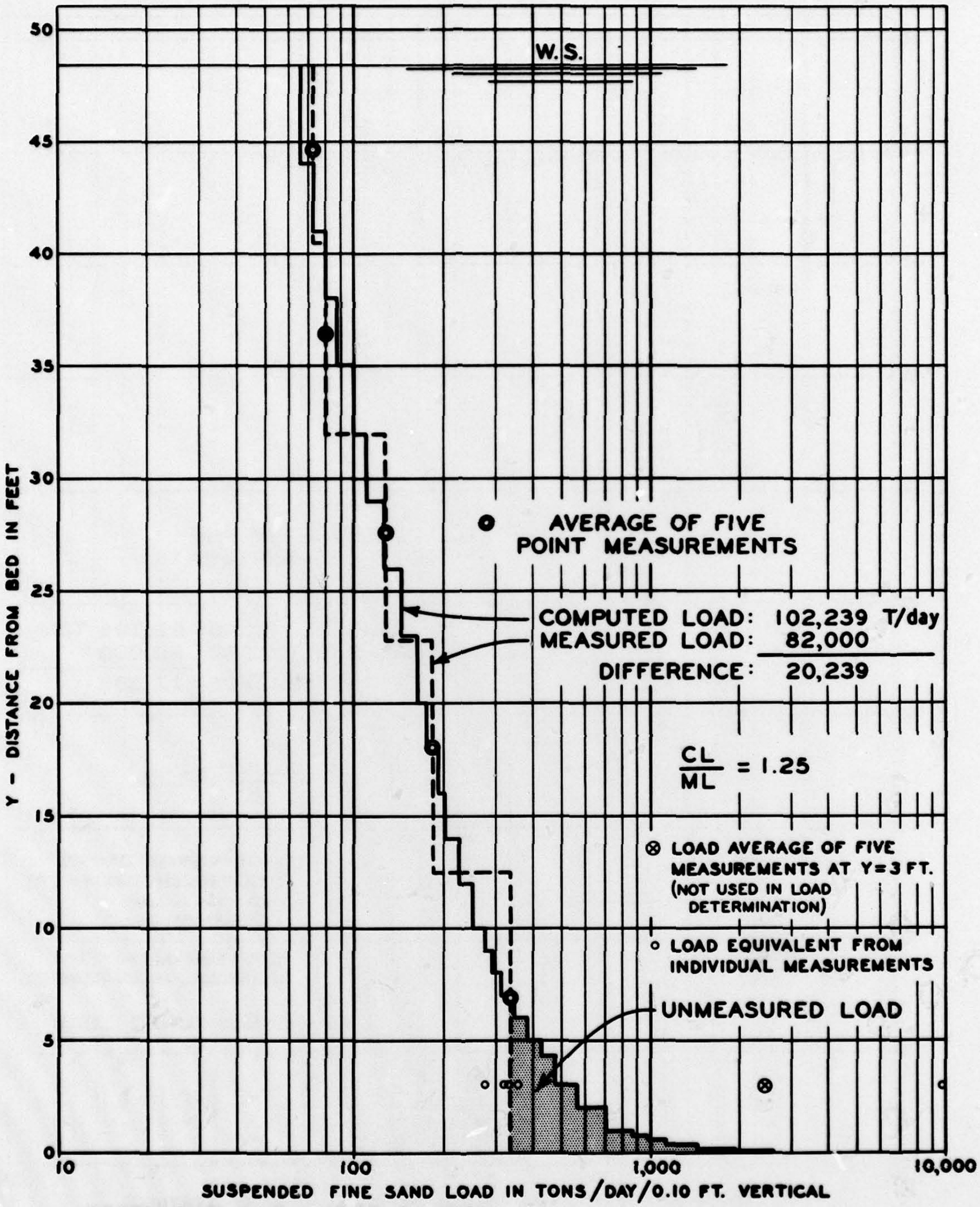
PERTINENT DATA : MAY 18, 1961

Q : 416,000 CFS
WIDTH : 1541 FT
ū : 5.65 FPS
d : 47.7 FT

S : 4.45×10^{-5}
D_{65} : 1.34×10^{-3} FT
WATER TEMP. : 69 °F
FINE SAND PORTION OF BED MATERIAL : 39.8 %

ATCHAFALAYA RIVER
SIMMESPORT
SEDIMENT RANGE

FIG. 16



PERTINENT DATA : APRIL 21, 1961

Q : 411,000 CFS S : 4.45×10^{-5}

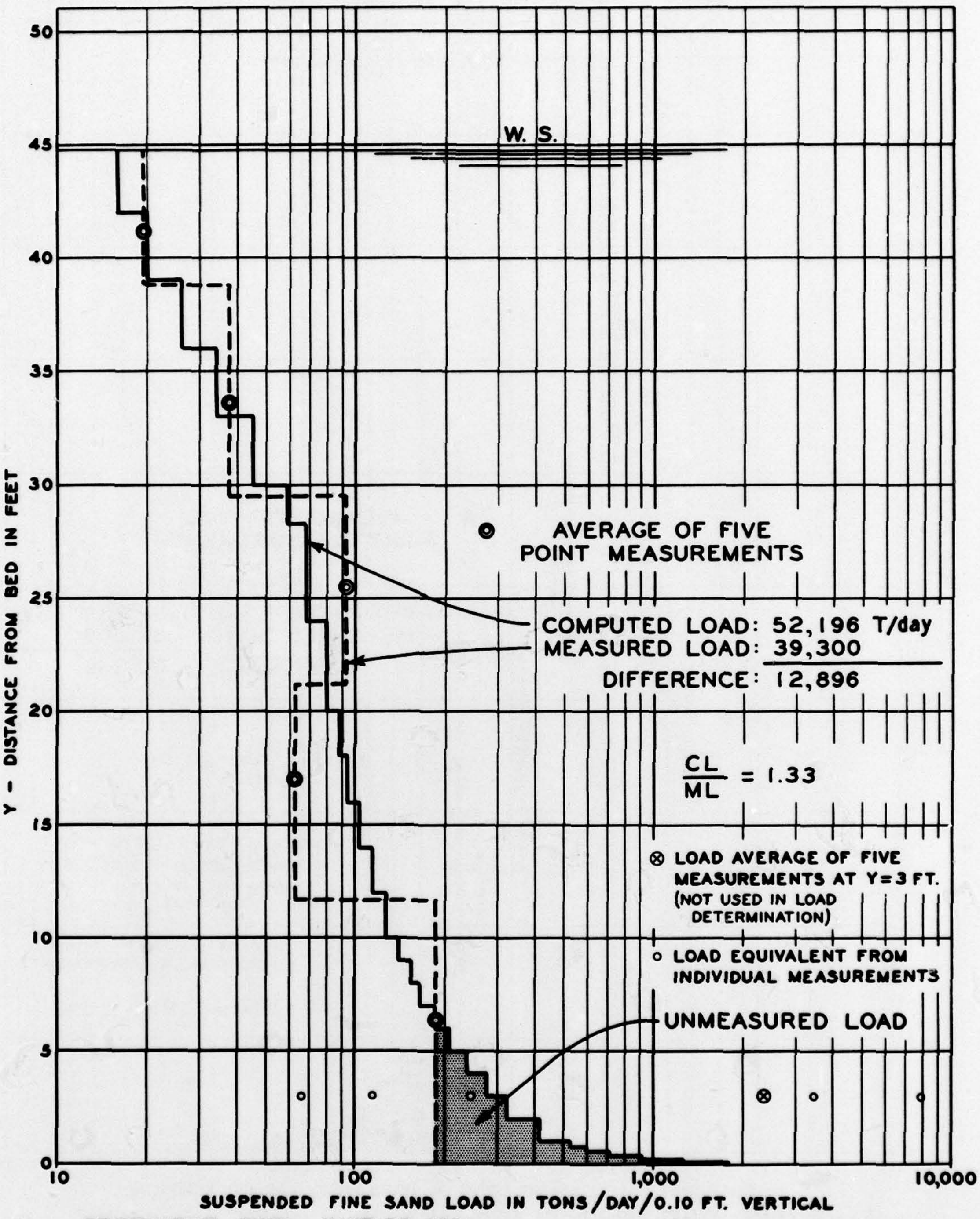
WIDTH : 1538 FT D_{65} : 1.13×10^{-3} FT

$\bar{u}$: 5.52 FPS WATER TEMP. : 61°F

d : 48.4 FT FINE SAND PORTION OF BED MATERIAL : 41.6 %

ATCHAFALAYA RIVER
SIMMESPORT
SEDIMENT RANGE

FIG. 17



PERTINENT DATA : JUNE 23, 1961

Q : 284,000 CFS — S : 3.74×10^{-5}

WIDTH : 1333 FT — D_{65} : 7.35×10^{-4} FT

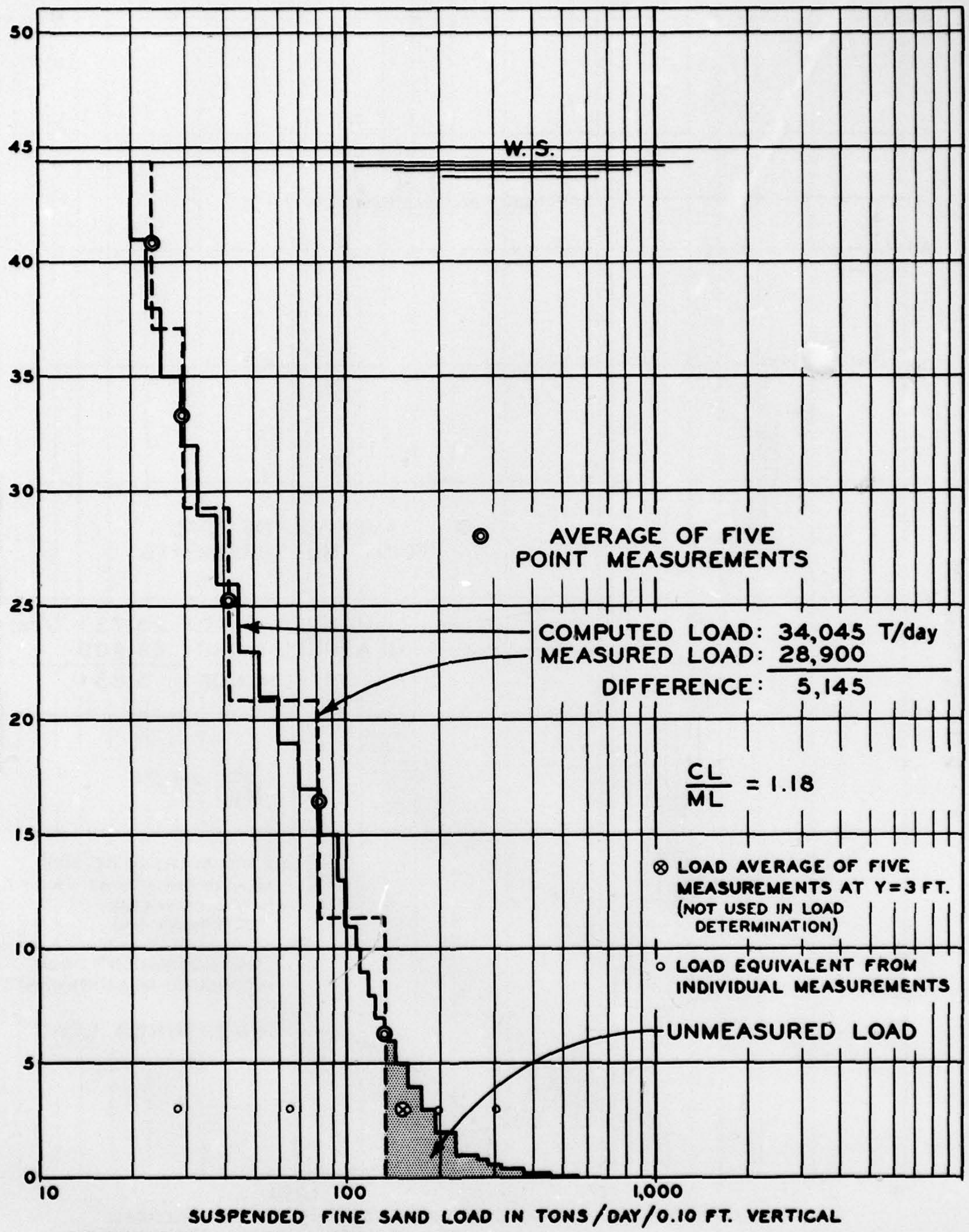
$\bar{u}$: 4.77 FPS — WATER TEMP. : 78 °F

d : 44.7 FT — FINE SAND PORTION OF BED MATERIAL : 68.3 %

ATCHAFALAYA RIVER

SIMMESPORT SEDIMENT RANGE

FIG. 18



PERTINENT DATA: NOV. 30, 1961

Q : 254,000 CFS
WIDTH : 1312 FT
$\bar{u}$: 4.36 FPS
d : 44.4 FT
S : 3.74×10^{-5}
D_{65} : 7.60×10^{-4} FT
WATER TEMP. : 52°F
FINE SAND PORTION OF BED MATERIAL : — %

ATCHAFALAYA RIVER
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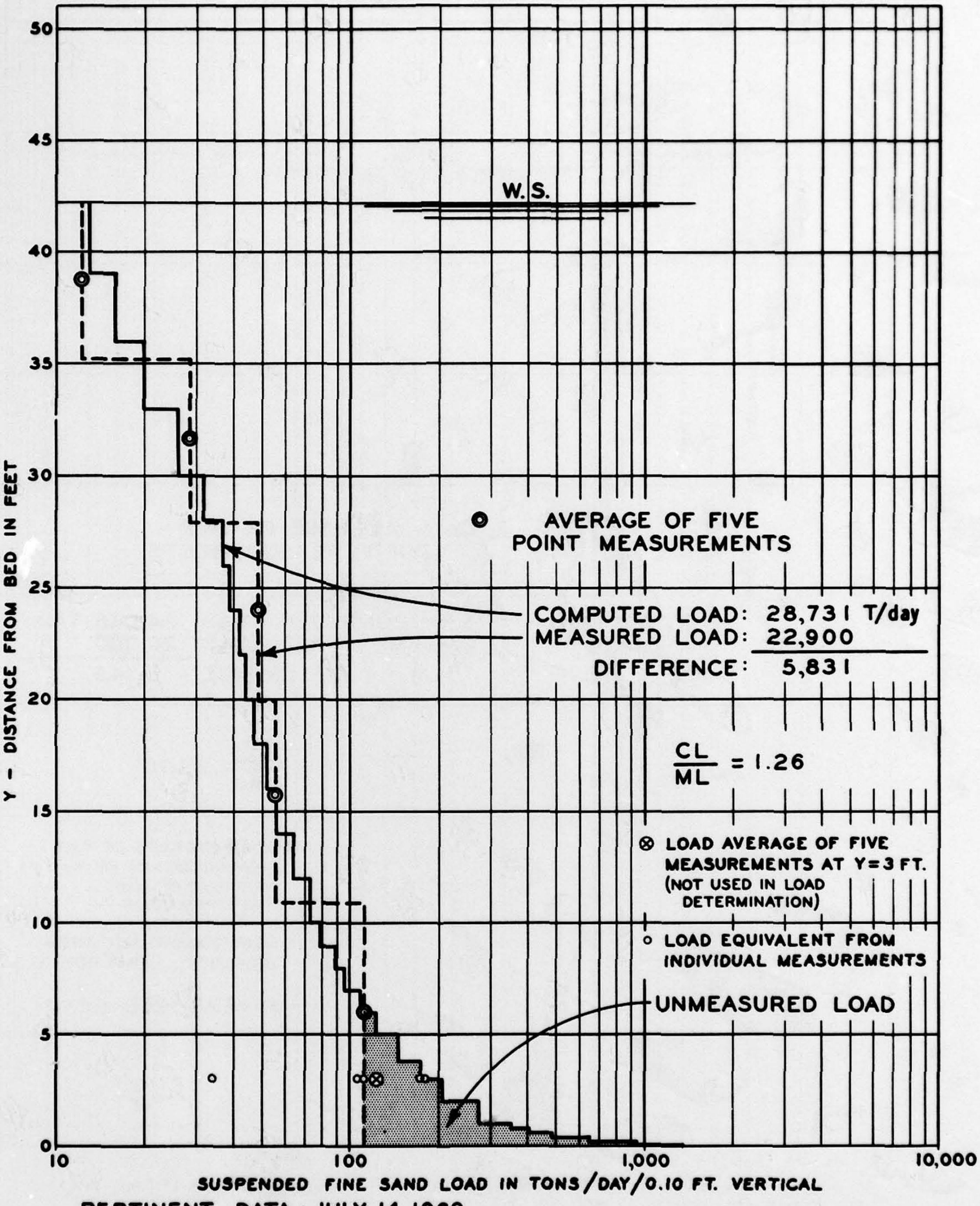
FIG. 19



PERTINENT DATA : JULY 14, 1960

Q : 233,000 CFS
S : 3.42×10^{-5}
WIDTH : 1290 FT
D_{65} : 7.57×10^{-4} FT
$\bar{u}$: 4.28 FPS
WATER TEMP. : 84°F
d : 42.2 FT
FINE SAND PORTION OF BED MATERIAL : 40.5 %

ATCHAFALAYA RIVER
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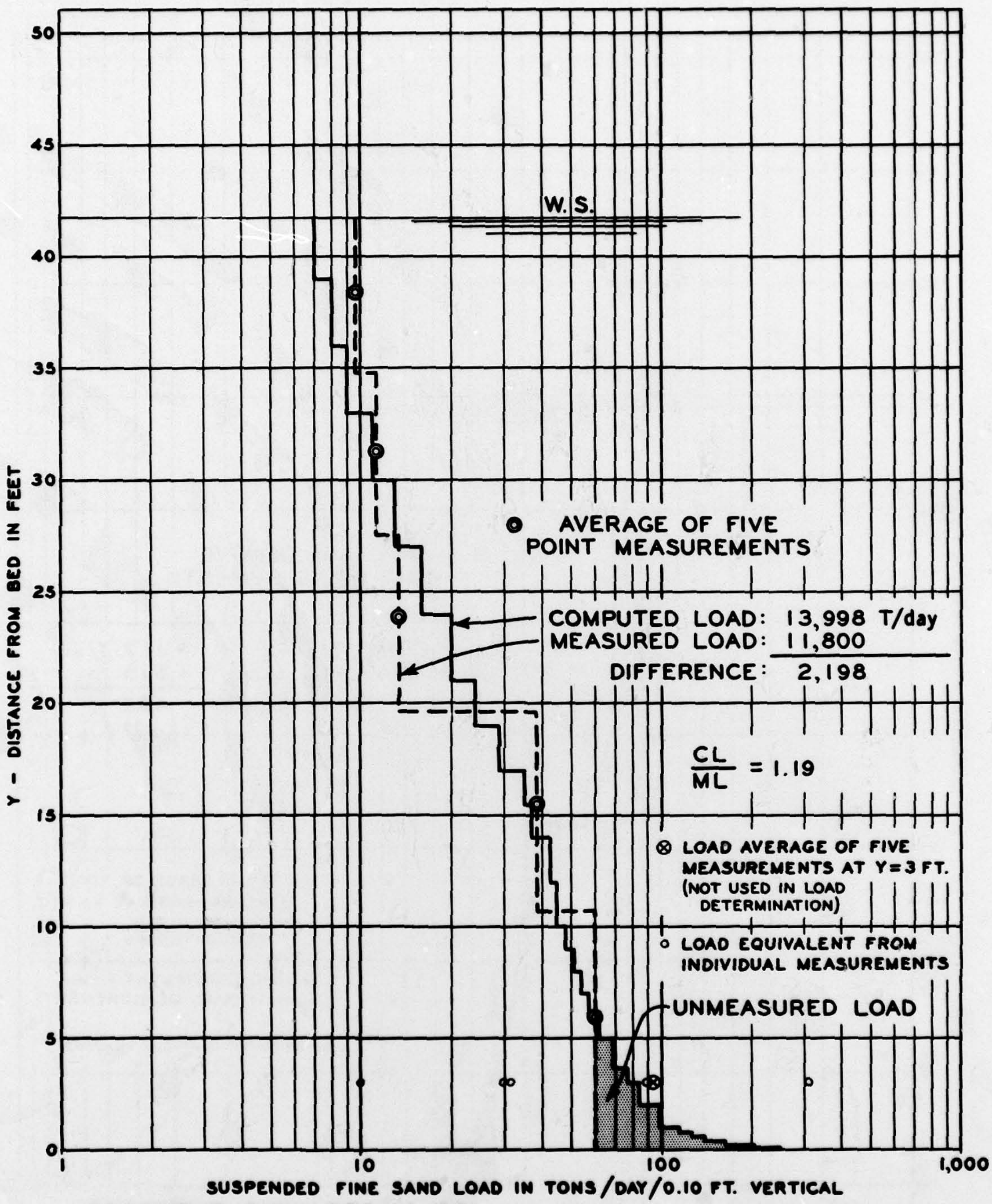
FIG. 20



PERTINENT DATA: DEC. 14, 1961

Q : 218,000 CFS
S : 3.36×10^{-5}
WIDTH : 1305 FT
D_{65} : 7.60×10^{-4} FT
$\bar{u}$: 4.01 FPS
WATER TEMP. : 52°F
d : 41.7 FT
FINE SAND PORTION OF BED MATERIAL : — %

ATCHAFALAYA RIVER
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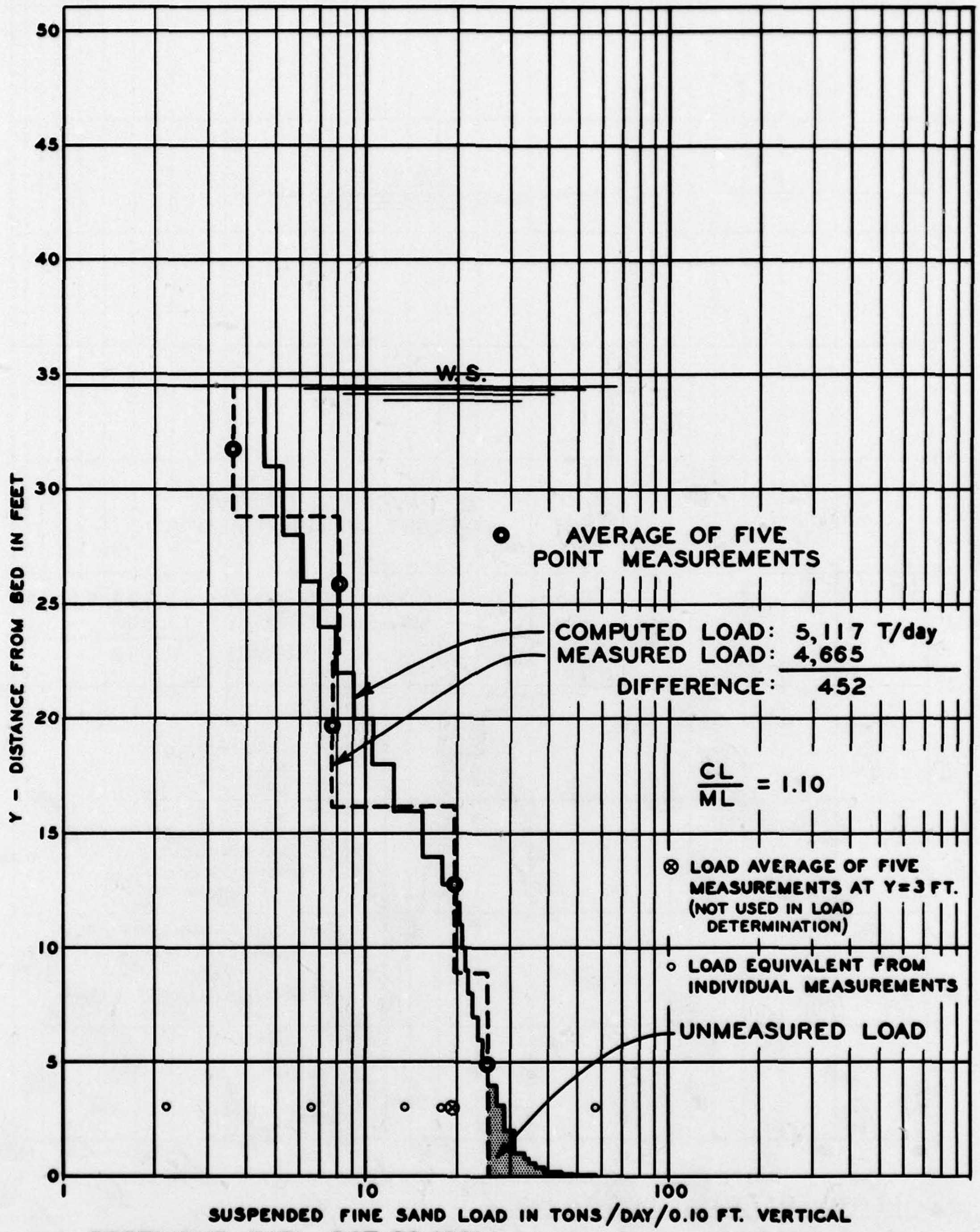
FIG. 21



PERTINENT DATA : OCT. 26, 1961

Q : 120,000 CFS
WIDTH : 1224 FT
$\bar{u}$: 2.84 FPS
d : 34.5 FT
S : 2.91×10^{-5}
D_{65} : 1.00×10^{-3} FT
WATER TEMP. : 66°F
FINE SAND PORTION OF BED MATERIAL : 20.8 %

ATCHAFALAYA RIVER
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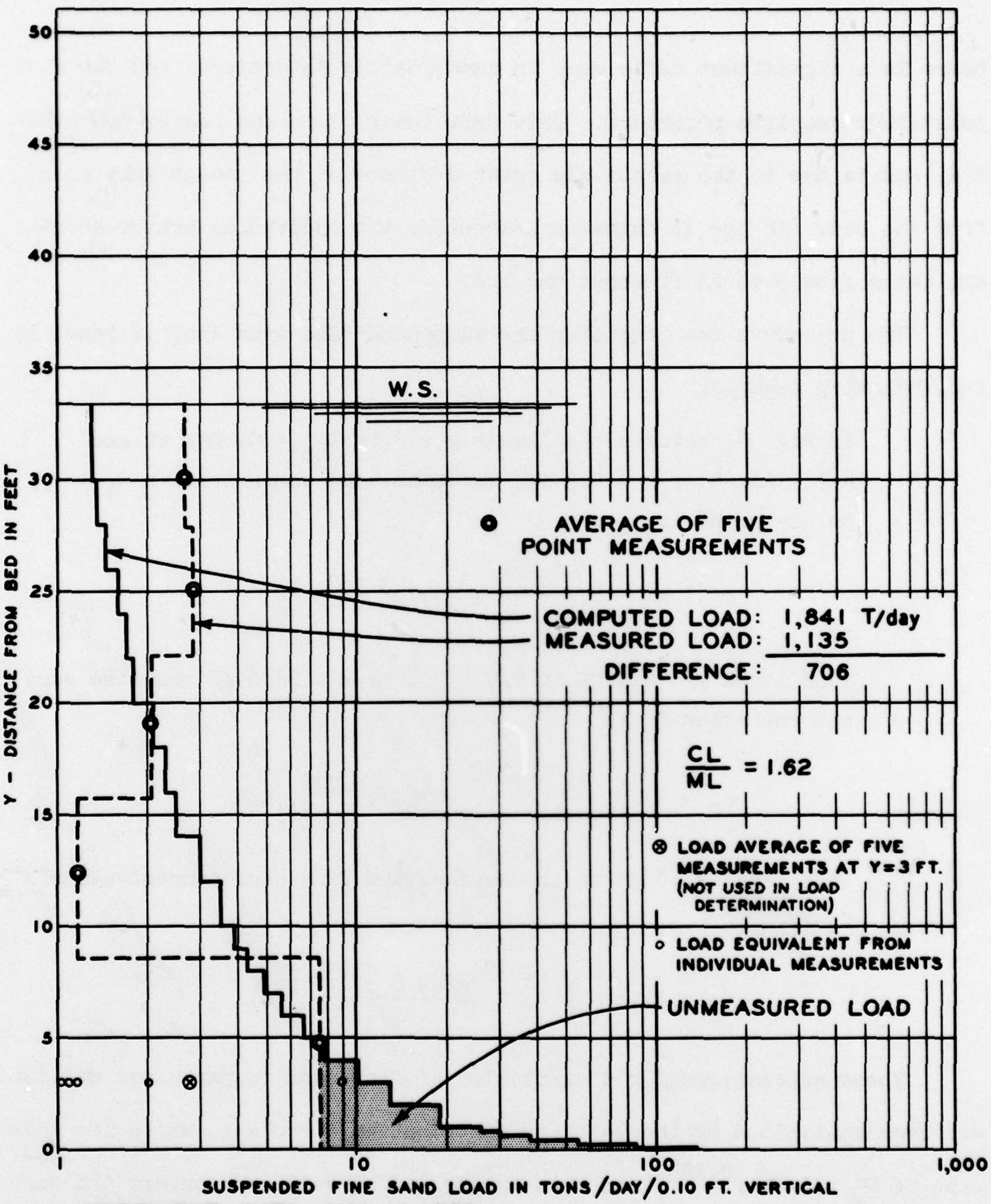
FIG. 22



PERTINENT DATA : AUG. 11, 1960

Q : 80,800 CFS

WIDTH : 1076 FT

$\bar{u}$: 2.25 FPS

d : 33.4 FT

S : 1.96×10^{-5}

D_{65} : 7.96×10^{-4} FT

WATER TEMP. : 87°F

FINE SAND PORTION OF BED MATERIAL : 54.9 %

ATCHAFALAYA RIVER
SIMMESPORT
SEDIMENT RANGE

FIG. 23

there is a significant deficiency in sand load as determined from the five-point Luby sampling procedure. This deficiency is in the region near the bed, and is due to the relatively great distance of the lowest Luby point from the bed. In the 11 examples presented, the individual bottom samples are taken from 5 to 13 ft above the bed.

The procedure for computing the suspended fine sand load is shown by the following example:

In Fig. 6, between the levels $y = 3.68\ D_{65} = 0.0042$ ft and $d/y = 11.24$ or $y = 4.3$ ft, the fine sand concentration C_1 at any point is

$$C_1 = 59 \left(\frac{d}{y} \right)^{0.588} = 577/y^{0.588}.$$

From level $y = 4.3$ ft to $d/y = 2.1$ or $y = 23.0$ ft the fine sand concentration C_2 is

$$C_2 = 37.5 \left(\frac{d}{y} \right)^{0.778} = 767/y^{0.778}, \text{ and}$$

from level 23.0 ft to the surface the fine sand concentration C_3 is

$$C_3 = 23.8 \left(\frac{d}{y} \right)^{1.38} = \frac{23.8\ d^{1.38}}{y^{1.38}}.$$

These expressions for distribution of fine sand in parts per million are each multiplied by the velocity distribution formula 1, which for this case is $U_y = 3.48\ y^{0.155}$, and then multiplied by 4.146 to convert the distribution to tons per day over the width of channel. The resulting expressions are

$$C_1U_y = \frac{8325}{y^{0.433}};\ C_2U_y = \frac{11{,}066}{y^{0.623}};\ C_3U_y = \frac{343.4\ d^{1.38}}{y^{1.225}}$$

We can now determine the total or incremental sediment loads within the prescribed limits of each by integration. Resultant expressions are:

$$\text{Sediment load } S_1 = 14{,}683\ y^{0.567}\Big]_{y=0.0042}^{y=4.3}$$

$$\text{Sediment load } S_2 = 29{,}353\ y^{0.377}\Big]_{y=4.3}^{y=23.0}$$

$$\text{Sediment load } S_3 = 134{,}613\left(\frac{d}{y}\right)^{0.225}\Bigg]_{y=48.4}^{y=23.0}$$

To check the accuracy of fitting the distribution lines to measured data, the computed load above the lowest measured value coincident with the computed load graphs in Figs. 13 through 23 was added to the load encompassed by the measured load graph below that point. This load in every case was within 3 percent of the total measured load, which indicates a satisfactory alignment of distribution lines above the lowermost Luby point. As the analytical treatment of the load below this level logically assumes that the concentration of sand will increase toward the bed, any significant difference in measured and computed load is generally in that portion of the load between the lowest Luby point and the bed. It is thus indicated in the 11 examples presented that an upward adjustment of the measured fine sand loads in amounts from 8 to 84 percent is warranted. The overall average for the 11 cases is +32 percent. If these examples, which were selected at random, are typical and it is assumed that the total measured sand load in suspension is equally deficient, the unmeasured sand load in the 10-year period would total 106 million tons. The examples used in this study could well be typical, and it is reasonable to assume that measurements of all of the sand load are equally short.

Discussion

It must be realized that in field operations an abnormal or atypical sample cannot be recognized. Also, when the samples are received in the laboratory a settling period of at least two weeks is required before an analysis can be made. Therefore, since it is several weeks after a set of samples is taken before a load determination can be made, averaging is depended on to equalize the deviations. The unreliability of such dependence is exemplified in the measurements at a flow of 489,000 cfs as shown in Figs. 3 and 14. In this case two samples at the lowermost Luby point in two of the five verticals are apparently in error, and in sufficient amount to greatly affect the evaluation of measured load. The total sediment content of each of these samples was about one-half of that in the next two samples 13 ft farther from the bed. The sand contents were 15 and 22 percent, respectively, of those in the next higher sampling level. It is considered that of the 117,774 tons per day difference between the computed and measured fine sand load, about 55,000 tons is attributable to the two abnormal samples.

Conclusions

The examination and analysis of the velocity and sediment profiles selected for presentation in this paper suggest the following conclusions:

a. The vertical velocity distribution formula 3 in USDA Soil

Conservation Service Technical Bulletin No. 1026 is not applicable to large rivers such as the Lower Mississippi River and the Atchafalaya River.

b. In studies involving the velocity and sedimentation characteristics of large rivers, the treatment of entire channel sections as a unit is a satisfactory procedure.

c. There is a significant deficiency in measurements of the suspended sand load by the Luby method.

d. As a supplement to point sampling by the Luby method, additional samples are required near the bed to define sediment transport in that region. A basic weakness in the Luby method is that regardless of the number of points measured, more samples will always be taken above middepth than below. Therefore, an excessive total number of samples would be required for adequate sampling below middepth, and the cost would be prohibitive.

e. The accuracy of point sampling should be evaluated by a plot of data as presented herein, and the measured loads adjusted as necessary to describe the apparent actual load.