Fluvial Sediment in Salem Fork Watershed, West Virginia

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1798-K

Prepared in cooperation with the U.S. Department of Agriculture Soil Conservation Service

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By RUSSELL F. FLINT

SEDIMENTATION IN SMALL DRAINAGE BASINS

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By RUSSELL F. FLINT

ABSTRACT

Suspended sediment discharged from the 8.32-square-mile Salem Fork study area in Harrison County, W. Va., averaged 3,500 tons per year during the first 4-year period of investigation and 1,770 tons per year during the second 4-year period. The difference was attributed to increased flow control, effected by the completion of detention structures and other conservation measures, the absence of appreciable sediment-producing construction activities, and a reduction of the amounts of rainfall and runoff during the second 4-year period.

Particle-size distribution of the suspended sediment discharged from the watershed remained unchanged during the two 4-year periods. Although sand and some silt were deposited in upstream reservoirs, sands and other sediments were evidently entrained in the flow below the reservoirs.

During the 7.75-year period, reservoir 11A had a trap efficiency of 88 percent. The average annual sediment yield of subwatershed 11A was 1.31 tons per acre, or 837 tons per square mile. Outflow from reservoir 11A occurred during 81 percent of the investigation period, October 1954 to June 1962, and 78 percent of the sediment discharge from the reservoir occurred during less than 6 percent of the investigation period. A comparison of particle-size distribution of inflow sediment with that of outflow sediment revealed that practically all sands and some silts entering reservoir 11A were deposited in the reservoir. Chemical analyses of inflow water and the particle-size analyses suggested that flocculation of fine sediments occurred in the reservoir.

Analysis of the sediment data collected at the outflow of reservoir 9 during 1956–62 revealed that the average annual sediment discharge was 128,000 pounds per year. Limited particle-size data suggested that practically no sand was discharged from reservoir 9, even though the inflow contained sand.

Average annual inflow to reservoirs 11A and 9 compared favorably with average annual runoff for the entire watershed-study area.

INTRODUCTION

The Salem Fork watershed-evaluation project in Harrison County (fig. 1) was started in 1954 under the direction of the

U.S. Department of Agriculture, Soil Conservation Service, to evaluate the physical and economic effects of a watershed-protection program.

As part of the overall physical evaluation of the watershed area, the U.S. Geological Survey, in cooperation with the Soil Conservation Service, began to investigate streamflow and sedimentation on October 1, 1954. The investigations were designed

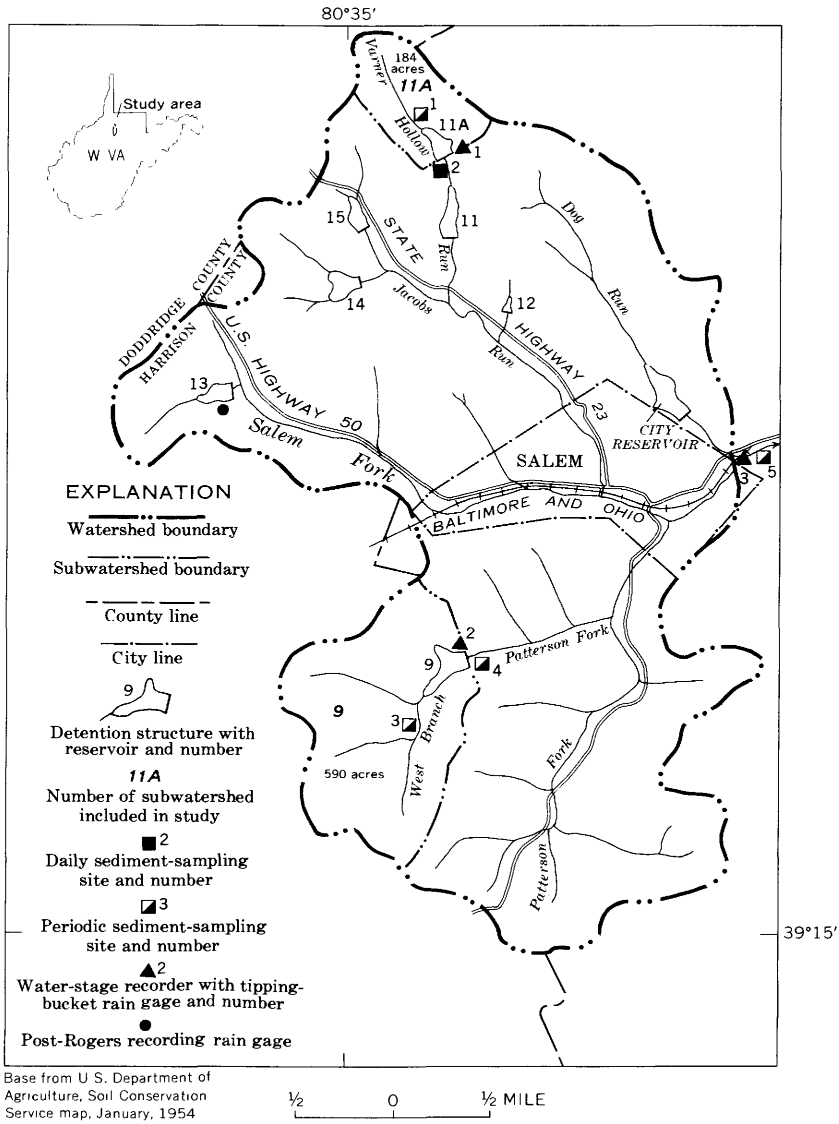

FIGURE 1.—Area of the Salem Fork watershed evaluation project in western Harrison County.

to yield continuous data on streamflow and periodic data on discharge and particle-size characteristics of suspended sediment at two locations, Salem Fork at Salem, which has a drainage area of 8.32 sq mi (square miles), and Salem Fork subwatershed 11A (Varner Hollow Run) near Salem, which has a drainage area of 0.288 sq mi. (See fig. 1.) In February 1955, subwatershed 11A was selected as one station in a national network of sediment stations established to determine the trap efficiency of small floodwater-retarding basins. A daily record of sediment discharges from the reservoir and the collection of suspended-sediment samples in the inflow channel were started.

The collection of continuous streamflow and periodic suspended-sediment data at Salem Fork subwatershed 9 (West Branch Patterson Fork) near Salem, which has a drainage area 0.92 sq mi, was started January 25, 1956 (fig. 1). The suspended-sediment data at reservoir 9 provide an index of the water-sediment discharge relationship. Limited suspended-sediment data were also collected at the inflow of reservoir 9 for reasons similar to those mentioned for reservoir 11A.

The streamflow station at Salem Fork at Salem was established January 1, 1951, with support from the Federal Inter-Agency River Basin Committee, and continued under this arrangement through the study period. Streamflow from the entire study area was measured at this station.

This report summarizes and interprets the basic sediment and chemical-quality data collected for each drainage area studied as part of the Salem Fork watershed evaluation project and presents sediment-yield and trap-efficiency figures for reservoir 11A. The report includes supplementary hydrologic characteristics of reservoirs 11A and 9 and their respective subwatershed areas.

No other reports of similar investigations in this area are available; however, Mundorff (1964) reported the results of a similar investigation conducted during 1955–61 in Kiowa Creek basin in northeastern Colorado.

ACKNOWLEDGMENTS

R. E. Quilliam, State conservationist, Soil Conservation Service, provided data on soil descriptions and rainfall in the project area. John W. Roehl, geologist, Soil Conservation Service, provided data on stage-capacity relations for reservoir 11A, and a summary of current data for reservoir 11A.

ENVIRONMENTAL FACTORS

The Salem Fork basin lies in western Harrison County and is included on 7.5-minute topographic maps of the Salem and Big Isaac quadrangles. Salem Fork rises near the west edge of the county and flows east into Tenmile Creek, a tributary of the West Fork River, which is a tributary of the Monongahela River. The Salem Fork watershed project area (fig. 1), 8.32 sq mi (5,325 acres), is in the headwaters of the Salem Fork basin and includes those areas drained by Patterson Fork in the south and Jacobs Run and Dog Run in the north. The town of Salem, whose population is 2,510, lies near the center of the area, about 14 miles west of Clarksburg.

The area is served by east-west U.S. Highway 50, which passes along the main street of Salem. State Highway 23 follows Jacobs Run, enters Salem from the northwest, and terminates near the center of town. A paved county highway follows Patterson Fork before entering Salem from the south. A main line of the Baltimore and Ohio Railroad parallels Salem Fork and U.S. Highway 50 as it passes through Salem.

The area, part of the unglaciated Allegheny Mountain section of the Appalachian Plateaus physiographic province (Fenneman, 1938, p. 283), has rugged topography. Elevations range from about 1,030 feet above sea level near the mouth of Dog Run to about 1,500 feet in the extreme southern and western parts of the area. Hillside slopes are long and steep, but some are broken by structural rock benches as shown in figure 2. Thornbury (1954, p. 112) attributed the formation of such benches to the alternating weak and strong underlying strata.

CLIMATE

The climate in the Salem-Clarksburg area is temperate and of the humid-continental type. Clarksburg's mean annual precipitation of about 42 inches is fairly evenly distributed throughout the year. However, high-intensity rainstorms are common during June and July. Many of these storms are cloudbursts and cause flash flooding. The rugged topography of the area includes many small drainage basins which are subject to frequent severe flash flooding. Snow, which constitutes about 20 to 25 percent of the winter precipitation, averages about 25 inches annually and occurs mostly between December and April (Weedfall, no date).

Mean daily temperatures range from a minimum of 22°F for January to a maximum of 87°F for July. The lowest recorded temperature for Clarksburg was −32°F in February 1932, and the highest temperature, 102°F, occurred in July 1934 and September 1953. The length of frost-free season averages about 150 days but varies owing to differences in elevation (U.S. Dept. Agriculture, 1954, p. 2).

Pan-evaporation data collected at Clarksburg indicate average evaporation ranging from about 2 inches in October to 5.5 inches in July (U.S. Dept. Commerce, 1965) and an average annual lake evaporation of about 30 inches (Kohler and others, 1959).

FIGURE 2. — View of reservoir 9 in Salem Fork watershed, showing structural rock benches which break the long hillside slopes of the area. Photograph reprinted by permission of West Virginia Chamber of Commerce.

GEOLOGY

The Salem area is strongly dissected. The hills are worn down and rounded by erosion. Ridge skylines are irregular, and there are many gaps in the watershed divides (fig. 3).

The rocks which underlie the area were formed during the Permian and Pennsylvanian Periods of the Paleozoic Era. Nace and Bieber (1958, p. 24) stated that these rocks, collectively called the Dunkard Group, are the youngest sedimentary rocks in West Virginia. The group is composed of interstratified gray, green, and brown sandstone, red and varicolored sandy or limy shale, black carbonaceous shale, limestone, and impure coal. Two formations of the Dunkard Group, the Greene and the Washington, are in the Salem area. The Proctor Sandstone of White (1883), the topmost unit of the Greene Formation, caps some of the higher hills of the area; rocks of the Washington Formation are about 600 feet below the Proctor Sandstone (Nace and Bieber, 1958, p. 17). The relief of the area indicates that rocks of the Greene Formation make up the principal parent materials for the soils of the Salem area.

FIGURE 3. — View of Varner Hollow, looking upstream beyond reservoir 11A construction site and showing dissected area and irregular skyline which is typical of the area. Photograph by Soil Conservation Service.

SOILS AND LAND USE

The soils of the upland areas of the Salem Fork watershed are part of the Upshur-Gilpin complex, a result of the erosion and intermingling of the Upshur and Gilpin soils. Vandalia soils occur on the footslopes, and Moshannon, Senecaville, and Melvin soils make up the bottom lands (R. E. Quilliam, written commun., 1970). The Upshur soils are moderately deep or deep, well drained, and clayey; the Gilpin soils are loamy, moderately deep, gently sloping to very steep, and well drained (Beverage and others, 1968). Vandalia soils are typically deep and well drained, and their subsoil textures range from silty clay to clay. The deep Moshannon, Senecaville, and Melvin soils, formed from alluvium washed into the bottom lands from upland areas, are well drained, moderately well drained, and poorly drained, respectively. Their textures range from silt loam to silty clay loam (Gorman and Rayburn, 1961).

Detailed acreage figures are not available for the different soils of the watershed; however, the land of the watershed was divided into capability classes by the Soil Conservation Service in 1954. Figure 4 shows this classification. Less than 9 percent of the land comprised classes 1, 2*w*, and 3*e* and was suitable for

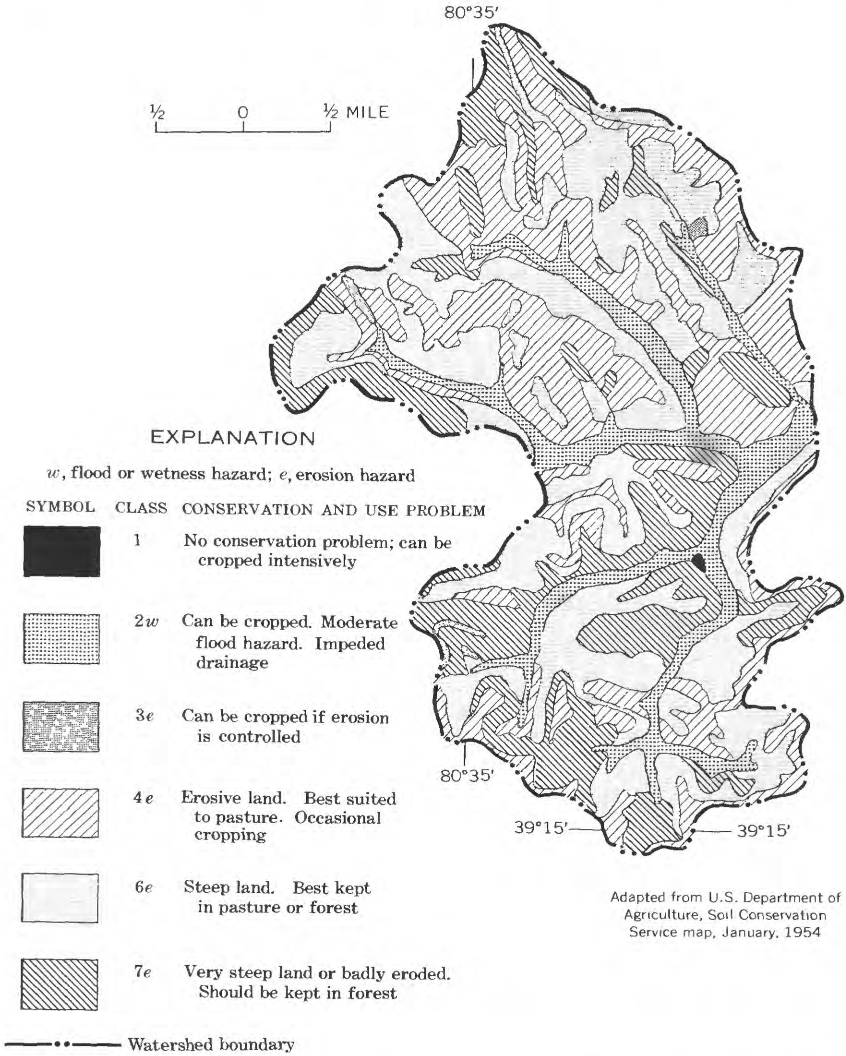

FIGURE 4. — Map of Salem Fork watershed, showing generalized use-capability classes of the land.

cropping, but most of this land had flood or wetness and erosion hazards, denoted by subclasses *w* and *e*, respectively (Buckman and Brady, 1960, p. 333). Class 4*e* included 34 percent of the land and could be used for occasional cropping though it was erosive and recommended for pasture. The 39 percent of the land in class 6*e* was steep and best suited to pasture or forest. The remaining 18 percent of the area was steep or badly eroded land in class 7*e* and was recommended for forest only (U.S. Dept. Agriculture, 1954, p. 2).

Dairying and beef production are the chief enterprises of the grassland farming that is carried out in the area. The hillsides tend to be overgrazed since bottom lands are reserved principally for hay crops (U.S. Dept. Agriculture, 1954, p. 3). Some pasturing is allowed in the bottom lands during selected seasons of the year.

HYDRAULIC STRUCTURES

Seven of the eight detention structures shown in figure 1 were built for flood control. The structure on Dog Run, completed in November 1954 by the city of Salem to impound water for municipal water supply, has a limited flood-control capability.

The principal detention structure with which this report deals is that of reservoir 11A, on Varner Hollow Run. Storage in reservoir 11A began in 1954 when the earth dam was completed. The structure detains runoff from a drainage area of 184 acres (0.288 sq mi). At the time of its completion, reservoir 11A had a storage capacity of 53.00 acre-feet and a surface area of 6.75 acres at the crest of the emergency spillway (elev 1,145.6 ft above mean sea level). The permanent (sediment) pool had an area of 0.92 acre and a capacity of 7.05 acre-feet at elevation 1,132.7 feet. The reservoir is 211 feet wide and 1,390 feet long (U.S. Dept. Agriculture, 1970). Table 1 gives the stage and capacity of reservoir 11A for 1-foot increments of elevation.

The outlet structure of reservoir 11A (fig. 5) consists of a 3-foot-square concrete drop inlet which is 17 feet in depth and connects to a 24-inch steel outlet pipe. A 12-inch horizontal steel pipe serves as a low-stage outlet which carries the flow from the reservoir to the drop inlet. An emergency earth spillway, 44 feet wide, is at the left end of the dam (fig. 6).

Reservoir 9 (see fig. 2) is on West Branch Patterson Fork in the southwestern part of the Salem Fork basin. The detention structure was completed and storage began in January 1956. The structure detains runoff from a drainage area of 590 acres (0.92 sq mi). As calculated from a survey made in November 1956, reservoir 9 had a storage capacity of 180.72 acre-feet at the crest of the emergency spillway (elev 1,105.1 ft above mean sea level). The permanent (sediment) pool had a capacity of 19.07 acre-feet at elevation 1,088.1 feet. Table 2 gives the capacity of reservoir 9 for 1-foot increments of elevation.

The outlet structure of reservoir 9 consists of a 3-foot-square concrete drop inlet which connects to a 24-inch steel outlet pipe.

TABLE 1. — *Stage and capacity of reservoir 11A from survey made in the fall of 1954*

Gage height (feet)	Elevation (feet above mean sea level)	Capacity (acre-feet)	Remarks
0.00	1,127.18	0.28	Datum of gage.
.82	1,128	.67	
1.82	1,129	1.60	
2.82	1,130	2.78	
3.82	1,131	4.18	
4.82	1,132	5.76	
5.52	1,132.7	7.05	Level of 12-inch outlet pipe.
5.82	1,133	7.55	
6.82	1,134	9.44	
7.82	1,135	11.50	
8.82	1,136	13.82	
9.82	1,137	16.45	
10.82	1,138	19.09	
11.82	1,139	22.05	
12.82	1,140	25.66	
13.72	1,140.9	29.40	Level of principal spillway.
13.82	1,141	29.80	
14.82	1,142	33.83	
15.82	1,143	38.40	
16.82	1,144	43.59	
17.82	1,145	49.30	
18.42	1,145.6	53.00	Level of emergency spillway.

FIGURE 5. — View of upstream face of detention dam of reservoir 11A, showing outlet works (middleground), stage-recorder house (background), and gage-well intakes (foreground). Photograph by C. R. Collier.

FIGURE 6. — View of reservoir 11A, showing part of emergency spillway (right foreground). Photograph by Soil Conservation Service.

TABLE 2. — *Stage and capacity of reservoir 9 from survey made in November 1956*

Gage height (feet)	Elevation (feet above mean sea level)	Capacity (acre-feet)	Remarks
0.00	1,079.80	0.40	Datum of gage.
.20	1,080	.59	
1.20	1,081	1.60	
2.20	1,082	3.07	
3.20	1,083	5.15	
4.20	1,084	7.51	
5.20	1,085	10.00	
6.20	1,086	12.72	
7.20	1,087	15.70	
8.20	1,088	18.76	
8.30	1,088.1	19.07	Level of 16-inch outlet pipe.
9.20	1,089	22.05	
10.20	1,090	25.88	
11.20	1,091	30.10	
12.20	1,092	35.51	
13.20	1,093	41.25	
14.20	1,094	48.10	
15.20	1,095	55.50	
16.20	1,096	64.06	
17.20	1,097	73.60	
18.20	1,098	83.71	
19.20	1,099	94.00	
20.20	1,100	105.01	
21.20	1,101	117.80	
22.20	1,102	131.63	
23.20	1,103	146.50	
24.20	1,104	162.15	Level of principal spillway.
25.20	1,105	179.00	
25.30	1,105.1	180.72	Level of emergency spillway.

A 16-inch horizontal steel pipe serves as a low-stage outlet and connects the reservoir with the drop inlet. An emergency spillway is at the right end of the dam.

There is a total capacity of 376 acre-feet below the emergency spillways of the seven flood-control reservoirs of the watershed. In addition, the municipal reservoir on Dog Run has a capacity of 155 acre-feet.

RUNOFF

Outflow from the Salem Fork study area was determined from gaging-station records at Salem Fork at Salem. (See fig. 1.) Flow from 1,498 of the total 5,325 acres of the area was partly controlled by seven floodwater-detention reservoirs. The municipal reservoir on Dog Run exerts a slight additional control over the flow from its 566-acre drainage area.

Gaging-station records at the outlets of reservoirs 11A and 9, shown on figure 1, were the bases for computations of outflow from their corresponding subwatersheds.

Records of streamflow for the period October 1954 to September 1962 for Salem Fork at Salem and for reservoirs 11A and 9 are published in U.S. Geological Survey water-supply papers (U.S. Geol. Survey, 1957; 1958; 1959; 1960a, b; and 1961a) and in basic-data releases entitled "Surface Water Records of West Virginia" for water years 1961 and 1962 (available from the U.S. Geol. Survey, Charleston, W. Va.). Summaries of water discharge and other hydrologic data pertaining to the two reservoir stations and for Salem Fork at Salem are given in table 3. Total inflow to and runoff from the two reservoirs have been computed and are also included in table 3.

The average annual inflow to reservoir 11A was 20.5 inches during a 7.75-year period. During this same period, the average annual runoff for Salem Fork at Salem was 21.6 inches. The average annual inflow to reservoir 9 was 23.6 inches, compared with an average annual runoff of 22.1 inches for Salem Fork at Salem during the 6.5-year period of record. The computed inflow values for both reservoirs compared favorably with the runoff values of the entire watershed as measured at Salem Fork at Salem.

FLUVIAL SEDIMENT

Fluvial sediment can be divided into two general classes, bedload and suspended load. Bedload is sediment that moves along and stays in almost continuous contact with the streambed. Suspended sediment is either colloidally suspended or held in suspension owing to upward components of turbulence.

The suspended-sediment discharge of a stream depends chiefly upon the physical characteristics of the drainage basin and the hydraulic characteristics of the stream. Precipitation intensity-duration relations, the erodibility and transportability of soil material, land use, and topography affect the amounts of sediment delivered from an area. The nature of the fluvial-sediment study in the Salem Fork watershed did not afford an opportunity to evaluate the importance of each of the above factors but only the net effect of all factors. The effects of some of the individual factors were observed in the course of the study, however.

For the reservoir outflows, the entire depth of the flow was sampled at the outlet pipes; thus the total sediment discharge was represented by these samples. Because the sand fraction, some coarse silts, and some flocculated fine sediments were deposited in the reservoirs, sediment discharges at the reservoir outflow stations did not reflect the total sediment delivered from their watersheds.

For Salem Fork at Salem, nearly all the sediment moved as suspended sediment. Therefore, the records of suspended sedi-

TABLE 3. — *Water discharge and miscellaneous reservoir computations, subwatersheds 11A and 9 and Salem Fork at Salem*

	Subwatershed 11A	Subwatershed 9	Salem Fork at Salem
Water discharge, in acre-feet, for the indicated water year			
1955	297.1	....	9,823
1956	382.2	[1]1,264	11,290
1957	251.8	968	7,840
1958	405.1	1,415	11,552
1959	216.9	794	6,858
1960	303.4	1,097	9,053
1961	304.2	1,054	9,378
1962[2]	281.1	953	8,432
Total	2,441.8	7,545	74,226
Precipitation, in inches, for the indicated water year			
1955[3]	43.03	....	43.03
1956[4]	57.16	[1]49.89	57.16
1957[3]	33.90	33.90	33.90
1958[5]	55.79	55.79	55.79
1959[5]	36.19	36.19	36.19
1960[5]	47.79	47.79	47.79
1961[5]	41.92	41.92	41.92
1962[2 5]	31.58	31.58	31.58
Total	347.36	297.06	347.36
Miscellaneous reservoir computations, 1954–62			
Drainage area ... acres	184	590	5,325
Do ... sq mi	.288	.92	8.32
Average surface area ... acres	1.81	3.54	....
Estimated evaporation from surface[6] ... acre-feet	35	57	....
Change in storage ... do	+6	+19	....
Estimated seepage loss ... do	3	6	....
Precipitation onto reservoir surface ... do	52	88	....
Total runoff for watershed[7] ... do	2,486	7,627	....
Total inflow into reservoir[8] ... do	2,434	7,539	....
Average annual inflow ... inches	20.5	23.6	....

[1]Period from January to September only.
[2]Period from October to June only.
[3]Average of totals for Clarksburg and Smithburg (U.S. Dept. Commerce, 1965).
[4]Salem official rain gage, unpublished data.
[5]Salem Post-Rogers official rain gage (U.S. Dept. Commerce, 1957–62).
[6]Based on pan-evaporation data at Clarksburg (U.S. Dept. Commerce, 1965) and on information from Kohler, Nordenson, and Baker (1959).
[7]Total runoff above dam = outflow from reservoir + evaporation from reservoir surface + estimated seepage loss + change in storage during period.
[8]Inflow = total runoff − precipitation on reservoir surface.

ment were considered as the total load, and no adjustments were made for bedload.

Depth-integrated stream samples, collected by standard samplers, were analyzed in the laboratory to obtain the suspended-sediment concentration. Particle-size determinations for selected suspended-sediment samples were made by sieve-sedimentation methods or by sedimentation methods alone. Sedimentation methods are based on the fall velocity of the particles. Suspended-sediment data collected at the three sediment stations are presented in the following three sections.

RESERVOIR 11A

SUSPENDED SEDIMENT

All discharge from reservoir 11A, which occurred 81 percent of the time, was through the outlet pipe (fig. 7) during the period of sediment record. Daily sediment discharges in excess of 500 pounds occurred on 163 days during the period of investigation, or 5.8 percent of the total time. For these days, sediment discharge totaled 357,266 pounds, or 78 percent of the total sediment discharge. Thus, 78 percent of the sediment discharge occurred during less than 6 percent of the period of investigation. Table 4 summarizes data for all outflow periods at reservoir 11A.

FIGURE 7. — Downstream face of dam of reservoir 11A, showing outlet pipe and riprap section. Photograph by C. R. Collier.

TABLE 4. — *Summary of outflow from reservoir 11A, 1954–62*
[mg/l, milligrams per liter]

Outflow period	Total days	Water discharge		Sediment discharge		Discharge-weighted suspended-sediment concentration (mg/l)
		Cubic feet per second-days	Acre-feet	Pounds	Tons	
Oct. 15, 1954–May 25, 1955	223	146.84	291.26	66,339	33	84
June 7–18, 1955	12	.58	1.15	48	.02	15
Aug. 22–Sept. 2, 1955	12	2.36	4.68	1,492	.75	117
Oct. 7, 1955–May 30, 1957	602	319.59	633.91	140,829	70	82
Oct. 24, 1957–May 27, 1958	216	151.00	299.51	52,127	26	64
June 13–July 2, 1958	20	1.79	3.55	433	.22	45
July 6–Aug. 22, 1958	48	45.17	89.59	14,365	7.2	59
Aug. 24–Sept. 12, 1958	20	1.22	2.42	47	.02	7
Sept. 17–Oct. 21, 1958	35	6.31	12.52	749	.37	22
Oct. 26, 1958–June 10, 1959	228	107.82	213.86	31,585	16	54
Aug. 9–14, 1959	6	.28	.56	17	.01	11
Aug. 18–19, 1959	2	.02	.04	1	....	9
Nov. 4, 1959–June 8, 1960	218	125.04	248.02	33,322	17	49
June 12–18, 1960	7	.46	.91	13	.01	5
June 21–28, 1960	8	.33	.65	8	....	4
July 1–8, 1960	8	.77	1.53	56	.03	13
July 11–12, 1960	2	.02	.04	1	....	9
July 14–Oct. 16, 1960	95	26.60	52.76	10,319	5.2	72
Oct. 19, 1960–July 1, 1961	256	140.43	278.54	35,919	18	47
July 3–9, 1961	7	.27	.54	33	.02	23
July 13–Aug. 29, 1961	48	12.41	24.62	4,045	2.0	60
Oct. 5–9, 1961	5	.08	.16	5	....	12
Oct. 14–27, 1961	14	.82	1.63	87	.04	20
Oct. 31–Nov. 2, 1961	3	.05	.10	3	....	11
Nov. 4, 1961–May 14, 1962	192	140.67	279.02	63,608	32	84
May 27–29, 1962	3	.06	.12	4	....	12
June 5–8, 1962	4	.10	.20	6	....	11
June 11–13, 1962	3	.04	.08	2	....	9
Total	2,297	1,231.13	2,441.97	455,463	227.89	....

Table 5, a summary of monthly water and sediment discharges from reservoir 11A, shows that 76 percent of the water and 78 percent of the sediment, on the average, were discharged during the 5-month period from December to April. At no time during December to April was flow interrupted. Flow usually persisted from October to May.

During the entire period of record for reservoir 11A, the discharge-weighted suspended-sediment concentration was about 69 mg/l (milligrams per liter). The maximum observed instantaneous concentration during the period of record was 626 mg/l on May 5, 1958. The maximum daily mean concentration during the period of record was 309 mg/l on December 30, 1954.

The maximum daily load during the period of record was 13,000 pounds on December 30, 1954. The maximum observed instantaneous suspended-sediment discharge of reservoir 11A was 25,600 pounds per day on May 5, 1958.

Particle-size analyses of both the inflow and outflow samples from reservoir 11A were made by standard sieve and sedimentation methods. The results of these analyses for the inflow and outflow of reservoir 11A are shown in tables 6 and 7, respectively. Inflow sediment averaged 51 percent clay (0.0002–0.004 mm), 42 percent silt (0.004–0.062 mm), and 7 percent sand (0.062–2.00 mm). Outflow sediment averaged 81 percent clay and 19 percent silt and no sand.

TABLE 5.—*Monthly water and sediment discharges, reservoir 11A*

Water year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Yearly total	Percentage of total
Water discharge, in cfs-days														
1955	8.96	3.92	28.25	13.51	40.48	32.38	17.50	1.84	0.58	0	2.34	0.02	149.78	12
1956	1.28	4.48	3.56	14.91	42.93	50.80	12.23	13.07	14.96	5.78	27.08	1.59	192.67	16
1957	.88	.66	36.95	26.98	28.02	9.42	22.11	1.90	0	0	0	0	126.92	10
1958	1.50	6.60	41.69	22.40	25.05	11.54	16.54	25.68	1.73	30.54	15.26	5.71	204.24	17
1959	1.40	4.28	7.70	32.00	21.07	11.18	19.21	10.23	2.00	0	.30	0	109.37	9
1960	0	6.35	15.01	22.24	25.69	21.83	11.80	21.59	1.32	2.91	17.67	6.55	152.96	12
1961	1.26	6.39	9.80	13.81	30.81	33.23	29.37	7.38	8.63	6.28	6.41	0	153.37	12
1962	.92	9.71	19.15	25.72	27.80	26.40	31.55	.43	.14	....	....	....	141.82	12
Monthly total	16.20	42.39	162.11	171.57	241.85	196.78	160.31	82.12	29.36	45.51	69.06	13.87	1,231.13	....
Percentage of total	1	3	13	14	20	16	13	7	2	4	6	1	....	100
Sediment discharge, in pounds														
1955	6,840	478	19,389	3,713	13,088	11,687	10,944	200	48	0	1,491	1	67,879	15
1956	99	837	250	8,509	17,582	30,786	2,781	1,660	4,593	525	20,743	96	88,461	19
1957	115	66	17,269	14,220	11,704	862	7,962	170	0	0	0	0	52,368	11
1958	110	1,241	17,074	5,154	6,188	1,022	3,106	18,232	432	6,930	7,463	715	67,667	15
1959	60	374	397	10,757	9,761	901	4,897	4,323	169	0	18	0	31,657	7
1960	0	906	1,503	13,906	4,726	7,478	2,150	2,635	39	478	8,756	1,122	43,699	10
1961	111	395	826	678	8,502	11,722	12,097	902	705	2,040	2,039	0	40,017	9
1962	93	3,011	2,570	11,029	18,064	13,985	14,932	23	8	....	....	....	63,715	14
Monthly total	7,428	7,308	59,278	67,966	89,615	78,443	58,869	28,145	5,994	9,973	40,510	1,934	455,463	....
Percentage of total	2	2	13	15	20	17	13	6	1	2	9	....	....	100

TABLE 6.—*Particle-size analyses of suspended sediment, inflow to reservoir 11A*

[Method of analysis: B, bottom-withdrawal tube; W, in distilled water; C, chemically dispersed; S, sieve; N, in native water. Sampling site 1, shown in fig. 1]

Date	Time	Water discharge (cfs)	Suspended sediment											Method of analysis
			Concentration (mg/l)	Percentage finer than indicated size, in millimeters										
				0.002	0.004	0.008	0.016	0.031	0.062	0.125	0.250	0.500	1.000	
1955														
Mar. 11	0755	....	1,710	56	67	82	93	98	100	....	....	....	....	BWC
Apr. 24	2300	....	1,660	35	49	62	76	89	94	98	99	100	....	SBWC
June 7	1350	....	7,500	40	56	75	93	98	99	100	....	....	....	SBWC
June 7	1350	....	7,500	23	34	52	71	97	100	....	....	....	....	BN
Aug. 22	1540	....	1,450	59	75	87	96	99	100	....	....	....	....	BWC
Aug. 22	1540	....	1,450	41	53	81	97	100	....	....	....	....	....	BN
1956														
Jan. 29	1140	....	1,950	21	32	47	60	74	80	89	96	99	....	SBWC
Jan. 29	1140	....	1,950	18	27	40	53	74	81	89	96	100	....	SBN
Feb. 25	1000	....	6,250	41	59	78	91	98	99	100	....	....	....	SBWC
Feb. 25	1000	....	6,250	31	43	60	81	98	99	100	....	....	....	SBN
Mar. 14	0735	14.6	781	32	44	56	70	81	87	93	98	100	....	SBWC
Mar. 14	0735	14.6	781	25	35	48	65	79	86	92	98	100	....	SBN
June 23	1835	....	3,890	35	52	70	87	94	98	99	100	....	....	SBWC
June 23	1835	....	3,890	27	41	63	81	96	99	99	100	....	....	SBN
July 17	1235	....	3,410	23	50	70	89	97	99	100	....	....	....	SBWC
July 17	1235	....	3,410	25	43	65	85	98	99	100	....	....	....	SBN
Aug. 5	1420	....	1,760	36	50	63	80	90	94	98	99	100	....	SBWC
Aug. 5	1420	....	1,760	21	39	55	73	89	95	98	99	100	....	SBN
Aug. 28	1810	....	643	42	57	74	88	96	98	99	100	....	....	SBWC
Aug. 28	1810	....	643	29	46	69	88	96	98	99	100	....	....	SBN
Dec. 14	0730	....	1,490	32	48	65	79	88	93	97	99	100	....	SBWC
Dec. 14	0730	....	1,490	14	29	52	76	88	93	97	99	100	....	SBN
1957														
Jan. 9	2335	....	4,160	27	40	56	72	83	91	96	98	100	....	SBWC
Jan. 9	2335	....	4,160	16	32	48	60	80	85	92	96	99	100	SBN
Apr. 8	2135	....	4,760	30	43	57	72	84	93	98	99	100	....	SBWC
Apr. 8	2135	....	4,760	22	31	48	68	85	91	97	99	100	....	SBN
Dec. 7	1750	....	544	40	58	76	89	93	95	98	99	100	....	SBWC
Dec. 7	1750	....	544	15	30	58	90	94	96	98	99	100	....	SBN
Dec. 20	1540	....	3,180	31	46	65	79	87	93	97	99	100	....	SBWC
Dec. 20	1540	....	3,180	12	23	36	58	83	94	97	99	100	....	SBN
1958														
Apr. 29	0810	....	2,060	36	48	60	74	85	90	96	99	100	....	SBWC
Apr. 29	0810	....	2,060	10	20	31	51	84	90	97	99	100	....	SBN
May 5	0715	....	5,080	28	40	56	73	81	88	94	98	100	....	SBWC
May 5	0715	....	5,080	20	30	46	62	84	89	95	98	100	....	SBN
July 15	2250	....	183	42	56	70	83	90	91	95	98	100	....	SBWC
July 15	2250	....	183	13	34	59	90	91	94	98	99	100	....	SBN
Aug. 8	0320	....	1,190	38	51	65	79	87	92	96	97	100	....	SBWC

1959														
Jan. 15	1530	....	711	31	47	59	73	83	88	94	99	100	....	SBWC
Jan. 15	1530	....	711	19	34	49	69	82	87	95	98	100	....	SBN
Jan. 20	1355	....	913	31	41	55	70	82	86	93	96	100	....	SBWC
Jan. 20	1355	....	913	20	30	54	69	83	88	94	98	100	....	SBN
Feb. 10	1240	....	7,200	37	50	64	81	88	93	97	99	100	....	SBWC
Feb. 10	1240	....	7,200	21	33	52	74	87	91	96	99	100	....	SBN
Apr. 10	1130	....	2,200	34	45	58	70	82	88	94	98	100	....	SBWC
Apr. 10	1130	....	2,200	21	33	46	62	80	84	93	98	100	....	SBN
May 4	1335	....	5,080	35	48	61	77	87	91	96	100	....	....	SBWC
May 4	1335	....	5,080	28	38	54	70	86	91	96	100	....	....	SBN
1960														
Jan. 15	0320	....	4,380	42	54	69	83	91	95	98	100	....	....	SBWC
Jan. 15	0320	....	4,380	30	41	60	76	90	95	98	100	....	....	SBN
Aug. 4	0420	....	664	48	64	77	89	96	99	100	....	....	....	SBWC
Aug. 4	0420	....	664	35	52	73	88	96	99	100	....	....	....	SBN
Aug. 21	1435	....	725	39	56	69	83	95	98	100	....	....	....	SBWC
Aug. 21	1435	....	725	23	37	59	80	94	98	100	....	....	....	SBN
1961														
Dec. 18	0930	....	992	42	57	68	83	93	96	100	....	....	....	SBWC
Dec. 18	0930	....	992	14	35	59	81	88	94	100	....	....	....	SBN

TABLE 7. — *Particle-size analyses of suspended-sediment, outflow from reservoir 11A*

[Method of analysis: B, bottom-withdrawal tube; W, in distilled water; C, chemically dispersed; S, sieve; N, in native water. Sampling site 2, shown in fig. 1]

Date	Time	Water discharge (cfs)	Suspended sediment									Method of analysis
			Concentration (mg/l)	Percentage finer than indicated size, in millimeters								
				0.002	0.004	0.008	0.016	0.031	0.062	0.125	0.250	
1955												
Mar. 1	1330	7.0	109	60	84	94	97	100	....	....	....	BWC
Apr. 25	0230	7.2	340	64	83	95	98	99	100	....	....	BWC
1956												
Feb. 25	1700	5.9	226	52	86	98	99	99	100	....	....	BWC
Feb. 25	1700	5.9	226	50	74	96	100	....	....	....	....	BN
Mar. 8	1810	7.4	257	78	94	99	100	....	....	....	....	BWC
Mar. 14	1300	7.2	164	37	80	91	97	98	....	....	....	BWC
June 23	2200	3.4	205	71	87	96	99	99	100	....	....	BWC
June 23	2200	3.4	205	68	82	95	97	100	....	....	....	BN
Aug. 5	1710	7.1	260	70	84	96	99	99	100	....	....	BWC
Aug. 5	2205	10.0	362	59	77	94	98	99	100	....	....	BWC
Aug. 6	0310	10.9	217	79	95	98	98	99	100	....	....	BWC
Aug. 6	0310	10.9	217	52	76	94	97	98	100	....	....	BN
Dec. 14	0955	10.0	315	58	77	93	98	99	100	....	....	BWC
Dec. 14	1400	10.0	212	65	83	94	98	99	99	100	....	SBWC
Dec. 14	1400	10.0	212	48	72	92	96	97	99	99	100	SBN

TABLE 7. — *Particle-size analyses of suspended-sediment, outflow from reservoir 11A* — Continued

Date	Time	Water discharge (cfs)	Suspended sediment: Concentration (mg/l)	Percentage finer than indicated size, in millimeters: 0.002	0.004	0.008	0.016	0.031	0.062	0.125	0.250	Method of analysis
1957												
Jan. 10	0010	7.5	515	38	57	78	92	97	99	100	....	SBWC
Jan. 10	0410	8.3	323	60	79	93	98	99	99	100	....	SBWC
Apr. 8	1050	5.0	322	50	70	83	94	98	99	100	....	SBWC
Dec. 20	1800	7.0	358	64	77	92	98	99	100	....	....	BWC
Dec. 20	2100	7.3	247	75	81	94	99	100	....	....	....	BWC
Dec. 20	2100	7.3	247	37	67	93	100	....	....	....	....	BN
1958												
May 5	0840	7.6	626	34	57	81	97	99	100	....	....	BWC
May 5	1440	9.8	316	65	83	96	99	100	....	....	....	BWC
May 5	1440	9.8	316	53	76	97	100	....	....	....	....	BN
July 16	0200	7.2	102	64	84	97	99	100	....	....	....	BWC
Aug. 8	0405	7.2	381	58	74	88	98	99	100	....	....	BWC
1959												
Feb. 10	1730	6.8	233	67	79	90	94	99	100	....	....	BWC
Feb. 10	1730	6.8	233	50	72	93	97	98	100	....	....	BN
May 4	1450	3.6	292	52	72	87	97	98	99	100	....	SBWC
1960												
Jan. 15	0800	8.2	301	70	88	94	98	99	100	....	....	BWC
Jan. 15	1010	8.2	253	69	86	95	98	99	100	....	....	BWC
Jan. 15	1010	8.2	253	60	79	95	97	98	100	....	....	BN
Mar. 31	0755	7.0	236	70	87	95	97	99	100	....	....	BWC
Aug. 4	0710	6.6	231	68	86	94	98	99	100	....	....	BWC
Aug. 4	0710	6.6	231	43	65	94	98	99	100	....	....	BN
Aug. 21	1720	6.2	158	64	84	95	97	99	100	....	....	BWC
1961												
Feb. 25	1900	6.0	216	70	83	92	99	100	....	....	....	BWC
Feb. 25	1900	6.0	216	38	65	91	99	99	100	....	....	BN
Apr. 26	1915	2.6	160	93	95	98	99	100	....	....	....	BWC
1962												
Feb. 26	1220	6.3	215	67	82	93	98	99	100	....	....	BWC
Mar. 21	1830	7.0	536	48	66	85	94	100	....	....	....	BWC

For practically all of the inflow samples and many of the outflow samples of reservoir 11A, particle-size distribution of the silt-clay fraction was determined in both distilled- and native-water settling mediums. To determine the percentage distribution of the primary particles, a chemical dispersing agent was added to the distilled-water medium to cause deflocculation. Analyses were made of samples in the native-water medium to partially preserve the particle-size characteristics of the sediments, including the floccules of particles. Native-water analyses could then be used to predict the likelihood of flocculation and the settling characteristics of the sediments for the natural setting. These native-water analyses did show flocculation. The results of 26 pairs of analyses of inflow samples from reservoir 11A in which both settling mediums were used showed an average of 15 percent less clay in the native-water settling medium than in the distilled-water medium.

A high calcium-sodium ratio in water causes flocculation of soil colloids, and a high sodium-calcium ratio causes dispersion of soil colloids (Rainwater and Thatcher, 1960, p. 127, 265). Chemical analyses of the inflow water of reservoir 11A (table 8) indicate an average calcium-sodium ratio of about 3:1; but, because calcium and sodium concentrations are extremely low, the ratio is probably insignificant relative to the flocculation of the sediments. Dissolved solids, calculated from conductance values (0.6 $\times$ conductance), are low, ranging from 31 to 109 mg/l and averaging 49 mg/l. The slightly acid condition of the water (pH 6.4) may encourage some of the flocculation.

About the same degree of flocculation was detected in the particle-size analyses of outflow and inflow. Dissolved solids again averaged 49 mg/l. The calcium-sodium ratio of 3.3:1 for the outflow was as insignificant as that for the inflow because concentrations of calcium and sodium were very low; the pH of the outflow was about equal to that of the inflow. Because natural conditions of temperature and turbulence cannot be duplicated in the laboratory, the degree of flocculation in the natural setting is uncertain.

DEPOSITED SEDIMENT, TRAP EFFICIENCY, AND SEDIMENT YIELD

Surveys of reservoir 11A, made by the Soil Conservation Service in October 1954, 1956, and 1958, December 1960, and June 1962 (U.S. Dept. Agriculture, 1970), consisted of 19 ranges across various parts of the reservoir. The original survey indicated a reservoir capacity of 53.00 acre-feet (below the emergency spillway) ; the capacity after the 1962 survey was 51.75 acre-feet. The 2.36-percent decrease in capacity was attributed to sediment deposition. The average dry weight per cubic foot of the deposited sediment was assumed to be 60 pounds (U.S. Dept. Agriculture, 1970). The computed weight of the sediment which accumulated during the 7.75-year period was 1,633 tons.

Listed in table 9 are sediment discharge, weight of deposited sediment, computed trap efficiency, and sediment yield during each of the periods between surveys of reservoir 11A. The high sediment yield of the first 2-year period was due largely to the high and continuous flow during the 1956 water year. During the 1955 and 1956 water years, 65 percent of the water and 73 percent of the sediment was discharged during December 1954, February and March 1955, and February, March, and August 1956. (See table 5.)

The trap efficiency, 88 percent, is about 3 percent below the estimated figure based on the capacity-inflow ratio method given by Brune (1953, p. 414). The capacity-inflow ratio used for reservoir 11A was 0.169.

RESERVOIR 9, SUSPENDED SEDIMENT

From January 1956 to June 1962 periodic suspended-sediment samples at Salem Fork subwatershed 9 (West Branch Patterson Fork) near Salem were collected to provide an index of the water-sediment discharge relationships and to provide data pertaining to the particle-size characteristics of the incoming and outgoing suspended sediment of the reservoir.

Instantaneous sediment discharges were computed for all samples taken at the outflow from reservoir 9. During most of the period, samples were collected too infrequently to make possible the computation of daily loads.

An average annual sediment discharge of 128,000 pounds per year was computed from measured flow-duration data for the outflow and from a computed curve showing the relation of instantaneous sediment discharge to instantaneous water discharge. This method was described by Jordan, Jones, and Petri (1964, p. 61–62). The curve rating instantaneous sediment discharge was applicable for all periods of outflow.

Particle size was analyzed for selected inflow and outflow samples. The limited data on inflow particle size suggest that the inflow contained up to 12 percent sand. The outflow contained an average of 20 percent silt and 80 percent clay and no sand. Particle-size analyses using native water and chemical analyses were not made for reservoir 9, but all particle-size analyses of suspended sediment for reservoir 9 are given in table 10.

TABLE 8. — *Chemical analyses of water in Salem Fork basin*

Date of collection	Instantaneous water discharge (cfs)	Calcium, Ca (mg/l)	Sodium, Na (mg/l)	Specific conductance (micromhos at 25°C)	pH
		Reservoir 11A (sampling site 1, shown in fig. 1)			
June 7, 1955	....	4.8	4.1	79	6.6
Aug. 22, 1955	....	11	2.6	111	7.1
Jan. 29, 1956	....	6.7	2.6	96	6.5
Feb. 25, 1956	....	7.5	3.6	91	6.9
Mar. 14, 1956	14.6	4.9	1.5	59	7.1
June 23, 1956	....	3.3	1.6	50	5.9
July 17, 1956	....	3.3	3.1	58	6.1
Aug. 5, 1956	....	4.6	2.3	69	6.4
Aug. 28, 1956	....	6.8	2.4	82	7.2
Dec. 14, 1956	....	4.2	1.6	52	6.6
Jan. 9, 1957	....	7.6	2.3	59	6.8
Apr. 8, 1957	....	5.1	1.6	58	7.2
Dec. 7, 1957	....	8.6	1.8	93	6.3
Dec. 20, 1957	....	8.7	1.7	95	6.1
Apr. 29, 1958	....	14	2.4	182	4.3
May 5, 1958	....	7.3	.8	82	5.4
July 15, 1958	....	6.8	2.1	86	7.1
Jan. 15, 1959	....	9.2	2.6	108	4.5
Jan. 20, 1959	....	6.9	2.1	80	5.9
Feb. 10, 1959	....	7.5	2.1	85	6.3
Apr. 10, 1959	....	6.4	2.0	75	7.0
May 4, 1959	....	7.8	3.2	100	5.9
Jan. 15, 1960	....	9.0	4.1	81	5.5
Aug. 4, 1960	....	5.3	.4	72	6.3
Aug. 21, 1960	....	5.2	....	69	6.1
Feb. 25, 1961	....	5.6	2.3	79	6.5
Dec. 18, 1961	....	7.8	3.2	90	7.5
Feb. 26, 1962	....	6.5	2.8	65	7.3
		Reservoir 11A (sampling site 2, shown in fig. 1)			
Feb. 25, 1956	5.9	6.0	2.7	69	6.8
June 23, 1956	3.4	7.6	2.7	84	6.8
Aug. 6, 1956	10.9	5.2	2.2	66	6.5
Dec. 14, 1956	10	6.2	3.1	76	6.9
Dec. 20, 1957	7.3	6.7	2.3	88	6.5
May 5, 1958	9.8	6.0	1.0	66	6.0
Feb. 10, 1959	6.8	6.5	2.5	75	7.2
Jan. 15, 1960	8.2	8.4	1.9	77	6.6
Aug. 4, 1960	6.6	9.5	.8	122	5.4
Feb. 25, 1961	6.0	10	2.8	100	7.1
		Salem Fork (sampling site 5, shown in fig. 1)			
July 17, 1955	72	20	21	253	7.6
Feb. 25, 1956	152	7.1	3.0	81	7.0
Apr. 8, 1957	231	9.2	2.0	81	7.2
Dec. 7, 1957	388	7.1	1.8	78	6.6
May 5, 1958	916	6.7	1.6	71	6.8
Feb. 10, 1959	270	11	3.4	108	6.6
Jan. 15, 1960	302	10	3.5	87	6.4

TABLE 9. — *Sediment data for periods between surveys of reservoir 11A*

Period	Number of years	Sediment load (tons)			Sediment yield (tons per year)[4]		
		Discharged from reservoir[1]	Deposited in reservoir[2]	Total	Trap efficiency (percent)[3]	Per square mile	Per acre
Oct. 1954–Sept. 1956	2	78	980	1,058	93	1,843	2.88
Oct. 1956–Sept. 1958	2	60	261	321	81	559	.87
Oct. 1958–Nov. 1960	2.17	38	131	169	78	271	.42
Dec. 1960–June 1962	1.58	52	261	313	83	690	1.08
Oct. 1954–June 1962	7.75	228	1,633	1,861	88	837	1.31

[1]Computed from table 5.
[2]Based on an assumed average dry weight of 60 pounds per cubic foot of deposited sediment (U.S. Dept. Agriculture, 1970).
[3]Trap efficiency (percent) = weight of deposited sediment (tons) × 100 ÷ weight of sediment (tons) delivered into reservoir.
[4]From contributing area of 0.287 sq mi (U.S. Dept. Agriculture, 1970).

SALEM FORK AT SALEM, SUSPENDED SEDIMENT

Periodic records of suspended sediment were compiled for this location (see fig. 1) throughout the period from October 1954 to June 1962. Because more frequent sampling was carried on during the first 2 water years, 1955 and 1956, daily loads were determined. During periods of increased runoff, samples were collected more than once each day. During steady flow, samples were collected weekly. Instantaneous suspended-sediment discharge was determined for each sample.

The effects of intense storms that occur during the summer months were observed, to a degree, at this sediment station. The highest instantaneous concentration, 5,980 mg/l, was measured June 7, 1955; the highest instantaneous suspended-sediment discharge, 10,500 tons per day, was measured August 22, 1955.

In analyzing sediment data for Salem Fork at Salem, the study period was divided into two periods, from October 1954 to September 1958 and from October 1958 to June 1962. During the first period, which was one of reservoir construction, conditions in the watershed were generally unstable, but during the second period, after completion of conservation measures, conditions in the watershed were fairly stable. A curve rating instantaneous suspended-sediment discharge for each of the two periods was plotted on the basis of average relations of instantaneous suspended-sediment discharge to water discharge (fig. 8). Average annual sediment discharges were determined for the two periods (Jordan and others, 1964) from flow-duration curves (fig. 9). The average annual sediment discharge for water years 1954–58 was 3,500 tons, adjusted by daily records collected from October 1954 to September 1956. During the second period, the average annual sediment discharge was 1,770 tons.

The average annual sediment discharge of 1,770 tons during the second period was only 51 percent of the adjusted average annual sediment discharge for the first period. Some of the factors contributing to the difference are as follows: (1) At the beginning of the first period, control or partial control of the flow from the watershed existed only on 899 of the 5,325 acres in the watershed, but during the second period, control or partial control had been increased to, and remained at, 2,064 acres, (2) construction activities in the watershed and the implementation of other conservation measures which were in progress during the first period were essentially complete at the beginning of the second period, (3) average annual rainfall was 8.1 inches higher for the first period than for the second, and (4) average annual runoff at the gaging station at Salem Fork at Salem was 3.8 inches higher for the first period than for the second. Neither the relative importance of the above factors nor the importance of other contributing factors was evaluated in this study.

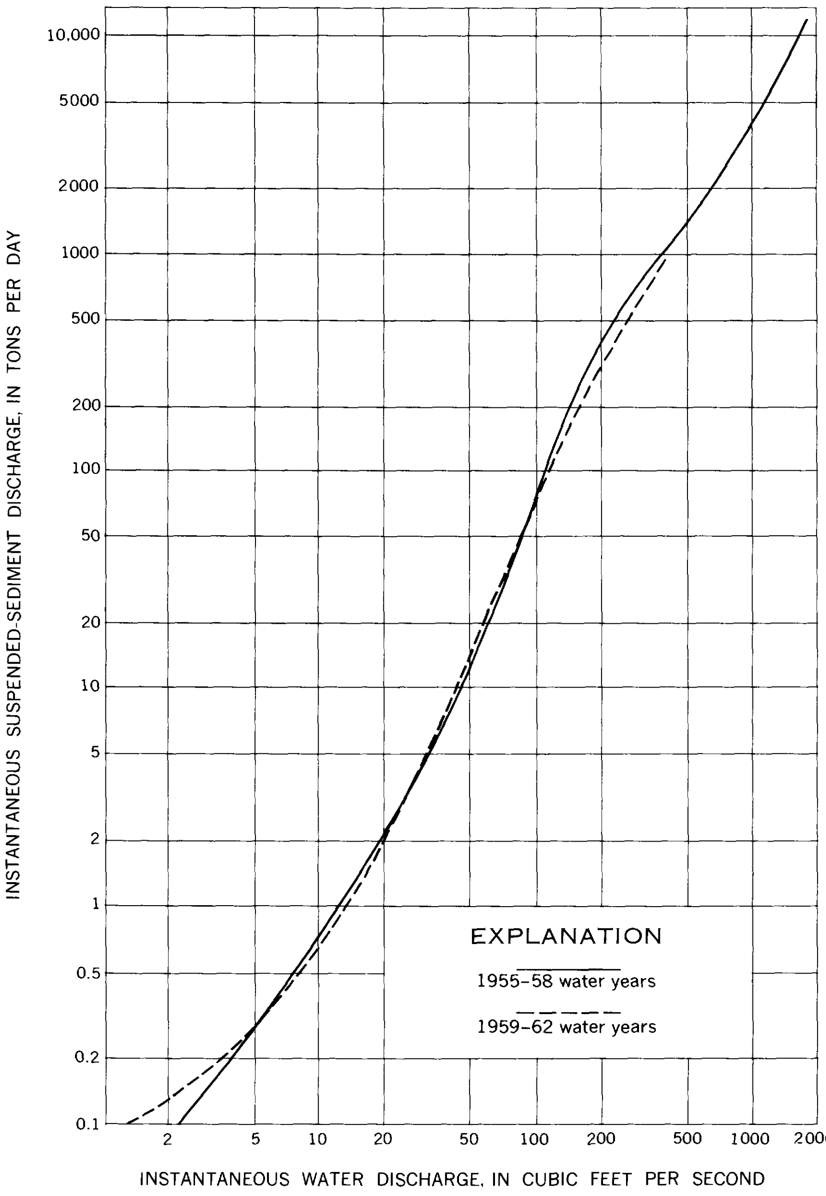

FIGURE 8. — Average relations of suspended-sediment discharge to water discharge, Salem Fork at Salem.

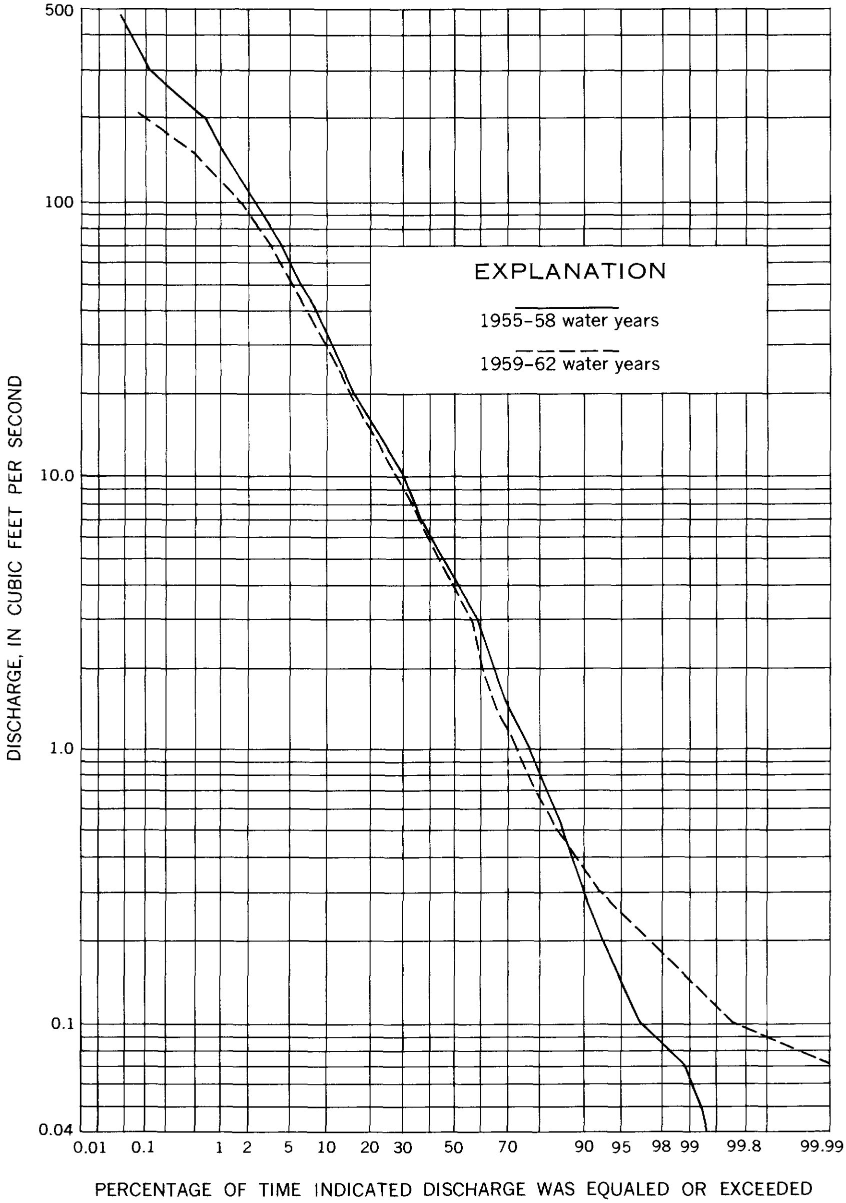

FIGURE 9. — Duration curves of daily flow for the two 4-year periods of investigation, Salem Fork at Salem.

Particle-size analyses of the samples from the first period were compared with those from the second. There was no appreciable difference between the averages of the analyses for the two periods.

Thus, although the amount of suspended sediment discharged was reduced following reservoir completion, the particle-size distribution of the suspended sediment carried past the main-channel station did not change. Particle-size analyses for Salem Fork at Salem are summarized in table 11.

Flow leaving the reservoirs was essentially free of sand; however, the capacity of the flow for carrying various sizes of particles did not decrease. Apparently, adjustments in particle-size distribution in the flow were made below the reservoirs by the entraining of available channel sediments above the Salem Fork station.

CONCLUSIONS

Investigations of runoff and fluvial sediment, made at three sites in the Salem Fork basin from October 1954 to June 1962, have resulted in the following conclusions:

1. Both water discharge and sediment discharge were significantly affected by upstream developments which began in October 1954.
2. Particle-size analyses of suspended sediment of the inflow and outflow from reservoirs 11A and 9 indicated that sand delivered to the reservoirs was deposited in the reservoirs.
3. Clay and silt constituted the bulk of sediment discharged from reservoirs 11A and 9.
4. Laboratory analyses indicated that the native water of both inflow and outflow from reservoir 11A was capable of causing flocculation of the clay. The degree of natural flocculation could not be determined from the data.
5. Average annual sediment discharge of 3,500 tons at Salem Fork at Salem during the unstable 4-year period from 1954 to 1958 was about twice the amount of 1,770 tons for the stable 4-year period from 1958 to 1962. Factors which may have contributed to this difference during the latter period are (a) there was more control of the flow in the watershed resulting from completed detention structures and conservation measures, (b) there were fewer sediment-contributing construction activities, and (c) there was less rainfall and runoff than during the 1954–58 period.
6. Trap efficiency of reservoir 11A for the period of investigation was 88 percent and ranged from 73 to 93 percent for periods between surveys.
7. The annual sediment yield of subwatershed 11A for the entire period of investigation was 1.31 tons per acre.

TABLE 10.—*Particle-size analyses of suspended sediment, inflow to and outflow from reservoir 9*

[Method of analysis: B, bottom-withdrawal tube; W, in distilled water; C, chemically dispersed; S, sieve]

Date	Time	Water discharge (cfs)	Suspended sediment: Concentration (mg/l)	Percentage finer than indicated size, in millimeters: 0.002	0.004	0.008	0.016	0.031	0.062	0.125	0.250	0.500	Method of analysis
Inflow to reservoir. Sampling site 3, shown in fig. 1													
1957													
Apr. 8	1135	....	445	30	41	53	63	73	88	96	99	100	SBWC
Oct. 7	1130	....	223	56	66	81	88	94	98	99	100	....	SBWC
Outflow from reservoir. Sampling site 4, shown in fig. 1													
1958													
May 5	1215	19.2	432	52	74	88	97	99	100	....	....	....	BWC
May 5	1535	21.3	372	62	79	95	97	99	100	....	....	....	BWC
July 15	2330	13.7	411	58	73	89	96	99	100	....	....	....	BWC
1959													
Feb. 10	1600	10.6	287	57	73	88	96	98	100	....	....	....	BWC
1960													
Aug. 4	1440	19.0	417	77	87	98	99	99	100	....	....	....	BWC
Aug. 5	2330	16.9	173	84	97	99	99	99	100	....	....	....	BWC

TABLE 11.—*Particle-size analyses of suspended sediment, Salem Fork at Salem*

[Method of analysis: B, bottom-withdrawal tube; W, in distilled water; C, chemically dispersed; N, in native water; S, sieve. Sampling site 5, shown in fig. 1]

Date	Time	Water discharge (cfs)	Suspended sediment: Concentration (mg/l)	Percentage finer than indicated size, in millimeters: 0.002	0.004	0.008	0.016	0.031	0.062	0.125	0.250	0.500	1.000	Method of analysis
1954														
Oct. 15	1445	375	1,730	32	46	62	77	89	94	98	100	....	....	SBWC
Dec. 29	1100	....	2,680	34	48	62	77	87	94	98	100	....	....	SBWC
Dec. 30	0100	....	721	32	41	53	67	74	82	92	98	100	....	SBWC
1955														
Feb. 6	1830	515	797	28	36	49	61	71	81	90	98	100	....	SBWC
Mar. 1	1200	268	620	29	39	52	66	76	87	93	99	100	....	SBWC
Mar. 11	0925	98	1,270	52	70	85	96	99	100	....	....	....	....	BWC
Mar. 22	0940	118	508	44	59	77	91	97	100	....	....	....	....	BWC
June 7	1430	150	5,980	44	58	75	90	97	100	....	....	....	....	BWC
June 7	1430	150	5,980	29	44	63	83	98	99	100	....	....	....	SBN
July 17	1510	80	454	47	65	82	91	98	99	100	....	....	....	SBWC
July 17	1615	72	3,260	41	56	77	94	98	100	....	....	....	....	BWC
July 17	1615	72	3,260	30	49	70	93	99	100	....	....	....	....	BWC

1956														
Jan. 29	1500	248	1,220	30	43	60	76	92	97	99	100	....	....	SBWC
Jan. 29	1730	231	918	28	40	54	70	86	86	96	99	100	....	SBWC
Jan. 30	0830	350	1,140	27	36	50	65	78	95	99	100	....	....	SBWC
Feb. 2	1540	338	825	30	41	51	67	79	90	96	99	100	....	SBWC
Feb. 7	0015	280	457	28	35	43	55	65	79	92	98	100	....	SBWC
Feb. 18	1115	150	191	....	49	54	73	85	92	96	100	....	....	SBWC
Feb. 25	1400	152	2,010	26	39	55	68	84	92	98	100	....	....	SBWC
Feb. 25	1400	152	2,010	20	32	50	68	84	92	98	100	....	....	SBN
Mar. 14	0850	388	880	25	42	50	63	74	86	94	99	100	....	SBWC
Apr. 3	0900	185	265	37	48	58	71	82	91	97	100	....	....	SBWC
June 18	1355	128	1,860	48	62	78	91	98	99	99	100	....	....	SBWC
Aug. 5	1000	1,890	502	44	60	74	85	90	93	96	98	100	....	SBWC
Dec. 14	0745	1,090	984	32	41	56	70	81	87	93	98	100	....	SBWC
Dec. 14	0900	1,490	931	34	47	61	76	84	90	93	97	99	100	SBWC
1957														
Apr. 8	1100	295	2,240	31	44	58	72	86	95	99	100	....	....	SBWC
Apr. 8	1230	231	676	25	39	52	67	81	90	96	99	100	....	SBWC
Apr. 8	1230	231	676	17	29	49	66	77	89	95	99	100	....	SBN
Dec. 7	2015	388	538	43	51	65	80	86	92	96	99	100	....	SBWC
Dec. 7	2015	388	538	24	34	52	66	83	89	95	99	100	....	SBN
1958														
May 5	1245	916	657	24	36	50	65	75	81	90	97	100	....	SBW
May 5	1245	916	657	22	32	49	67	80	84	92	98	100	....	SBN
July 15	2300	776	1,330	46	56	72	86	93	95	98	100	....	....	SBWC
1959														
Jan. 15	1640	208	1,280	31	41	53	70	84	90	95	99	100	....	SBWC
Jan. 21	1130	265	1,480	24	33	49	65	77	86	95	99	100	....	SBWC
Feb. 10	1400	270	4,240	28	40	54	69	85	92	98	100	....	....	SBWC
Feb. 10	1400	270	4,240	19	31	49	67	86	91	98	100	....	....	SBN
Apr. 10	1345	425	783	34	46	56	69	82	88	96	100	....	....	SBWC
1960														
Jan. 15	1000	....	342	34	47	55	70	78	88	95	100	....	....	SBWC
1961														
Mar. 21	1215	362	650	46	58	72	85	94	97	100	....	....	....	SBWC

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