PROGRESS REPORT NUMBER 1

INVESTIGATIONS OF SOME SEDIMENTATION CHARACTERISTICS OF A SAND-BED STREAM

By

D. W. Hubbell and Others

Open File Report

GEOLOGICAL SURVEY

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CONTENTS

ILLUSTRATIONS

Page

TABLES

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INTRODUCTION

Several important aspects of sediment transport have been investigated by utilizing data from the turbulence flume in the Middle Loup River at Dunning, Nebr. These data have also been used to evaluate sedimentation formulas. However, additional work of a research nature is needed to provide information on specific transport phenomena and on field procedures. On August 26, 1955, representatives of the U. S. Bureau of Reclamation and U. S. Geological Survey met in Denver, Colo., to discuss these needs and the sediment investigations to be made at the Middle Loup River at Dunning, Nebr., during 1956. Those attending the meeting were:

Mr. O. C. Hansen, Region 7, U. S. B. R., Denver, Colo.
Mr. K. B. Schroeder, Hydrology Branch, Assistant Commissioner and Chief Engineer's office, U. S. B. R., Denver, Colo.
Mr. R. F. Kreiss, Geological Survey, Lincoln, Nebr.
Mr. D. M. Culbertson, Geological Survey, Norton, Kans.
Mr. C. H. Hembree, Geological Survey, Lincoln, Nebr.

The conclusion of the group was that future cooperative research investigations at Dunning should be limited to problems that apply to alluvial-type streams in general and that the objectives of the cooperative research program for 1956 should be (1) to test the adequacy of the

ETR (equal transit rate) method of measuring suspended-sediment discharge (Kreiss, 1955), (2) to study methods for collecting representative bed-material samples, and (3) to study the applicability of the modified Einstein procedure for computing total sediment discharge immediately after frazil ice conditions and at water temperatures between 32° and 37°F. These objectives are given in detail in a U. S. Bureau of Reclamation memorandum dated September 5, 1955.

These investigations were programmed by Region 6, Region 7, and the Chief Engineer's office of the U. S. Bureau of Reclamation and by the U. S. Geological Survey. The investigations by the U. S. Geological Survey were financed with Missouri River basin project funds and were made under the supervision of the regional office, Quality of Water Branch, Geological Survey, Lincoln, Nebr. Field and laboratory work was done by employees of the Geological Survey, Lincoln, Nebr., under the supervision of D. M. Culbertson, area engineer.

Total load computations for eight sets of data were made by Bureau of Reclamation personnel. Mr. K. B. Schroeder, Hydrology Branch of the Assistant Commissioner and Chief Engineer's office, cooperated with Geological Survey personnel in the analysis of some data and assisted on June 4-8, 1956, with the preparation of an outline for this report. The report was prepared by D. W. Hubbell, P. R. Jordan, D. M. Culbertson, and C. H. Hembree.

FIELD INVESTIGATIONS

The Middle Loup River upstream from Dunning is in the sandhills region of Nebraska. Flow of the river is predominantly from groundwater accretion, and sediment loads are composed almost entirely of particles of sand size. The channel is alluvial and is confined laterally by low banks. More detailed explanations of the character of the river are given by Vice and Serr (1951), Benedict, Albertson, and Matejka (1955), and Hubbell and Matejka (in preparation).

For this investigation, measurements were made at sections A, B_1, C_2, D, and E. (See fig. 1.) Section A is about 7,200 feet upstream from the turbulence flume. During the measurement on May 8, 1956, the flow was divided into 2 channels, and bank-to-bank width of the stream was about 346 feet. Sand dunes were generally only 0.1 to 0.2 foot high; however, the front of a submerged bar that was moving into the section at the time of the measurement was about 2.0 feet high. Section B_1 is about 1,400 feet upstream from the turbulence flume. During the measurements on March 8, 1956, the section was about 96 feet wide. No sand dunes were observed; however, the depth of the stream at the center of the flow was less than the depth near the banks. Section C_2 is 600 feet upstream from the turbulence flume in a straight uniform reach. The banks in this reach have been stabilized by brush riprap, which confines the width to about 80 feet. At the time of

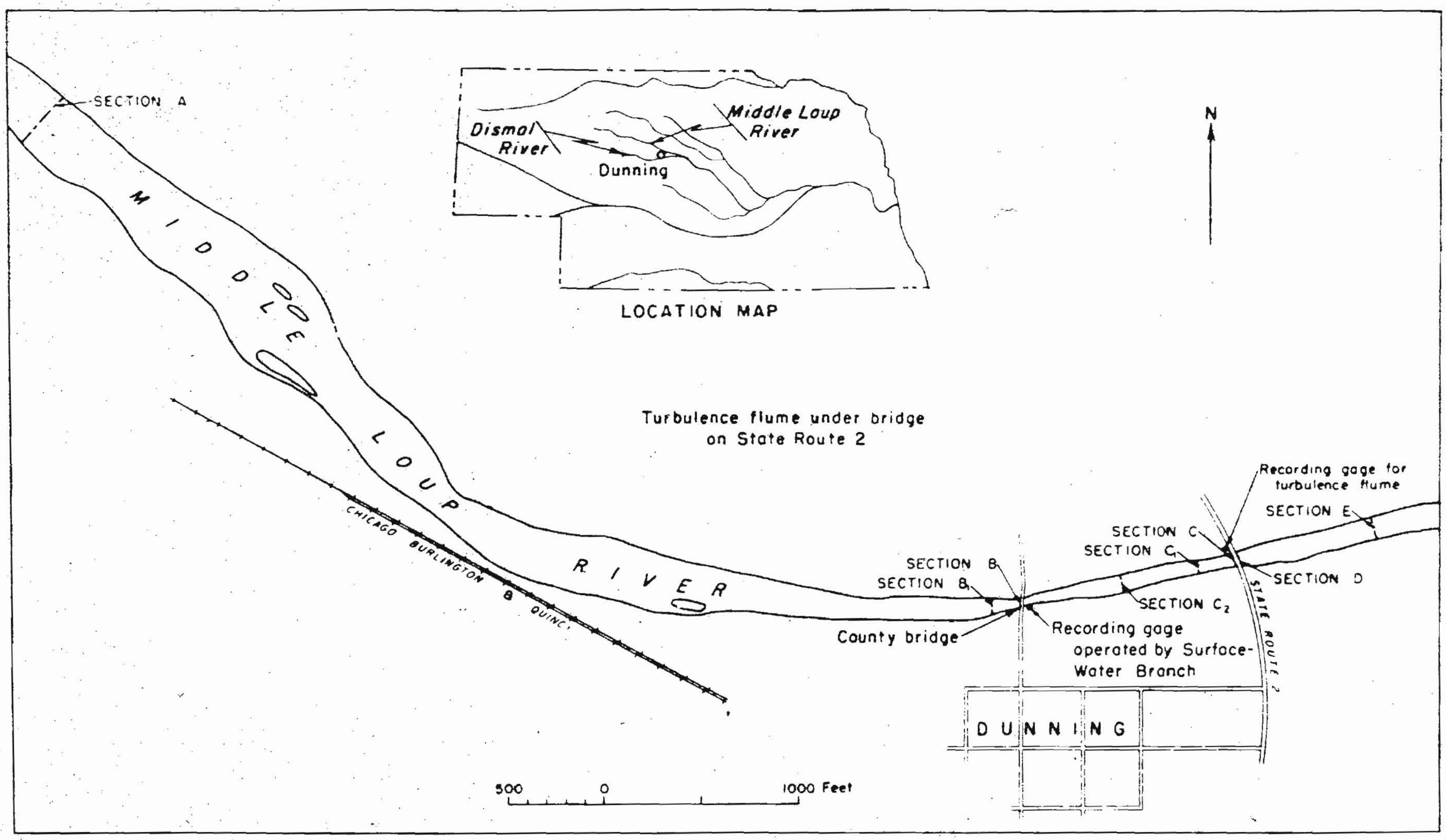


Figure 1.--Reach of the Middle Loup River near Dunning, Nebr.

all the winter measurements no dunes were present on the bed; the height of the dunes at this section seems to be the greatest when the water temperature is above 70 degrees. The total sediment discharge of the river is measured at section D at the measuring sill of the turbulence flume. A detailed explanation of the flume is given by Benedict, Albertson, and Matejka (1955). Section E is about 700 feet downstream from the turbulence flume. The width of this section at the time of the measurement on May 8 was 157 feet. The height of the sand dunes was about 0.2 foot; however, the cross section was irregular because of submerged bars.

Collection of field data, except on September 7, 1955, and May 8, 1956, was as follows: A water-discharge measurement was made immediately after frazil ice melted. At about the same time, sediment sampling by the ETR method was started. The interval between sampling verticals for the ETR method was selected so that lateral changes in water discharge and suspended-sediment concentration within the interval would be small, so that samples would not be too numerous, and so that the distance from each bank to the nearest sampling vertical would be about one-half the width of the sampling interval. Care was taken to maintain a constant transit rate. Water-sediment mixture at each station of an ETR was collected in a separate bottle with DH-48 samplers having 3/16-inch nozzles. After the ETR sampling was completed, point-integrated samples were collected at about 5 points in each of 5 verticals in the cross section at the centroids of equal segments of water discharge. After point sampling was completed at a vertical, point velocities were measured with a Price current meter. Lastly, bed-material samples were collected with core- and surface-type samplers. The surface-type sampler collects bed material from only the top few layers of the stream bed. Water temperatures were recorded continuously by a thermograph located near the turbulence flume. Because data were to be used for comparison with the total sediment discharge, ETR measurements were made at the turbulence flume (section D) at about the same time as at the normal section. The data for September 7, 1955, and May 8, 1956, were collected by the same procedures as outlined above except that no point-integrated samples were obtained on either day and no bed-material samples were obtained on September 7.

Size analyses of the depth-integrated suspended sediment for sections A, B_1, C_2, D, and E are given in table 1. Size analyses of point-integrated suspended sediment for sections B_1 and C_2 are given in table 2. Size analyses of bed-material samples for sections A, B_1, C_2, and E are given in table 3. A summary of hydraulic data is given in table 4.

SUSPENDED-SEDIMENT SAMPLING

General Theory

For an adequate determination of the mean concentration of suspended sediment at any cross section, one basic requirement in sampling must be satisfied. This requirement is that the concentration of every increment of flow must be represented by an amount of water-sediment mixture that is in the same proportion to the amount of total mixture as the increment of discharge is to the total water discharge. Both the commonly used centroids-of-discharge method and the ETR method satisfy this basic requirement, but in slightly different ways.

In the centroids-of-discharge method the stream cross section is divided laterally into segments of equal water discharge. Samples collected in each segment at the vertical of 50-percent accumulation of water discharge within the segment are assumed to be representative of the concentration of the entire segment. These samples, because each represents the same quantity of water discharge, are usually composited before analysis for the mean concentration of the stream. The primary requisites of this method are that the segments of water discharge must be sufficiently small so the concentration of each sample will be representative of its segment and that the volumes of all samples must be the same. Some of the disadvantages of the method are (1) a water-discharge measurement is necessary to determine the lateral distribution of flow, (2) the concentration of a sample may not be representative of the segment of discharge it is assumed to represent, and (3) sampling difficulties somewhat limit the observer's ability to collect an equal volume in each sample bottle.

Theoretically, in the ETR method a constant (equal) transit rate is maintained for all sampling verticals, and the verticals are spaced equidistant apart. Because sediment samplers admit water-sediment mixture at the stream velocity at every point of the sampler's travel, the volume of a sample is proportional to the water discharge passing through an area as wide as the nozzle and as deep as the depth traversed by the nozzle. The water discharge passing through a sampling vertical is assumed to be the same as that passing through any other vertical within the interval represented by the sampling vertical; therefore, the volume of mixture collected at the sampling vertical is proportional to the water discharge in the entire interval. If the concentrations at all verticals within the interval are assumed to be the same, the concentration determined from a sample will be the concentration that can be multiplied by the water discharge in the interval to obtain the sediment discharge in the interval. The total sediment discharge for the cross section is the sum of the sediment discharges for all the intervals. It is also the product of the total water discharge and the summation of weighted concentrations for all the intervals; the weighting factor is the ratio of the water discharge in the interval to the total water discharge. Each concentration can be weighted during the sampling procedure by using the same transit rate and the same sampling interval throughout a section. Thus, the concentration of the sample from each interval will be represented in a composite of all samples in the same ratio as the ratio of the water discharge in the interval to the total water discharge, and the concentration of the composite will be the concentration that can be multiplied by the total water discharge to give the sediment discharge for the cross section. For an accurate determination of concentration, the sampling interval must be sufficiently small so that lateral changes in concentration and water discharge are sampled. Some of the disadvantages of the method are (1) the samples may not be representative of the concentration in the interval they are assumed to represent, (2) the volumes of the samples may not be proportional to the water discharge in the sampling interval, (3) an equal transit rate is somewhat difficult to maintain throughout an entire cross section, and (4) every sampling interval must be determined by dividing the interval by the horizontal angle coefficient if the horizontal angle of flow varies from one part of a cross section to another.

The common disadvantage of both these methods is that a sample may not be representative of the concentration and water discharge it is assumed to represent. In order to increase the possibility of obtaining representative samples, many samples must be collected.

The kind of sediment load carried by the stream, the shape of the channel, and the height and spacing of bed irregularities are some of the factors that affect the optimum lateral spacing of samples.

Interpretation of the Data

Theoretically, both the ETR method and the centroids-of-discharge method are acceptable for collecting suspended-sediment samples. However, the adequacy of either method is dependent not only on the validity of the method but also on the suitability of the method for practical field application. Consequently, the errors that result from different sampling intervals in the ETR method and from different numbers of verticals in the centroids-of-discharge method have been studied and compared. Basic data utilized in this study are given in tables 5 and 6, and concentrations and deviations from ETR measurements are given in table 7.

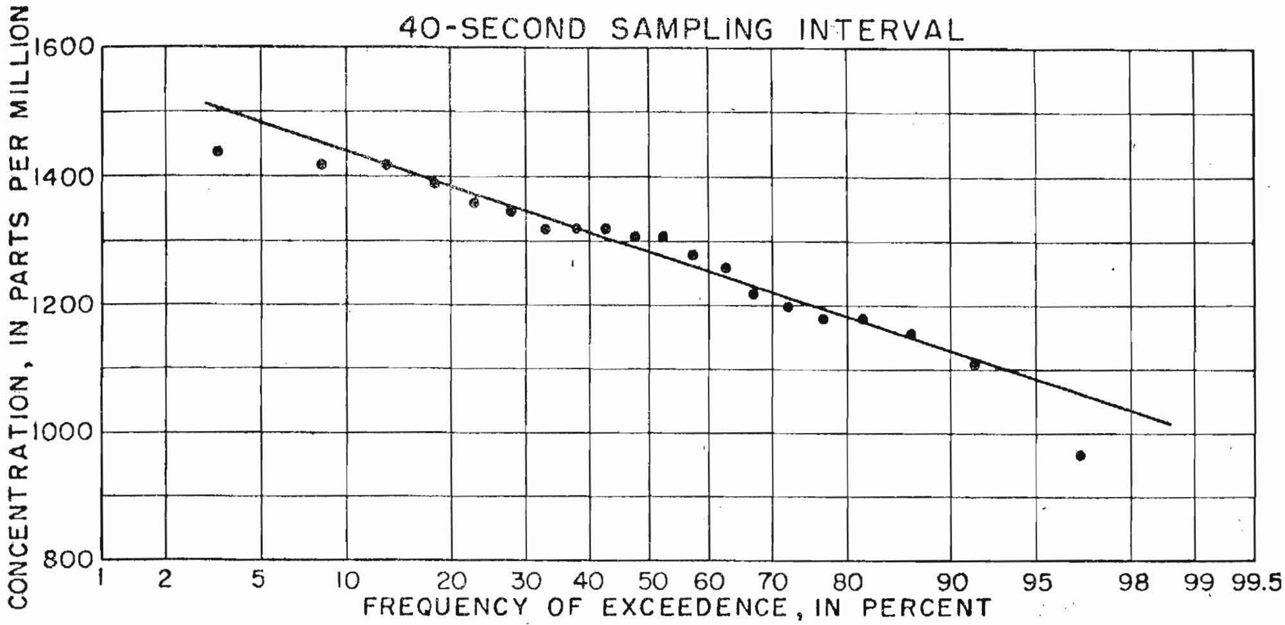
Because most of the interpretative analyses in this study are statistical, short-duration concentration changes have been studied to determine whether the concentrations are normally distributed so that they can be treated with ordinary statistical procedures. Field data pertinent to this aspect of the study are given in table 8. Figure 2 shows the frequency distribution of concentration. Plotting positions for this graph are those given by Beard (1954, p. 16). Because data

Table 7.--Concentrations and deviations from ETR measurements

Multiples of base sampling interval......					1	2	4	6	8	10	20	1	2	4	6	8	10	20
Date	Section	ETR number	Number of verticals sampled	Base sampling interval (feet)	Concentration, in parts per million							Deviation, in percent, from base concentration						
1955																		
Sept. 7	B_1	1	31	3	355	357	341	495	427	261	283	0	0.56	3.94	39.44	20.28	26.48	20.28
Do...	E	1	39	4	315	320	295	267	360	349	313	0	1.59	6.35	15.24	14.29	10.79	.63
Nov. 24	B_1	1	37	2.5	1,147	1,119	1,122	1,129	1,085	1,461	973	0	2.44	2.18	1.57	5.40	27.38	15.17
Do...	B_1	2	37	2.5	1,143	1,111	1,084	1,103	1,001	1,584	1,023	0	2.80	5.16	3.50	12.42	38.58	10.50
Do...	C_2	1	40	2	1,010	1,015	993	970	1,009	1,017	974	0	.50	1.68	3.96	.10	.69	3.56
Do...	C_2	2	40	2	1,051	1,045	1,049	1,078	1,000	1,047	929	0	.57	.19	2.57	4.85	.38	11.61
1956																		
Jan. 7.	C_2	1	40	2	1,200	1,194	1,218	1,219	1,213	1,244	1,507	0	.50	1.50	1.58	1.08	3.67	25.58
Do...	C_2	2	40	2	1,196	1,199	1,186	1,164	1,288	1,215	1,619	0	.25	.84	2.68	7.69	1.59	35.37
May 8..	A	1	45	3	677	677	646	626	629	522	724	0	0	4.58	7.53	7.09	22.90	6.94
Do...	A	2	45	3	732	700	705	848	613	499	686	0	4.37	3.69	15.85	16.26	31.83	6.28
Do...	A	3	45	3	678	685	673	651	616	550	648	0	1.03	.74	3.98	9.14	18.88	4.42
Do...	E	1	50	3	505	522	507	563	556	465	510	0	3.37	.40	11.49	10.10	7.92	.99
Do...	E	2	50	3	505	510	492	548	507	449	467	0	.99	2.57	8.51	.40	11.09	7.52
Do...	E	3	50	3	518	563	528	547	500	479	502	0	8.69	1.93	5.60	3.47	7.53	3.09

Table 8.--Concentrations of depth-integrated samples collected in sequence at two selected verticals

Sample number	Concentration (ppm)	Sample number	Concentration (ppm)
Time interval, 20 sec.		Time interval, 40 sec.	
1	644	1	1,310
2	647	2	1,180
3	753	3	1,280
4	644	4	1,320
5	563	5	1,160
6	645	6	1,320
7	690	7	1,310
8	694	8	970
9	690	9	1,320
10	524	10	1,110
11	669	11	1,360
12	719	12	1,350
13	626	13	1,420
14	587	14	1,440
15	655	15	1,200
16	610	16	1,260
17	573	17	1,420
18	701	18	1,220
19	633	19	1,390
20	655	20	1,180



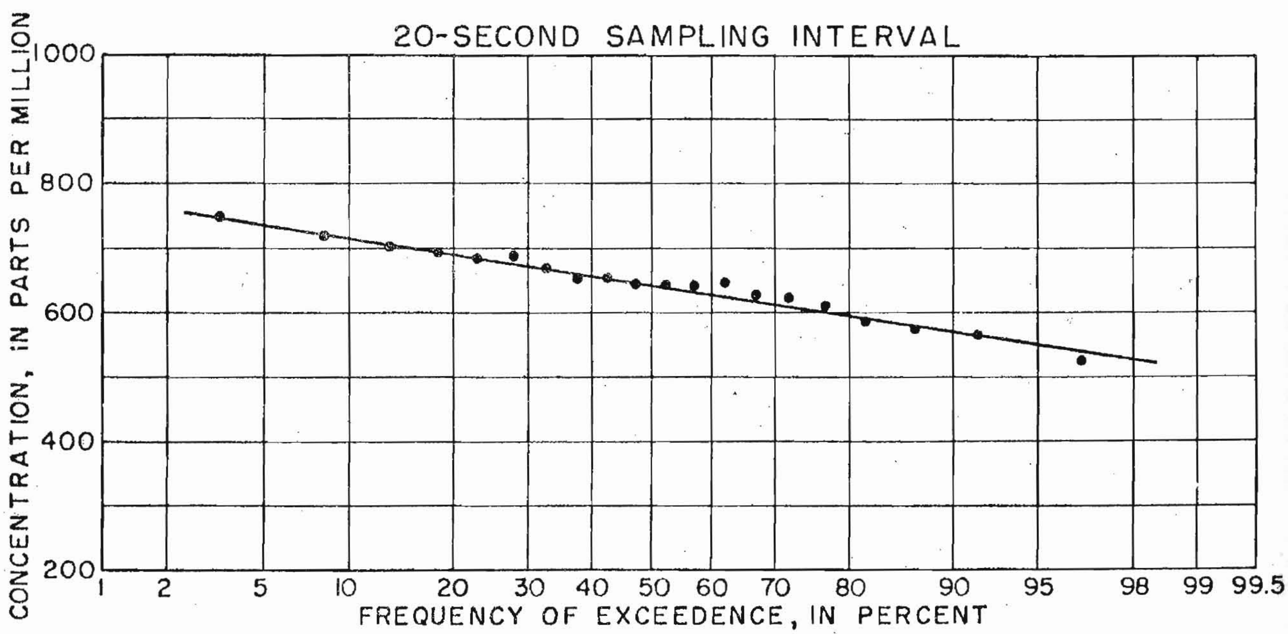


Figure 2.--Frequency distribution of concentration at a single vertical.

generally follow a straight line on probability paper, the concentrations are normally distributed.

For the ETR method, errors that result from different sampling intervals cannot be determined unless the transit rate remained relatively constant for each set of samples used in the analyses. Figures 3-6, which show the accumulated water-sediment mixture plotted against the accumulated water discharge, indicate that a relatively uniform transit rate was maintained. The fact that the rate of change in water-sediment mixture is about the same as the rate of change in water discharge shows that the mixture was collected at each vertical in proportion to the water discharge in the sampling interval. However, this kind of graph does not show conclusively that an equal transit rate was maintained because other factors may cause the curves to deviate from or approach the line of perfect agreement. Two of these factors are changes in the flow conditions from the time of the water-discharge measurement to the time of the sediment sampling and differences in the percentage of flow in the unsampled zone across the section. Also, relative errors that result from different sampling intervals cannot be determined unless samples have been collected at a small enough interval (the base interval) so that the sample from each vertical actually represents a width of relatively constant concentration and water discharge. Figures 7-11, which show the lateral distribution of concentration, water

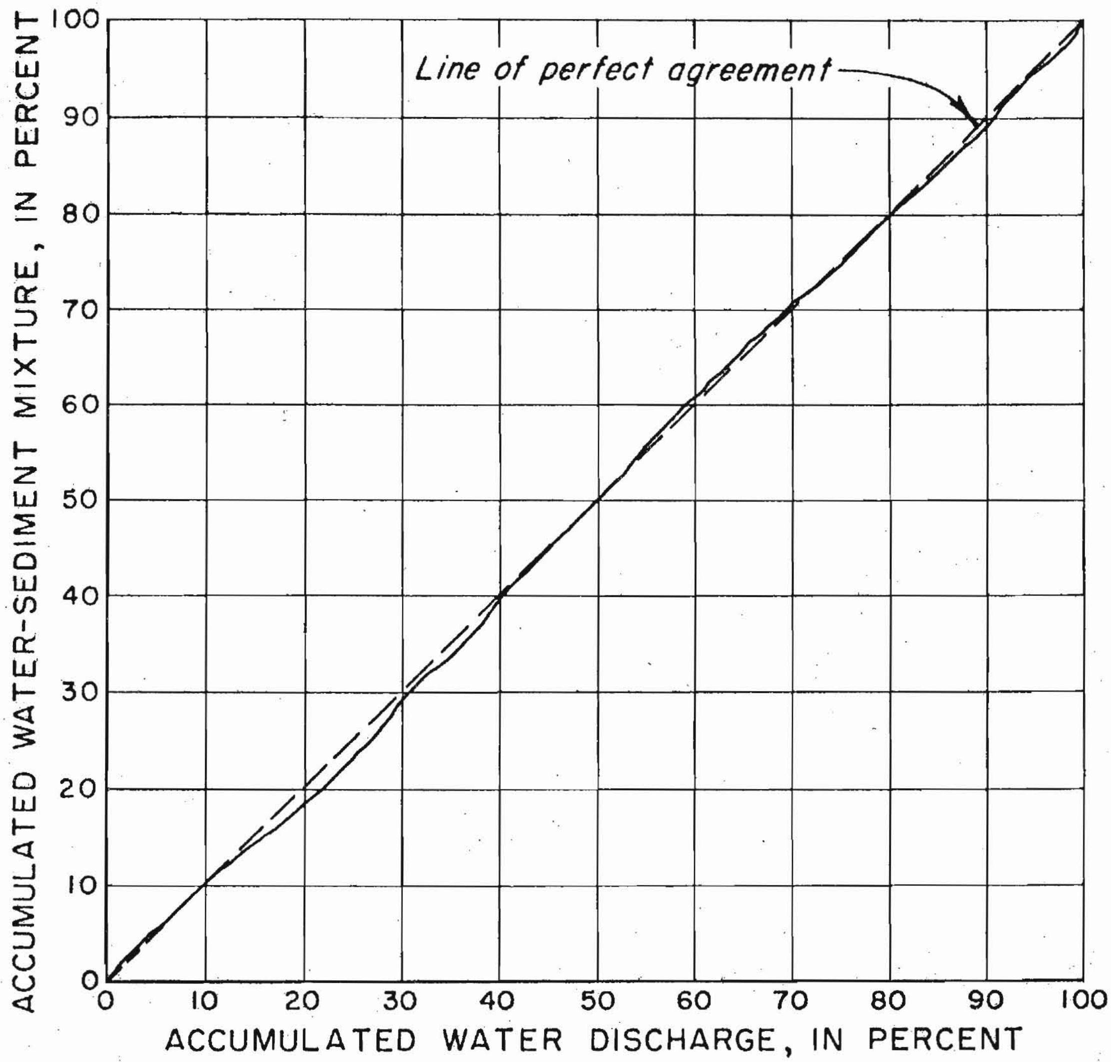


Figure 3.--Comparison of accumulated water-sediment mixture and accumulated water discharge, ETR No. 1, section B_1, November 24, 1955.

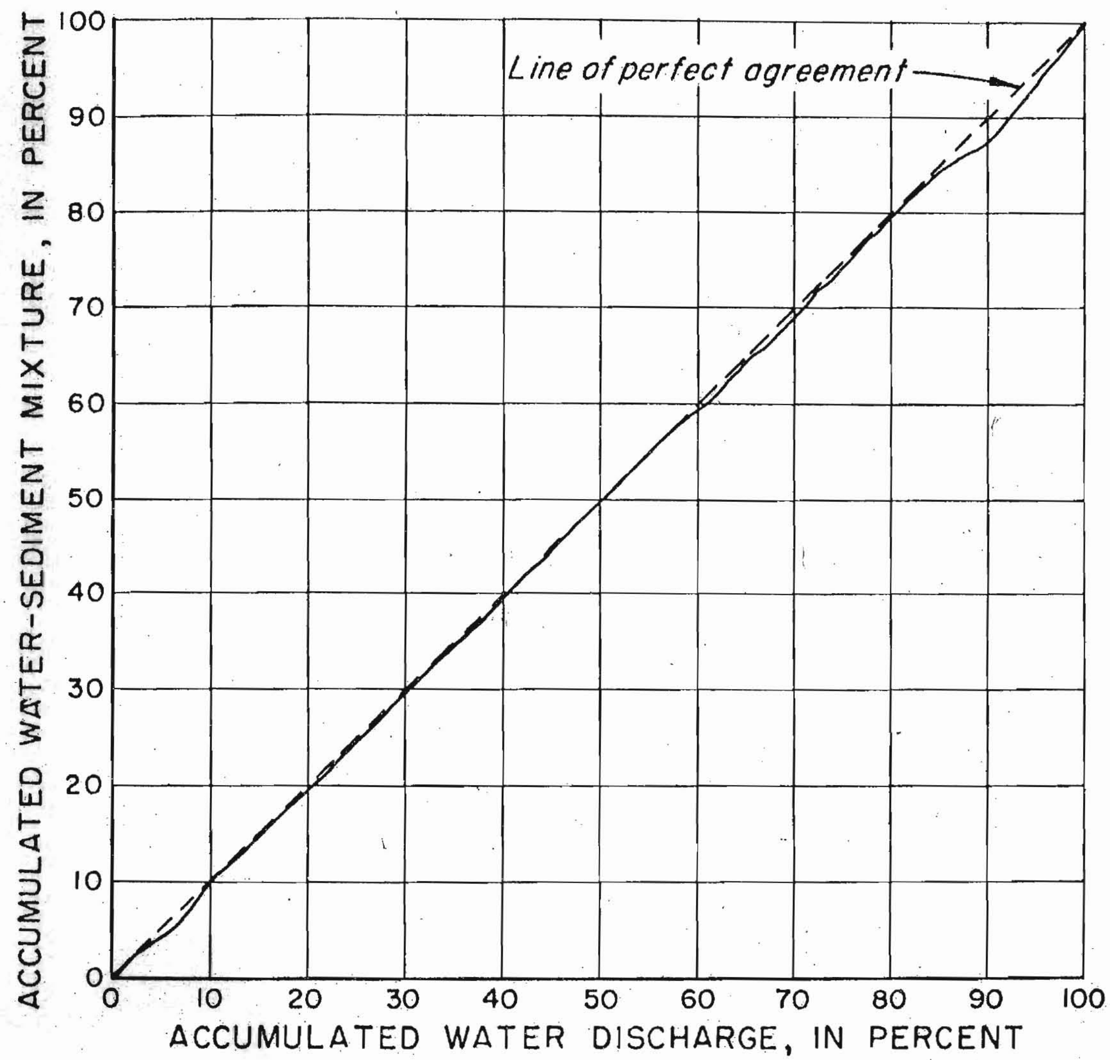


Figure 4.--Comparison of accumulated water-sediment mixture and accumulated water discharge, ETR No. 1, section C_2, November 24, 1955.

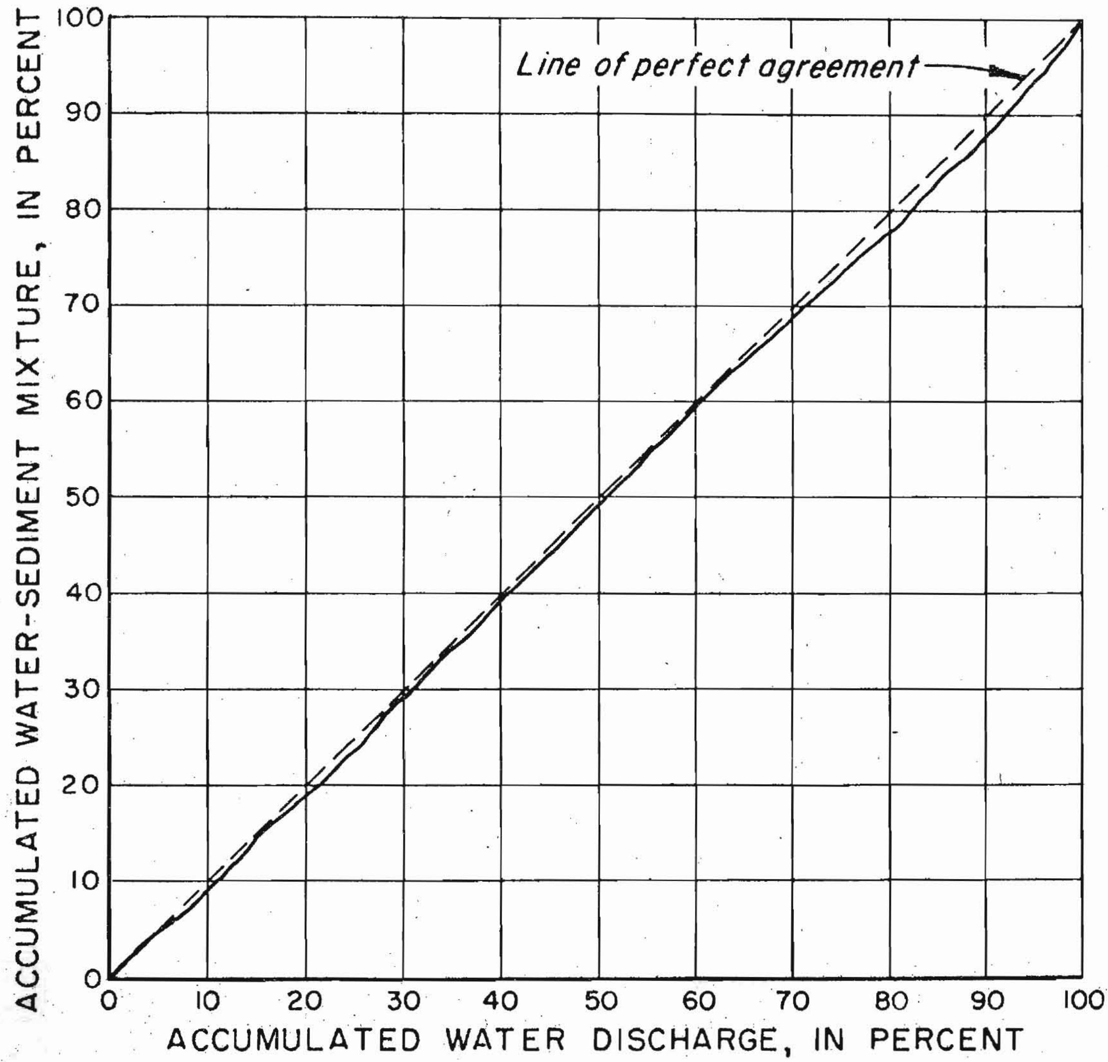


Figure 5.--Comparison of accumulated water-sediment mixture and accumulated water discharge, ETR No. 1, section C_2, January 7, 1956.

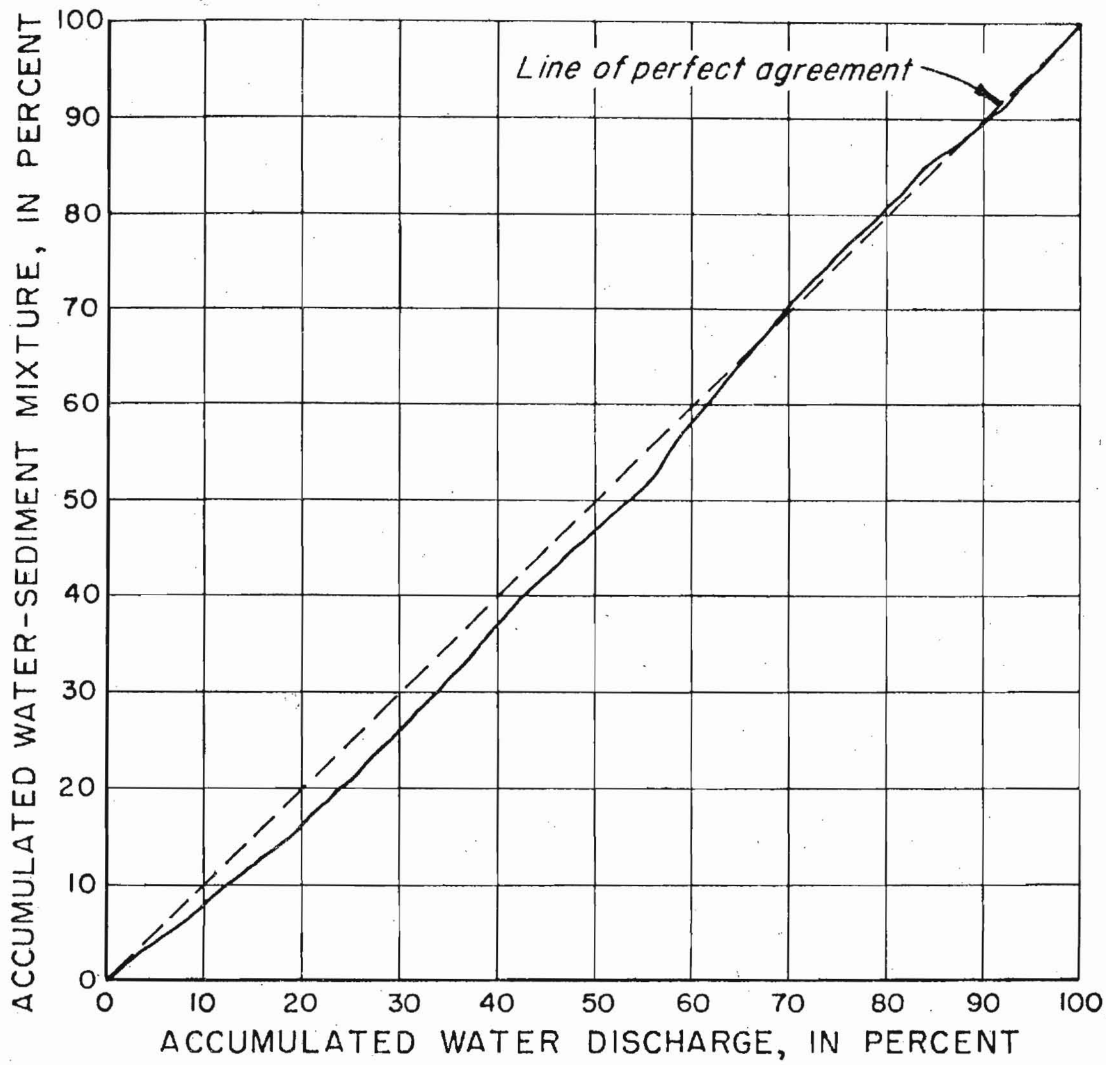


Figure 6.--Comparison of accumulated water-sediment mixture and accumulated water discharge, ETR No. 1, section E, May 8, 1956.

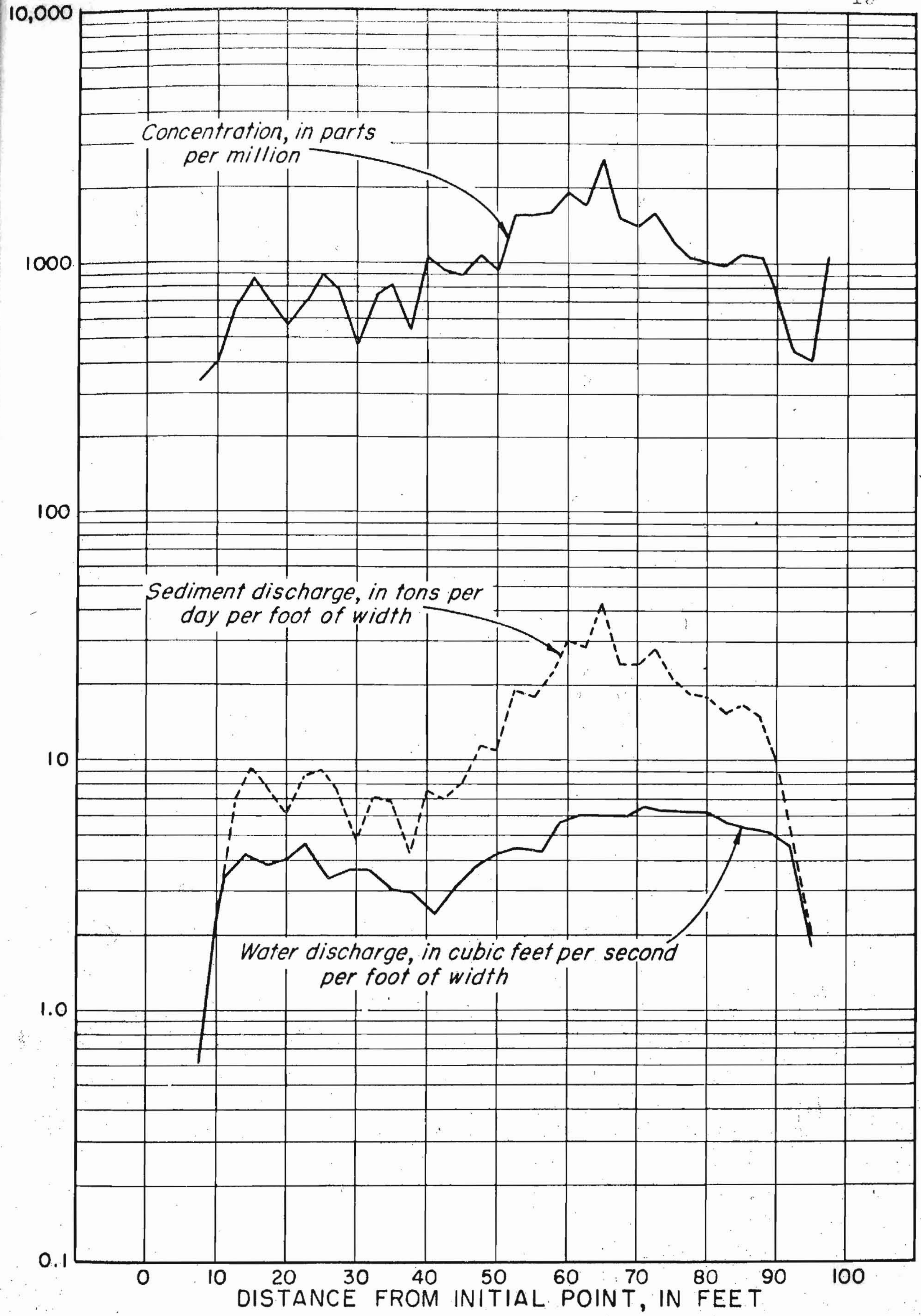


Figure 7.--Lateral distribution of water discharge, concentration, and sediment discharge, section B_1, ETR No.1, November 24, 1955.

Figure 8.--Lateral distribution of water discharge, concentration, and sediment discharge, section B_1, ETR No. 2, November 24, 1955.

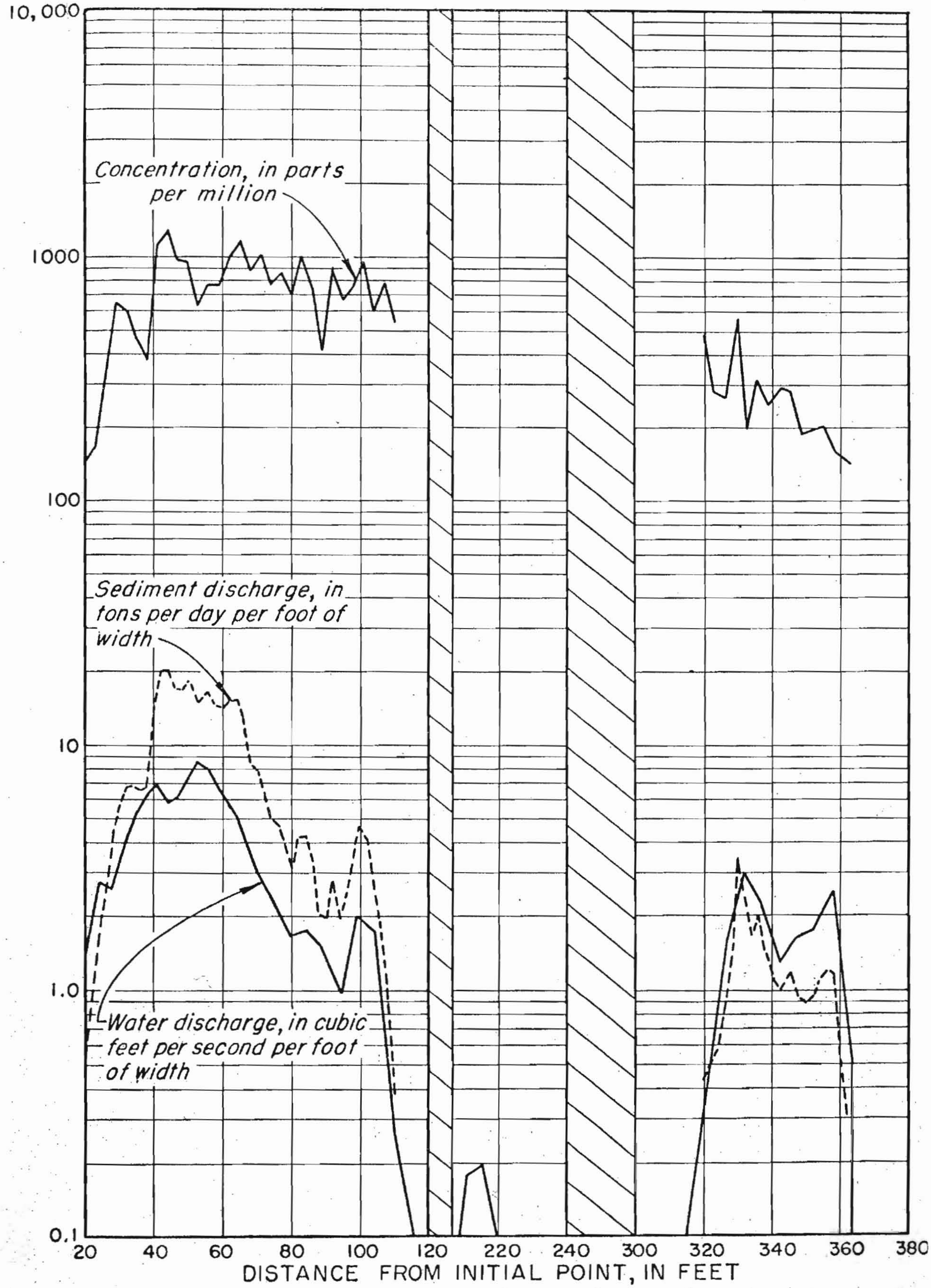


Figure 9.--Lateral distribution of water discharge, concentration, and sediment discharge, section A, ETR No. 1, May 8, 1956.

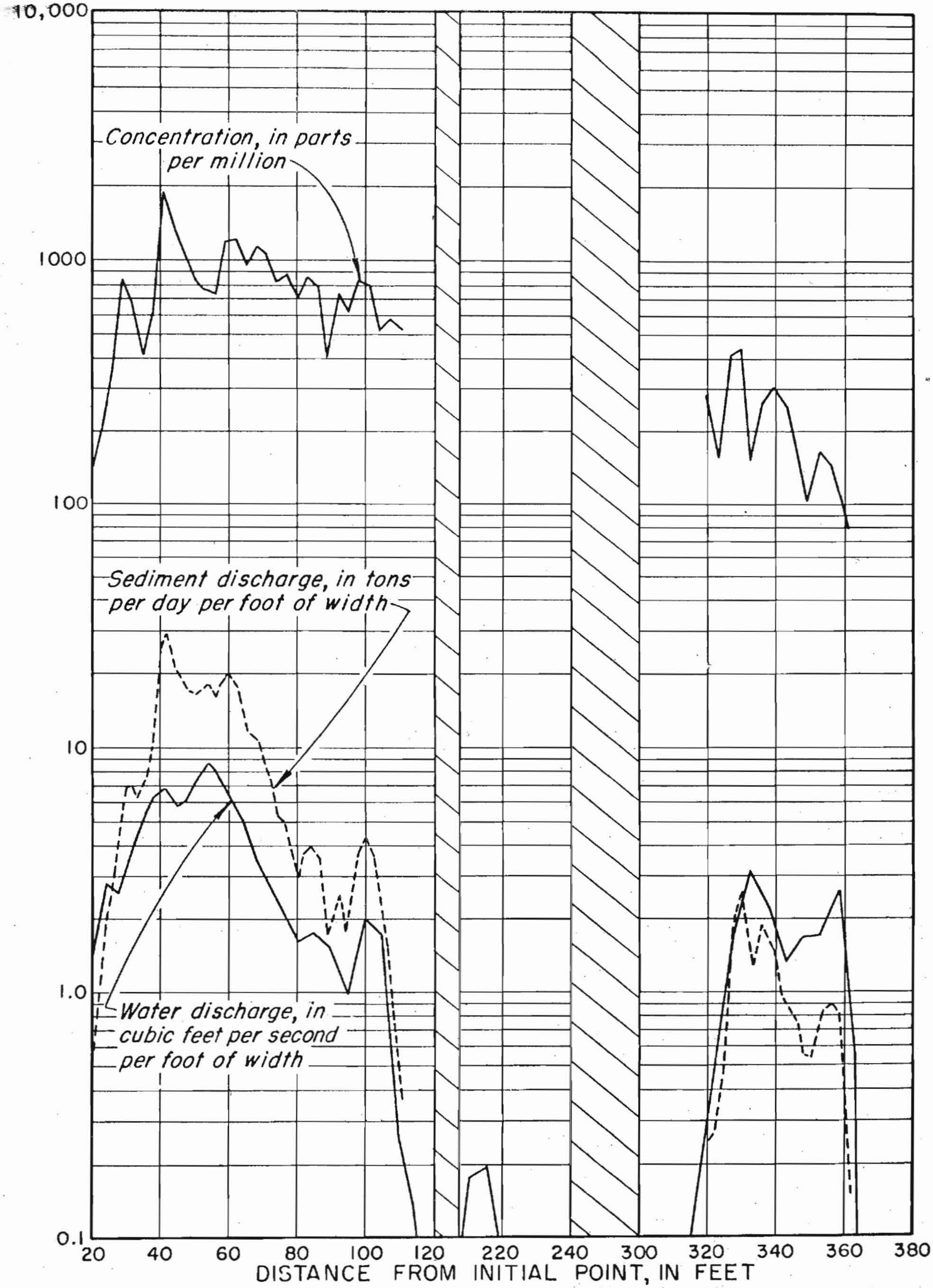


Figure 10.--Lateral distribution of water discharge, concentration, and sediment discharge, section A, ETR No.2, May 8, 1956.

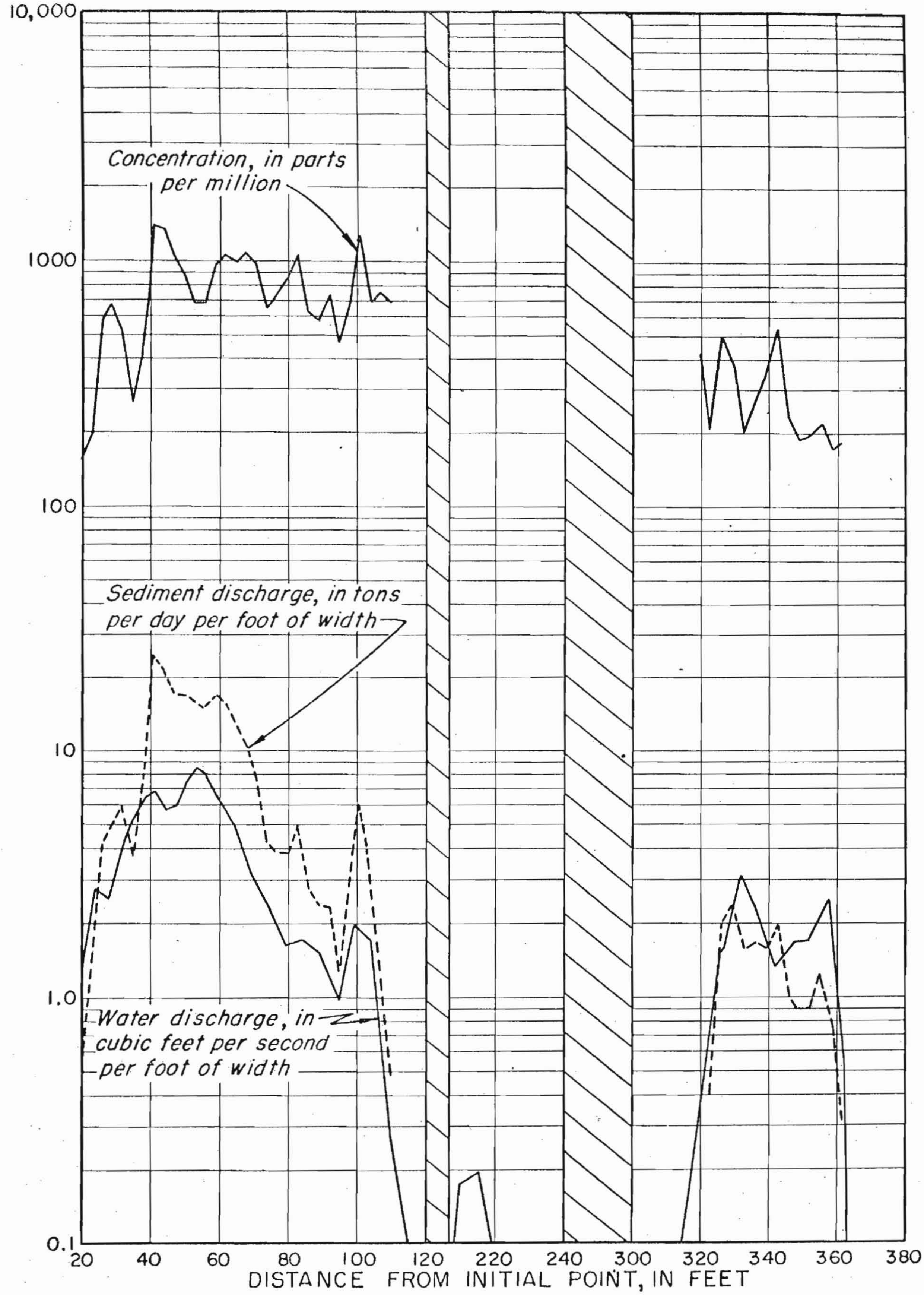


Figure 11.--Lateral distribution of water discharge, concentration, and sediment discharge, section A, ETR No. 3, May 8, 1956.

discharge, and sediment discharge, indicate that the base interval was sufficiently small.

Errors in the mean concentration result if the ETR sampling interval is too large. Figure 12, which was plotted from the analysis in table 9, shows the extent of these errors for different sampling intervals. Deviations shown by this graph are based on differences from the concentration at the base interval; the concentration at the base interval is assumed to have no error. Data for this analysis were from different cross sections, for different base intervals, and at different times; and the fact that different lateral distributions of concentration and flow produce different deviations was ignored. As a result, the graph should only be used as a rough guide, and deviations given by the graph should not be expected to be reliable for any particular section. The graph shows that deviations from the base interval increase as the sampling interval increases and that concentrations can be accurate only if sampling intervals are small.

The errors that result from different sampling intervals with various lateral distributions of flow and concentration are analyzed in table 10. Lines 16 and 17 in the table are the confidence limits of the deviations; where no confidence limits are shown, deviations are not statistically significant. Index ratios in the table describe different lateral distributions of concentration and flow. Lateral distribution of

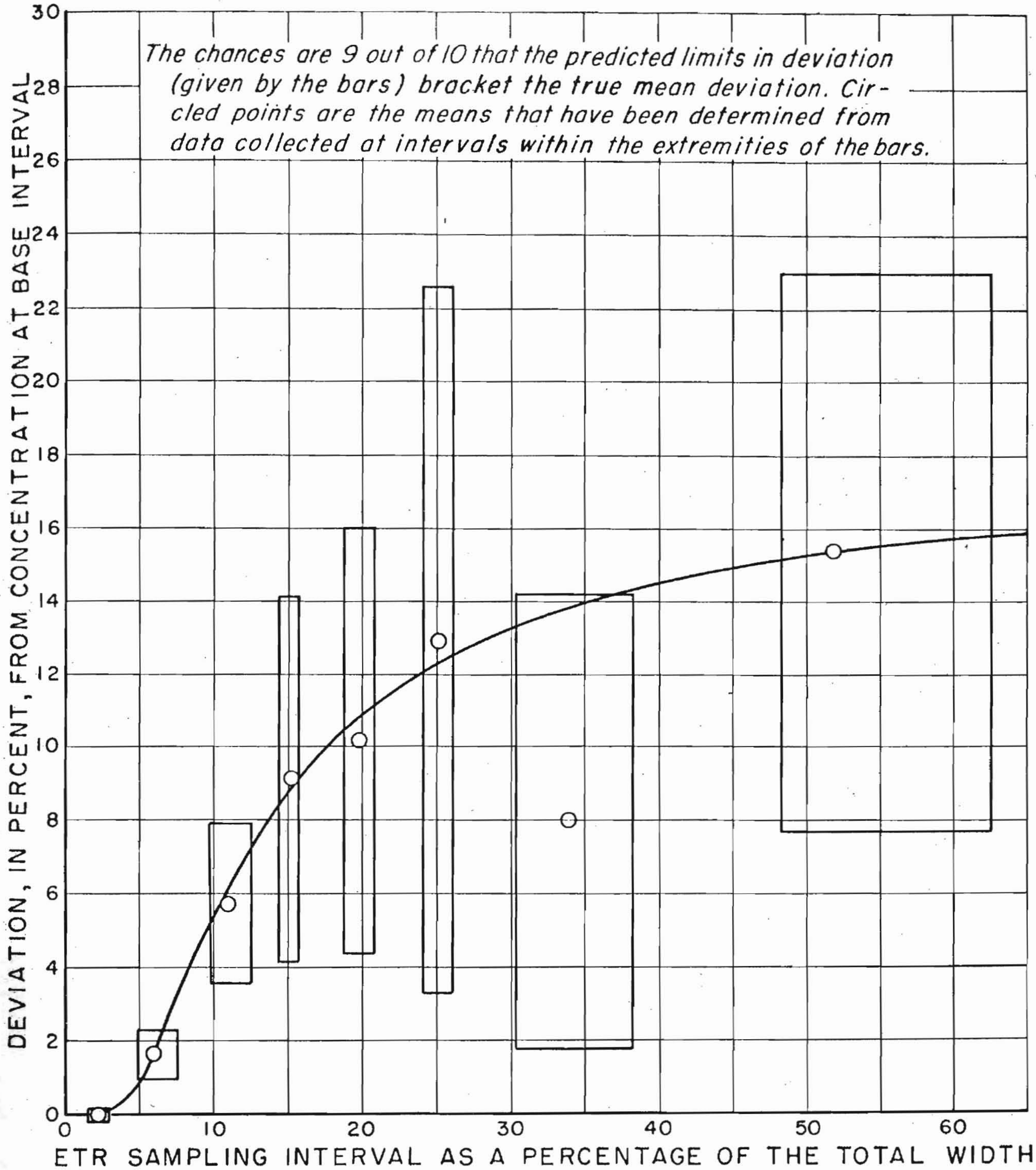


Figure 12.--Deviations in concentration plotted against ETR sampling interval.

Table 9.--Deviation in concentration from base interval concentration for different ETR sampling intervals

ETR sampling interval as a percentage of total width....	4.82-7.68	9.64-12.50	14.46-15.62	18.75-20.83	24.10-26.04	30.20-38.20	48.20-62.50
d..........................	0.56	3.94	....	39.44	20.28	26.48	20.28
	1.59	6.35	15.24	14.29	10.79	....	.63
	2.44	2.18	1.57	5.40	27.38	....	15.17
	2.80	5.16	3.50	12.42	38.58	....	10.50
	.50	1.68	3.96	.10	.69	....	3.56
	.57	.19	2.57	4.85	.38	....	11.61
	.50	1.50	1.58	1.08	3.67	....	25.58
	.25	.84	2.68	7.69	1.59	....	35.37
	4.58	7.09	22.90	....	....	6.94	......
	3.69	16.26	31.83	....	....	6.28	......
	.74	9.14	18.88	....	....	4.42	......
	.40	11.49	10.10	7.92	....	.99	......
	2.57	8.51	.40	11.09	....	7.52	......
	1.93	5.60	3.47	7.53	....	3.09	......
Σd	23.12	79.93	118.68	111.81	103.36	55.72	122.70
$\Sigma d/n$..........................	1.65	5.71	9.13	10.16	12.92	7.96	15.34
Σd^2..........................	63.15	727.0	2,287	2,269	2,782	875.4	2,805
$(\Sigma d)^2/n$..........................	38.18	456.3	1,083	1,136	1,335	443.5	1,882
$\Sigma d^2 - (\Sigma d)^2/n$	24.97	270.7	1,204	1,133	1,447	431.9	923
$(S.D.)^2 = \dfrac{\Sigma d^2 - (\Sigma d)^2/n}{n-1}$	1.921	20.82	100.3	113.3	206.7	71.98	131.9
S.D.	1.386	4.563	10.01	10.64	14.38	8.484	11.48
$S.D./\sqrt{n}$	.370	1.219	2.776	3.208	5.084	3.207	4.059
t	1.771	1.771	1.782	1.812	1.895	1.943	1.895
$t(S.D.)/\sqrt{n}$..........................	.655	2.159	4.947	5.813	9.634	6.231	7.692
Confidence limits	2.31	7.87	14.1	16.0	22.6	14.2	23.0
	.99	3.55	4.18	4.35	3.29	1.73	7.65

d Deviation, in percent, from base concentration (from table 7).
S.D. Standard deviation.
t A statistical measure of confidence selected at the 90% level of significance.

Table 10.—Confidence limits of deviations from the base concentration

Date and section / Index ratio	Nov. 24, 1955, sec. B_1 0.88							Nov. 24, 1955, sec. C_2 0.52						
Multiples of base sampling intervals	1	2	4	6	8	10	20	1	2	4	6	8	10	20
(1) Conc. ETR 1—ppm	1,147	1,119	1,122	1,129	1,085	1,461	973	1,010	1,015	993	970	1,009	1,017	974
(2) Conc. ETR 2—ppm	1,143	1,111	1,084	1,103	1,001	1,584	1,023	1,051	1,045	1,049	1,078	1,000	1,047	929
(3) Conc. ETR 3—ppm	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
(4) (1) + (2) + (3)—ppm	2,290	2,230	2,206	2,232	2,086	3,045	1,996	2,061	2,060	2,042	2,048	2,009	2,064	1,903
(5) Mean concentration—ppm	1,145	1,115	1,103	1,116	1,043	1,522	998	1,030	1,030	1,021	1,024	1,004	1,032	952
(6) Sum of squares of deviations from mean	8	32	722	338	3,528	7,564	1,250	841	450	1,568	5,832	41	450	1,013
(7) (6) for base + (6) for multiple	.....	40	730	346	3,536	7,572	1,258	.....	1,291	2,409	6,673	882	1,291	1,854
(8) $(S.D.)^2$ = (7) ÷ degrees of freedom	.....	20	365	173	1,768	3,786	629	.....	646	1,204	3,336	441	646	927
(9) S. D. (Standard deviation)	.....	4.47	19.10	13.15	42.05	61.53	25.08	.....	25.42	34.70	57.76	21.00	25.42	30.43
(10) Difference between mean of base and multiple	.....	30	42	29	102	377	147	.....	0	9	6	26	2	78
(11) $t = (10)\sqrt{\frac{nm}{n+m}}\Big/ S.D.$	.....	6.71	2.20	2.20	2.43	6.14	5.86	.....	0	.26	.10	1.24	.08	2.56
(12) t_c = Critical value of t at 90% level	.....	2.92	2.92	2.92	2.92	2.92	2.92	.....	2.92	2.92	2.92	2.92	2.92	2.92
(13) $S_d = S.D.\Big/\sqrt{\frac{nm}{n+m}}$	.....	4.47	.....	.....	.....	61.53	25.08	.....	.....	.....	.....	.....	.....	.....
(14) $t_c S_d$	.....	13	.....	.....	.....	180	73	.....	.....	.....	.....	.....	.....	.....
(15) (10) as a percentage of base concentration	.....	2.62	.....	.....	.....	32.97	12.84	.....	.....	.....	.....	.....	.....	.....
(16) (10) + (14) as a percentage of base	.....	3.76	.....	.....	.....	48.64	19.21	.....	.....	.....	.....	.....	.....	.....
(17) (10) - (14) as a percentage of base	.....	1.48	.....	.....	.....	17.21	6.46	.....	.....	.....	.....	.....	.....	.....

	Jan. 7, 1956, sec. C_2 0.58						
	1	2	4	6	8	10	20
(1)	1,200	1,194	1,218	1,219	1,213	1,244	1,507
(2)	1,196	1,199	1,186	1,164	1,288	1,215	1,619
(3)	.....	.....	.....	.....	.....	.....	.....
(4)	2,396	2,393	2,404	2,383	2,501	2,459	3,126
(5)	1,198	1,196	1,202	1,191	1,250	1,230	1,563
(6)	8	13	512	1,513	2,813	421	6,272
(7)	.....	21	520	1,521	2,821	429	6,280
(8)	.....	10.5	260	760	1,410	214	3,140
(9)	.....	3.24	16.12	27.57	37.55	14.63	56.04
(10)	.....	2	4	7	52	32	365
(11)	.....	.62	.25	.25	1.38	2.19	6.51
(12)	.....	2.92	2.92	2.92	2.92	2.92	2.92
(13)	.....	.....	.....	.....	.....	.....	56.04
(14)	.....	.....	.....	.....	.....	.....	164
(15)	.....	.....	.....	.....	.....	.....	30.5
(16)	.....	.....	.....	.....	.....	.....	44.2
(17)	.....	.....	.....	.....	.....	.....	16.8

	May 8, 1956, sec. A 1.80						
	1	2	4	6	8	10	20
(1)	677	677	646	626	629	522	724
(2)	732	700	705	848	613	499	686
(3)	678	685	673	651	616	550	648
(4)	2,087	2,062	2,024	2,125	1,858	1,571	2,058
(5)	696	687	675	708	619	524	686
(6)	1,981	273	1,745	29,573	145	1,305	2,888
(7)	.....	2,254	3,726	31,554	2,126	3,286	4,869
(8)	.....	564	932	7,888	532	822	1,217
(9)	.....	23.75	30.53	88.81	23.07	28.67	34.89
(10)	.....	9	21	12	77	172	10
(11)	.....	.46	.84	.17	4.09	7.35	.35
(12)	.....	2.132	2.132	2.132	2.132	2.132	2.132
(13)	.....	.....	.....	.....	18.84	23.41	.....
(14)	.....	.....	.....	.....	40	50	.....
(15)	.....	.....	.....	.....	11.06	24.71	.....
(16)	.....	.....	.....	.....	16.81	31.90	.....
(17)	.....	.....	.....	.....	5.32	17.53	.....

	May 8, 1956, sec. B 1.34						
	1	2	4	6	8	10	20
(1)	505	522	507	563	556	465	510
(2)	505	510	492	548	507	449	467
(3)	518	563	528	547	500	479	502
(4)	1,528	1,595	1,527	1,658	1,563	1,393	1,479
(5)	509	532	509	553	521	464	493
(6)	113	1,545	654	161	1,862	451	1,046
(7)	.....	1,658	767	274	1,975	564	1,159
(8)	.....	414	192	68.5	494	141	290
(9)	.....	20.35	13.86	8.28	22.23	11.87	17.03
(10)	.....	23	0	44	12	45	16
(11)	.....	1.38	0	6.51	.66	4.64	1.15
(12)	.....	2.132	2.132	2.132	2.132	2.132	2.132
(13)	.....	.....	.....	6.76	.....	9.69	.....
(14)	.....	.....	.....	14	.....	21	.....
(15)	.....	.....	.....	8.64	.....	8.84	.....
(16)	.....	.....	.....	11.39	.....	12.97	.....
(17)	.....	.....	.....	5.89	.....	4.72	.....

Rows (16) and (17) are the upper and lower confidence limits.

concentration is considered to be a function of the lateral distribution of flow. Distribution of flow for a cross section is indexed by the ratio of the width having flow per foot of width below the average to the width having flow per foot of width above the average. The significance of this ratio can be understood by considering the difference between a rectangular section that has uniform flow laterally and an irregular section that has a wide shallow part of low sediment discharge and a deep narrow part of high sediment discharge. The ratio for the rectangular section is low, and the deviation from the base-interval concentration is affected little by the ETR interval. The ratio for the irregular section is high, and the deviation is large if the deep narrow part is inadequately sampled. The analyses in table 10 indicate that for low index ratios, deviations from the base-interval concentration are generally insignificant regardless of the interval and for high index ratios, the deviations are significant for large intervals. A graph of this effect could not be made because of the insufficient number of significant deviations.

According to statistical theory, the probability of obtaining a mean concentration within certain limits of the true mean increases as the number of samples used to determine the mean concentration increases. Table 11 gives data for three centroids of discharge and an analysis of these data. For the three centroids, deviations of the mean concentration from the true mean concentration change as the number of sets of

Table 11.--Deviation of mean concentration of samples collected at 3 centroids of discharge from the true mean concentration at the 3 centroids of discharge

Sec. E, May 8, 1956				Sec. A, May 8, 1956			
Concentration				Concentration			
Sta. 35	Sta. 59	Sta. 98	Mean for set	Sta. 38	Sta. 59	Sta. 326.5	Mean for set
1,120	484	294	633	398	770	266	478
1,170	484	325	660	615	1,170	418	734
1,330	533	282	715	442	962	501	635
1,210	414	169	598	874	1,350	427	884
990	465	112	522	507	1,010	539	685
996	507	161	555	685	1,260	366	770
1,170	531	154	618	653	1,370	433	819
1,120	456	219	598	768	1,010	450	743
1,080	547	201	609	603	1,100	553	752
910	511	114	512	669	974	543	729
1,070	541	167	593	712	1,170	543	808
1,000	506	96	534	592	1,220	464	759
Mean for all sets............ 596				Mean for all sets............ 733			

$$L = \left[\frac{t(S.D.)}{\sqrt{n}}\right]\left(\frac{100}{\text{mean for all sets}}\right)$$

where L is the deviation from the true mean concentration, expressed as a percentage of the mean concentration for all sets.
t is at the 20-percent level of probability
n is the number of sets of samples.

Sec. E, S.D. = 59.0

For n = 12, L = 3.90%
For n = 10, L = 4.33%
For n = 8, L = 4.95%
For n = 6, L = 5.96%
For n = 4, L = 8.11%
For n = 3, L = 10.8%
For n = 2, L = 21.5%

Sec. A, S.D. = 102.4

For n = 12, L = 5.50%
For n = 10, L = 6.11%
For n = 8, L = 6.98%
For n = 6, L = 8.42%
For n = 4, L = 11.4%
For n = 3, L = 15.2%
For n = 2, L = 30.4%

samples changes. Figure 13 shows the results of the analysis graphically. The mean concentration for the cross section based on the average of all samples at the 3 centroids is 105 and 117 percent of the mean concentration determined from an average of 3 ETR's collected at the base interval at sections A and E, respectively.

Concentrations determined from samples collected at different numbers of centroids have been compared with the mean concentration for the cross section. The mean concentration for the cross section was determined in the following way: From curves of the lateral distributions of flow and concentration, a curve of lateral distribution of sediment discharge per foot of width was determined. The sediment-discharge curve was graphically integrated to obtain the sediment discharge for the cross section. The load for the cross section divided by the water discharge and the appropriate constant is the mean concentration for the cross section. Concentrations for different numbers of centroids were determined by linear interpolation from concentration curves. An analysis of the differences between the concentrations for different numbers of centroids and the integrated mean concentration is given in table 12. Index ratios for the different cross sections are given in the table. This analysis indicates that regardless of the index ratio, deviations from the mean concentration of the cross section are not substantial

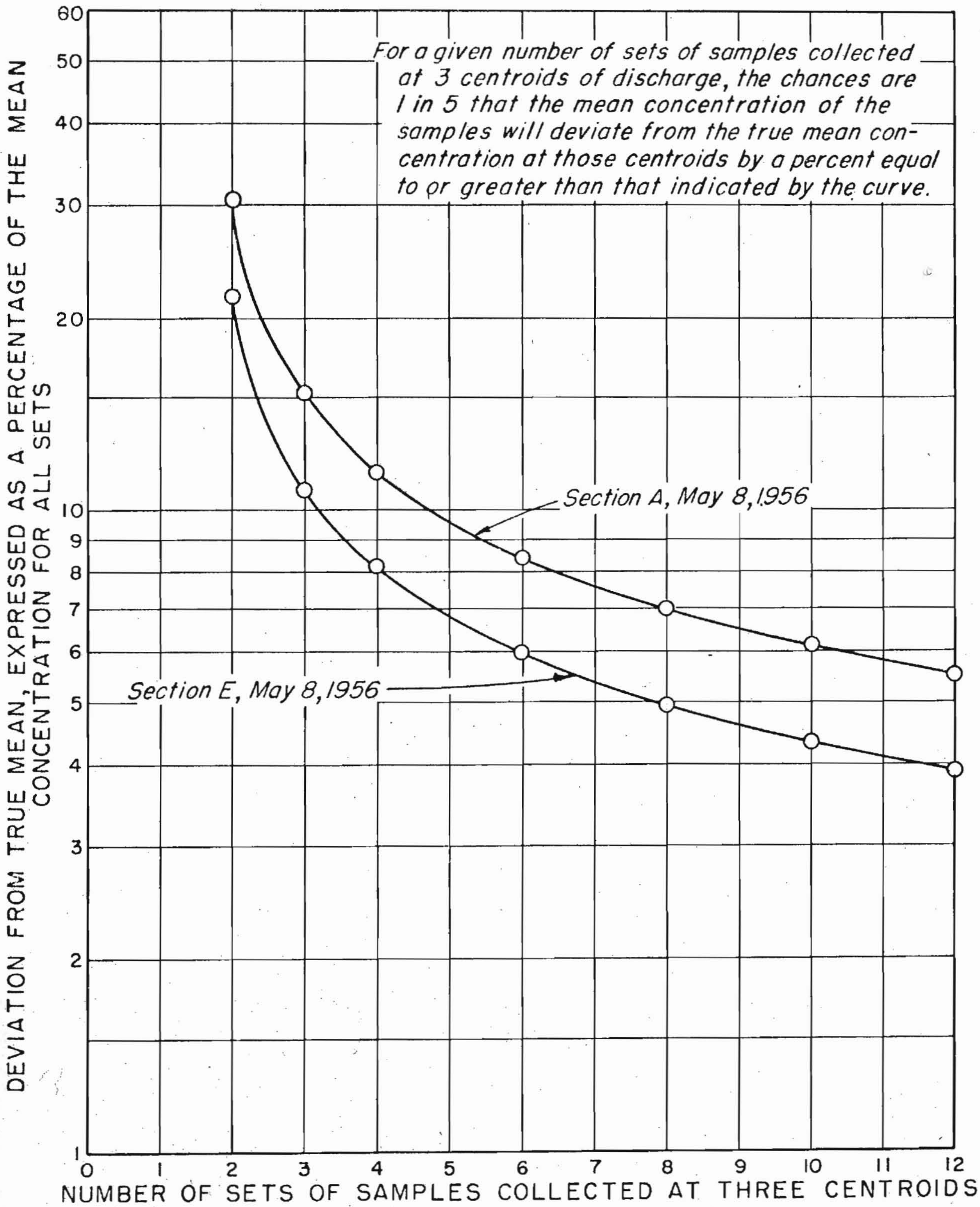


Figure 13.--Deviation of mean concentration of samples collected at three centroids of discharge from the true mean concentration at those centroids.

Table 12.—Confidence limits of deviations from integrated mean concentration

Row number	Explanation	Nov. 24, 1955, sec. B_1, index = 0.88						May 8, 1956, sec. A, index = 1.80					
		Integrated concentration	20 centroids	15 centroids	10 centroids	5 centroids	2 centroids	Integrated concentration	20 centroids	15 centroids	10 centroids	5 centroids	2 centroids
(1)	Concentration of set no. 1....ppm..	1,130	1,120	1,150	1,150	1,200	980	662	678	698	717	680	1,000
(2)	Concentration of set no. 2....ppm..	1,110	1,120	1,140	1,160	1,110	965	736	757	777	768	742	1,050
(3)	Concentration of set no. 3....ppm..	......	......	......	......	......	......	681	720	752	696	710	955
(4)	(1) + (2) + (3)....ppm..	2,240	2,240	2,290	2,310	2,310	1,945	2,079	2,155	2,227	2,181	2,132	3,005
(5)	Mean concentration....ppm..	1,120	1,120	1,145	1,155	1,155	972	693	718	742	727	711	1,002
(6)	Sum of squares of deviations from mean....	200	0	50	50	4,050	113	2,954	3,125	3,261	2,742	1,923	4,517
(7)	(6) for integration plus (6) for centroids....	......	200	250	250	4,250	313	......	6,079	6,215	5,696	4,877	7,471
(8)	$(S.D.)^2 = (7) \div$ degrees of freedom....	......	100	125	125	2,125	156	......	1,520	1,554	1,424	1,219	1,868
(9)	S.D. (standard deviation)....	......	10	11.18	11.18	46.10	12.49	......	38.99	39.42	37.73	34.91	43.22
(10)	Difference between mean of integration and centroids....	......	0	25	35	35	148	......	25	49	34	18	309
(11)	$t = (10) \sqrt{\frac{nm}{n+m}} / S.D.$....	......	0	2.236	3.131	.759	11.85	......	.785	1.522	1.104	.631	8.756
(12)	t_c = critical value of t at 90% level....	......	2.92	2.92	2.92	2.92	2.92	......	2.132	2.132	2.132	2.132	2.132
(13)	$S_d = S.D. / \sqrt{\frac{nm}{n+m}}$....	......	......	......	11.18	......	12.49	......	......	......	......	......	35.29
(14)	$t_c S_d$....	......	......	......	33	......	36	......	......	......	......	......	75
(15)	(10) as a percentage of mean integrated concentration....	......	......	......	3.12	......	13.21	......	......	......	......	......	44.59
(16)	(10) + (14) as a percentage of mean integrated concentration.	......	......	......	6.07	......	16.43	......	......	......	......	......	55.41
(17)	(10) - (14) as a percentage of mean integrated concentration.	......	......	......	.17	......	10.00	......	......	......	......	......	33.77

Note: Rows (16) and (17) are the upper and lower confidence limits.

if more than five verticals are sampled by the centroids-of-discharge method.

The particle-size distribution of samples collected by the centroids-of-discharge method has been compared with the particle-size distribution of samples collected by the ETR method. Figure 14 shows that the difference is negligible between particle sizes of samples collected by the two methods.

These particle-size distributions probably indicate that generally the size distribution of ETR samples collected at a sampling interval of less than 20 percent of the width will not be materially different from the size distribution of ETR samples collected at a very small sampling interval.

Although either the ETR method or the centroids-of-discharge method for collecting suspended-sediment samples is satisfactory when applied properly, at some stations costs of operation can be decreased and accuracy increased by the use of the ETR method. Generally, the time required to sample with the ETR method is less than the time required to measure water discharge and to sample with the centroids-of-discharge method; laboratory time is about the same for the analyses of samples collected by either method. Also, local observers and other personnel not familiar with stream-gaging procedures can sample with the ETR method and thus obtain directly samples that are representative of the entire cross section.

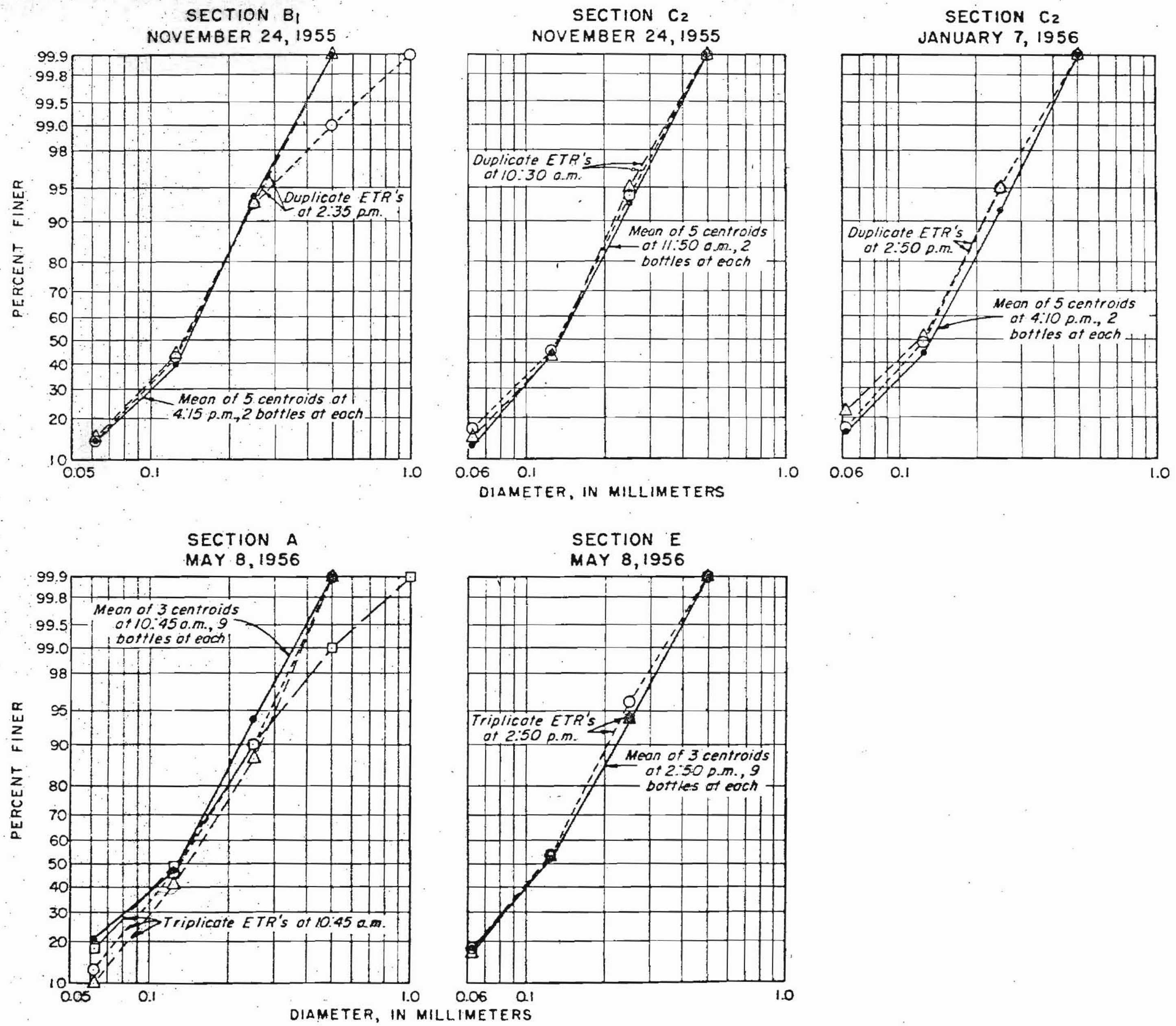


Figure 14.-- Particle-size distributions of suspended-sediment samples collected by the ETR method and the centroids-of-discharge method.

Conclusions From Study of Suspended-Sediment Sampling

Because this study is based on data from a single sand-bed stream, some of the following statements that include specific values may not be applicable to all streams.

The ETR method of measuring suspended-sediment discharge is satisfactory if the proper sampling interval is used.

An adequate sampling interval for the ETR method depends on the distribution of concentration and flow in the cross section. The lateral distributions can be classified by an index ratio. The data indicate that, if many ETR's were collected at different times and at different sections all of which have index ratios of about 1.00 and if the sampling interval is always about 10 percent of the stream width, the mean of all the errors in concentration would be about 5 percent of the concentration that would be obtained with a very small sampling interval.

Supplemental data for an extension of table 10 should provide a guide for determining the ETR sampling interval at any cross section of an alluvial stream.

The data indicate that the number of verticals necessary for an adequate determination of the mean cross-section concentration by the centroids-of-discharge method is fewer than the number of verticals necessary for the determination of the mean concentration by the ETR method.

The data indicate that the deviation of a cross-section concentration determined by the centroids-of-discharge method from a concentration determined from samples at many verticals does not depend on the lateral distribution of concentration and flow unless fewer than five verticals are sampled.

If only a few verticals are sampled, many consecutive samples at each vertical are required to obtain a mean concentration that is within reasonable limits of the true mean concentration for the verticals. For example, if only 2 samples are collected at each of 3 centroids of discharge, the chances are 1 out of 5 that the concentration will deviate from the true mean concentration at those verticals by more than about 25 percent.

In sand-bed streams samples should be collected at not less than five verticals if the centroids-of-discharge method is used.

Samples collected at a small sampling interval by the ETR method and samples collected at five centroids of discharge have essentially the same particle-size distribution.

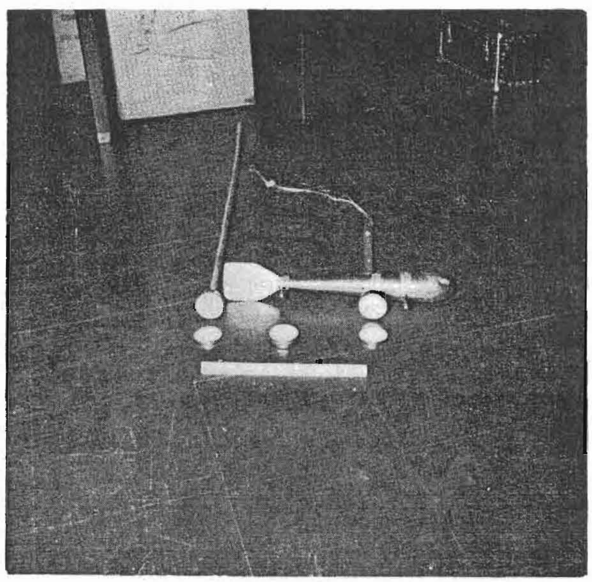
BED-MATERIAL SAMPLING

Bed-material sampling has been studied to obtain comparisons between the size distributions of samples collected with the core-type bed-material sampler and with a newly designed "disk" or surface bed-material sampler, and to gain information on the number of samples that are required for an adequate representation of the bed-material size distribution in a cross section.

The core-type sampler consists of a cylinder, about 2 inches in diameter, that is mounted on a handle (fig. 15A). Contained in the cylinder is a movable piston that can be raised as the cylinder is pushed into the stream bed. Any size core up to 6 inches in length can be obtained with the sampler. Hence, the sampler has wide application and can be used to sample many different kinds of bed material; large volume samples can be collected where large particles are present in the bed, and small volume samples can be collected where the bed material is primarily sand. Samples collected with this sampler are analyzed in the laboratory by sieving or by the visual-accumulation-tube method or by a combination of the two. Often samples can be composited for one analysis; however, the samples of the composite must be similar in gradation.

The surface bed-material sampler consists of a small container that is filled with petrolatum and is affixed to a rubber suction cup, which is attached to the end of a metal rod or to the bottom of a sounding weight (fig. 15B). The sampler is lowered to the bed until the petrolatum contacts the surface of the bed. A variety of petrolatum-filled containers can be used; the container adopted for general use is a small salve box about $2\frac{1}{2}$ inches in diameter and about 3/4 inch deep. The salve boxes are prepared by filling them with melted petrolatum, which contracts slightly when solidifying. A box lid furnishes

A. Core-type sampler.



B. Surface bed-material samplers.

Figure 15.--Bed-material samplers.

protection to the petrolatum before the sample is taken and to the sample after it is collected. Also, pertinent information can be recorded on the paper insert of the lid.

The bed-material sample is separated from the petrolatum by a hot-water elutriator (fig. 16) designed by J. C. Mundorff of the Lincoln office of the Geological Survey, who also designed the "disk" sampler. After the samples are cleaned, they may be analyzed by any of the standard methods.

Bed-material samples can be collected rapidly and conveniently with the surface bed-material sampler. However, the use of the surface bed-material sampler probably should be limited to streams where the bed material is mostly sand. If the bed material consists of any substantial quantity of material larger than sand, undue weight may be given to the larger particles. Samples are usually analyzed individually because the requisites for representative composites have not been thoroughly studied as yet. The time required for processing bed-material samples through the laboratory is about the same for both types of samplers if the samples are analyzed individually.

Discussion of Results

Surface and core-type bed-material samples for comparison were collected at section C_2 on November 24, 1955, January 7, 1956, and

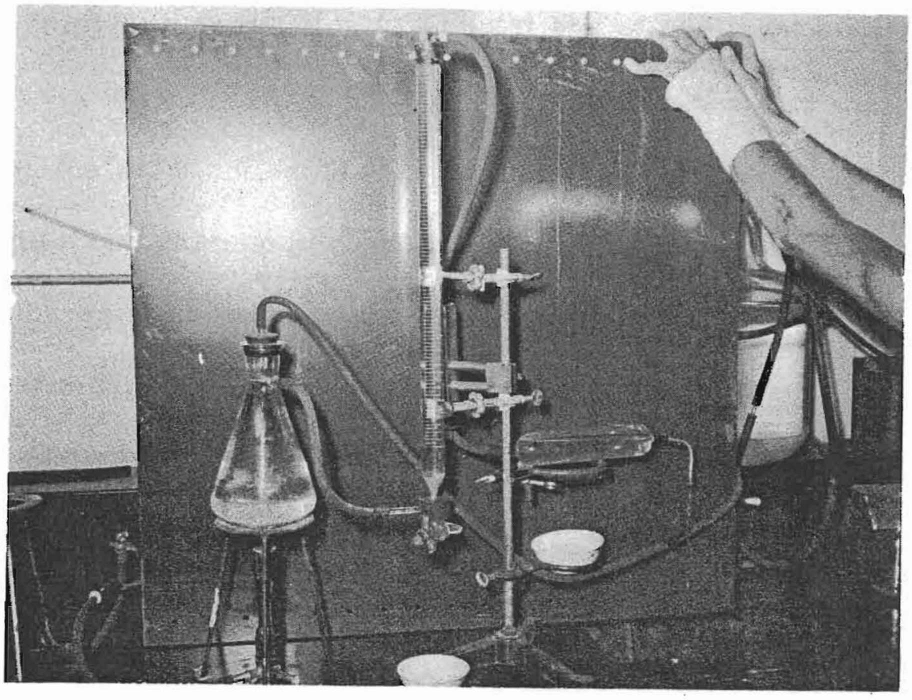


Figure 16.--Elutriator for cleaning bed-material samples collected with the surface bed-material sampler.

March 7, 1956. The size analyses of these samples are tabulated in table 3.

The size distributions of the bed material collected with the two types of samplers are in close agreement for individual days, especially for D_{35}, D_{50}, and D_{65}, which are the critical points on the size-distribution curve for computations of sediment discharge. Figures 17A, B, and C show comparisons of the size distributions of bed material collected with the two types of samplers. Figure 17A is a comparison between the size distributions of a surface bed-material sample and a 3-inch bed-material sample taken with the core-type sampler. Figures 17B and C are comparisons of the size distributions of bed-surface samples and ½-inch core samples.

Figure 17D is a comparison between samples collected with the surface bed-material sampler at section C_2 and 100 feet upstream and the average of 97 core samples collected at section C_2 on 29 days. The size-distribution curves show the variation of bed material in a reach and indicate that bed-material samples taken at a single cross section may not be representative for even short reaches.

The median particle size of 40 bed-surface samples collected at section C_2 on January 7, 1956, ranged from 0.089 to 0.44 millimeter and averaged 0.28 millimeter (table 3 and fig. 17B). The median particle size for an average of 97 core samples collected during a period of several years is 0.39 millimeter. Figure 17E shows the

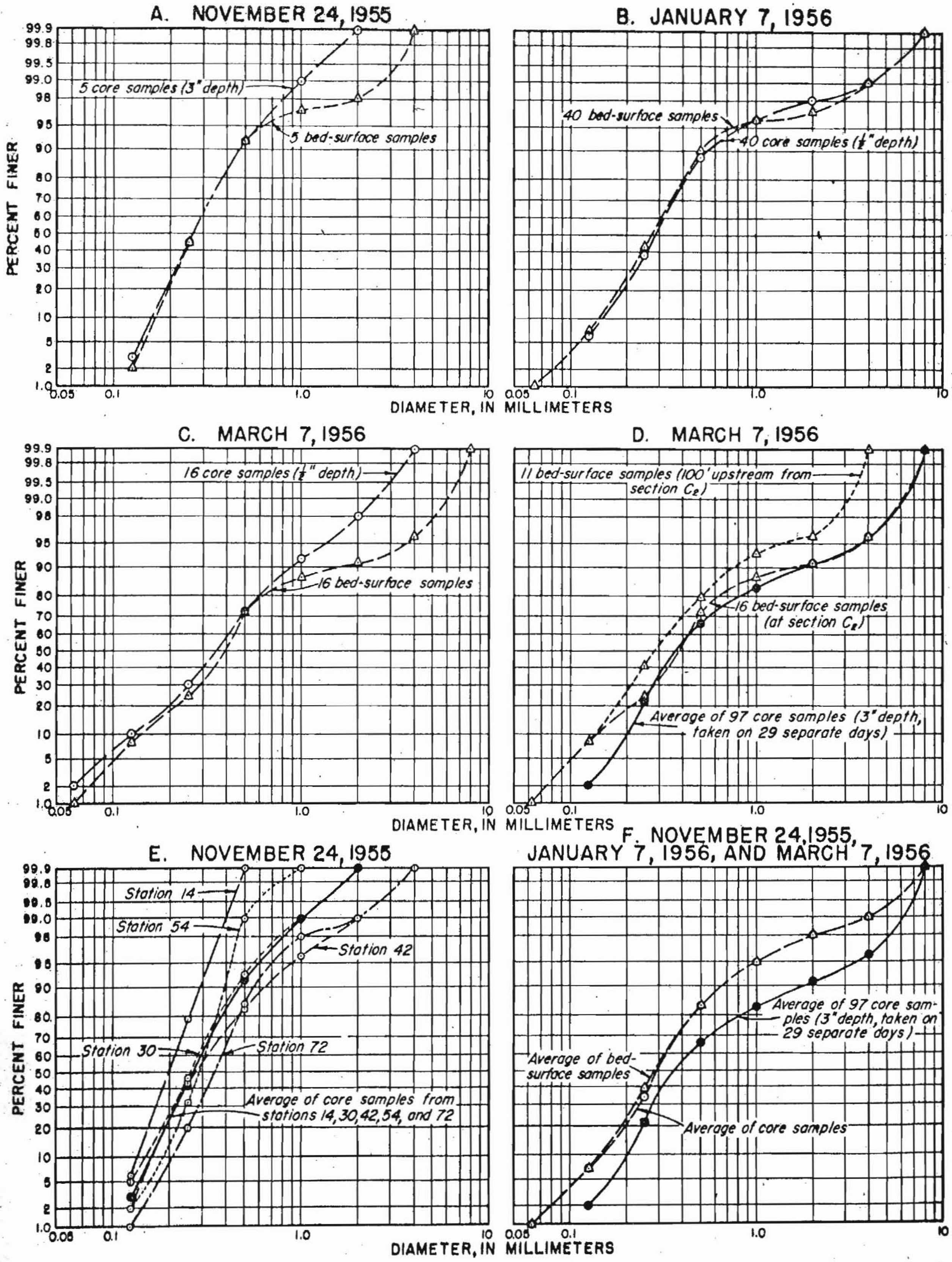


Figure 17.--Particle-size distributions of bed-material samples collected by surface- and core-type samplers, Middle Loup River at Dunning, Nebr.

differences in particle-size distribution of five samples. Because of the wide differences in individual samples, 1 or 2 samples probably will not be representative of the average bed-material sizes. Therefore, numerous bed-material samples in the cross section should be collected to obtain a representative bed-material sample. Also, unless a great many samples are collected in the cross section at the Middle Loup River at Dunning, samples should not be collected near the banks because the bed material is finer near the banks and the average will be unduly weighted with fine material. (See table 3.)

A statistical analysis of the size distribution of surface bed-material samples collected at section C_2 on January 7, 1956, was made to determine the effects of computing a size distribution for the cross section from different numbers of samples. Thirty-six samples were used; the two samples nearest the bank at each end of the cross section were omitted because they consisted of unusually fine material. One basic assumption of the analysis is that the number of samples required to obtain any desired degree of precision is governed by the percent-finer values, of any separation size, that have the greatest standard deviation. The percent-finer values of the 0.25-millimeter size had the greatest standard deviation (17.67 percent) of any separation size; therefore, these values were used for the analysis. The results are plotted in figure 18, which shows that if 15 samples had been collected and averaged, the chances are 7 out of 10 that the greatest deviation of the mean percent-finer value

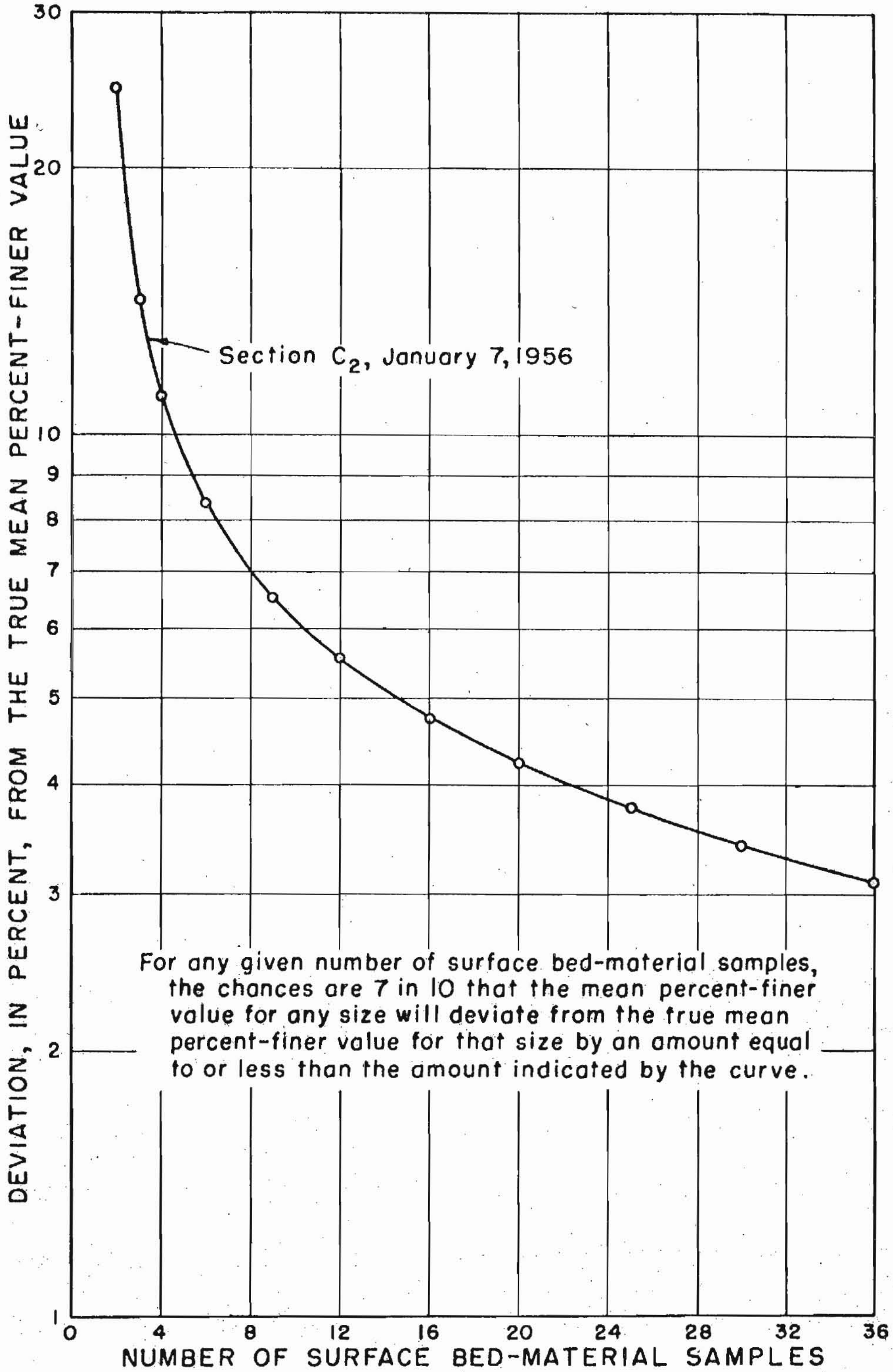


Figure 18.--Deviation of mean percent-finer value from the true mean percent-finer value.

for any size from the true mean percent-finer value would have been 5 percent.

A study of the bed-material size analyses for November 24, 1955, January 7, 1956, and March 7, 1956, at section C_2 shows a progressive coarsening of the bed material (fig. 19) but a slight decrease in the particle size of suspended sediment and total sediment discharges. The mean velocities on the 3 days were 3.45, 3.53, and 3.40 feet per second; the mean depths were 1.37, 1.45, and 1.77 feet; the instantaneous water discharges were 393, 410, and 516 cfs; and the computed total loads were 2,500, 2,650, and 3,650 tons per day, respectively.

A possible explanation of the coarsening of the bed material is that during the winter the banks of the stream are usually frozen and protected by shore ice; therefore, the coarsening of the bed may be the result of selective sorting by the stream because practically the only source of sediment is the bed of the stream. Admittedly, the data at hand are insufficient to indicate more than the possibility that this hypothesis has some merit. If the postulated reason for the apparent coarsening of the bed is true, the bed material during the summer and early fall should show a gradual decrease in size. However, the possible effect of a change in bed material on other parameters of streamflow and sediment discharge makes further testing of this hypothesis worthy of consideration.

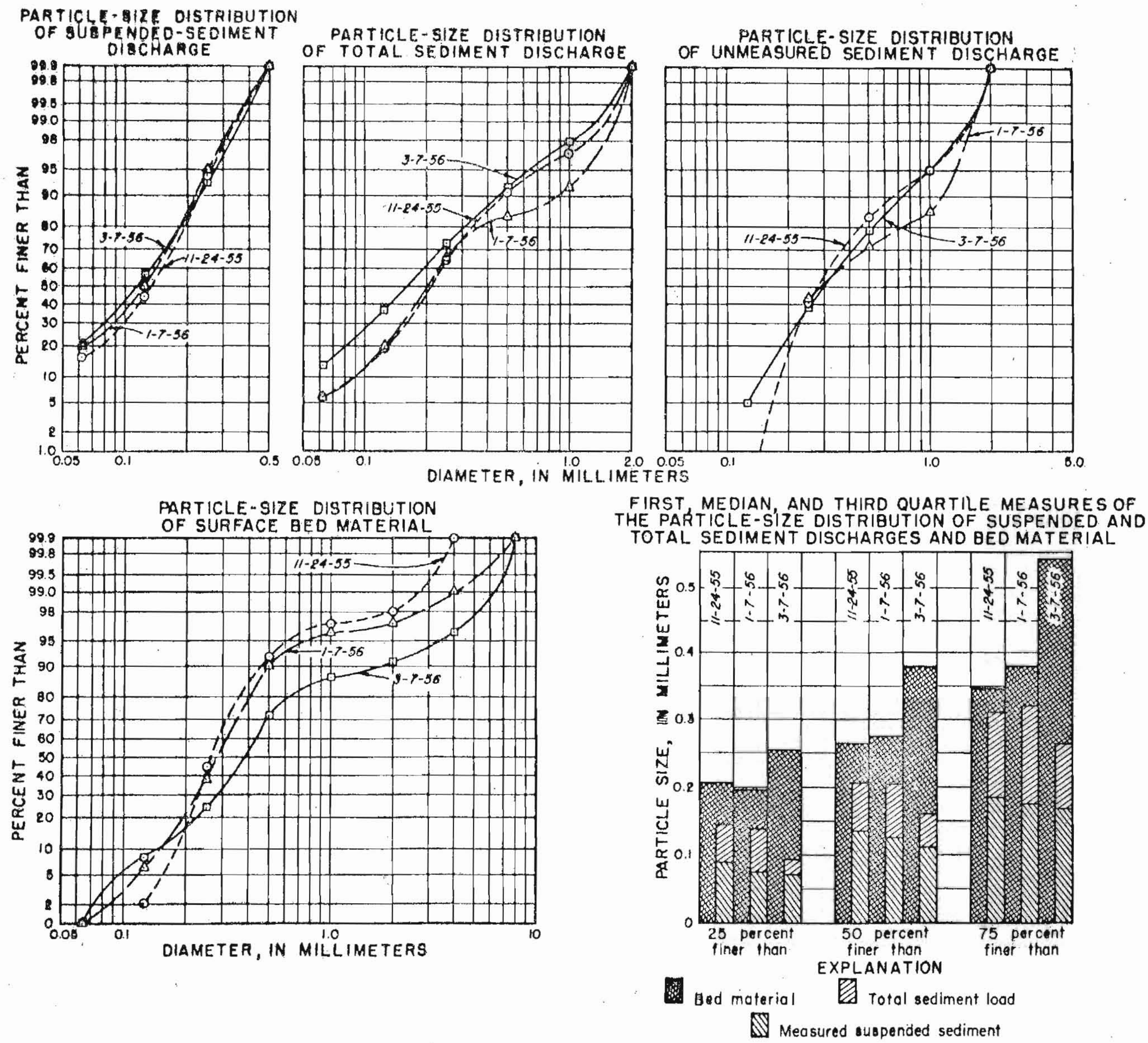


Figure 19.--Progressive change of particle size during winter, section C_2, Middle Loup River at Dunning, Nebr.

Conclusions From Study of Bed-Material Sampling

To date, on the Middle Loup River at Dunning, Nebr., the particle-size distributions obtained by using data from the new surface bed-material sampler compare favorably with those from the core-type sampler.

Bed-material samples can be collected more rapidly and conveniently with the surface bed-material sampler than with the core-type sampler. However, the use of the surface bed-material sampler probably should be limited to streams where the bed material is mostly sand. The time required for processing bed-material samples through the laboratory is about the same for both types of samples if the samples are analyzed individually.

Because of the wide differences in individual bed-material samples, many samples are necessary for an adequate representation of the average bed-material sizes in a cross section. A statistical study of surface bed-material samples indicates that at least 15 verticals should be sampled at section C_2.

Bed-material size analyses for November 24, 1955, January 7, 1956, and March 7, 1956, at section C_2 show a progressive coarsening of the bed material.

TOTAL SEDIMENT DISCHARGE DURING OPEN-FLOW PERIODS AT LOW TEMPERATURES

Total sediment discharge and several related sediment and hydraulic parameters have been studied to determine the effects of low water temperatures during open-flow periods. The primary concern in this study was the effects of low water temperatures on total sediment discharges computed with the modified Einstein procedure (Colby and Hembree, 1955).

Computations of total sediment discharge with the modified Einstein procedure were made for section B_1 from data collected on November 24, 1955, and March 8, 1956, and for section C_2 from data collected on November 24, 1955, January 7 and 8, 1956, and March 7, 1956. The basic data used for the computations are listed in tables 1, 3, and 4. A summary of the results of the computations is given in table 13. Computed total loads for the times when the water temperature ranged from 32° to 37°F agreed well with the measured total loads at section D. The computations were made by using concentrations determined from samples collected with the centroids-of-discharge and ETR methods and by using particle-size analyses of bed material determined from samples collected with both kinds of bed-material samplers. The results of the computations show that concentrations from either the centroids-of-discharge method or the ETR method seem to be equally

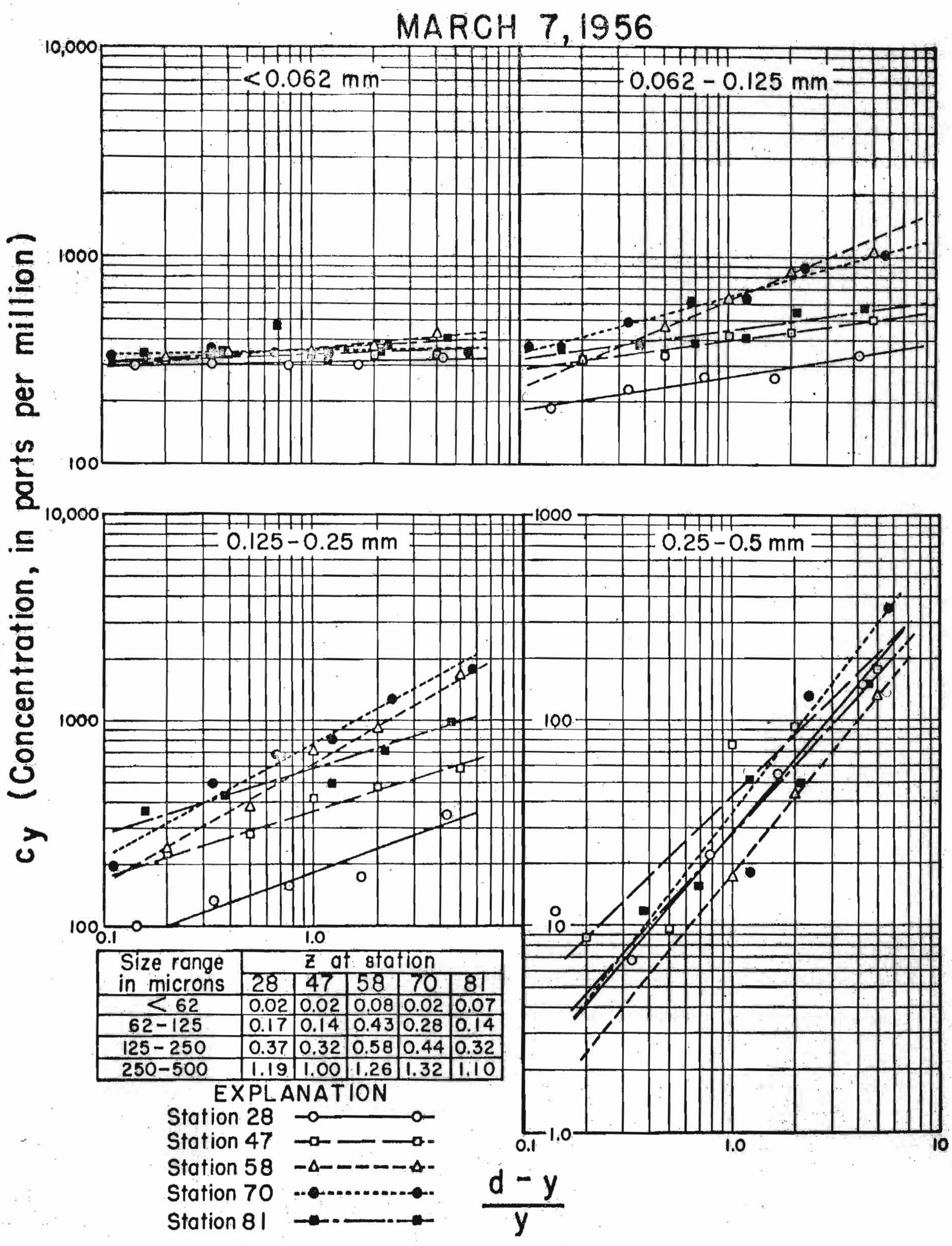
Table 13.--Measured sediment discharge and computed total sediment discharge at sections B_1 and C_2 and measured sediment discharge at section D

Date	Water discharge (cfs)	Section	Type of sediment discharge	Sediment discharge in tons per day: Finer than 0.062 mm	0.062 to 0.125 mm	0.125 to 0.25 mm	0.25 to 0.50 mm	0.50 to 1.00 mm	1.00 to 2.00 mm	2.00 to 4.00 mm	Total	Percentage of sediment discharge at the total-load section	Type and number of bed-material samples	Type and number of suspended-sediment samples
1955 Nov. 24.	398	B_1	Measured	172	369	603	86	....	....	....	1,230	44	....	ETR (36)
		B_1	Computed	177	448	1,117	625	136	10	1	2,510	91	3-in. core (5)	....
		B_1	Measured	150	278	578	64	....	....	....	1,070	39	....	Centroid (5)
		B_1	Computed	132	352	1,046	610	133	10	1	2,280	82	3-in. core (5)	....
		D	Measured	222	388	1,220	721	166	55	....	2,770	100	....	ETR
	393	C_2	Measured	174	305	545	65	....	....	....	1,090	43	....	ETR (40)
		C_2	Computed	178	377	1,327	488	64	0	2	2,440	96	Surface ? (5)	....
		C_2	Measured	150	356	564	80	....	....	....	1,150	45	....	Centroid (5)
		C_2	Computed	144	430	1,355	509	66	0	2	2,510	99	Surface ? (5)	....
		D	Measured	152	329	1,138	683	152	76	....	2,530	100	....	ETR
1956 Jan. 7.	410	C_2	Measured	266	399	598	66	....	....	....	1,330	44	....	ETR (40)
		C_2	Computed	268	469	1,022	580	245	80	17	2,680	88	3-in. core (97)	....
		C_2	Computed	272	486	1,195	594	109	15	2	2,670	88	Surface ? (40)	....
		C_2	Measured	216	378	648	108	....	....	....	1,350	45	....	Centroid (5)
		C_2	Computed	221	467	1,249	609	113	15	2	2,680	88	Surface ? (40)	....
		D	Measured	182	424	1,394	545	242	242	....	3,030	100	....	ETR
Jan. 8.	412	C_2	Measured	118	332	514	107	....	....	....	1,070	35	....	ETR (40)
		C_2	Computed	123	389	836	528	193	56	9	2,130	70	3-in. core (97)	....
		C_2	Computed	123	399	1,031	399	97	15	2	2,070	68	½-in. core (16)	....
		C_2	Measured	197	325	592	46	....	....	....	1,160	38	....	Centroid ? (5)
		C_2	Computed	124	395	882	433	212	40	10	2,090	69	½-in. core (5)	....
		D	Measured	242	364	1,606	697	61	61	....	3,030	100	....	ETR
Mar. 7.	516	C_2	Measured	452	752	796	150	....	....	....	2,150	63	....	ETR (17)
		C_2	Computed	455	830	1,265	752	264	72	13	3,650	107	3-in. core (97)	....
		C_2	Computed	455	864	1,333	715	299	48	4	3,720	109	½-in. core (16)	....
		C_2	Computed	455	855	1,157	885	245	35	11	3,640	107	Surface (16)	....
		D	Measured	443	818	1,228	648	205	68	....	3,410	100	....	ETR
Mar. 8	479	B_1	Measured	294	761	606	69	....	....	....	1,730	49	....	ETR (18)
		B_1	Computed	295	900	1,288	582	231	65	16	3,380	95	3-in. core (55)	....
		D	Measured	356	819	1,566	641	178	....	....	3,560	100	....	ETR

applicable for computing total load and that the modified Einstein procedure is rather insensitive to small changes in the size distribution of bed material. For March 7, 1956, section C_2, the total loads that were computed by using the analyses for 3 different types of bed-material samples varied from one another by only 1 percent. The procedure seems to compensate for small changes in bed-material size distribution mostly by a change in z_2.

In order to determine the effect of low water temperatures on z (the exponent of the equation for the vertical distribution of suspended sediment), computations of z were made from the data in table 2. For any given vertical and time, c_y (the concentration at any point y distance above the bed) can be expressed by $c_y = K(\frac{d - y}{y})^z$ where K is a constant and d is the depth. In a plot of cy against $(\frac{d - y}{y})$ on logarithmic coordinate paper, z for a size fraction is the slope of the line. (See fig. 20.) Values of z are given in table 14.

Values of z from field data are not directly used in the modified Einstein procedure; however, the assumption is made in the procedure that z varies on the average with about the 0.7 power of the fall velocity according to the Rubey equation. Figure 21 shows that at low water temperatures z does vary on the average with about the 0.7 power of the fall velocity. The value of each z in figure 21 is the average of all z's for a size range at a cross section.



Size range in microns	z at station 28	47	58	70	81
< 62	0.02	0.02	0.08	0.02	0.07
62-125	0.17	0.14	0.43	0.28	0.14
125-250	0.37	0.32	0.58	0.44	0.32
250-500	1.19	1.00	1.26	1.32	1.10

Figure 20.--Vertical distribution of suspended sediment, section C_7.

Table 14.--Measured values of z, k, and Manning's n

Station	z for indicated size range[1]				k	Manning's n
	0-0.062	0.062-0.125	0.125-0.250	0.25-0.50		
Nov. 24, 1955, Section B_1						
22	0.03	0.22	0.32	0.86	.....	....
40	.09	.29	.54	1.33	.....	....
54	.06	.13	.35	.60	.....	....
68	0	.19	.66	1.87	.....	....
82	-.02	.26	.71	1.83	.....	....
Mean..	0.03	0.22	0.52	1.30	.....	....
Nov. 24, 1955, Section C_2						
14	-0.03	0.29	0.44	1.22	0.276	....
30	.06	.25	.59	1.38	.376	....
42	.04	.29	.67	1.36	.362	....
54	.02	.25	.53	2.24	.505	....
72	.01	.32	.61	1.99	1.32	....
Mean..	0.02	0.28	0.57	1.64	0.568	0.0190
Jan. 7, 1956, Section C_2						
28	0.01	0.05	0.09	0.13	0.322	....
46	0	.25	.56	1.64	.270	....
60	.01	.31	.80	1.98	.240	....
70	.03	.35	.61	1.36	.246	....
81	.08	.09	.30	.74	.356	....
Mean..	0.03	0.21	0.47	1.17	0.287	0.0178
Jan. 8, 1956, Section C_2						
26	-0.02	0.14	0.24	0.50	.....	....
43	.04	.19	.49	.88	0.397	....
54	0	.18	.50	1.12	.323	....
67	-.04	.08	.25	.40	.665	....
78	.03	.35	.58	....	.507	....
Mean..	0	0.19	0.41	0.72	0.473	0.0209
Mar. 7, 1956, Section C_2						
28	0.02	0.17	0.37	1.19	0.355	....
47	.02	.14	.32	1.00	.326	....
58	.08	.43	.58	1.26	.246	....
70	.02	.28	.44	1.32	.239	....
81	.07	.14	.32	1.10	.317	....
Mean..	0.04	0.23	0.41	1.17	0.297	0.0195
Mar. 8, 1956, Section B_1						
17	0.07	0.47	0.98	....	.....	....
34	.12	.42	.90	1.99	.....	....
46	.14	.39	.67	2.11	.....	....
69	.04	.33	.53	1.03	.....	....
82	.02	.23	.45	1.05	.....	....
Mean..	0.08	0.37	0.71	1.54	.....	....

1 Size range in millimeters.

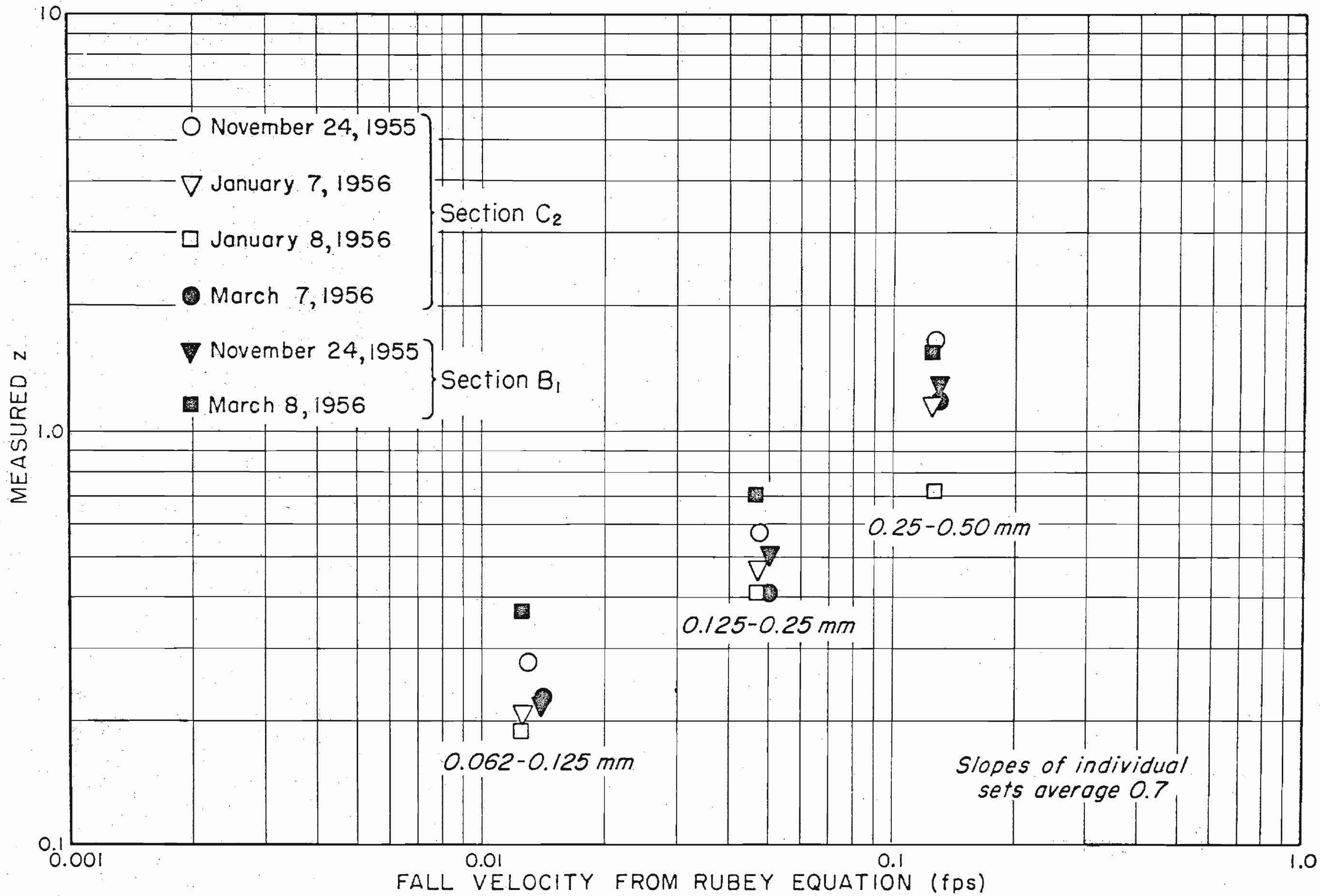
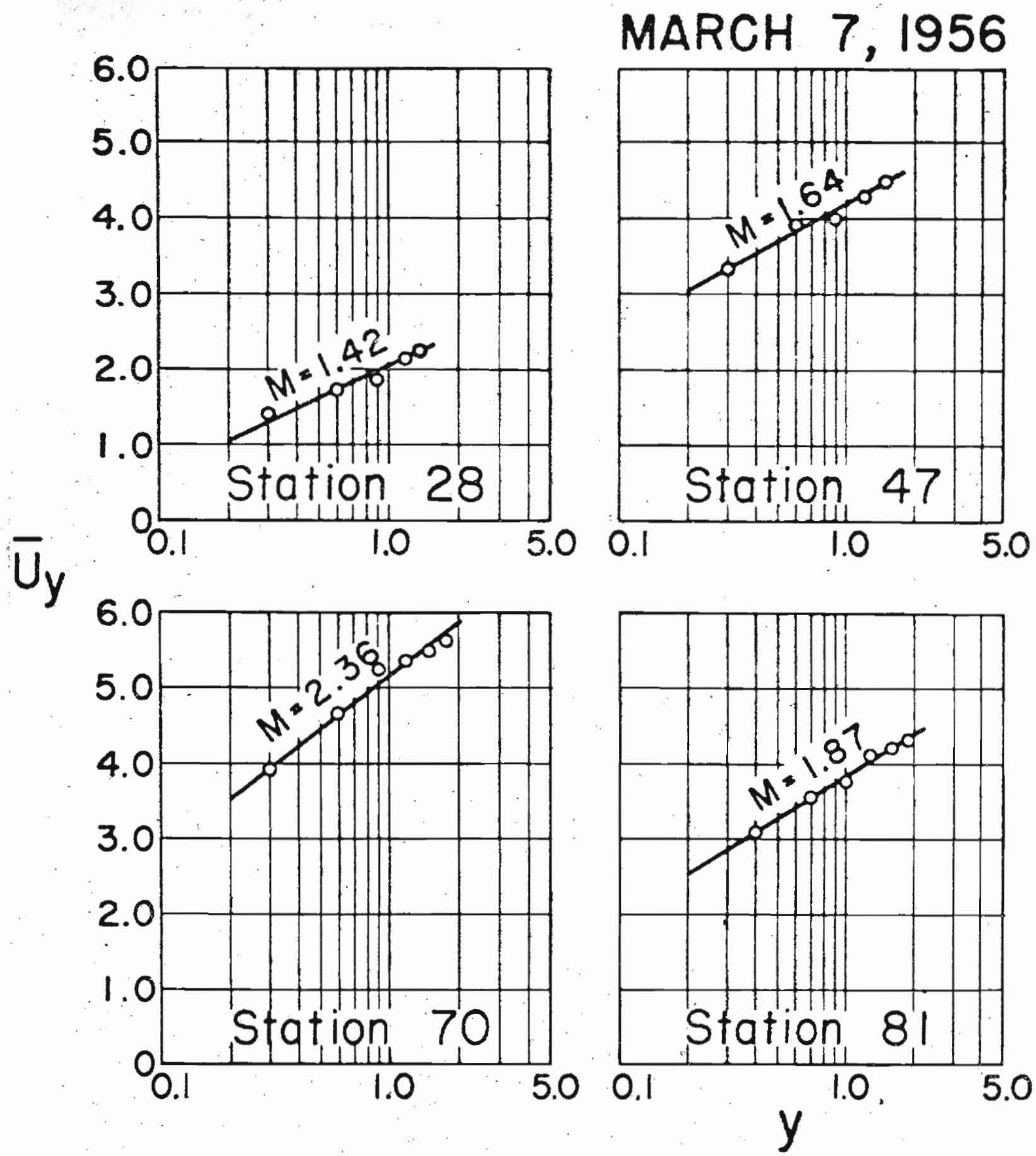


Figure 21.--Variation of measured z with fall velocity.

Values of k, the von Karman constant, were determined from the data collected during this study. The Keulegan equation for the vertical distribution of velocity, if written for a given vertical and time, is $\overline{u}_y = C + (2.303\ u_*/k) \log_{10} y$, where C is a constant and u_* is the shear velocity; k can be determined from $M = 2.303\ u_*/k$, where M is the slope of a line determined from plotting $\overline{u}_y$ (the stream velocity at a distance y above the bed) against y on semi-logarithmic paper. (See fig. 22.) Values of k are given in table 14.

Comparisons of total loads throughout a range of water temperatures were made in order to determine the effects of low water temperatures on the sediment discharge. Supplemental data for these comparisons were obtained mostly from Hubbell and Matejka (in preparation). At section C_2 for a given range of water discharge, total sediment discharge tended to be low at high temperatures and high at low temperatures. This tendency was studied further by using computed values of Manning's n (table 14). Values of n tended to be low at low temperatures and high loads, and values of n tended to be high at high temperatures and low loads. Figure 23 shows Manning's n plotted against total sediment discharge, with water temperature and discharge as the third and fourth variables. Possibly, interrelations similar to those shown in figure 23 exist in other alluvial streams.



Station	$k = \frac{2.303 u_*}{M}$
28	0.36
47	0.33
58	0.25
70	0.24
81	0.32

Water discharge, 516 cfs
Manning n, 0.020
Planar bed, no dunes

Figure 22.--Vertical distribution of stream velocity, section C_2.

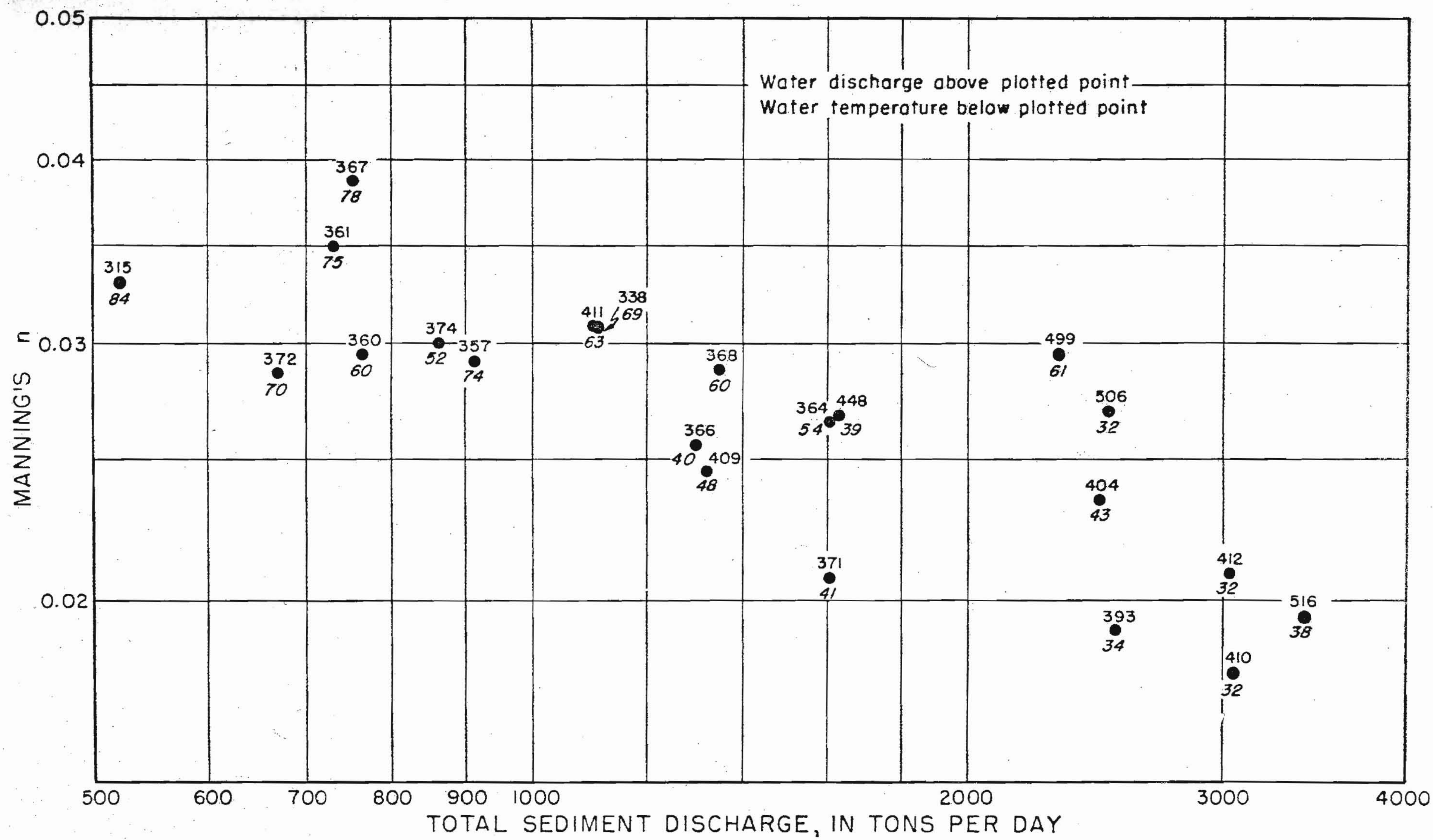


Figure 23.--Relation of Manning's n and total sediment discharge, section C_2.

Conclusions From Low-Temperature Study

The modified Einstein procedure is adequate for computing total load when the water temperature is near freezing.

Total-load computations can be made equally well by using samples collected with the centroids-of-discharge or the ETR method.

The modified Einstein procedure is insensitive to small changes in bed-material size.

Differences in water temperature have no effect on the relation that z varies with about the 0.7 power of the fall velocity when fall velocities are determined from the Rubey equation.

Generally the rate of increase of the measured z's with respect to fall velocity is less than that of z's computed from the equation $z = V_s/0.4u_*$, where V_s is the fall velocity.

Values of Manning's n are low at low temperatures and high sediment loads.

RECOMMENDATIONS FOR FUTURE INVESTIGATIONS

The results of the studies to date indicate that Manning's n is related to sediment discharge; the independent variable is unknown (fig. 23). The verification and definition of the relation as well as the definition of changes in other parameters, such as slope and width-to-depth ratio, are important in the diversion and regulation of water in alluvial channels. Of particular importance are the limitations of the changes that take place. Limitations in the change of hydraulic parameters probably exist, otherwise streams would neither aggrade nor degrade.

It is proposed that a study be made of the Middle Loup River in the vicinity of Dunning, Nebr. The Dismal River joins the Middle Loup River about 2 miles downstream from the Dunning turbulence flume. The sediment concentrations and size distribution, for practical purposes, are comparable. The Dismal River has an average discharge of 315 cfs, and the Middle Loup has an average discharge of 380 cfs. Therefore, downstream from the confluence the water discharge is about twice the discharge of either stream; however, the sediment concentration may be about the same as that in either stream. If hydraulic parameters are affected by sediment concentration, the magnitudes of these parameters downstream from the confluence should be different from those of the two separate streams. The field investigations as contemplated at this time (1956) would consist of the following:

1. Total load measurements at section D.

2. Measurements at section C_2.

A. For computation of total load by the modified Einstein procedure.

B. For determinations of n.

3. Measurements of the Dismal River upstream from the confluence.

A. For computation of total load by the modified Einstein procedure.

B. For determinations of n.

4. Measurements of two sections downstream from the confluence of the Dismal and Loup Rivers.

A. For computation of total load by the modified Einstein procedure.

B. For determinations of n.

Six sets of these measurements that cover a range in discharge and temperature would be made.

It is also proposed that further field tests of bed-material samplers be made at the Middle Loup River and at other streams to determine the limitation and applicability of the samplers.

The work described above will probably be as much as can be done in 1957. The knowledge of sediment transport is still far from complete, and practically no knowledge of sediment transport during certain periods of the year on some types of streams exists. Consequently, in future planning, consideration should be given to studies of the sediment-transport characteristics of stream under ice cover and of streams that have bed-material sizes generally coarser than sand.

Little data are available concerning transport characteristics of streams during periods of ice cover. For many streams an unknown percentage of the annual load is transported at these times. Consideration should be given to the collection of data for determining the vertical distribution of sediment and velocity during these periods. These data would be used to define the relationship of sediment concentration with characteristics of flow under ice cover so that the present methods of computing total load could be evaluated and, if necessary, modified.

The total sediment load of cobble-bed streams cannot be defined adequately by present techniques, especially when the bed is armored for part of the range in discharge. The relation between the bed material and the sediment in transport probably does not follow the normal concept. Another problem is that of obtaining adequate bed-material and suspended-sediment samples on this type of stream. Considerable thought must be given to the equipment needed, the investigational procedure, and the location for the investigation. Planning and field reconnaissance within the next year for investigation of sediment loads under ice cover and in cobble-bed streams are recommended.

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TABLES OF BASIC DATA

Table 1.--Particle-size analyses of suspended sediment, depth-integrated samples, Middle Loup River at Dunning, Nebr.
[Method of analysis, visual accumulation tube]

Date	Time	Water temperature (°F)	Measured instantaneous discharge (cfs)	Suspended sediment								Remarks
				Concentration (ppm)	Suspended-sediment discharge (tons per day)	Percent finer than indicated size, in millimeters						
						0.062	0.125	0.250	0.500	1.000	2.000	
					Section A							
May 8, 1956....	10:45 a.m.	55	....	781	....	12	45	89	100	.....	.....	ETR no. 1, stas. 20 to 107.
	10:45 a.m.	55	....	254	....	31	62	99	100	.....	.....	ETR no. 1, stas. 110 to 361.6.
	10:45 a.m.	55	416	677	....	13	46	90	100	.....	.....	ETR no. 1.
	10:45 a.m.	55	....	871	....	10	41	87	100	.....	.....	ETR no. 2, stas. 20 to 107.
	10:45 a.m.	55	....	196	....	14	50	94	97	100	.....	ETR no. 2, stas. 110 to 361.6.
	10:45 a.m.	55	416	732	....	10	41	87	100	.....	.....	ETR no. 2.
	10:45 a.m.	55	....	781	....	15	46	89	99	100	.....	ETR no. 3, stas. 20 to 107.
	10:45 a.m.	55	....	269	....	57	78	99	100	.....	.....	ETR no. 3, stas. 110 to 361.6.
	10:45 a.m.	55	416	678	....	18	49	90	99	100	.....	ETR no. 3.
	10:45 a.m.	55	416	696	782	14	45	89	100	.....	.....	Average of ETR no. 1, ETR no. 2, and ETR no. 3.
	10:25 a.m.	54	....	672	....	23	44	85	100	.....	.....	Nine samples, sta. 38.
	10:50 a.m.	55	....	1,160	....	11	50	98	100	.....	.....	Nine samples, sta. 59.
	11:15 a.m.	55	....	500	....	30	47	99	100	.....	.....	Nine samples, sta. 326.5
					Section B_1							
Sept. 7, 1955..	10:50 a.m.	60	360	355	345	21	47	93	100	.....	.....	ETR.
	9:35 a.m.	58	360	333	....	25	46	85	100	.....	.....	Sta. 21.
	9:50 a.m.	58	360	327	....	26	53	94	100	.....	.....	Sta. 54.
	10:00 a.m.	59	360	596	....	21	39	91	100	.....	.....	Sta. 78.
Nov. 24........	2:35 p.m.	38	398	1,150	....	14	43	93	99	100	.....	ETR no. 1, 37 verticals.
	2:35 p.m.	38	398	1,140	....	15	44	93	100	.....	.....	ETR no. 2, 37 verticals.
	2:35 p.m.	38	398	1,140	1,230	14	44	93	100	.....	.....	Average of ETR no. 1 and ETR no. 2.
	3:30 p.m.	38	398	563	....	20	42	94	100	.....	.....	Sta. 22.
	4:00 p.m.	38	398	711	....	20	51	97	100	.....	.....	Sta. 40.
	4:15 p.m.	38	398	1,350	....	10	38	88	100	.....	.....	Sta. 54.
	4:30 p.m.	38	398	1,520	....	8	35	96	100	.....	.....	Sta. 68.
	4:45 p.m.	37	398	846	....	13	36	93	100	.....	.....	Sta. 82.
Mar. 8, 1956...	10:05 a.m.	32	479	1,340	1,730	17	61	96	100	.....	.....	ETR.
	11:15 a.m.	35	479	1,380	....	20	53	97	100	.....	.....	Sta. 17.
	11:05 a.m.	34	479	1,690	....	18	51	98	100	.....	.....	Sta. 34.
	11:00 a.m.	34	479	1,780	....	17	52	97	100	.....	.....	Sta. 46.
	10:50 a.m.	34	479	1,260	....	22	54	91	100	.....	.....	Sta. 69.
	10:35 a.m.	33	479	1,350	....	20	56	93	100	.....	.....	Sta. 82.

Table 1.--Particle-size analyses of suspended sediment, depth-integrated samples, Middle Loup River at Dunning, Nebr.--Continued

Date	Time	Water temperature (°F)	Measured instantaneous discharge (cfs)	Suspended sediment								Remarks
				Concentration (ppm)	Suspended-sediment discharge (tons per day)	Percent finer than indicated size, in millimeters						
						0.062	0.125	0.250	0.500	1.000	2.000	
					Section C_2							
Nov. 24, 1955..	10:30 a.m.	32	393	1,010	....	17	45	94	100	.....	.....	ETR no. 1, 40 verticals.
	10:30 a.m.	32	393	1,050	....	15	43	95	100	.....	.....	ETR no. 2, 40 verticals.
	10:30 a.m.	32	393	1,030	1,090	16	44	94	100	.....	.....	Average of ETR no. 1 and ETR no. 2.
	11:35 a.m.	35	393	784	....	15	46	97	100	.....	.....	Sta. 14.
	11:25 a.m.	35	393	1,300	....	10	41	93	100	.....	.....	Sta. 30.
	11:45 a.m.	35	393	1,650	....	8	37	95	100	.....	.....	Sta. 42.
	11:55 a.m.	36	393	944	....	15	45	93	100	.....	.....	Sta. 54.
	12:10 p.m.	36	393	749	....	18	49	88	100	.....	.....	Sta. 72.
Jan. 7, 1956...	2:50 p.m.	32	410	1,200	....	17	49	95	100	.....	.....	ETR no. 1, 40 verticals.
	2:50 p.m.	32	410	1,200	....	22	51	95	100	.....	.....	ETR no. 2, 40 verticals.
	2:50 p.m.	32	410	1,200	1,330	20	50	95	100	.....	.....	Average of ETR no. 1 and ETR no. 2.
	4:35 p.m.	32	410	1,060	....	17	40	71	100	.....	.....	Sta. 28.
	4:20 p.m.	32	410	995	....	19	52	96	100	.....	.....	Sta. 46.
	4:10 p.m.	32	410	1,320	....	15	43	99	100	.....	.....	Sta. 60.
	3:55 p.m.	32	410	1,490	....	13	42	97	100	.....	.....	Sta. 70.
	3:40 p.m.	32	410	1,230	....	16	43	97	100	.....	.....	Sta. 81.
Jan. 8.........	2:50 p.m.	32	412	990	....	11	45	90	100	.....	.....	ETR no. 1, 40 verticals.
	2:50 p.m.	32	412	943	....	11	40	89	100	.....	.....	ETR no. 2, 40 verticals.
	2:50 p.m.	32	412	966	1,070	11	42	90	100	.....	.....	Average of ETR no. 1 and ETR no. 2.
	4:15 p.m.	32	412	663	....	24	55	95	100	.....	.....	Sta. 26.
	4:05 p.m.	32	412	1,200	....	14	40	94	100	.....	.....	Sta. 43.
	3:50 p.m.	32	412	1,490	....	12	38	96	100	.....	.....	Sta. 54.
	3:45 p.m.	32	412	1,060	....	14	39	93	100	.....	.....	Sta. 67.
	3:30 p.m.	32	412	793	....	20	52	100	.....	.....	.....	Sta. 78.
Mar. 7.........	1:55 p.m.	37	516	1,540	2,150	21	56	93	100	.....	.....	ETR
	3:55 p.m.	40	516	645	....	46	76	95	100	.....	.....	Sta. 28.
	3:45 p.m.	40	516	1,100	....	30	62	96	100	.....	.....	Sta. 47.
	3:30 p.m.	39	516	1,940	....	18	54	97	100	.....	.....	Sta. 58.
	3:20 p.m.	39	516	1,990	....	18	52	95	100	.....	.....	Sta. 70.
	3:10 p.m.	39	516	1,090	....	30	61	100	.....	.....	.....	Sta. 81.
					Section D							
Nov. 24, 1955..	10:00 a.m.	32	393	2,290	....	6	19	62	91	97	100	ETR no. 1.
	10:00 a.m.	32	393	2,460	....	5	19	67	91	97	100	ETR no. 2.
	10:00 a.m.	32	393	2,380	2,530	6	19	64	91	97	100	Average of ETR no. 1 and ETR no. 2.
	2:35 p.m.	38	398	2,560	....	7	21	67	92	97	100	ETR no. 1.
	2:35 p.m.	38	398	2,590	....	8	22	66	92	98	100	ETR no. 2.

Table 1.--Particle-size analyses of suspended sediment, depth-integrated samples, Middle Loup River at Dunning, Nebr.--Continued

Date	Time	Water temper-ature (°F)	Measured instanta-neous discharge (cfs)	Suspended sediment								Remarks
				Concen-tration (ppm)	Suspended-sediment discharge (tons per day)	Percent finer than indicated size, in millimeters						
						0.062	0.125	0.250	0.500	1.000	2.000	
						Section D--Continued						
Nov. 24, 1955..	2:35 p.m.	38	398	2,580	2,770	8	22	66	92	98	100	Average of ETR no. 1 and ETR no. 2
Jan. 7, 1956...	2:50 p.m.	32	410	2,840	....	5	18	62	80	92	100	ETR no. 1.
	2:50 p.m.	32	410	2,650	....	8	23	70	87	92	100	ETR no. 2.
	2:50 p.m.	32	410	2,740	3,030	6	20	66	84	92	100	Average of ETR no. 1 and ETR no. 2
Jan. 8.........	2:45 p.m.	32	412	2,760	....	7	20	72	96	97	100	ETR no. 1.
	2:45 p.m.	32	412	2,670	....	8	21	74	97	98	100	ETR no. 2.
	2:45 p.m.	32	412	2,720	3,030	8	20	73	96	98	100	Average of ETR no. 1 and ETR no. 2
Mar. 7..........	2:45 p.m.	38	516	2,450	3,410	13	37	73	92	98	100	ETR.
Mar. 8..........	10:35 a.m.	33	479	2,750	3,560	10	33	77	95	100	.....	ETR.
May 8..........	9:20 a.m.	54	416	1,700	1,910	4	21	68	92	99	100	ETR.
	1:37 p.m.	59	408	1,240	1,370	6	23	64	89	98	100	ETR.
						Section E						
Sept. 7, 1955..	9:00 a.m.	58	....	315	....	25	54	92	100	.....	.....	ETR.
May 8, 1956....	2:50 p.m.	64	....	564	....	17	53	96	100	.....	.....	ETR no. 1, stas. 14 to 95.
	2:50 p.m.	64	....	172	....	36	84	99	100	.....	.....	ETR no. 1, stas. 98 to 164.
	2:50 p.m.	64	408	505	....	18	54	96	100	.....	.....	ETR no. 1.
	2:50 p.m.	64	....	557	....	16	52	94	100	.....	.....	ETR no. 2, stas. 14 to 95.
	2:50 p.m.	64	....	211	....	56	90	99	100	.....	.....	ETR no. 2, stas. 98 to 164.
	2:50 p.m.	64	408	505	....	17	54	94	100	.....	.....	ETR no. 2.
	2:50 p.m.	64	....	576	....	15	52	94	100	.....	.....	ETR no. 3, stas. 14 to 95.
	2:50 p.m.	64	....	192	....	50	88	98	100	.....	.....	ETR no. 3, stas. 98 to 164.
	2:50 p.m.	64	408	518	....	17	54	94	100	.....	.....	ETR no. 3.
	2:50 p.m.	64	408	509	561	17	54	95	100	.....	.....	Average of ETR no. 1, ETR no. 2, an ETR no. 3.
	2:20 p.m.	63	....	1,060	....	8	31	82	99	100	.....	Nine samples, sta. 35.
	2:50 p.m.	64	....	496	....	19	57	99	100	.....	.....	Nine samples, sta. 59.
	3:15 p.m.	65	....	153	....	27	69	100	.....	.....	.....	Nine samples, sta. 98.

Table 2.—Particle-size analyses of suspended sediment, point-integrated samples, Middle Loup River at Dunning, Nebr.
[Duplicate samples collected with DH-48 sediment sampler having 3/16-in. nozzle. Method of analysis, visual accumulation tube.]

Date	Time	Water temperature (°F)	Measured water discharge (cfs)	Sampling station	Total depth (ft)	Suspended sediment								
						Sampling point				Percent finer than indicated size, in millimeters				
						Velocity [1] (ft/sec)	Nozzle velocity [2] (ft/sec)	Depth (ft)	Concentration (ppm)	0.062	0.125	0.250	0.500	1.000
						Section B_1								
Nov. 24, 1955..	3:30 p.m.	38	398	22	1.5	2.33	2.62	0.3	423	30	55	98	100	......
	3:30 p.m.	38	398	22	1.5	2.33	2.35	.6	576	23	47	98	100	......
	3:30 p.m.	38	398	22	1.5	2.27	2.67	.8	630	19	42	96	100	......
	3:30 p.m.	38	398	22	1.5	2.22	2.75	1.0	732	17	39	93	100	......
	3:30 p.m.	38	398	22	1.5	2.22	2.58	1.2	871	15	38	92	100	......
	4:00 p.m.	38	398	40	1.1	1.96	2.46	.3	580	23	61	99	100	......
	4:00 p.m.	38	398	40	1.1	1.64	2.37	.45	681	21	59	99	100	......
	4:00 p.m.	38	398	40	1.1	1.44	2.15	.6	820	18	57	98	100	......
	4:00 p.m.	38	398	40	1.1	1.38	1.69	.75	1,060	15	49	97	100	......
	4:00 p.m.	38	398	40	1.1	1.24	1.51	.8	1,120	12	46	96	100	......
	4:15 p.m.	38	398	54	1.6	3.96	4.05	.3	1,050	12	45	91	100	......
	4:15 p.m.	38	398	54	1.6	3.73	4.24	.5	1,360	10	41	89	100	......
	4:15 p.m.	38	398	54	1.6	3.60	4.22	.7	1,440	8	38	90	100	......
	4:15 p.m.	38	398	54	1.6	3.64	4.58	.9	1,430	9	38	87	100	......
	4:15 p.m.	38	398	54	1.6	3.47	3.93	1.1	1,880	7	33	86	100	......
	4:15 p.m.	38	398	54	1.6	3.31	2.47	1.3	3,650	4	19	75	97	100
	4:30 p.m.	38	398	68	1.3	....	5.67	.2	970	13	48	99	100	......
	4:30 p.m.	38	398	68	1.3	....	5.53	.4	1,100	13	46	99	100	......
	4:30 p.m.	38	398	68	1.3	....	5.62	.6	1,600	7	35	98	100	......
	4:30 p.m.	38	398	68	1.3	....	5.12	.8	2,070	6	30	97	100	......
	4:30 p.m.	38	398	68	1.3	....	4.90	1.0	3,810	3	18	86	100	......
	4:45 p.m.	37	398	82	1.5	....	4.68	.2	473	22	55	99	100	......
	4:45 p.m.	37	398	82	1.5	....	5.02	.4	528	22	54	100	.....	......
	4:45 p.m.	37	398	82	1.5	....	4.98	.6	606	17	46	99	100	......
	4:45 p.m.	37	398	82	1.5	....	4.64	.8	810	12	40	97	100	......
	4:45 p.m.	37	398	82	1.5	....	4.59	1.0	1,110	9	32	94	100	......
	4:45 p.m.	37	398	82	1.5	....	4.36	1.2	1,930	5	22	88	100	......
Mar. 8, 1956...	11:15 a.m.	35	479	17	1.4	4.78	4.27	.3	615	44	80	100	.....	......
	11:15 a.m.	35	479	17	1.4	4.68	4.90	.5	866	31	70	100	.....	......
	11:15 a.m.	35	479	17	1.4	4.50	4.42	.7	1,170	24	63	100	.....	......
	11:15 a.m.	35	479	17	1.4	4.10	4.38	.9	1,670	18	54	99	100	......
	11:15 a.m.	35	479	17	1.4	3.54	4.02	1.1	3,140	10	34	93	100	......

1 Measured with Price current meter.
2 Computed from volume of sample, time of collection and area of nozzle.

Table 2.--Particle-size analyses of suspended sediment, point-integrated samples, Middle Loup River at Dunning, Nebr.--Continued

Date	Time	Water temperature (°F)	Measured water discharge (cfs)	Sampling station	Total depth (ft)	Suspended sediment: Sampling point: Velocity [1] (ft/sec)	Nozzle velocity [2] (ft/sec)	Depth (ft)	Concentration (ppm)	Percent finer than indicated size, in millimeters: 0.062	0.125	0.250	0.500	1.000
Section B_1--Continued														
Mar. 8, 1956...	11:05 a.m.	34	479	34	1.3	4.78	4.48	0.3	856	32	73	100	.....	......
	11:05 a.m.	34	479	34	1.3	4.78	4.53	.5	1,480	20	59	99	100	......
	11:05 a.m.	34	479	34	1.3	4.59	4.35	.7	1,860	15	53	98	100	......
	11:05 a.m.	34	479	34	1.3	4.30	4.53	.9	2,600	12	44	94	100	......
	11:05 a.m.	34	479	34	1.3	3.92	3.88	1.0	3,930	9	35	91	100	......
	11:00 a.m.	34	479	46	1.2	4.68	4.43	.3	960	29	68	100	.....	......
	11:00 a.m.	34	479	46	1.2	4.50	4.55	.5	1,480	19	58	98	100	......
	11:00 a.m.	34	479	46	1.2	4.20	4.54	.7	1,820	16	53	99	100	......
	11:00 a.m.	34	479	46	1.2	3.68	3.30	.9	4,010	10	33	92	100	......
	10:50 a.m.	34	479	69	1.6	3.47	3.43	.4	938	28	63	99	100	......
	10:50 a.m.	34	479	69	1.6	3.40	3.79	.7	1,130	25	55	96	100	......
	10:50 a.m.	34	479	69	1.6	3.32	3.01	1.0	1,350	21	51	92	100	......
	10:50 a.m.	34	479	69	1.6	3.09	3.14	1.3	2,460	12	38	92	100	......
	10:35 a.m.	33	479	82	2.4	4.30	4.03	.3	779	34	74	99	100	......
	10:35 a.m.	33	479	82	2.4	4.20	4.04	.6	1,050	25	62	98	100	......
	10:35 a.m.	33	479	82	2.4	4.01	4.28	.9	1,200	24	62	96	100	......
	10:35 a.m.	33	479	82	2.4	3.76	4.23	1.2	1,390	20	58	97	100	......
	10:35 a.m.	33	479	82	2.4	3.32	3.98	1.5	1,630	17	54	93	100	......
	10:35 a.m.	33	479	82	2.4	2.71	4.06	1.8	1,910	15	50	92	100	......
	10:35 a.m.	33	479	82	2.4	1.57	3.32	2.1	2,700	12	39	83	100	......
Section C_2														
Nov. 24, 1955..	11:35 a.m.	35	393	14	1.6	3.80	3.07	0.3	413	28	58	100	.....	......
	11:35 a.m.	35	393	14	1.6	3.64	3.82	.5	693	17	47	100	.....	......
	11:35 a.m.	35	393	14	1.6	3.39	3.60	.8	1,010	11	39	99	100	......
	11:35 a.m.	35	393	14	1.6	2.92	3.43	1.1	1,150	10	35	97	100	......
	11:35 a.m.	35	393	14	1.6	2.38	3.50	1.3	1,420	7	28	95	100	......
	11:25 a.m.	35	393	30	1.6	4.84	5.31	.3	603	19	57	100	.....	......
	11:25 a.m.	35	393	30	1.6	4.84	5.31	.5	1,010	12	45	99	100	......
	11:25 a.m.	35	393	30	1.6	4.72	5.11	.7	1,240	9	41	99	100	......
	11:25 a.m.	35	393	30	1.6	4.51	5.04	.9	1,670	7	35	94	100	......
	11:25 a.m.	35	393	30	1.6	4.21	4.73	1.1	2,110	6	29	90	100	......
	11:25 a.m.	35	393	30	1.6	3.96	4.12	1.3	3,250	4	19	83	100	......
	11:45 a.m.	35	393	42	1.6	4.61	4.98	.3	745	17	57	100	.....	......
	11:45 a.m.	35	393	42	1.6	4.61	5.18	.5	1,060	12	49	99	100	......
	11:45 a.m.	35	393	42	1.6	4.61	5.01	.7	1,330	10	44	98	100	......
	11:45 a.m.	35	393	42	1.6	4.40	4.74	.9	1,710	8	39	97	100	......
	11:45 a.m.	35	393	42	1.6	4.13	4.48	1.1	2,340	4	30	97	100	......
	11:45 a.m.	35	393	42	1.6	3.66	3.85	1.3	3,440	4	25	92	100	......

1 Measured with Price current meter.
2 Computed from volume of sample, time of collection and area of nozzle.

Table 2.--Particle-size analyses of suspended sediment, point-integrated samples, Middle Loup River at Dunning, Nebr.--Continued

Date	Time	Water temper-ature (°F)	Measured water discharge (cfs)	Sampling station	Total depth (ft)	Suspended sediment								
						Sampling point				Percent finer than indicated size, in millimeters				
						Velocity [1] (ft/sec)	Nozzle velocity [2] (ft/sec)	Depth (ft)	Concen-tration (ppm)	0.062	0.125	0.250	0.500	1.000
						Section C_2—Continued								
Nov. 24, 1955..	11:55 a.m.	36	393	54	1.5	4.31	4.35	0.2	451	26	68	97	100	......
	11:55 a.m.	36	393	54	1.5	4.26	4.72	.4	553	23	63	98	100	......
	11:55 a.m.	36	393	54	1.5	4.21	4.50	.6	706	18	57	99	100	......
	11:55 a.m.	36	393	54	1.5	4.04	4.73	.8	808	17	52	97	100	......
	11:55 a.m.	36	393	54	1.5	3.88	4.24	1.0	1,070	12	44	95	100	......
	11:55 a.m.	36	393	54	1.5	....	3.49	1.2	2,090	6	27	81	100	......
	12:10 p.m.	36	393	72	1.4	3.55	3.63	.3	476	25	62	98	100	......
	12:10 p.m.	36	393	72	1.4	3.51	2.67	.5	573	20	54	96	100	......
	12:10 p.m.	36	393	72	1.4	3.47	3.62	.7	633	20	55	97	100	......
	12:10 p.m.	36	393	72	1.4	3.39	3.82	.9	970	13	43	90	100	......
	12:10 p.m.	36	393	72	1.4	3.31	2.76	1.1	1,900	6	25	72	100	......
Jan. 7, 1956...	4:35 p.m.	32	410	28	1.5	1.84	1.77	.3	1,190	17	41	75	100	......
	4:35 p.m.	32	410	28	1.5	2.12	2.30	.6	1,170	16	37	72	99	100
	4:35 p.m.	32	410	28	1.5	1.96	1.82	.8	1,290	16	38	74	99	100
	4:35 p.m.	32	410	28	1.5	1.71	2.06	1.0	1,330	15	38	72	99	100
	4:35 p.m.	32	410	28	1.5	1.84	2.34	1.2	1,400	14	33	69	100	......
	4:20 p.m.	32	410	46	1.5	4.32	3.49	.3	676	32	66	99	100	......
	4:20 p.m.	32	410	46	1.5	4.16	3.43	.6	938	22	55	98	100	......
	4:20 p.m.	32	410	46	1.5	4.07	3.21	.8	1,070	20	51	97	100	......
	4:20 p.m.	32	410	46	1.5	3.76	3.10	1.0	1,450	14	43	91	100	......
	4:20 p.m.	32	410	46	1.5	3.17	2.87	1.2	2,060	10	32	84	100	......
	4:10 p.m.	32	410	60	1.8	4.96	4.58	.3	663	30	64	100	.....	......
	4:10 p.m.	32	410	60	1.8	4.86	4.26	.6	1,040	21	57	100	.....	......
	4:10 p.m.	32	410	60	1.8	4.56	4.31	.9	1,270	17	48	99	100	......
	4:10 p.m.	32	410	60	1.8	4.12	3.39	1.2	2,130	10	34	97	100	......
	4:10 p.m.	32	410	60	1.8	3.40	3.39	1.5	3,990	5	20	92	100	......
	3:55 p.m.	32	410	70	1.8	5.52	4.96	.3	706	27	62	100	.....	......
	3:55 p.m.	32	410	70	1.8	5.32	4.64	.6	1,110	18	53	99	100	......
	3:55 p.m.	32	410	70	1.8	5.02	4.68	.9	1,440	15	48	99	100	......
	3:55 p.m.	32	410	70	1.8	4.80	4.43	1.2	2,010	10	38	97	100	......
	3:55 p.m.	32	410	70	1.8	3.39	3.60	1.5	8,620	3	11	70	98	100
	3:40 p.m.	32	410	81	1.9	4.02	3.66	.4	892	22	55	98	100	......
	3:40 p.m.	32	410	81	1.9	3.98	3.63	.7	855	22	54	99	100	......
	3:40 p.m.	32	410	81	1.9	3.65	3.35	1.0	1,080	18	49	98	100	......
	3:40 p.m.	32	410	81	1.9	3.40	2.91	1.3	1,140	18	47	98	100	......
	3:40 p.m.	32	410	81	1.9	2.99	2.78	1.6	1,720	15	37	90	100	......

1 Measured with Price current meter.
2 Computed from volume of sample, time of collection and area of nozzle.

Table 2.--Particle-size analyses of suspended sediment, point-integrated samples, Middle Loup River at Dunning, Nebr.--Continued

Date	Time	Water temperature (°F)	Measured water discharge (cfs)	Sampling station	Total depth (ft)	Suspended sediment: Sampling point: Velocity [1] (ft/sec)	Nozzle velocity [2] (ft/sec)	Depth (ft)	Concentration (ppm)	Percent finer than indicated size, in millimeters: 0.062	0.125	0.250	0.500	1.000
						Section C_2--Continued								
Jan. 8, 1956...	4:15 p.m.	32	412	26	0.9	....	2.31	0.3	783	21	51	92	100	......
	4:15 p.m.	32	412	26	.9	....	2.88	.4	864	19	51	92	100	......
	4:15 p.m.	32	412	26	.9	....	2.99	.5	763	21	53	94	100	......
	4:15 p.m.	32	412	26	.9	....	3.04	.6	1,010	16	44	88	100	......
	4:05 p.m.	32	412	43	2.0	4.90	3.91	.3	713	22	53	99	100	......
	4:05 p.m.	32	412	43	2.0	4.80	4.02	.6	823	20	49	96	100	......
	4:05 p.m.	32	412	43	2.0	4.96	3.68	.8	1,230	14	40	92	100	......
	4:05 p.m.	32	412	43	2.0	4.55	3.41	1.1	1,420	12	36	92	100	......
	4:05 p.m.	32	412	43	2.0	4.16	3.32	1.4	2,050	9	28	89	100	......
	4:05 p.m.	32	412	43	2.0	2.99	2.47	1.7	2,430	7	24	83	100	......
	3:50 p.m.	32	412	54	2.1	4.60	4.32	.3	574	28	61	100	.....	......
	3:50 p.m.	32	412	54	2.1	4.42	4.21	.6	991	18	50	99	100	......
	3:50 p.m.	32	412	54	2.1	4.26	3.56	.9	1,440	11	39	98	100	......
	3:50 p.m.	32	412	54	2.1	3.98	3.45	1.2	1,480	11	38	97	100	......
	3:50 p.m.	32	412	54	2.1	3.61	3.31	1.5	1,970	9	31	94	100	......
	3:50 p.m.	32	412	54	2.1	3.21	3.07	1.8	2,870	6	24	92	100	......
	3:45 p.m.	32	412	67	1.7	4.12	2.63	.3	1,030	16	39	91	100	......
	3:45 p.m.	32	412	67	1.7	3.98	2.70	.6	1,160	12	37	87	100	......
	3:45 p.m.	32	412	67	1.7	3.84	2.41	.8	1,350	13	34	84	100	......
	3:45 p.m.	32	412	67	1.7	3.80	2.92	1.1	1,310	12	34	87	100	......
	3:45 p.m.	32	412	67	1.7	3.58	3.07	1.4	1,700	8	28	86	100	......
	3:30 p.m.	32	412	78	2.1	3.50	3.04	.3	353	38	74	100	.....	......
	3:30 p.m.	32	412	78	2.1	3.34	3.16	.6	502	29	67	100	.....	......
	3:30 p.m.	32	412	78	2.1	3.22	3.04	.9	732	23	56	100	.....	......
	3:30 p.m.	32	412	78	2.1	3.13	3.76	1.2	624	25	58	100	.....	......
	3:30 p.m.	32	412	78	2.1	2.83	2.99	1.5	844	19	54	100	.....	......
	3:30 p.m.	32	412	78	2.1	2.50	2.69	1.8	1,450	11	44	100	.....	......
Mar. 7.........	3:55 p.m.	40	516	28	1.6	2.24	3.29	.2	592	50	81	98	100	......
	3:55 p.m.	40	516	28	1.6	2.18	3.59	.4	670	45	79	99	100	......
	3:55 p.m.	40	516	28	1.6	1.87	3.77	.7	747	40	76	97	100	......
	3:55 p.m.	40	516	28	1.6	1.72	3.61	1.0	790	38	71	93	100	......
	3:55 p.m.	40	516	28	1.6	1.41	2.36	1.3	1,160	28	57	87	100	......

1 Measured with Price current meter.
2 Computed from volume of sample, time of collection and area of nozzle.

Table 2.--Particle-size analyses of suspended sediment, point-integrated samples, Middle Loup River at Dunning, Nebr.--Continued

Date	Time	Water temperature (°F)	Measured water discharge (cfs)	Sampling station	Total depth (ft)	Suspended sediment								
						Sampling point				Percent finer than indicated size, in millimeters				
						Velocity [1] (ft/sec)	Nozzle velocity [2] (ft/sec)	Depth (ft)	Concentration (ppm)	0.062	0.125	0.250	0.500	1.000
						Section C_2--Continued								
Mar. 7, 1956...	3:45 p.m.	40	516	47	1.8	4.50	4.27	0.3	871	36	73	99	100	......
	3:45 p.m.	40	516	47	1.8	4.30	3.65	.6	959	35	70	99	100	......
	3:45 p.m.	40	516	47	1.8	4.01	3.88	.9	1,260	28	61	94	100	......
	3:45 p.m.	40	516	47	1.8	3.92	3.76	1.2	1,330	25	57	93	100	......
	3:45 p.m.	40	516	47	1.8	3.32	3.68	1.5	1,610	21	52	89	100	......
	3:30 p.m.	39	516	58	1.8	5.49	6.08	.3	886	37	73	100	.....	......
	3:30 p.m.	39	516	58	1.8	5.23	5.72	.6	1,180	29	68	100	.....	......
	3:30 p.m.	39	516	58	1.8	4.89	4.58	.9	1,710	20	57	99	100	......
	3:30 p.m.	39	516	58	1.8	4.59	4.86	1.2	2,170	17	56	98	100	......
	3:30 p.m.	39	516	58	1.8	4.10	4.43	1.5	3,280	13	45	96	100	......
	3:20 p.m.	39	516	70	2.0	5.62	6.03	.2	895	37	78	100	.....	......
	3:20 p.m.	39	516	70	2.0	5.49	5.61	.5	1,340	27	63	100	.....	......
	3:20 p.m.	39	516	70	2.0	5.36	5.61	.8	1,630	21	58	100	.....	......
	3:20 p.m.	39	516	70	2.0	5.23	5.50	1.1	1,810	19	54	99	100	......
	3:20 p.m.	39	516	70	2.0	4.68	4.70	1.4	2,660	14	47	95	100	......
	3:20 p.m.	39	516	70	2.0	3.92	3.54	1.7	3,480	10	39	90	100	......
	3:10 p.m.	39	516	81	2.2	4.30	4.12	.3	1,080	32	66	100	.....	......
	3:10 p.m.	39	516	81	2.2	4.20	4.07	.6	1,170	30	62	99	100	......
	3:10 p.m.	39	516	81	2.2	4.10	3.21	.9	1,540	30	55	99	100	......
	3:10 p.m.	39	516	81	2.2	3.76	3.33	1.2	1,270	25	57	96	100	......
	3:10 p.m.	39	516	81	2.2	3.54	3.53	1.5	1,640	21	54	97	100	......
	3:10 p.m.	39	516	81	2.2	3.09	3.28	1.8	2,110	19	46	93	100	......

1 Measured with Price current meter.
2 Computed from volume of sample, time of collection and area of nozzle.

Table 3.--Particle-size analyses of bed material, Middle Loup River at Dunning, Nebr.
[Methods of analysis: S, sieve; V, visual accumulation tube.]

Date	Number of samples	Measured instantaneous discharge (cfs)	Mean velocity (fps)	Bed material: Percent finer than indicated size, in millimeters									Methods of analysis	Remarks
				0.062	0.125	0.250	0.500	1.000	2.000	4.000	8.000	16.000		
Section A														
May 8, 1956...	14	416	....	0	2	41	83	91	94	97	100	......	SV	Composite of ½-in. core samples collected at 10-ft intervals from stas. 20 to 110 and stas 320 to 350.
Section B_1														
Nov. 24, 1955.	1	398	....	0	1	49	93	99	100	.....	.....	......	SV	Sta. 22.
	1	398	....	0	4	53	92	97	98	100	.....	......	SV	Sta. 40.
	1	398	....	.....	0	7	59	85	90	95	100	......	SV	Sta. 54.
	1	398	....	.....	0	16	82	99	100	.....	.....	......	SV	Sta. 68.
	1	398	....	.....	0	19	95	100	.....	.....	.....	......	V	Sta. 82.
	5	398	....	0	1	29	84	96	98	99	100	......	SV	Average of stas. 22, 40, 54, 68, 82.
Mar. 8, 1956..	1	479	....	0	4	40	97	100	.....	.....	.....	......	S	Sta. 18, core sample.[1]
	1	479	....	0	2	40	96	100	.....	.....	.....	......	V	
	1	479	....	0	6	50	92	99	100	.....	.....	......	S	Sta. 34, core sample.[1]
	1	479	....	0	4	52	92	99	100	.....	.....	......	SV	
	1	479	....	0	2	27	82	98	100	.....	.....	......	S	Sta. 53, core sample.[1]
	1	479	....	0	1	24	75	98	100	.....	.....	......	SV	
	1	479	....	0	6	62	97	99	100	.....	.....	......	S	Sta. 67, core sample.[1]
	1	479	....	0	3	60	96	99	100	.....	.....	......	SV	
	1	479	....	0	2	24	71	85	92	96	100	......	S	Sta. 82, core sample.[1]
	1	479	....	0	1	21	68	85	92	96	100	......	SV	
	5	479	....	0	4	41	88	96	98	99	100	......	S	Average of stas. 18, 34, 53, 67 and 82.[1]
	5	479	....	0	2	39	85	96	98	99	100	......	SV	
	17	479	....	0	4	38	83	92	95	97	100	......	S	Composite of ½-in. core samples collected at 5-ft intervals.[1]
	17	479	....	0	2	33	80	90	95	97	100	......	SV	
	1	479	....	0	1	11	30	52	72	88	100	......	S	Sta. 10, disk sample.
	1	479	....	0	5	34	84	91	100	.....	.....	......	S	Sta. 15, disk sample.
	1	479	....	0	2	12	48	81	91	100	.....	......	S	Sta. 20, disk sample.
	1	479	....	0	3	63	100	.....	.....	.....	.....	......	S	Sta. 25, disk sample.
	1	479	....	0	9	50	96	100	.....	.....	.....	......	S	Sta. 30, disk sample.
	1	479	....	0	12	66	98	100	.....	.....	.....	......	S	Sta. 35, disk sample.
	1	479	....	0	4	39	97	100	.....	.....	.....	......	S	Sta. 40, disk sample.
	1	479	....	0	2	30	96	100	.....	.....	.....	......	S	Sta. 45, disk sample.
	1	479	....	0	6	40	91	99	100	.....	.....	......	S	Sta. 50, disk sample.
	1	479	....	0	2	30	81	92	96	100	.....	......	S	Sta. 55, disk sample.

1 Same sample used for both analyses.

Table 3.—Particle-size analyses of bed material, Middle Loup River at Dunning, Nebr.—Continued

Date	Number of samples	Measured instantaneous discharge (cfs)	Mean velocity (fps)	Bed material: Percent finer than indicated size, in millimeters 0.062	0.125	0.250	0.500	1.000	2.000	4.000	8.000	16.000	Methods of analysis	Remarks
				Section B_1—Continued										
Mar. 8, 1956..	1	479	....	0	2	24	82	94	96	100	.....	......	S	Sta. 60, disk sample.
	1	479	....	0	1	33	93	97	98	100	.....	......	S	Sta. 65, disk sample.
	1	479	....	0	6	61	99	100	.....	.....	.....	......	S	Sta. 70, disk sample.
	1	479	....	0	3	47	99	100	.....	.....	.....	......	S	Sta. 75, disk sample.
	1	479	....	1	7	58	99	100	.....	.....	.....	......	S	Sta. 80, disk sample.
	15	479	....	0	4	40	86	94	97	99	100	......	S	Average of stas. 10 to 80.
				Section C_2										
Nov. 24, 1955.	1	393	....	0	6	79	100	.....	.....	.....	.....	......	S	Sta. 14, core sample.[1]
	1	393	....	0	5	80	100	.....	.....	.....	.....	......	V	
	1	393	....	0	5	46	93	99	100	.....	.....	......	S	Sta. 30, core sample.[1]
	1	393	....	0	4	50	95	100	.....	.....	.....	......	V	
	1	393	....	0	2	42	83	96	99	100	.....	......	S	Sta. 42, core sample.[1]
	1	393	....	0	2	36	83	96	98	100	.....	......	SV	
	1	393	....	0	2	32	99	100	.....	.....	.....	......	S	Sta. 54, core sample.[1]
	1	393	....	0	1	33	99	100	.....	.....	.....	......	V	
	1	393	....	0	1	20	85	98	99	100	.....	......	S	Sta. 72, core sample.[1]
	1	393	....	.....	0	16	88	98	99	100	.....	......	SV	
	5	393	....	0	3	44	92	99	100	.....	.....	......	S	Average of stas. 14, 30, 42, 54, and 72.[1]
	5	393	....	0	2	43	93	99	99	100	.....	......	SV	
	5	393	....	0	2	44	92	97	98	100	.....	......	S	Composite of disk samples from stas. 14, 30, 42, 54, and 72.
Jan. 7, 1956..	10	410	....	1	11	40	94	99	99	100	.....	......	S	Composite of ½-in. core samples collected at 2-ft intervals from stas. 11 to 29.[1]
	10	410	....	0	8	41	91	99	99	100	.....	......	SV	
	10	410	....	0	1	18	85	97	98	99	100	......	S	Composite of ½-in. core samples collected at 2-ft intervals from stas. 31 to 49.[1]
	10	410	....	.....	0	14	83	97	98	99	100	......	SV	
	10	410	....	0	2	35	82	94	98	99	100	......	S	Composite of ½-in. core samples collected at 2-ft intervals from stas. 51 to 69.[1]
	10	410	....	0	2	30	82	94	98	99	100	......	SV	
	10	410	....	1	10	56	92	96	96	97	98	100	S	Composite of ½-in. core samples collected at 2-ft intervals from stas. 71 to 89.[1]
	10	410	....	0	6	52	92	96	96	97	98	100	SV	
	40	410	....	0	6	37	88	96	98	99	100	......	S	Average of stas. 11 to 89.[1]
	40	410	....	0	4	34	87	96	98	99	100	......	SV	
	1	410	0.25	13	71	94	100	.....	.....	.....	.....	......	S	Sta. 11, disk sample.
	1	410	1.16	6	54	98	100	.....	.....	.....	.....	......	S	Sta. 13, disk sample.
	1	410	....	0	12	58	96	100	.....	.....	.....	......	S	Sta. 15, disk sample.

1 Same sample used for both analyses.

Table 3.—Particle-size analyses of bed material, Middle Loup River at Dunning, Nebr.—Continued

Date	Number of samples	Measured instantaneous discharge (cfs)	Mean velocity (fps)	Bed material: Percent finer than indicated size, in millimeters 0.062	0.125	0.250	0.500	1.000	2.000	4.000	8.000	16.000	Methods of analysis	Remarks
				Section C_2—Continued										
Jan. 7, 1956..	1	410	2.10	0	6	81	100	.....	.....	.....	.....	......	S	Sta. 17, disk sample.
	1	410	....	0	14	78	99	100	.....	.....	.....	......	S	Sta. 19, disk sample.
	1	410	2.92	0	5	38	67	78	82	82	100	......	S	Sta. 21, disk sample.
	1	410	....	0	1	13	61	79	85	92	100	......	S	Sta. 23, disk sample.
	1	410	3.29	0	4	43	96	100	.....	.....	.....	......	S	Sta. 25, disk sample.
	1	410	....	0	2	15	80	98	100	.....	.....	......	S	Sta. 27, disk sample.
	1	410	3.21	.....	0	10	93	100	.....	.....	.....	......	S	Sta. 29, disk sample.
	1	410	....	0	6	53	100	.....	.....	.....	.....	......	S	Sta. 31, disk sample.
	1	410	3.21	0	8	70	100	.....	.....	.....	.....	......	S	Sta. 33, disk sample.
	1	410	....	0	5	49	96	100	.....	.....	.....	......	S	Sta. 35, disk sample.
	1	410	3.43	0	2	36	100	.....	.....	.....	.....	......	S	Sta. 37, disk sample.
	1	410	....	0	1	20	98	100	.....	.....	.....	......	S	Sta. 39, disk sample.
	1	410	3.80	0	2	40	98	100	.....	.....	.....	......	S	Sta. 41, disk sample.
	1	410	....	0	4	31	67	77	88	100	.....	......	S	Sta. 43, disk sample.
	1	410	3.80	0	1	11	80	100	.....	.....	.....	......	S	Sta. 45, disk sample.
	1	410	....	0	4	45	97	100	.....	.....	.....	......	S	Sta. 47, disk sample.
	1	410	3.80	.....	0	10	68	96	99	100	.....	......	S	Sta. 49, disk sample.
	1	410	3.80	0	1	13	85	99	99	100	.....	......	S	Sta. 51, disk sample.
	1	410	....	0	1	32	98	100	.....	.....	.....	......	S	Sta. 53, disk sample.
	1	410	....	0	1	31	99	100	.....	.....	.....	......	S	Sta. 55, disk sample.
	1	410	3.98	0	1	22	93	100	.....	.....	.....	......	S	Sta. 57, disk sample.
	1	410	....	0	2	41	96	100	.....	.....	.....	......	S	Sta. 59, disk sample.
	1	410	....	0	1	42	100	.....	.....	.....	.....	......	S	Sta. 61, disk sample.
	1	410	4.65	0	1	44	82	83	85	100	.....	......	S	Sta. 63, disk sample.
	1	410	4.75	0	1	30	64	70	86	100	.....	......	S	Sta. 65, disk sample.
	1	410	....	0	1	32	96	100	.....	.....	.....	......	S	Sta. 67, disk sample.
	1	410	4.90	0	2	52	93	94	96	100	.....	......	S	Sta. 69, disk sample.
	1	410	....	0	2	47	96	97	97	100	.....	......	S	Sta. 71, disk sample.
	1	410	4.85	0	1	26	74	92	97	100	.....	......	S	Sta. 73, disk sample.
	1	410	4.75	0	2	28	69	77	80	81	100	......	S	Sta. 75, disk sample.
	1	410	....	0	1	31	84	92	94	100	.....	......	S	Sta. 77, disk sample.
	1	410	4.55	0	3	49	98	100	.....	.....	.....	......	S	Sta. 79, disk sample.
	1	410	3.72	0	2	41	98	100	.....	.....	.....	......	S	Sta. 81, disk sample.
	1	410	....	0	3	36	94	100	.....	.....	.....	......	S	Sta. 83, disk sample.
	1	410	2.97	0	2	37	88	97	100	.....	.....	......	S	Sta. 85, disk sample.
	1	410	1.96	1	23	83	100	.....	.....	.....	.....	......	S	Sta. 87, disk sample.
	1	410	.57	2	32	98	100	.....	.....	.....	.....	......	S	Sta. 89, disk sample.
	40	410	[2]3.53	1	7	43	90	96	97	99	100	......	S	Average of stas. 11 to 89.

2 Mean velocity in cross section.

Table 3.—Particle-size analyses of bed material, Middle Loup River at Dunning, Nebr.—Continued

Date	Number of samples	Measured instantaneous discharge (cfs)	Mean velocity (fps)	Bed material: Percent finer than indicated size, in millimeters									Methods of analysis	Remarks
				0.062	0.125	0.250	0.500	1.000	2.000	4.000	8.000	16.000		
Section C_2—Continued														
Jan. 8, 1956..	1	412	....	.....	0	12	59	87	95	99	100	......	S	Sta. 26, core sample.[1]
	1	412	....	.....	0	6	54	84	94	99	100	......	SV	
	1	412	....	0	2	24	64	77	83	90	95	100	S	Sta. 43, core sample.[1]
	1	412	....	.....	0	22	62	79	84	92	98	100	SV	
	1	412	....	0	2	32	65	84	90	94	97	100	S	Sta. 54, core sample.[1]
	1	412	....	.....	0	27	64	85	91	95	98	100	SV	
	1	412	....	0	1	29	83	93	95	96	98	100	S	Sta. 67, core sample.[1]
	1	412	....	.....	0	27	80	92	97	99	99	100	SV	
	1	412	....	0	2	41	74	92	96	99	100	......	S	Sta. 78, core sample.[1]
	1	412	....	0	1	32	74	92	96	99	100	......	SV	
	5	412	....	0	1	28	69	87	92	96	98	100	S	Average of stas. 26, 43, 54, 67, and 78.[1]
	5	412	....	.....	0	23	67	86	92	97	99	100	SV	
	16	412	....	0	7	33	87	96	98	99	100	......	S	Composite of ½-in. core samples collected at 5-ft intervals from stas. 12½ to 87½.[1]
	16	412	....	2	3	37	84	95	98	99	100	......	SV	
Mar. 7........	1	516	....	0	1	12	69	92	97	99	99	100	S	Sta. 28, core sample.[1]
	1	516	....	.....	0	8	69	93	97	99	99	100	SV	
	1	516	....	0	1	10	62	87	93	97	100	......	S	Sta. 44, core sample.[1]
	1	516	....	.....	0	9	61	88	93	97	100	......	SV	
	1	516	....	0	2	35	79	96	99	100	.....	......	S	Sta. 58, core sample.[1]
	1	516	....	0	1	30	77	96	99	100	.....	......	SV	
	1	516	....	0	2	40	82	98	100	.....	.....	......	S	Sta. 70, core sample.[1]
	1	516	....	0	2	40	80	98	100	.....	.....	......	SV	
	1	516	....	0	5	25	61	90	97	100	.....	......	S	Sta. 84, core sample.[1]
	1	516	....	0	2	19	58	91	97	100	.....	......	SV	
	5	516	....	0	2	24	71	93	97	99	100	......	S	Average of stas. 28, 44, 58, 70, and 84.[1]
	5	516	....	0	1	21	69	93	97	99	100	......	SV	
	7	516	....	5	16	26	60	90	96	99	100	......	S	Composite of ½-in. core samples collected at 5-ft intervals from stas. 10 to 40.[1]
	7	516	....	2	16	26	63	91	96	99	100	......	SV	
	9	516	....	0	3	35	80	95	99	100	.....	......	S	Composite of ½-in. core samples collected at 5-ft intervals from stas. 45 to 85.[1]
	9	516	....	0	2	29	76	94	99	100	.....	......	SV	
	16	516	....	2	10	30	73	92	98	100	.....	......	S	Average of stas. 10 to 85.[1]
	16	516	....	1	9	28	70	92	98	100	.....	......	SV	

1 Same sample used for both analyses.

Table 3.—Particle-size analyses of bed material, Middle Loup River at Dunning, Nebr.—Continued

Date	Number of samples	Measured instantaneous discharge (cfs)	Mean velocity (fps)	Bed material: Percent finer than indicated size, in millimeters: 0.062	0.125	0.250	0.500	1.000	2.000	4.000	8.000	16.000	Methods of analysis	Remarks
							Section C_2—Continued							
Mar. 7, 1956..	1	516	....	0	3	16	37	58	77	100	.....	......	S	Sta. 12, disk sample.
	1	516	....	0	5	7	99	100	.....	.....	.....	......	S	Sta. 17, disk sample.
	1	516	....	0	2	50	96	100	.....	.....	.....	......	S	Sta. 22, disk sample.
	1	516	....	.....	0	14	39	45	52	70	100	......	S	Sta. 27, disk sample.
	1	516	....	0	1	14	33	64	67	90	100	......	S	Sta. 32, disk sample.
	1	516	....	0	2	31	66	68	70	70	100	......	S	Sta. 37, disk sample.
	1	516	....	0	5	48	84	93	96	100	.....	......	S	Sta. 42, disk sample.
	1	516	....	0	1	17	98	100	.....	.....	.....	......	S	Sta. 47, disk sample.
	1	516	....	.....	0	3	60	96	100	.....	.....	......	S	Sta. 52, disk sample.
	1	516	....	.....	0	7	92	99	100	.....	.....	......	S	Sta. 57, disk sample.
	1	516	....	0	2	36	95	100	.....	.....	.....	......	S	Sta. 62, disk sample.
	1	516	....	.....	0	5	75	99	100	.....	.....	......	S	Sta. 67, disk sample.
	1	516	....	0	1	3	79	92	100	.....	.....	......	S	Sta. 72, disk sample.
	1	516	....	0	1	6	52	94	100	.....	.....	......	S	Sta. 77, disk sample.
	1	516	....	1	12	26	54	89	99	100	.....	......	S	Sta. 82, disk sample.
	1	516	....	22	87	98	100	.....	.....	.....	.....	......	S	Sta. 87, disk sample.
	16	516	....	1	8	24	72	87	91	96	100	......	S	Average of stas. 12 to 87.
(3)	1	516	....	4	26	49	80	100	.....	.....	.....	......	S	Sta. 8, disk sample.
(3)	1	516	....	2	4	27	85	100	.....	.....	.....	......	S	Sta. 16, disk sample.
(3)	1	516	....	.....	0	5	13	83	95	100	.....	......	S	Sta. 24, disk sample.
(3)	1	516	....	0	4	32	81	98	98	100	.....	......	S	Sta. 32, disk sample
(3)	1	516	....	.....	0	5	37	53	69	100	.....	......	S	Sta. 40, disk sample.
(3)	1	516	....	0	5	51	99	100	.....	.....	.....	......	S	Sta. 48, disk sample.
(3)	1	515	....	0	2	37	95	100	.....	.....	.....	......	S	Sta. 56, disk sample.
(3)	1	516	....	0	2	46	98	99	100	.....	.....	......	S	Sta. 64, disk sample.
(3)	1	516	....	1	4	42	81	85	92	100	.....	......	S	Sta. 72, disk sample.
(3)	1	516	....	0	3	62	99	100	.....	.....	.....	......	S	Sta. 80, disk sample.
(3)	1	516	....	3	33	90	99	100	.....	.....	.....	......	S	Sta. 88, disk sample.
(3)	11	516	....	1	8	41	79	93	96	100	.....	......	S	Average of stas. 8 to 88.
							Section E							
May 8, 1956...	15	408	....	0	3	41	83	94	96	98	100	......	SV	Composite of ½-in. core samples collected at 10-ft intervals from stas. 20 to 160.

3 Samples collected 100 ft upstream from section C_2.

Table 4.--Water-discharge measurements of the Middle Loup River at Dunning, Nebr.

Date	Section	Mean time	Effective width (feet)	Effective area (sq ft)	Mean velocity (fps)	Discharge (cfs)	Slope[1]	Number meas. sections	Gage height (feet)[2]	Condition of bed
1955										
Sept. 7..	B_1	8:30 a.m.	96	137	2.63	360	....	32	3.09	Dunes
Nov. 24..	B_1	2:35 p.m.	96	130	3.06	398	....	32	3.05	Do.
Do.....	C_2	10:15 a.m.	83	114	3.45	393	0.00129	29	3.12	No dunes
1956										
Jan. 7...	C_2	2:15 p.m.	80	116	3.53	410	.00109	27	3.01	Do.
Jan. 8...	C_2	2:50 p.m.	80	124	3.32	412	.00121	27	3.04	Do.
Mar. 7...	C_2	2:10 p.m.	86	152	3.40	516	[3] .00093	25	3.14	Do.
Mar. 8...	B_1	10:05 a.m.	96	134	3.57	479	....	27	3.06	Do.
May 8....	A	9:30 a.m.	197	185	2.25	416	....	41	....	Dunes
Do.....	E	1:20 p.m.	152	159	2.57	408	....	37	....	Do.

1 For about a 1,100-foot reach.
2 Not adjusted for datum correction, if any.
3 For about a 500-foot reach.

Table 5.—Weight of sediment and weight of water-sediment mixture, Sept. 7 and Nov. 24, 1955, and Jan. 7, 1956

Sept. 7, 1955, sec. B_1		
	ETR No. 1	
Station	Weight of mixture (grams)	Weight of sediment (grams)
REW 0	....	....
3	68.0	0.0085
6	168.5	.0396
9	262.5	.1324
12	253.5	.1230
15	218.8	.0910
18	233.4	.0522
21	217.5	.0862
24	229.6	.0639
27	184.6	.0498
30	153.0	.1175
33	220.6	.0451
36	254.4	.0688
39	205.5	.0528
42	207.3	.0380
45	210.6	.0567
48	269.2	.0586
51	254.0	.0725
54	250.9	.0706
57	288.6	.0787
60	262.6	.1037
63	281.0	.1335
66	245.5	.1433
69	255.0	.1049
72	272.5	.0928
75	261.7	.1048
78	305.7	.1004
81	266.6	.1313
84	297.7	.1608
87	241.0	.0775
90	189.5	.0356
93	55.3	.0192
LEW 96	....	....
....	....	....
....	....	....
....	....	....
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....	....	....
....	....	....
....	....	....
....	....	....
....	....	....

Sept. 7, 1955, sec. E		
	ETR No. 1	
Station	Weight of mixture (grams)	Weight of sediment (grams)
LEW 9	....	....
12	384.0	0.0339
16	353.1	.1083
20	302.5	.1168
24	292.4	.1287
28	282.0	.0907
32	405.1	.2069
36	229.9	.1164
40	63.4	.0296
44	85.8	.0155
48	88.5	.0281
52	104.2	.0359
56	78.5	.0316
60	127.0	.0351
64	127.6	.0461
68	145.9	.0555
72	154.1	.0377
76	165.2	.0577
80	168.9	.0497
84	159.7	.0437
88	210.0	.0572
92	147.5	.0520
96	173.0	.0387
100	113.5	.0400
104	127.4	.0459
108	119.8	.0518
112	191.0	.0567
116	113.9	.0719
120	133.5	.0477
124	279.3	.0676
128	347.3	.1084
132	218.5	.0935
136	285.1	.0832
140	171.3	.0537
144	267.4	.0440
148	105.2	.0300
152	97.4	.0268
156	116.8	.0317
160	299.8	.0270
164	69.1	.0065
REW 166	....	....
....	....	....

Nov. 24, 1955, sec. B_1				
	ETR No. 1		ETR No. 2	
Station	Weight of mixture (grams)	Weight of sediment (grams)	Weight of mixture (grams)	Weight of sediment (grams)
REW 3	....	....	....	....
7.5	89.3	0.0305	100.0	0.0383
10	208.3	.0857	181.9	.0838
12.5	213.8	.1441	248.9	.1451
15	240.0	.2101	242.0	.2054
17.5	....	....	....	....
20	226.6	.1257	238.3	.1389
22.5	206.5	.1436	199.5	.1353
25	212.3	.1919	224.5	.1935
27.5	205.1	.1601	207.9	.1738
30	221.3	.1034	275.7	.1260
32.5	216.7	.1623	231.0	.1531
35	177.7	.1471	184.5	.1524
37.5	246.5	.1275	222.2	.1180
40	193.8	.2052	155.7	.2193
42.5	160.5	.1505	180.3	.1259
45	183.5	.1652	198.4	.1759
47.5	218.0	.2353	211.7	.2520
50	295.4	.2788	282.0	.3009
52.5	264.7	.4155	262.4	.4215
55	326.7	.5044	312.5	.4731
57.5	336.2	.5340	329.0	.5797
60	423.2	.8151	394.9	.7486
62.5	360.6	.6166	383.0	.7071
65	387.8	1.0225	365.6	.9630
67.5	408.6	.6162	399.5	.6708
70	373.3	.5268	373.0	.4737
72.5	372.5	.5980	373.7	.4920
75	352.2	.4351	362.0	.4105
77.5	368.9	.3985	370.8	.4183
80	359.9	.3735	339.0	.4317
82.5	347.4	.3450	349.9	.3498
85	335.6	.3683	352.6	.3623
87.5	277.3	.2974	326.4	.2535
90	334.5	.2516	285.6	.2739
92.5	254.4	.1151	238.5	.1443
95	157.2	.0661	181.0	.0758
97.5	35.3	.0383	49.3	.0235
LEW 99	....	....	....	....
....	....	....	....	....
....	....	....	....	....
....	....	....	....	....

Nov. 24, 1955, sec. C_2				
	ETR No. 1		ETR No. 2	
Station	Weight of mixture (grams)	Weight of sediment (grams)	Weight of mixture (grams)	Weight of sediment (grams)
LEW 4	....	....	....	....
8	82.5	0.0357	126.9	0.0630
10	176.1	.0922	146.7	.0876
12	175.3	.1310	232.6	.1548
14	211.8	.1581	335.1	.2309
16	381.2	.2950	318.0	.2545
18	359.5	.3225	352.3	.3059
20	347.4	.3011	370.1	.3116
22	378.2	.3496	373.8	.3532
24	360.0	.3077	378.5	.3369
26	401.0	.4305	407.2	.4155
28	399.9	.3564	349.0	.3689
30	430.4	.5856	420.3	.5626
32	392.5	.5732	358.4	.5426
34	384.6	.6046	447.0	.7465
36	390.3	.5843	457.5	.6279
38	356.9	.5234	381.6	.6625
40	386.6	.5550	387.2	.5808
42	320.7	.4639	343.3	.5055
44	355.4	.5014	349.6	.5693
46	289.7	.3327	342.4	.4340
48	315.8	.3902	356.6	.4085
50	380.1	.3737	367.9	.3819
52	306.2	.3107	311.0	.3435
54	316.8	.2646	347.9	.3200
56	299.7	.2415	309.9	.2988
58	324.3	.1971	322.3	.2281
60	289.8	.1723	351.7	.2459
62	271.4	.1997	263.6	.1934
64	261.9	.2079	296.6	.2087
66	226.1	.1804	261.6	.2058
68	238.3	.1746	241.1	.1973
70	278.5	.2372	331.1	.3061
72	266.9	.2922	226.8	.2801
74	264.3	.1911	222.4	.1720
76	137.6	.1091	134.9	.0970
78	139.7	.0786	149.8	.0901
80	151.2	.1027	144.2	.0861
82	81.9	.0422	78.2	.0449
84	31.9	.0125	31.1	.0131
86	13.1	.0024	15.4	.0027
REW 87	....	....	....	....

Jan. 7, 1956, sec. C_2				
	ETR No. 1		ETR No. 2	
Station	Weight of mixture (grams)	Weight of sediment (grams)	Weight of mixture (grams)	Weight of sediment (grams)
REW 10	....	....	....	....
11	65.6	0.0270	68.2	0.0296
13	82.5	.0526	98.8	.0705
15	111.7	.0760	103.5	.0933
17	86.5	.0680	90.9	.0626
19	102.5	.0722	110.2	.0753
21	95.0	.0818	142.7	.0965
23	129.0	.0922	116.1	.0892
25	121.4	.0937	111.0	.0993
27	122.2	.1298	131.5	.1604
29	148.5	.1762	136.6	.2099
31	182.6	.2136	173.7	.1917
33	229.7	.2407	213.9	.2660
35	213.4	.2133	197.0	.1909
37	203.2	.2211	216.9	.2150
39	224.5	.2341	225.3	.2207
41	229.6	.1817	235.1	.1886
43	289.0	.2467	290.6	.2507
45	284.5	.2203	343.8	.2757
47	280.5	.2241	242.0	.2234
49	251.3	.2178	273.2	.2390
51	260.8	.2843	293.3	.2781
53	293.0	.3379	293.2	.3231
55	317.5	.3350	295.1	.3111
57	318.0	.3692	379.7	.4006
59	343.0	.4998	307.9	.3721
61	342.9	.4960	337.3	.4666
63	369.9	.6003	304.1	.4508
65	355.4	.5974	331.3	.6634
67	374.6	.6287	416.0	.7158
69	353.5	.6697	394.5	.6374
71	361.1	.6058	352.9	.6607
73	298.7	.5207	341.0	.5045
75	364.1	.5977	344.5	.5661
77	394.0	.5720	340.2	.5375
79	398.0	.5224	368.1	.5607
81	374.9	.4505	384.0	.4989
83	351.2	.3457	354.6	.3344
85	328.5	.2483	297.9	.2543
87	295.3	.2092	299.5	.2108
89	58.4	.0276	51.0	.0341
LEW 90	....	....	....	....

Table 6.—Weight of sediment and weight of water-sediment mixture, May 8, 1956

May 8, 1956, sec. A						
	ETR No. 1		ETR No. 2		ETR No. 3	
Station	Weight of mixture (grams)	Weight of sediment (grams)	Weight of mixture (grams)	Weight of sediment (grams)	Weight of mixture (grams)	Weight of sediment (grams)
LEW 18	....	....	....	....	....	....
20	66.9	0.0095	66.0	0.0091	67.0	0.0102
23	145.8	.0247	120.7	.0247	212.5	.0419
26	139.5	.0482	150.6	.0530	106.0	.0599
29	96.7	.0637	91.5	.0769	88.0	.0591
32	120.5	.0731	125.5	.0833	127.0	.0668
35	130.0	.0607	125.2	.0522	213.0	.0561
38	208.2	.0829	154.7	.0951	162.7	.0719
41	181.2	.2006	154.0	.2845	159.4	.2213
44	176.5	.2286	204.7	.2746	194.0	.2649
47	330.5	.3250	320.7	.3418	291.0	.3028
50	297.6	.2827	384.0	.3263	275.0	.2409
53	368.2	.2355	282.4	.2206	290.5	.1969
56	301.8	.2337	293.0	.2159	376.4	.2581
59	327.3	.2520	249.9	.2916	250.7	.2412
62	243.0	.2415	235.3	.2879	250.0	.2634
65	123.7	.1444	147.2	.1402	131.1	.1305
68	159.9	.1426	119.0	.1346	127.3	.1369
71	102.7	.1042	95.0	.0975	95.8	.0925
74	99.5	.0776	88.4	.0737	141.3	.0910
77	96.1	.0834	89.3	.0790	117.6	.0884
80	74.4	.0524	81.3	.0567	62.0	.0531
83	71.2	.0717	71.8	.0618	68.8	.0740
86	62.2	.0464	61.0	.0486	58.2	.0363
89	64.5	.0268	60.0	.0242	68.0	.0394
92	54.7	.0494	62.0	.0463	59.5	.0441
95	80.5	.0540	73.5	.0448	144.6	.0666
98	67.1	.0521	66.0	.0553	66.3	.0449
101	79.1	.0781	127.3	.1022	75.5	.0956
104	51.4	.0299	44.5	.0234	47.6	.0327
107	47.1	.0378	55.5	.0322	45.0	.0337
110	16.5	.0090	14.5	.0075	15.7	.0109
320	14.1	.0070	10.5	.0030	12.5	.0054
323.2	34.6	.0098	28.4	.0045	31.8	.0066
326.5	54.2	.0144	49.0	.0205	53.3	.0267
329.7	77.3	.0438	66.6	.0287	80.0	.0301
332.9	89.4	.0175	86.2	.0132	116.9	.0237
336.2	66.0	.0207	64.0	.0173	86.0	.0233
339.4	101.0	.0252	64.0	.0199	67.9	.0225
342.6	61.9	.0182	61.0	.0164	62.5	.0338
345.9	51.0	.0145	55.0	.0099	52.0	.0119
349.1	42.7	.0081	45.7	.0046	73.4	.0138
352.4	106.5	.0210	115.5	.0191	117.4	.0229
355.6	179.6	.0365	159.7	.0240	138.6	.0302
358.6	117.5	.0185	137.2	.0149	122.7	.0214
361.6	66.5	.0096	134.2	.0106	73.5	.0133
REW 364	....	....	....	....	....	....
....	....	....	....	....	....	....
....	....	....	....	....	....	....
....	....	....	....	....	....	....
....	....	....	....	....	....	....
....	....	....	....	....	....	....

May 8, 1956, sec. E						
	ETR No. 1		ETR No. 2		ETR No. 3	
Station	Weight of mixture (grams)	Weight of sediment (grams)	Weight of mixture (grams)	Weight of sediment (grams)	Weight of mixture (grams)	Weight of sediment (grams)
LEW 12	....	....	....	....	....	....
14	7.9	0.0019	8.7	0.0005	18.0	0.0009
17	96.5	.0225	108.7	.0207	99.0	.0204
20	125.6	.0533	128.1	.0476	119.9	.0400
23	165.4	.0959	160.7	.0744	175.2	.1137
26	200.0	.0919	207.6	.1073	189.5	.1037
29	237.6	.1593	253.0	.1539	254.7	.1695
32	255.0	.2285	242.8	.2216	233.5	.1831
35	219.5	.2462	206.5	.2408	221.4	.2944
38	364.5	.1305	366.7	.1604	357.3	.1687
41	395.0	.1906	400.5	.1798	385.8	.2673
44	386.2	.2316	473.2	.2421	484.9	.2833
47	362.0	.1642	401.2	.1940	402.6	.2189
50	388.1	.2603	364.9	.2195	396.2	.2347
53	413.0	.3008	379.9	.2324	356.5	.2060
56	334.9	.1470	339.2	.1313	322.5	.1157
59	347.6	.1684	365.0	.1767	295.0	.1572
62	290.2	.2274	295.0	.2204	281.0	.2028
65	455.9	.2678	422.6	.2894	464.4	.3085
68	352.8	.1862	341.5	.1877	313.5	.1537
71	330.4	.2384	316.0	.2188	355.0	.2576
74	286.5	.1366	289.5	.1714	297.9	.1608
77	251.3	.1235	318.0	.1579	267.8	.1239
80	187.7	.1353	224.7	.1732	221.7	.1473
83	226.5	.1177	244.2	.1208	241.4	.1461
86	212.4	.0783	215.0	.0860	269.1	.0823
89	162.6	.0687	183.0	.0739	192.6	.0760
92	199.1	.0461	138.5	.0383	150.7	.0433
95	94.0	.0262	92.1	.0267	107.4	.0280
98	52.1	.0153	59.0	.0192	52.5	.0148
101	58.0	.0162	47.8	.0172	49.0	.0118
104	27.0	.0051	30.4	.0078	23.5	.0051
107	15.0	.0031	16.0	.0039	18.8	.0037
110	15.5	.0038	18.4	.0044	17.0	.0058
116	29.0	.0052	24.7	.0060	33.3	.0068
119	54.5	.0075	59.6	.0076	103.6	.0118
122	80.9	.0102	71.0	.0095	71.5	.0066
125	76.8	.0095	77.3	.0117	73.6	.0070
128	106.5	.0199	88.4	.0175	84.0	.0159
131	93.8	.0384	88.0	.0395	99.6	.0378
134	72.2	.0213	77.4	.0312	84.1	.0293
137	60.0	.0094	57.3	.0142	53.3	.0128
140	46.0	.0058	47.0	.0101	44.9	.0095
143	48.8	.0015	49.7	.0067	54.3	.0045
146	73.1	.0039	88.0	.0108	80.4	.0055
149	86.3	.0129	92.0	.0169	83.9	.0141
152	70.2	.0117	76.5	.0116	70.8	.0145
155	58.3	.0072	70.7	.0097	56.0	.0122
158	55.1	.0066	62.2	.0087	58.9	.0104
161	82.2	.0076	86.5	.0109	78.4	.0101
164	31.0	0	41.5	.0058	31.2	.0034
REW 169	....	....	....	....	....	....