UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

TRAP-EFFICIENCY INVESTIGATION BERNALILLO FLOODWATER RETARDING RESERVOIR NO. 1 (PIEDRA LISA ARROYO) NEAR BERNALILLO, NEW MEXICO, WATER YEARS 1956-1974

By D. E. Funderburg

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Albuquerque, New Mexico

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TRAP-EFFICIENCY INVESTIGATION

BERNALILLO FLOODWATER RETARDING RESERVOIR NO. 1

(PIEDRA LISA ARROYO) NEAR BERNALILLO, NEW MEXICO

WATER YEARS 1956-1974

By D. E. Funderburg

Abstract

The U.S. Geological Survey, in cooperation with the U.S. Soil Conservation Service, began an investigation of sedimentation of Bernalillo Floodwater Retarding Reservoir No. 1 (Piedra Lisa Arroyo) near Bernalillo, New Mexico in 1956. This investigation was part of a natiowide investigation of the trap efficiency of detention reservoirs. Reservoir No. 1 is normally a dry reservoir and runoff from the 4.1 m^2 (10.6 km^2) drainage area generally occurs from high-intensity summer thundershowes. The mesa area of the drainage basin was treated to prevent erosion and gullying and to retard rapid runoff of rainfall. The land treatment consisted of pits, terraces, seeding, and restricted grazing. The total outflow recorded for the period of record (July 19, 1956 to June 30, 1974) was 133 acre-feet (0.164 hm^3), yielding 1,439 tons (1,305 tonnes) of sediment. Over 99 percent of the coarse sediments and a high percentage of the silts and clays were deposited in the reservoir before reaching the outflow pipe. The determined trap efficiency of Reservoir No. 1 was 96 percent for the period of record.

Introduction

On October 17, 1955, representatives of the Soil Conservation Service and the U.S. Geological Survey met in Albuquerque, N. Mex. to discuss the objectives of the national program for collection of data on trap efficiency of detention reservoirs in the United States. A field reconnaissance of Bernalillo Floodwater Retarding Reservoir No. 1 (Piedra Lisa Arroyo) near Bernalillo, N. Mex. led to the formation of a joint program to measure the trap efficiency of the reservoir. A joint investigation was initiated at the request of the Soil Conservation Service under authorization of Public Law 566 and executed by the Geological Survey with funds transferred by the Soil Conservation Service under letter of agreement dated December 29, 1954. Funds for the 1958 and subsequent fiscal years were provided through the Soil Conservation Service.

Through appraisal and evaluation of hydrologic principles, this study was intended to (a) provide planning data for the design of small detention reservoirs; (b) distinguish the principal factors that influence trap efficiency; and (c) study sediment yield as related to the physical characteristics of small drainage basins.

A progress report of trap-efficiency studies of Bernalillo Reservoir No. 1 on Piedra Lisa Arroyo near Bernalillo, N. Mex. for the water years 1956 and 1957 was prepared in April 1958, and incorporated with reports on similar projects from other parts of the country (Guy and others, written commun., 1958). This report outlined the physical nature of the drainage basins and objectives of the over-all program.

A supplemental progress report for Bernalillo Floodwater Retarding Reservoir No. 1, was submitted for water year 1958.

This report was followed by a summary progress report for the same station, water years 1956-1963.

The present summary report, for water years 1956 through 1974, includes revised sediment-load computations for the period.

In this report some measurements are given in English units followed by metric units in parentheses. The conversion factors used are:

English unit	Multiply by		Metric unit
acre-feet (acre-ft)	1233	=	cubic meters (m^3)
acre-feet (acre-ft)	0.0012335	=	cubic hectometers (hm^3)
foot (ft)	0.3048	=	meter (m)
mile (mi)	1.609	=	kilometer (km)
square mile (mi^2)	2.59	=	square kilometer (km^2)
inch (in)	25.4	=	millimeter (mm)
cubic feet per second (ft^3/s)	0.0283	=	cubic meter per second (m^3/s)
ton (short)	0.9072	=	tonne (t)

Description of the drainage basin

Bernalillo Floodwater Retarding Reservoir No. 1 on Piedra Lisa Arroyo (Lat 35°18'50"N., Long 106°31'44"W.) is located in Sandoval County in Bernalillo Grant, 0.3 mi (0.5 km) east of intersection of State Highway 44 and Interstate 25, 1.5 mi (2.4 km) northeast of Bernalillo, and 17 mi (27 km) north of Albuquerque, N. Mex. (fig. 1).

Runoff flows generally northwest into the reservoir. The drainage area is 4.1 mi^2 (10.6 km^2), about 0.4 to 0.9 mi (0.6 to 1.4 km) wide, and 5.9 mi (9.5 km) long. The drainage basin extends from the top of Sandia Mountain [9,350 ft (2,850 m) above mean sea level] down steep slopes for 2.1 mi (3.4 km) [6,000 ft (1,829 m) above mean sea level] and then flattens out on mesa land for the remaining 3.8 mi (6.1 km).

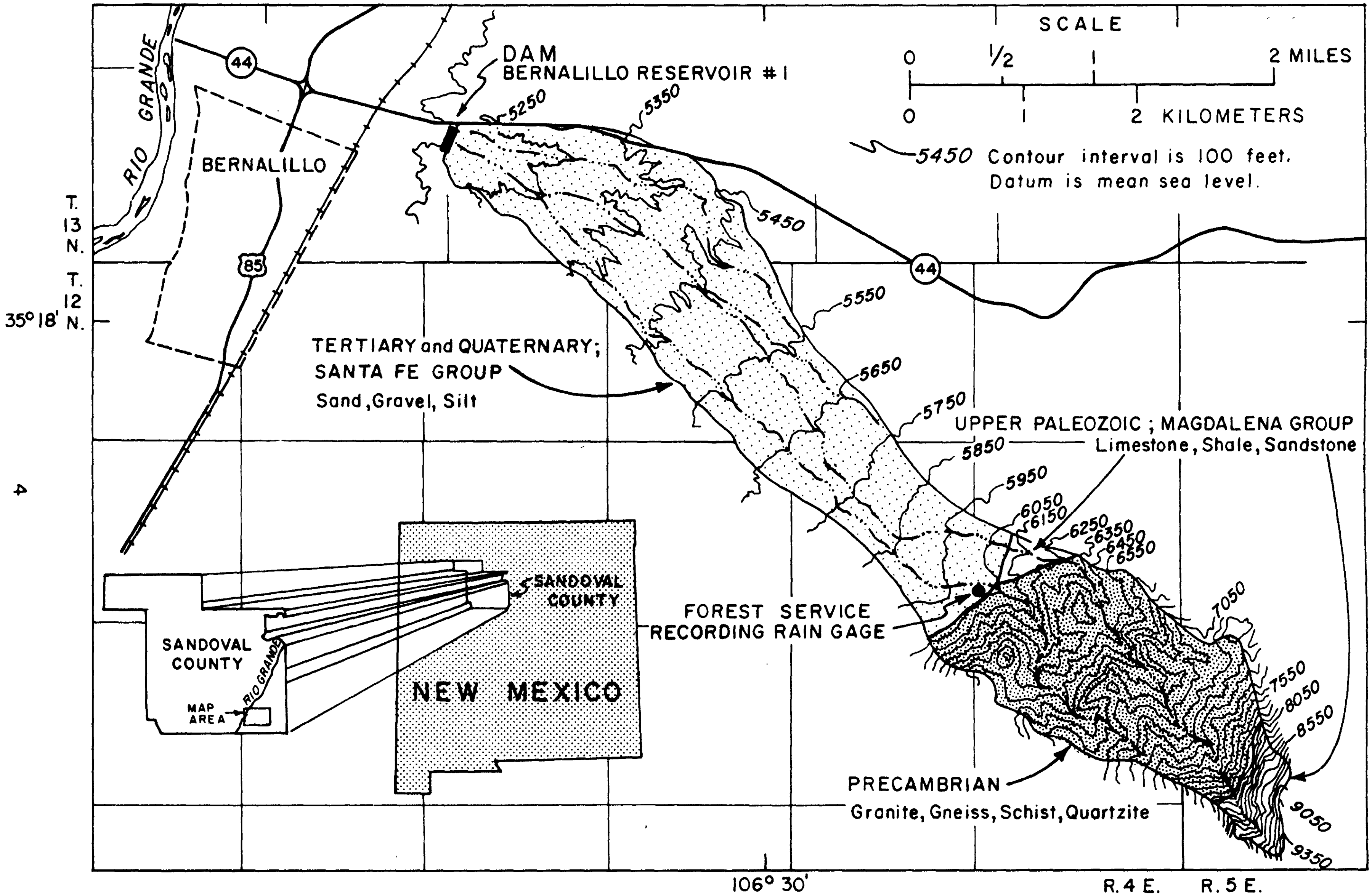
The steep and rugged terrain of the upper drainage basin changes abruptly at the break in slope to the gently sloping terrain of the lower basin. During 1956, the mesa area was treated in accordance with recommendations of the Soil Conservation Service to prevent erosion and gullying and to retard rapid runoff of rainfall. The land treatment consisted of pits, terraces, seeding, and restricted grazing. Figure 2 is an aerial photograph that shows part of the treated area.

Exposed in the drainage basin are: Precambrian rocks in the foothills, upper Paleozoic rocks (Magdalena Group) in the mountains and along the lower edge of the foothills, and Tertiary and Quaternary semi-consolidated sands and gravels (Santa Fe Formation) in the lower two-thirds of the basin.

The Precambrian rocks, consisting of granite, gneiss, quartzite, and schist, are resistant. The more erodible Paleozoic rocks are approximately 60 to 80 percent limestone with the remainder as shale and sandstone, and the semi-consolidated Santa Fe Formation is easily eroded by running water.

Description of reservoir

The reservoir is formed by earth-fill structure 1,030 ft (314 m) in length, about 200 ft (61 m) wide at the base, 15 ft (5 m) wide at the top with a maximum height of 37 ft (11 m), an upstream slope of 3:1 and a downstream slope of 2:1. The large open spillway crest at the south end of the dam is at elevation 5,197.0 ft (1,584.0 m) (27.0 ft gage datum) and the top of the dam is at elevation 5,205.0 ft (1,586.5 m).


DAM
BERNALILLO RESERVOIR # 1
SCALE
0 1/2 1 2 MILES
0 1 2 KILOMETERS
5450 Contour interval is 100 feet.
Datum is mean sea level.
RIO GRANDE
44
BERNALILLO
85
T. 13 N.
T. 12 N.
35° 18' N.
5250
5350
5450
5550
5650
5750
5850
5950
6050
6150
6250
6350
6450
6550
7050
7550
8050
8550
9050
9350
TERTIARY and QUATERNARY;
SANTA FE GROUP
Sand, Gravel, Silt
UPPER PALEOZOIC; MAGDALENA GROUP
Limestone, Shale, Sandstone
FOREST SERVICE
RECORDING RAIN GAGE
PRECAMBRIAN
Granite, Gneiss, Schist, Quartzite
SANDOVAL COUNTY
SANDOVAL COUNTY
RIO GRANDE
MAP AREA
NEW MEXICO
106° 30'
R. 4 E.
R. 5 E.

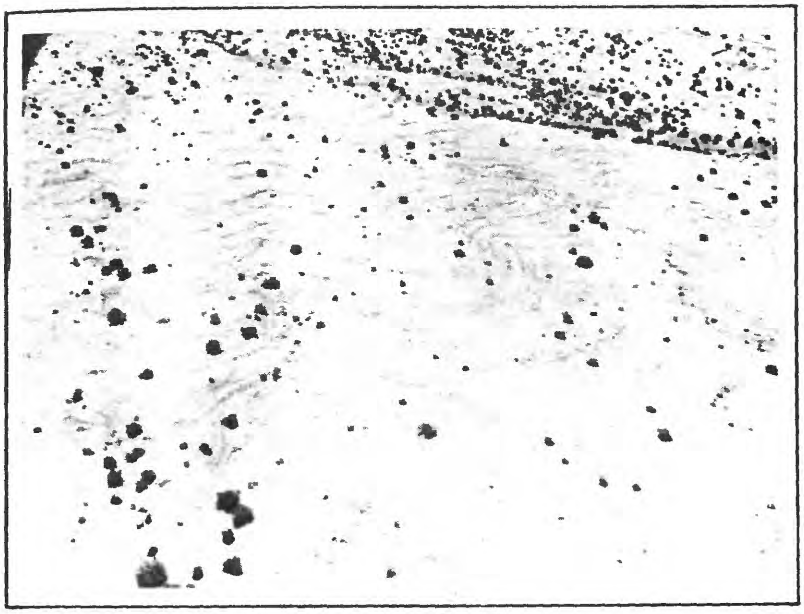


Figure 2.--Aerial view of lower portion of drainage basin showing terraces built by the Soil Conservation Service to retard flow.

The reservoir is roughly a semicircle with the dam forming the straight side. The original capacity of the reservoir below the emergency spillway elevation was 310.6 acre-ft (0.383 hm^3). This storage represents approximately 1.5 in (38 mm) of runoff from the drainage basin. Two tributaries enter the reservoir at the upper end as shown in figure 3. This photograph also shows deltas of sediment at the entrance of the two tributaries.

The outlet structure in the reservoir is a 3.0 ft (0.9 m) square concrete riser connected to a 2.0 ft (0.6 m) diameter pipe 192 ft (59 m) long extending through the base of the dam (fig. 4). The riser has a plank cover to top and nine ports in the walls. Each port is 2.0 ft (0.6 m) wide and 1.0 ft (0.3 m) high. The sill of the lowest port is at elevation 5,173.89 ft (1,577.00 m) (3.91 ft gage datum) or at the approximate bottom of the reservoir. In 1963, a concrete weir was built upstream from the lowest port opening. This raised the elevation at which flow would begin (point of zero flow) from 5,173.89 ft (1,577.00 m) to 5,174.74 ft (1,577.26 m) (4.76 ft gage datum).

Hydrologic measurements

Rainfall was measured by a recording rain gage in the drainage basin (fig. 1). This gage was read and records kept by Forest Service personnel. Most of the precipitation was the result of spring and summer thunderstorms.

A gaging station was installed in the reservoir on September 20, 1955 by the U.S. Geological Survey. The gaging structure and outlet tower are shown in figures 4 and 5. This recording gage provided a continuous record of water-surface elevation in the reservoir. Inflow to the reservoir was computed using these data and reservoir-contents data. Outflow discharge from the reservoir was determined based on change in contents of the reservoir when there was no inflow and checked by discharge measurements downstream from the outlet pipe.

Improvements to the gaging facilities

A sampling platform was attached to the end of the outflow pipe after the first flow (fig. 6). Additional bracing beneath the outflow pipe was added in 1963 to prevent swaying of the outflow pipe during periods of flow. Riprap also was added below the outflow pipe to prevent further undercutting of the bank.

A supplementary outflow gage 390 ft (120 m) downstream from the toe of dam (water-stage recorder and Parshall flume) was installed in July 1958 (fig. 7). The Parshall flume has a 5 ft (1.5 m) throat width, a 2.5 ft (0.8 m) throat depth, and a capacity of 86 ft^3/s (2.44 m^3/s). Since 1958, most of the outflow water-discharge records were computed from the outflow gage.

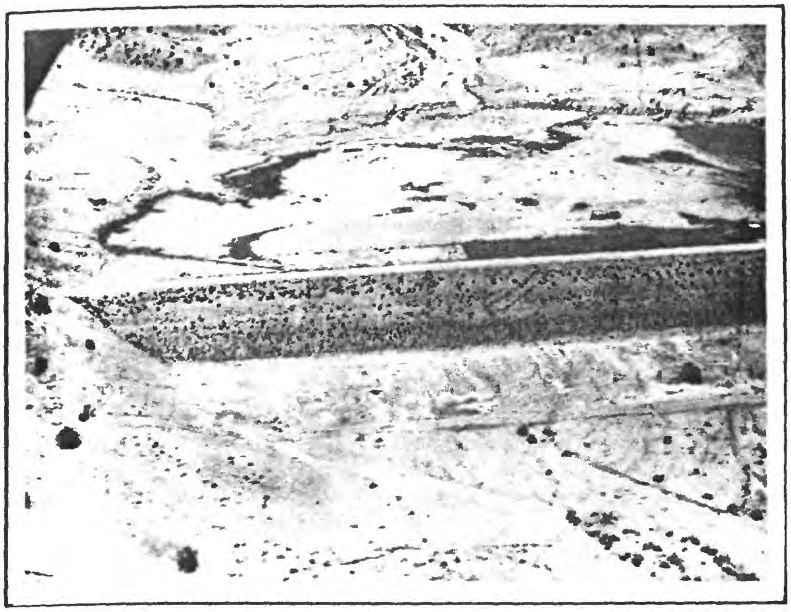


Figure 3.--Aerial view of dam and detention reservoir looking upstream.

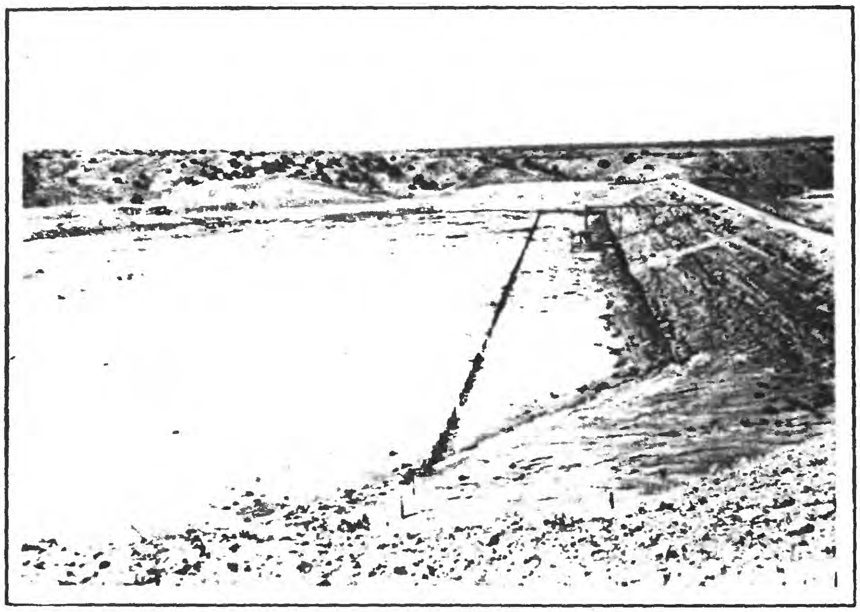


Figure 4.--Photograph showing general view of dam and detention reservoir subsequent to first flow on July 20, 1956.

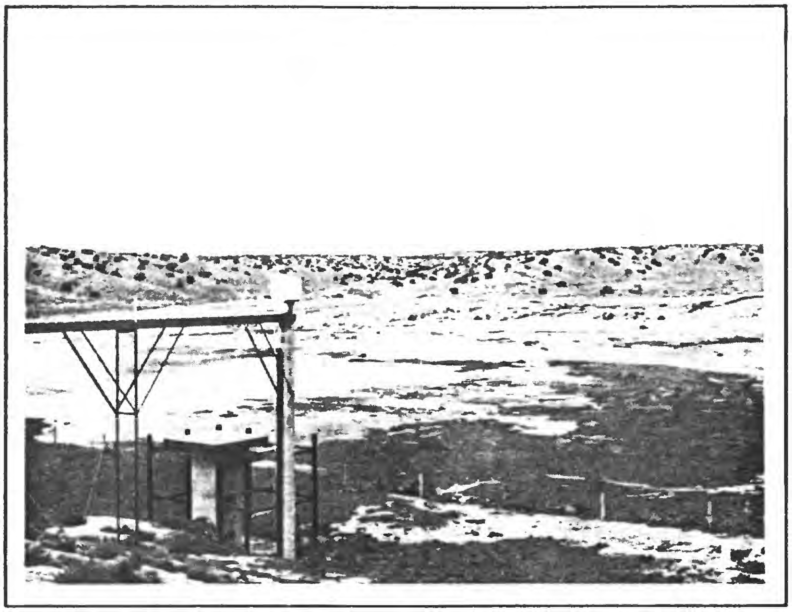


Figure 5.--Photograph of gaging structure and outlet tower in detention reservoir.

Figure 6.--Photograph of outlet pipe below dam, with sampling platform and equipment box.

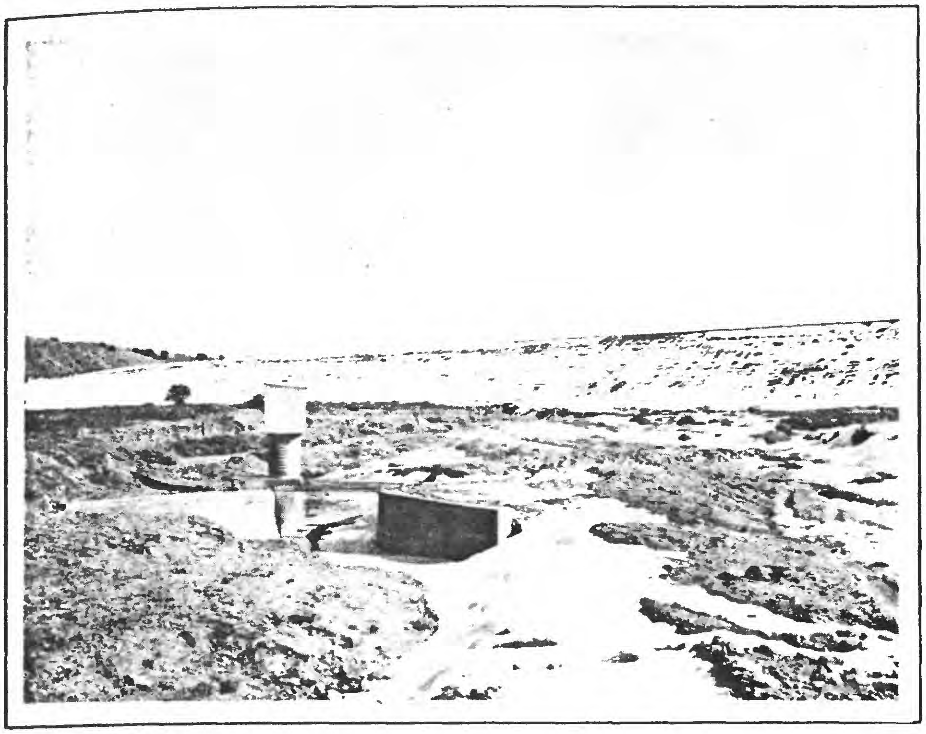


Figure 7.--Photograph of Parshall flume and recording gage downstream from outlet pipe.

Sediment sampling operations

Outflow-sediment samples were collected from the sampling platform at the downstream end of the outlet pipe. Inflow samples were collected from the tributaries immediately upstream from the reservoir.

Whenever possible outflow sampling started concurrent with the beginning of flow and was continued at frequent intervals to define the variation in sediment concentration throughout the flow event. Inflow samples were obtained when possible from each of the two tributaries at or near the crest of each rise.

Inflow samples were difficult to obtain because inflow peaks are of short duration and high velocity. Some material carried by the inflow was larger than the standard 1/4-inch (6.36 mm) nozzle on the DH-48 suspended-sediment sampler.

Outflow samples were easier to obtain; however, as with the inflow sampling, the presence of personnel at the infrequent runoff events was most difficult to arrange. Single-stage samplers were installed on the outlet tower in 1957 to supplement the manual sampling program. Since the installation of the single-stage sampler, no flows were large enough to allow valid comparisons between these samples and outflow samples, therefore, the few samples obtained from the fixed sampler have not been included in this report.

Discussion of flow events

1956 Water Year. Flow event Nos. 1 and 2 occurred during this water year. Event 1 was the largest flow event that occurred during the period covered by this report, yielding an outflow-sediment load of 570 tons (517 t). The first flow (July 19-20, 1956) caused gullying at the entrance of the south tributary into the reservoir. The alluvial fan composed of the material eroded from the drainage basin, and this cut is visible in the upper center of the aerial photograph of figure 3. A Forest Service report on the Bernalillo Watershed storm of July 19, 1956, (Palpant, 1956) stated that "many of the terrace type strucures were of insufficient capacity to hold the volume of runoff from the area immediately above them. This was especially noted where structures were located in areas which had fairly steep slopes with defined watercourses. If one structure was not of sufficient capacity it flowed over and eventually cut through to the common ground level. The volume of water thus released would fill the structure below it. The structure would again cut out but at a more rapid rate. As a result, a complete series of structures would be washed out, releasing water in large volumes but more rapidly than normal for untreated lands. The capacity of other terraces was reduced by sediment inflow. Overall percentage of breakage, however, was small." Events 1 and 2 scoured a plunge pool about 15 ft (5 m) deep below the outlet pipe (fig. 6).

Curves and hydrographs showing cumulative rainfall at rain gage No. 1, inflow and outflow discharge, and outflow-sediment concentration for flow events 1 and 2 are presented in figures 8 and 9. None of the outflow samples taken during event No. 1 contained material in the sand range, as the inflow apparently was ponded sufficiently before making its way to the outlet tower. The 9:30 p.m. outflow sample collected on August 2, 1956 contained 15 percent sand, probably due to the high-velocity flow reaching the outlet tower before ponding. Rainfall-runoff data for other flow events are shown graphically in figures 10 through 22.

Outflow-sediment load as well as outflow volume and average concentration of outflow sediment for all 33 outflow events covered by this report are presented in table 1. All particle-size analyses are presented in table 2, and all chemical analyses of the native water from these size analyses are presented in table 3. Chemical analyses were discontinued after 1966.

1957 Water Year.--There were no outflow events this water year.

1958 Water Year.--There were four flow events; the two smallest of these events were not sampled.

Curves and hydrographs showing cumulative rainfall at rain gage No. 1, inflow and outflow discharge, and outflow-sediment concentration of flow events No. 3 and No. 5 are presented in figures 10 and 11. All outflow sediment was finer than sand size (0.062 mm) this water year.

The outflow-sediment load for flow events 4 and 6 was estimated from a sediment-transport curve based on instantaneous data collected during this water year. An estimate was made for each subdivision in the computation, then totaled. The estimates appear reasonable as indicated by figure 23, a plot of outflow volume (acre-feet) per event against outflow-sediment load (tons).

1959 Water Year.--One flow event (No. 7) occurred during this water year, and no sand was observed in the outflow. The average concentration of 13,700 mg/L (milligrams per liter) was the highest observed for the period of this report. Curves and hydrographs showing accumulative rainfall, inflow and outflow discharge, and outflow-sediment concentration for the event are presented in figure 12.

1960 Water Year.--There was one unsampled flow event (No. 8) and the outflow-sediment load was estimated in the same manner as events 4 and 6.

1961 Water Year.--Only one of the two flow events this water year was sampled. The outflow-sediment load for the unsampled event was estimated as before. Inflow and outflow-discharge hydrographs and outflow-sediment concentration curve for event No. 9 are presented in figure 13.

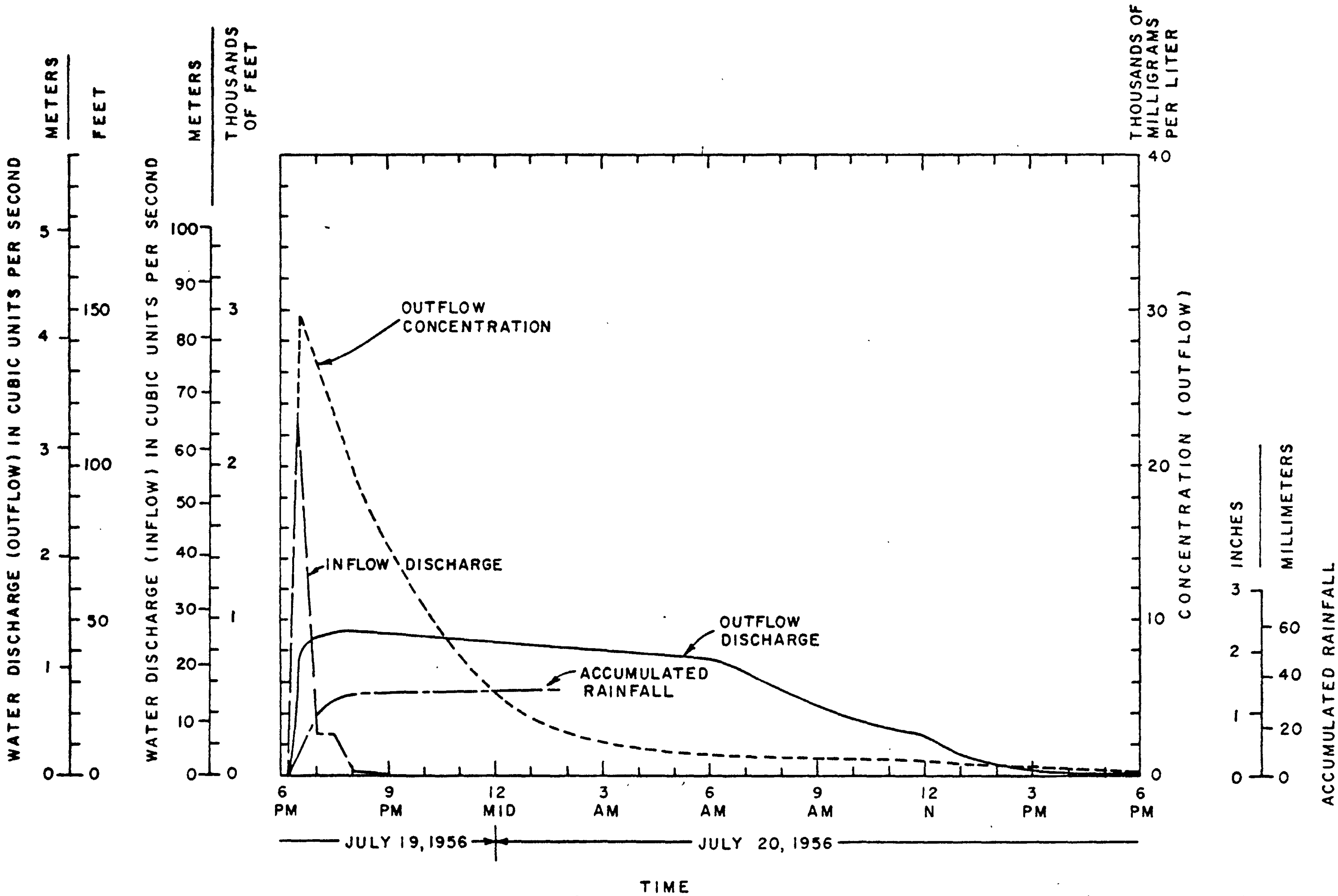


Figure 8.--Inflow and outflow-water discharge, accumulated rainfall, and outflow-sediment concentration for flow event 1, July 19-20, 1956.

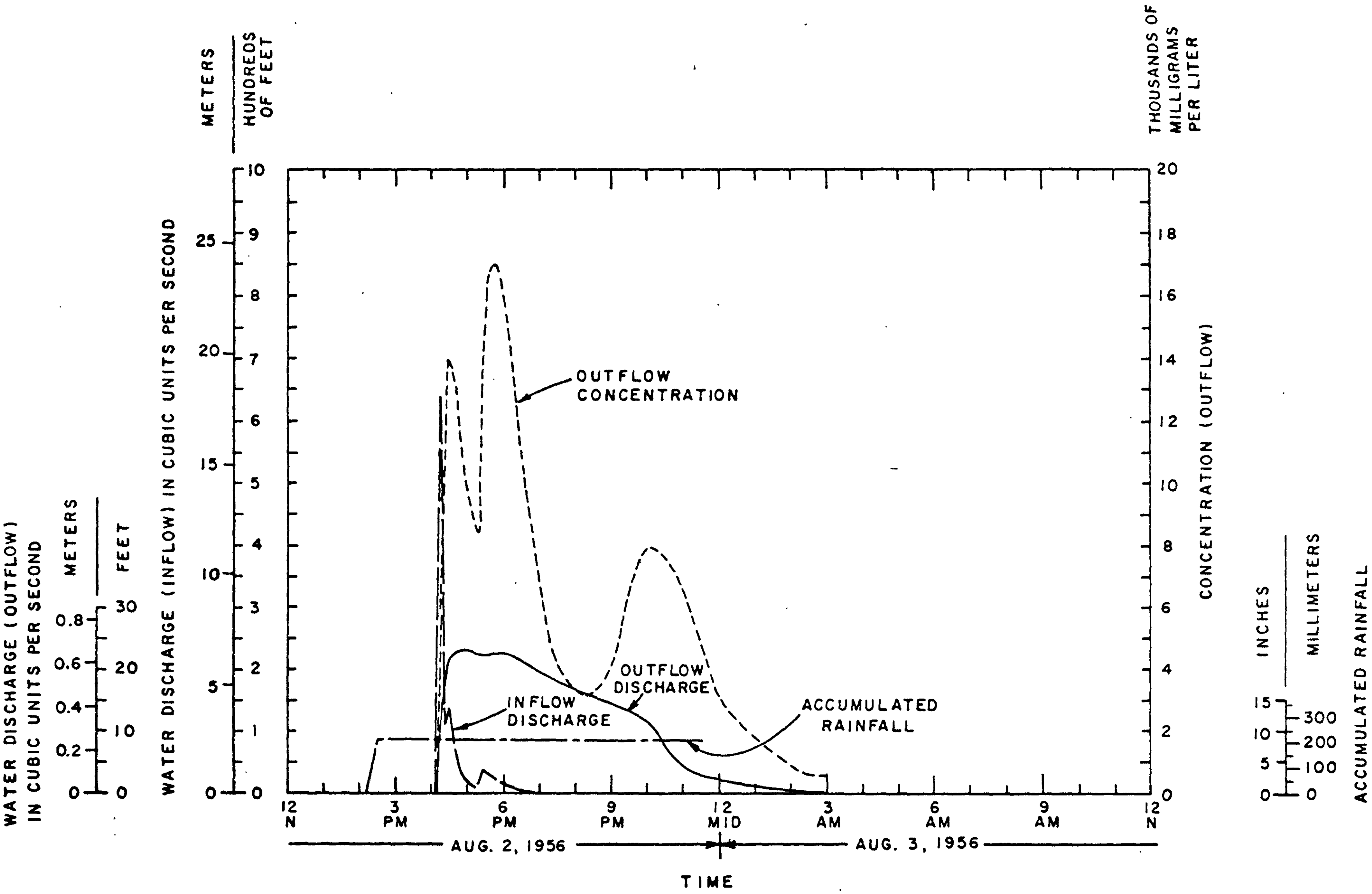


Figure 9.--Inflow and outflow-water discharge, accumulated rainfall, and outflow-sediment concentration for flow event 2, August 2-3, 1956.

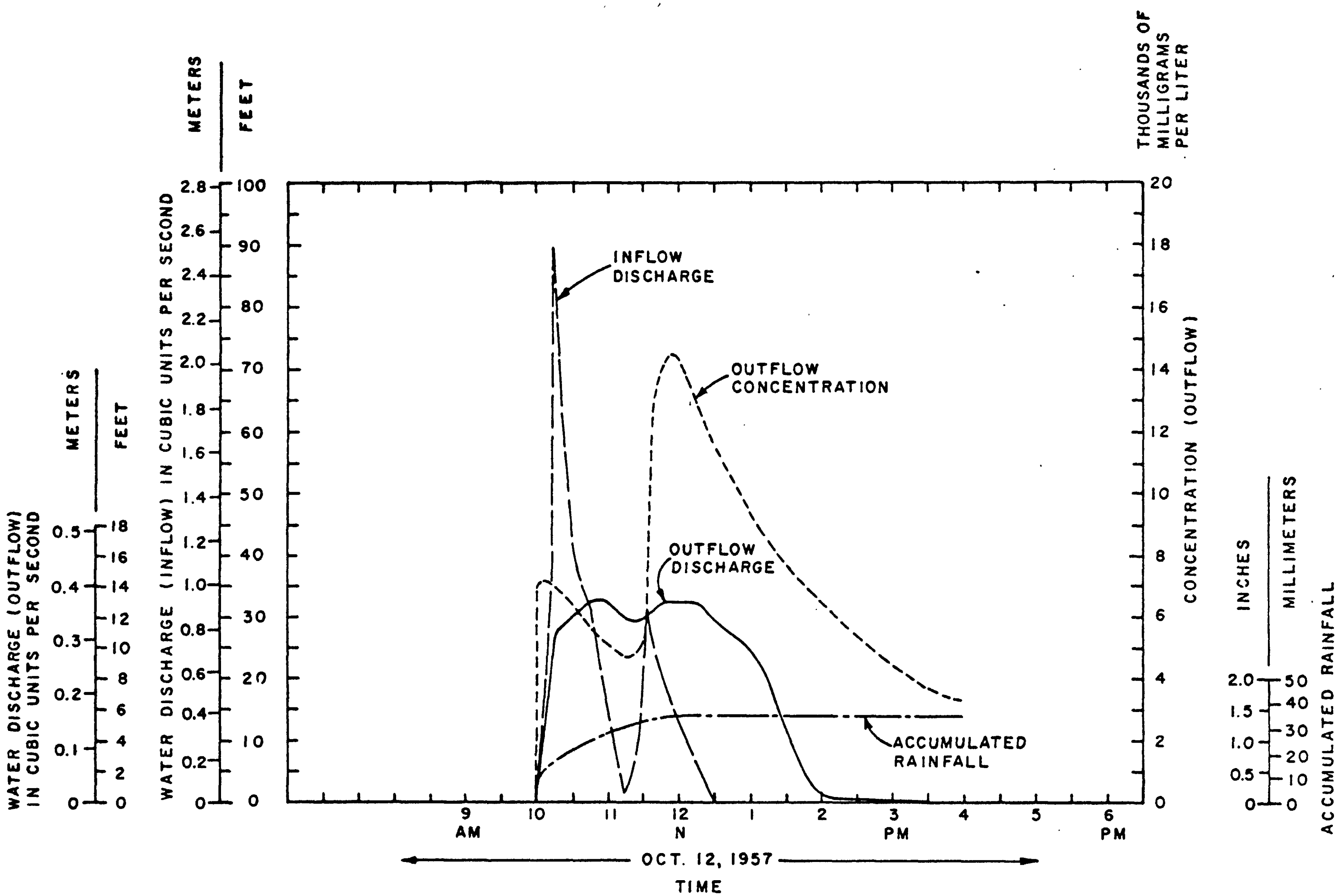


Figure 10.--Inflow and outflow-water discharge, accumulated rainfall, and outflow-sediment concentration for flow event 3, October 12, 1957.

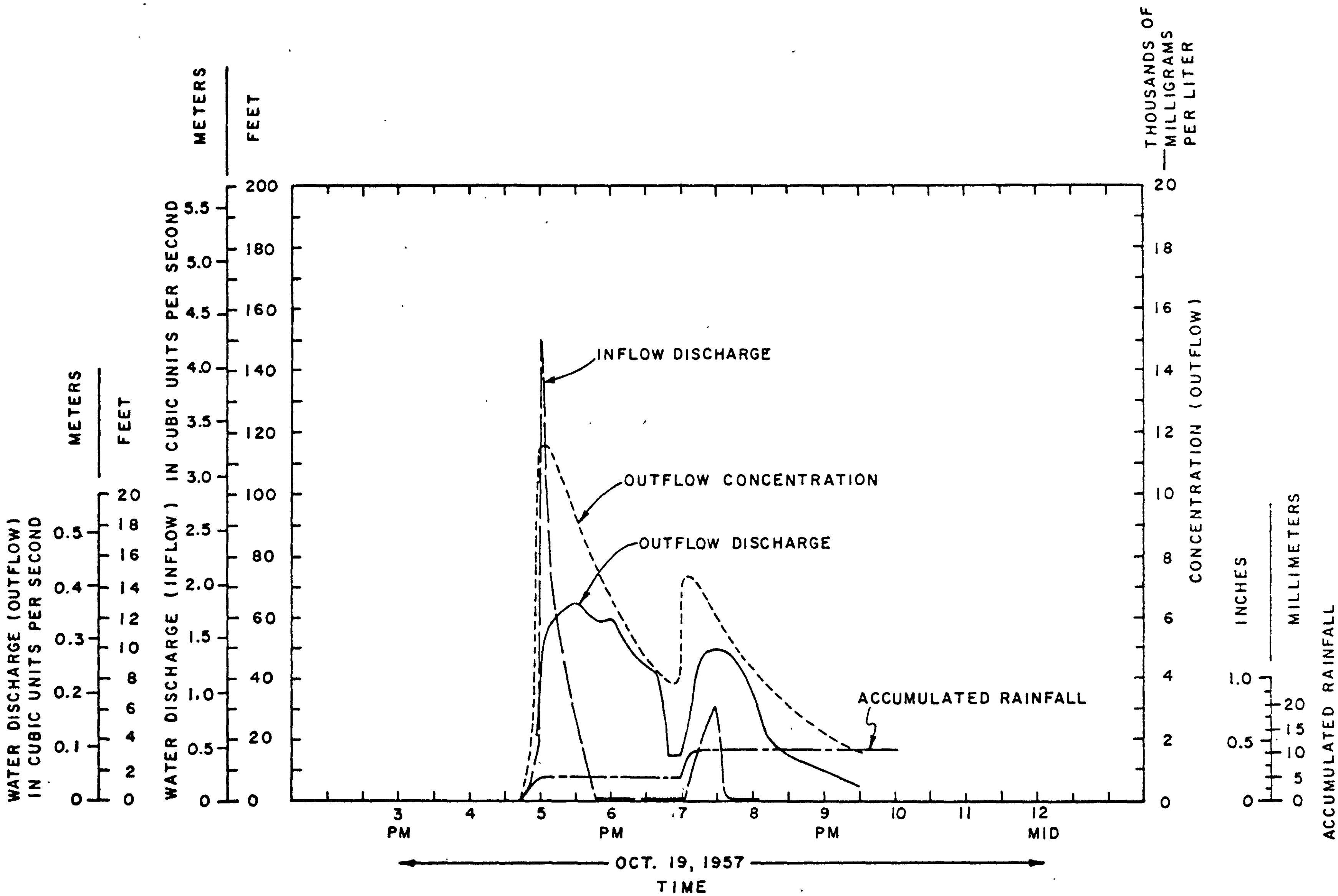


Figure 11.--Inflow and outflow-water discharge, accumulated rainfall, and outflow-sediment concentration for flow event 5, October 19, 1957.

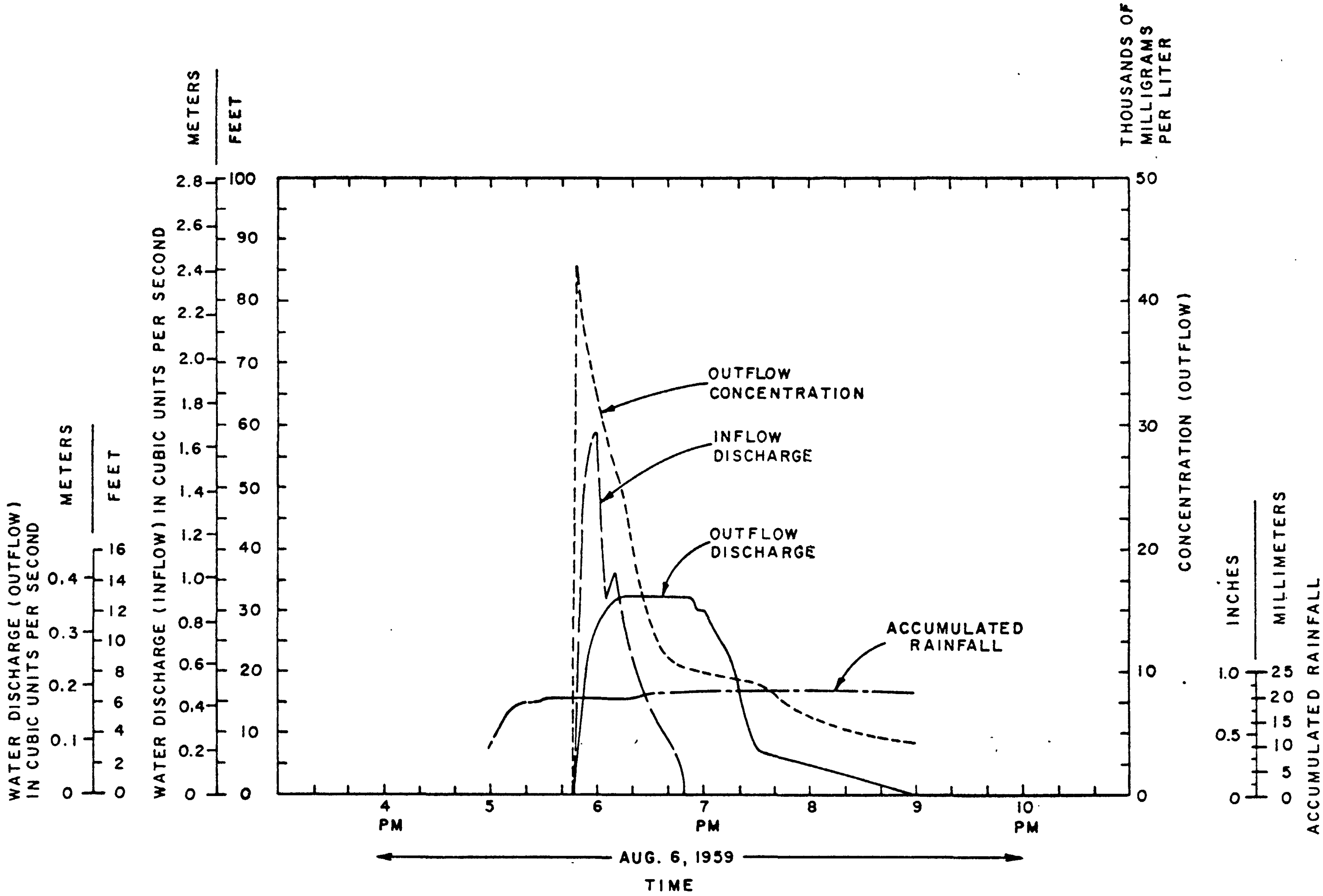


Figure 12.--Inflow and outflow-water discharge, accumulated rainfall, and outflow-sediment concentration for flow event 7, August 6, 1959.

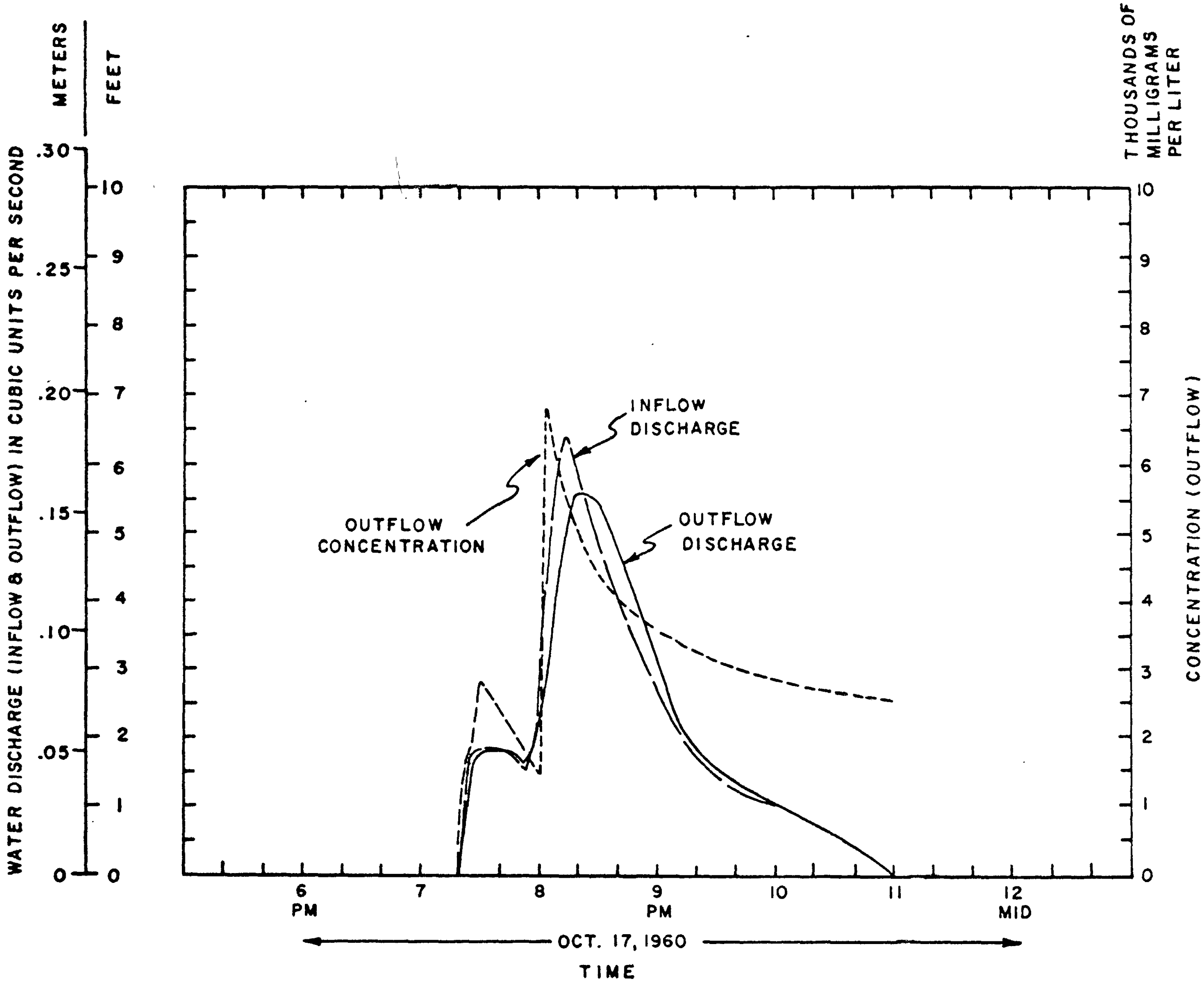


Figure 13.--Inflow and outflow-water discharge, and outflow-sediment concentration for flow event 9, October 17, 1960.

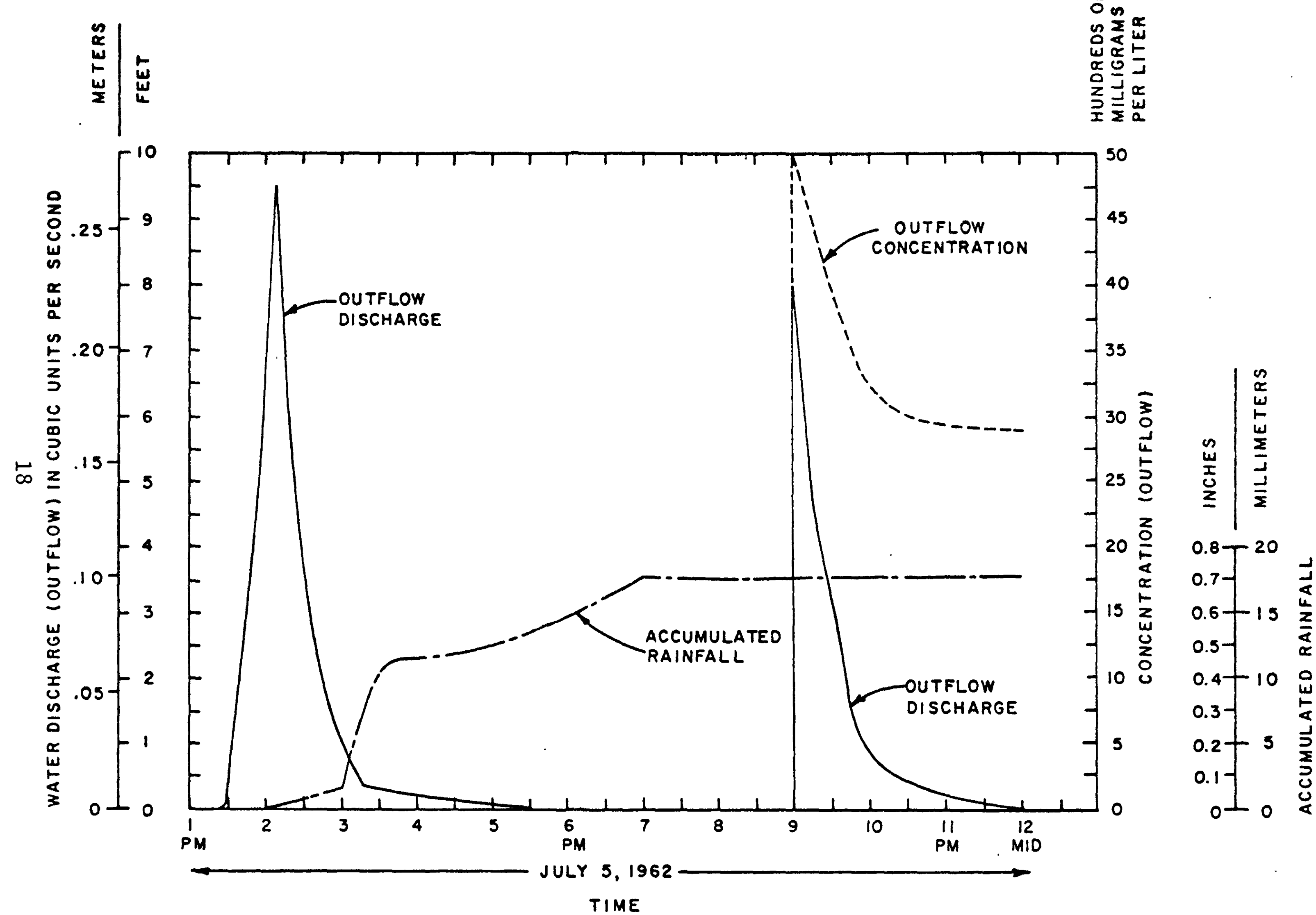


Figure 14.--Outflow-water discharge, accumulated rainfall, and outflow-sediment concentration for flow events 11 and 12, July 5, 1962.

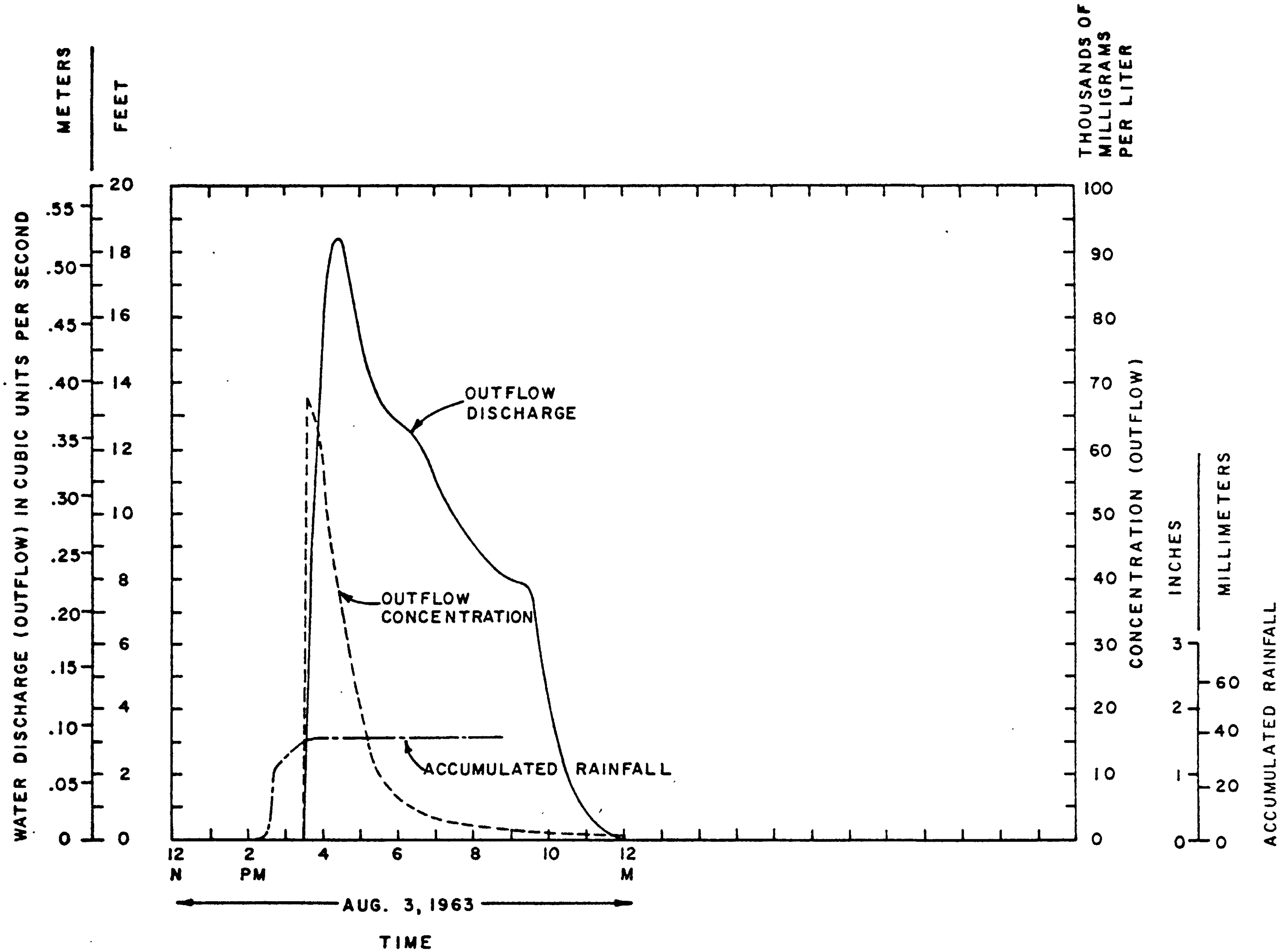


Figure 15.--Outflow-water discharge, accumulated rainfall, and outflow-sediment concentration for flow event 14, August 3, 1963.

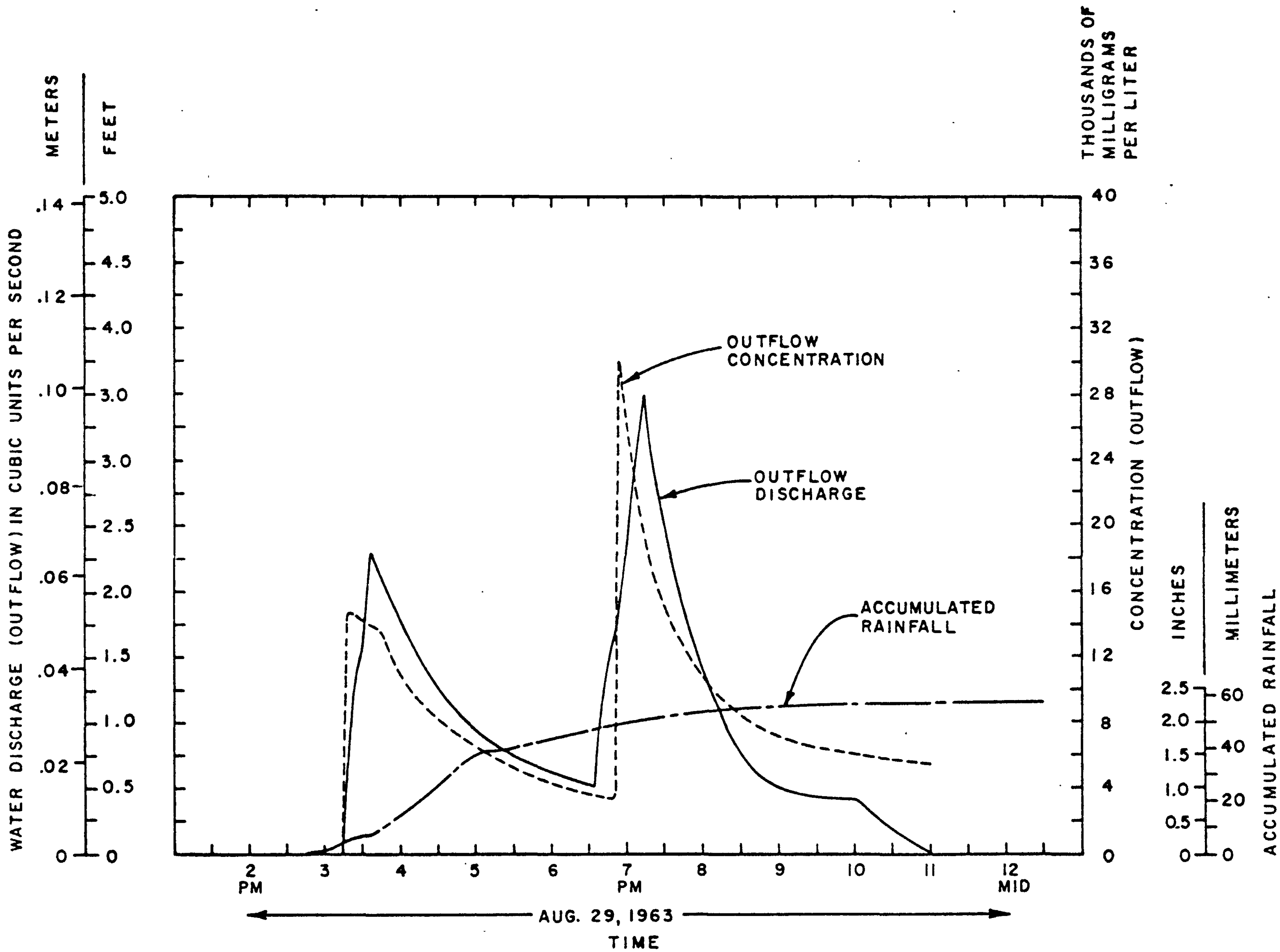


Figure 16.--Outflow-water discharge, accumulated rainfall, and outlfow-sediment concentration for flow event 15, August 29, 1963.

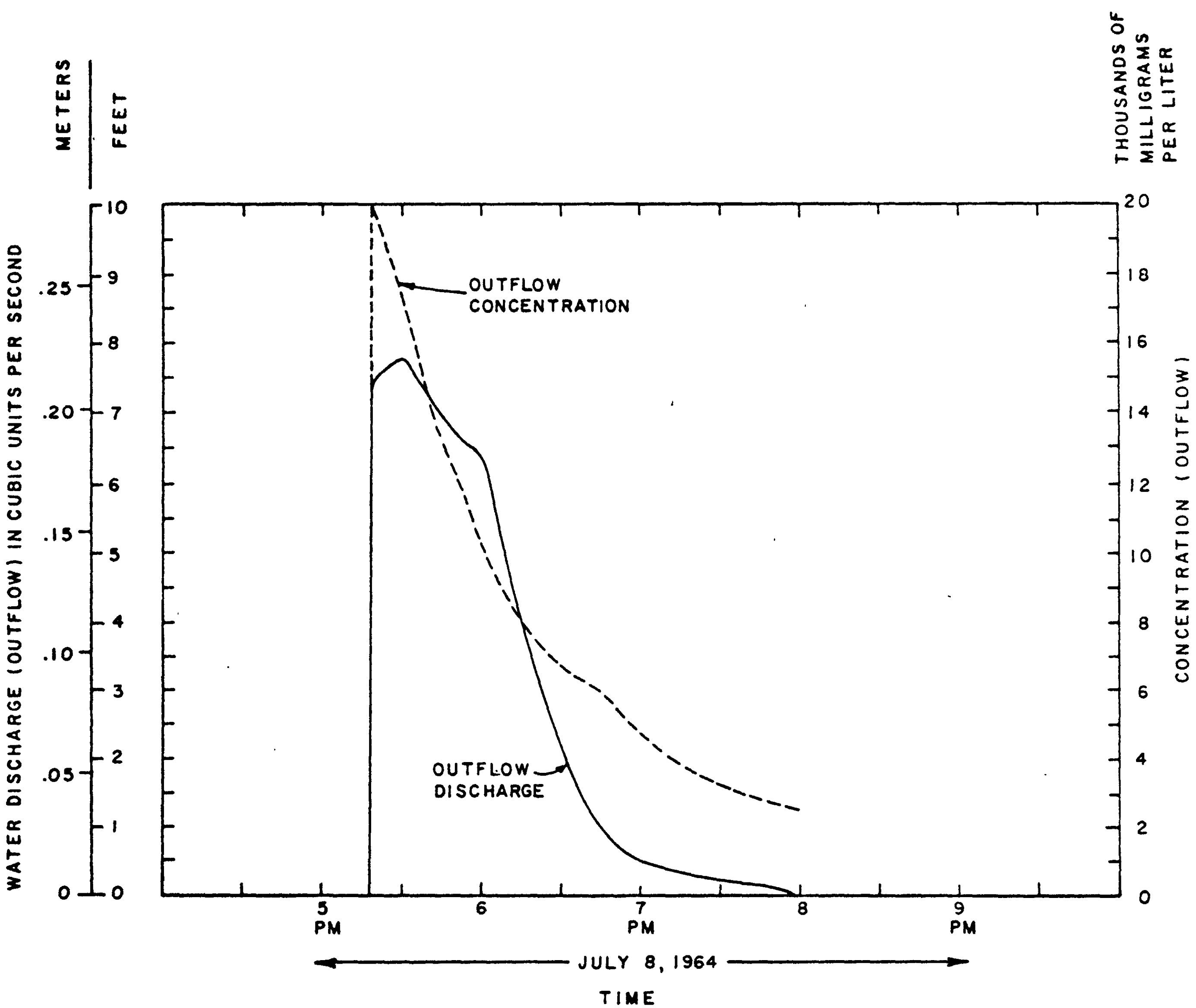


Figure 17.--Outflow-water discharge and outflow-sediment concentration for flow event 16, July 8, 1964.

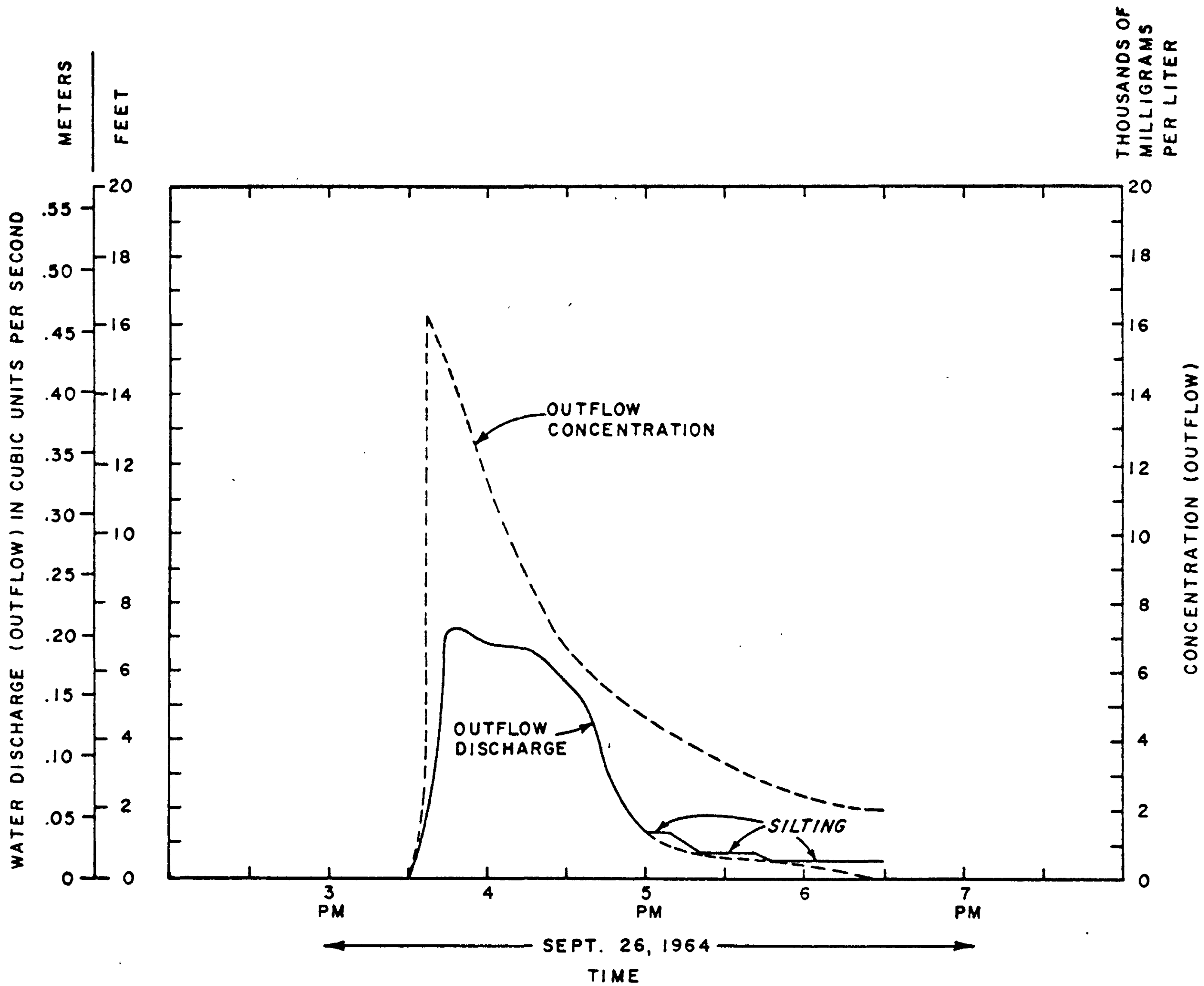


Figure 18.--Outflow-water discharge and outflow-sediment concentration for flow event 17, September 26, 1964.

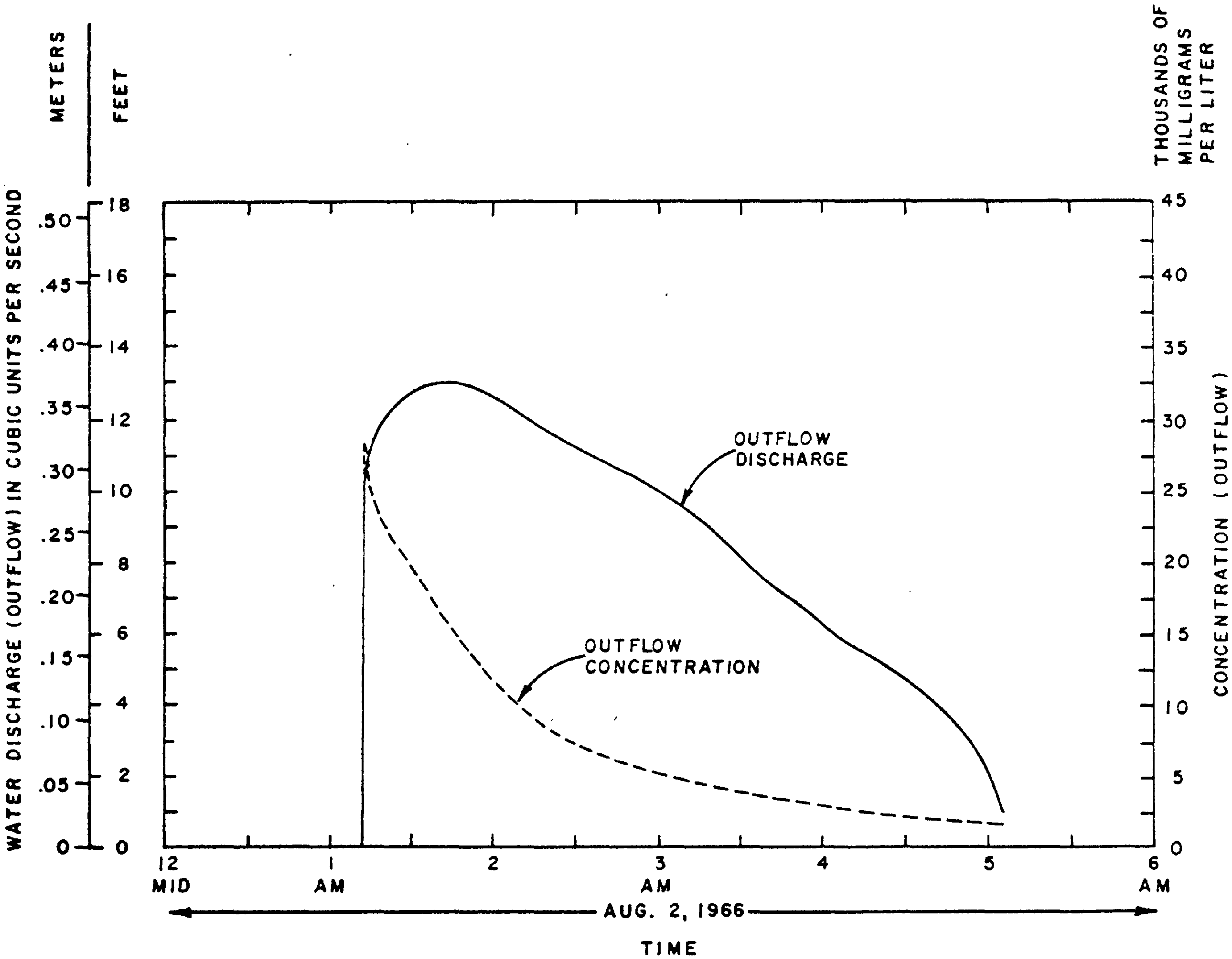


Figure 19.--Outflow-water discharge and outflow-sediment concentration for flow event 19, August 2, 1966.

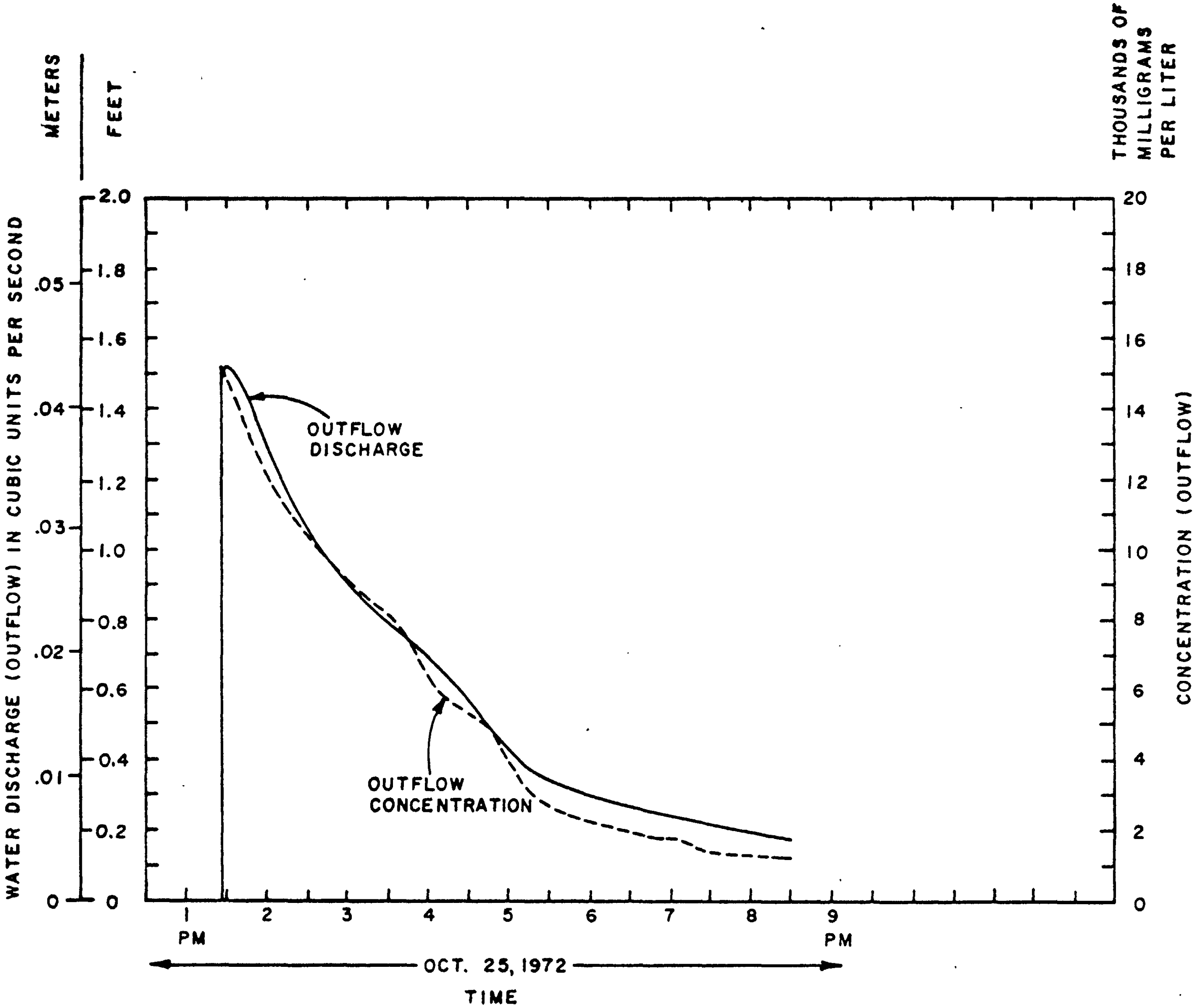


Figure 20.--Outflow-water discharge and outflow-sediment concentration for flow event 30, October 25, 1972.

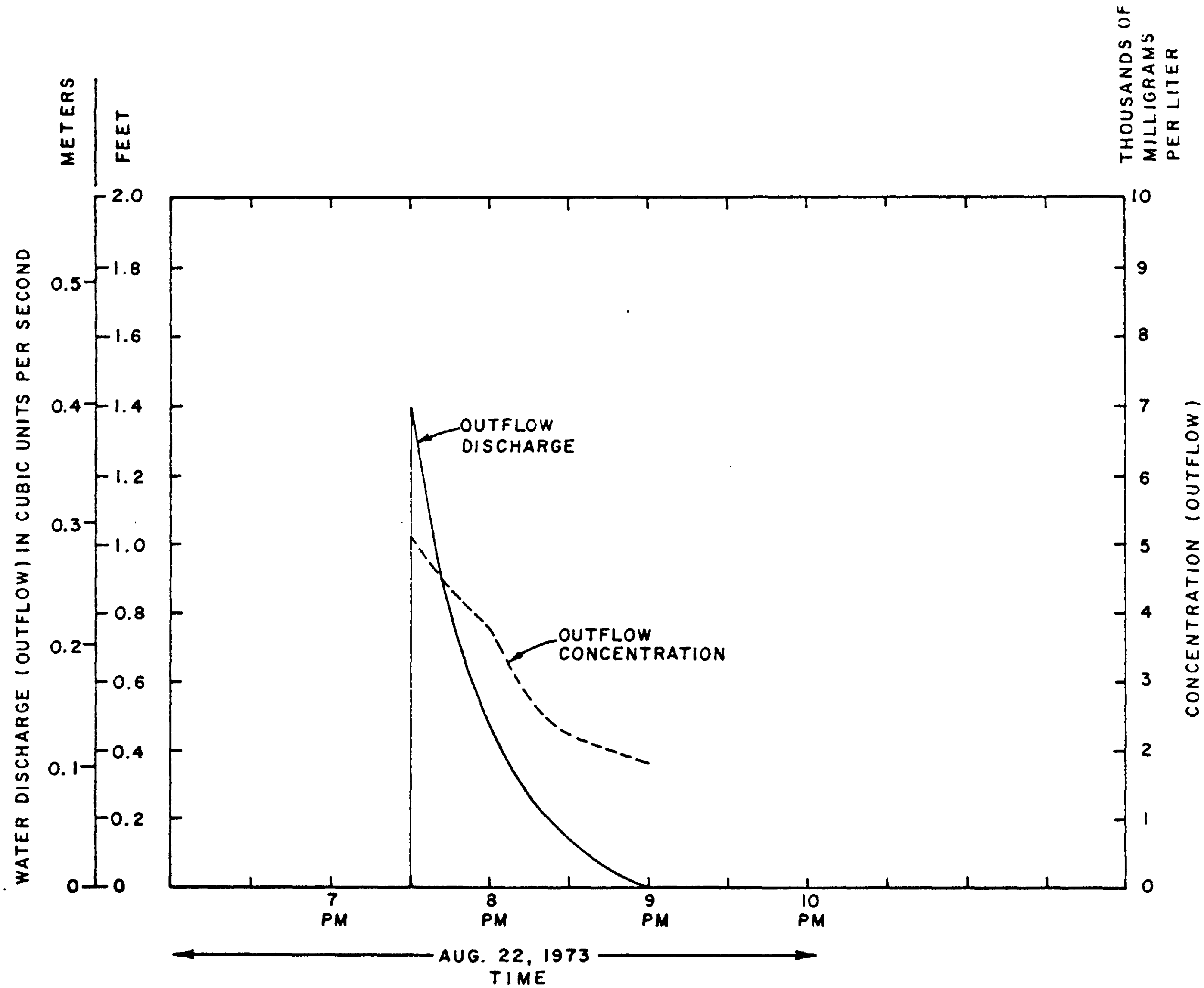


Figure 21.--Outflow-water discharge and outflow-sediment concentration for flow event 32, August 22, 1973.

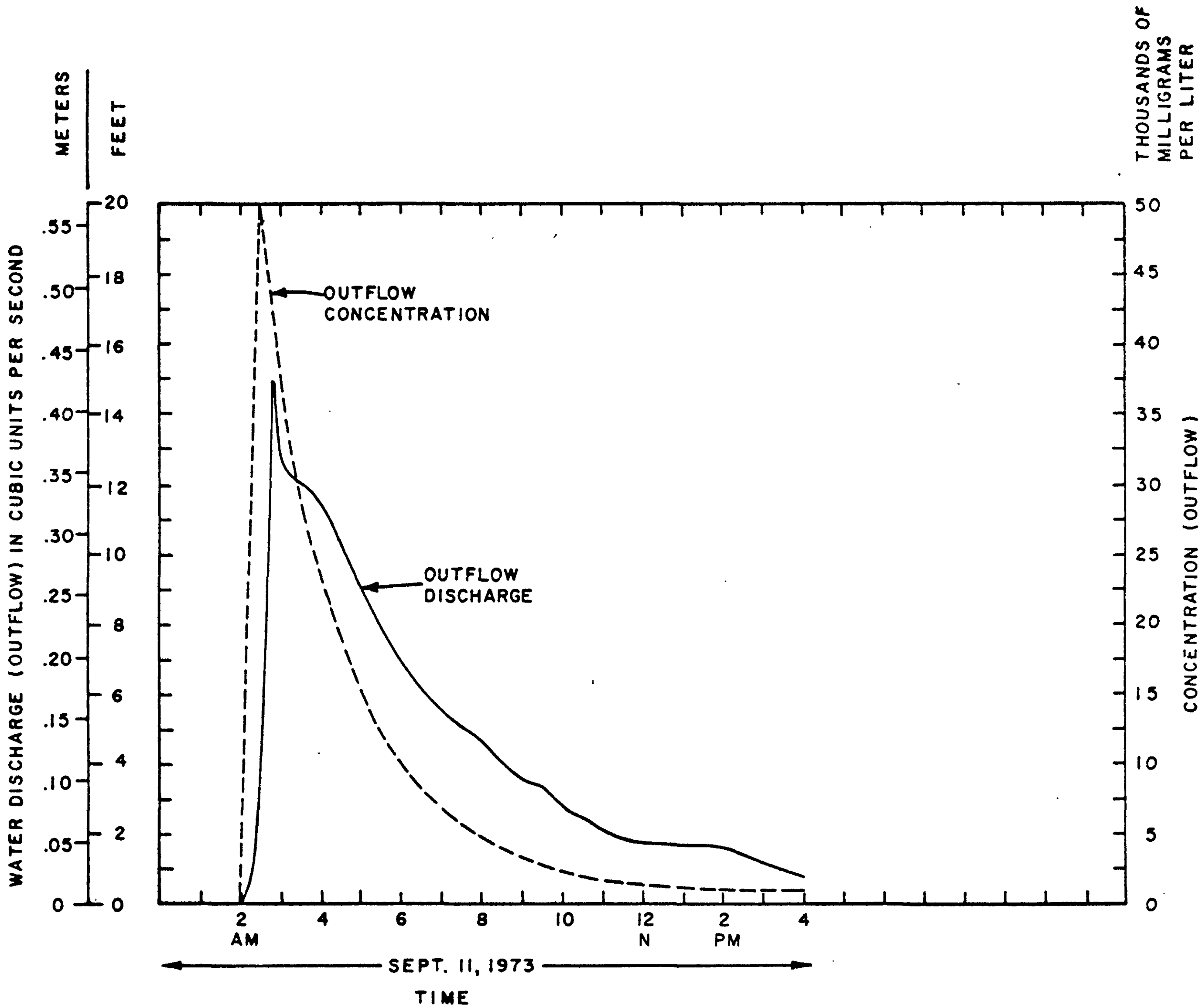


Figure 22.--Outflow-water discharge and outflow-sediment concentration for flow event 33, September 11, 1973.

Table 1.--Outflow-sediment load, outflow volume, and average outflow-sediment concentrations, July 1956 to June 1974

Water Year	Flow event No.	Date	Outflow duration (hours)	Total outflow (acre-ft)	Average outflow for period (ft^3/s)	Average outflow-sediment concentration (mg/L)	Outflow-sediment load (tons)
1956	1	July 19-20, 1956	23.8	53.0	26.9	5,290	570
	2	Aug. 2-3, 1956	8.0	10.23	15.5	8,540	129
1957	No flow						
1958	3	Oct. 12, 1957	4.0	3.99	12.1	8,250	49
	4	Oct. 12-13, 1957	1.8	1.15	7.7	---	e10
	5	Oct. 19, 1957	5.0	3.14	7.6	5,940	31
	6	Nov. 4, 1957	3.0	.48	1.9	---	e 4
1959	7	Aug. 6, 1959	2.8	1.65	7.1	13,600	37
1960	8	Aug. 31, 1960	3.0	.51	2.1	---	e 4
1961	9	Oct. 17, 1960	3.2	.59	2.2	2,370	3
	10	Aug. 15, 1961	1.2	.19	1.9	---	e 1
1962	11	Jul. 5, 1962	3.7	.58	.29	---	e 3
	12	Jul. 5, 1962	3.0	.75	.38	3,840	5
1963	13	Oct. 19, 1962	1.0	0	0	0	0
	14	Aug. 3, 1963	8.1	6.0	.75	6,850	90
	15	Aug. 29, 1963	6.9	.6	.08	9,300	10
1964	16	Jul. 8, 1964	2.7	.65	2.99	7,740	12
	17	Sept. 26, 1964	3.0	.71	2.88	6,690	11

Table 1.--Outflow-sediment load, outflow volume, and average outflow-sediment concentrations, July 1956 to June 1974 - Continued

Water Year	Flow event No.	Date	Outflow duration (hours)	Total outflow (acre-ft)	Average outflow for period (ft^3/s)	Average outflow-sediment concentration (mg/L)	Outflow sediment load (tons)
1965	No flow						
1966	18	July 16, 1966	1.3	0.18	1.7	---	e 2.0
	19	Aug. 2, 1966	4.2	2.66	7.7	8,380	34
1967	20	July 19, 1967	5.0	0.69	1.7	---	e 3.0
	21	July 26-27, 1967	7.5	4.90	7.9	---	e64
	22	July 29-30, 1967	17.0	30.3	21.6	---	e220
	23	Aug. 9, 1967	2.0	0.24	1.43	---	e 1.0
	24	Aug. 11, 1967	5.0	0.52	1.23	1,810	1.6
	25	Aug. 29, 1967	3.0	1.07	4.31	1,900	3.5
1968	No flow						
1969	26	Aug. 29, 1969	6.75	0.32	0.56	---	e 2.0
1970	No flow						
1971	27	July 23, 1971	0.75	0.04	0.81	---	e .21
1972	28	July 24, 1972	7.5	0.50	0.85	---	e10

Table 1.--Outflow-sediment load, outflow volume, and average outflow-sediment concentrations, July 1956 to June 1974 - Concluded

Water Year	Flow event No.	Date	Outflow duration (hours)	Total outflow (acre-ft)	Average outflow for period (ft^3/s)	Average outflow-sediment concentration (mg/L)	Outflow-sediment load (tons)
1973	29	Oct. 19, 1972	.75	0	0.20	---	e 0.17
	30	Oct. 25, 1972	10.75	0.40	0.45	5,040	4.8
	31	Aug. 2-3, 1973	12.0	1.30	1.22	---	e24
	32	Aug. 22, 1973	2.0	0.04	.25	3,300	0.19
	33	Sep. 11, 1973	15.0	5.6	4.52	6,060	71
1974	Station discontinued June 30, 1974: no flow to June 30.						

e -- Estimated

Table 2.--Particle-size analyses

(Methods of analysis: P, pipet; S, sieve; N, in native water; W, in distilled water; C, chemically dispersed; V, visual-accumulation tube)

Summary of particle-size analyses of suspended sediment, period July 1956 to June 1974

Date	Time	Dis-charge (ft^3/s)	Sediment Conc. of Sample (mg/L)	Percent finer than indicated size, in millimeters											Method
				0.002	0.004	0.008	0.016	0.031	0.062	0.125	0.250	0.500	1.00	2.00	
						OUTFLOW									
July 19, 1956	2040	47	16,900	5	22	68	95	100	--	--	--	--	--	--	PN
July 19......	2040	47	16,900	44	62	81	95	99	100	--	--	--	--	--	PWC
July 20......	0200	41	2,820	8	32	99	100	--	--	--	--	--	--	--	PN
July 20......	0200	41	2,820	87	97	99	99	99	100	--	--	--	--	--	PWC
Aug. 2.......	1655	23	10,800	4	19	74	96	99	100	--	--	--	--	--	PN
Aug. 2.......	1655	23	10,800	49	69	86	97	100	--	--	--	--	--	--	PWC
Aug. 2.......	2130	13	6,400	4	17	29	39	59	85	97	100	--	--	--	VPN
Aug. 2.......	2130	13	6,400	30	35	42	48	62	85	97	100	--	--	--	VPWC
						INFLOW									
Aug. 2.......	1740	20	278,000	2	8	21	29	39	53	62	67	73	79	86	SPN
Aug. 2.......	1740	20	278,000	15	18	24	29	38	53	62	67	73	79	86	SPWC
						OUTFLOW									
Oct. 12, 1957	1105	13	4,960	--	79	--	99	--	100	--	--	--	--	--	PWC
Oct. 12......	1315	8	8,500	5	21	75	88	90	100	--	--	--	--	--	PN
Oct. 12......	1315	8	8,500	67	90	99	99	99	100	--	--	--	--	--	PWC
Oct. 19......	1745	12	7,850	--	80	--	99	--	100	--	--	--	--	--	PWC
Oct. 19......	2100	2	2,240	--	92	--	98	--	100	--	--	--	--	--	PWC

Table 2.--Particle-size analyses - Continued

(Methods of analysis: P, pipet; S, sieve; N, in native water; W, in distilled water; C, chemically dispersed; V, visual accumulation tube)

Summary of particle-size analyses of suspended sediment, period July 1956 to June 1974

Date	Time	Dis-charge (ft^3/s)	Sediment Conc. of Sample (mg/L)	Percent finer than indicated size, in millimeters											Method
				0.002	0.004	0.008	0.016	0.031	0.062	0.125	0.250	0.500	1.00	2.00	
INFLOW (NORTH ARROYO)															
Oct. 12, 1957	1045	--	13,400	--	27	--	38	--	63	83	93	99	100	--	VPWC
Oct. 19......	1730	--	3,960	--	83	--	95	--	100	--	--	--	--	--	PWC
INFLOW (SOUTH ARROYO)															
Oct. 12......	1055	--	21,700	--	39	--	61	--	86	93	96	98	100	--	VPWC
Oct. 19......	1735	--	10,800	--	55	--	77	--	89	93	96	98	100	--	VPWC
OUTFLOW															
Aug. 6, 1959	1800	11	33,000	42	60	81	95	100	--	--	--	--	--	--	PWC
Aug. 6......	1800	11	33,000	6	21	62	90	99	100	--	--	--	--	--	PN
Aug. 6......	1845	13	11,000	--	76	--	100	--	--	--	--	--	--	--	PWC
Aug. 6......	1925	4	9,320	62	87	92	97	99	100	--	--	--	--	--	PWC
Aug. 6......	1925	4	9,320	6	21	84	97	100	--	--	--	--	--	--	PN
INFLOW (NORTH ARROYO)															
Aug. 6......	1750	Est.30	66,400	21	26	35	42	54	76	93	97	99	100	--	VPWC
Aug. 6......	1750	Est 30	66,400	6	13	25	35	52	76	93	97	99	100	--	VPN
INFLOW (SOUTH ARROYO)															
Aug. 6......	1825	Est 10	24,500	31	39	52	63	76	91	98	100	--	--	--	VPWC
Aug. 6......	1825	Est 10	24,500	8	23	42	58	74	91	98	100	--	--	--	VPN

Table 2.--Particle-size analyses - Continued

(Methods of analysis: P, pipet; S, sieve; N, in native water; W, in distilled water; C, chemically dispersed; V, visual accumulation tube)

Summary of particle-size analyses of suspended sediment, period July 1956 to June 1974

Date	Time	Discharge (ft^3/s)	Sediment Conc. of Sample (mg/L)	Percent finer than indicated size, in millimeters											Method
				0.002	0.004	0.008	0.016	0.031	0.062	0.125	0.250	0.500	1.00	2.00	
INFLOW (NORTH ARROYO)															
Aug. 11, 1960	1550	Est 0.5	8,690	54	75	85	91	95	96	98	98	100	--	--	VPWC
Aug. 11......	1550	Est 0.5	8,690	5	19	61	90	94	96	98	98	100	--	--	VPN
OUTFLOW															
Aug. 31......	1720	0.2	2,090	92	97	--	99	--	100	--	--	--	--	--	PWC
Oct. 17......	2030	5.3	4,430	66	87	--	99	--	100	--	--	--	--	--	PWC
Oct. 17......	2115	1.7	3,360	75	95	--	98	--	100	--	--	--	--	--	PWC
July 5, 1962	2050	--	7,930	57	68	78	97	100	--	--	--	--	--	--	PWC
July 5......	2050	--	7,930	5	14	58	99	100	--	--	--	--	--	--	PN
OUTFLOW															
Aug. 3, 1963	1600	11.8	58,300	34	48	65	84	100	--	--	--	--	--	--	PWC
Aug. 3......	1600	11.8	58,300	4	16	51	82	100	--	--	--	--	--	--	PN
INFLOW (SOUTH ARROYO)															
Aug. 3......	1615	--	61,400	22	28	38	50	64	79	88	92	94	97	--	VPWC
Aug. 3......	1615	--	61,400	1	9	30	45	60	79	88	92	94	97	--	VPN

Table 2.--Particle-size analyses - Continued

(Methods of analysis: P, pipet; S, sieve: N, in native water; W, in distilled water; C, chemically dispersed; V, visual-accumulation tube)

Summary of particle-size analyses of suspended sediment, period July 1956 to June 1974

Date	Time	Dis-charge (ft^3/s)	Sediment Conc. of Sample (mg/L)	Percent finer than indicated size, in millimeters											Method
				0.002	0.004	0.008	0.016	0.031	0.062	0.125	0.250	0.500	1.00	2.00	
OUTFLOW															
Aug. 3, 1963	1700	17.2	20,100	57	77	97	98	100	--	--	--	--	--	--	PWC
Aug. 3......	1700	17.2	20,100	3	14	73	99	100	--	--	--	--	--	--	PN
Aug. 3......	2000	9.3	2,370	95	98	--	100	--	--	--	--	--	--	--	PWC
INFLOW (NORTH ARROYO)															
Aug. 29.....	1510	--	65,400	45	62	--	86	--	95	99	100	--	--	--	VPWC
INFLOW (SOUTH ARROYO)															
Aug. 29.....	1520	--	48,300	43	59	--	91	--	91	94	97	100	--	--	VPWC
OUTFLOW															
Aug. 29.....	1530	3.0	14,300	55	79	93	98	100	--	--	--	--	--	--	PWC
Aug. 29.....	1530	3.0	14,300	4	15	69	99	100	--	--	--	--	--	--	PN
Aug. 29.....	2110	.2	6,890	90	99	--	100	--	--	--	--	--	--	--	PWC
OUTFLOW															
July 8, 1964	1720	7.6	18,000	42	64	86	98	100	--	--	--	--	--	--	PWC
July 8......	1720	7.6	18,000	4	12	41	96	99	100	--	--	--	--	--	PN
July 8......	1740	7.3	12,700	54	75	93	99	100	--	--	--	--	--	--	PWC
July 8......	1740	7.3	12,700	6	16	72	99	100	--	--	--	--	--	--	PN
Sep. 26.....	1630	5.2	6,810	61	84	96	99	100	--	--	--	--	--	--	PWC
Sep. 26.....	1630	5.2	6,810	5	14	59	97	99	100	--	--	--	--	--	PN
Sep. 26.....	1745	.8	2,890	76	94	--	98	--	100	--	--	--	--	--	PWC

Table 2.--Particle-size analyses - Continued

(Methods of analysis: P, pipet; S, sieve; N, in native water; W, in distilled water; C, chemically dispersed; V, visual-accumulation tube)

Summary of particle-size analyses of suspended sediment, period July 1956 to June 1974

Date	Time	Dis-charge (ft^3/s)	Sediment Conc. of Sample (mg/L)	Percent finer than indicated size, in millimeters											Method
				0.002	0.004	0.008	0.016	0.031	0.062	0.125	0.250	0.500	1.00	2.00	
INFLOW (NORTH ARROYO)															
July 8, 1964	1700	Est20	85,800	14	18	24	30	40	65	89	96	98	99	100	VPWC
July 8......	1700	Est20	85,800	3	8	18	28	42	65	89	96	98	99	100	VPWC
INFLOW (SOUTH ARROYO)															
July 8......	1705	Est 1.0	85,300	12	17	21	27	38	57	65	69	78	96	100	VPWC
July 8......	1705	Est 1.0	85,300	3	7	13	23	37	57	65	69	78	96	100	VPN
OUTFLOW															
Aug. 2, 1966	0845	0.1	860	93	94	95	96	96	100	--	--	--	--	--	PWC
Aug. 2......	0845	0.1	860	15	38	97	98	98	100	--	--	--	--	--	PN
Aug. 6, 1967	1900	--	5,760	76	93	98	98	99	99	100	--	--	--	--	SPWC
Aug. 6......	1900	--	5,760	3	16	85	98	98	99	100	--	--	--	--	SPN
Aug. 11.....	1140	0.7	1,060	82	88	91	96	97	98	98	99	100	--	--	SPWC
Aug. 11.....	1140	0.7	1,060	3	27	91	94	95	98	98	99	100	--	--	SPN
Aug. 29.....	1840	--	1,140	73	85	93	97	100	--	--	--	--	--	--	PWC
Aug. 29.....	1840	--	1,140	2	16	80	96	99	100	--	--	--	--	--	PN

Table 2.--Particle-size analyses - Concluded

(Methods of analysis: P, pipet; S, sieve; N, in native water; W, in distilled water; C, chemically dispersed; V, visual accumulation tube)

Summary of particle-size analyses of suspended sediment, period July 1956 to June 1974

Date	Time	Dis-charge (ft^3/s)	Sediment Conc. of Sample (mg/L)	Percent finer than indicated size, in millimeters											Method
				0.002	0.004	0.008	0.016	0.031	0.062	0.125	0.250	0.500	1.00	2.00	
						OUTFLOW									
Oct. 25, 1972	1530	.81	8,310	57	68	--	93	--	100	--	--	--	--	--	SPWC
Oct. 25......	1600	.71	6,460	59	75	--	97	--	100	--	--	--	--	--	SPWC
Oct. 25......	1615	.60	5,750	71	89	--	100	--	--	--	--	--	--	--	SPWC
Oct. 25......	1645	.50	4,980	71	90	--	99	--	100	--	--	--	--	--	SPWC
Oct. 25......	1730	.35	2,700	82	96	--	99	--	100	--	--	--	--	--	SPWC
Aug. 22, 1973	1930	1.4	5,160	81	98	--	100	--	--	--	--	--	--	--	PWC
Sep. 11......	1045	1.96	1,740	95	98	--	98	--	100	--	--	--	--	--	SPWC
Sep. 11......	1505	1.32	1,170	94	97	--	100	--	--	--	--	--	--	--	PWC

Table 3.--Chemical analyses

[mg/L]

Date of Collection	7/19/56	7/20/56	8/2/56	8/2/56	8/2/56	10/12/57	8/6/59	8/6/59
Time of Collection	2040	0200	1655	2130	1740	1315	1750	1800
Calcium (Ca)	44	38	39	54	58	43	47	50
Magnesium (Mg)	5.7	3.8	5.0	6.2	6.2	2.6	3.3	4.1
Sodium (Na)	8.1	7.8	6.0	13	9.0	5.1	7.6	7.5
Dissolved solids-Residue on Evaporation	206	176	183	248	272	163	182	209
Hardness as $CaCO_3$	134	110	118	160	170	118	131	142
Specific Conductance (micromhos at 25°C)	288	253	260	362	397	262	290	316
pH	7.8	8.3	7.8	8.3	8.0	7.8	7.9	7.8
Percent Sodium	12	13	10	15	10	9	11	10
Sodium Adsorption Ratio	0.3	0.3	0.2	0.5	0.3	0.2	0.3	0.3
Dissolved solids (tons per acre-foot)	.28	.24	.25	.34	.37	.22	.25	.28

Table 3.--Chemical analyses - Concluded

[mg/L]

Date of Collection	8/6/59	8/6/59	8/11/60	7/5/62	8/3/63	8/3/63	8/3/63	8/29/63	8/2/66
Time of Collection	1825	1925	1550	2050	1615	1600	1700	1530	0845
Calcium (Ca)	40	42	49	34	50	51	39	37	38
Magnesium (Mg)	2.2	2.2	6.9	1.7	2.7	2.4	1.3	3.8	2.9
Sodium (Na)	4.3	5.3	8.3	3.3	3.6	2.6	2.3	2.6	4.4
Dissolved solids-Residue on Evaporation	150	166	234	130	212	208	171	146	158
Hardness as $CaCO_3$	109	114	151	92	136	137	103	108	122
Specific Conductance (micromhos at 25°C)	237	255	330	199	283	281	215	218	240
pH	8.2	8.0	7.3	7.6	7.7	7.6	7.7	7.2	8
Percent Sodium	8	9	11	7	6	4	5	5	8
Sodium Adsorption Ratio	0.2	0.2	0.3	-	0.1	0.1	0.1	0.1	0.2
Dissolved solids (tons per acre-foot)	.20	.23	.32	.18	.29	.28	.23	.20	.21

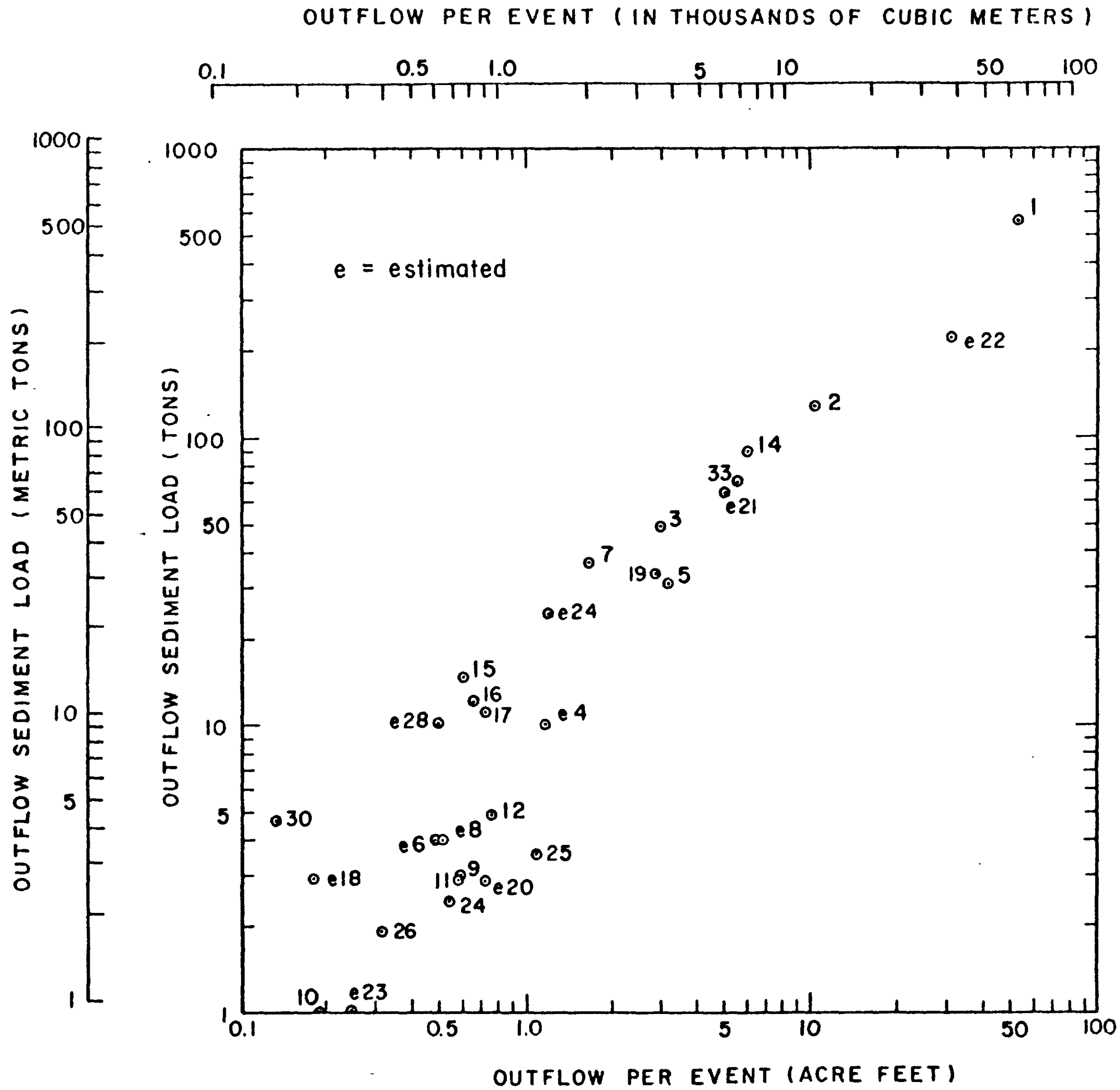


Figure 23.--Relationship of outflow in acre-feet per event to outflow-sediment load.

1962 Water Year.--There were two flow events (No. 11 and No. 12) during the water year, both occuring on the same day. Flow event No. 11 was not sampled and the outflow-sediment load was estimated as in previous cases. Curves and hydrograph showing accumulative rainfall, outflow discharge, and outflow-sediment concentration for the events are presented in figure 14.

1963 Water Year.--There were three flow events (Nos. 13, 14, and 15). The first one was a very minor event of 0.4 ft^3/s (0.01 m^3/s) lasting one hour, and no samples were collected. Flow event No. 14 was the largest since 1956, moving 90 tons (82 t) of sediment in 6.0 acre-ft (7,398 m^3) of outflow. Curves and hydrographs showing accumulative rainfall, outflow discharge, and outflow-sediment concentration for events 14 and 15 are presented in figures 15 and 16.

1964 Water Year.--There were two flow events (Nos. 16 and 17). Both events were of the single peak variety and were nearly identical with respect to discharge, flow duration, and sediment yield. Numerous samples were taken during both events, including seven discharge measurements on flow event 16. Hydrographs and curves showing outflow discharge and sediment concentration for the events are presented in figures 17 and 18.

1965 Water Year.--There were no outflow events this water year.

1966 Water Year.--Only one of the two flow events (Nos. 18 and 19) was sampled. The outflow-sediment load for the unsampled event was estimated. Outflow-discharge hydrograph and sediment concentration curve for event No. 19 are presented in figure 19.

1967 Water Year.--Six events (Nos. 20 through 25) occurred during this water year. Samples were collected on two events and samples were also collected on August 6, a non-recorded event because the small flow did not reach the gage 390 ft (119 m) downstream. The outflow-sediment loads for the unsampled events were estimated. The estimated outflow-sediment load for flow event 22 was the greatest since 1956, moving 220 tons (200 t) of sediment in 30.3 acre-ft (37,359.9 m^3) of outflow.

1968 Water Year.--There were no outflow events this water year.

1969 Water Year.--There was one unsampled-flow event (No. 26) and the outflow-sediment load was estimated.

1970 Water Year.--There were no outflow events this water year.

1971 Water Year.--There was one unsampled-flow event (No. 27) and the outflow-sediment load was estimated.

1972 Water Year.--There was one unsampled-flow event (No. 28) and the outflow-sediment load was estimated.

1973 Water Year.--Five flow events (Nos. 29 through 33) occurred during the water year and sediment samples were collected on three of the events. The outflow-sediment loads for the unsampled events were estimated; the estimates appear reasonable as indicated by figure 23. The outflow-sediment load for event 33 was the fifth largest for the period of record, moving 71 tons (64 t) of sediment in 5.6 acre-ft (6,904.8 m^3) of outflow. Hydrographs and curves showing outflow discharge and sediment concentration for events 30, 32, and 33 are presented in figures 20 to 22.

1974 Water Year.--The station operation was discontinued on June 30, 1974. There was no flow during the period to June 30.

Computation of trap efficiency

Particle-size analyses of both inflow and outflow samples were made by standard sedimentation methods. Twenty inflow and 54 outflow samples were analyzed for particle size. Sediment concentration ranged from 3,960 to 278,000 mg/L for the inflow samples and from 860 to 58,300 mg/L for the outflow samples. The results, shown in table 2, indicate that all sand-size particles (>0.062 mm) were trapped in the reservoir except for a few small flows where there was virtually no ponding of the flow and small amounts of sand did pass through the outflow. Of the 74 particle-size analyses, 50 were analyzed in a distilled water settling medium. The remaining 24 were analyzed in a native-water settling medium. The distilled water, with a chemical dispersing agent added for deflocculation of the fine particles (<0.062 mm), was used to determine the particle-size distribution and thus represent "standardized" conditions. Analysis of samples in the native-water medium was intended to represent the particle-size characteristics of the sediment as they might occur in the natural setting. Flocculation occurred in the native-water settling medium in the laboratory. Analyses in native water indicated an average difference of 46 percent in the clay (<0.002 mm) size compared to the same analyses made with distilled water having a dispersing agent added. The chemical analyses, shown in table 3, provides the probable cause of this flocculation. A high calcium-sodium ratio in water will cause flocculation of soil colloids, and water with a low calcium-sodium ratio will tend to disperse soil colloids (Rainwater and Thatcher 1960, p. 127, 265). It can be assumed that flocculation occurred in the reservoir, but the degree to which it occurred is unknown.

The reservoir was surveyed in 1967 and again in 1976 by the U.S. Soil Conservation Service. The surveys were made in order to determine sediment deposition. The reservoir capacity loss for the period between the initial survey (1955) and the final survey (1976), was 16.61 acre-ft (20,480 m^3), as shown in table 4. This represents a 5.35 percent storage loss in 21 years.

Table 4.--Summary of reservoir-sedimentation surveys

Date of Survey	Period Years	Capacity (acre-ft)	Total sediment deposits to date (acre-ft)	Average specific mass (lb. per cu. ft.)
August, 1955	--	310.6	---	---
August, 1967	12	298.1	12.5	94.6
January, 1976	9	293.99	16.61	90

The trap efficiency of the reservoir was computed using data from the reservoir surveys. Trap efficiency is a ratio, expressed as a percentage, of the weight of sediment retained in a reservoir to the weight of sediment entering the reservoir. As shown by Anttila (1970), the equation used for the calibration of the trap efficiency of the reservoir is

$$TE = 100 \frac{A}{A + B}$$

where

TE = trap efficiency of the reservoir, in percent,

A = weight of sediment deposited in reservoir (tons),

B = weight of sediment discharged from reservoir (tons).

A trap efficiency of 96 percent was determined for Bernalillo Floodwater Retarding Reservoir No. 1.

The trap efficiency of a reservoir depends upon various factors. Some of these factors that Brune (1953, p. 407-418) and others have studied in attempts to correlate trap efficiency include: ratio between storage capacity and drainage area; ratio between storage capacity and inflow; age of the reservoir; shape of the reservoir basin; the type of outlets and method of operation; the particle-size characteristics of the sediment; and the behavior of the finer sediment fractions under various conditions. Most of the correlations shown by Brune were for normal ponded reservoirs ("normal" meaning "conventional reservoirs as distinguished from desilting basins and dry reservoirs") (p. 411).

Bernalillo Floodwater Retarding Reservoir No. 1 is normally dry except for summer storm-runoff events. The inflows from these storm events are usually small and of short duration. Over 99 percent of the coarse sediments (>0.062 mm) and a high percentage of the silts and clays are deposited in the reservoir before reaching the outflow pipe. The 96 percent trap-efficiency value appears to be reasonable for this type of reservoir and the quantity of inflow.

Summary

Flow events Nos. 3 and 24 were made up of three distinct peaks of outflow discharge, six flow events (Nos. 2, 5, 6, 9, 15 and 25) were made up of two distinct peaks, and the remaining 14 were single peaks. All flow events, except No. 6, occurred in the 3-month period from mid-July to mid-October. Many rain showers were observed over the drainage basin, but apparently the retaining structures were sufficient to impede runoff except for the very heavy thundershowers. Therefore, high volume and high intensity summer thundershowers appear necessary to load the drainage basin's conservation structures and cause runoff. At times, summer thundershowers tend to soak one or more separated parts of the drainage basin causing flow in only one of the two major inflow tributaries to the reservoir.

The total outflow recorded for the period of record (July 19, 1956 to June 30, 1974) was 133 acre-ft (0.164 hm^3), yielding 1,439 tons (1,305 tonnes) of sediment.

The trap efficiency of reservoir 1 was 96 percent for the period of record.

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