A Study of Methods Used in

MEASUREMENT AND ANALYSIS OF SEDIMENT LOADS IN STREAMS

REPORT D

Progress Report

COMPARATIVE FIELD TESTS ON SUSPENDED-SEDIMENT SAMPLERS

As of January 1946

March 1957

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MEASUREMENT AND ANALYSIS OF SEDIMENT LOADS IN STREAMS

Planned and conducted jointly by

Tennessee Valley Authority, Corps of Engineers,

Department of Agriculture, Geological Survey,

Bureau of Reclamation, Indian Service, and

Iowa Institute of Hydraulic Research

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Published by
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at
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SYNOPSIS

The study of "Methods Used in Measurement and Analysis of Sediment Loads in Streams" was inaugurated in 1939 by the Tennessee Valley Authority, Corps of Engineers, Department of Agriculture, Geological Survey, Bureau of Reclamation, and Office of Indian Affairs in conjunction with the Iowa Institute of Hydraulic Research. This study led to the development of improved equipment for sampling suspended fluvial sediment. Experimental models of the US D-43 depth-integrating sampler and the P-43 point-integrating sampler were completed in 1943. These experimental models and several duplicates of the D-43 sampler were subsequently tested in the field in conjunction with other sediment samplers in current use to obtain comparative data on the accuracy, sampling characteristics, and practicability of the samplers developed under this program. Comparative test data submitted by thirteen field offices were compiled in a progress report dated December 1944, entitled "Comparative Field Tests on Suspended Sediment Samplers". The present report summarizes comparative field tests conducted between the submission of the above report and December 1946, or for which the data was not available at the time of the earlier report.

The US P-43 and D-43 Samplers were tested by the Omaha and Little Rock Districts, Corps of Engineers, and by a field party of representatives of the Geological Survey, Bureau of Reclamation, the Corps of Engineers, and the Soil Conservation Service. The results of these tests generally agree with those of the preceding progress report; and indicate that the sampling characteristics and basic principles of the US P-43 and D-43 sediment samplers are superior to those of the samplers previously used. Considerable revision in the P-43 sampler appeared to be necessary; and as a result an improved model was designed and constructed. The D-43 sampler justified itself and is being adopted widely for routine sediment sampling in streams of average depths and velocities. Under severer conditions a heavier sampler with a valve to close the intake upon reaching the stream bed would be desirable. The basic principles of these samplers may be modified for special sampling conditions which preclude their use in present form.

This report was initiated in December 1946 when the laboratory work of the Interdepartmental Committee was centered at the Iowa Institute for Hydraulic Research. In 1948 the Committee's laboratory work was transferred to the St. Anthony Falls Hydraulic Laboratory, University of Minnesota, where this report was prepared for publication.

TABLE OF CONTENTS

APPENDICES

REPORT D

COMPARATIVE FIELD TESTS ON SUSPENDED SEDIMENT SAMPLERS

1. Introduction--Between 1943 and 1946, several of the Federal agencies which have sponsored the joint study for improvement of the methods of measurement and analysis of sediment loads in streams have conducted field tests to determine the sampling characteristics and correlation factors of various sediment samplers. The purpose of these tests was to compare the sampling efficiency and utility of old types of samplers with the point- and depth-integrating samplers developed under the committee sponsorship. This is the second progress report on comparative tests made by field agencies. The first progress report was submitted to the Committee in December 1944.

After the completion of the December 1944 Progress Report, other field agencies submitted test data on sampler comparisons which are compiled and discussed here. This report also includes notes on field conferences, sampler demonstrations, and other activities pertaining to the further development of suspended sediment samplers and sampling equipment.

2. Field tests by Corps of Engineers, Omaha, Nebraska--During September and October 1944, the Omaha District Corps of Engineers conducted comparative field tests on the Omaha regular, Omaha modified, US P-43, and US D-43 samplers. The results of these tests were submitted 8 January, 1945. (See Appendix-A) The samplers used in these tests are described in the December, 1944 Progress Report.

The tests were conducted in the Little Sioux River at Kennebec, Iowa, and in the Missouri River at Omaha. The flow in both streams was approximately normal and the sediment loads were not exceptional. The depths at the sampling verticals in the Missouri ranged from about 11.0 to 15.0 feet and in the Little Sioux from 5.0 to 8.0 feet. The sediment concentration in the Missouri ranged from about 1.0 to 2.0 grams per liter and in the Little Sioux from about 0.5 to 1.5 grams per liter. The samplers were tested under as nearly comparable sampling conditions as practicable. The results, therefore, are believed to reflect correctly the effect of the inherent differences in sampling action and sampling method of the respective samplers.

The sampling ratios indicated by the Omaha tests are given in Table 1. These results confirm those found in previous tests by the Omaha District which were reviewed in the December 1944 Progress Report in respect to the regular Omaha and the D-43 samplers. The data indicate that the concentrations in samples taken with the regular Omaha sampler are about 32 per cent higher than in D-43 samples. A difference of 14 per cent in the same direction was indicated in the earlier tests. The variation in

the results of these groups of tests undoubtedly is due to the fluctuation of the sediment concentration in the streams and to the fact that precise testing technique cannot be used in field operations. The various groups of tests made on the Omaha regular and the D-43 samplers consistently indicate that samples taken with the former contain an excess amount of sediment.

TABLE 1
SUMMARY OF FIELD TESTS ON SEDIMENT SAMPLERS
BY U. S. ENGINEER OFFICE, OMAHA, NEBRASKA
SEPTEMBER-OCTOBER 1944

Samplers	No. of Comparisons	Sampling Ratio	Remarks
Omaha/P-43	40	1.11	Missouri 9-23 September
Omaha/P-43	18	1.12	Little Sioux 6 September
Omaha/P-43	24	1.21	Little Sioux 4-5 October
Omaha/P-43	25	1.28	Missouri 10 October
	Mean	1.18	
Omaha/D-43	24	1.29	Little Sioux 4-5 October
Omaha/D-43	25	1.34	Missouri 10 October
	Mean	1.32	
Omaha (Mod.)/P-43	24	0.99	Little Sioux 4-5 October
Omaha (Mod.)/D-43	24	1.06	Little Sioux 4-5 October

In the September-October tests, the Omaha regular samples show 18 per cent higher concentration than those taken with the P-43 sampler. These results are reasonable in view of the discrepancy in sampling performance of the Omaha sampler in respect to the D-43 sampler discussed in the foregoing paragraph.

The tests on the Omaha modified sampler in respect to the D-43 and P-43 samplers indicate sampling ratios of 1.06 and 0.99, respectively. These values are somewhat smaller than those given for corresponding comparisons in the 1944 Progress Report. As in the earlier comparisons, tests indicate that the Omaha modified sampler also obtains heavier concentrations than the US depth- or point-integrating samplers. Correlation factors based on these tests would be unreliable due to lack of precision in making the tests and an inadequate number of comparisons.

The results obtained concurrently with the Omaha samplers under supposedly identical sampling conditions are more erratic than those obtained with the P-43 sampler. The variation of individual sample

concentrations from the mean concentration at a given point is greater for the Omaha samplers than for the P-43. Sediment size analyses indicate also that the Omaha samplers collect a larger percentage of coarse particles than does the P-43. This discrepancy may be attributed to the flat surface on top of the Omaha sampler around the intake which probably permits falling particles to lodge near the intake and to be washed into the sampler jar during the sampling period.

In testing the P-43 sampler in the Omaha District, the mechanical performance was closely observed and failures of various types were noted. A tabulation showing the number of times each type occurred is given in Appendix A. All of these difficulties can be corrected in the proposed electrically operated point-integrating sampler.

3. Field tests by the Corps of Engineers, Little Rock, Arkansas--The Little Rock District Corps of Engineers tested the US P-43 and the Texas samplers in November and December 1944. The results of these tests were submitted in reports dated 25 January 1945 and 25 August 1945. (See Appendix B.) The tests were made in the Arkansas River at the Main Street bridge in Little Rock.

The Texas sampler, also known as the Faris or U.S.D.A. sampler, is described in the 1944 Progress Report. This sampler is ordinarily lowered to the 0.6-depth point in the sampling vertical, the intake being plugged with a rubber stopper. The stopper is jerked out of the intake by means of an auxiliary line. The sampler is left at the sampling point for a short period to permit the container to fill, then raised to the surface without replacing the stopper. Obviously, faulty samples are obtained due to the initial inrush which occurs immediately after the intake is opened and due to contamination from levels above the sampling point during the ascent of the sampler. In the Little Rock tests, the Texas sampler was operated as described above and also without using a stopper at all. In the latter type of tests, the sampler was lowered rapidly to the sampling point, and after a brief sampling period it was raised rapidly to the surface. In this case, contamination would occur on both the descending and ascending trips of the sampler.

The results of the tests made in the Little Rock District are summarized in Table 2.

TABLE 2

SUMMARY OF FIELD TESTS ON SEDIMENT SAMPLERS
BY U. S. ENGINEER OFFICE, LITTLE ROCK, ARKANSAS
DECEMBER 1944

Samplers compared	No. of comparisons	Concentration per cent	Sampling ratio	Remarks
Texas NS/Texas S	17	.192/.201	.96	Samples taken at 0.6 depth
Texas NS/P-43 DI	28	.140/.143	.98	Texas sampler at 0.6 depth. P-43 used as depth-integrator
Texas NS/P-43	19	.210/.220	.95	Samples taken at 0.6 depth
Texas NS/P-43	13	.118/.141	.84	Samples taken at 0.6 depth. Only sediment coarser than 0.01 mm.

S - Texas Sampler with stopper; NS - Texas sampler without stopper.

The sampling ratios indicated by these tests may not reflect the true sampling characteristics of the Texas sampler in respect to the US P-43 sampler. The results in Table 2 are consistent with those obtained in similar tests made by the Albuquerque Engineer District, which were discussed in the December 1944 Progress Report, but the possibilities of error in the Texas sampler are greater than would be evident in the Little Rock tests. Table 2 shows that the average concentrations obtained with the Texas sampler without the stopper at 0.6-depth are 5 per cent lower than those obtained with the P-43 sampler at the same points and that the former sampler missed about 16 per cent of the particle sizes larger than 0.01 millimeters in diameter. Had the latter comparison been made between 0.6-depth Texas samples and the integrated, or point integrated--velocity traverse samples, the discrepancy would have been greater. Vertical velocity curves corresponding to the point-integrated samples taken with the US P-43 sampler at various depths in the sampling verticals were not obtained and, consequently, the point integrated--velocity traverse method of determining the mean concentrations and sediment loads could not be applied. The sediment distribution curves described by samples taken with the US P-43 sampler show increasingly

higher concentrations of sediment toward the bottom of the stream and had size analyses of the samples been made, undoubtedly these would have shown increasingly larger percentages of coarser particles toward the bottom.

The Little Rock District points out that the P-43 sampler can be used under a greater range of stream conditions than is possible with the present model by attaching standard stream-gaging weights to the hanger bar. A device was used on the sampler to transmit the messenger weight impact to the tripping mechanism head around the current meter spiral connector and around the supplementary weights. These details will not be necessary in the proposed electrically operated point-integrator. Difficulties in operating the mechanical tripper on the P-43 sampler and in securing sample jars of proper size were reported by the Little Rock District. In addition, some trouble was caused by freezing of water in and around moving parts.

The Little Rock report questions whether the equalizing chamber is of sufficient capacity to sample to depths as great as 60 feet, such as are encountered in the lower Arkansas River. The volume of the air chamber in the P-43 sampler is 5 pints, five times the volume of the sample container. The Little Rock Engineer District operated the sampler in depths as great as 50 feet. The practical maximum sampling depth for the air chamber provided is not known, but it would be somewhat greater than 50 feet. Obviously, the weight of the P-43 sampler is inadequate for depths such as these and special models designed for these depths could be provided with more air capacity to balance pressures encountered at any practicable depth.

The Little Rock Engineer District proposes a depth-integrating sampler for use in the lower Arkansas River with the following features:

a. An air chamber similar to that in the P-43 sampler.

b. A valve to be opened by a lever upon striking the bottom, the sample being taken on the ascending trip.

c. Possibly a 1/8-inch nozzle and a quart sample jar.

Plans of the proposed sampler were submitted to the St. Paul District Corps of Engineers and were reviewed by Messrs. P. C. Benedict and M. E. Nelson. (See Appendix D.)

A point-integrator of the type now being developed appears to be preferable to a depth-integrator under the maximum sampling conditions indicated. The point-integrating sampler as such is not restricted as to transit velocity and provides data for a sediment distribution curve for the sampling vertical. Larger intake nozzles and shorter sampling periods

can be used to minimize the tendency to clog with debris. The point-samples, taken in equal periods of time, can be combined for a composite laboratory analysis if desired. Although more time and effort are required to sample a vertical by the point-integrating method than by the depth-integration, the data obtained in deep streams by the former method will be more indicative of the true sediment loads and the sediment characteristics of the stream.

4. Results of comparative field tests on suspended sediment samplers in the Colorado River and Rio Grande Basins, April and May 1945--Representatives of the U. S. Geological Survey and the Corps of Engineers conducted field tests in the Colorado River and Rio Grande basins between 16 April and 1 May 1945 to compare the sampling characteristics of the P-43, D-43, and other sediment samplers, and to obtain sediment data from various streams and stations within the area. At the suggestion of the Interdepartmental Committee, a representative of the Bureau of Reclamation participated in the field tests; and later a representative of the Soil Conservation Service took part in tests and sampler demonstrations in the Rio Grande.

The basic data obtained in the field tests on various samplers and the general observations of sampler performances are given in Appendix C.

The point-integrating sampler, US P-43, equipped with a trial solenoid tripping device performed satisfactorily in shallow depths and relatively clear water (Animas River at Farmington, New Mexico) but its performance in streams with higher concentrations (San Juan River near Bluff, Utah, and Colorado River at Lees Ferry, Arizona) was erratic and unsatisfactory. The water-sediment mixture penetraded into the solenoid and tripping mechanism causing it to stick. This prevented further use until the mechanism could be cleaned and dried.

A number of samples from the Rio Grande at Albuquerque, New Mexico, were collected with the P-43 sampler with the mechanical tripping device. The performance under the field conditions encountered (samples collected from highway bridge with stream gaging crane) was fairly satisfactory considering the weight of the experimental sampler. For higher stages the collection of weeds, grass, etc., on the suspension cable would not permit the drop weights to strike the tripping mechanism.

The field tests, in general, indicated that the P-43 sampler with a positive tripping mechanism electrically operated is necessary for sampling deep streams and for determining the vertical distribution and particle size of suspended sediments.

The 50-lb. experimental D-43 sampler with an auxiliary head and a 50- or 100-lb. C-type sounding weight as a bottom closing device instead of a flat plate was tested in the Colorado River at Lees Ferry and near

Grand Canyon. This arrangement closed the intake nozzle and air exhaust about 1 foot above the stream bed. The valve and tripping device never failed to operate at the former station but during 13-16 May at the latter station the mechanism had to be cleaned several times. A minor change in the end bearings and a rubber seal for the head cover would eliminate most of the field maintenance resulting from sand penetrating the valve at maximum depths.

A dual purpose sampler (AD-45) constructed by the Albuquerque District was tested in the San Juan River near Bluff and in the Colorado River at Lees Ferry. The shape of the sampler resembled the C-type sounding weight, being cast of lead with a steel tubing forming the sample container recess. The bottle is held in place by bronze springs in a cast aluminum nose which is fastened to the body by a tapered slip fit. A short section of suspension cable, which coils around the bottle when inserted into the recess, connects the head and the body to prevent accidental loss of the head. The sampler, which weighs 125 lbs., uses intake nozzles identical to those for the D-43 sampler. It was first used as a sounding weight with a current meter to obtain a set of velocity observations and then several sets of sediment samples were collected. The field operation of the sampler appeared satisfactory, but it is believed that the current meter should be "rated" when attached to the sampler in order to insure accurate velocity determinations. The weight of the sampler should also be reduced to about 75 lbs. for normal field use.

The conclusions for further improvement in the sediment sampling equipment are as follows:

1. Point-integrating sampler

   a. Construct a second test model weighing about 75 lbs. with an electrical tripping device for opening and closing the intake valve and air exhaust.

2. Depth-integrating sampler

   a. Construct a sampler weighing 75-100 lbs. with an auxiliary head and bottom closing device for use in deep streams. The shape of the sampler should approximate that of the present 100-lb. C-type sounding weight.

   b. Develop a wading or hand sampler with the same filling characteristics as the present D-43 sampler.

   c. Adapt a standard head to the heavy sampler mentioned under item (a) in order that the sampler itself may be used as a sounding weight. This adaptation will

permit, as may be desired or feasible, the consecutive determination of stream depth and velocities together with the collection of sediment samples without removing the current meter.

5. Report of local meeting on the development and construction of point- and depth-integrating samplers held on 2 July 1945 in the Corps of Engineers St. Paul District Sub-Office, Hydraulic Laboratory, Iowa City, Iowa--As the Omaha and Little Rock Engineer District Offices had indicated an interest in obtaining an improved point-integrating sampler, they were invited to review the preliminary plans for an electrically operated sampler, to discuss the field conditions under which the sampler would be operated, and to discuss plans for construction of the pilot model and the field samplers.

The following personnel were present at the meeting:

U. S. Engineer District Offices

R. J. Pafford and B. T. Mitchell, Omaha, Nebraska; E. G. Smith, Little Rock, Arkansas; and M. E. Nelson, St. Paul, Minnesota;

U. S. Geological Survey District Office

L. C. Crawford and P. C. Benedict, Iowa City, Iowa.

After discussion of the sediment sampling equipment needed as outlined in the progress report, "Field Tests of Suspended Sediment Samplers", and as authorized by the Interdepartmental Committee on 10 April 1945, it was agreed that plans for an electrically operated point-integrating sampler would be furnished to the Omaha District Engineer Office as soon as practicable; that the Omaha Office would have the patterns and two castings made locally; that the heads and electrical equipment would be constructed in Iowa City or some near-by city where close supervision could be given the machine work by Messrs. Nelson and Benedict. A model of the proposed electrical tripping device and escapement for operation of the point-integrating sampler valve was demonstrated. The principle of operation was considered satisfactory and the device was approved for development of details.

Mr. Smith presented the plans of the Little Rock District for construction of a depth-integrating sampler for which contracts have been let. As requested, Messrs. Nelson and Benedict reviewed the plans and made certain comments on the design of the sampler. (See Appendix D.)

The consensus of the meeting was that the independent work on sampler development carried out by the Little Rock District could have been avoided had the field offices of the cooperating agencies been advised promptly of actions taken by the Committee at the meeting of 10 April 1945. The minutes of future meetings, therefore, should be distributed to field offices of the respective agencies as soon as practicable after each meeting.

6. Report of joint conference with Tennessee Valley Authority engineers on the development of point- and depth-integrating sediment sampling equipment and a field demonstration of the US D-43 sampler--At its meeting of 10 April 1945 the Interdepartmental Committee decided that representatives of other agencies immediately connected with the development of the US sediment sampling equipment should visit the Tennessee Valley Authority to discuss sediment sampling problems, to observe field conditions, and to demonstrate the use of the US D-43 sampler. On 25 October a joint conference was held in the TVA office, Hydraulic Section, Knoxville, Tennessee. The following personnel were present:

Tennessee Valley Authority

A. S. Fry, M. A. Churchhill, and Messrs. Smallshaw and Burleigh

Corps of Engineers

M. E. Nelson, St. Paul, Minnesota

Geological Survey

F. M. Bell, A. O. Patterson, M. J. Slaughter, J. O. Joerns, Chattanooga, Tennessee; P. C. Benedict, Iowa City, Iowa

The use and limitations of both the point- and depth-integrating samplers, constructed at the Hydraulics Laboratory in Iowa City, were discussed. A 50-lb. D-43 sampler used by the Geological Survey in Iowa was presented for inspection. Preliminary plans illustrating the proposed electrically operated point-integrating sampler were left with the Authority for review and comment.

The field demonstration of the D-43 sampler was made at the gaging station on the French Broad River near Newport, Tennessee. Sediment samples were collected with the TVA and D-43 samplers.

Messrs. Benedict and Nelson held general conferences on sediment sampling equipment, including presentation of the D-43 sampler for inspection, at the U. S. Engineer Offices, Nashville, Tennessee, and Louisville, Kentucky; U. S. Geological Survey, Louisville, Kentucky, Indianapolis, Indiana, and Urbana, Illinois.

7. Development of the electrically operated point-integrating sampler (P-46)--The second experimental point-integrating sampler (P-43) was equipped with a mechanical valve-tripping mechanism activated by the impact from messenger weights. Field tests on this sampler were made by district offices of the cooperating agencies during 1943, 1944, and 1945. Field tests were also made by representatives of the Interdepartmental Committee in the Colorado River and Rio Grande Basins in 1945. During a part of the latter tests, the sampler was equipped with an experimental electrical valve-tripping mechanism.

A simplified laboratory model of the valve-tripping mechanism was constructed for test purposes. Several sizes of solenoids were tested, each wound with insulated copper wire of a different diameter to obtain the most efficient size of both wire and solenoid. These tests indicated that the tripping mechanism can be operated on 18 to 24 volts using six-volt lantern batteries with a 100-ft. length of Ellsworth two-conductor cable and type-B sounding reel.

The sampler, as planned, will weigh about 90 lbs. in air and about 70 lbs. when submerged in water. The shape is based on the 150-lb. C-type weight. The use of the pint milk bottle as a sample container, however, requires a modification in shape at the forward end of the sampler.

8. Modification of the plans for the 50-lb. D-43 sampler--To provide a set of working drawings and specifications from which any contractor could make suitable patterns for the castings and do the necessary machine work, the original drawings were revised. The revised plans include the improved type of head catch developed at Iowa City, and minor changes in the shape of the body and the hinge for the head.

Copies of these plans were furnished to the Chief Hydraulic Engineer of the Geological Survey for distribution to members of the Interdepartmental Committee and for use in letting a contract for the construction of 35 samplers.

PROGRESS REPORT

COMPARATIVE FIELD TESTS ON SUSPENDED SEDIMENT SAMPLERS

APPENDICES A TO D, INCLUSIVE

JANUARY 1946

APPENDIX - A

FIELD TESTS ON SEDIMENT SAMPLERS
(US D-43, US P-43, Omaha, and Omaha Modified Samplers)

by

Corps of Engineers, U. S. Army
Omaha, Nebraska

1. During the September and October tests, the Little Sioux River at Kennebec and the Missouri River at Omaha were flowing normally. Although no attempt was made to determine the mean sediment concentration in the entire river cross sections, no exceptional sediment loads appeared to be carried by either stream.

2. The Omaha Modified sampler is a regular Omaha sampler fitted with a 3/16-inch intake tube facing into the current, collecting samples from a point about 2-1/2 inches above and 4 inches forward of the intake orifice in the regular Omaha sampler. The Omaha Modified sampler has a 4-inch vertical exhaust tube with the top beveled in the same fashion as for the regular Omaha sampler.

3. Two sampling outfits were used to take the corresponding samples as simultaneously as possible. Due to the inconsistency in operation of the P-43 sampler it was necessary to first observe whether or not the sample taken was usable before the corresponding sample was taken with the other samplers. In order that a minimum of variation in stream conditions would be encountered the two outfits were placed approximately 5 feet apart. In the October studies the position of the samplers was changed from one outfit to the other after about half the samples had been taken. On the Missouri River where depths of over 10 feet prevailed, five points were taken in a vertical to make one composite sample. On the Little Sioux River where the depth was less than 10 feet only three points were taken in a vertical.

4. In all cases, point-integrated samples were analyzed separately by the laboratory. Because such samples were taken at specified percentages of stream depth in accordance with the Luby method, the mean concentration in the entire vertical was calculated as an average of the sample concentrations.

5. Preliminary correlations of the results of the comparison tests have been made by this office. (See Tables A-1 to A-6 and Figs. A-1 and A-2.) There is considerable variation in the concentrations obtained by a particular sampler in a number of trials made under essentially the same stream conditions. This applies more to the Omaha Regular and Omaha Modified samplers than to the P-43.

6. The mean concentrations obtained from a number of trials of each point-integrating sampler at the various depths and ratios of the concentrations obtained by the other samplers to those obtained by the P-43 are given in Tables A-1, A-2 and A-3. Comparisons are made to the P-43 sampler because it was used in all four groups of trials. The mean concentrations in the entire verticals as obtained by the various samplers are given. If depth integration data for the D-43 were available they were shown directly under the mean concentration for other methods.

7. In drawing conclusions from these experiments, a basis for comparison is difficult to determine; that is, which sampler most nearly approaches the ideal of obtaining the true sediment concentration in the vertical. On the basis of experiments made at Iowa City when the D-43 sampler was designed, it should probably approach the ideal very closely. The P-43 results conform very closely with the D-43 results, particularly for higher sediment concentrations, however there is a decided lack of correlation with the Omaha Regular sampler.

8. These experiments show that the Omaha Regular sampler collects more sediment than either the D-43 or the P-43. There is as great or greater variation from the mean concentration at any depth in the samples taken with the Omaha Regular sampler than with the P-43. This is possibly due to the size of sediment collected, because there is a tendency for greater variation to occur near the bottom of the stream than elsewhere in the vertical. The Omaha Regular sampler collects more coarse material than the P-43. This might be due to collection of comparatively large particles falling almost vertically through the water into the intake or onto the cap where they could wash into the intake hole. Such material would not be collected to any such degree by an intake which faces into the stream. This condition also would apply to the vertical exhaust tube of both the Omaha samplers to a lesser degree.

9. In order to supplement information from other offices on field operation of the P-43 sampler, the following summary of operation notes is included. Two hundred trials were made with the P-43 sampler to secure the one hundred twenty-one samples analyzed. A log of operations indicates failures due to the following:

Valve failed to close	24 times
Valve failed to open	12 times
Valve failed to open until 2nd wt. was dropped	8 times
Valve open but no sample in jar	6 times
Time valve open too short	5 times
Time valve open too long	6 times
Tripping mechanism bound by sediment	7 times
Sample head unlatached	2 times

Vertical rod broke off near striking bar	2 times
Hammer pin stuck and had to be filed down	2 times
Wrong adjustment on set screws	2 times
Spring on valve loose	1 time
Pin in front of hammer pin stuck with sediment	1 time
Nuts on end of plunger rods loose	1 time

The use of wrong size of weights may have caused part of the valve failures noted above.

10. Difficulty was experienced with sediment binding moving parts of the tripping mechanism; and much time and effort were lost determining the time the sampler should be open and in selecting a weight that would operate the valve properly and not harm the tripping mechanism.

11. With the P-43 sampler it was impossible to take equal volumes of sample from each section of the vertical. An attempt was made to close the sample intake with a cork float when the jar was full but the float did not make a satisfactory closure.

12. Certain improvements in design would facilitate the operation and increase the accuracy of the P-43. As indicated in paragraph 9, mechanical failure of the tripping mechanism caused most of the difficulty in operating the sampler. A solenoid or other electrical mechanism for opening the valve should provide more positive action. Provision could be made for the valve to close when a given volume of sample had been obtained.

13. This office is satisfied with the valve intake used on the P-43 sampler. During the tests, the spring-actuated valve did not bind with sediment or give any other noticeable trouble. The diving-bell principle to prevent initial inrush is a desirable feature. The P-43 sampler will approach the ideal for precise field suspended-sediment measurement when the problems involving the tripping mechanism are solved.

TABLE A-1

COMPARISON TESTS OF SUSPENDED-SEDIMENT SAMPLERS

Depth in feet	OMAHA REGULAR SAMPLER: Sample volume cc	OMAHA REGULAR SAMPLER: Concentration sample gm/liter	US P-43 SAMPLER: Sample volume cc	US P-43 SAMPLER: Time submerged secs.	US P-43 SAMPLER: Concentration sample gm/liter	RATIO: Omaha regular to P-43
6 Sept. 1944, Little Sioux River, Kennebec, Iowa, depth 7.8 ft., Sta. 1+15						
1.6	305	1.246	355	20	0.958	
4.7	315	1.556	275	20	1.345	
6.2	330	1.333	263	25	1.559	
Mean		1.378			1.287	1.071
1.6	320	1.375	340	21	0.941	
4.7	325	1.354	420	30	1.167	
6.2	330	1.758	213	35	1.502	
Mean		1.496			1.203	1.244
1.6	320	1.094	400	22	0.925	
4.7	305	1.311	475	30	1.200	
6.2	335	1.552	385	35	1.325	
Mean		1.319			1.150	1.147
1.6	310	0.839	405	22	0.938	
4.7	320	1.781	440	30	1.318	
6.2	305	1.410	470	28	1.106	
Mean		1.343			1.121	1.198
1.6	305	1.148	395	22	0.886	
4.7	325	1.354	445	28	1.079	
6.2	315	1.778	455	30	1.341	
Mean		1.427			1.102	1.295
1.6	310	1.097	405	22	0.988	
4.7	305	1.311	445	28	1.281	
6.2	305	1.213	450	30	1.355	
Mean		1.207			1.208	0.999
1.6	315	1.048	413	22	1.041	
4.7	330	1.182	400	28	1.175	
6.2	325	1.262	425	30	1.412	
Mean		1.164			1.209	0.963

TABLE A-1 (Cont.)

COMPARISON TESTS OF SUSPENDED-SEDIMENT SAMPLERS

Depth in feet	OMAHA REGULAR SAMPLER: Sample volume cc	OMAHA REGULAR SAMPLER: Concentration sample gm/liter	US P-43 SAMPLER: Sample volume cc	US P-43 SAMPLER: Time submerged secs.	US P-43 SAMPLER: Concentration sample gm/liter	RATIO: Omaha regular to P-43
9 Sept. 1944 Missouri River at Omaha Depth 14.6 ft.						
Sta. 1+85			Sta. 1+80			
1.3	330	1.485	375	17	1.547	
3.8	310	1.677	435	20	1.655	
6.4	315	2.095	470	22	1.894	
9.2	315	2.032	315	25	2.000	
12.7	320	2.813	385	28	2.494	
Mean		2.020			1.918	1.053
1.3	305	1.639	380	17	1.579	
3.8	340	1.824	455	20	1.780	
6.4	310	1.742	480	22	1.813	
9.2	320	2.094	465	25	1.935	
12.7	325	2.369	400	28	2.700	
Mean		1.934			1.961	0.986
12 Sept. 1944 Missouri River at Omaha Depth 13.2 ft.						
Sta. 1+90			Sta. 1+85			
1.1	320	1.688	325	17	1.385	
3.4	310	1.548	355	20	1.409	
5.8	330	1.667	400	22	1.450	
8.3	310	2.032	410	25	1.439	
11.5	305	2.393	310	25	2.129	
Mean		1.866			1.562	1.195
1.1	325	2.123	345	18	1.217	
3.4	320	1.719	340	21	1.529	
5.8	325	1.600	445	22	1.506	
8.3	310	1.806	385	25	1.481	
11.5	320	1.344	395	28	1.696	
Mean		1.718			1.486	1.156

TABLE A-1 (Cont.)

COMPARISON TESTS OF SUSPENDED-SEDIMENT SAMPLERS

Depth in feet	OMAHA REGULAR SAMPLER: Sample volume cc	OMAHA REGULAR SAMPLER: Concentration sample gm/liter	US P-43 SAMPLER: Sample volume cc	US P-43 SAMPLER: Time submerged secs.	US P-43 SAMPLER: Concentration sample gm/liter	RATIO Omaha regular to P-43
13 Sept. 1944 Missouri River at Omaha Depth 12.8 ft.						
	Sta. 1+90			Sta. 1+85		
1.1	310	1.290	350	19	1.171	
3.3	325	1.415	325	21	1.169	
5.6	300	1.633	340	23	1.500	
8.1	315	1.651	450	25	1.444	
11.1	345	1.739	360	28	1.833	
Mean		1.546			1.423	1.086
1.1	310	1.548	310	17	1.194	
3.3	295	1.661	385	21	1.351	
5.6	315	1.651	365	23	1.534	
8.1	325	1.692	410	25	1.634	
11.1	315	2.286	400	28	1.725	
Mean		1.768			1.488	1.188
1.1	325	1.385	310	19	1.516	
3.3	300	3.033	430	25	1.465	
5.6	300	2.000	430	23	1.535	
8.1	310	2.000	385	25	1.974	
11.1	305	2.459	355	28	1.746	
Mean		2.175			1.647	1.321
1.1	340	1.441	365	19	1.370	
3.3	355	1.972	350	21	1.371	
5.6	315	1.841	360	23	1.444	
8.1	305	2.197	360	23	2.250	
11.1	310	2.742	370	28	1.730	
Mean		2.039			1.633	1.249
23 Sept. 1944 Missouri River at Omaha Depth 11.6 ft.						
	Sta. 1+85			Sta. 1+80		
1.0	308	1.916	355	19	2.028	
3.0	335	2.000	405	22	1.852	
5.1	305	2.262	410	23	1.805	
7.3	320	2.156	428	25	1.986	
10.1	303	2.112	385	27	2.286	
Mean		2.089			1.991	1.049

TABLE A-2

COMPARISON TESTS OF SUSPENDED-SEDIMENT SAMPLERS
MISSOURI RIVER AT OMAHA
10 October 1944 Depth 11.4 ft.

Depth in feet	OMAHA REGULAR SAMPLER Sta. 1+85: Sample volume cc	OMAHA REGULAR SAMPLER Sta. 1+85: Concentration sample gm/liter	US P-43 SAMPLER Sta. 1+80: Sample volume cc	US P-43 SAMPLER Sta. 1+80: Time submerged secs.	US P-43 SAMPLER Sta. 1+80: Concentration sample gm/liter	RATIO: Omaha regular to P-43
1.0	335	1.164	325	18	1.108	
3.0	320	1.094	345	20	1.072	
5.0	300	1.333	360	23	1.056	
7.2	315	1.238	390	25	1.205	
9.9	325	1.385	320	27	1.438	
Mean		1.243			1.176	1.057
D-43			355	21.5	1.183	
1.0	320	1.156	345	18	1.159	
3.0	310	1.161	360	20	1.056	
5.0	315	1.365	380	25	1.263	
7.2	305	1.705	390	25	1.231	
9.9	315	2.190	365	28	1.315	
Mean		1.515			1.205	1.257
D-43			350	22.6	1.143	
1.0	305	1.377	315	18	0.921	
3.0	300	1.367	365	20	0.959	
5.0	300	1.167	365	23	1.068	
7.2	315	1.714	340	25	1.176	
9.9	305	2.825	345	28	1.449	
Mean		1.690			1.115	1.516
D-43			375	23.5	1.067	
1.0	305	1.344	345	18	1.043	
3.0	300	1.067	390	20	1.026	
5.1	305	1.279	400	23	1.250	
7.3	320	1.625	390	25	1.077	
10.1	325	1.877	355	28	1.268	
Mean		1.438			1.133	1.269
D-43			330	20	1.030	
1.0	300	1.133	330	18	1.121	
3.0	305	1.443	350	20	0.886	
5.1	325	1.231	420	23	1.048	
7.3	310	1.548	440	25	1.068	
10.1	310	1.968	365	28	1.479	
Mean		1.465			1.120	1.308
D-43			335	26	1.045	

TABLE A-3

COMPARISON TESTS OF SUSPENDED-SEDIMENT SAMPLERS
LITTLE SIOUX RIVER AT KENNEBEC, IOWA
4,5 October 1944 Depth 5.0 ft.

Depth in feet	OMAHA REGULAR SAMPLER Sta. 1+03		OMAHA MODIFIED SAMPLER Sta. 1+03		US P-43 SAMPLER Sta. 1+07			RATIO
	Sample volume cc	Concentration sample gm/liter	Sample volume cc	Concentration sample gm/liter	Sample volume cc	Seconds submerged	Concentration sample gm/liter	Omaha regular to US P-43
1.0	300	0.633	345	0.522	320	20	0.500	
3.0	255	0.431	350	0.429	400	22	0.550	
4.0	305	0.787	355	0.592	350	26	0.514	
Mean		0.617		0.514			0.521	1.184
D-43					285	21	0.596	
1.0	300	0.600	320	0.469	330	20	0.424	
3.0	300	0.367	350	0.486	315	22	0.508	
4.0	320	0.813	355	0.423	355	26	0.592	
Mean		0.593		0.459			0.508	1.167
D-43					370	24	0.622	
1.0	310	0.484	350	0.400	315	20	0.444	
3.0	315	0.540	350	0.543	330	22	0.605	
4.0	325	0.769	360	0.639	355	26	0.620	
Mean		0.600		0.527			0.556	1.079
D-43					365	25	0.548	

TABLE A-3 (Cont.)

COMPARISON TESTS OF SUSPENDED-SEDIMENT SAMPLERS
LITTLE SIOUX RIVER AT KENNEBEC, IOWA
4,5 October 1944 Depth 5.0 ft.

Depth in feet	OMAHA REGULAR SAMPLER Sta. 1+03		OMAHA MODIFIED SAMPLER Sta. 1+03		US P-43 SAMPLER Sta. 1+07			RATIO
	Sample volume cc	Concentration sample gm/liter	Sample volume cc	Concentration sample gm/liter	Sample volume cc	Seconds submerged	Concentration sample gm/liter	Omaha regular to US P-43
1.0	335	0.896	350	0.829	325	20	0.431	
3.0	325	0.554	355	0.620	355	22	0.451	
4.0	300	0.700	350	0.800	365	27	0.630	
Mean		0.717		0.750			0.504	1.423
D-43					385	26	0.416	
1.0	300	0.633	355	0.620	320	20	0.438	
3.0	305	0.656	335	0.567	445	22	0.472	
4.0	350	1.114	325	0.615	295	22	0.610	
Mean		0.801		0.601			0.507	1.580
D-43					330	23	0.515	
1.0	315	0.603	355	0.507	315	20	0.540	
3.0	300	0.600	345	0.696	280	22	0.571	
4.0	315	0.857	355	0.535	295	25	0.712	
Mean		0.687		0.579			0.608	1.130
D-43					350	24	0.343	

TABLE A-3 (Cont.)

COMPARISON TESTS OF SUSPENDED-SEDIMENT SAMPLERS
LITTLE SIOUX RIVER AT KENNEBEC, IOWA
4,5 October 1944 Depth 5.0 ft.

Depth in feet	OMAHA REGULAR SAMPLER Sta. 1+03		OMAHA MODIFIED SAMPLER Sta. 1+03		US P-43 SAMPLER Sta. 1+07			RATIO
	Sample volume cc	Concentration sample gm/liter	Sample volume cc	Concentration sample gm/liter	Sample volume cc	Seconds submerged	Concentration sample gm/liter	Omaha regular to US P-43
1.0	330	0.606	355	0.535	320	20	0.531	
3.0	320	0.781	355	0.507	330	22	0.424	
4.0	360	0.750	355	0.592	285	25	0.667	
Mean		0.712		0.545			0.541	1.316
D-43					375	23	0.293	
1.0	325	0.462	315	0.508	300	20	0.333	
3.0	315	0.508	350	0.486	300	22	0.467	
4.0	315	0.540	325	0.554	250	25	0.520	
Mean		0.503		0.516			0.440	1.143
D-43					320	20	0.563	
1.0	325	0.462	350	0.371	315	21	0.349	
3.0	320	0.563	350	0.486	330	25	0.424	
4.0	350	0.600	320	0.438	340	28	0.647	
Mean		0.542		0.432			0.473	1.146
D-43					355	25	0.394	
1.0	320	0.594	360	0.472	325	21	0.369	
3.0	315	0.794	355	0.479	340	25	0.500	
4.0	325	0.800	355	0.592	350	28	0.571	
Mean		0.729		0.514			0.480	1.519
D-43					345	24	0.493	

TABLE A-4

OPERATION TESTS OF OMAHA REGULAR SAMPLER
MISSOURI RIVER AT OMAHA
10 October 1944 Sta. 1+80 Depth 11.0 ft.

Depth in feet	FLOAT NORMAL MAKING GOOD SEAL: Sample volume cc	FLOAT NORMAL MAKING GOOD SEAL: Concentration sample gm/liter	FLOAT INVERTED MAKING POOR SEAL: Sample volume cc	FLOAT INVERTED MAKING POOR SEAL: Concentration sample gm/liter	RATIO: Inverted to normal
1.0	315	1.111	375	1.253	
2.9	335	1.075	340	1.441	
4.8	325	1.446	350	1.543	
6.9	305	1.279	350	1.400	
9.6	315	1.778	355	2.085	
Mean		1.338		1.544	1.154
1.0	310	1.290	360	1.417	
2.9	315	1.206	360	1.444	
4.8	315	1.143	360	1.444	
6.9	300	1.033	365	1.616	
9.6	325	1.600	345	2.174	
Mean		1.254		1.619	1.291
1.0	310	1.129	355	1.155	
2.9	320	1.156	365	1.342	
4.8	320	1.313	350	1.314	
6.9	315	1.238	350	1.514	
9.6	315	1.587	350	1.971	
Mean		1.285		1.459	1.135
1.0	315	1.175	365	1.151	
2.9	325	1.231	350	1.171	
4.8	315	1.270	340	1.353	
6.9	325	1.692	360	1.500	
9.6	330	1.818	365	1.973	
Mean		1.437		1.430	0.995
1.0	325	1.231	355	1.239	
2.9	305	1.279	315	1.206	
4.8	320	1.344	355	1.380	
6.9	305	1.672	355	1.437	
9.6	310	1.935	345	4.638	
Mean		1.492		1.980	1.327

TABLE A-5

COMPARISON TESTS OF OMAHA-TYPE SUSPENDED-SEDIMENT SAMPLERS
MISSOURI RIVER AT OMAHA
23 September 1944 Depth 10.5 ft.

Time submerged secs.	OMAHA REGULAR SAMPLER: Sample volume cc	Concentration sample gm/liter	Ratio*	OMAHA MODIFIED SAMPLER 3/16" diam. orifice: Sample volume cc	Concentration sample gm/liter	Ratio*
25	320	2.156	1.000	345	2.174	0.992
900	335	2.418	0.892	340	9.412	0.229
900 (1)	345	18.725	0.115			
900 (2)	315	2.667	0.808			
* (3)	335	2.657	0.811	350	5.229	0.412
900 (4)	450	17.356	0.124	440	15.455	0.140

* Ratio of sediment concentration for the first sample to sediment concentration in the individual sample

(1) Float upside down in sampler

(2) Float right side up in sampler

(3) Sampler left in sampling position minimum time to fill, then raised and lowered between sampling level and river surface ten times. Both samples.

(4) Float removed, both samples

TABLE A-6

SUMMARY OF COMPARATIVE SAMPLES
[Average Sediment Concentration in Samples in grams/liter]

Stream and date	Number of Samples	SEDIMENT SAMPLER			
		P-43	D-43	Omaha Reg.	Omaha Mod.
Missouri R.					
9-23 Sept.	40[a]	1.683		1.872	
10 Oct.	25	1.150		1.470	
10 Oct.	5		1.094		
Little Sioux					
6 Sept.	18[b]	1.193		1.332	
4,5 Oct.	24[c]	0.516		0.623	0.511
4,5 Oct.	8		0.482		

a 9 series of samples in the vertical, but No. 7 omitted from averages
b 7 series of samples in the vertical, but No. 4 omitted from averages
c 10 series of samples in the vertical, but Nos. 4 & 5 omitted from averages

NOTE: This table is based on data of Tables A-1, A-2, and A-3. Samples with the P-43, Omaha Regular, and Omaha Modified samplers were taken at 3 or 5 points in the vertical to give an average concentration for the vertical. Samples with the D-43 were depth-integrated over the entire vertical. Some groups of samples were discarded from the averages because samples with the Omaha Regular sampler were inconsistent for that group.

Sampling ratios of Table 1 in the text are based on these average concentrations.

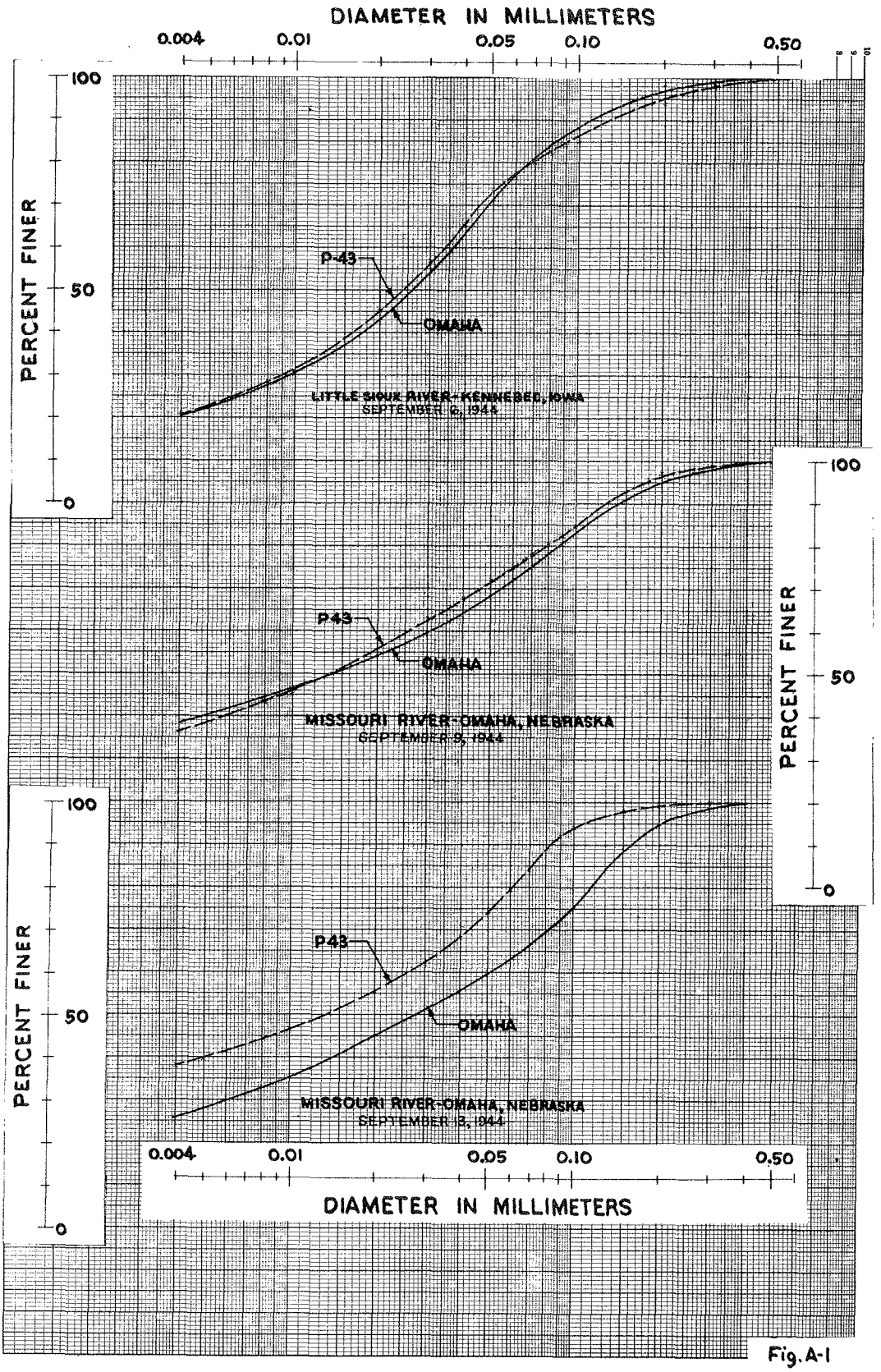
DIAMETER IN MILLIMETERS
0.004
0.01
0.05
0.10
0.50
PERCENT FINER
100
50
0
P-43
OMAHA
LITTLE SIOUX RIVER-KENNEBEC, IOWA
SEPTEMBER 6, 1944
P43
OMAHA
MISSOURI RIVER-OMAHA, NEBRASKA
SEPTEMBER 8, 1944
P43
OMAHA
MISSOURI RIVER-OMAHA, NEBRASKA
SEPTEMBER 13, 1944

Fig. A-1

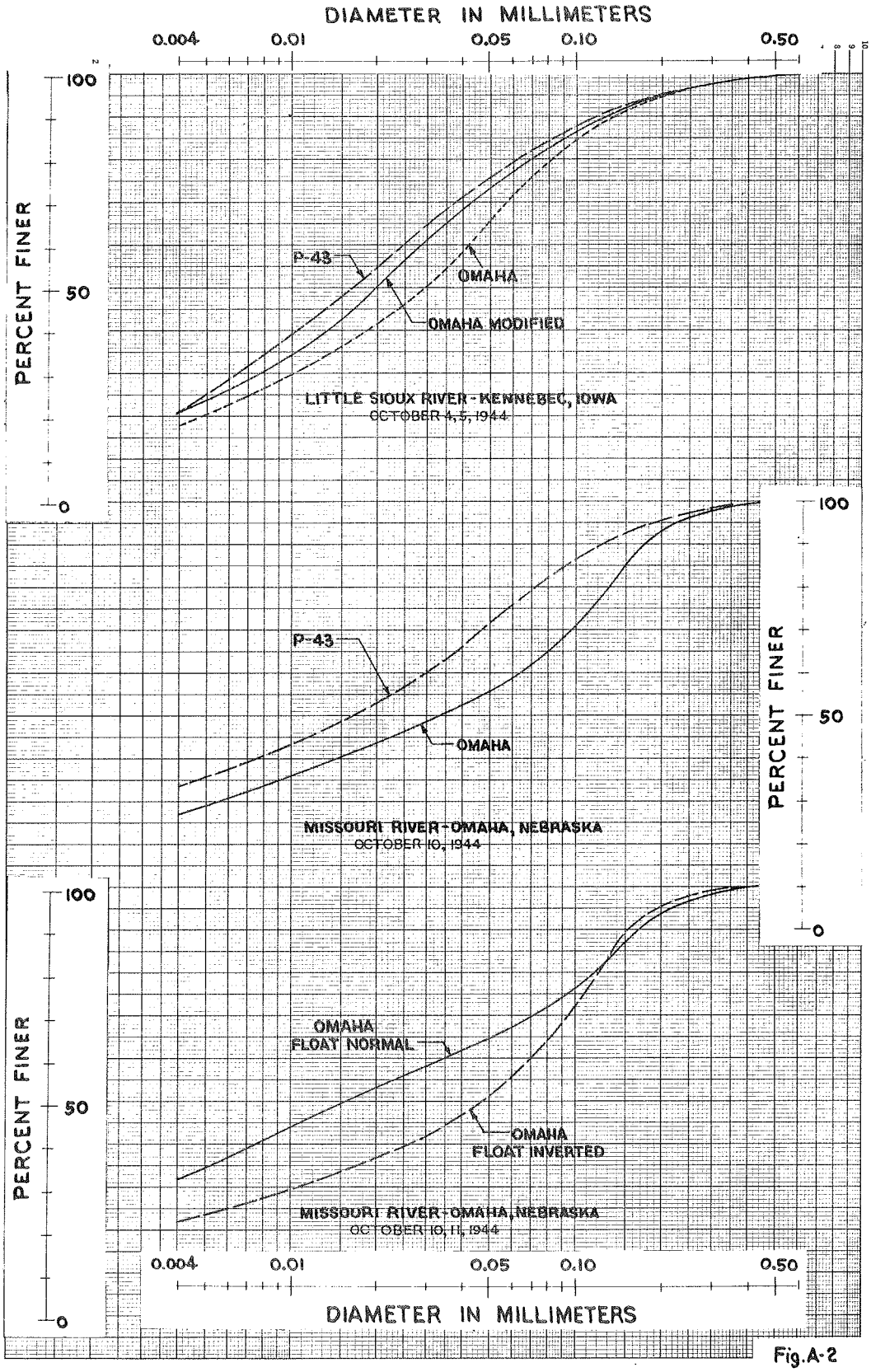
DIAMETER IN MILLIMETERS
0.004
0.01
0.05
0.10
0.50
PERCENT FINER
100
50
0
P-43
OMAHA
OMAHA MODIFIED
LITTLE SIOUX RIVER - KENNEBEC, IOWA
OCTOBER 4, 5, 1944
P-43
OMAHA
MISSOURI RIVER - OMAHA, NEBRASKA
OCTOBER 10, 1944
OMAHA
FLOAT NORMAL
OMAHA
FLOAT INVERTED
MISSOURI RIVER - OMAHA, NEBRASKA
OCTOBER 10, 11, 1944
DIAMETER IN MILLIMETERS

Fig. A-2

APPENDIX - B

FIELD TESTS ON SEDIMENT SAMPLERS
(US P-43 and Texas Samplers)
by
Corps of Engineers, U. S. Army
Little Rock, Arkansas

1. Introduction. - These comments on the US P-43 Sampler are based on field tests conducted in the Little Rock Engineer District between 29 November to 26 December 1944. Sediment samples were taken from the Arkansas River at the Main Street Bridge in Little Rock, Arkansas. During the period of the tests, one small rise reached a stage of about 14 feet on the Little Rock gage, which corresponds to a discharge of about 130,000 cfs. The minimum stage at which tests were made was 1.7 ft. on the gage, which corresponds to a flow of about 11,000 cfs. Point samples were taken in the vertical with the P-43 sampler at the bed of the stream, at 0.8, 0.6, 0.4, and 0.2 depths, and at the water surface. Depth-integrated samples were taken with the P-43 sampler at each station where the requirements for minimum and maximum rates of raising the sampler could be satisfied. Samples for comparison were taken with the Texas-type sampler at 0.6 depth with the bottle open when lowered and raised, and with the bottle closed when lowered but open when raised. About 146 samples were taken with the P-43 sampler.

2. Bypass frame for spiral connector. - A regular discharge rig was used to sample the Arkansas River from the Main Street Bridge. A bypass frame was used so that the regular spiral connector did not prevent operation of the messenger weights. This frame consisted of a piece of 3/16-in. by 1-1/2-in. iron bar bent into a rectangle about 2-1/2 in. wide and 6 in. high. A slot was cut through the bottom large enough to insert a short hanger bar which connected the spiral connector and the sampler. Another slot was cut in the top of the frame to accommodate the 0.10-in. Ellsworth meter cable. The slot was tapped for a set screw to hold the bypass frame in place. The frame rested on the anvil of the sampler and had enough clearance above the top of the connector to allow for the 1/4-in. movement of the anvil. The bypass frame was entirely satisfactory, and it made the use of a second discharge rig for taking samples with the Texas sampler unnecessary.

3. Methods for adding weights. - During the December rise considerable vertical angle existed in the cable supporting the sampler requiring attachment of weights to the sampler. Two methods were devised for attaching the weights. One method for adding two 15-lb. or two 25-lb. weights was by use of a 5/16-in. steel rod long enough to pass through the P-43 sampler pin hole and support a weight a short distance out from each side of the sampler. The other method was to use a bypass frame similar to that described in the preceding paragraph. The frame was made from 1/8-in. by 1-in. iron bar and extended around both the spiral connector and the weight which was suspended on the hanger bar above the sampler. The frame

functioned satisfactorily. It was made from a smaller size bar than the frame for the spiral connector alone and was rather flexible but did not bend under the impact of the weights.

4. Weight of sampler. - The small weight of the P-43 sampler (38 pounds) is considered less of a disadvantage than has been contended by other offices that have used the sampler. If the sampler were made heavy enough for use in extreme high water it would be too heavy for convenient use during low and medium stages. A sampler weighing between 30 and 60 pounds with provision for adding weights during high water would be the most practicable one for use in this District.

5. Tripping mechanism. - The valve tripped satisfactorily up to depths of about 35 feet when the velocity and the sediment concentration were low. However, during the December rise, the maximum depth of water was about 50 ft. and the messenger weights did not consistently trip the valve in the greater depths. Frequently the valve could not be tripped when sampling on the bottom even after cleaning and oiling the mechanism of the sampler. The mechanism of the sampler had to be cleaned frequently during high stages when the sediment concentration was high. The horizontal plunger pin stuck fast several times, and the valve cylinder became so clogged with sediment that the spring would hardly turn the valve. Since a large percentage of the suspended material in the lower Arkansas River is less than 0.0001 inch in size, it would be difficult to design a point-integrating sampler that would prevent all sediment from reaching the mechanism. The use of an inclosed solenoid for releasing the valve and a waterproof head to keep out sediment might eliminate the more important defects in the sampler.

6. Effect of freezing temperatures. - The temperature was below freezing part of the time during the December rise, and water froze in the sampler parts when raising the sampler from the water surface to the bridge. Ice collected beneath the bottom of the piston in the sample jar compartment, and new jars could not be inserted without first thawing out the sampler. Further waterproofing of the sampler might overcome this difficulty.

7. Sampler jar. "Difficulty was encountered in obtaining sufficient mason jars. Many of the jars were too large in diameter to fit in the sampler and it was necessary to file off part of the ribs of the jars to make them fit. An additional 1/16-in. in the diameter of the sample container would permit using any pint mason jars.

8. Shape of sampler. -The sampler yawed some in fast water when no weights were attached. A sampler with a more streamlined shape and a flat bottom similar to that on the Columbus weight would be desirable.

The sampler tended to turn over on its side on reaching the bottom. The cable was badly bent at a distance above the spiral connector frame equal to the length of the large size messenger weight. This indicates that the sampler was partially on its side when at least one of the bottom samples was taken and as a result the messenger weight bent the cable. Water may have entered the sampler through the exhaust tube when sampling on the bottom, as it was found that water would flow rapidly into the exhaust when the sampler was tilted about 30 degrees toward the side on which the exhaust is located.

9. Air chamber. The question arises as to the extent to which the present design of the air chamber limits the depth at which a sample can be taken. At depths of 60 feet, which are experienced on the lower Arkansas River, the air in the chamber of the P-43 sampler would be compressed to about one-third of the volume of the chamber, and water might enter the bottle from the compression chamber.

10. Use of sampler for depth integration. The P-43 sampler was tested as a depth integrator by lowering it to the bottom, opening the nozzle, and taking the sample during the raising period. During the high stages in December, the sampler could not be raised in time to prevent filling at stations where the water was deep and the velocity swift. The river section at the bridge is comparatively deep during periods of low stages, and difficulty was experienced during these periods in meeting the limiting value of 0.36 for the ratio of rate of raising to the mean velocity in the vertical (R_r/V_m).

11. Sediment Concentration in samples. The concentrations, in percent by weight, of the point-integrated samples taken to define the sediment distribution in the vertical on 8, 9, 10, 14, 15, and 16 Dec. are shown in Figs. B-1 and B-2 together with the corresponding samples taken at 0.6 depth with the Texas sampler or depth-integrated with the P-43. The concentrations of depth-integrated samples and point samples at 0.6 depth are shown in Tables B-1 and B-2. Table B-1 shows the total sediment concentration and Table B-2 shows only the concentration of sediment coarser than 0.010 mm.

The average concentration for the Texas sampler without the stopper was about 4 percent less than that for the Texas sampler with the stopper. The average concentration for the P-43 sampler was about 5 percent larger than that for the Texas sampler without the stopper for samples at 0.6 depth. The average concentration for the P-43, used as a depth-integrator, was about 1 percent larger than that for the Texas sampler without the stopper but the individual ratios varied from the mean ratio by as much as 40 percent. These large and erratic variations indicate that single depth-integrated samples do not adequately determine the concentration of sediment in a vertical.

12. Because the Texas sampler was supported in a vertical position, it received part of the sample while being lowered to 0.6 depth when used without a stopper. A comparison was made of the amounts of the coarser material trapped by the Texas sampler at 0.6 depth without the stopper and that trapped by the P-43 sampler at the same depth (Table No. 2). For 11 of the 13 comparisons shown in Table No. 2, the P-43 sampler trapped more sediment coarser than 0.010 millimeters than was trapped by the Texas sampler without the stopper. Table No. 2 indicates that the percentage of material coarser than 0.010 millimeter trapped by the Texas sampler without the stopper is about 14 per cent less than that trapped by the P-43 sampler.

13. Conclusions. - The following conclusions were reached regarding the P-43 sampler when used for point integration and depth integration.

a. Point integration.

(1) By using a bypass frame described in paragraph 3, samples can be obtained satisfactorily without detaching the spiral connector on the regular discharge rig.

(2) Weights can be added to the sampler by use of a bypass arrangement similar to that described in paragraph 4. Adding weight is preferable to the design of a sampler heavy enough to be suitable at high stages.

(3) The use of a solenoid as a substitute for the messenger weights for releasing the valve and the use of a water-proof head to keep out sediment and to prevent water from freezing in the sampler are necessary changes in design.

(4) Milk bottles for catching the sample are preferable to mason jars, provided suitable tops can be devised. An increase of about 1/16-in. in the diameter of the sample container is necessary to permit use of all pint mason jars.

(5) Changes in the shape of the sampler to conform more closely to that of the Columbus weight are desirable.

b. Depth integration.

(1) Because of large depths and velocities during high stages on the Arkansas River and the great depths which accompany small velocities at low stages, the use of the P-43 sampler in its present form as a depth integrator is limited on the lower Arkansas River.

(2) A sampler equipped with the following features would be best for integrating on the lower Arkansas River from the bottom up:

(a) An air chamber similar to that on the P-43 sampler.

(b) A valve to be opened by a lever upon striking the bottom.

(c) Possibly a one-eighth-inch nozzle and a quart sample jar.

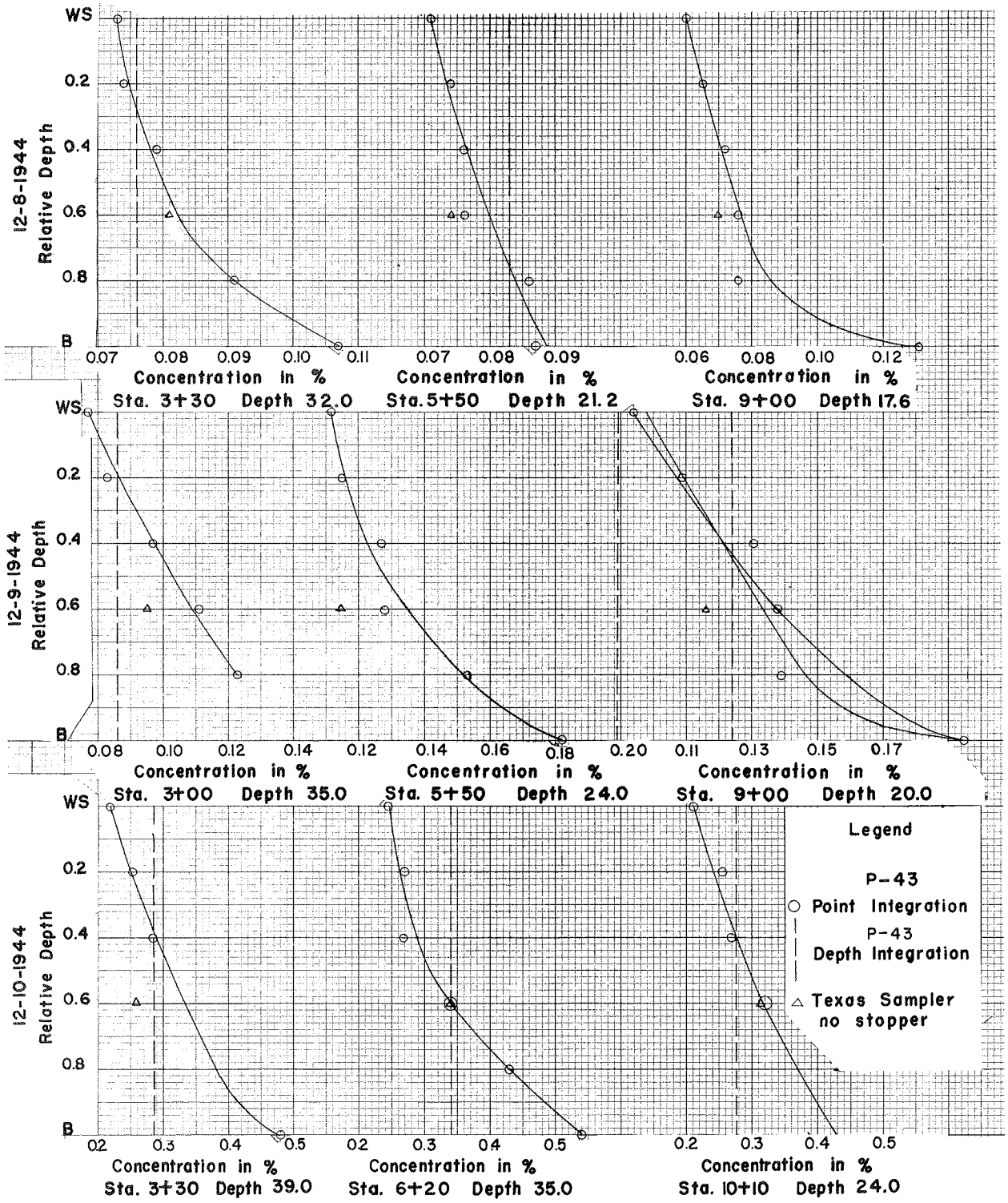

FIGURE B-1 -- SEDIMENT DISTRIBUTION IN VERTICAL

ARKANSAS RIVER, LITTLE ROCK, ARKANSAS

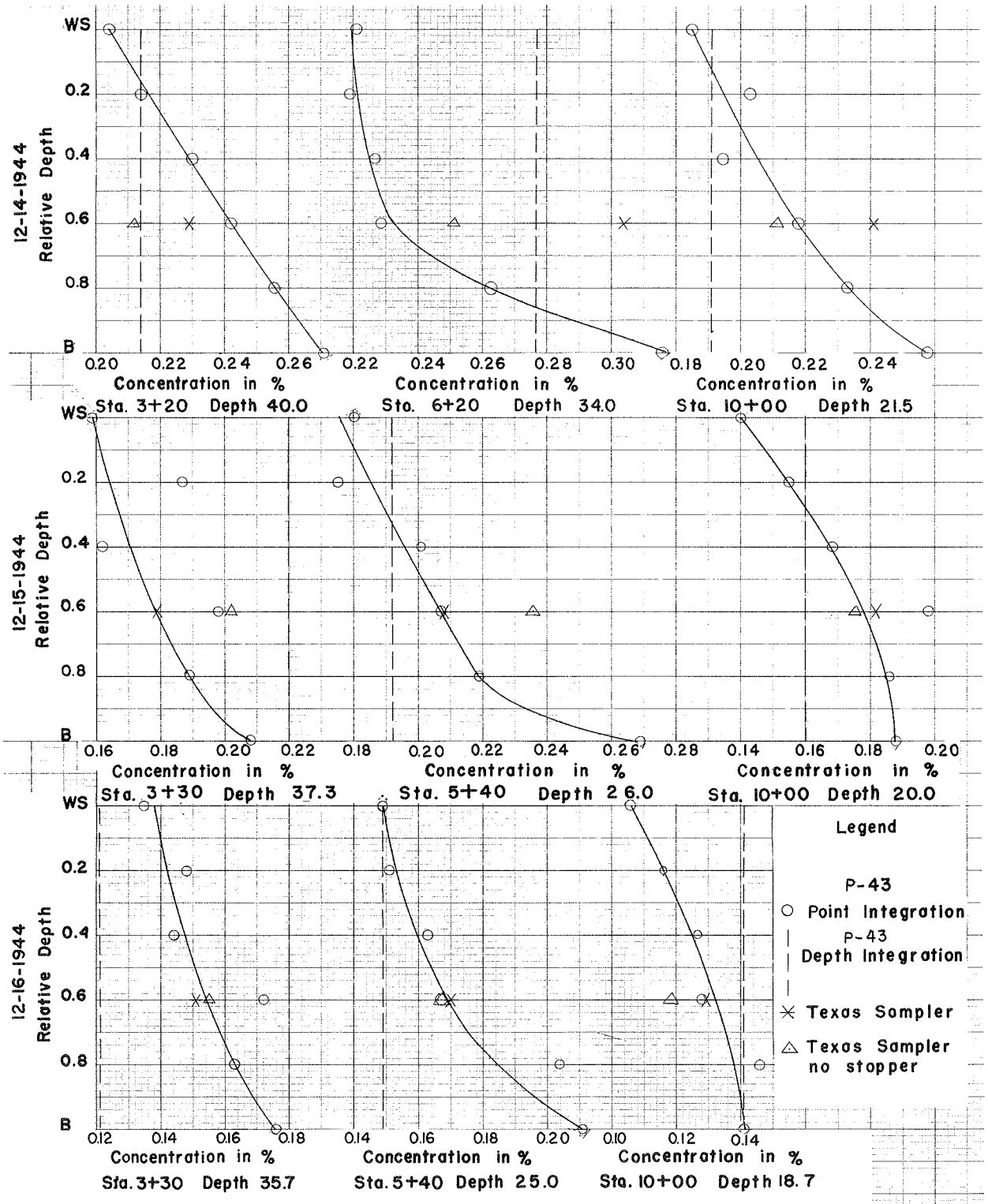

FIGURE B-2 -- SEDIMENT DISTRIBUTION IN VERTICAL

ARKANSAS RIVER, LITTLE ROCK, ARKANSAS

TABLE B-1

COMPARISON TEXAS AND P-43 SAMPLERS

Date 1944	CONCENTRATION - percent			
	Texas sampler - 0.6 depth		P-43 Sampler	
	With stopper	W/o stopper	0.6 depth	Depth-Integ.
Nov. 29		0.019		0.016
		0.022		0.017
		0.018		0.022
Dec. 8		0.081		0.076
		0.074	0.076	0.083
		0.070	0.076	0.094
Dec. 9		0.095	0.111	0.086
		0.115	0.128	0.199
		0.116	0.138	0.124
Dec. 10		0.257		0.286
		0.339	0.339	0.339
		0.314	0.318	0.276
Dec. 11		0.411	0.464	
		0.408	0.430	
Dec. 12		0.331	0.340	0.337
Dec. 13	0.278	0.267		
	0.284	0.272		
	0.327	0.283		
	0.277	0.272		
	0.265	0.262		
Dec. 14	0.229	0.212	0.242	0.214
	0.304	0.251	0.229	0.277
	0.241	0.211	0.218	0.191
Dec. 15	0.179	0.202	0.198	0.220
	0.208	0.235	0.207	0.192
	0.182	0.175	0.198	0.160
Dec. 16	0.151	0.155	0.172	0.121
	0.170	0.167	0.167	0.149
	0.129	0.118	0.128	0.141
Dec. 21	0.061	0.060		0.064
	0.074	0.060		0.065
	0.058	0.058		0.061
Dec. 26		0.055		0.060
		0.056		0.082
		0.050		0.046

TABLE B-1 (Cont.)

COMPARISON TEXAS AND P-43 SAMPLERS

Date 1944	CONCENTRATION - percent			
	Texas sampler - 0.6 depth		P-43 Sampler	
	With stopper	W/o stopper	0.6 depth	Depth-Integ.
	Average Concentration for Corresponding Samples			
	.201	.192		
	.199		.195	
	.166			.155
		.210	.220	
		.140		.143
			.193	.188

TABLE B-2

COMPARISON OF TEXAS AND P-43 SAMPLERS
FOR COLLECTION OF COARSER SEDIMENT FRACTION

Date 1944	CONCENTRATION--Sand coarser than 0.010 mm.	
	Texas Sampler without stopper - 0.6 depth	P-43 Sampler 0.6 depth
Dec. 8	0.039	0.043
8	.040	.044
Dec. 9	.057	.080
9	.079	.093
9	.073	.104
Dec. 10	.246	.266
10	.239	.234
Dec. 11	.201	.322
11	.197	.234
Dec. 12	.141	.163
14	.080	.093
15	.099	.093
16	.043	.061
Average concentration	.118	.141

Ratio - Texas sampler without stopper to D-43 - 0.84

APPENDIX - C

FIELD TESTS ON SUSPENDED SEDIMENT SAMPLERS IN THE COLORADO RIVER AND RIO GRANDE BASINS (US P-43, US D-43, Colorado River, and Albuquerque Samplers)

1. The point integrating sampler P-43 equipped with a trial solenoid tripping device performed satisfactorily when tested in the Animas River at Farmington in depths of 1 to 2.5 feet. When tested in the San Juan River near Bluff and in the Colorado River at Lees Ferry the sampler performed satisfactorily for 2 or 3 samples but subsequently silt and water seeping into the solenoid and tripping mechanism caused it to stick and it could not be used until cleaned and dried. The clock spring provided to drive the valve broke and had to be repaired several times and finally it was replaced by another. Tests indicated that a sampler of the P-43 type will be very easy to use and will find considerable application for sampling in deep streams and for determining vertical distribution of sediment loads if provided with a revised positive tripping mechanism electrically operated and with a streamlined body which will minimize downstream drag and yawing.

2. The D-43 sampler was used at each station. The D-43 sampler with a bottom tripping device utilizing an auxiliary stream gaging weight in place of a bottom trip plate was tested in the Colorado River at Lees Ferry and Grand Canyon (Bright Angel) gaging stations. The valve and tripping device never failed to operate and the sampler was considered very practicable for use in streams with depths varying from 15 to about 30 feet.

3. A dual purpose sampler (AD-45) constructed by the Albuquerque Engineer District was tested in the San Juan River near Bluff, the Colorado River at Lees Ferry and the Rio Grande at Albuquerque. It was first used as a stream gaging weight to complete a set of current meter velocity observations and then several sediment samples were collected. The tests indicated that the sampler performed satisfactorily for both operations. However, under the conditions mentioned at these sampling stations the weight was excessive. A weight of 75 pounds would be more practicable for general use.

4. Data on samples taken in this series of tests are presented in Tables C-1 and C-4 with summaries of the data in Tables C-3 and C-5. Size analyses in the M.I.T. classification as determined by B.W. tube analysis are shown in Tables C-2 and C-4.

5. The samples obtained with the US D-43 sampler were consistent except that the concentrations in samples obtained with the 3/16-in. nozzle were generally higher than those in samples taken with the 1/8-in. nozzle. The difference probably resulted from a difference in intake ratios for the two nozzles. Although precise information is not available, a study of the volumes of the samples collected with the two sizes of nozzles indicated that the 1/8-in. nozzle had a higher intake ratio or relative sampling rate.

The Albuquerque dual purpose AD-45 sampler compared favorably with the US D-43 sampler under the available limited number of comparisons; but the data are not adequate to support any definite conclusions on the merits of the sampler.

The sediment concentrations obtained with the Colorado River sampler were erratic in comparison with the results obtained with the D-43 sampler. The direction of integration, type of bottle cap used, and conditions in the stream seemed to cause serious variations in the sampling efficiency of the Colorado River sampler.

The samples obtained with the Texas sampler (Faris sampler) were not considered satisfactory.

The size analyses shown in Table C-2 appear to be consistent except for samples A and C in which the concentrations appear to be abnormally high. Most of the excess in these samples was in the sand sizes.

6. The general conclusions for further sampler developments are as follows:

a. Redesign the P-43 sampler with a streamlined body, electrical tripping device, and weight of about 75 lbs.

b. Design a depth-integrating sampler weighing about 75 lbs. with a bottom tripping device and streamlining patterned after that of the C-type current-meter weight.

c. Develop a wading sampler with the same filling characteristics as the simple depth-integrating sampler.

d. Construct a dual type, simple depth-integrating sampler with the same filling characteristics as the present depth-integrators for use both as a stream gaging weight and sediment sampler.

TABLE C-1

RESULTS OF COMPARATIVE FIELD TESTS
ON SUSPENDED SEDIMENT SSMPLERS

Sampler	Nozzle	Integration	Sample number or hour	Fill time secs.	Concentration percent
SAN JUAN RIVER, BLUFF, UTAH					
April 18, 1945: station 150; depth 2.6 ft.; velocity 6.28 ft./sec.					
AD-45	3/16"	Round trip:	1	7	0.40
	"	"	2	7	0.39
	"	"	3	6	0.38
	"	"	4	7	0.39
AD-45	1/8"	Round trip	5	14	0.33
	"	"	6	21*	0.39
US D-43	3/16"	Round trip	10:51 a.m.	11.5	0.34
	"	"	10:53 a.m.	11.0	0.37
	"	"	10:58 a.m.	8.3	0.38
	"	"	11:03 a.m.	10.0	0.35
US D-43	1/8"	Round trip	11:08 a.m.	32.7	0.35
	"	"	11:13 a.m.	19.5	0.37
	"	"	11:17 a.m.	28.3	0.38
COLORADO RIVER, LEES FERRY, ARIZONA					
April 22, 1945: station 730; depth 7.2 ft.; velocity 4.04 ft./sec.					
AD-45	1/4"	Round trip	1	42	0.27
	"	"	2	25	0.33
	"	"	3	-	0.30
	"	"	4	18	0.29
	"	"	5	10	0.24
	"	"	6	10	0.25
US D-43	3/16"**	Round trip	7	13.5	0.25
	"	"	8	10.5	0.28
	"	"	9	16.0	0.27

* Some spill
** Sampler equipped with auxiliary (bottom tripping) head
\- No record
Round-trip samples were depth-integrated from the water surface to the stream bed and return

TABLE C-1 (Cont.)

RESULTS OF COMPARATIVE FIELD TESTS
ON SUSPENDED SEDIMENT SAMPLERS

Sampler	Nozzle	Integration	Sample number or hour	Fill time secs.	Concentration percent
COLORADO RIVER, LEES FERRY, ARIZONA					
April 23, 1945: station 680; depth 10.5 ft.; velocity 4.82 ft./ sec.					
US D-43	3/16"**	Downward	11:00 a.m.	14.2	0.37
"	"	"	11:05 a.m.	15.4	xx
"	"	"	11:08 a.m.	15.2	0.39
"	"	"	11.11 a.m.	12.6	0.38
US D-43	3/16"**	Round trip	11.19 a.m.	11.0	0.40
"	"	"	11.22 a.m.	17.0	xx
"	"	"	-	16.7	0.39
COLORADO RIVER, GRAND CANYON, ARIZONA					
April 25, 1945: station 120; depth 17.6 ft.					
Colo. R.	-	Round trip	1	22.5	0.69
US D-43	3/16"	"	5	16.0	0.71
Station 180; depth 20.5 ft.					
Colo. R.	-	Round trip	2	21.0	0.69
US D-43	3/16"	"	6	18.0	0.70
Station 250; depth 19.0 ft.					
Colo. R.	-	Round trip	3	22.0	0.71
US D-43	3/16"	"	7	20.0	0.70
Station 310; depth 18.5 ft.					
Colo. R.	-	Round trip	4	-	0.72
US D-43	3/16"	"	8	-	-

** Sampler equipped with auxiliary (bottom tripping) head
xx Samples were to have been analyzed for size--no record
- No record
Downward samples were depth-integrated from the water surface downward to the stream bed.

TABLE C-1 (Cont.)

RESULTS OF COMPARATIVE FIELD TESTS
ON SUSPENDED SEDIMENT SAMPLERS

Sampler	Nozzle	Integration	Sample number or hour	Fill time secs.	Concentration percent
		COLORADO RIVER, GRAND CANYON, ARIZONA			
April 26, 1945: station 300; depth 22.0 ft.; velocity 4.30 ft./sec. Discharge, 20,400 sec. ft.					
US D-43	3/16"	Round trip:	10.44 a.m.	18.0	1.13
	"	"	10.48 a.m.	-	1.14
	"	"	10.53 a.m.	20.1	1.13
	"	"	10:58 a.m.	19.5	1.09
Colo. R.	5/16"*	Round trip	11.06 a.m.	21.3	1.13
	"	"	11:09 a.m.	19.8	1.14
	"	"	11:11 a.m.	17.0	1.15
	"	"	11:14 a.m.	16.3	1.13
Colo. R.	9/16"x	Upward	11:27 a.m.	6.0	1.19
	"	"	11:35 a.m.	6.4	1.25
	"	"	11:40 a.m.	6.2	1.18
	"	"	11:44 a.m.	6.2	1.15
US D-43	3/16"	Round trip	11:48 a.m.	18.6	1.07
	"	"	11:51 a.m.	21.0	1.10
	"	"	11:54 a.m.	17.4	1.08
	"	"	11:57 a.m.	21.4	1.09
April 27, 1945: station 200; depth 23.2 ft.; velocity 5.01 ft./sec.					
Colo. R.	-x	Upward	10:13 a.m.	5.8	0.96
	"	"	10:18 a.m.	5.5	0.92 A
	"	"	10:22 a.m.	5.6	0.98
	"	"	10:26 a.m.	5.4	-

* With 1/8 in. air exhaust
x No air exhaust
xx Samples were to have been analyzed for size--no record
- No record
Upward samples were depth-integrated by opening the intake at the stream bed and sampling upward to the water surface.
Letters following concentration identify samples analyzed for size

TABLE C-1 (Cont.)

RESULTS OF COMPARATIVE FIELD TESTS
ON SUSPENDED SEDIMENT SAMPLERS

Sampler	Nozzle	Inte-gration	Sample number or hour	Fill time secs.	Concentration percent	
COLORADO RIVER, GRAND CANYON, ARIZONA						
April 27, 1945: station 200; depth 23.2 ft.; velocity 5.01 ft./sec.						
Colo. R.	-x	Round trip	10:30 a.m.	20.4	-	
	"	"	10:33 a.m.	34.0	0.77	B
	"	"	10:36 a.m.	29.6	0.79	
	"	"	10:39 a.m.	34.6	0.78	
Colo. R.	-x	Upward	10:44 a.m.	14.6	0.95	
	"	"	10:50 a.m.	14.0	1.00	C
	"	"	10:54 a.m.	17.2	0.88	
	"	"	10:59 a.m.	15.0	0.89	
US D-43	3/16"**	Downward	11:40 a.m.	13.8	0.77	
	"	"	11:45 a.m.	17.0	0.77	D
	"	"	11:48 a.m.	15.8	0.80	
	"	"	12:03 p.m.	14.5	0.77	
	"	"	2:08 p.m.	13.0	0.75	
	"	"	2:12 p.m.	15.0	0.76	E
	"	"	2:21 p.m.	12.0	0.81	
	"	"	2:25 p.m.	13.0	0.75	
US D-43	1/8"**	Downward	2:42 p.m.	24.8	0.76	
	"	"	3:04 p.m.	20.2	0.79	
	"	"	3:08 p.m.	27.0	0.72	F
	"	"	3:13 p.m.	28.6	0.75	
US D-43	1/8"**	Round trip	3:20 p.m.	27.8	0.76	
	"	"	3:26 p.m.	29.8	0.76	
	"	"	3:30 p.m.	28.0	0.74	G
	"	"	3:37 p.m.	31.2	0.75	
US D-43	3/16"**	Round trip	3:47 p.m.	16.2	0.79	
	"	"	3:49 p.m.	19.3	0.77	
	"	"	3:53 p.m.	16.2	0.76	H
	"	"	4:02 p.m.	18.8	0.79	

** Sampler equipped with auxiliary (bottom tripping) head
x No air exhaust
- No record

TABLE C-1 (Cont.)

RESULTS OF COMPARATIVE FIELD TESTS
ON SUSPENDED SEDIMENT SAMPLERS

Sampler	Nozzle	Integration	Sample number or hour	Fill time secs.	Concentration percent
COLORADO RIVER, GRAND CANYON, ARIZONA					
May 14, 1945: station 200; depth 29.0 ft.*; velocity 9.22 ft. /sec. Discharge, 59,000 sec.-ft.					
US D-43	1/8"**	Downward	11:10 a.m.	13.5	0.79
	"	"	11:15 a.m.	14.4	0.76
	"	"	11:35 a.m.	15.7	xx
	"	"	11:45 a.m.	14.9	-
Colo. R.	-x	Round trip	1:20 p.m.	26.0	xx
	"	"	1:25 p.m.	27.5	0.77
Colo. R.	-x	Upward	1:45 p.m.	18.5	0.70
	"	"	1:50 p.m.	18.3	xx
	"	"	2:00 p.m.	18.8	0.76
May 15, 1945: station 200; depth 29.5 ft.*; velocity 9.57 ft. / sec. Discharge, 62,000 sec.-ft.					
US D-43	1/8"**	Downward	9:40 a.m.	15.8	0.85
	"	"	9:45 a.m.	16.8	0.90
	"	"	9:50 a.m.	16.5	xx
US D-43	3/16"**	Downward	10:00 a.m.	9.4	0.87
	"	"	10:05 a.m.	12.0	xx
	"	"	10:10 a.m.	10.0	0.87
US D-43	1/8"**	Downward	10:15 a.m.	16.6	0.88
	"	"	10:20 a.m.	18.3	0.73
	"	"	10:25 a.m.	19.4	0.76
Colo. R.	5/16"	Upward	11:05 a.m.	15.5	0.83
	"	"	11:20 a.m.	18.5	xx
	"	"	11:25 a.m.	14.8	0.79
	"	"	11:30 a.m.	17.0	0.74

* Not corrected for downstream drift of the sampler
** Sampler equipped with auxiliary (bottom tripping) head
x No air exhaust
xx Samples were to have been analyzed for size--no record
- No record

TABLE C-1 (Cont.)

RESULTS OF COMPARATIVE FIELD TESTS
ON SUSPENDED SEDIMENT SAMPLERS

Sampler	Nozzle	Integration	Sample number or hour	Fill time secs.	Concentration percent
COLORADO RIVER, GRAND CANYON, ARIZONA					
May 16, 1945: station 200; depth - - - - ; velocity - - - - -					
US D-43	1/8"**	Downward	9:35 a.m.	22.4	0.82
	"	"	9:40 a.m.	21.0	-
	"	"	9:50 a.m.	20.4	0.75
US D-43	3/16"**	Downward	9:55 a.m.	11.6	0.78
	"	"	10:00 a.m.	12.0	-
	"	"	10:05 a.m.	12.4	0.84
	"	"	10:15 a.m.	10.3	0.91
US D-43	1/8"**	Downward	10:20 a.m.	19.8	0.71
	"	"	10:25 a.m.	19.6	0.83

** Sampler equipped with auxiliary (bottom tripping) head
- No record

TABLE C-2

SIZE ANALYSES OF SAMPLES FROM
COLORADO RIVER, GRAND CANYON, ARIZONA

Reference Symbol	Sediment Concen. in sample Percent	PERCENT OF SAMPLE IN SIZE RANGE SHOWN (M.I.T. CLASSIFICATION)						
		Clay	Fine silt	Med. silt	Coar. silt	Fine sand	Med. sand	Coar. sand
A	0.92	21	10	17	23	23	5	1
B	0.77	26	12	17	27	16	2	0
C	1.00	19	11	14	22	24	10	0
D	0.77	23	14	19	23	16	4	1
E	0.76	23	15	18	22	16	5	1
F	0.72	23	13	21	20	16	5	2
G	0.74	24	14	18	23	15	3	3
H	0.76	24	13	18	22	18	4	1

TABLE C-3

SUMMARY OF COMPARATIVE FIELD TESTS
ON SUSPENDED SEDIMENT SAMPLERS

Sampler	Nozzle	Integration	Total Samples	Average Concen. percent	CONCENTRATION RATIOS Base, D-43 / 3/16" RT	Base, D-43 / 1/8" RT	Base, D-43 / 3/16" Dn	Base, D-43 / 1/8" Dn
SAN JUAN RIVER, BLUFF, UTAH								
April 18, 1945	Station 150		Depth 2.6 ft.		Velocity 6.28 ft. per sec.			
AD-45	3/16"	Rnd.trip	4	0.390	1.08	1.06		
AD-45	1/8"	"	2	0.360	1.00	0.98		
US D-43	3/16"	"	4	0.360	1.00	0.98		
US D-43	1/8"	"	3	0.367	1.02	1.00		
COLORADO RIVER, LEES FERRY, ARIZONA								
April 22, 1945	Station 730		Depth 7.2 ft.		Velocity 4.04 ft. per sec.			
AD-45	1/4"	Rnd.trip	6	0.280	1.05			
US D-43	3/16"	"	3	0.267	1.00			
April 23, 1945	Station 680		Depth 10.5 ft.		Velocity 4.82 ft. per sec.			
US D-43	3/16"	Downward	3	0.380	0.96		1.00	
US D-43	3/16"	Rnd.trip	2	0.395	1.00		1.04	
COLORADO RIVER, GRAND CANYON, ARIZONA								
April 25, 1945	Station 120, 180, 250		Approx. depth 19 ft.		Velocity - - -			
Colo. R.	-	Rnd.trip	3	0.697	0.99			
US D-43	3/16"	"	3	0.703	1.00			

TABLE C-3 (Cont.) SUMMARY OF COMPARATIVE FIELD TESTS

April 26, 1945		Station 300			Depth 22.0 ft.	Velocity 4.30 ft. per sec.		
US D-43	3/16"	Rnd.trip	8	1.104*	1.00			
Colo. R.	5/16"**	"	4	1.138	1.03			
Colo. R.	9/16"x	Upward	4	1.192	1.08			
April 27, 1945		Station 200			Depth 23.2 ft.	Velocity 5.01 ft. per sec.		
Colo. R.	-x	Rnd.trip	3	0.780	1.00	1.04	1.01	1.03
Colo. R.	-x	Upward	7	0.940*	1.21	1.25	1.22	1.25
US D-43	3/16"	Downward	8	0.772	0.99	1.03	1.00	1.02
US D-43	1/8"	"	4	0.755	0.97	1.00	0.98	1.00
US D-43	1/8"	Rnd.trip	4	0.752	0.97	1.00	0.97	1.00
US D-43	3/16"	"	4	0.778	1.00	1.03	1.01	1.03
May 14, 1945		Station 200			Depth 29.0	Velocity 9.22 ft. per sec.		
US D-43	1/8"	Downward	2	0.775				1.00
Colo. R.	-x	Rnd.trip	1	0.770				0.99
Colo. R.	-x	Upward	2	0.730				0.94
May 15, 1945		Station 200			Depth 29.5	Velocity 9.57 ft. per sec.		
US D-43	1/8"	Downward	5	0.824*			0.95	1.00
US D-43	3/16"	"	2	0.870			1.00	1.06
Colo. R.	5/16"	Upward	3	0.787			0.90	0.96
May 16, 1945		Station 200			Depth - - -	Velocity - - -		
US D-43	1/8"	Downward	4	0.778*			0.92	1.00
US D-43	3/16"	"	3	0.843			1.00	1.08

* Average of all samples in two similar groups

** With 1/8 in. air exhaust

x No air exhaust

\- No record

TABLE C-4

COMPARATIVE FIELD TESTS OF SUSPENDED-SEDIMENT SAMPLERS
Rio Grande - Albuquerque, New Mexico

Sampler	Date & Discharge (cfs)	Time	Depth	Fill Time (sec)	Nozzle Size (in)	% Sedim. by Wt.	% of Sample in Size Range Shown						
							Clay	Fine Silt	Med. Silt	Coarse Silt	Fine Sand	Med. Sand	Coarse Sand
D-43	5-4-45	12:16 pm	Integ.	8.4	3/16	.6376							
"	5344	12:20 pm	"	8.2	"	.6241	12	14	16	24	24	10	0
"	"	12:23 pm	"	10.0	"	.6524	16	9	17	19	26	11	2
"	"	12:26 pm	"		"	.6211							
"	"	12:28 pm	"	9.0	"	.6690	14	12	14	18	25	11	6
"	"	12:30 pm	"		"	.6075	14	11	14	24	25	12	0
"	"	2:49 pm	"	9.4	"	.5998	19	11	14	22	22	9	3
"	"	2:52 pm	"	8.2	"	.5697							
"	"	2:54 pm	"	10.2	"	.5145	18	16	16	23	22	4	1
"	"	2:56 pm	"	9.4	"	.5807							
AD-45	5-4-45	12:40 pm	Integ.	6.6	3/16	.7140	14	7	13	22	34	10	0
"	5344	12:42 pm	"	9.0	"	.5733							
"	"	12:45 pm	"	10.2	"	.6547	14	10	16	21	28	11	0
"	"	12:47 pm	"	9.8	"	.6086							
"	"	12:53 pm	"	10.0	"	.6063	16	11	15	22	24	10	2
"	"	12:58 pm	"	10.5	"	.6498	16	8	15	21	27	11	2
P-43	5-4-45	2:17 pm	1.0[a]	7.2	3/16	.4800	16	12	20	28	16	7	1
"	5344	2:20 pm	2.0[a]	8.8	"	.4732	14	12	20	28	20	5	1
"	"	2:23 pm	3.0[a]	9.0	"	.5812	11	12	16	24	30	7	0
"	"	2:24 pm	4.0[a]	11.0	"	.5843	13	10	17	24	16	20	0
"	"	2:26 pm	5.0[a]	12.2	"	.7279	11	8	15	18	30	14	4
"	"	2:29 pm	5.6[a]	13.0	"	1.7434	3	4	4	11	23	50	5
"	"	2:34 pm	5.6[a]	14.6	"	.8609	12	5	10	17	22	26	8
"	"	2:36 pm	5.0[a]	13.4	"	.8583	11	6	13	15	38	17	0
"	"	2:38 pm	3.0[a]	10.8	"	.5699	15	12	17	24	24	8	0
"	"	2:40 pm	1.0[a]	11.0	"	.4667	23	12	21	23	18	2	1
D-43	5-8-45	11:20 am	Integ.	10.0	3/16	2.1824	4	2	4	8	16	22	44
"	10800	11:22 am	"	16.0	"	1.4862	6	4	5	12	38	35	0
"	"	11:30 am	"	14.0	"	1.0214	9	5	8	15	43	20	0
"	"	11:40 am	"	12.0	"	1.1224	8	4	8	13	40	27	0
"	"	11:42 am	"	11.0	"	1.1255	7	6	7	15	32	30	3
"	"	11:45 am	"	11.0	"	1.9300	5	3	4	6	22	37	23
Texas	5-10-45	12:45 pm	Integ.	-	Open	.2482							
"	10700	12:45 pm	"	-	"	.2844							
"	"	12:48 pm	"	-	"	.2492							
"	"	12:52 pm	"	-	"	.2720							
"	"	12:55 pm	"	-	"	.2525							
"	"	12:57 pm	"	-	"	.2822							
"	"	1:00 pm	0.6[b]	-	"	.6557							
"	"	1:00 pm	"	-	"	.3982							
"	"	1:02 pm	"	-	"	.3860	11	7	12	21	30	18	1
"	"	1:05 pm	"	-	"	.4619							
"	"	1:05 pm	"	-	"	.2057							
"	"	1:06 pm	"	-	"	.5705							
"	"	1:08 pm	1.0[a]	-	"	.4339							
"	"	1:13 pm	"	-	"	.2246							
"	"	1:18 pm	"	-	"	.2394							
"	"	1:21 pm	"	-	"	.2128							
"	"	1:23 pm	"	-	"	.2399							
"	"	1:27 pm	"	-	"	.2168	20	9	23	23	6	10	0
D-43	5-10-45	1:55 pm	Integ.	10.0	3/16	.8997	6	3	7	17	46	21	0
"	10700	2:00 pm	"	-	"	.7927	5	2	7	16	57	13	0
"	"	2:05 pm	"	-	"	1.1264	4	3	5	11	50	26	1
"	"	2:06 pm	"	10.0	"	1.2160	3	3	4	11	31	40	8
"	"	2:08 pm	"	-	"	1.2186	2	2	6	13	28	48	1
"	"	2:10 pm	"	12.0	"	1.0668	4	2	5	14	32	39	4

a - Point sample at indicated depth in ft. below water surface
b - Point sample at 0.6 of total depth

TABLE C-4 (Cont.)

COMPARATIVE FIELD TESTS OF SUSPENDED-SEDIMENT SAMPLERS
Rio Grande - Albuquerque, New Mexico

Sampler	Date & Discharge (cfs)	Time	Depth	Fill Time (sec)	Nozzle Size (in)	% Sedim. by Wt.	% of Sample in Size Range Shown: Clay	Fine Silt	Med. Silt	Coarse Silt	Fine Sand	Med. Sand	Coarse Sand
D-43	5-10-45	2:15 pm	0.6[a]	-	3/16	.6509	8	2	10	18	46	16	0
"	10700	2:17 pm	"	-	"	.5994	6	5	9	19	44	17	0
"	"	2:20 pm	"	-	"	.5995	6	4	7	20	48	15	0
"	"	2:23 pm	"	-	"	.6252	6	6	8	16	38	26	0
"	"	2:25 pm	"	-	"	.5721	6	6	8	24	44	12	0
"	"	2:27 pm	"	-	"	.5688	9	5	9	19	45	13	0
"	"	2:32 pm	1.0[b]	-	"	.3155	14	10	18	32	22	4	0
"	"	2:34 pm	"	10.0	"	.2578	10	9	19	37	22	3	0
"	"	2:34 pm	"	-	"	.3447	12	4	13	33	32	6	0
"	"	2:35 pm	"	-	"	.2724	15	12	20	34	16	2	1
"	"	2:36 pm	"	10.0	"	.2818	14	9	15	32	28	2	0
"	"	2:37 pm	"	-	"	.2792	16	14	18	31	17	3	1
AD-45	5-10-45	3:03 pm	Integ.	-	3/16	.3582							
"	10700	3:08 pm	"	-	"	.3152	11	8	16	29	30	5	1
"	"	3:10 pm	"	-	"	.3080							
"	"	3:15 pm	"	-	"	2.0722							
"	"	3:20 pm	"	-	"	1.2358							
"	"	3:25 pm	"	-	"	.8136							
"	"	3:27 pm	"	-	"	.7109							
"	"	3:29 pm	"	-	"	.7983	6	3	8	15	35	33	0
"	"	3:30 pm	"	-	"	.9938	5	3	6	11	27	40	8
D-43	5-16-45	9:45 am	Integ.	15	3/16	.8544							
"	10800	9:47 am	"	15	"	.7771							
"	"	9:50 am	"	14	"	.8967							
"	"	9:52 am	"	12	"	.9214							
"	"	9:55 am	"	11	"	1.0189							
"	"	10:00 am	"	11	"	.8910							
"	"	10:10 am	0.6[a]	14	1/8	.5229							
"	"	10:12 am	"	13	"	.4713							
"	"	10:14 am	"	16	"	.4103							
"	"	10:16 am	"	15	"	.4469	6	3	10	19	38	19	5
"	"	10:18 am	"	17	"	.3339	6	4	8	19	36	27	0
"	"	10:20 am	"	16	"	.4341	7	5	14	20	36	18	0
"	"	10:22 am	1.0[b]	15	"	.2750	16	6	12	28	38	0	0
"	"	10:24 am	"	17	"	.2417	15	6	16	30	33	0	0
"	"	10:26 am	"	19	"	.2694	14	7	16	24	36	3	0
"	"	10:28 am	"	20	"	.2513	16	7	15	30	29	3	0
"	"	10:30 am	"	21	"	.2576	18	15	13	27	33	4	0
"	"	10:32 am	"	22	"	.2431	11	10	14	28	31	6	0
Texas	5-16-45	10:45 am	Integ.	13	Open	.3004	11	4	12	25	30	14	4
"	10800	10:47 am	"	15	"	.2879	9	2	14	26	34	14	1
"	"	10:55 am	"	15	"	.3052	13	3	11	26	36	11	0
"	"	10:57 am	"	10	"	.1601	18	8	20	34	15	5	0
"	"	10:57 am	"	13	"	.2470	14	6	15	27	27	11	0
"	"	10:59 am	"	13	"	.1452	21	17	13	49	0	0	0
"	"	11:01 am	"	-	"	.1388	24	4	21	31	16	4	0
"	"	11:03 am	"	-	"	.1695	20	13	6	33	19	9	0
D-43	5-19-45	3:00 pm	Integ.	11.6	3/16	.3489							
"	7906	3:02 pm	"	11.7	"	.5935							
"	"	3.04 pm	"	12.0	"	.4568							
"	"	3:06 pm	"	16.0	"	.5109							
"	"	3:08 pm	"	21.7	1/8	.4679							
"	"	3:10 pm	"	28.0	"	.3243	7	0	8	15	44	26	0
"	"	3:17 pm	"	12.2	3/16	.6719							
"	"	3:20 pm	"	12.4	"	.4614							
"	"	3:23 pm	"	12.4	"	.5388							
"	"	3:26 pm	"	28.0	1/8	.5408							
"	"	3:30 pm	"	24.0	"	.4334							
"	"	3:32 pm	"	23.6	"	.5678	3	4	3	11	35	42	2
"	"	4:25 pm	"	13.7	3/16	.4795							
"	"	4:27 pm	"	14.6	"	.1285							
"	"	4:35 pm	"	14.0	"	.2647							

a - Point sample at 0.6 of total depth - sampler lowered to 0.6 depth, opened and allowed to sample, then removed from stream while still open.

b - Point sample at 1.0 ft. below water surface by same procedure as (a).

TABLE C-4 (Cont.)

COMPARATIVE FIELD TESTS OF SUSPENDED - SEDIMENT SAMPLERS
Rio Grande - Albuquerque, New Mexico

Sampler	Date & Discharge (cfs)	Time	Depth	Fill Time (sec)	Nozzle Size (in)	% Sedim. by Wt.	% of Sample in Size Range Shown						
							Clay	Fine Silt	Med. Silt	Coarse Silt	Fine Sand	Med. Sand	Coarse Sand
P-43	5-19-45	3:50 pm	1.0[a]	21.0	3/16	.1964	15	6	10	29	33	7	0
"	7906	3:56 pm	1.0[a]	19.0	"	.1752	14	8	11	26	34	7	0
"	"	3:58 pm	3.0[a]	19.8	"	.2088	11	6	11	22	30	14	6
"	"	4:00 pm	3.0[a]	19.6	"	.2112	10	7	9	26	32	12	4
"	"	4.02 pm	8.0[a]	15.5	"	.2739	6	7	8	20	36	21	2
"	"	4.05 pm	8.0[a]	16.6	"	.2453	6	5	10	19	42	11	7
"	"	4:07 pm	10.0[a]	13.4	"	.5009	3	2	3	15	60	17	0
"	"	4:10 pm	10.0[a]	13.4	"	.3845	4	3	5	14	50	23	1
"	"	4:14 pm	12.5[a]	13.8	"	.8989	2	1	3	8	53	33	0
"	"	4:17 pm	12.5[a]	15.4	"	.5221	1	2	6	12	48	31	0
D-43	5-22-45	10:00 am	Integ.	11.5	3/16	.6103							
"	8214	10:02 am	"	12.0	"	.6010							
"	"	10:04 am	"	14.7	"	.5771							
"	"	10:06 am	"	27.0	1/8	.6302							
"	"	10:08 am	"	27.3	"	.5823							
"	"	10:10 am	"	26.4	"	.5110	1	2	5	15	43	27	7
AD-45	5-22-45	10:20 am	Integ.	27.2	1/8	.7181							
"	8214	10:23 am	"	27.8	"	.6843							
"	"	10:26 am	"	21.2	"	.6131							
"	"	10:30 am	"	10.7	3/16	.6506							
"	"	10:32 am	"	11.6	"	.6911							
"	"	10:35 am	"	12.4	"	.5901	3	4	4	14	42	29	4
P-43	5-22-45	10:58 am	0.5[a]	10.8	3/16	.3222	7	6	6	20	29	29	3
"	8214	11:03 am	0.5[a]	11.6	"	.3062	10	3	9	20	39	19	0
"	"	11:05 am	3.0[a]	11.0	"	.9908	40	40	3	1	6	6	4
"	"	11:07 am	3.0[a]	11.4	"	.0661	39	23	16	3	2	11	6
"	"	11:09 am	4.5[a]	13.2	"	.7374	4	1	3	13	39	36	4
"	"	11:11 am	4.5[a]	11.8	"	.7317	1	4	2	12	41	40	0
"	"	11:17 am	5.7[a]	21.2	"	.3356	0	2	3	8	38	40	0
Texas	5-22-45	10:39 am	Integ.	-	Open	.2563							
"	8214	10:42 am	"	-	"	.2586							
"	"	10:43 am	2.0[a]	-	"	.1365							
"	"	10:43 am	4.0[a]	-	"	.1887							
"	"	10:47 am	4.0[a]	-	"	.1660							
"	"	10:48 am	2.0[a]	-	"	.1632	22	1	13	30	27	7	0
D-43	5-25-45	10:22 am	Integ.	16.0	3/16	.8273							
"	6270	10:24 am	"	13.0	"	.5779							
"	"	10:25 am	"	12.0	"	.8660							
"	"	10:26 am	"	11.0	"	.7797							
"	"	10:27 am	"	12.0	"	.7592							
"	"	10:29 am	"	12.0	"	.4718	2	1	4	10	35	48	0
Texas	5-25-45	10:40 am	-	12	Open	.0821							
"	6270	10:42 am	-	16	"	.0862							
"	"	10:45 am	-	16	"	.1017							
"	"	10:46 am	-	16	"	.0888							
"	"	10:47 am	-	14	"	.1686							
"	"	10:55 am	-	20	"	.0956							
"	"	10:58 am	-	17	"	.1036							
"	"	11:00 am	-	12	"	.1357							
"	"	11:03 am	-	14	"	.1115							
"	"	11:10 am	-	14	"	.2156							
"	"	11:12 am	-	14	"	.2534							

a - Point sample at indicated depth in ft. below water surface.

TABLE C-5

PARTIAL SUMMARY OF COMPARATIVE FIELD TESTS OF SUSPENDED-SEDIMENT SAMPLERS
Rio Grande - Albuquerque, New Mexico

Sampler	Date	Depth	Nozzle Size (in)	Average % Sedim. by Wt.	Ratios	
D-43	5-4-45	Integ.	3/16	0.6076		
AD-45	"	"	"	.6345	Ratio to D-43 with 3/16" nozzle	1.044
Texas	5-10-45	Integ.	Open	.2648	Ratio to comparable D-43 samples	0.251
"	"	0.6[a]	"	.4463	" " " " "	0.741
"	"	1.0[b]	"	.2612	" " " " "	0.895
D-43	"	Integ.	3/16	1.0534		
"	"	0.6[a]	"	.6027	Ratio to integrated D-43 samples	0.572
"	"	1.0[b]	"	.2919		
AD-45	"	Integ.	3/16	.8451	Ratio to integrated D-43 samples	0.802
D-43	5-16-45	Integ.	3/16	.8933		
"	"	0.6[a]	1/8	.4366	Ratio to integrated D-43 samples	0.489
Texas	"	Integ.	Open	.2193	" " " " "	0.245
D-43	5-19-45	Integ.	3/16	.4455		
"	"	"	1/8	.4668		
D-43	5-22-45	Integ.	3/16	.5961)	Average = .5853	
"	"	"	1/8	.5745)		
AD-45	"	"	1/8	.6718	Ratio to average of D-43 samples	1.148
"	"	"	3/16	.6439	" " " " " "	1.100
Texas	"	"	Open	.2575	" " " " " "	.440

a 0.6 of total depth

b 1.0 ft. below water surface

APPENDIX - D

MEMORANDUM ON REVIEW OF PLANS FOR PROPOSED LITTLE ROCK DISTRICT DEPTH-INTEGRATING SUSPENDED SEDIMENT SAMPLER

By

Paul C. Benedict and M. E. Nelson

The following comments are offered based on a review of the plans of the depth-integrating sampler proposed by the Little Rock District:

(1) Field tests on the D-43 sediment sampler have indicated that 1/8-in. diameter intakes give more erratic results than larger nozzles, particularly during high river stages. These inconsistencies may be due to the greater tendency of the smaller intakes to clog with wastes and organic solids. Some difficulty may be anticipated in using a 1/8-in. diameter intake in the stream conditions encountered in the Little Rock District, especially during flood stages.

(2) The vertical tailvane should be about 3 in. higher than shown on the plans to facilitate orientation in streams, but the length of vane could be reduced about 2 in.

(3) The point of suspension should be as low as possible, but not less than about 3/4 in. above the center of gravity of the sampler.

(4) A conical compression spring in the bottom of the container recess may be more satisfactory than the flat plate and recessed spring shown.

(5) The tripping lever should be reversed to minimize the tendency of fouling with sand, weeds, roots, etc.

(6) A single lever action head catch is believed to be more satisfactory than the toggles shown. The single, wide toggle catch used on the P-43 sampler, with some slight modifications, is believed to be a satisfactory alternate to the lever action catch developed for the D-43 sampler.

(7) A better fitting valve can be obtained if the stem is slightly tapered rather than straight, and the rolling surfaces are lapped before the passages are drilled.

(8) Stream gaging experience indicates that better stability is obtained with sounding weights having circular cross-sections than with those having elliptical sections. Every cross-section of a sediment sampler should have a circular periphery.

When the development of the depth-integrating sediment sampler was initiated by the Interdepartmental Committee, it was thought that a round-trip sampler of this type could be used in streams of 30-ft. depth and that a one-way, bottom-closing depth-integrator could be used in streams of 60-ft. depth. A careful analysis of the effect of unbalanced pressure, transit rates, and relative velocity of sampler and stream, has indicated that the theoretical maximum depths in which these samplers can be used are 19 and 38 ft., respectively. Sufficient field tests to substantiate the opinion have not been performed, but apparently for practical reasons sampling depths for the two-way and one-way depth-integrating sediment samplers should be limited to about 15 and 30 feet, respectively.

The depth-integration method lends itself well to routine sampling within these limitations, but the true characteristics of the sediment loads in deeper streams and during flood periods can be obtained only with the point-integration method of sampling. While the operating range of a depth-integrating sampler is materially increased by utilizing a pressure compensating air chamber, as proposed in the Little Rock design, it is still subject to restrictions imposed by practicable transit rates, limiting relative velocity, and capacity of sample container. These restrictions are sufficiently important to question whether a simple depth-integration should be attempted at all in streams of greater depth than 30 ft. A single sample, even as large as one quart, does not adequately reflect the sediment load in a stream vertical 30 ft. or more deep, particularly in turbulent and fast flowing streams. Under these conditions several samples should be taken to obtain an accurate measurement of the mean sediment load transported. Obviously, the advantages of depth-integration, its simplicity and rapidity of sampling, which make this method more feasible than point-integration for routine and shallow sampling, lose their significance when multiple samples in a vertical are required.

The abundance of sediment data collected in past years which are now considered of doubtful value because of inaccurate methods and equipment should be an incentive to obtain the best possible basic information on sediment discharge, recognizing that the cost of sampling increases as the sampling procedure becomes more meticulous. If such information is of sufficient importance to collect at all, attempts should be made to obtain a degree of accuracy in sediment discharge measurements commensurate with that expected in stream gaging.

In deep streams and during flood periods, the point-integration method would provide accurate determinations of sediment load and would also indicate the quantitative distribution of sediment and particle sizes vertically and horizontally. The point-integrating sampler authorized by the Interdepartmental Committee will incorporate some new features

in design which will broaden its scope considerably without excessive increase in cost. The sampler which is now being designed will utilize either a pint milk bottle or a round pint fruit jar sample container, an electrical opening and closing device, and a streamlined body with a weight of 75 to 100 lbs. This sampler is satisfactory for average streams under normal flow conditions. In larger and deeper streams and under more extreme flow conditions, a similar sampler with larger container and greater weight may be required. The point-integrating sampler may be used also to collect depth-integrated samples. In shallow streams, depth-integration can be performed throughout the total depth, as with the regular depth-integrating samplers, while in deeper streams depth-integration can be accomplished in increments, taking a fraction of the depth at a time.