SEDIMENT DEPOSITION RATES IN THREE SMALL NORTH MISSISSIPPI RESERVOIRS

by

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INTRODUCTION

When the hilly uplands of the upper Coastal Plains in northern Mississippi were cleared for agriculture the land eroded severely. By 1950, erosion had become so widespread that many fields had been abandoned and left to heal naturally or to erode unabated. Extensive gullies developed in many areas where erosion cut through the loessial deposits into highly erosive, underlying Coastal Plains sands. Woodburn (1949) estimated that one-third of the 294,000-acre Little Tallahatchie watershed had been damaged by gullies.

In the late 1940's, the USDA Soil Conservation Service began an extensive erosion-flood control program in the Yazoo-Little Tallahatchie River basins. One conservation measure employed was to construct reservoirs on small upland streams to retard runoff of flood waters and to trap sediment below severely eroding drainage basins. This paper gives information on sediment deposition rates and amounts in three of these structures.

Description and Methods

The reservoirs selected for this study were constructed in 1953. All have earth-fill dams. Drop-inlet pipe spillways were installed at some elevation below an emergency spillway. Reservoir volume below the pipe spillway elevation is the conservation (or sediment) pool, and storage between the pipe and emergency spillways is called the flood pool. Normally, small reservoirs of this type are designed so that the pipe spillway will empty a full flood pool in 1 to 5 days, thus providing flood water control. Storage is provided in the conservation pool for the estimated sediment volume that will accumulate in the 50- or 100-yr design life of the structure.

Some physical characteristics of the reservoirs studied are given in Table 1. Smith and Murphy reservoirs are located adjacent to each other in Marshall County, and their drainage basins have a common boundary on one side. Watershed soils, derived from wind-deposited loess, are primarily Loring (series) and Providence (series) silt loams with moderate-to-steep slopes. Powerline reservoir, located in Lafayette County, has predominately Providence and Lexington silt loams with steep slopes. Extensive gulleying has occurred in this watershed. Gully slopes are primarily Coastal Plains sands, varying from consolidated to extremely friable.

The three reservoirs are similar in size, capacity, and depth, but differ in shape (Table 1). The approximate mean slope of the drainage basins was determined from land use surveys. Approximate slopes were determined for individual parcels of land, and these values were then area-weighted to determine the average watershed slope.

Volumetric surveys were made on all of the reservoirs soon after construction was completed in 1953. Subsequent surveys were made periodically to determine the volume and location of sediment deposits. Deposits were sampled to determine their specific weight or bulk density.

Land-use surveys were made in the Powerline drainage basin in 1954 and in Smith and Murphy basins in 1957 (Table 2). Subsequent surveys in all three basins in 1968 revealed significant land-use changes. Most of the cultivated, pasture, and idle land in Powerline had been converted to forest by 1968. Additional land was being cultivated in Smith and Murphy, and the area in active sediment producing gullies had been reduced in all three watersheds by establishing pine trees and other native vegetation. Estimated erosion rates for the three watersheds were computed using the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1965) and the 2 inches per year (in/yr) gully erosion rate derived by Woodburn, 1949.

Results and Discussion

Computed erosion rates decreased between 1954-57 and 1968 in all three watersheds (Table 2). The large decrease in erosion rates for Powerline is attributed to gully healing and the cessation of cultivation in the watershed. Smaller decreases in Smith and Murphy are attributed to gully healing and improved vegetative cover on idle land. No doubt, annual erosion rates varied as the cultivated acreage varied from year to year in Smith and Murphy watersheds. Recent cursory observations in the watersheds indicated that gross erosion rates are probably less now, 1976, than they were in 1968.

Sediment deposition data for the three reservoirs are summarized in Table 3. For the 22-yr record period, the volume of sediment deposited ranged from 11.9 acre-feet (ac-ft) for Murphy, the smallest structure, to 22.1 ac-ft for Powerline, the largest. On a drainage area basis, deposition rates were more nearly equal, ranging from 2.57 acre-feet per year per square mile (ac-ft/yr/mi^2) of drainage for Murphy to 1.98 ac-ft/ yr/mi^2 for Powerline.

Sediment accumulation rates were highest in all of the reservoirs during the years immediately after construction, reflecting the highly erosive condition of the watersheds at that time. As conservation practices were applied and non-cultivated land healed naturally, sediment deposition decreased, as shown by subsequent surveys in 1959, 1960, 1963, 1967, and 1975. The small increase in deposition rates in Powerline between 1967 and 1976 was caused by the development of a small residential subdivision along the outer boundary of the watershed. Huge quantities of sediment eroded from the construction site before it was stabilized, and some of this sediment eventually reached the reservoir.

Computed erosion rates of 32.4, 24.3, and 56.3 tons per acre per year (t/ac/yr), for Murphy, Smith, and Powerline, respectively, were assumed to represent the erosion potential of the watersheds when the reservoirs were constructed (Table 2). These values were used to compute the total weight of eroded material in each watershed for the period between the first and second surveys. For subsequent periods, erosion rates determined during the 1968 land-use surveys (Table 2) were used to compute watershed erosion. Weights of computed erosion and reservoir deposits for the various time periods are given in Table 4. The column headed "proportion deposited" gives the percentage of the computed erosion deposited in the reservoirs.

The proportion of computed erosion deposited in Smith and Murphy reservoirs was much greater than that for Powerline. This is probably due to unusually high computed erosion rates for the hilly forest areas in Powerline watershed. The USLE predicted abnormally high erosion rates for the relatively steep slopes in this watershed, even though forest cover was generally good. Measured erosion rates from comparable small forest watersheds in the vicinity were small in comparison (Ursic and Dendy, 1963).

The proportion of computed erosion deposited in the reservoirs decreased with reservoir age, probably because: (1) as gullies healed and vegetative cover on pasture, idle, and forest land improved, actual erosion was much less than computed erosion and (2) delta deposits, where streams enter the reservoirs, frequently caused upstream flooding resulting in sediment deposition upstream above the emergency spillway elevation.

Sediment deposits significantly reduced the storage capacity in all of the reservoirs. Average annual storage loss rates for the 22-year record period were 0.87, 1.08, and 1.08% of original capacity for Murphy, Smith, and Powerline, respectively. Storage loss with time for both the sediment pool and the total reservoir is shown graphically in Figure 1. While initial losses were relatively high, ranging from 2.3 to 2.9% during the first few years after construction, recent loss rates were less than 1% in all reservoirs. And, in spite of varying intermediate loss rates during the 22-yr period, the total capacity loss was roughly the same in all three reservoirs, ranging from 19.3 to 24.6%. Storage losses in the sediment pools were also about the same, ranging from 41 to 43%.

The useful life of these reservoirs will probably exceed the 50-yr design life. At the most recent sediment deposition rates (Table 3), 0.31, 0.62, and 0.38 ac.-ft./yr. for Murphy, Smith, and Powerline, respectively, an additional 10 to 35 years will be required before the volume of sediment deposits equals the sediment pool volume. And future sediment accumulation rates will probably decrease more as vegetative cover improves on non-cultivated land. Gullies, initially a major sediment source in all watersheds, are healing quite rapidly as pine trees and other native vegetation become established. In 1974, only about 0.7 ac of active gullies remained in Murphy and Smith watersheds.

Sediment deposits in the reservoirs (Table 3) do not necessarily represent watershed sediment yields--some sediment flowed through the reservoirs and some was deposited above the emergency spillway elevation. Reservoir sediment trap efficiency studies indicated that 75 to 90% of inflowing sediments are trapped in reservoirs of this type (Dendy, 1974; Brune 1953). Channel ranges, extending about 1200 ft. upstream from Powerline emergency spillway elevation, showed nearly 3 acre-feet of sediment deposits within the original flow line of the channel. Extensive additional deposits were observed, but not measured, in the stream valley several thousand feet further upstream.

Summary and Conclusions

Sediment deposition rates in three small sediment detention reservoirs were studied for a 22-yr period. Reservoir capacities ranged from 62 to 90 ac-ft and drainage areas from 133 to 312 acres.

These structures have quite effectively trapped sediment below highly erosive drainage basins in the hilly uplands of the upper Coastal Plains in northern Mississippi. Sediment deposition rates decreased with reservoir age, ranging from an initial mean rate of 2.0 ac-ft/yr to about 0.4 ac-ft/yr.

Estimated watershed erosion, computed with the USLE, also decreased with reservoir age, due largely to natural healing of gullies and improved vegetative cover on other major sediment sources. The proportion of eroded material deposited in the reservoirs varied widely between reservoirs and with time, ranging from 8 to 61%. For the 22-yr record period, the proportion deposited was less variable ranging from 16 to 31%. Assuming comparable sediment trap efficiencies for the three reservoirs, this variability suggest large inaccuracies in the computed erosion rates and/or highly variable watershed sediment delivery rates.

Sediment deposits have reduced the storage capacity of all the reservoirs. The proportion of total storage capacity filled with sediment was roughly the same for all three structures, ranging from 19.3 to 24.6% of original capacity. Initial losses of 2.3 to 2.9% annually have been reduced to less than 1% by decreasing watershed sediment yields.

The useful life of these reservoirs will probably exceed their 50-yr design life unless there are extensive land use changes in the watersheds. Their utility for flood control will not be seriously impaired until sediment deposits exceed the sediment pool volume. At present sediment accumulation rates, an additional 10 to 35 years will be required before deposits exceed sediment pool volume, and the reservoirs will continue to function as effective sediment traps until their total capacity is filled with sediment.

Acknowledgement

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Table 1.--Reservoir characteristics

	Murphy	Smith	Powerline
Reservoir Capacity (ac-ft)			
At Emergency Spillway Elev.	61.8	70.1	90.0
Sediment Pool	22.7	22.7	30.5
Surface Area (ac)			
At Emergency Spillway Elev.	7.50	10.03	13.58
Sediment Pool	4.57	4.62	6.0
Maximum Reservoir Depth (ft)			
At Emergency Spillway Elev.	16.3	19.6	21.05
Sediment Pool	11.7	12.8	15.05
Maximum Reservoir Length (ft)[1/]			
At Emergency Spillway Elev.	1510	2300	2000
Sediment Pool	1100	1800	1250
Maximum Reservoir Width (ft)			
At Emergency Spillway Elev.	1300	800	750
Sediment Pool	1170	700	550
Drainage Area (ac)	133.0	218.0	312.0
Approximate Mean Slope of Drainage Area (%)	8.0	8.8	15.0

1/ Approximate distances measured along thalweg

Table 2.--Land use and estimated erosion rates in reservoir drainage basins

Land use or cover class	Murphy			Smith			Powerline		
	Area	Erosion		Area	Erosion		Area	Erosion	
	(ac)	(t/ac/yr)	(t/yr)	(ac)	(t/ac/yr)	(t/yr)	(ac)	(t/ac/yr)	(t/yr)
	1957 Survey			1957 Survey			1954 Survey		
Cultivated	4.8	45.3	217	16.8	39.5	664	19.1	80.6	1539
Idle	87.8	23.2	2037	178.1	15.2	2707	85.5	4.5	385
Pasture	33.7	1.3	45	3.1	2.0	6	0	0	0
Forest	0	0	0	13.8	5.1	70	162.1	12.6	2042
Gullies	6.7	300.0	2010	6.2	300.0	1860	45.3	300.0	13590
Total	133.0	32.4	4308	218.0	24.3	5307	312.0	56.3	17556
	1968 Survey			1968 Survey			1968 Survey		
Cultivated	22.0	42.7	939	72.5	37.5	2719	0	0	0
Idle	54.0	10.3	556	104.2	2.6	271	7.7	0.1	1
Pasture	52.7	1.7	90	0	0	0	14.2	1.5	21
Forest	0	0	0	38.3	1.7	65	277.5	14.3	3968
Gullies	4.3	300.0	1290	3.0	300.0	900	12.6	300.0	3780
Total	133.0	21.6	2875	218.0	18.4	3955	312.0	24.9	7770

Table 3.--Summary of reservoir sediment deposition data

Date of survey (mo-yr)	Period of record (yr)	Sediment deposits: Sediment pool Total (ac-ft)	Sediment pool Per year (ac-ft)	To emergency spillway elevation Total (ac-ft)	To emergency spillway elevation Per year (ac-ft)
		Murphy Reservoir			
11-53	original survey				
5-56	2.5	2.96	1.18	3.54	1.42
9-59	3.3	1.88	.57	2.12	.64
11-63	4.2	2.07	.49	2.46	.59
12-75	12.1	2.43	.20	3.80	.31
Total	22.1	9.34	.42 1/	11.92	.54 1/
		Smith Reservoir			
11-53	original survey				
5-56	2.5	3.85	1.54	4.70	1.88
9-59	3.3	1.02	.31	2.13	.65
11-63	4.2	1.24	.30	2.40	.57
12-75	12.1	3.22	.27	7.46	.62
Total	22.1	9.33	.42 1/	16.69	.76 1/
		Powerline Reservoir			
4-53	original survey				
10-58	5.5	9.20	1.67	14.47	2.63
6-60	1.7	1.27	.75	3.07	1.81
8-62	2.2	.67	.30	.50	.23
9-67	5.0	.19	.04	.91	.18
1-76	8.4	1.84	.22	3.17	.38
Total	22.8	13.17	.58 1/	22.12	.97 1/

1/ Average per year for total period of record

Table 4.--Summary of computed erosion, reservoir sediment deposits, and proportion of computed erosion deposited in the reservoirs

Dates		Murphy			Smith			Powerline		
From mo. yr.	To mo. yr.	Computed erosion (tons)	Reservoir deposits 1/ (tons)	Proportion deposited (%)	Computed erosion (tons)	Reservoir deposits 2/ (tons)	Proportion deposited (%)	Computed erosion (tons)	Reservoirs deposits 3/ (tons)	Proportion deposited (%)
11-53	5-56	10,773	5,937	55	13,244	8,087	61	--	--	--
4-53	10-58	--	--	--	--	--	--	96,611	23,637	24
5-56	11-63	21,546	7,681	36	30,084	7,794	26	--	--	--
10-58	9-67	--	--	--	--	--	--	69,142	7,318	11
11-63	12-75	34,761	6,373	18	48,536	12,836	26	--	--	--
9-67	1-76							65,258	5,178	8
Total		67,080	19,991	30	91,864	28,717	31	231,011	36,133	16

1/ Average specific weight of deposits = 1.23 grams per cubic centimeter
2/ Average specific weight of deposits = 1.26 grams per cubic centimeter
3/ Average specific weight of deposits = 1.20 grams per cubic centimeter

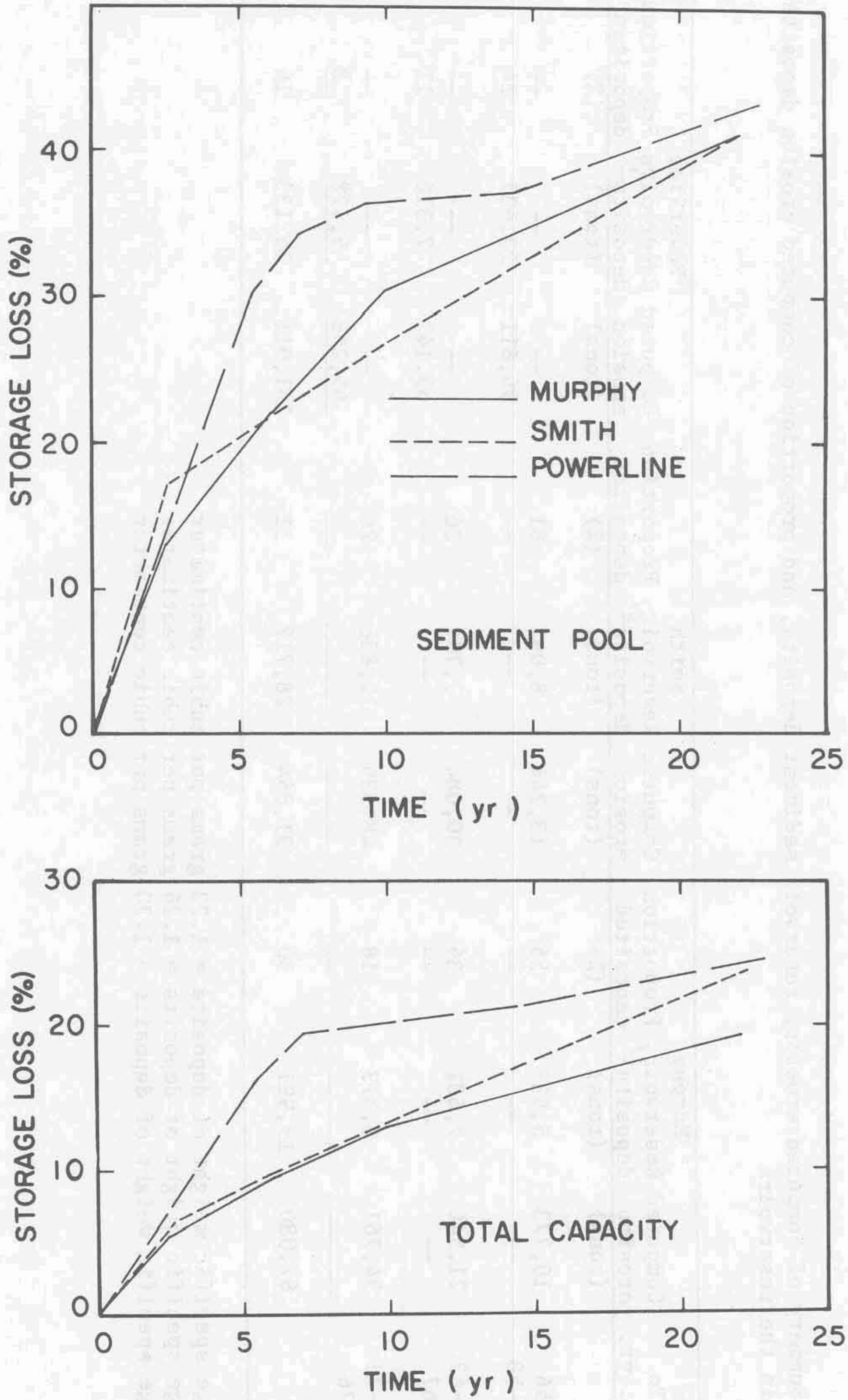

FIGURE 1 - RESERVOIR STORAGE LOSS WITH TIME