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DEPARTMENT OF THE INTERIOR
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BRANCH OF PROJECT PLANNING, HYDROLOGY DIVISION
BRANCH OF DESIGN AND CONSTRUCTION, RESEARCH AND GEOLOGY DIVISION

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STUDY OF SEDIMENT LOADS IN CHERRY CREEK

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ILLUSTRATIONS

Introduction

Many dams and sills have been constructed on Cherry Creek for the purpose of preventing degradation of the channel in and above the city limits of Denver. The existence of these degradation checks affords an excellent opportunity to compare the total sediment load with the suspended sediment load as measured with a D-48 hand sampler. When the Corps of Engineers announced that water which had been impounded behind the Cherry Creek Dam was to be released on April 11, 1950, it was decided to utilize the opportunity to take some suspended and total-load sediment samples. This study was undertaken primarily for the purpose of obtaining data on the amount and type of bed load carried by Cherry Creek. Bed load, as defined for this report, is the difference between the measured total load and the measured suspended load within a given section of the stream. It was also hoped that some information could be obtained on aggradation or degradation of the channel between the Cherry Creek Dam and the confluence of Cherry Creek and the South Platte River.

Acknowledgment

This study was initiated by E. W. Lane. Both he and W. M. Borland provided supervision and technical advice. Charts and special sampling equipment were furnished by the District Office, Corps of Engineers, U. S. Department of the Army, Denver, Colorado.

Preliminary Field Work

On April 10, 1950, an inspection trip of the Cherry Creek channel, from the mouth upstream to the Cherry Creek Dam, was completed by E. W. Lane, E. J. Carlson, and C. R. Miller. Notes on the channel condition were taken, and measurements of the drop in water surface at the various dams and sills were made for future reference relative to aggradation or degradation.

Two dams or stream-bed drops were chosen for the locations of the sediment sampling during the period of water release. These drops were approximately 4.18 and 4.46 miles, respectively, below the Cherry Creek Dam as indicated on Figure 1. Typical samples of the bed material were taken at these drops for future analysis.

Field Work

The field work of the sampling program was carried out on April 12, 1950, under the supervision of L. M. Seavy. Assisting in the field work were E. L. Pemberton, F. T. Brand, A. C. Carter, O. C. Hansen, and C. R. Miller.

The two drops which were chosen during the preliminary field trip were numbered Drop No. 1 and Drop No. 2, respectively, in a downstream direction. These drops, which include the reach immediately upstream, will be referenced by this nomenclature throughout this report.

The procedure in the vicinity of each drop consisted of the following operations:

1. The slope of the water surface was determined for a distance of 1,000 feet above the drop by levelling to stakes driven to the water surface near the drop and at a point located 1,000 feet above the drop. The elevations obtained were checked at the completion of sampling to see that no major change in the water stage occurred.

2. A cross section located approximately 500 feet above each drop was selected for the suspended sediment sampling and discharge determinations. Sediment samples were taken at various points across the stream as determined by dividing the stream into portions of equal flow-volumes and taking two samples in each flow division. Standard procedure was followed using a D-48 suspended-sediment hand sampler.

3. Total-load samples were taken at the drop with the D-48 suspended sediment hand sampler. Because of the nature of the drops, it was possible to lower the nozzle of the sampler to the stream bottom and thereby measure the total load (Figures 5 and 6). Samples referred to as open-neck samples were those obtained by lowering a bottle without the sampler apparatus to obtain sediment sizes larger than accommodated by the nozzle of the sampler.

4. The number of sediment samples taken at each cross section are shown in the following table:

Drop	No. of susp. samples	No. of total load samples	No. of open neck samples	Total
No. 1	16	14	2	32
No. 2	14	12	2	28
TOTAL	30	26	4	60

Photographs of the stream cross sections used for the sampling operation and of the D-48 hand sampler appear in Figures 2, 3, 4, 5, 6, and 7.

A 1/4-inch nozzle was used with the D-48 hand sampler; however, in taking the total-load samples as stated in Item 4 of the procedure, it was apparent that some of the particles were of a size not likely to enter the nozzle. The open-neck samples, therefore, were taken in an attempt to pick up this unmeasured load. Because of the limited supply of sampling bottles, it was not possible to take more open-neck samples. However, examination of the size-analysis curves indicates that the sizes larger than the nozzle diameter were a small percent of the total measured sediment load. In measuring the total load the nozzle, or bottle, in the case of the open-neck samples, was lowered until it touched the edge of the drop. In the process of taking the suspended samples, it was noted that the stream bed was shifting. Visible evidence of this condition was provided by moving sand bars.

The following is a table of the results of the measurements made in the field:

Drop	Slope	Width	Mean depth	Discharge	Temp.
No. 1	.00469	145 ft.	0.35 ft.	156.8 cfs	53° F
No. 2	.00420	144 ft.	0.34 ft.	156.6 cfs	52° F

Graphs of width versus depth and velocity relationships appear in Figures 8 and 9.

Laboratory Work

The 60 samples taken in this program were analyzed for concentration and size distribution under the supervision of O. S. Hanson in the sediment analysis laboratory of the Hydraulic Laboratory, Research and Geology Division, Branch of Design and Construction.

The bottle and entire sample as received in the laboratory were weighed on a balance to the nearest 0.1 g. The samples were then allowed to stand for a period of at least 48 hours and the clear water siphoned off. The sediment samples were washed into 50 ml beakers of known weight and dried in an electric oven at a temperature of 110° F. Empty sample bottles were then weighed, and the net weight of total sample was computed. After thorough drying the 50 ml beakers containing the sediment samples were reweighed to find the net weight of the sediment. From these data the concentration in each sample was found by the formula:

$$\text{Concentration in ppm} = \frac{\text{weight of sediment}}{\text{weight of total sample}} \times 1{,}000{,}000$$

The following table shows the concentration found for each sample and the average concentration in each section:

Drop	Sample	Verticals								Avg.
No.1	Suspended	2632	3290	2950	2943	2747	2669	3314	7304	3169
		2888	3974	2724	2406	2630	2750	2982	2507	
	Total	8151	4946	42900	18780	4246	15263	21146		15884
		8220	8693	20051	20959	3339	11638	34048		
	*Open neck	6841	3009							4952
No.2	Suspended	2679	3508	3077	3066	2655	2645	2046		
		2740	3554	3441	3128	2875	2276	2060		2839
	Total	2377	3127	5856	4397	3115	5873			
		2271	4108	14012	5293	3934	12257			5552
	*Open neck	15417	5029							10220

*Open neck samples taken in attempt to pick up particles too large to enter 1/4-inch nozzle during total load sampling.

After obtaining the concentrations of the individual samples, the samples were combined for the purpose of making a size analysis. In this operation all of the samples of a particular type, i.e., suspended-load, or total-load, or open-neck, which were obtained at a cross section, were composited. These composite samples were then washed through a 200-mesh screen. The sand retained on the screen was analyzed by sieving through U. S. Standard screens Nos. 10, 18, 35, 60, 120, and 230. That portion of each composited sample that passed the 200-mesh screen was allowed to settle and the clear water siphoned off. The balance of the sample was split into two portions, redispersed in distilled water, and analyzed by the bottom withdrawal tube method. The open-neck sample from Drop No. 1 contained such a small quantity of sand that the entire sample was analyzed by this method.

Procedures used in the bottom withdrawal tube analysis were those recommended in Report No. 7, "A Study of New Methods for Size Analysis of Suspended Sediment Samples," June 1943, published by St. Paul U. S. Engineers District Sub-Office, Iowa City, Iowa. Withdrawal fractions were filtered through Gooch crucibles using asbestos filter mats. All weighing was done on a chain-o-matic balance with an accuracy of 0.0001 g.

Figures 10 and 11 show size analysis curves for the suspended- and total-load samples.

A sieve analysis was also made of the two bed-material samples taken from the dry bed of the stream immediately above Drops No. 1 and No. 2 before the release of the impounded water. Figure 12 shows the size-analysis curves for these samples.

Summary

Since very little change occurred in the stream-bed elevations during this release, no information was obtained on aggradation or on degradation of the stream bed. Data obtained at this time will be kept on file and used for future reference after releases of larger and longer duration are made.

Analyses of these data show that practically the entire silt-size load carried by this stream moves in suspension. The concentration of silt sizes was the same in both suspended- and total-load samples. Since there was no silt size present in the bed material, this entire silt load must be coming from some upstream location and is carried through this reach without settling to the bed. The following table shows suspended and total loads and silt fraction thereof:

Drop	Susp. load tons per day	Total load tons per day	Silt fraction Susp. percent	Silt fraction Total percent	Silt fraction Susp. tons per day	Silt fraction Total tons per day
No.1	1335	6690	52.0	11.0	694	735
No.2	1208	2339	43.5	28.5	525	666

To arrive at a figure for the bed load carried by Cherry Creek, the difference between the measured suspended and total loads was assumed to be the bed load. As can be seen in the table above, the samples taken at the two sections agree very well as far as the suspended load is concerned. The total-load measurements, however, show a wide variation. This results in a rather wide variation in the bed-load figures. The table below shows the bed load as determined in this manner and that obtained by various bed-load formulas. In computing the bed load by use of the formulas, a mean diameter of 0.64 mm at Drop No. 1 and 0.53 mm at Drop No. 2 was used, except in applying Einstein's formula where the diameter used was 0.46 mm. The bed-material load is that portion of the total load which contains the bed-material sizes and which is determined from the size-analysis curves.

Drop	Measured load Total	Measured load Susp.	Bed	Bed-material load	Computed bed load Straub 1/	Computed bed load Einstein 2/	Schoklitsch 3/
No.1	6690	1335	5355	5220	2428	1302	909
No.2	2339	1208	1131	1265	2003	1022	836

In order to provide a means of estimating the bed load carried by streams where suspended-load data are available, an attempt has been made to develop the bed load as a percentage of the suspended load or of the total load. The percentage figures for these data are shown below:

1/ "Detritus Transportation," House Document No. 238, 73d Congress, 2d session, Missouri River, 1935, pp. 1124-1150

2/ Einstein, H. A., "Formulas for the Transportation of Bed Load," Transactions, A.S.C.E., New York, A.S.C.E., 1942, Vol. 107, pp. 561-574

3/ Shulits, S., "The Schoklitsch Bed Load Formula," Engineering, London, June 1935, pp. 644-646 and 687

DROP NO. 1

$$\frac{\text{Bed load}}{\text{Suspended load}} = \frac{5355 \text{ tons per day}}{1335 \text{ tons per day}} = 401 \text{ percent}$$

$$\frac{\text{Bed load}}{\text{Total load}} = \frac{5355 \text{ tons per day}}{6690 \text{ tons per day}} = 82 \text{ percent}$$

DROP NO. 2

$$\frac{\text{Bed load}}{\text{Suspended load}} = \frac{1131 \text{ tons per day}}{1208 \text{ tons per day}} = 94 \text{ percent}$$

$$\frac{\text{Bed load}}{\text{Total load}} = \frac{1131 \text{ tons per day}}{2339 \text{ tons per day}} = 48 \text{ percent}$$

AVERAGE OF ALL SAMPLES

$$\frac{\text{Bed load}}{\text{Suspended load}} = \frac{2581 \text{ tons per day}}{1271 \text{ tons per day}} = 203 \text{ percent}$$

$$\frac{\text{Bed load}}{\text{Total load}} = \frac{2581 \text{ tons per day}}{3852 \text{ tons per day}} = 67 \text{ percent}$$

Recommendations

Before definite figures and conclusions can be established, many additional studies such as this one must be made on Cherry Creek and on any other similar streams having drop structures where the total load can be measured. It was also apparent from these data that the total load of a stream fluctuates quite widely with time; and in order to obtain a satisfactory average value, a great many total-load samples should be taken at each section over a period of several hours.

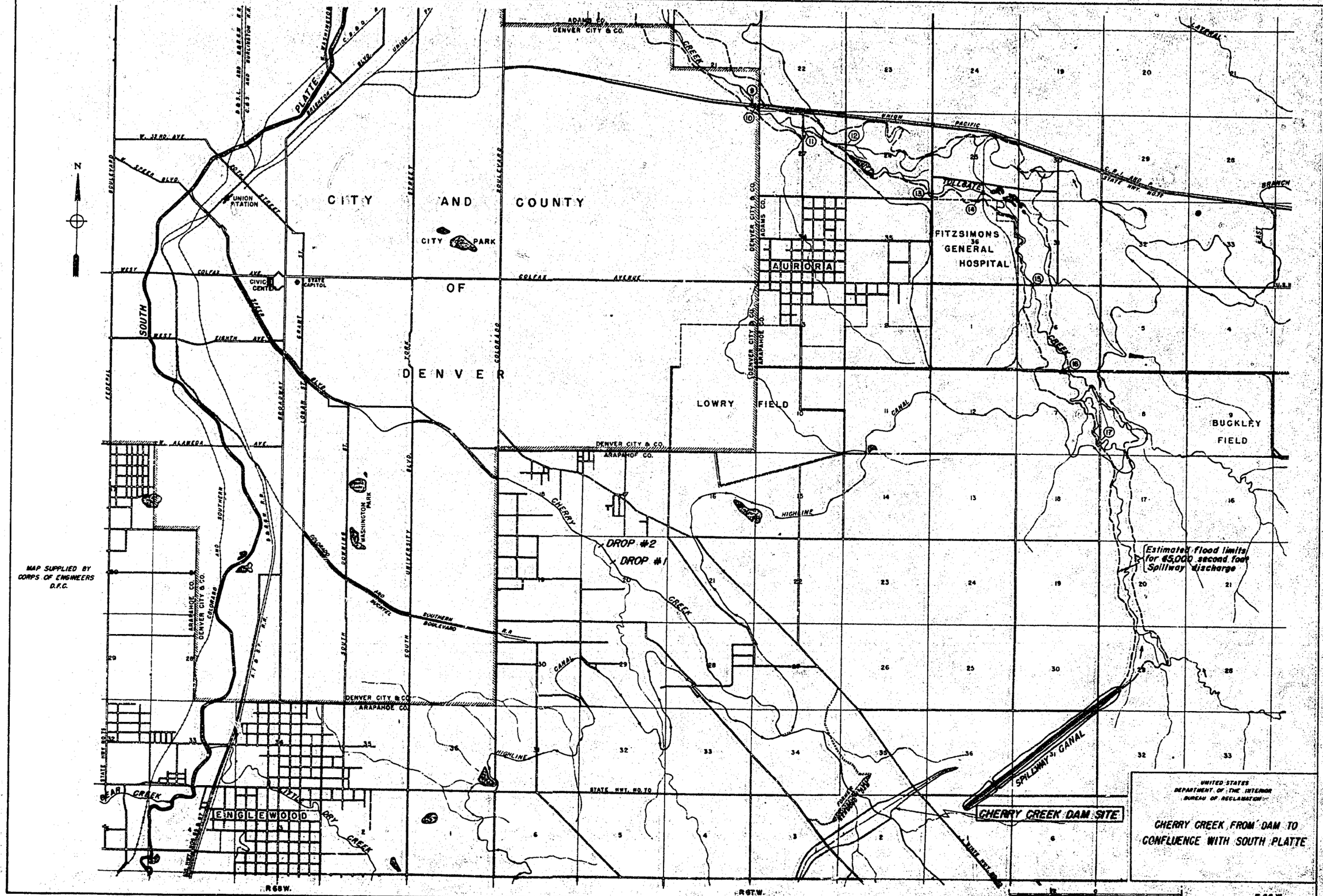

FIGURE 1
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(a) Gaging station 500 feet above 1st drop downstream from Cherry Creek Dam.

(b) Location the same as in (a) above. View from left bank looking towards right bank and slightly upstream.

DISCHARGE & SEDIMENT MEASUREMENTS
CHERRY CREEK, COLO. 4/2/50

FIGURE 2

(a) 1st drop on Cherry Creek below Cherry Creek Dam. Total load sediment measurements being obtained.

(b) Gaging station 195 feet above 2nd drop downstream from Cherry Creek Dam.

DISCHARGE & SEDIMENT MEASUREMENTS
CHERRY CREEK, COLO. 4/2/50

FIGURE 3

(a) 2nd drop on Cherry Creek below Cherry Creek Dam.

(b) View taken from left bank at 2nd drop below Cherry Creek Dam - looking upstream - 1st drop in background.

DISCHARGE & SEDIMENT MEASUREMENTS
CHERRY CREEK, COLO. 4/2/50

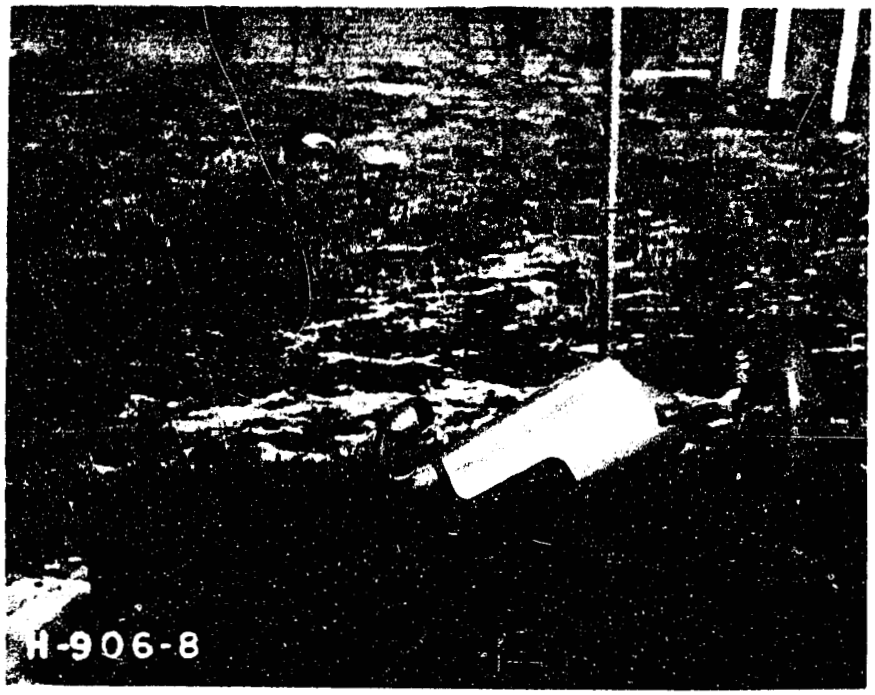
FIGURE 4

Drop No. 1--Site of total load samples.
Location: 4.18 miles downstream from Cherry Creek Dam.

FIGURE 5

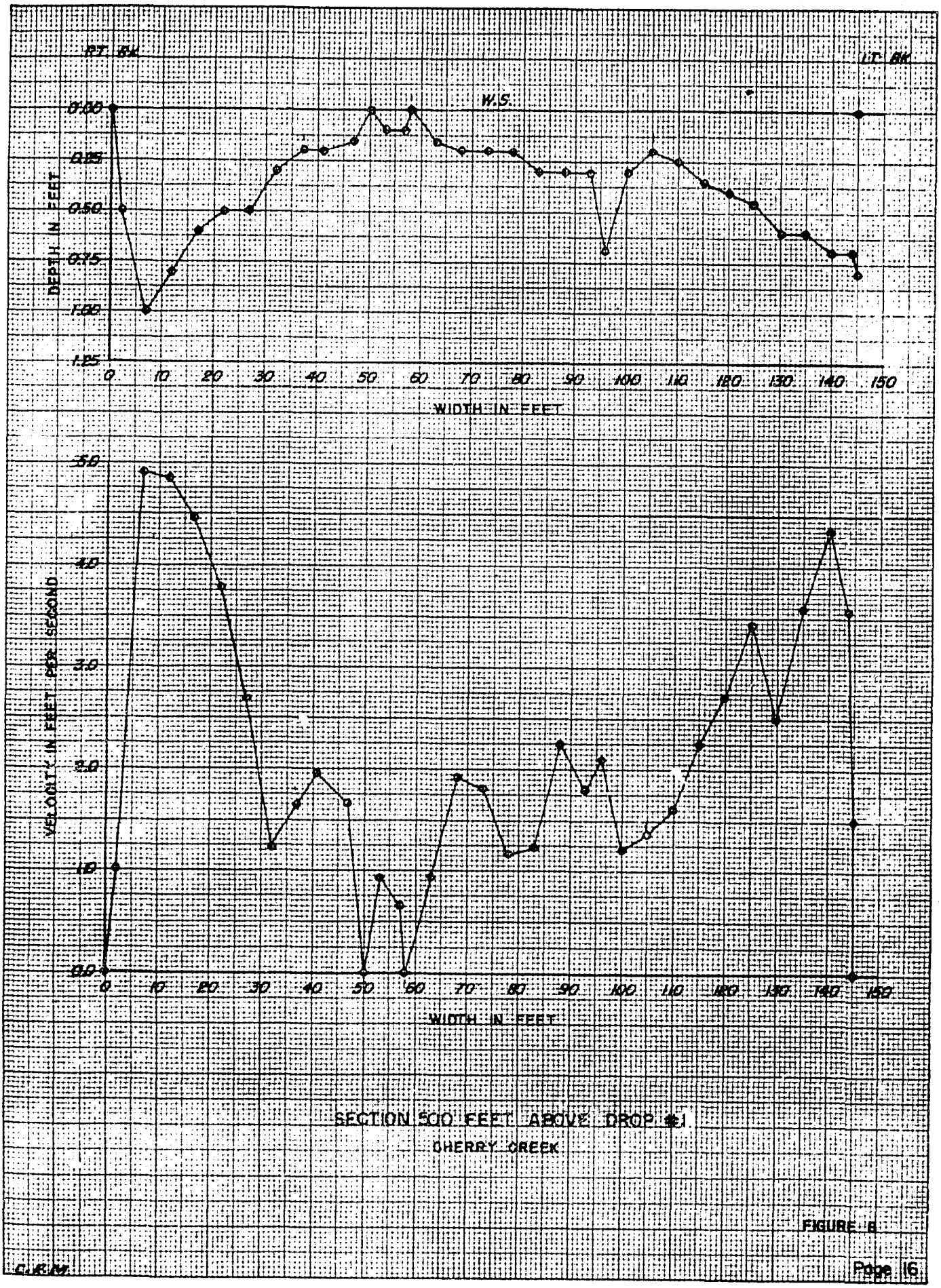
Drop No. 2--Site of total load samples.
Location: 4.46 miles downstream from Cherry Creek Dam.

FIGURE 6



Type D-48--Suspended sediment hand sampler used in suspended and total load sampling of Cherry Creek.

FIGURE 7

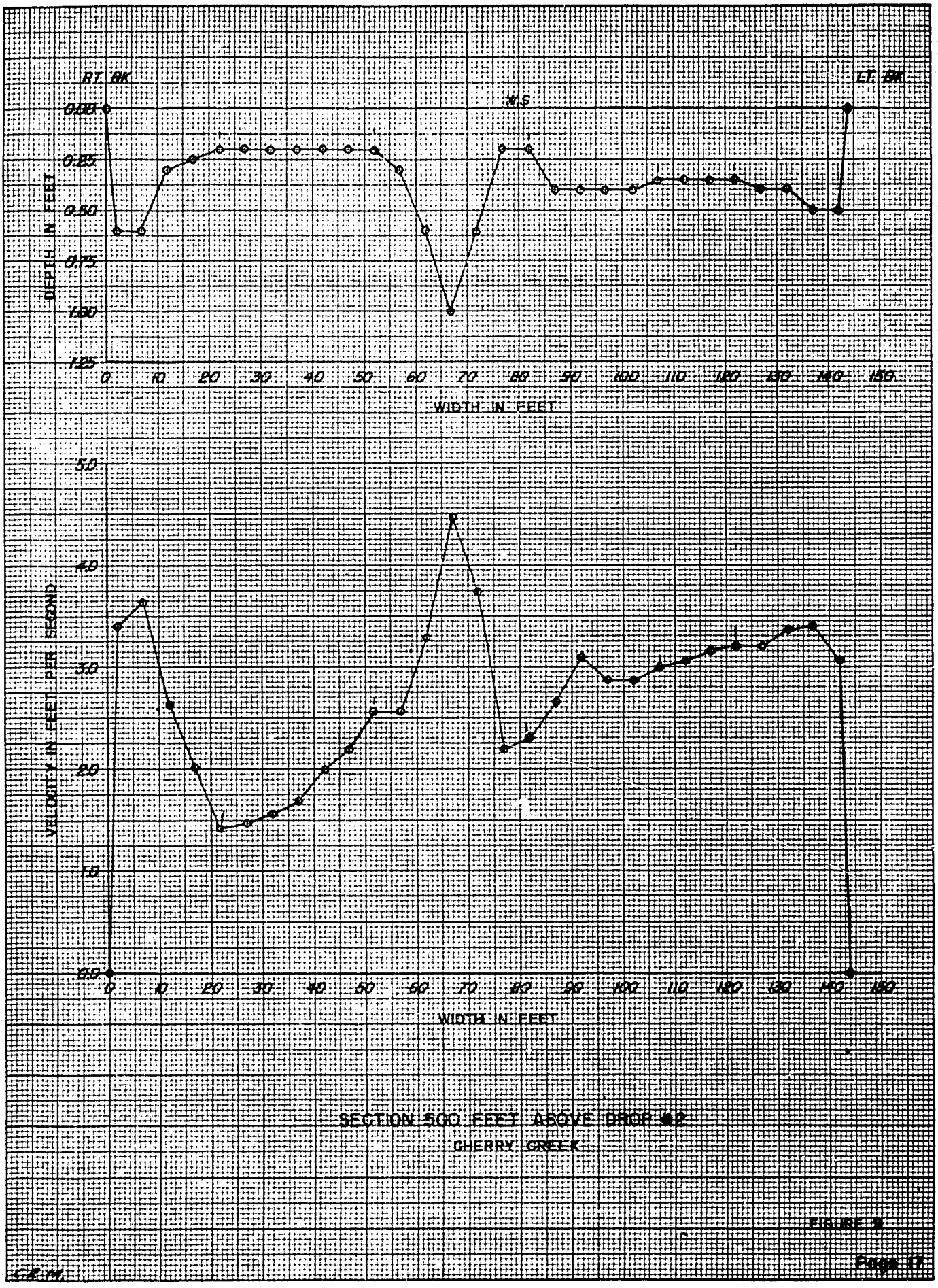


SECTION 500 FEET ABOVE DROP #1

CHERRY CREEK

FIGURE 8

C.R.M.

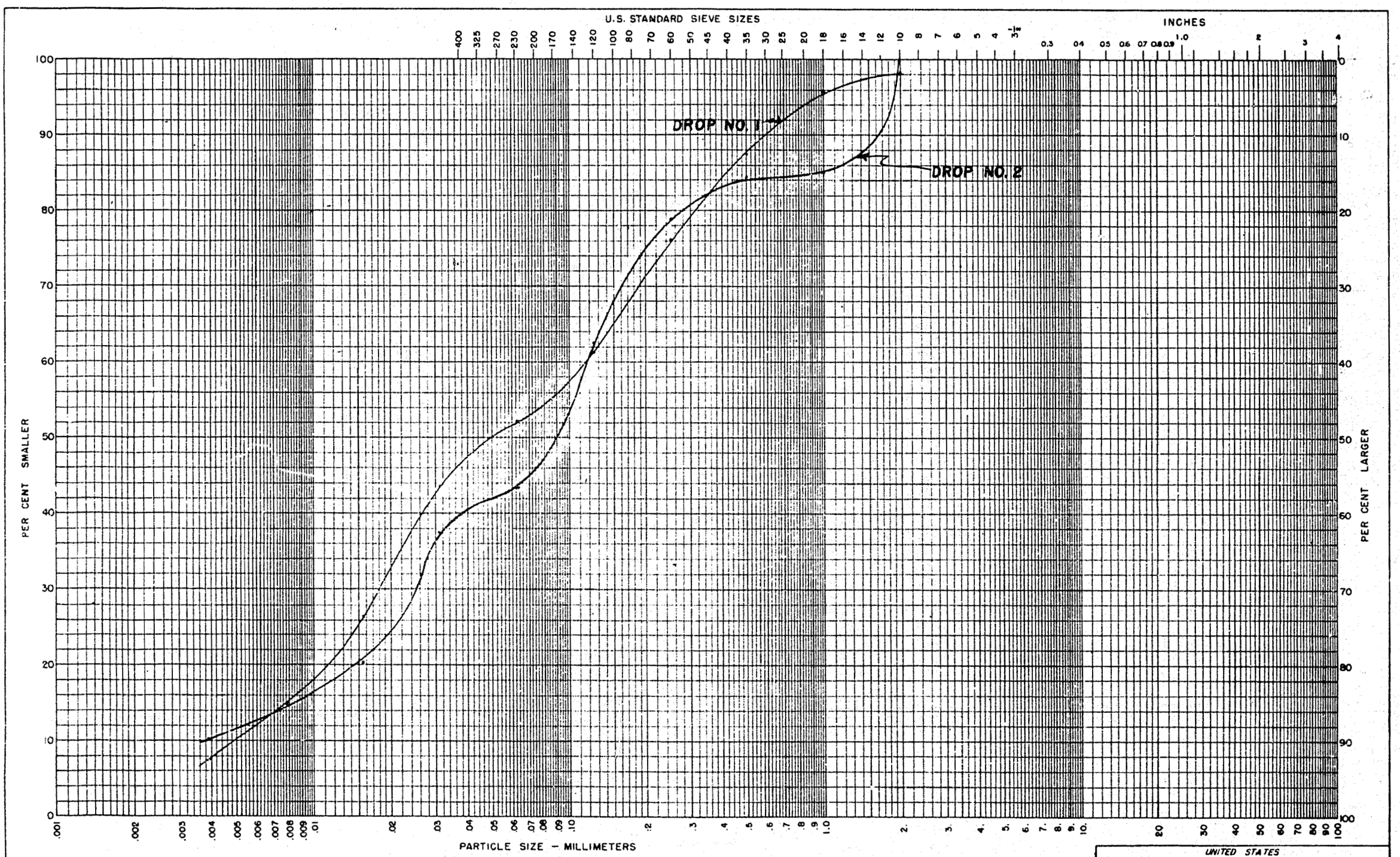


SECTION 500 FEET ABOVE DROP #2

CHERRY CREEK

FIGURE 9

C.E.M.



CLAY			SILT				SAND					GRAVEL		
Fine	Medium	Coarse	Very Fine	Fine	Medium	Coarse	Very Fine	Fine	Medium	Coarse	Very Coarse	Very Fine	Fine	Med.

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SAMPLES TAKEN
APRIL 12, 1950

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SEDIMENT SIZE ANALYSIS

CHERRY CREEK
SUSPENDED LOAD

DRAWN O.S.H. | SUBMITTED
TRACED | RECOMMENDED
CHECKED C.R.M. | APPROVED

DENVER, COLORADO

FIGURE 10
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U.S. STANDARD SIEVE SIZES

400 325 270 230 200 170 140 120 100 80 70 60 50 45 40 35 30 25 20 18 16 14 12 10 8 7 6 5 4 3½

INCHES

0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 2 3 4

DROP NO. 2 SAMPLER

DROP NO. 1 SAMPLER

DROP NO. 1 OPEN NECK

DROP NO. 2 OPEN NECK

PER CENT SMALLER

100 90 80 70 60 50 40 30 20 10 0

PER CENT LARGER

0 10 20 30 40 50 60 70 80 90 100

.001 .002 .003 .004 .005 .006 .007 .008 .009 .01 .02 .03 .04 .05 .06 .07 .08 .09 .10 .12 .3 .4 .5 .6 .7 .8 .9 1.0 2. 3. 4. 5. 6. 7. 8. 9. 10. 20 30 40 50 60 70 80 90 100

PARTICLE SIZE – MILLIMETERS

CLAY			SILT				SAND					GRAVEL		
Fine	Medium	Coarse	Very Fine	Fine	Medium	Coarse	Very Fine	Fine	Medium	Coarse	Very Coarse	Very Fine	Fine	Med.

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SAMPLES TAKEN
APRIL 12, 1950

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SEDIMENT SIZE ANALYSIS
CHERRY CREEK
TOTAL LOAD

DRAWN Q.S.H. SUBMITTED
TRACED RECOMMENDED
CHECKED C.R.M. APPROVED

DENVER, COLORADO

FIGURE 11
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U.S. STANDARD SIEVE SIZES

400 325 270 230 200 170 140 120 100 80 70 60 50 45 40 35 30 25 20 18 16 14 12 10 8 7 6 5 4 3½

INCHES

0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 2 3 4

DROP NO. 2

DROP NO. 1

PER CENT SMALLER

100 90 80 70 60 50 40 30 20 10 0

PER CENT LARGER

0 10 20 30 40 50 60 70 80 90 100

.001 .002 .003 .004 .005 .006 .007 .008 .009 .01 .02 .03 .04 .05 .06 .07 .08 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 2. 3. 4. 5. 6. 7. 8. 9. 10. 20 30 40 50 60 70 80 90 100

PARTICLE SIZE — MILLIMETERS

CLAY			SILT				SAND					GRAVEL		
Fine	Medium	Coarse	Very Fine	Fine	Medium	Coarse	Very Fine	Fine	Medium	Coarse	Very Coarse	Very Fine	Fine	Med.

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APRIL 10, 1950

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SEDIMENT SIZE ANALYSIS
CHERRY CREEK
BED MATERIAL

DRAWN A.S.H. SUBMITTED
TRACED RECOMMENDED
CHECKED C.R.M. APPROVED

DENVER, COLORADO

FIGURE 12
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