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FLUVIAL SEDIMENT IN DOUBLE CREEK SUBWATERSHED NO. 5, WASHINGTON COUNTY, OKLAHOMA

By

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ABSTRACT

Double Creek subwatershed No. 5 in Washington County, Oklahoma, is one of six detention structures within the Double Creek watershed and includes 1,530 acres (2.39 square miles). The subwatershed receives runoff from approximately 5 percent of the total area of the watershed.

Most precipitation falling on subwatershed No. 5 does not flow through the reservoir. During this study approximately three-fourths (47,000 acre-feet) of the precipitation was lost by evaporation and transpiration; a small amount is lost by deep subsurface percolation.

Fifty-nine percent of the total sediment load was discharged from the reservoir during four major outflow periods representing 34 percent of the outflow days. The highest percentage of runoff and sediment yield occurs from March through June. Fifty-three percent of the water discharged and 63 percent of the sediment yield occurred during this 4-month period. The average annual yield of fluvial sediment from watershed No. 5 was 607 tons per square mile, or 0.95 ton per acre.

A total of 21,370 tons of fluvial sediment was transported into reservoir No. 5 and a total of 19,930 tons was deposited. Seventy-eight percent of the total fluvial sediment was deposited during the first 9.2 years, or 63 percent of time of reservoir operation. The computed trap efficiency of reservoir No. 5 was 93 percent.

INTRODUCTION

As part of a nationwide investigation of the trap efficiency of flood-retarding reservoirs, the U.S. Geological Survey in cooperation with the U.S. Soil Conservation Service studied sedimentation in Double Creek subwatershed No. 5, Washington County, Oklahoma, from October 1954 to September 1969. Data collected during the study are summarized and analyzed in this report. These data together with similar data for other watersheds should be of value in the design of detention structures, the determination of sediment yields from specific watersheds, and the trap efficiency of specific reservoirs.

Double Creek subwatershed No. 5, lies within Double Creek watershed. The Double Creek watershed project was initiated under authorization of PL 566 and was developed for improved land utilization of the watershed and flood protection. Installation of six flood-water retarding structures was started in 1954 and was completed in 1955; storage in reservoir No. 5 began on February 1, 1955.

CHARACTERISTICS OF DRAINAGE AREA

From its point of origin in extreme eastern Osage County, Double Creek crosses Washington County in a southeasterly direction for approximately 9 miles before entering Caney River at river mile 33.3. Figure 1 shows general location of subwatershed No. 5 and the pattern of drainage into reservoir No. 5.

Drainage Area and Topography

Double Creek subwatershed reservoir No. 5 is one of six detention structures within the Double Creek watershed which covers an area of 30,250 acres (47.3 square miles). These six detention structures receive runoff from 15,649 acres (24.46 square miles) in the upper basin or 52 percent of the total area of the watershed. Subwatershed No. 5 encompasses 1,530 acres (2.39 square miles) and thus reservoir No. 5 receives runoff from approximately 5 percent of the total area of Double Creek watershed.

The major tributaries of Double Creek are North Double, South Double, and Nellie Bly Creeks. Subwatershed reservoir No. 5 is located on Nellie Bly Creek in the extreme southern part of the watershed, 1.8 miles southwest of Ramona.

Topography of Double Creek watershed is gently rolling prairie. The surface elevation of the prairie rises westward from 620 feet above mean sea level where Double Creek enters Caney River to about 720 feet near the Osage-Washington County line. The main alluvial valley of Double Creek ranges in width from approximately 4,300 feet at its junction with the flood plain of Caney River to 200 feet near its head waters (H. P. Guy, written commun., 1958).

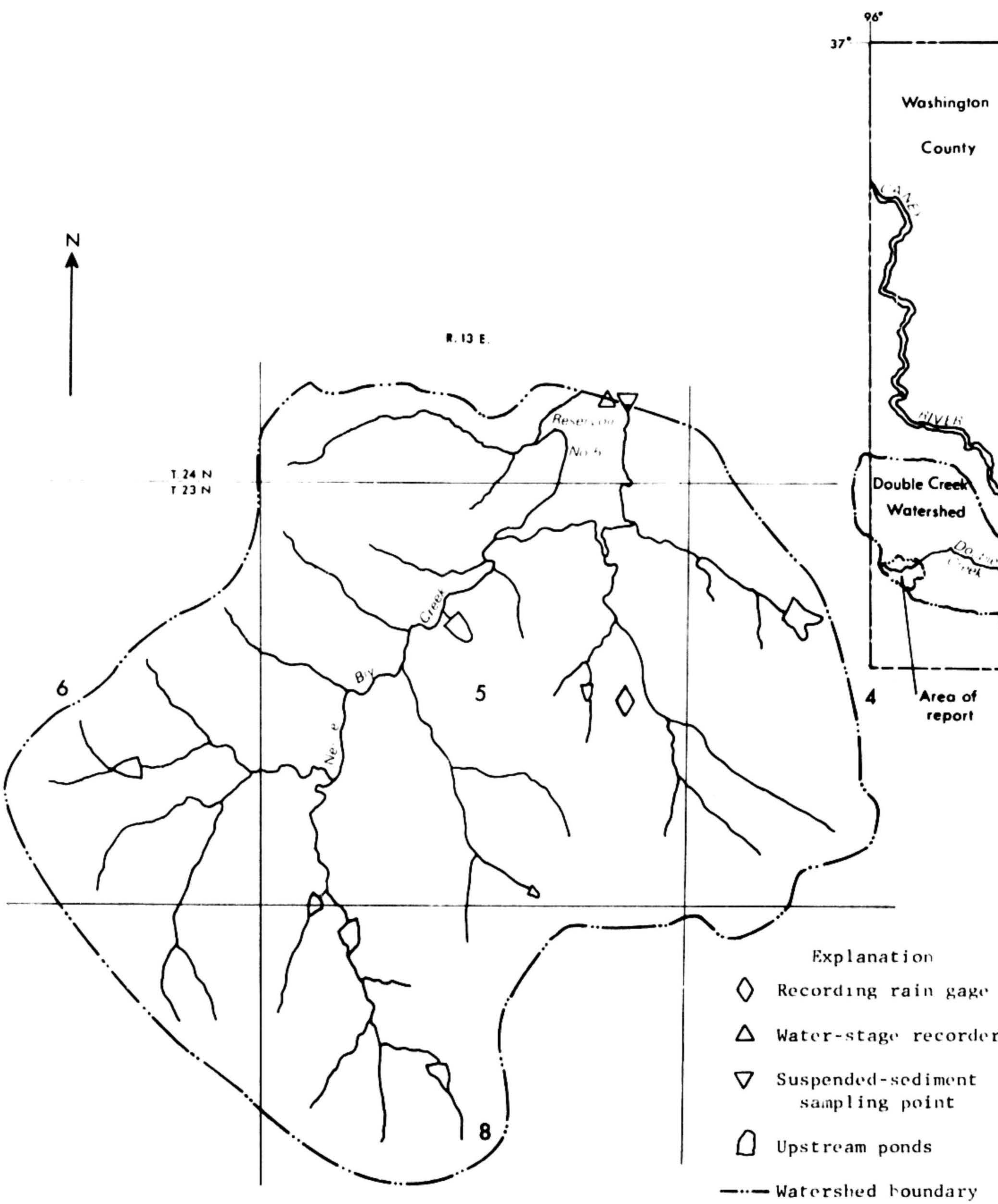

Figure 1.--General location showing subwatershed No. 5 drainage and hydrologic instrumentation.

Land Use and Soils

Land in the Double Creek watershed is primarily used for grazing cattle. Approximately 61 percent is in native pasture, 15 percent in wooded pasture, 18 percent in cultivation, 3 percent in miscellaneous use including urban areas and roads, and 3 percent idle. Ramona with an estimated average population of 568 during this study is the only town in the watershed.

Land use in the drainage basin of subwatershed No. 5 is almost entirely range land consisting of 31 acres of deep loamy prairie, 438 acres of stoney prairie, 634 acres of shallow prairie and 402 acres of very shallow prairie (H. P. Guy, written commun., 1958). There was no significant change in land use during the period of this study.

According to the U.S. Department of Agriculture, Soil Conservation Service (1968), the major soil associations in the basin are the Summit-Sogn and the Collinsville-Eram-Bates (fig. 2). These soil associations consist of six major soil types as shown in table 1. These soils are developed on shale, sandstone, clay, and limestone of the Dewey and Nellie Bly Formations of Pennsylvanian age.

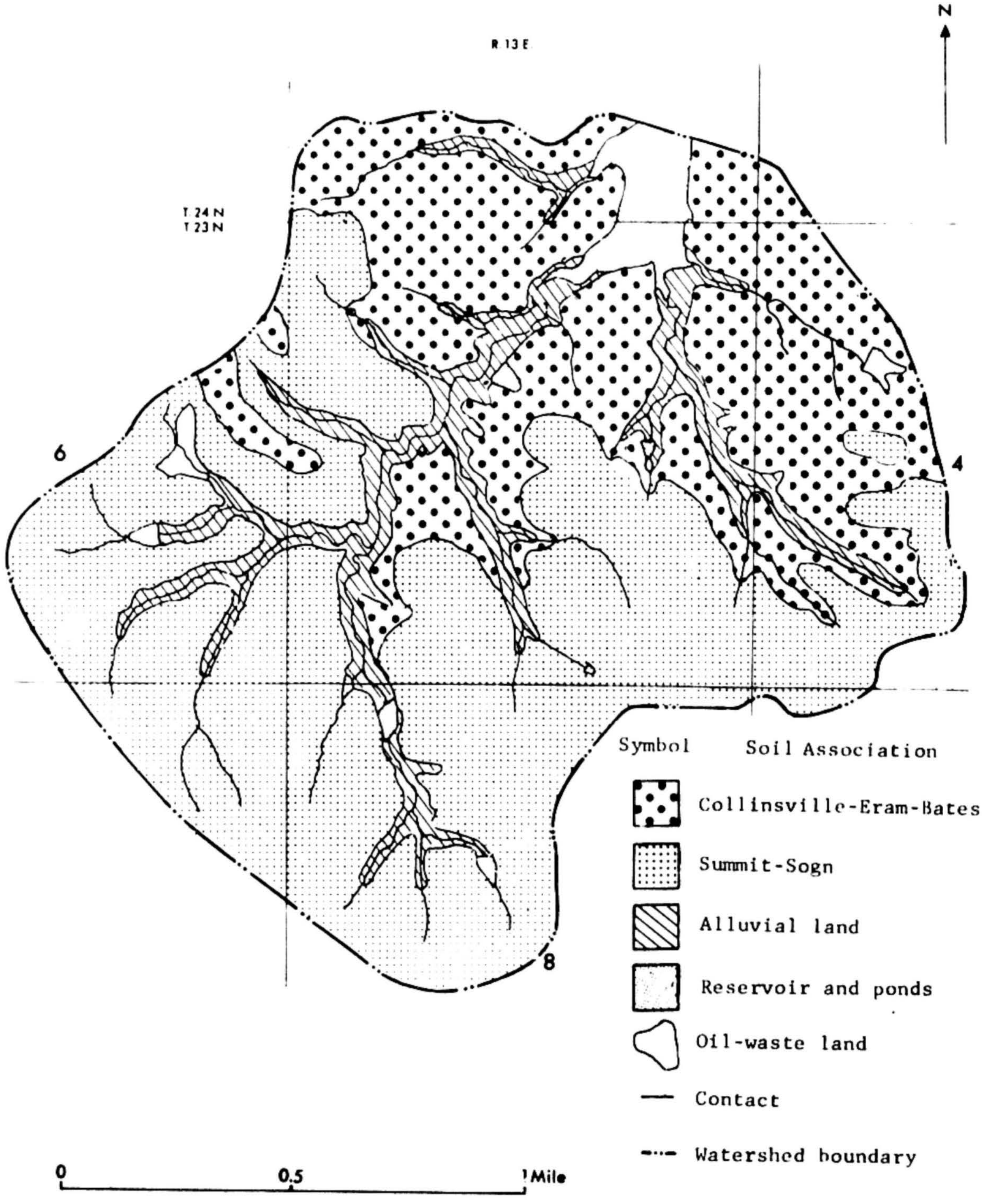

Figure 2.--General soil map.

Climate

The Double Creek watershed is in a moist subhumid zone. Mean temperatures range from 82°F in summer to 36°F in winter. The extreme recorded temperatures have reached 25°F below zero and 114°F above. The average date of the last killing frost is March 30 and that of the first killing frost is October 30, thus the normal frost-free period is 214 days. The mean annual precipitation is about 35 inches and is generally well distributed throughout the watershed.

Years of severe drought in the watershed were 1910, 1917, 1934, 1936, 1947, and 1952 before the completion of watershed structures, and 1956 after their completion. All farm ponds and most wells failed during these years (Double Creek Watershed Completion Report, January 1961). There was no outflow from reservoir No. 5 during the drought of 1956. The following year, 1957, was a period of devastating floods in the watershed.

The mean annual rainfall in subwatershed No. 5 during the period of this study was 33.65 inches as compared with 34.62 inches recorded during the same period at the National Weather Service station in Bartlesville approximately 16 miles north. Generally, most rain falls during April (10 percent), May (13 percent), June (13 percent), August (11 percent) and September (15 percent). Monthly and yearly mean precipitation amounts recorded from April 1955 to September 1969 are shown in table 2.

Chemical Quality of Water in Reservoir No. 5

Water in reservoir No. 5 is of good quality and may be used for many purposes. The median dissolved-solids content of samples from outflow is 320 mg/l (milligrams per liter) (table 3) which is well below the 500 mg/l suggested by the U.S. Public Health Service (1962). The sodium-adsorption-ratio (SAR) is low, thus the water is chemically suitable for irrigation.

According to Guy (1969) clay and fine silt in waters containing sodium as the dominant cation in solution will tend to behave as discrete units resisting flocculation. Therefore, the relatively high calcium (Ca) to sodium (Na) ratio in the water in reservoir No. 5 increases trap efficiency by causing flocculation and settling of fine-sediment particles.

Chemical analyses of a few samples collected from inflow into the reservoir indicate that inflow water has a varied dissolved-solids content. Although the samples of inflow water were too few to define its chemical characteristics in detail, the average dissolved-solids content of inflow water is probably about the same as that of reservoir water.

HYDRAULIC STRUCTURES

The top of the 900-foot dam of reservoir No. 5 is at elevation 722.5 feet above mean sea level and has a maximum height of about 36 feet. The emergency spillway on the east end of the dam has a length of 150 feet and has a crest elevation of 717.5 feet above mean sea level. The surface area and capacity of the reservoir from elevation 686 to 717.5 feet based on three surveys is shown in table 4.

Initially, outflow from the reservoir was controlled by a reinforced 12-inch concrete pipe through the sodded earth dam and the open spillway at the southeast end of the dam. In April 1964, a 12-inch diameter opening in a steel plate on a 24-inch pipe through the dam was installed to provide additional outflow. The sediment pool can be drained down through a valve-controlled pipe. Figure 3 shows the two outflow pipes and the location of the sediment sample collecting point on the 12-inch outlet pipe.

Figure 3.--View of outflow pipes and sediment sampling platform.

METHODS OF INVESTIGATION AND RECORDS

During this 14.7-year study, continuous records of stage and water discharge at the outflow were obtained by operation of a stream gaging station. Suspended-sediment loads were computed from the flow data and the sediment-concentration data derived from samples collected once daily during periods of sustained outflow and more frequently during periods of major outflow. The frequency of sample collection is believed adequate to define suspended-sediment concentrations and load values of outflow from the reservoir during the period of this study.

A continuous record of reservoir stage was obtained from operation of a water-stage recorder. The recorder was housed in a 36-inch metal shelter over a 36-inch corrugated-iron pipe stilling well near the center of the dam. (See fig. 4.) Staff gages are on the upstream face of the dam. The initial stage-discharge relationship for outflow was established by discharge measurements. After installation of the second outlet pipe a new rating was established by additional measurements. No attempt was made to gage reservoir inflow.

A DH-48 sediment sampler was used to collect instantaneous depth-integrated sediment samples from a platform constructed above the end of one of the outflow pipes (fig. 4). Only a few inflow samples were collected because of the remoteness of sampling sites and difficulties in collecting representative samples.

Figure 4.--View of reservoir No. 5 looking east along dam.

All samples were analyzed for concentrations and selected samples were analyzed for particle-size distribution.

The concentration of suspended sediment was determined in the laboratory by weighing the sediment-water mixture of each sample and then filtering, drying, and weighing the sediment. Outflow concentration values were plotted to form a continuous temporal concentration graph. Daily increments from the graph were used with water discharge for the same increment to compute daily mean-concentration and daily suspended-sediment discharge. When the sediment-concentration and water discharge changed rapidly daily loads were computed by subdivision of the daily increments into smaller increments. For days on which no samples were collected, daily loads were computed from an estimated concentration graph.

The particle size of suspended sediment was determined in precent of dry weight by combination of the sieve and bottom-withdrawal-tube methods. The sand fraction, that which is coarser than 0.062 mm (millimeter) was determined by wet sieving. The silt and clay fractions, particles finer than 0.062 mm were defined by the bottom-withdrawal method using a dispersing agent in a distilled-water settling medium. A few determinations were made by using native water as a settling medium. However, the results obtained by this method are shown but not used in defining particle-size distribution.

Precipitation data were obtained from records obtained from a standard recording rain gage located approximately one-half mile south of the reservoir. (See fig. 1.)

Original records of precipitation, streamflow, sediment, and chemical-quality data, used in this report, are maintained on file in the Oklahoma District Office of the U.S. Geological Survey.

Records of daily water discharge were published in annual State reports, "Water Resources Data for Oklahoma, Part 1, Surface Water Reccords" and also in a 5-year water-supply paper series published by the Geological Survey.

Most records of chemical-quality data were published in annual State reports, "Water Resources Data for Oklahoma, Part 2, Water Quality Records" and also in an annual water-supply paper series.

Records of suspended-sediment data used in this report are unpublished.

The first outflow from the reservoir occurred on March 29, 1955. Summaries of water discharge are shown in tables 5 and 6. Table 5 shows a prolonged drought that resulted in no outflow from the reservoir from July 1955 to March 1957. Immediately following this drought a period of well-above-normal runoff occurred during April through June 1957. The water discharged during this 4-month period exceeded the total discharge for other water years with the exception of the 1960 water year which had the greatest water discharge during the period of this study.

Table 5 also shows that about one-half of total yearly outflow (53 percent during this study) occurs from March through June. The percentage of outflow during this 4-month period is higher than the percentage of precipitation (table 2) that falls during the same period. The higher outflow to precipitation ratio is most likely the result of greater local runoff during high-intensity storms that pass through the area in the spring and early summer months.

From March 1955 to September 1969, there were 2,133 days of outflow represented by 60 separate continuous outflow periods as shown in table 7. The number of outflow days is 37 percent of total days of reservoir operation during this period. During these 60 outflow periods about 14,800 acre-feet (116.1 inches) of water was discharged; this amount was about 24 percent of the total precipitation (490.8 inches) falling on the watershed. The relatively low percentage of discharge is indicative of the very large quantity of water lost to evaporation and transpiration. Since the Dewey and Nellie Bly Formations are virtually impermeable, only a very small amount of water may be lost by ground-water runoff. During this study, approximately 47,000 acre-feet of water entering the watershed was expended by these processes.

Water loss by evaporation at Hulah Reservoir, approximately 28 miles northwest of reservoir No. 5, probably closely approximates the loss by evaporation at reservoir No. 5. Pan-evaporation data, collected at Hulah Reservoir during the same period of this study, indicates a loss by evaporation at an average rate of 5.80 inches per month. However, because of incomplete data, the average surface area of reservoir No. 5 during this study is not known and the loss by evaporation from the reservoir pool could not be determined.

FLUVIAL SEDIMENT

Fluvial sediment is of two classes, bedload and suspended load. Bedload is sediment that moves close to the stream bed and stays in almost continuous contact with the bed of the stream. Suspended sediment is that part of the fluvial sediment held in suspension. The fluvial sediment discussed in this report is mostly suspended sediment in inflow and entirely suspended sediment in outflow waters.

Sediment Yield

Sediment yield is defined as the quantity of sediment derived from a drainage area and is generally expressed in tons per unit area or tons per unit of runoff. There was no apparent temporal trend in average sediment yield with respect to runoff over the period of this study as shown in table 8. The amount of sediment trapped in the reservoir must be considered if an expression of sediment yield per unit area is desired.

Surveys by the Soil Conservation Service show that 19,930 tons of sediment were deposited in reservoir No. 5 during the period of record, while the total suspended sediment discharged from the reservoir was 1,443 tons. Thus, a total of 21,370 tons of sediment was removed by runoff from the land surface of the watershed during the period of record. The average annual sediment yield from subwatershed No. 5 was computed to be 609 tons per square mile, or 0.95 ton per acre.

Table 9 shows that the suspended sediment discharged from the reservoir during the 1957 and 1960 water years accounted for 46 percent of the total suspended sediment outflow from the reservoir. The largest monthly sediment outflow was 16 percent (233.7 tons) of the total during October 1959. Assuming that sediment outflow is proportional to sediment inflow to the reservoir, table 9 also shows that the largest sediment yield can be expected during March through June. An average of 63 percent of the sediment discharge and 53 percent of the water discharge occurred during this 4-month period. (See tables 5 and 8.)

The summary of water and sediment discharge for each continuous outflow period in table 7 shows that periods of continuous outflow occurred on numerous occasions during this study. The longest period of no outflow was from June 29, 1955, to April 19, 1957. The four periods of greatest continuous discharge occurred over a combined total of 718 days, or 34 percent of the total outflow days. The periods of major discharge and sediment yield occurred during April 19 to July 17, 1957; September 25, 1959, to April 11, 1960; August 12, 1961, to May 9, 1962; and January 10 to June 4, 1968. During these four periods, 59 percent of the total sediment and 55 percent of the total water discharge was released through reservoir No. 5.

The particle-size data from analysis of inflow and outflow water samples collected during this study are shown in table 10. The particle-size distribution pattern indicates that the suspended sediment transported into reservoir No. 5 was predominantly silt- and clay-sized particles and that sand-sized particles comprise a comparatively small percent of the total sediment. The particle-size distribution of suspended sediment transported out of reservoir No. 5 averaged 4 percent sand, 25 percent silt, and 71 percent clay. These percentages were computed only from the standardized conditions of the chemically dispersed settling method of analysis shown in table 10.

The predominance of silt and clay in inflow water is a reflection of the texture of the surficial soils exposed to erosion by overland runoff. Table 1 shows that soil types nearest the land surface are mostly comprised of silt and clay. However, any soil type having loam in its name could have as much as 20 percent sand (Flint, R. F., written commun., 1972), but it appears that the sandy type soils are least prevalent and generally deeper and less exposed to surface runoff.

Sediment Deposition

As shown by table 4, reservoir No. 5 had a sediment-pool capacity of 747.38 acre-feet in February 1955, 734.29 acre-feet in April 1964, and 730.53 acre-feet in 1969. Therefore, in a period of 14.7 years, the total amount of sediment deposited was 16.85 acre-feet, or 19,930 tons based on an average dry weight of 54.3 pounds per cubic feet as shown in table 11. Seventy-eight percent of the total sediment load was deposited in the reservoir during the first 9.2 years of this study, between February 1955 and April 1964, or approximately 63 percent of the time of reservoir operation; and approximately 22 percent was deposited during the remaining 5.5 years of this study.

Trap Efficiency of Reservoir No. 5

The trap efficiency of a reservoir is principally dependent upon the character of sediment, the chemical character of the impounded water, the detention storage time, and the shape of the reservoir. 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. The measure of trap efficiency of reservoir No. 5 is computed from the weight of sediment outflow and the computed weight of sediment deposited.

The equation used for the determination of the trap efficiency of the reservoir is

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

where

TE = trap efficiency of the reservoir

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

B = weight of sediment discharged from reservoir (tons)

The trap efficiency of reservoir No. 5 was 93 percent for the 14.7-year period covered by this report.

CONCLUSIONS

The following conclusions were reached after compilation and analysis of data collected during the 14.7 years of this study.

1. Rainfall records for the period of this study are good. The mean annual rainfall for subwatershed No. 5 of 33.65 inches, recorded during the study, is comparable to that recorded by the National Weather Service in nearby Bartlesville.
2. Most precipitation falling on the watershed does not flow through reservoir No. 5. Approximately three-fourths (47,000 acre-feet) was lost by evaporation, transpiration, and a small amount was lost by deep percolation (ground-water runoff).
3. The chemical quality of the water in reservoir No. 5 indicates that the water has many useful purposes, including effects on improving trap efficiency of sediments.
4. The highest percent of runoff and sediment yield occurs from March through June. During this study, 53 percent of the water discharged and 63 percent of the sediment yield occurred during this 4-month period. This period of high runoff and high-sediment yield is most likely the result of greater local runoff from high-intensity thunderstorms during the spring and early summer months.
5. Fifty-nine percent of the total sediment load was discharged from the reservoir during four major outflow periods representing 34 percent of total outflow days.
6. The total outflow occurred during 37 percent of the time of reservoir operation.

7. Sediment yield from 1955 to 1969 has no apparent increasing or decreasing trend.

8. A total of 21,370 tons of fluvial sediment was transported into and a total of 19,930 tons was deposited in reservoir No. 5. Seventy-eight percent of the total fluvial sediment was deposited during the first 9.2 years, or 63 percent of time of reservoir operation.

9. The average annual yield of suspended sediment from subwatershed No. 5 was 607 tons per square mile, or 0.95 ton per acre.

10. The suspended sediment transported into reservoir No. 5 was mostly silt and clay and a comparatively small percent was sand size. The average particle-size distribution of sediment carried by outflow water was 4 percent sand, 25 percent silt, and 71 percent clay.

11. Reservoir No. 5 was effective in trapping silt and clay particles. The computed trap efficiency of reservoir No. 5 was 93 percent.

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Table 1.--Soil associations, major soil series and general description of soils in subwatershed No. 5.

Soil Association	Soil Types	Percentage (1)	USDA Texture Classification	Depth (inches)
Summit-Sogn	Sogn	33	Silty clay loam	0-8
			Limestone	8
	Summit	21	Silty clay loam	0-16
			Clay	
Collinsville-Eram-Bates	Collinsville	19	Loam	0-6
			Sandy Loam	6-10
			Sandstone	10
	Eram	7	Clay loam	0-9
			Clay	9-22
	Bates	6	Fine sandy loam	0-12
			Sandy clay loam	12-34
			Sandstone	34
Other	Alluvial land	11	Properties variable	--

(1) Does not include reservoir No. 5 (2 percent) and oil-waste land and small ponds (1 percent).

Table 2.--Monthly and yearly precipitation, in inches, at reservoir No. 5.

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total	Percent of Total
1955	--	--	--	--	--	--	2.95	5.30	3.11	.86	4.03	1.41	17.66	4
1956	3.05	.20	..10	.38	.78	1.42	2.53	3.64	3.06	.92	.72	.55	17.35	4
1957	2.10	2.00	1.91	.58	1.72	2.37	8.20	11.59	10.70	.93	1.58	4.50	48.18	10
1958	1.99	3.13	1.15	.84	.43	4.31	1.31	2.59	2.00	3.67	4.28	2.36	28.06	6
1959	.23	3.15	.17	.58	1.92	3.12	1.50	3.97	2.26	9.26	.05	22.24	48.45	10
1960	10.94	.65	3.05	.90	1.70	.46	2.89	7.75	1.47	4.26	2.72	.65	37.44	8
1961	5.65	.49	1.97	.75	.90	2.18	1.20	6.63	4.55	8.34	9.92	10.12	52.70	11
1962	2.26	3.45	1.74	.55	.87	2.28	2.51	1.00	5.40	2.13	3.13	10.08	35.40	7
1963	2.34	1.55	.35	1.03	0	3.17	.91	2.83	1.35	2.41	3.80	1.07	20.81	4
1964	.83	1.58	.32	.40	1.67	2.25	5.65	3.94	8.22	.61	8.03	2.56	36.06	7
1965	.93	4.11	1.06	1.35	.68	.68	4.15	5.93	2.55	1.70	6.48	5.40	35.02	7
1966	0	.20	3.20	.15	1.43	.80	2.12	2.06	1.77	1.98	3.05	4.24	21.90	4
1967	.69	.16	1.00	1.12	.57	1.55	4.46	3.00	4.07	5.10	.25	4.56	27.43	5
1968	3.90	.68	1.14	2.03	.45	4.90	4.95	2.50	2.13	.75	2.95	.75	27.13	5
1969	3.50	5.95	.90	1.42	1.13	2.00	2.30	2.38	11.18	.50	1.50	4.43	37.19	8
Period Total	38.41	27.30	18.06	12.08	14.25	31.49	47.63	66.01	63.82	43.42	52.49	75.82	490.78	
Percent of Total	8	6	4	2	3	6	10	13	13	9	11	15		100

Table 3.--Chemical analyses of water from reservoir No. 5, 1955-69.

Constituent	Chemical analysis in mg/l except as indicated			
	Maximum	Minimum	Median	No. of Analysis
Calcium (Ca)...............................	61	23	46	28
Magnesium (Mg).............................	6.7	1.8	4.5	28
Sodium + potassium (as Na)..................	35	4.5	26	23
Bicarbonate (HCO_3)...........................	190	24	119	33
Carbonate (CO_3)............................	8	0	0	32
Chloride (Cl)...............................	68	6.3	20	22
Dissolved solids (R.O.E. at 180°C).........	366	140	320	19
Hardness as $CaCO_3$..........................	178	70	146	33
Non-Carbonate hardness as $CaCO_3$............	60	2	21	18
Sodium-adsorption-ratio (SAR)..............	1.2	.2	.6	11
Specific conductance (micromhos/cm at 25°C.)	540	169	341	34
pH (units).................................	8.9	7.0	7.6	33

Table 4.--Summary of stage, area and capacity of reservoir No. 5.

(From surveys by Soil Conservation Service)

Elevation (ft. msl)	1955 Survey Area (acres)	1955 Survey Capacity (ac-ft.)	1964 Survey Area (acres)	1964 Survey Capacity (ac-ft.)	1969 Survey Area (acres)	1969 Survey Capacity (ac-ft.)
	684.52 1/		685.9 1/		686.2 1/	
686	1.50	0.74	0.07	0.02	0	0
688	3.27	5.39	2.41	2.54	2.10	1.90
690	5.20	13.78	4.45	9.29	4.04	7.94
692	7.14	26.07	6.24	19.93	5.90	17.82
694	8.60	41.79	7.97	34.10	7.71	31.38
696	9.94	60.32	9.23	51.29	9.24	48.30
698	11.64	81.88	11.12	71.61	11.11	68.62
700	13.43	106.93	13.05	95.76	13.13	92.84
702.5 2/	17.00	144.88	16.91	133.11	17.07	130.49
704	21.10	173.40	20.85	161.38	20.96	158.96
706	26.60	220.99	26.50	208.62	26.45	206.26
708	32.56	280.05	32.35	267.38	32.17	264.78
710	38.70	351.22	38.57	338.21	38.62	335.48
712	45.78	435.60	45.80	422.48	45.63	419.64
714	52.72	534.02	52.71	520.91	52.65	517.84
716	62.01	648.63	62.02	635.52	61.80	632.16
717.5 3/	69.74	747.38	69.74	734.29	69.44	730.53

1/ Elevation of low point in reservoir.
2/ Elevation of conservation pool - Principal spillway.
3/ Elevation of flood pool - Emergency spillway.

Table 5.--Monthly and yearly water discharge, reservoir No. 5.

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total	Percent of Total
						Water discharge, in cfs days								
1955	--	--	--	--	--	2.0	40.5	80.3	9.9	0	0	0	132.7	2
1956	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1957	0	0	0	0	0	0	134.4	363.5	478.3	266.6	0	0	1242.8	17
1958	0	0	0	0	4.3	217.0	57.7	8.8	0	0	0	0	287.8	4
1959	0	0	0	0	0	33.2	25.4	19.3	4.1	122.7	3.0	20.6	228.3	3
1960	709.4	80.8	110.0	57.6	59.8	76.6	82.1	179.7	19.6	0	0	0	1375.6	18
1961	0	0	0	0	14.2	27.1	35.4	194.6	53.2	76.0	315.6	349.0	1065.1	14
1962	75.6	128.3	99.6	48.5	23.1	78.7	59.7	3.4	29.3	0	0	141.3	687.5	9
1963	20.2	27.4	24.7	44.3	12.3	54.5	10.5	1.4	0	0	0	0	195.3	3
1964	0	0	0	0	0	0	57.7	0	51.2	5.4	27.1	5.2	146.6	2
1965	0	49.1	40.0	49.2	26.8	16.9	159.3	109.2	2.5	0	0	53.8	506.8	7
1966	0	0	0	3.1	3.1	12.0	9.4	40.0	1.0	0	0	15.3	83.9	1
1967	0	0	0	0	0	0	102.2	14.4	6.1	53.3	1.5	.4	178.1	2
1968	17.9	46.9	11.6	63.9	44.6	185.0	273.8	14.4	.1	0	0	0	658.2	9
1969	0	42.6	45.1	61.3	34.4	126.6	62.3	12.6	279.4	11.9	0	0	676.2	9
Period total	823.1	375.1	331.0	327.9	222.6	829.6	1110.0	1041.6	934.7	535.9	347.2	585.6	7464.9	
Percent of total	11	5	4	4	3	11	15	14	13	7	5	8		100

Table 6.--Reservoir discharge, reservoir No. 5.

Period	Reservoir discharge in acre-feet
April - Sept. 1955-------	263.21
1956 water year----------	0
1957 water year----------	2,465.09
1958 water year----------	570.85
1959 water year----------	452.83
1960 water year----------	2,728.50
1961 water year----------	2,112.62
1962 water year----------	1,363.66
1963 water year----------	387.38
1964 water year----------	290.78
1965 water year----------	1,005.24
1966 water year----------	166.42
1967 water year----------	353.26
1968 water year----------	1,305.54
1969 water year----------	1,341.24
Total	14,806.62

Table 7.--Summary of outflow from reservoir No. 5.

Outflow period	Total days (a)	Discharge		Sediment discharge	Discharge-weighted suspended-sediment concentration (mg/l)
		Cfs-days	Acre-feet	Tons	
Apr. 1-20, 1955	20	38.8	77.0	3.4	32
Apr. 28-29, 1955	2	1.7	3.4	.2	44
May 9-18, 1955	10	5.3	10.5	.2	14
May 20-June 9, 1955	21	77.9	154.5	10.6	50
June 14-16, 1955	3	.8	1.6	(b)	18
June 18, 1955	1	.1	.2	(b)	42
June 22-29, 1955	3	6.1	12.1	1.0	61
1956 No outflow	0	0	0	0	0
Apr. 19-July 27, 1957	100	1242.8	2465.0	250.7	75
Feb. 6-May 13, 1958	97	248.0	563.3	42.7	56
May 15-16, 1958	2	.2	.4	(b)	74
May 23-27, 1958	5	3.6	7.1	.5	51
March 25-May 1, 1959	38	58.9	116.8	18.0	113
May 6-June 13, 1959	39	23.4	46.4	4.4	70
July 15-Aug. 6, 1959	23	125.7	249.3	10.7	32
Sept. 25, 1959-Apr. 11, 1960	200	1118.1	2217.7	301.5	100
Apr. 13-June 16, 1960	65	278.1	551.6	103.2	137
Feb. 8-March 9, 1961	30	17.3	34.3	1.2	26
March 15, 1961	1	.1	.2	(b)	37
March 17-Apr. 24, 1961	39	59.2	117.4	6.1	38
Apr. 30-May 30, 1961	31	194.7	386.2	51.9	99

Table 7.--Summary of outflow from reservoir No. 5.--Continued.

Outflow period	Total days (a)	Discharge		Sediment discharge	Discharge-weighted suspended-sediment concentration (mg/l)
		Cfs-days	Acre-feet	Tons	
June 2-26, 1961	25	53.2	105.5	10.5	73
July 14-Aug. 1, 1961	19	76.0	150.7	4.5	22
Aug. 12, 1961-May 9, 1962	271	1181.4	2343.3	166.3	52
June 9-15, 1962	7	29.3	58.1	8.2	104
Sept. 9-Oct. 14, 1962	36	149.5	296.5	18.6	46
Oct. 18, 1962-Feb. 26, 1963	134	120.7	239.4	8.8	27
March 1-Apr. 15, 1963	46	65.0	128.9	16.1	92
May 16-19, 1963	4	1.4	2.8	.2	53
April 4-13, 1964	10	41.4	82.1	11.2	100
April 16-23, 1964	8	16.3	32.3	2.5	57
June 14-19, 1964	6	44.8	88.8	14.5	120
June 30-July 3, 1964	4	11	21.8	.8	25
Aug. 28-Sept. 1, 1964	5	27.3	54.1	3.9	53
Sept. 5-7, 1964	3	5.0	9.9	.2	15
Nov. 16, 1964-May 1, 1965	167	341.4	677.2	56.3	61
May 8-June 8, 1965	32	111.0	220.2	11.3	38
June 22-25, 1965	4	.6	1.2	(b)	6
Sept. 21-27, 1965	7	53.8	106.7	11.7	80
Jan. 1-8, 1966	8	1.5	3.0	(b)	10
Jan. 15-28, 1966	14	1.6	3.2	(b)	2
Feb. 6-16, 1966	11	1.2	2.4	(b)	6
Feb. 27-March 22, 1966	24	13.9	27.6	.8	21

Table 7.--Summary of outflow from reservoir No. 5.--Continued.

Outflow period	Total days (a)	Discharge		Sediment discharge	Discharge-weighted suspended-sediment concentration (mg/l)
		Cfs-days	Acre-feet	Tons	
March 29-April 1, 1966	4	.1	.2	(b)	37
April 23-June 1, 1966	40	49.4	96.0	3.0	22
June 8-10, 1966	3	1.0	2.0	.1	37
Sept. 2-7, 1966	6	15.3	30.3	.7	17
April 12-May 11, 1967	30	107.4	213.0	68.4	236
May 14-26, 1967	13	8.9	17.6	.4	17
May 29-June 3, 1967	6	.6	1.2	(b)	18
June 11-12, 1967	2	(c)	(d)	(b)	17
June 25-July 12, 1967	18	15.1	30.0	.7	18
July 16-22, 1967	7	2.7	5.4	.1	14
July 25-Aug. 7, 1967	14	43.0	85.3	.6	5
Sept. 27-30, 1967	4	.4	.8	(b)	28
Oct. 15-24, 1967	10	8.8	17.4	.3	13
Oct. 29-Dec. 26, 1967	59	67.6	134.1	3.0	16
Jan. 10-June 4, 1968	147	581.9	1154.2	138.2	88
Nov. 15-24, 1968	10	18.3	36.3	3.3	67
Nov. 26, 1968-May 22, 1969	178	366.6	727.1	43.6	44
June 1-July 9, 1969	39	291.4	577.9	26.8	34
Totals	2133	7463.4	14,799.5	1443.1	--

(a) Excludes days of zero flow or essentially zero flow.
(b) Less than 0.1 ton.
(c) Less than 0.1 cfs.
(d) Less than 0.1 acre-foot.

Table 8.--Suspended-sediment discharge, reservoir No. 5.

Period	Tons of sediment discharged per acre-foot of water discharged from reservoir
April - Sept. 1955---	.058
1956 water year-----	0
1957 water year-----	.102
1958 water year-----	.076
1959 water year-----	.076
1960 water year-----	.148
1961 water year-----	.070
1962 water year-----	.087
1963 water year-----	.066
1964 water year-----	.114
1965 water year-----	.079
1966 water year-----	.029
1967 water year-----	.199
1968 water year-----	.109
1969 water year-----	.055
April 1955 to September 1969	.097

Table 9.--Monthly and yearly sediment discharge, reservoir No. 5.

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total tons	Percent of total
						Sediment discharge in tons								
1955	--	--	--	--	--	0	3.5	10.4	1.5	0	0	0	15.4	1
1956	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1957	0	0	0	0	0	0	29.5	85.9	112.4	22.9	0	0	250.7	18
1958	0	0	0	0	1.0	25.5	14.8	2.0	0	0	0	0	43.3	3
1959	0	0	0	0	0	13.0	5.0	3.3	1.1	10.6	.1	1.2	34.3	2
1960	233.7	9.3	13.8	12.9	12.8	15.8	27.4	71.1	6.7	0	0	0	403.5	28
1961	0	0	0	0	1.0	2.3	4.0	51.9	10.5	4.5	42.4	31.1	147.7	10
1962	11.3	10.9	12.2	5.4	3.1	33.5	15.8	.7	8.2	0	0	18.2	119.3	8
1963	1.3	1.1	1.0	4.0	1.8	12.4	3.7	.2	0	0	0	0	25.5	2
1964	0	0	0	0	0	0	13.7	0	14.8	.5	3.9	.2	33.1	2
1965	0	1.9	2.4	2.3	.9	.7	48.1	11.2	.2	0	0	11.7	79.4	6
1966	0	0	0	(a)	(a)	.9	.2	2.8	.1	0	0	.7	4.8	(b)
1967	0	0	0	0	0	0	68.2	.6	.3	1.0	(a)	(a)	70.2	5
1968	1.3	2.0	.6	9.4	3.3	53.9	70.6	1.1	0	0	0	0	142.2	10
1969	0	7.1	4.4	3.1	3.3	22.0	6.1	.9	26.0	.8	0	0	73.7	5
Total tons	247.6	32.3	34.4	37.2	27.2	180.0	310.6	242.1	181.8	40.3	46.4	63.1	1443.1	
Percent of total	17	2	2	3	2	12	22	17	13	3	3	4	--	100

(a) Less than 0.05 ton.
(b) Less than 1 percent.

Table 10.--**Particle-size analyses of suspended sediment, reservoir No. 5.**

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

Date of Collection	Time (24 hrs)	Discharge (cfs)	Suspended sediment: Sediment concentration (mg/l)	Suspended sediment: Percent finer than size indicated, in millimeters: 0.002	0.004	0.008	0.016	0.031	0.062	0.125	0.250	0.500	Methods of analysis
1955													
							Inflow						
May 20	0905	a	276	68	72	73	85	92	97	100	--	--	BWC
20	0910	a	281	36	--	77	92	96	98	100	--	--	BN
20	1745	a	141	31	49	54	77	92	100	--	--	--	BWC
20	1745	a	97	--	27	30	75	92	100	--	--	--	BN
							Outflow						
May 22	b	10	50	71	82	91	94	96	100	--	--	--	BWC
May 23	1745	9.8	191	47	66	84	94	99	100	--	--	--	BWC
23	1745	9.8	135	--	21	29	64	92	100	--	--	--	BN
May 26	1345	7.7	105	59	72	76	81	88	97	100	--	--	BWC
May 28	1630	8.3	66	61	79	87	90	98	100	--	--	--	BWC
1957													
April 19	0815	10.2	156	47	55	58	72	82	92	98	100		SBNM
19	0900	11.0	634	25	47	88	98	99	100	--	--		SBWCM
19	1315	11.2	576	73	85	90	94	96	98	99	100	--	SBWCM
19	1315	11.2	558	56	82	93	98	99	--	100	--	--	SBNM
April 21	0830	11.5	109	--	--	--	--	96	97	98	99	100	SBWCM
April 23	0815	11.6	51	--	--	--	--	96	97	99	--	100	SBNM
May 16	1715	11.0	401	73	85	96	97	98	100	--	--	--	SWCM
May 16	0600	11.2	388	53	70	94	98	100	--	--	--	--	BNM
May 18	0845	11.5	131	--	--	--	--	98	99	100	--	--	SBWCM
May 18	0930	11.5	128	88	96	99	--	100	--	--	--	--	BNM
May 21	0330	12.0	105	82	90	94	99	100	--	--	--	--	BWCM
May 21	0415	12.0	123	73	--	95	99	100	--	--	--	--	BNM
June 12	0730	545	439	45	54	60	69	76	82	94	95	96	SBWCM
June 23	1030	131	914	32	39	46	51	52	79	94	98	99	SBWCM
June 23	1100	154	202	66	80	90	94	95	100	-	-		DWCM

a-Inflow during 24 hour period - 25.9 acre-feet.
b-Composite of 2-4 bottle samples.

Table 11.--Summary of sedimentation in reservoir No. 5.

(Survey Data From Soil Conservation Service)

Date of Survey	Period (years)	Capacity (Acre-ft.)	Sediment Deposition		
			Total to Date		Average Dry weight
			Acre-ft	Tons	(lb per cu. ft.)
February 1955	0	747.38	--	--	--
April 1964	9.2	734.29	13.09	15,480	54.3 (1)
September 1969	5.5	730.53	16.85	19,930	54.3 (2)

(1) Average of 20 samples collected January 1965.
(2) Average of 14 samples collected September 1969.