STUDIES OF FLOW IN ALLUVIAL CHANNELS
BASIC DATA FROM FLUME EXPERIMENTS

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INTRODUCTION

The data presented in this report were collected by the U. S. Geological Survey to study resistance to flow and sediment transport in alluvial channels. The data presented were collected during the period September 1956 to December 1960. The principal investigators were D. B. Simons, E. V. Richardson and W. L. Haushild. They were assisted in various phases of the project by D. W. Hubbell and R. K. Fahnestock of the Geological Survey, and graduate students Hubert J. Morel-Seytoux, R. J. Gardi, A. A. Bishop, Khalid S. Al-Shaikh Ali, and E. C. Hilbrand of Colorado State University, where the investigation was carried out. The major portion of the data were collected in a recirculating flume 8 ft wide, 150 ft long, and 2 ft deep with a discharge capacity ranging from 0 to 22 cfs and an adjustable slope from 0 to 1.5 percent, Fig. 1. In addition, a small recirculating flume 2 ft wide, 60 ft long and 2.5 ft deep, with a discharge capacity from 0 to 8 cfs and a slope from 0 to 2 percent, was used for supplementary investigations involving viscosity effects, Fig. 2. The investigations covered flow phenomena ranging from no movement of sediment with a plane bed to Gilbert's (1914) antidunes. This, to the investigators' knowledge, is the only set of data covering this range of flow phenomena.

The sands used as bed material in the investigation are identified by their median fall diameter. The median fall diameter of the sand, where they were obtained, how they were obtained, and some of the conditions under which they were investigated are given in Table 1. In addition, particle size distribution curves for each bed material are presented with the basic data.

The sand bed material was placed in the flumes to a depth of 0.5 foot to 0.7 of a foot. In the 8 ft flume this depth of sand was sufficient that even under maximum dune conditions the floor of the flume was not exposed except at one or two pot holes which were two or three square feet in area. The bed was never exposed in the two-foot wide flume under test conditions.

PROCEDURE

The data collection procedure for the investigation was the same, in general, for both flumes, and for the various sand sizes, except that for the 0.47 mm and 0.54 mm sand a fine clay (bentonite) was added to the flow to investigate the affect of the increase in viscosity resulting from this fine clay on flow phenomena. Also, the effect of viscosity on flow phenomena was investigated using the 0.32 mm sand by varying temperature. The deviations from the general procedure for these three sands will be described later. There were some changes in method of measuring some of the variables during the course of the investigation which will be described under "Data Obtained".

The general procedure followed for each individual run involved recirculating a given discharge of the water-sediment mixture in the flume at a given slope until equilibrium conditions were established. Slope selection was accomplished in a general sense. In any flow system where discharge, depth and slope can be varied, only two of the three variables can be considered as independent. In a natural stream, the discharge and slope are normally independent, with depth dependent. In the flume, the discharge was independent, slope was independent within limits, and depth was dependent. The slope was preset at the beginning of a run by adjusting the tail gate. Such adjustment indirectly influenced the depth as a dependent variable. Generally, especially at the flatter slopes (0.00014 to 0.006 ft/ft), the slope of the water surface was adjusted parallel with a screeded bed. With the development of the bed configuration, the slope and depth adjusted to the new condition of bed roughness.

Thus, for these experiments the slope and depth are a function of discharge and a roughness which develops for that regime of flow. The non-uniformity of flow caused by change of bed roughness was eliminated by continuing the run until the bed slope and the slope of the water surface again became parallel to each other by natural adjustment of the sand bed. Equilibrium flow was considered as established and measurement of the data started when (1) the bed configuration was established for the full length of the flume, excluding the sections influenced by entrance or exit conditions, and (2) the water surface slope remained essentially constant with respect to time. The period of time required to establish equilibrium conditions varied with the slope and discharge. Some runs with flat slopes required three and four days to achieve equilibrium, whereas, with the steeper slopes, equilibrium was established within two or three hours. Every run involved continuous flume operations until it was completed. Whether or not equilibrium conditions are established in the final analysis rests on the measured data and the judgment of the experimenter. To insure the achievement of equilibrium conditions, most of the experiments were continued longer than the required time as indicated by measurements.

The general procedure was different for the 0.47, 0.54 and 0.32 mm sand in the following way. After equilibrium was established and the data collected for a given run, bentonite was added or extracted from the flow for the 0.47 and 0.54 sand or the temperature changed for the 0.32 mm sand without stopping the run. The new run was then continued until equilibrium was again established and then the necessary data were collected. This procedure of adding or extracting bentonite or changing the temperature without stopping the flow was continued for a series of runs ranging from 2 to 5 in number.

BASIC DATA

The data obtained for each equilibrium run were: water surface slope, water-sediment discharge, water temperature, depth, average velocity, velocity profiles, concentration of total bed material transport, concentration of fine sediment transport when fine sediment had been added to the flow, suspended sediment concentration, characteristics of the bed material, bed configuration, kinematic viscosity, apparent kinematic viscosity of the water-fine sediment complex, and descriptions and photographs of the water surface and corresponding bed configuration.

Water Surface Slope

The water surface slope was determined by measuring the water surface elevation with a level and mechanical point gage and also by a differential bubbler gage. Both methods were in close agreement. The bubble gage continuously records the difference in elevation of the water surface to within 0.001 ft between two points from which water surface slope can be computed. The continuous record of the bubble gage slope was used to determine when equilibrium conditions were established. Equilibrium exists when average slope does not change with time. The bubble gage was not used in the 2 ft flume or for the 0.45 mm sand study.

Water-Sediment Discharge

Discharges of the water-sediment mixture were measured with calibrated orifice meters and water-air manometers. The calibration of the orifice meters was checked periodically to determine if any change had occurred in the calibration.

Water Temperature

The water temperature was measured to the nearest half degree centigrade with a mercury thermometer. Water temperature was essentially constant for a particular run but varied from run to run. The variation in water temperature for experiments with any given sand are given in Table 1. Although Table 1 indicates a wide variation in temperature for each sand size, the temperature range for most of the runs for the 0.19, 0.28, and 0.93 mm sand was less than 3° Centigrade. In the experiments in the 2-ft flume with the 0.32 mm sand, the water temperature was deliberately changed to determine the effect on flow phenomena.

Depth

The average depth of flow was determined by measuring the difference in elevation between the water surface and the sand bed with a point gage. Measurements were made at selected intervals down the length of the flumes. The selection of the interval depended upon the bed configuration that existed for the run, the intervals being closer spaced for a dune bed configuration than for an antidune or a ripple bed configuration. This method of measuring depth was used for all the sands except the 0.45 mm size. Measurements of depth for the 0.45 mm sand were obtained by screeding a 30-40 ft central section of the sand bed, determining the average elevation of the sand bed and subtracting this elevation from the average elevation of the water surface. The two methods of measuring depths yield essentially the same results. The measurements of average depth are accurate to within ± 0.03 ft.

Velocity

The mean velocity was calculated by dividing the measured discharge by the area of the water cross-section. Therefore, it accumulates errors inherent in the depth and discharge measurements.

Velocity Profiles

Velocity profiles were obtained for most of the runs. The profiles were measured in 3 verticals in the cross-section located 90 to 100 ft downstream from the entrance in the 8-ft flume and at 1 vertical located 35 ft downstream from the entrance in the 2-ft flume. The velocity profile data is not given in this report.

Concentration of Total Bed Material Discharge

The total sediment discharge was measured with a width-depth integrating total load sampler located where the water discharged from the flume into the tail box. With a dune bed configuration eight samples were collected during a two-hour period. With all other bed configurations, four to six samples were collected during a 1-to 2-hour period. This procedure was used for experiments with all sand sizes except the 0.45 mm sand. With the 0.45 mm sand only, four to six samples were obtained in a 1-hour period for the dune bed configuration. This number of samples over this short time period was not sufficient to accurately determine the average concentration of the bed material discharge.

Each sample consisted of 70-110 pounds of the water-sediment mixture. Concentration of sediment in parts per million was computed on a dry weight basis.

In the experiments where fine sediment was added to the flow (0.47 and 0.54 mm sand experiments), the concentration of fine sediment was determined by separating the total load samples into a fine material fraction and a bed material fraction. The fine material fraction was determined by taking a sample of the water-sediment mixture after it had been allowed to settle 1 minute. The bed material fraction of the total sediment discharge was that material retained after washing on a 200 sieve.

The size distribution of each total load sample was determined in the visual accumulation tube (Colby and Christensen, 1956). The median diameter and the gradation as measured by K are given in the tables of basic data.

Suspended Sediment Concentration

Suspended sediment was sampled 95 to 100 ft downstream from the entrance of the 8-ft flume and 35 ft downstream from the entrance of the 2-ft flume with a specially designed depth integrating sampler. The sampler consisted of a brass nozzle, 3" long and 1/4" in diameter, attached to a wading rod. The nozzle was connected to a flexible tube. A water-sediment sample was drawn through the tube to a container by a vacuum pump which was adjusted to draw water at a velocity approximately equal to the velocity of the flow. Using this equipment a 5 to 8 pound sample was collected by the equal transit rate method for each run.

Some suspended bed material concentrations were larger than corresponding total bed material concentration. This was due, in part, to the inadequate number of suspended sediment samples and the possibility of sampling in a region of flow where local shear stress and turbulence was much larger than average values.

Bed Material Characteristics

A large sample of the bed material was collected for each run. Each sample consisted of several one-inch diameter cores, 5 to 8 inches in length, taken at random from the bed of the flume. The samples were dried, split and analyzed in the visual accumulation tube (Colby and Christensen, 1956) to determine the fall diameter distribution. In the runs where fine sediment was added, the fine sediment was rinsed from the sample before drying, spliting, and analyzing. The median size and gradation for the sample for each run is given in the Tables of Basic Variables. The particle-size distribution curves given in the basic data were determined by averaging the analyses of the bed material for all the runs with a given sand. The gradation (K) was determined from the following equation:

$$K = 1/2 \left(\frac{d}{d_{16}} + \frac{d_{84}}{d} \right)$$

in which

d is the median size.

d_{16} is the size for which 16 percent is finer.

d_{84} is the size for which 84 percent is finer.

The fall velocity for the average median fall diameter of the bed material at the temperature of the water-sediment mixture of the run is given in the basic data. For the 0.47 mm sand and 0.54 mm sand, the fall velocity of the average median fall diameter of the bed material, as it is affected by the increase in viscosity that results from the addition of the fine material, is also given. This fall velocity is denoted by w' . The d' given in the table for the bed material is the fall diameter corresponding to w' .

Bed Configuration

The amplitude, the length, and the velocity of the various bed configurations in feet per minute were evaluated by:

1. Measurement at the observation windows.
2. Measurement using a point gage and foot attachment.
3. Utilizing a sonic depth sounder. This method was only applicable when the form of bed roughness was ripples, dunes, or transition dunes.

The sonic depth sounder was in the development stage while collecting most of these data and was not available to measure the bed configuration of all the ripple and dune runs.

Kinematic Viscosity

The viscosity of the water-sediment mixture is given in the basic data as determined from the temperature of the water and appropriate standard tables. Where fine material (bentonite) was added to the flow, the apparent kinematic viscosity as affected by the fine material is also given. Apparent kinematic viscosity was determined from Fig. 3. The viscosities given in Fig. 3 were determined by testing various percentages of water-bentonite mixtures in a Stormer Viscometer. These measurements were made for concentrations of 0.5, 1, 2, 3, 5, and 10 percent bentonite on a dry weight basis. The temperature for these measurements was varied from 5 to 45 degrees centigrade for each concentration. The apparent kinematic viscosities given on Fig. 3 were computed using dynamic viscosity values and the specific density of the fine sediment.

Bed Form

As a result of these experiments, we have classified the various bed forms that will occur in the flumes and more important, in the field into an upper and lower flow regime on the basis of their form, resistance to flow and sediment transport (Simons and Richardson, 1960). In the lower flow regime, the bed form consists of plain bed without sediment movement, ripples, and dunes. The bed form in the upper flow regime consists of plain bed after dunes, standing waves, and antidunes. These bed configurations are illustrated in Fig. 4.

Ripples are small ridges and crests, triangular in shape which have amplitudes less than 0.2 ft and length less than 2 ft. Dunes are triangular shaped elements which have amplitudes larger than 0.2 ft and length greater than 2 ft. Standing waves are symmetrical in phase (coupled) sand and water waves which gradually build up and just as gradually die down. Waves of this type are stationary, or essentially so, and usually develop in series. They reform somewhat periodically after disappearing. Antidunes are symmetrical sand and water surface waves which are in phase (coupled) and which move upstream. The surface waves build up with time, becoming gradually steeper on the upstream side, until they break like the sea surf, or a hydraulic jump, and disappear. These waves usually develop, break, and reform in groups of two or more.

Dunes and ripples travel downstream as the result of the movement of the sediment up the upstream slope, and deposit most of this material on the downstream slope. This is the mode of sediment movement with ripples and dunes; whereas, with plane bed, standing waves, and antidunes, the sediment moves as individual particles in continuous contact with the bed. They do not move downstream in a wave front similar to ripples and dunes. The bed form given in the basic data is based on the classification given in Fig. 4.

REPORTS

The data presented in this report have been or are being used for the following reports:

1. Simons, D. B., Richardson, E. V., and Albertson, M. L., 1959, Studies of flow in alluvial channels, Flume studies using medium sand: U. S. Geol. Survey Water-Supply Paper 1498A, in press.

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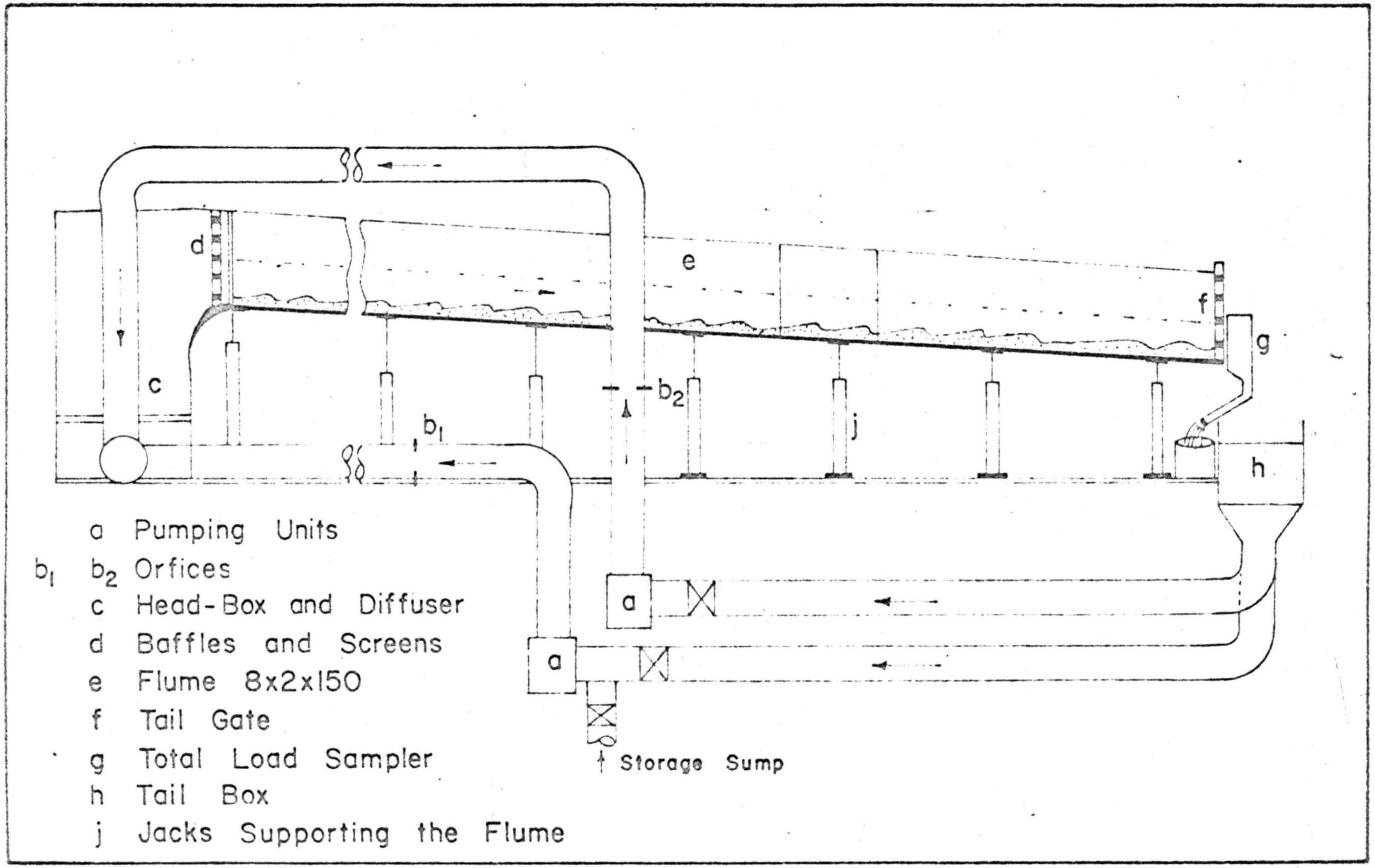

Fig. 1 Schematic diagram of the flume

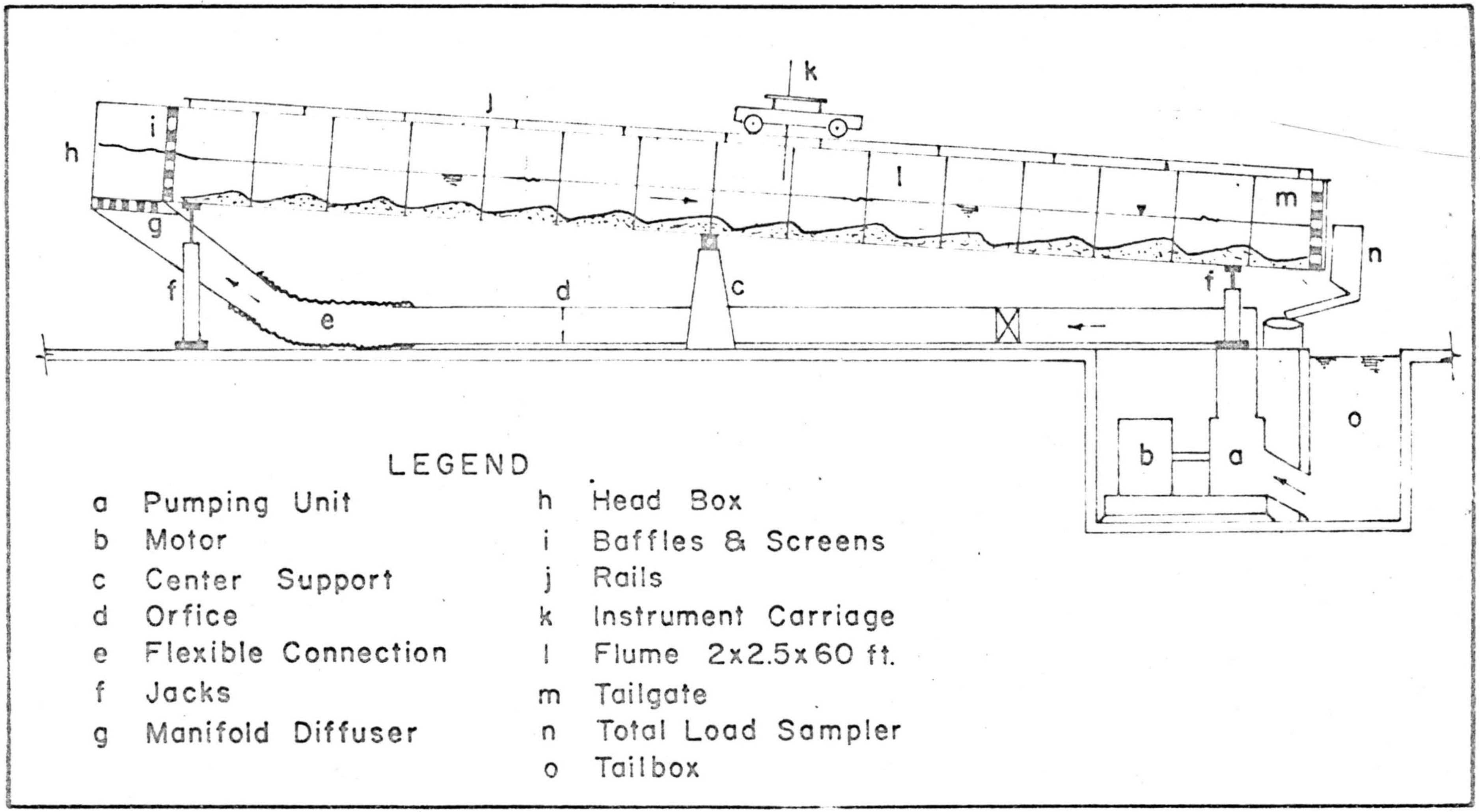

Fig. 1. Schematic Diagram of the Flume

TABLE 1 - GENERAL INFORMATION ABOUT THE SANDS USED IN THE EXPERIMENTS.

d_{50} mm	K Gradation	Where Sands Were Obtained	Method of Obtaining Sand and Amount of Processing	Temperature Variation °C	Type Of Study	Flume Used ft
0.19	1.30	Decomposed sandstone deposits located near Denver, Colorado	Commercial Sand Company. The sandstone was run through a hammermill to break up the large chunks and washed to remove the clay binder.	12.3 to 19.7	General	8
.27	1.54	Elkhorn River near Waterlou, Nebraska	Obtained by wet screening 0.28 mm sand to remove material coarser than 2.0 mm.	10.2 to 18.5	General	8
.28	1.67	do	By dragline scooping sand from middle of flowing river. No processing.	9.0 to 17.6	General	8
.32	1.57	do	From 0.27 mm sand. No processing. Sand became coarser as a result of fines washing away in overflow.	7.0 to 34.3	Effect of viscosity by varying temperature	2
.45	1.60	Cache la Poudre River at Fort Collins, Colorado	Commercial Gravel Company. Washed and scalped on 8 mesh screen and retained on 200 mesh.	9.0 to 20.0	General	8
.47	1.54	do	Same sand as .45 mm. Sand became coarser as a result of fines washing away.	10.7 to 24.5	Effect of viscosity by varying conc. of fine sediment.	8
.54	1.52	do	do		do	2
.93	1.54	North Platte River near Scottsbluff, Nebraska	Commercial Sand Co. Washed and scalped on a 4 mesh screen and retained on a 16 mesh	16.7 to 22.7	General	8

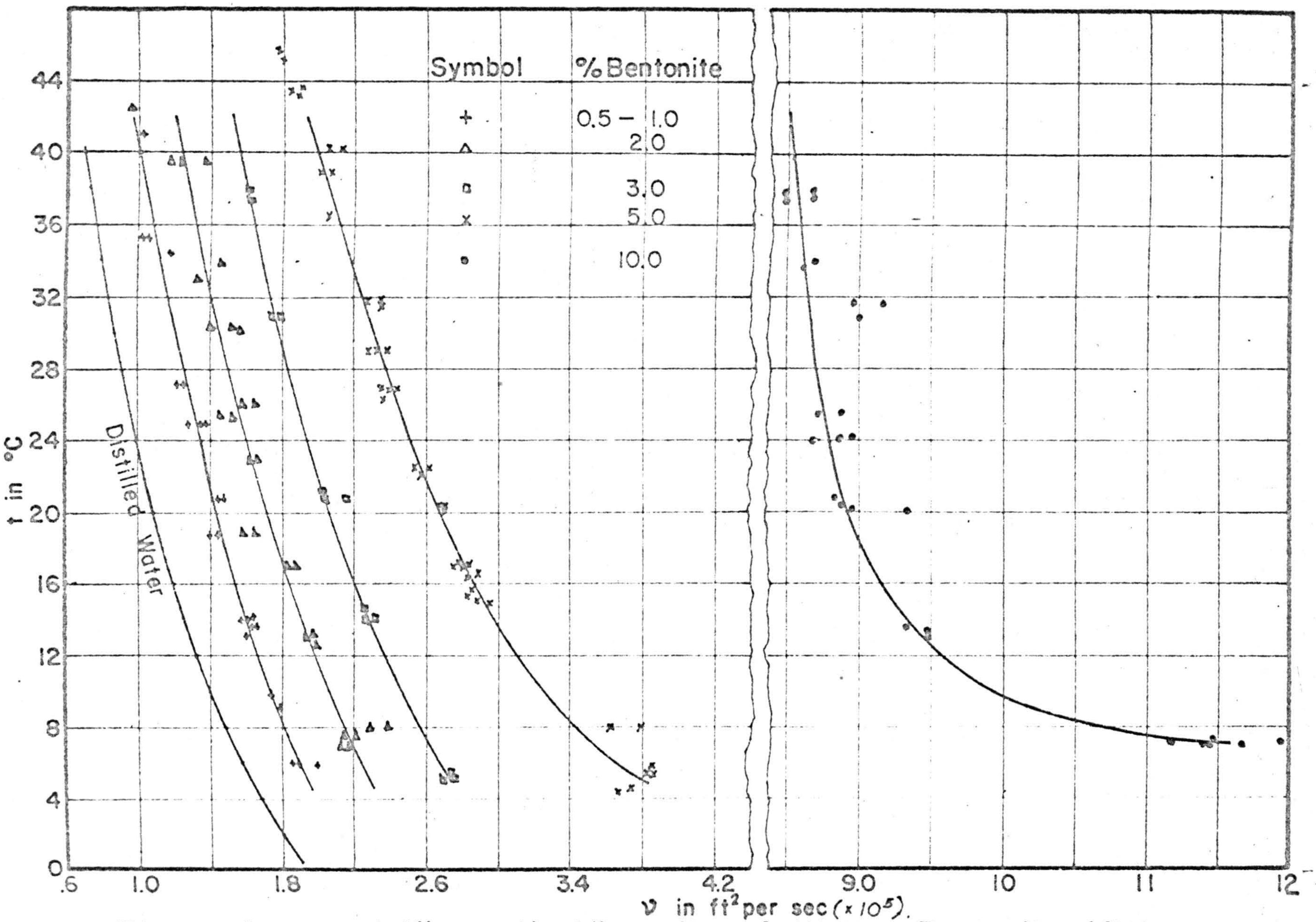

Fig. 3. Apparent Kinematic Viscosity of Water-Bentonite Mixtures

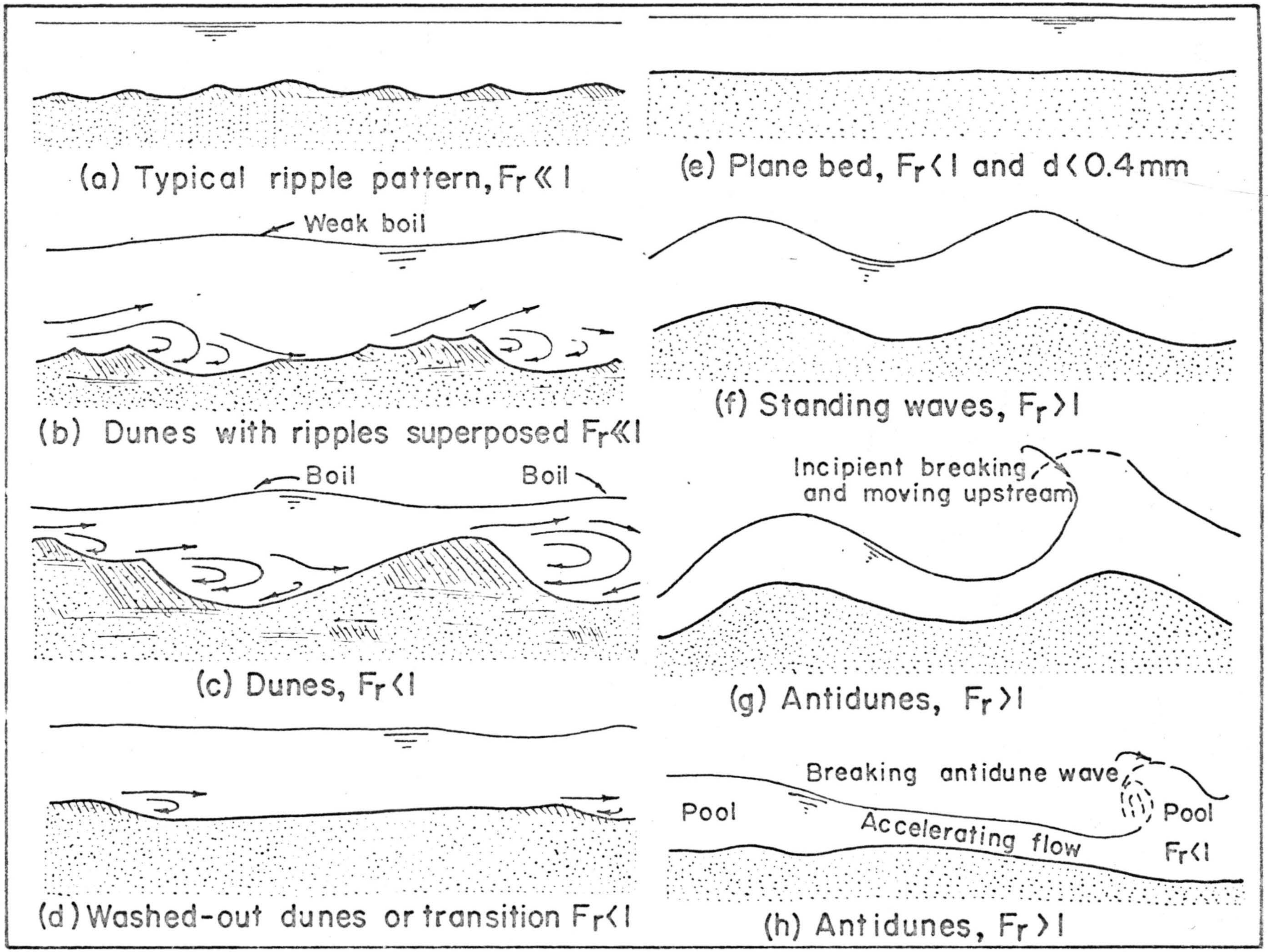

Fig. 6. Forms of Bed Roughness in Alluvial Channels
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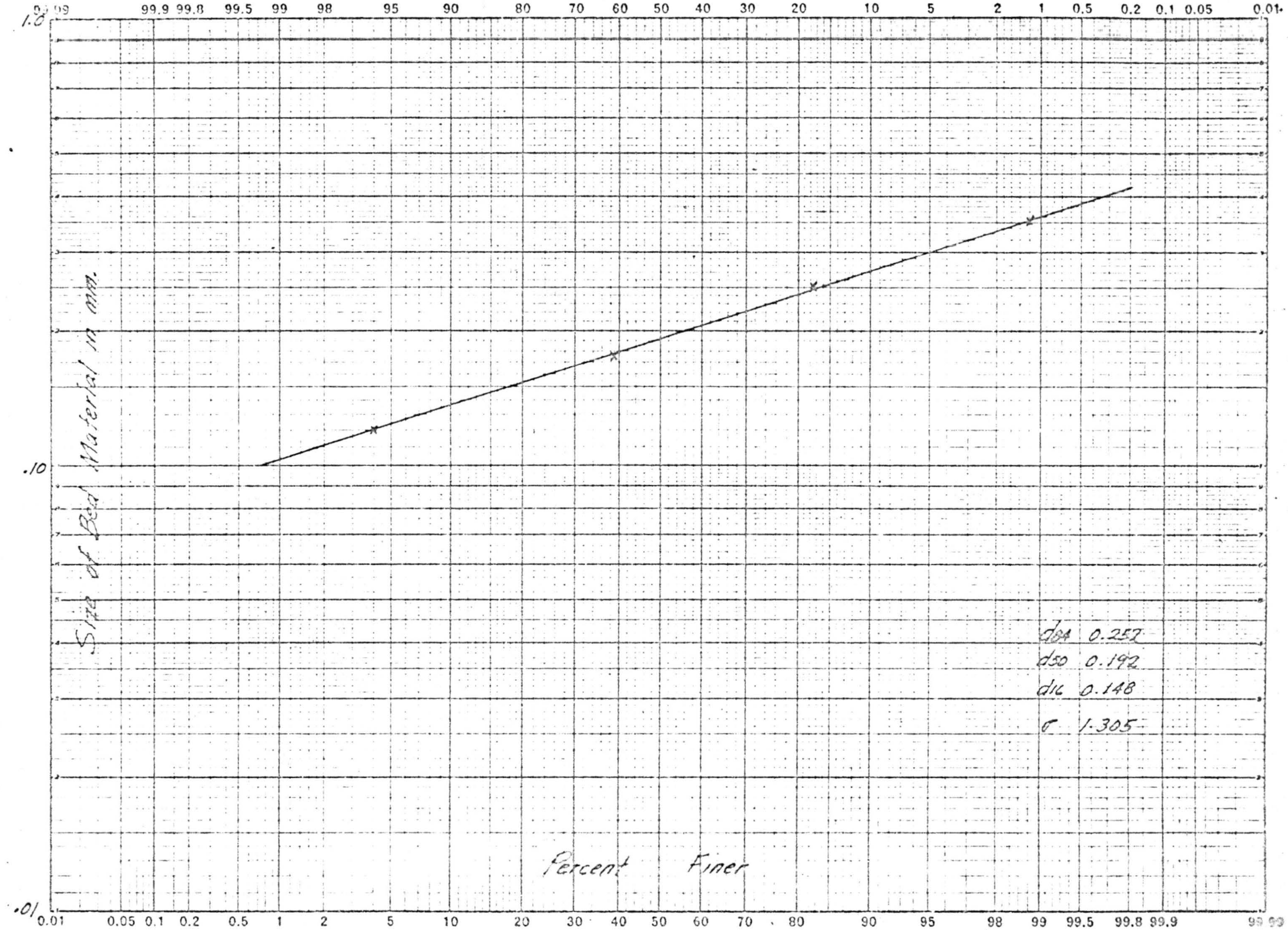
Table .—Basic variables for runs with 0.19 mm sand in the 8 foot Flume.

Run	Susp. Load PPM	Bed Material			Sand Waves			Bed Forms	Remarks
		$d \times 10^3$ ft	σ -	W ft/sec	L ft	H ft	V_s ft/min		
24B	-	-	-	0.0724	-	-	-	Plane	General Movement
24A	-	-	-	.0717	-	-	-	Plane	General Movement
22A	-	-	-	.0705	0.57	0.023	-	Plane	No Movement
2	0	0.656	1.34	.0637	-		0.00098	Ripples	
22B	-	-	-	.0709	-	-	-	Plane	Movement
26	-	.626	1.33	.0727	-	-	-	Plane	
25	-	.613	1.30	.0727	.44	.034	-	Ripples	
22C	-	-	-	.0712				Plane	Ripples forming
30	7.0	.626	1.28	.0699	.62	.032	.024	Ripples	
1	0	.643	1.32	.0654	.49	.023	.00085	Ripples	
31	42	.623	1.27	.0713	.58	.038	-	Ripples	
27	-	.623	1.32	.0713	.53	.033	-	Ripples	
5	105	.640	1.36	.0691	.92	.045	.080	Ripples	
23	0	.597	1.33	.0713	.45	.031	.0029	Ripples	This run developed from 22c overnight
32	362	.649	1.30	.0714	3.97	.096	.23	Dunes	Ripples Superposed
8	506	.630	1.33	.0716	5.39	.18	.17	Dunes	Ripples superposed
28	-	.623	1.28	.0712	.58	.038	-	Ripples	
33	927	.656	1.30	.0704	8.0	.65	.13	Dunes	Ripples Superposed
29	31	.643	1.31	.0726	.60	.038	-	Ripples	
3	-	.659	1.32	.0637	.70	.035	.032	Ripples	Close to dunes
11	795	.583	1.32	.0724	11.6	.39	.21	Dunes	
13	772	.590	1.31	.0728	13.4	.13	.20	Transition	Some Dunes upstream
14	950	.564	1.29	.0729	18.8	.17	-	Transition	Long Dunes upstream
15	1130	.584	1.32	.0728	20.5	.04		Transition	Plane
34	393	.653	1.30	.0693	1.67	.044	.26	Dunes	Ripples Superposed
12	929	.593	1.36	.0732	17.7	.32	.20	Dunes	
6	550	.620	1.33	.0676	5.06	.18	.10	Dunes	Ripples Superposed
7	918	.614	1.33	.0712	7.4	.31	.24	Dunes	Some Ripples Superposed
35	729	.656	1.27	.0718	4.50	.13	.24	Dunes	Some Ripples Superposed
16	1350	.597	1.31	.0722	-	-	-	Transition	Plane bed
10	861	.587	1.33	.0726	24.0	.10	.78	Transition	Long Sand Waves
9	697	.623	1.34	.0720	5.19	.20	.15	Dunes	Some Ripples Superposed
17	4030	.561	1.39	.0726	4.4	.10	-	Antidunes	
18	7270	.597	1.30	.0724	4.9	.10	-	Antidunes	
19	13400	.564	1.36	.0721	-	-	-	Antidunes	
39	20100	-	-	.0722	-	-	-	Antidunes	No Chute and Pool
20	23300	.590	1.30	.0718	-	-	-	Antidunes	Chute and Pool
21	21900	-	-	.0721	-	-	-	Antidunes	
38	31600	-	-	.0711	-	-	-	Antidunes	Occasional Chute
36	38800	.676	1.26	.0696	-	-	-	Antidunes	Chute and Pool
37	57300	.689	1.22	.0702	-	-	-	Antidunes	Chute and Pool

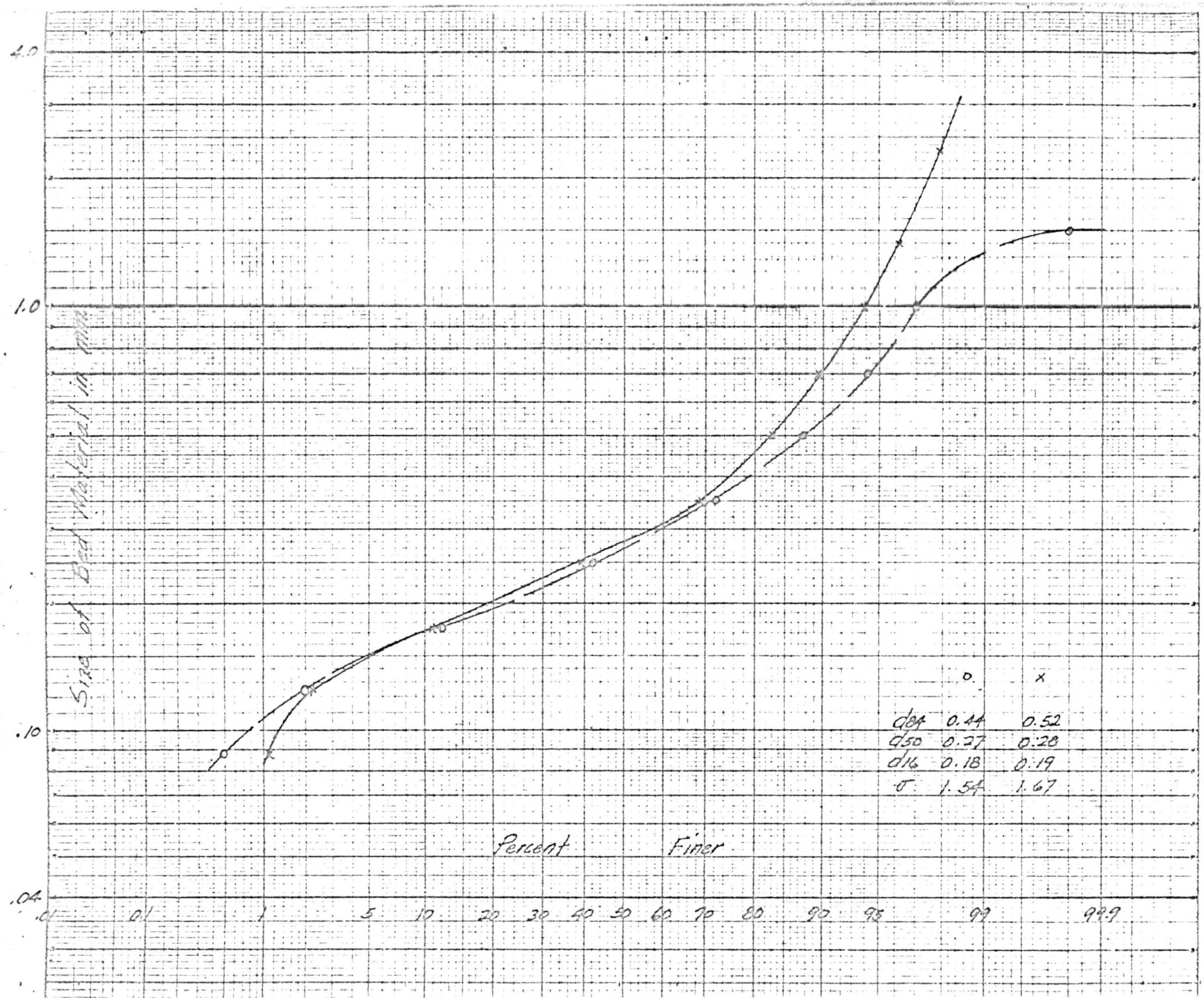


99.99 99.9 99.8 99.5 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
1.0
.10
.01
Size of Bed Material in mm.
d84 0.252
d50 0.192
d16 0.148
σ 1.305
Percent Finer
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.5 99.8 99.9 99.99

Table —Basic variables for runs with 0.19 mm sand in the 8 foot Flume.

Run	Slope $\times 10^2$ ft/ft	Discharge cfs	Depth ft	Velocity ft/sec	Viscosity $\times 10^5$ ft^2/sec	Temp. °C	Total load Bed Material PPM	Total load $d \times 10^3$ ft	Total load σ —
24B	0.005	6.61	0.96	0.86	1.11	18.9	-	-	-
24A	.006	6.44	.91	.88	1.13	18.4	-	-	-
22A	.010	2.99	.48	.78	1.16	17.5	-	-	-
2	.015	6.68	1.06	.79	1.33	12.3	0.2	-	-
22B	.016	2.99	.43	.87	1.15	17.8	-	-	-
26	.017	-	.30	-	1.10	19.2	-	-	-
25	.018	6.45	.93	.87	1.10	19.2	.3	-	-
22C	.018	2.99	.42	.89	1.14	18.0	-	-	-
30	.028	8.91	1.00	1.11	1.17	17.0	3.7	0.321	1.80
1	.034	3.42	.58	.74	1.28	13.6	1.0	.712	1.40
31	.043	10.62	1.02	1.30	1.14	18.1	29.4	.433	1.59
27	.057	4.08	.55	.93	1.14	18.1	4.0	.334	1.61
5	.058	12.67	1.03	1.54	1.19	16.4	120	.499	1.62
23	.061	2.99	.44	.85	1.14	18.1	2.0	.499	1.38
32	.066	13.64	.95	1.79	1.13	18.2	281	.456	1.53
8	.070	14.81	.93	1.99	1.13	18.3	519	.427	1.67
28	.079	4.49	.54	1.04	1.14	18.0	34	.518	1.32
33	.083	16.66	1.06	1.96	1.16	17.4	836	.482	1.46
29	.084	5.08	.56	1.13	1.11	19.1	58	.558	1.45
3	.092	5.20	.55	1.18	1.33	12.3	84	.528	1.36
11	.099	20.47	1.09	2.35	1.11	18.9	1300	.446	1.55
13	.100	21.98	.89	3.09	1.10	19.3	1240	.453	1.54
14	.106	22.12	.86	3.22	1.10	19.4	1490	.522	1.43
15	.112	21.84	.79	3.46	1.10	19.3	2000	.561	1.38
34	.127	7.00	.52	1.68	1.18	16.6	503	.518	1.36
12	.130	21.96	1.02	2.69	1.09	19.7	1270	.436	1.54
6	.130	8.14	.61	1.67	1.22	15.3	861	.489	1.42
7	.140	9.66	.68	1.78	1.14	18.0	1240	.499	1.56
35	.147	7.52	.52	1.81	1.12	18.5	999	.531	1.40
16	.156	22.14	.72	3.84	1.12	18.8	2750	.620	1.34
10	.170	11.68	.51	2.89	1.11	19.1	2480	.548	1.40
9	.194	8.22	.49	2.10	1.12	18.6	1210	.495	1.46
17	.196	22.19	.67	4.14	1.11	19.1	4650	.544	1.30
18	.300	22.16	.64	4.33	1.11	18.9	9240	.522	1.29
19	.350	22.19	.64	4.33	1.12	18.7	12900	.522	1.33
39	.390	22.33	.61	4.58	1.12	18.8	16200	.495	1.30
20	.460	22.17	.60	4.62	1.12	18.5	23900	.512	1.33
21	.542	16.13	.50	4.03	1.12	18.7	25200	.502	1.26
38	.582	22.00	.58	4.74	1.14	17.9	26600	.522	1.33
36	.845	15.54	.51	3.81	1.18	16.8	35500	.541	1.31
37	.95	21.84	.65	4.20	1.16	17.3	47300	.512	1.31

d = 0.623×10^3 ft, σ = 1.30



4.0
1.0
.10
.04
Size of Bed Material in mm
Percent Finer
.01
0.1
1
5
10
20
30
40
50
60
70
80
90
95
99
99.9
o
x
d84 0.44 0.52
d50 0.27 0.28
d16 0.18 0.19
σ 1.54 1.67

Table . —Basic variables for runs with 0.27 mm sand in the 8 foot flume.

Run	Slope $\times 10^2$ ft/ft	Discharge cfs	Depth ft	Velocity ft/sec	Viscosity $\times 10^5$ ft^2/sec	Temp. °C	Total load: Bed Material PPM	Total load: $d \times 10^3$ ft	Total load: σ —
49	0.005	6.04	1.03	0.73	1.38	10.8	0	-	-
50A	.007	6.09	.96	.79	1.25	14.5	-	-	-
50D	.018	6.09	.91	.84	1.21	15.8	0.5	-	-
51	.046	9.86	.99	1.24	1.20	16.0	12	0.705	1.71
52	.065	12.25	.94	1.63	1.20	16.0	98	.696	1.61
54	.084	13.62	.93	1.83	1.13	18.3	200	.607	1.56
53	.108	15.58	1.02	1.91	1.17	16.9	358	.584	1.49
57	.126	5.11	.48	1.33	1.27	13.9	93	.771	1.56
56	.126	11.09	.75	1.85	1.22	15.3	550	.623	1.58
55	.130	17.80	1.08	2.06	1.14	18.1	639	.646	1.48
45	.138	21.84	.84	3.25	1.15	17.8	1270	.755	1.76
43	.140	19.23	1.13	2.13	1.16	17.4	931	.686	1.60
44	.163	21.55	1.03	2.62	1.18	16.8	833	.630	1.56
42	.167	15.68	.94	2.09	1.24	14.8	704	.656	1.60
46	.167	21.76	.74	3.68	1.12	18.5	1670	.853	1.64
58	.185	6.75	.46	1.83	1.26	14.2	753	.702	1.53
47	.280	21.79	.63	4.32	1.28	13.6	4760	.758	1.73
48	.493	21.69	.59	4.60	1.20	15.9	9080	.646	1.53
39	.813	21.71	.55	4.93	1.40	10.2	28700	.656	1.46
41	.952	15.41	.45	4.28	1.38	11.0	35600	.636	1.42
40	1.022	21.35	.60	4.45	1.38	10.8	35800	.656	1.45

$d = 0.886 \times 10^3$ ft
$\sigma = 1.54$
$\rho = 1.94$
$\gamma = 62.41$
$\Delta\rho = 3.20$
$\Delta\gamma = 102.94$
~~= 0.114~~
$\rho_s = 5.14$
$\gamma_s = 165.35$
$g = 32.17$

Table .—Basic variables for runs with 0.27 mm sand in the 8 foot Flume.

Run	Susp. Load PPM	Bed Material			Sand Waves			Bed Forms	Remarks
		$d \times 10^3$ ft	σ -	W ft/sec	L ft	H ft	V_s ft/min		
49	0	-	-	0.104	-	-	-	Plane	no movement
50A	0	-	-	.110	-	-	-	Plane	.movement
50D	0	0.856	1.48	.112	0.41	0.04	0.0002	Ripple	
51	9	.889	1.60	.112	1.19	.03	.053	Ripple	
52	57	.820	1.52	.112	1.69	.06	.096	Ripple	
54	157	.935	1.57	.116	5.13	.17	.055	Dune	
53	461	.902	1.53	.114	6.00	.28	.29	Dune	
57	0	.951	1.52	.109	.66	.05	.080	Ripple	
56	407	.823	1.54	.111	4.88	.20	.16	Dune	
55	935	.886	1.43	.116	9.15	.36	.13	Dune	
45	679	.951	1.76	.116	-	-	-	Trans.	washed out dunes
43	556	.912	1.50	.115	9.69	.44	.13	Dune	
44	623	.856	1.42	.114	11.08	.41	.18	Dune	
42	416	.837	1.54	.110	8.47	.40	.086	Dune	
46	857	.827	1.56	.116	-	-	-	Trans.	Plane bed
58	751	.902	1.52	.109	9.01	.15	.26	Dune	Close to trans.
47	3770	.863	1.51	.108	-	-	-	Antidune	
48	10800	.856	1.54	.112	-	-	-	Antidune	
39	34000	.787	1.43	.102	-	-	-	Antidune	
41	43300	.955	1.47	.104	-	-	-	Antidune	
40	41400	1.033	1.64	.104	-	-	-	Antidune	

Table .--Basic variables for runs with 0.28 mm sand in the 8 foot Flume.

Run	Slope x 10^2 ft/ft	Discharge cfs	Depth ft	Velocity ft/sec	Viscosity x 10^5 ft^2/sec	Temp. °C	Total load		
							Bed Material PPM	dx10^3 ft	σ
6	0.005	3.79	0.90	0.53	1.46	9.0	0	-	-
7	.007	6.61	1.01	.82	1.27	13.9	0	-	-
8A	.011	7.76	1.00	.97	1.34	11.9	-	-	-
8B	.023	7.76	1.01	.96	1.38	10.9	3.3	-	-
10	.041	4.16	.59	.88	1.23	15.1	1.0	0.902	1.58
5	.045	10.73	1.00	1.34	1.19	16.5	12	.850	2.08
13B	.062	13.46	1.00	1.68	1.19	16.4	75	.663	1.82
4	.069	10.73	.86	1.56	1.25	14.6	51	.650	2.00
11	.073	4.92	.59	1.04	1.23	14.9	20	.906	1.60
33	.090	15.74	1.06	1.86	1.15	17.6	330	.630	1.60
* 1	.100	12.70	.88	1.80	1.18	16.7	405	.423	2.13
12	.108	7.19	.57	1.58	1.20	16.0	150	.751	1.92
14	.116	8.61	.62	1.74	1.21	15.6	298	.725	1.71
20	.120	18.14	1.05	2.16	1.21	15.6	506	.607	1.62
* 2	.131	15.19	.92	2.06	1.21	15.8	664	.554	1.96
21	.131	20.39	1.07	2.38	1.19	16.5	732	.591	1.64
19	.134	9.90	.65	1.90	1.23	14.9	563	.627	1.69
* 16	.134	17.23	1.02	2.11	1.21	15.8	549	.574	1.74
23	.134	22.02	.91	3.02	1.21	15.6	1230	.656	1.64
* 17	.136	10.01	.65	1.92	1.24	14.7	505	.630	1.72
* 3	.136	15.28	.88	2.17	1.22	15.2	733	.640	1.91
18	.141	11.96	.61	2.45	1.24	14.7	1040	.699	1.68
30	.142	15.68	.64	3.06	1.25	14.5	1370	.627	1.47
34	.150	5.50	.44	1.56	1.26	14.1	480	.788	1.69
22	.153	14.92	.60	3.11	1.31	12.7	1540	.755	1.62
* 15	.158	12.87	.75	2.14	1.30	13.0	789	.620	1.68
24	.172	21.98	.82	3.35	1.21	15.7	2350	.689	1.77
25	.199	21.85	.72	3.79	1.24	14.7	2710	.804	1.64
28	.229	15.72	.55	3.57	1.23	15.1	2760	.833	1.51
29	.278	15.70	.52	3.77	1.22	15.4	3120	.886	1.72
26	.328	15.51	.50	3.88	1.23	15.0	5060	.820	1.62
32	.470	21.76	.58	4.69	1.38	10.8	10500	.676	1.71
27	.533	15.47	.43	4.50	1.23	15.1	11500	.682	1.71
31	.593	21.34	.56	4.76	1.40	10.2	13000	.591	1.34
35	.815	21.33	.54	4.93	1.38	10.9	27600	.650	1.46
37	.820	8.34	.30	3.48	1.35	11.6	19900	.885	1.91
38	.930	15.26	.40	4.77	1.37	11.1	36100	.656	1.48
36	1.007	21.38	.57	4.69	1.36	11.5	42400	.669	1.43

$d = 0.919 \times 10^3$ ft $\sigma = 1.68$

$\rho_s = 5.14$

$\rho = 1.94$

$\Delta\rho = 3.20$

$\gamma_s = 165.35$

$\gamma = 62.41$

$\Delta\gamma = 102.94$

$g = 32.17$

* Slope poorly defined

Table .—Basic variables for runs with 0.28 mm sand in the 8 foot Flume.

Run	Susp. Load PPM	Bed Material $d \times 10^3$ ft	Bed Material σ –	Bed Material W ft/sec	Sand Waves L ft	Sand Waves H ft	Sand Waves V_s ft/min	Bed Forms	Remarks
6	0	–	–	0.105	–	–	–	Plane	no movement
7	0	–	–	.114	–	–	–	Plane	no movement
8A	0	0.985	1.64	.110	–	–	–	Plane	movement
8B	0	.985	1.78	.109	0.55	0.022	0.029	Ripple	
10	0	.866	1.52	.116	.49	.031	.055	Ripple	
5	0	.985	1.62	.118	.71	.036	.040	Ripple	
13B	99	.949	1.81	.118	1.15	.061	.31	Ripple	
4	0	.902	1.51	.115	.80	.060	.077	Ripple	
11	0	.951	1.57	.116	.62	.032	.027	Ripple	
33	377	.853	1.54	.120	6.15	.27	.10	Dune*	
1	734	1.064	1.69	.118	7.06	.29	–	Dune*	
12	74	.886	1.64	.117	.92	.043	.22	Ripple	
14	134	.853	1.61	.117	1.48	.066	.080	Dune*	
20	347	.928	1.65	.117	9.63	.46	.17	Dune*	
2	583	.918	1.80	.117	11.16	.35	–	Dune*	
21	528	.866	1.53	.118	9.76	.31	.16	Dune*	
19	423	.870	1.65	.116	5.82	.20	.123	Dune*	
16	436	.820	1.65	.117	7.81	.34	.12	Dune*	
23	608	.997	1.71	.117	11.82	.26	.38	Trans.	washed out dunes
17	262	.892	1.69	.115	6.21	.25	.11	Dune	
3	445	.843	1.68	.116	7.61	.27	.13	Dune	
18	439	.814	1.67	.115	11.66	.24	.20	Trans.	washed out dunes
30	548	.975	1.71	.115	–	.041	–	Trans.	washed out dunes
34	–	.951	1.72	.114	1.82	.063	.095	Dune*	
22	442	.951	1.72	.111	–	–	–	Plane	
15	389	0.837	1.69	.112	8.17	.35	.098	Dune	
24	763	.899	1.73	.117	16.22	.23	.36	Trans.	washed out dunes
25	972	1.031	1.70	.115	–	–	–	Plane	
28	804	.873	1.58	.116	–	–	–	Plane	
29	1240	.929	1.69	.116	–	–	–	Plane	
26	1740	.886	1.60	.116	–	–	–	Antidune	
32	9490	.846	1.65	.109	–	–	–	Antidune	
27	8240	.916	1.62	.116	–	–	–	Antidune	
31	16400	.906	1.68	.107	–	–	–	Antidune	
35	31800	.903	1.60	.109	–	–	–	Antidune	
37	7820	.935	1.70	.110	–	–	–	Antidune	
38	33800	.912	1.63	.109	–	–	–	Antidune	
36	47400	.984	1.85	.110	–	–	–	Antidune	


99.99 99.9 99.8 99.5 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
10
1.0
.10
Size of Bed Material in mm.
52-100
1-45
1-45 52-100
d16 0.28 0.31
d50 0.45 0.47
d84 0.70 0.71
σ 1.60 1.54
Percent Finer
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.5 99.8 99.9 99.99

Run	Slope x 10^3 ft/ft	Discharge cfs	Depth ft	Velocity ft/sec	Viscosity x 10^5 ft^2/sec	Temp. °C	Total load Bed Material PPM	$dx10^3$ ft	σ —
14	0.015	3.94	0.61	0.81	1.40	10.2	[illegible]	-	-
17	.016	6.22	.98	.80	1.34	12.0	.70	-	-
16	.017	5.11	.81	.79	1.34	12.0	1.4	0.728	2.70
13	.019	1.84	.35	.65	1.46	9.0	-	-	-
15A	.015	5.07	.71		1.38	11.0	-	-	-
15B	.023	5.07	.80	.79	1.38	11.0	.9	.837	2.68
18	.031	3.62	.58	.78	1.36	11.3	.4	-	-
2	.036	7.90	.82	1.20	1.38	11.0	94	.968	2.47
3	.039	7.90	.85	1.16	1.36	11.5	101	.935	2.79
9	.040	3.84	.55	.88	1.34	12.0	1.9	.361	3.80
1	.042	7.85	.80	1.23	1.46	9.0	23	1.160	3.95
5	.047	7.93	.75	1.32	1.38	11.0	26	.863	2.77
11	.049	1.95	.35	.70	1.36	11.5	4.7	-	-
4	.057	7.94	.69	1.44	1.41	10.0	92	1.030	2.29
8	.060	3.83	.51	.93	1.34	12.0	7.6	.846	2.78
7	.078	7.98	.70	1.43	1.36	11.5	268	.637	3.36
10	.088	1.95	.33	.75	1.39	10.5	20	1.400	1.64
6	.088	3.90	.46	1.07	1.43	9.5	42	1.440	1.86
12	.106	1.95	.29	.85	1.35	11.7	1.0	.771	3.70
19	.112	4.24	.41	1.30	1.14	18.0	208	.951	3.28
21	.114	12.12	.96	1.58	1.20	16.0	641	.820	2.81
22	.124	13.54	1.00	1.70	1.21	15.7	710	.791	2.58
25	.189	4.91	.42	1.47	1.17	17.0	378	1.100	2.03
20	.193	8.14	.61	1.68	1.19	16.4	508	.663	2.84
23	.247	13.34	.65	2.57	1.20	16.0	856	.755	2.43
24	.289	8.73	.62	1.76	1.17	17.0	1200	.820	2.29
40	.301	21.41	.81	3.32	1.11	19.0	2460	.810	1.97
39	.364	20.64	.55	4.71	1.11	19.0	3960	1.010	1.92
26	.366	14.45	.34	5.38	1.17	17.0	4580	1.140	1.87
28	.366	11.19	.40	3.52	1.20	16.0	4230	1.110	1.84
29	.369	4.54	.30	1.89	1.16	17.4	1850	1.190	2.08
31	.432	14.85	.44	4.24	1.16	17.5	4750	1.250	1.80
27	.436	7.91	.33	2.99	1.14	18.0	4100	1.210	1.98
36	.446	3.15	.19	2.04	1.11	19.0	1370	1.350	2.10
41	.466	21.62	.54	5.05	1.12	18.7	4340	1.380	1.76
30	.492	5.33	.27	2.47	1.16	17.2	3550	1.350	1.85
35	.494	5.58	.25	2.80	1.17	17.0	4610	1.330	1.71
34	.546	8.44	.28	3.73	1.16	17.5	5690	1.450	1.77
33	.607	10.02	.27	4.60	1.20	16.0	6810	1.360	1.85
38	.619	21.38	.50	5.38	1.11	19.0	6230	1.590	1.83
37	.620	18.87	.43	5.54	1.12	18.5	5570	1.740	1.83
32	.656	14.96	.37	5.03	1.14	18.0	6180	1.670	1.84
45	.862	5.58	.28	2.50	1.11	18.9	9630	1.590	1.61
44	.898	10.83	0.28	4.78	1.10	19.4	15100	1.570	1.60
42	.986	13.43	0.31	5.36	1.08	20.0	11400	1.720	1.65
43	1.01	21.42	0.43	6.18	1.12	18.5	11500	1.280	1.80

$d = 1.48 \times 10^{-3}$ ft σ = 1.60

Table .—Basic variables for runs with 45 mm sand in the 8 Foot Flume.

Run	Susp. Load PPM	Bed Material			Sand Waves			Bed Forms	Remarks
		$d \times 10^{4}$ ft	σ –	W ft/sec	L ft	H ft	V_s ft/min		
14		–	–	0.199	–	–		Plane	no movement
17		–	–	.204	0.77	0.44		Ripples	
16		–	–	.204	.69	.06		Ripples	
13		–	–	.196	–	–		Plane	no movement
15A		–	–	.201	–	–		Plane	movement
15B		1.44	1.60	.201	–	–		Ripples	
18		–	–	.202	.71	.04		Ripples	
2		1.35	1.60	.201	1.21	.07		Ripples	
3		1.48	1.60	.202	1.36	.09		Ripples	
9		1.54	1.60	.204	.73	.06		Ripples	
1		1.44	1.60	.196	2.00	.10		Ripples	
5		1.52	1.60	.201	1.00	.07		Ripples	
11		1.46	1.60	.202	.80	.06		Ripples	
4		1.51	1.60	.199	4.16	.15		Dunes	
8		1.39	1.60	.204	.73	.06		Ripples	
7		1.46	1.60	.202	4.41	.20		Dunes	
10		1.54	1.60	.200	.83	.08		Ripples	
6		1.64	1.60	.198	1.56	.10		Ripples	
12		1.54	1.60	.203	.89	.06		Ripples	
19		1.57	1.60	.218	6.42	.26		Dunes	
21		1.36	1.60	.213	4.82	.31		Dunes	
22		1.25	1.60	.212	7.50	.52		Dunes	
25		1.50	1.60	.216	6.29	.26		Dunes	
20		1.61	1.60	.214	5.37	.36		Dunes	
23		1.40	1.60	.213	6.60	.41		Dunes	
24		1.23	1.60	.216	5.51	.31		Dunes	
40		1.41	1.60	.221	7.35	.31		Dunes	
39		1.51	1.60	.221	3.68	.10		Trans.	
26		1.54	1.60	.216	–	–		Trans.	
28		1.65	1.60	.213	2.57	.05		Trans.	
29		1.48	1.60	.217	6.40	.23		Trans.	
31		1.58	1.60	.217	3.16	.06		Trans.	
27		1.66	1.60	.218	10.22	.19		Trans.	
36		1.50	1.60	.221	.93	.03		Trans.	
41		1.14	1.60	.220	3.93	.14		Trans.	
30		1.57	1.60	.216	6.02	.12		Trans.	
35		1.48	1.60	.216	2.20	.07		Trans.	
34		1.31	1.60	.217	2.46	.08		Trans.	
33		1.26	1.60	.213	2.76	.10		Trans.	
38		1.36	1.60	.223	3.81	.09		Trans.	
37		1.65	1.60	.220	3.82	.08		Trans.	
32		1.35	1.60	.218	3.71	.29		Antidune	
45		1.33	1.60	.221	1.59	.11		Antidune	
44		1.74	1.60	.222	2.95	.21		Antidune	
42		1.30	1.60	.223	3.62	.25		Antidune	
43		1.57	1.60	.220	5.81	.27		Antidune	

Table .—Basic variables for runs with 0.47 mm sand in the 8 foot Flume.

Run	Slope x 10² ft/ft	Disch. cfs	Depth ft	Velocity ft/sec	Viscosity x 10⁵ ft²/sec 1	Viscosity x 10⁵ ft²/sec 2	Temp. °C	W. L. PPM	Total Load Bed Material PPM	Total Load Total PPM	dx10³ ft	σ —
46	0.084	14.54	1.11	1.64	1.30	–	13.1	–	181	181	–	–
47	.042	9.59	.75	1.60	1.36	–	11.5	–	23	23	1.141	1.85
48	.052	15.26	1.23	1.55	1.36	–	11.5	–	60	60	1.148	1.85
49	.173	21.32	1.33	2.00	1.38	–	11.0	–	588	588	0.823	1.96
85	.047	7.11	.78	1.13	1.31	–	12.7	–	12	12	1.364	1.66
86	.046	6.92	.76	1.14	1.77	1.32	17.0	4,800	1.6	4,800	0.249	3.19
87	.046	6.96	.75	1.16	1.11	1.37	19.1	8,400	2.3	8,400	0.210	4.37
88	.049	7.10	.74	1.20	1.13	1.50	18.3	11,400	2.5	11,400	0.417	3.04
90	.053	6.97	.60	1.45	1.17	1.39	17.1	6,950	37	6,990	1.345	1.70
89	.065	7.08	.60	1.47	1.12	1.42	18.5	9,000	31	9,030	1.361	2.50
93	.072	7.20	.62	1.45	1.24	–	14.7	1	99	100	1.482	1.55
92	.090	7.14	.63	1.43	1.12	1.33	18.5	6,070	106	6,180	1.509	1.93
91	.117	7.12	.58	1.53	1.14	1.42	18.0	8,400	195	8,600	1.443	1.90
82	.248	8.16	.64	1.60	1.00	–	23.2	133	429	562	1.463	1.64
51	.236	8.11	.62	1.62	1.28	–	13.1	584	545	1,130	1.351	1.66
52	.222	8.01	.55	1.81	1.20	1.26	16.0	1,620	578	2,200	1.456	1.63
73	.222	8.20	.61	1.67	1.06	1.24	20.7	5,670	662	6,330	1.509	1.83
74	.215	8.18	.65	1.58	1.05	1.31	21.0	7,970	534	8,500	1.420	2.08
76	.203	8.49	.63	1.69	1.08	1.38	20.0	9,330	463	9,790	1.387	2.00
75	.204	8.24	.64	1.60	1.05	1.36	21.2	9,460	625	10,100	1.574	1.84
53	.235	8.01	.57	1.77	1.16	1.52	17.2	10,700	571	11,200	1.361	1.65
77	.199	8.76	.65	1.68	1.11	1.52	19.1	12,500	639	13,100	1.246	2.91
96	.201	8.31	.53	1.94	1.12	1.93	18.6	25,000	761	25,800	1.066	2.66
94	.237	11.30	.81	1.74	1.28	–	13.5	7	480	487	1.404	1.77
83	.200	15.58	.91	2.14	1.19	–	16.2	–	588	588	1.151	1.74
54	.240	15.36	.92	2.08	1.18	1.25	16.6	1,940	657	2,600	1.253	1.74
56	.242	15.36	.90	2.14	1.03	1.11	22.1	2,860	1100	3,960	1.148	1.70
55	.237	15.36	.74	2.04	1.12	1.26	18.5	4,060	765	4,820	1.164	1.88
57	.259	15.39	.87	2.20	1.05	1.19	21.3	4,320	761	5,080	1.325	[illegible]
58	.233	15.28	.90	2.11	1.08	1.25	20.1	5,270	807	6,080	1.210	1.94
95	.180	15.38	.80	2.39	1.12	2.03	18.7	28,300	1,640	29,900	1.099	2.42
78	.320	11.52	.72	2.00	1.07	1.41	20.3	12,000	1,510	13,500	1.089	2.88
59	.326	15.36	.65	2.96	1.04	1.20	21.7	4,570	2,920	7,490	1.312	1.73
60	.342	21.35	.62	4.28	1.06	1.18	21.1	3,600	3,290	6,890	1.427	1.64
61	.355	21.32	.61	4.36	1.00	1.20	23.2	6,170	3,390	9,560	1.440	1.68
71	.531	8.22	.32	3.21	1.04	1.18	21.4	3,600	5,250	8,850	1.525	1.68
72	.550	8.26	.32	3.26	1.08	1.31	20.2	7,100	5,680	12,800	1.505	1.55
70	.640	8.14	.30	3.41	1.08	1.20	20.2	3,910	6,310	10,200	1.476	1.60
63	.570	15.50	.43	4.48	1.05	1.16	21.2	3,020	5,360	8,380	1.633	1.60
64	.578	15.61	.41	4.76	1.05	1.26	21.2	6,440	5,480	12,000	1.630	1.60
65	.571	15.60	.42	4.63	1.04	1.34	21.6	9,090	5,160	14,200	1.584	1.64
66	.575	15.52	.45	4.34	1.01	1.38	23.0	12,300	5,130	17,400	1.647	1.76
80	.643	15.27	.39	4.91	1.04	1.43	21.8	12,100	7,140	19,100	1.624	1.76
81	.634	21.35	.55	4.85	1.38	–	10.7	7	4,480	4,490	2.076	1.61
62	.622	21.23	.54	4.89	.98	1.12	24.5	4,790	4,490	9,280	2.030	1.54
67	.646	20.87	.53	4.91	1.02	1.36	22.7	11,200	4,390	15,600	1.994	1.57
79	.651	21.31	.55	4.82	1.05	1.46	21.0	12,400	5,760	18,200	2.204	1.82
84	.740	15.36	.41	4.67	1.23	–	15.0	7	7,100	7,110	1.410	1.39
69	.734	15.54	.43	4.48	1.02	1.24	22.4	7,020	8,280	15,300	1.601	1.71
68	.740	20.94	.53	4.95	1.00	1.23	23.5	7,620	6,760	14,400	2.181	1.55
98	.821	15.80	.44	4.51	1.11	2.46	19.0	42,000	17,700	59,700	1.237	1.90
100	.790	21.42	.51	5.28	1.29	–	13.3	106	8,440	8,550	2.322	1.40
99	.806	21.27	.50	5.32	1.09	1.96	19.6	26,900	16,100	43,000	1.361	1.93
97	.960	12.01	.37	4.07	1.10	1.29	19.5	5,800	8,960	14,800	2.165	1.50

1 Temperature

2 Temperature and Bentonite

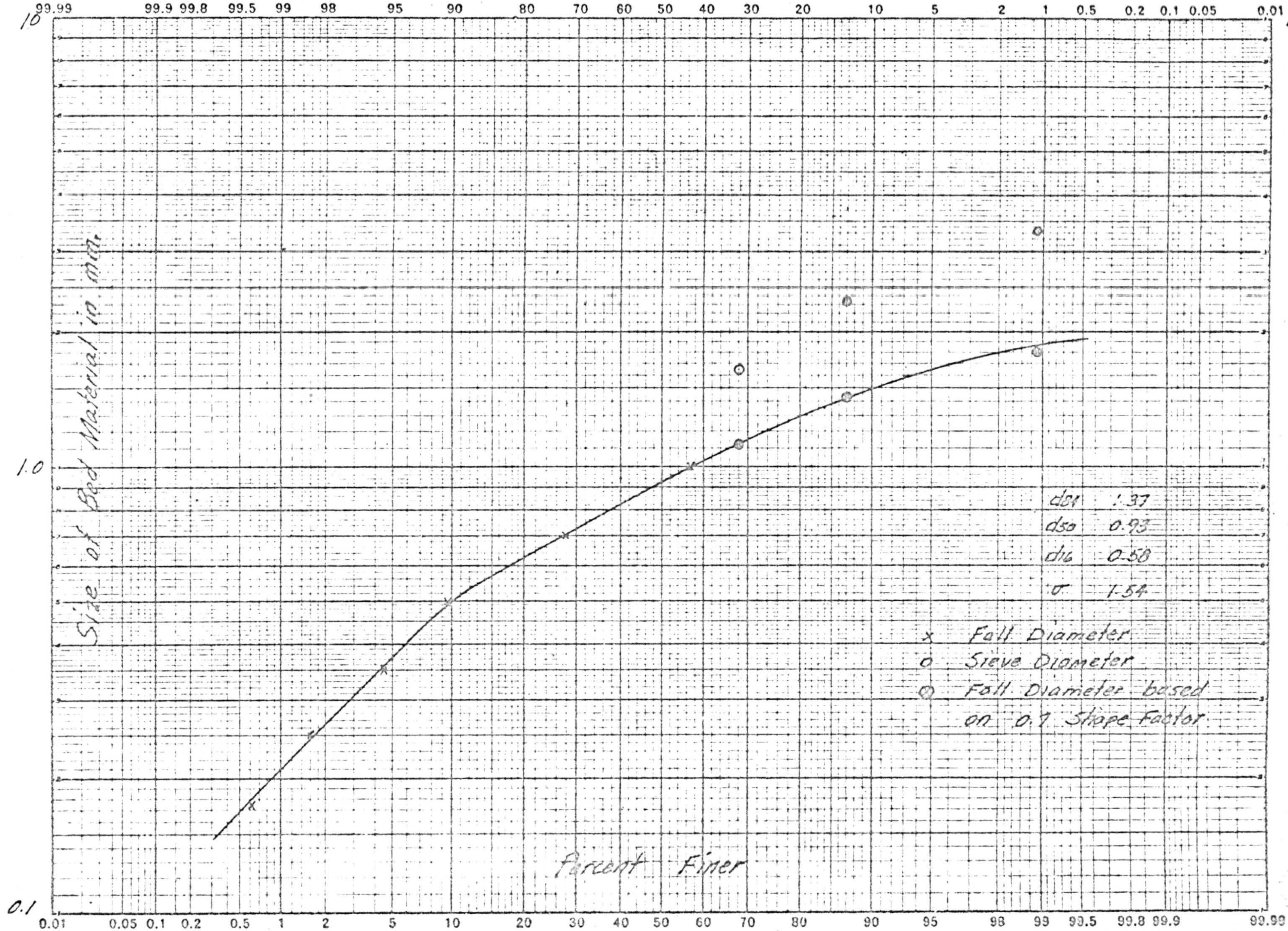
$d = 1.54 \times 10^{-3}$ ft

Table . - Basic variables for runs with 0.47 mm sand in the 8 foot Flume.

Run	Susp. Load PPM	Bed Material $d \times 10^3$ ft	σ —	W fps.	W' fps	$d' \times 10^3$ ft	Sand Waves L ft	H ft	V_s fpm	Bed Forms
46	-	-	-	0.217	-	-	5.98	0.41	-	Dunes
47	-	-	-	.214	-	-	8.20	0.22	0.035	Dunes
48	-	-	-	.214	-	-	6.24	0.32	.030	Dunes
49	-	-	-	.212	-	-	7.28	0.35	.080	Dunes
85	-	1.502	1.52	.216	-	-	1.20	0.07	.0074	Ripples
86	4070	1.437	1.56	.227	0.223	1.43	.96	0.06	.0033	Ripples
87	7100	1.521	1.56	.232	.224	1.44	.91	0.06	.0055	Ripples
88	10000	1.640	1.54	.230	.220	1.42	1.00	0.07	.0015	Ripples
90	6690	1.355	1.54	.227	.221	1.42	1.63	0.06	.027	Ripples
89	7490	1.509	1.48	.230	.223	1.43	1.62	0.06	.030	Ripples
93	53	1.742	1.50	.221	-	-	5.98	0.17	.039	Dunes
92	5350	1.619	1.55	.230	.225	1.45	4.56	0.25	.050	Dunes
91	8050	1.610	1.58	.229	.222	1.43	4.33	0.25	.084	Dunes
82	235	1.679	1.55	.240	-	-	4.12	0.28	.17	Dunes
51	-	-	-	.217	-	-	5.55	0.20	.19	Dunes
52	1830	1.417	1.47	.224	.223	1.43	5.33	0.26	.18	Dunes
73	-	1.565	1.52	.235	.231	1.48	5.45	0.29	.26	Dunes
74	-	1.627	1.55	.236	.229	1.47	5.50	0.34	.17	Dunes
76	9520	1.456	1.51	.234	.226	1.45	5.71	0.30	.16	Dunes
75	-	1.443	1.47	.236	.228	1.46	4.37	0.28	.15	Dunes
53	2750	1.564	1.59	.227	.217	1.41	5.81	0.34	.11	Dunes
77	-	1.581	1.53	.232	.220	1.42	5.12	0.29	.091	Dunes
96	-	1.588	1.52	.231	.205	1.32	4.31	0.24	.20	Dunes
94	-	1.624	1.54	.218	-	-	5.21	0.32	.28	Dunes
83	503	1.633	1.54	.225	-	-	5.78	0.43	.16	Dunes
54	2590	1.469	1.51	.226	.224	1.44	6.54	0.41	.33	Dunes
56	-	-	-	.238	.236	1.51	5.30	0.29	.20	Dunes
55	3140	1.692	1.53	.230	.227	1.46	5.87	0.27	.23	Dunes
57	5010	1.518	1.39	.237	.232	1.49	5.12	0.29	.29	Dunes
58	4220	1.535	1.48	.234	.230	1.48	5.36	.26	.21	Dunes
95	-	1.771	1.60	.231	.203	1.32	-	.33	.31	Dunes
78	13300	1.453	1.49	.235	.223	1.43	7.36	.39	.34	Dunes
59	5820	1.535	1.50	.237	.234	1.50	7.50	.07	.72	Dunes
60	4390	1.699	1.48	.236	.233	1.49	-	-	-	Plane
61	7910	1.722	1.55	.240	.234	1.50	-	-	-	Plane
71	3040	1.673	1.61	.237	.233	1.49	-	-	-	Plane
72	7490	1.588	1.56	.234	.228	1.46	-	-	-	Plane
70	3840	1.515	1.63	.234	.231	1.48	2.43	.12	-	Plane
63	4540	1.535	1.54	.236	.233	1.49	3.43	.23	-	Antidunes
64	8400	1.601	1.56	.236	.230	1.48	3.43	.20	-	Antidunes
65	11600	1.506	1.49	.237	.230	1.48	3.44	.20	-	Antidunes
66	16600	1.526	1.56	.240	.228	1.46	3.34	.20	-	Antidunes
80	14000	1.594	1.46	.238	.227	1.46	3.36	.26	-	Antidunes
81	3380	1.584	1.66	.211	-	-	4.40	.04	-	Standing Wave
62	7320	1.647	1.48	.243	.239	1.52	-	-	-	Standing Wave
67	11400	1.620	1.55	.239	.229	1.47	4.00	.10	-	Standing Wave
79	15200	1.355	1.48	.236	.224	1.44	3.90	.08	-	Standing Wave
84	3700	1.640	1.53	.222	-	-	3.60	.21	-	Antidune
69	9890	1.430	1.58	.239	.232	1.48	3.73	.26	-	Antidune
68	12400	1.738	1.58	.241	.234	1.50	4.00	.05	-	Standing Wave
98	57700	1.440	1.57	.232	.188	1.24	3.10	.24	-	Antidunes
100	4240	1.561	1.51	.218	-	-	-	-	-	Plane
99	42300	1.492	1.60	.233	.207	1.34	4.04	.31	-	Antidunes
97	6300	1.597	1.66	.233	.228	1.46	3.38	.16	-	Antidunes

W' fall velocity in bentonite-water dispersion

d' Effective fall diameter of the average median diameter ($d = 1.54 \times 10^{-3}$ ft)



99.99 99.9 99.8 99.5 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
10
1.0
0.1
Size of Bed Material in mm.
d84 1.37
d50 0.93
d16 0.58
σ 1.54
x Fall Diameter
o Sieve Diameter
Fall Diameter based on 0.7 Shape Factor
Percent Finer
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.5 99.8 99.9 99.99

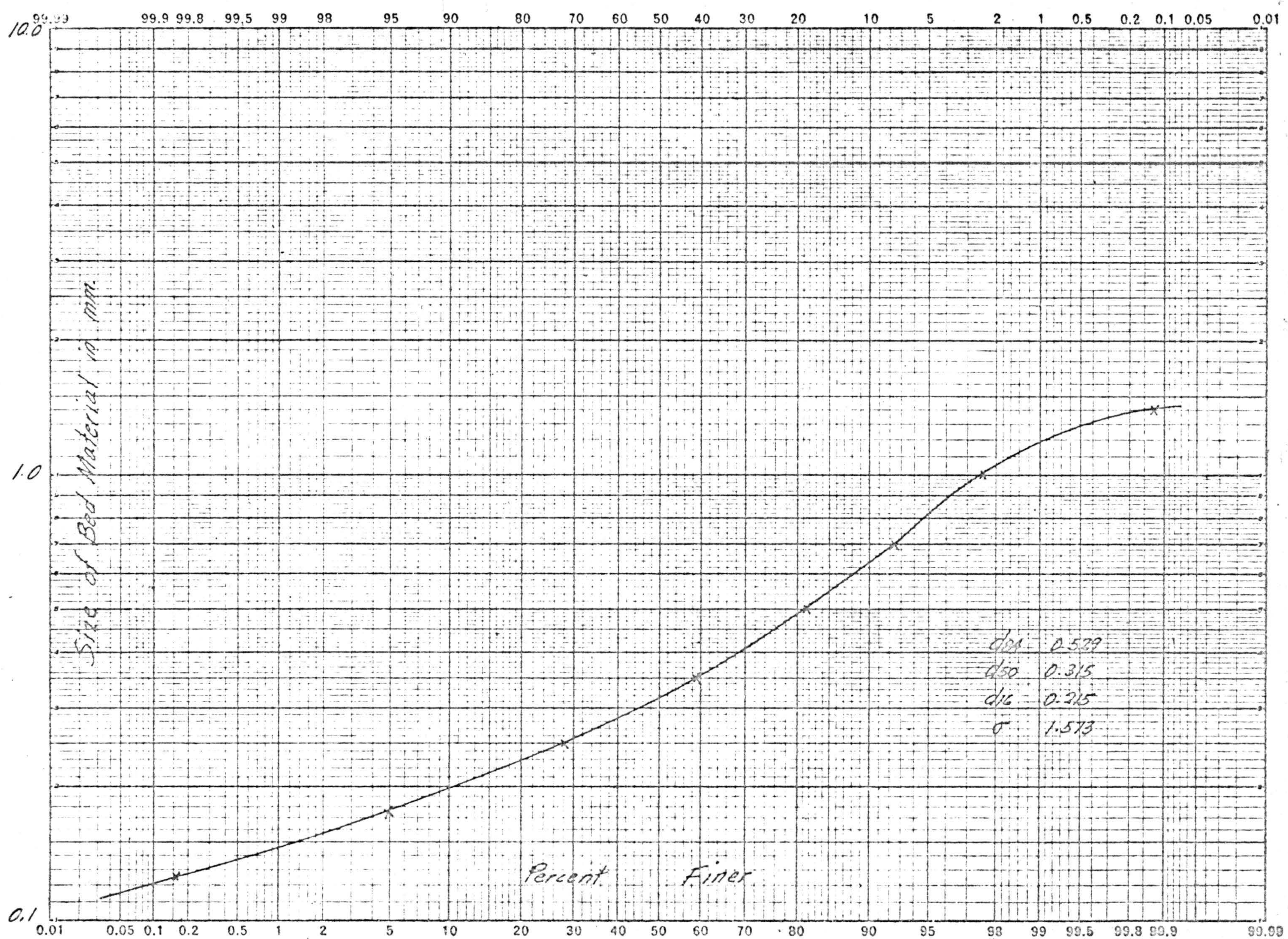
Table .--Basic variables for runs with 0.93 mm sand in the 8 foot flume.

Run	Slope $\times 10^2$ ft/ft	Discharge cfs	Depth ft	Velocity ft/sec	Viscosity $\times 10^5$ ft^2/sec	Temp. °C	Total load Bed Material PPM	$d \times 10^3$ ft	σ —
19	0.0129	8.06	1.01	1.00	1.09	19.8	0	-	-
26A	.0219	10.80	1.02	1.32	1.11	19.0	0	-	-
25	.0220	9.88	1.01	1.22	1.10	19.3	0	-	-
27	.0280	11.86	1.01	1.47	1.02	22.7	2.8	-	-
26	.0283	11.39	1.03	1.37	1.12	18.8	-	-	-
20	.0284	10.91	1.03	1.32	1.09	19.6	.4	-	-
21_s	.0295	12.06	1.01	1.49	1.07	20.5	.4	-	-
18	.0370	13.42	1.01	1.66	1.14	18.0	21	2.64	1.43
28	.0373	14.53	1.04	1.75	1.06	20.7	28	2.95	1.37
29	.0426	4.62	.50	1.16	1.11	18.9	0	-	-
22	.0430	4.49	.49	1.15	1.11	19.0	0	-	-
30	.0497	5.06	.51	1.25	1.11	18.9	-	-	-
31	.0537	5.42	.50	1.36	1.18	16.8	4.2	-	-
15	.0590	16.25	1.05	1.93	1.09	19.7	65	2.58	1.45
23	.0615	5.10	.49	1.30	1.10	19.2	-	-	-
32	.0640	6.25	.52	1.50	1.18	16.7	26	2.79	1.38
24	.0682	5.71	.49	1.46	1.10	19.3	15	-	-
14	.0710	7.41	.58	1.60	1.16	17.4	63	2.72	1.38
34	.0800	7.08	.54	1.64	1.10	19.5	73	2.56	1.40
16	.112	16.85	1.04	2.03	1.10	19.4	140	2.69	1.44
35	.130	7.64	.53	1.80	1.17	17.1	201	2.82	1.48
17	.136	16.83	1.00	2.10	1.10	19.2	211	2.89	1.50
33	.145	8.18	.56	1.83	1.11	19.0	253	2.53	1.54
5	.183	16.41	0.93	2.21	1.16	17.5	308	2.62	2.42
10	.192	6.90	.46	1.88	1.11	19.0	450	2.76	1.53
37	.275	22.58	1.11	2.54	1.14	18.0	601	2.35	2.40
36	.304	8.96	.55	2.04	1.16	17.3	519	2.69	1.62
6	.313	22.30	1.04	2.68	1.11	19.1	537	2.16	2.81
7	.339	10.10	.59	2.14	1.13	18.3	822	3.12	1.84
38	.356	22.69	1.02	2.78	1.11	18.9	1080	2.41	2.14
11	.393	22.22	.92	3.02	1.13	18.3	1180	2.39	2.74
8	.430	11.20	.57	2.46	1.16	17.4	1490	2.80	1.53
12	.437	22.19	.89	3.12	1.12	18.5	1900	2.49	2.33
13	.587	22.09	.82	3.37	1.13	18.4	2750	2.63	1.84
9	.600	11.32	.49	2.89	1.12	18.5	2620	3.05	1.64
3	.65	16.46	.60	3.43	1.16	17.3	3110	2.85	2.02
1	.71	22.33	.68	4.10	1.10	19.3	4020	2.21	2.28
2	.92	22.07	.53	5.20	1.13	18.2	6140	2.82	1.75
4	.94	15.64	.51	3.83	1.14	18.0	5090	2.76	2.11
41	1.12	15.67	.44	4.45	1.04	21.7	9480	2.68	1.96
42	1.16	20.44	.44	5.81	1.07	20.4	7320	2.95	1.51
40	1.23	15.53	.38	5.11	1.09	19.6	10200	3.47	1.34
43	1.26	20.63	.44	5.86	1.05	21.0	7000	3.45	1.42
39	1.28	20.88	.43	6.07	1.07	20.5	7010	3.35	1.50

$d = 3.05 \times 10^{-3}$ ft $\sigma = 1.54$

Table . Basic variables for runs with 0.93 mm sand in the 8 foot flume

Run	Susp. Load PPM	Bed Material $d \times 10^3$ ft	σ -	W ft/sec	Sand Waves L ft	H ft	V_s ft/min	Bed Forms	Remarks
19	0	-	-	0.483	-	-	-	Plane	no movement
26A	0	-	-	.481	-	-	-	Plane	some movement
25	0	-	-	.482	-	-	-	Plane	no movement
27	0	2.79	1.58	.487	-	-	-	Plane	general movement
26	0	-	-	.481	-	-	-	Plane	some movement
20	0	-	-	.482	-	-	-	Plane	some movement
21	0	-	-	.484	-	-	-	Plane	movement
18	0	3.15	1.52	.479	2.1	0.04	0.06	Dunes	very small
28	0	3.02	1.49	.484	3.7	.05	0.07	Dunes	small
29	0	-	-	.481	-	-	-	Plane	no movement
22	0	-	-	.481	-	-	-	Plane	no movement
30	0	-	-	.481	-	-	-	Plane	some movement
31	0	3.22	1.53	.476	-	-	-	Plane	general movement
15	4.1	3.28	1.52	.482	2.6	.09	.14	Dunes	
23	0	-	-	.481	-	-	-	Plane	movement
32	0	2.98	1.55	.476	-	-	-	Plane	general movement
24	0	-	-	.482	-	-	-	Plane	general movement
14	0	3.25	1.47	.478	2.8	.03	.07	Dunes	small
34	0	2.82	1.48	.482	2.9	.02	.12	Dunes	small
16	12	3.18	1.57	.482	3.6	.16	0.13	Dunes	
35	-	3.02	1.50	.477	2.9	.06	0.20	Dunes	small
17	30	3.08	1.56	.481	3.5	.18	.18	Dunes	
33	14	2.99	1.57	.481	3.3	.08	.18	Dunes	
5	281	2.98	1.50	.478	5.2	.28	.17	Dunes	
10	123	3.22	1.42	.481	3.9	.12	.24	Dunes	
37	440	2.43	1.58	.479	6.6	.34	0.27	Dunes	
36	56	3.07	1.54	.478	3.5	.13	.32	Dunes	
6	281	2.92	1.59	.481	5.8	.31	.45	Dunes	
7	437	3.38	1.42	.480	4.5	.19	.44	Dunes	
38	422	2.48	1.54	.481	6.3	.30	.58	Dunes	
11	3050	3.15	1.48	.480	7.4	.32	0.60	Dunes	
8	313	2.89	1.54	.478	5.9	.17	.56	Trans.	Dunes
12	1400	3.02	1.47	.480	4.8	.23	1.16	Trans.	Dunes
13	1900	3.02	1.49	.480	6.2	.25	.30	Trans.	
9	498	3.17	1.48	.480	2.7	.12	.44	Trans.	
3	4640	3.08	1.55	.478	3.2	.19	-	Trans.	
1	3770	3.28	1.47	.482	-	-	-	Trans.	
2	3120	3.02	1.49	.479	4.9	.31	-	Trans.	
4	2340	3.08	1.55	.479	4.5	.11	-	Trans.	
41	2230	3.41	1.54	.485	-	-	-	Trans.	
42	1610	2.66	1.52	.483	-	-	-	Stand. Waves	
40	1470	2.72	1.57	.482	-	-	-	Stand. Waves	Close to Antidunes
43	2500	2.49	1.60	.484	-	-	-	Stand. Waves	Close to Antidunes
39	2300	3.35	1.40	.484	-	-	-	Stand. Waves	Close to Antidunes



10.0
1.0
0.1
99.99 99.9 99.8 99.5 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.5 99.8 99.9 99.99
Size of Bed Material in mm.
Percent Finer
d84 0.529
d50 0.315
d16 0.215
σ 1.573

Table . —Basic variables for runs with 0.32 mm sand in the 2 foot flume.

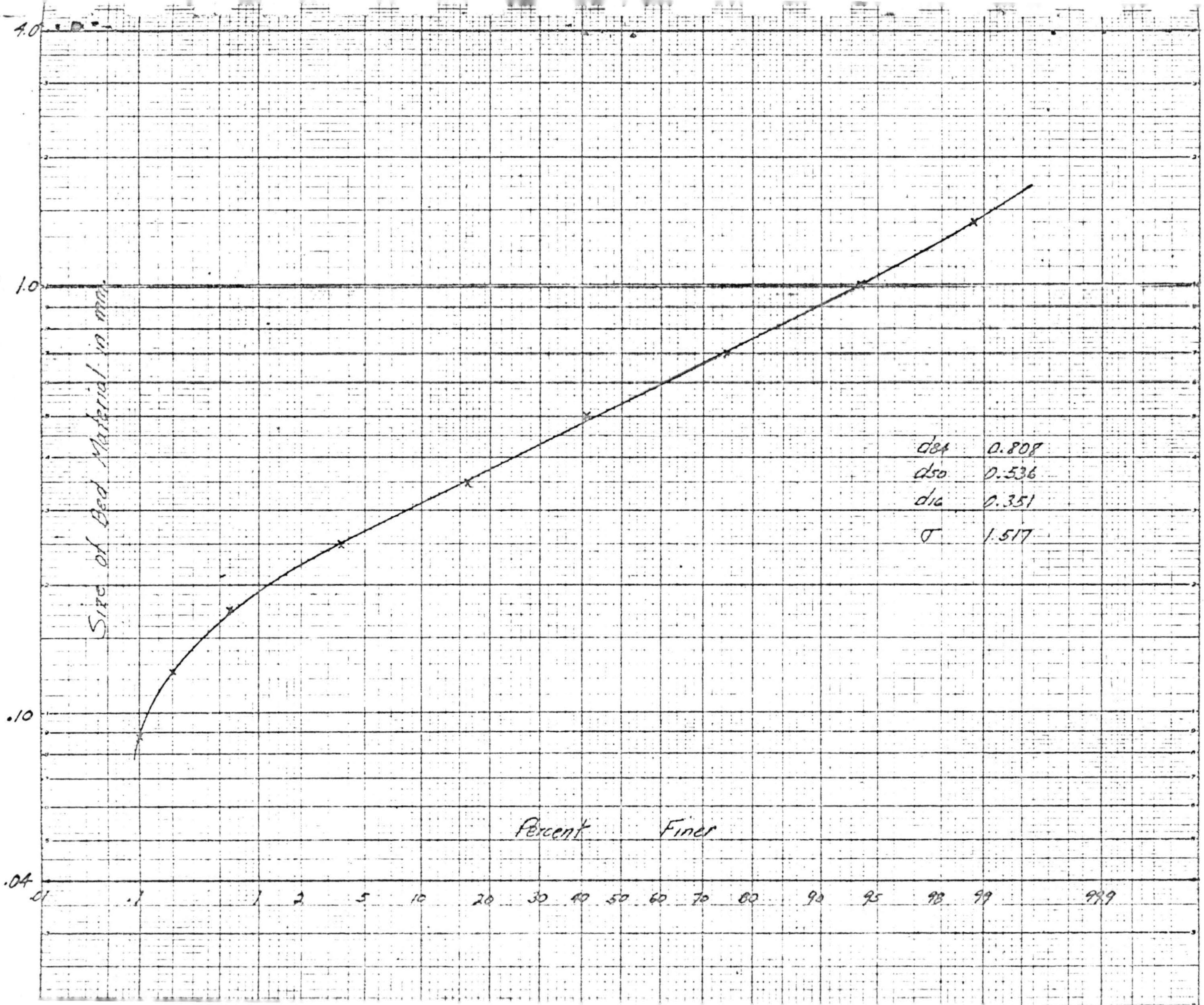
Run	Slope x 10^2 ft/ft	Disch. cfs	Depth ft	Velocity ft/sec	Viscosity x 10^5 ft^2/sec	Temp. °C	Total load Bed Material PPM	$d \times 10^3$ ft	σ
1	0.054	0.91	0.51	0.90	1.41	10.0	–	–	–
2	.015	.88	.52	.86	1.00	23.4	–	–	–
3	.112	1.31	.54	1.24	1.39	10.5	55	0.886	1.63
4	.086	1.31	.54	1.24	.91	27.8	61	.998	1.60
30	.110	1.56	.57	1.39	1.24	14.7	91	.886	1.47
29	.103	1.57	.56	1.43	.80	33.8	117	1.248	1.43
5	.139	1.88	.56	1.72	1.40	10.2	226	.782	1.57
6	.118	1.88	.59	1.62	.92	27.2	168	.788	1.48
27	.110	2.28	.58	2.01	1.26	14.3	455	.854	1.36
28	.214	2.29	.63	1.85	.79	34.3	787	.913	1.48
26	.201	2.67	.71	1.93	1.30	13.1	854	.933	1.46
25	.210	2.64	.66	2.05	.81	33.1	719	.867	1.56
21	.184	3.13	.58	2.74	1.32	12.4	907	.847	1.58
22	.166	3.13	.64	2.48	.80	33.9	1150	.886	1.63
24	.172	3.48	.74	2.39	1.34	12.1	663	.847	1.52
23	.261	3.48	.73	2.43	.81	32.8	1150	.894	1.52
7	.189	3.48	.60	2.95	1.34	11.9	1410	.925	1.58
8	.202	3.50	.72	2.48	.92	26.9	1720	.926	1.57
20	.566	4.55	.55	4.23	1.31	12.7	5600	1.012	1.49
19	.515	4.55	.56	4.18	.90	28.4	4340	.831	1.48
10	.710	4.78	.59	4.12	1.55	7.0	5180	1.015	1.54
9	.493	4.78	.56	4.35	1.00	23.5	5530	1.184	1.63
12	.456	5.32	.67	4.03	1.51	7.9	3520	.923	1.46
11	.408	5.30	.60	4.51	.98	23.8	5250	1.035	1.69
14	.942	5.70	.60	4.86	1.32	12.5	12300	.906	1.51
13	.574	5.70	.60	4.84	.84	31.7	8780	.991	1.43
15	.983	6.63	.63	5.36	1.36	11.4	26100	.801	1.39
16	.962	6.64	.62	5.42	.93	26.7	21000	.864	1.44
17	.970	6.79	.62	5.58	1.30	12.9	29600	.871	1.42
18	.656	6.82	.61	5.73	.90	27.9	20800	.886	1.62

$d = 1.05 \times 10^{-3}$ ft

Table .—Basic variables for runs with 0.32 mm sand in the 2 foot Flume.

Run	Susp. Load PPM	Bed Material				Sand Waves			Bed Forms	Remarks
		$d \times 10^3$ ft	σ —	W fps	$d' \times 10^3$ ft	L ft	H ft	V_s fpm		
1	0	–	–	0.126	0.890	–	–	–	Plane	No Movement
2	0	–	–	.151	1.030	–	–	–	Plane	No Movement
3	0	–	–	.127	.896				Ripples	
4	0	.854	1.56	.157	1.062				Ripples	
30	24	1.021	1.44	.131	.939				Ripples	
29	9	1.019	1.46	.164	1.104				Dunes	Ripples Superposed
5	56	.837	1.50	.126	.891				Dunes	Ripples Superposed
6	33	.854	1.58	.156	1.058				Dunes	Ripples Superposed
27	168	1.038	1.52	.134	.936				Dunes	Ripples Superposed
28	251	1.035	1.57	.165	1.108				Dunes	"
26	80	1.071	1.62	.131	.923				Dunes	Ripples Superposed
25	274	1.019	1.52	.161	1.086				Dunes	
21	196	1.035	1.65	.130	.915				Transition	
22	498	1.051	1.50	.165	1.105				Transition	
24	307	.969	1.49	.129	.912				Transition	
23	227	.916	1.46	.163	1.099				Transition	
7	196	.950	1.64	.129	.909				Transition	Plane Bed
8	248	1.003	1.59	.155	1.054				Transition	
20	1520	1.001	1.45	.131	.918				Antidunes	Mild
19	735	.979	1.42	.158	1.067				Transition	Plane Bed
10	2020	1.001	1.64	.114	.826				Transition	Plane Bed
9	1480	.935	1.50	.154	1.029				Antidunes	Mild
12	1480	1.051	1.56	.119	.851				Transition	Plane Bed
11	1810	1.051	1.48	.148	1.030				Antidunes	Mild
14	5340	1.215	1.56	.130	.916				Antidunes	Mild
13	2100	1.049	1.49	.162	1.090				Antidunes	Mild
15	19000	1.160	1.59	.128	.904				Antidunes	
16	14700	1.527	1.89	.155	1.052				Antidunes	
17	29900	1.103	1.52	.131	.920				Antidunes	
18	17400	1.231	1.60	.157	1.063				Antidunes	

d' = effective fall diameter.
$d = 1.05 \times 10^3$ ft



4.0
1.0
.10
.04
Size of Bed Material in mm
d84 0.808
d50 0.536
d16 0.351
σ 1.517
Percent Finer
.01 .1 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.9

Table .--Basic variables for runs with d = 0.54 mm sand in the 2 foot Flume.

Run	Slope $\times 10^2$ ft/ft	Disch. cfs	Depth ft	Velocity ft/sec	Viscosity $\times 10^5$ ft^2/sec 1	Viscosity 2	Temp. °C	Total load W. L. PPM	Total load Bed Material PPM	Total load Total PPM	dx10^3 ft	σ
1	0.016	1.06	0.61	0.89	1.20	-	15.9	-	-	-	-	-
2	.019	1.12	.60	.96	1.16	-	17.4	-	-	-	-	-
3	.026	1.21	.62	1.00	1.17	-	16.9	-	0.6	0.6	-	-
4	.038	1.59	.59	1.37	1.14	-	18.0	-	14	14	1.647	1.34
6	.170	2.45	.72	1.74	1.12	-	18.6	-	333	333	1.539	1.66
5	.201	3.12	.81	1.95	1.10	-	19.2	-	346	346	1.499	1.60
0	.336	4.28	.91	2.39	1.24	-	14.7	-	-	-	-	-
20	.338	4.74	.72	3.36	1.08	-	20.2	-	2450	2450	1.621	1.52
8	.351	3.82	.78	2.51	1.11	-	18.9	-	1020	1020	1.585	1.55
8A	.331	3.82	.84	2.33	1.12	1.31	18.7	5740	1050	6790	1.417	1.58
8E	.248	3.69	.88	2.15	1.00	1.46	23.3	14500	660	15200	1.673	1.47
8B	.293	3.84	.85	2.30	1.04	1.70	21.5	20600	842	21400	1.483	1.67
8C	.294	3.83	.86	2.28	1.02	1.79	22.4	24300	1040	25300	1.594	1.75
8D	.198	3.77	.72	2.65	0.96	3.20	25.0	63700	521	64200	0.787	2.92
7	.388	3.42	.72	2.44	1.06	-	20.6	-	1090	1090	2.224	1.55
14	.399	4.77	.89	2.74	1.10	-	19.3	-	1700	1700	1.667	1.45
14A	.366	4.78	.82	2.95	0.98	1.27	24.3	9580	1760	11300	1.532	1.64
14C	.377	4.80	.87	2.82	1.03	1.74	22.2	22400	1840	24200	1.739	1.64
14B	.339	4.84	.70	3.51	1.02	2.41	22.3	44100	2960	47100	1.296	2.91
19	.408	3.82	.76	2.58	1.04	-	21.5	-	1300	1300	1.463	1.56
9	.433	4.16	.72	2.93	1.15	-	17.7	-	1520	1520	1.421	1.58
10	.486	5.33	.64	4.30	1.07	-	20.3	-	2690	2690	1.706	1.47
18	.520	7.62	.71	5.44	1.02	-	22.6	-	3330	3330	1.870	1.61
18A	.508	7.57	.76	5.11	1.02	1.44	22.5	13200	3400	16600	1.804	1.62
18B	.790	7.59	.69	5.62	1.00	1.70	23.3	37900	9730	47600	1.558	1.61
18C	.900	7.59	.70	5.54	0.99	3.00	23.7	58700	22300	81000	1.421	1.40
15	.551	6.94	.74	4.75	1.04	---	21.7	-	3330	3330	1.821	1.53
15A	.550	6.99	.75	4.76	1.02	1.47	22.5	14200	4350	18600	1.519	1.88
15B	.537	6.96	.75	4.73	0.99	2.27	23.7	40900	4710	45600	1.476	3.17
15C	.628	6.99	.73	4.85	0.99	2.98	24.0	58600	7640	66200	1.247	2.69
13	.565	6.37	.72	4.52	1.14	-	18.1	-	3350	3350	1.847	1.60
11	.768	7.48	.66	5.80	1.08	-	19.9	-	5690	5690	2.067	1.46
16A	.980	7.82	.67	5.92	1.00	1.35	23.5	11200	5600	16800	2.198	1.33
16B	1.075	7.84	.66	6.03	0.96	1.93	25.0	31500	10300	41800	1.496	1.73
16C	1.305	7.86	.65	6.14	0.96	2.32	25.1	44500	15800	60300	1.132	2.22
17	1.175	7.89	.65	6.21	1.02	-	22.5	-	9180	9180	1.460	1.74
17A	1.365	7.83	.65	6.17	1.02	2.27	22.3	39600	23800	63400	1.214	1.63
17B	1.928	7.86	.68	5.87	0.99	2.60	24.0	51900	50000	102000	1.460	1.30
12	1.438	7.84	.64	6.27	1.17	-	16.9	-	26000	26000	1.486	1.74

Table .—Basic variables for runs with 0.54 mm sand in the 2 foot Flume.

	Bed Material					Sand Waves			Bed Form	Remarks
	$d \times 10^3$ ft	σ —	w fps	w′ fps	$d' \times 10^3$ ft	L ft	H ft	V_s fpm		
1	-	-	0.258	-	-	-	-	-	Plane	Some Movement
2	-	-	.262	-	-	-	-	-	Plane	Some Movement
3	1.585	1.53	.261	-	-	0.47	0.03	0.0001	Sand Waves	Artificially Induced
4	1.526	1.55	.264	-	-	-	.10	.0004	Plane	One Dune front
6	1.640	1.67	.266	-	-	4.6	.35	.0047	Dunes	-
5	1.575	1.57	.268	-	-	5.0	.26	.0080	Dunes	-
0	1.565	1.56	.254	-	-	4.0	.30	.0054	Dunes	-
20	1.716	1.51	.271	-	-	4.3	.17	.036	Transition	Dunes
8	1.903	1.48	.267	-	-	3.6	.23	.012	Dunes	-
8A	1.699	1.45	.265	.258	1.730	3.8	.20	.012	Dunes	-
8E	1.968	1.45	.278	.262	1.688	3.6	.19	.0073	Dunes	-
8B	1.949	1.49	.274	.252	1.654	3.6	.20	.010	Dunes	-
8C	1.772	1.47	.276	.248	1.632	4.4	.24	.011	Dunes	-
8D	1.706	1.51	.282	.208	1.343	0.7	.08	.0062	Sand Waves	-
7	1.804	1.53	.272	-	-	3.3	.17	.012	Dunes	-
14	1.903	1.50	.268	-	-	4.0	.20	.021	Transition	Dunes
14A	1.837	1.50	.280	.270	1.711	5.8	.20	.030	Transition	Dunes
14C	1.837	1.53	.275	.250	1.643	5.8	.19	.034	Transition	Dunes
14B	1.837	1.48	.276	.228	1.500	-	-	-	Transition	Plane
19	1.788	1.54	.274	-	-	4.2	.16	.018	Transition	Dunes
9	1.549	1.50	.263	-	-	4.2	.18	.022	Transition	Dunes
10	1.824	1.64	.271	-	-	-	-	-	Transition	Plane
18	1.870	1.49	.276	-	-	-	-	-	Standing Waves	-
18A	1.837	1.48	.276	.262	1.695	-	-	-	Standing Waves	-
18B	1.837	1.45	.278	.237	1.544	-	-	-	Standing Waves	-
18C	1.919	1.44	.279	.208	1.388	-	-	-	Anti-Dunes	-
15	1.732	1.48	.274	-	-	-	-	-	Standing Waves	
15A	1.854	1.52	.276	.261	1.689	-	-	-	Standing Waves	-
15B	1.837	1.49	.279	.232	1.522	-	-	-	Standing Waves	-
15C	1.722	1.44	.280	.213	1.388	-	-	-	Standing Waves	-
13	1.713	1.60	.265	-	-	-	-	-	Standing Waves	-
11	1.509	1.62	.270	-	-	-	-	-	Standing Waves	-
16A	-	-	.278	.266	1.703	-	-	-	Standing Waves	-
16B	1.713	1.45	.282	.248	1.587	-	-	-	Anti-Dunes	-
16C	1.837	1.38	.282	.232	1.497	-	-	-	Anti-Dunes	-
17	1.690	1.46	.276	-	-	-	-	-	Anti-Dunes	-
17A	1.837	1.42	.276	.233	1.532	-	-	-	Anti-Dunes	-
17B	2.100	1.40	.280	.221	1.441	-	-	-	Anti-Dunes	-
12	1.847	1.58	.261	-	-	-	-	-	Anti-Dunes	-

w′ Fall velocity in bentonite-water dispersions

d′ Effective fall diameter