Sediment-Trap Efficiency of a Multiple-Purpose Impoundment, North Branch Rock Creek Basin, Montgomery County, Maryland, 1968–76

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 2071

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By W. J. HERB

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To convert inch-pound unit	*Multiply by*	*To obtain metric units*
Inch (in.)	25.4	Millimeter (mm)
Foot (ft)	0.3048	Meter (m)
Acre	0.4047	Hectare (ha)
Square mile (mi^2)	2.590	Square kilometer (km^2)
Cubic foot (ft^3)	0.02832	Cubic meter (m^3)
Acre-foot (acre-ft)	1234	Cubic meter (m^3)
Cubic foot per second-day (ft^3/s-d)	2447	Cubic meter (m^3)
Ton	0.9072	Megagram (Mg)
Cubic foot per second (ft^3/s)	0.02832	Cubic meter per second (m^3/s)
Pound per cubic foot (lb/ft^3)	16.02	Kilogram per cubic meter (kg/m^3)
Cubic foot per second per square mile [(ft^3/s)/mi^2]	0.01093	Cubic meter per second per square kilometer [(m^3/s)/km^2]
Ton per acre	2.242	Megagram per hectare (Mg/ha)
Ton per square mile (ton/mi^2)	0.3503	Megagram per square kilometer (Mg/km^2)
Ton per acre per inch [(ton/acre)/in.]	0.0883	Megagram per hectare per millimeter [(Mg/ha)/mm]

SEDIMENT-TRAP EFFICIENCY OF A MULTIPLE-PURPOSE IMPOUNDMENT, NORTH BRANCH ROCK CREEK BASIN, MONTGOMERY COUNTY, MARYLAND, 1968-76

By William J. Herb

ABSTRACT

Lake Bernard Frank, a multiple-purpose reservoir in Montgomery County, Md., impounds runoff and sediment from 12.5 square miles of the upper North Branch Rock Creek basin. Sediment-trap efficiency was studied by the U.S. Geological Survey between 1967 and 1976.

Suspended-sediment inflow to the impoundment for unmeasured storm periods in 1968-76 was estimated from daily suspended-sediment transport curves. Bedload contribution was estimated by the Schoklitsch and Meyer-Peter and Muller bedload-transport equations. The sediment contribution for the 1.76-square-mile ungaged part of the basin was estimated from land use and land cover determinations derived from aerial photographs taken annually and land use and land cover sediment-yield relations.

The impoundment attenuated both streamflow peaks and instantaneous sediment loads. An instantaneous streamflow peak on North Branch Rock Creek was measured at 207 cubic feet per second per square mile above the impoundment, but, for the same storm, the peak downstream from the impoundment was only 7.0 cubic feet per second per square mile. For one storm, the maximum instantaneous suspended-sediment load was measured at 4,880 tons per day on North Branch Rock Creek upstream from the impoundment, while the maximum instantaneous suspended-sediment load below the reservoir was 33 tons per day.

Discharge-weighted percentages of sand, silt, and clay averaged 16, 50, and 34 for locations upstream from the impoundment and were zero, 16, and 84 below the reservoir.

From 1968 through 1976, about 136,000 tons of sediment was estimated to have entered the impoundment. Over the same years, 5,910 tons of sediment was measured to have left the impoundment. The measured trap efficiency was 96 percent, which closely agrees with the trap efficiency computed from the impoundment's capacity-inflow ratio.

INTRODUCTION

In the early 1960's, two Public Law 566 structures sponsored by the Montgomery Soil Conservation District, Maryland-National Capital Park and Planning Commission, and Montgomery

County were constructed in the Upper Rock Creek watershed. The purposes served by these structures were flood control, sediment reduction, fish and wildlife development, and recreation (Montgomery County and others, 1962). One structure is on Rock Creek, and the second structure, impounding Lake Bernard Frank, is on the North Branch Rock Creek just upstream from its confluence with Rock Creek.

The U.S. Geological Survey, in cooperation with the U.S. Soil Conservation Service, began investigations of streamflow and sedimentation in the North Branch Rock Creek basin (fig. 1), Montgomery County, Md., in September 1967. The investigation was part of a national effort to determine the sediment-trap efficiency of floodwater-retarding structures. Daily streamflow and suspended-sediment data were collected immediately downstream from Lake Frank at the North Branch Rock Creek near Rockville gaging station (01647740) (fig. 1). Daily streamflow and storm-period suspended-sediment data were collected at two upstream gaging stations in conjunction with a separate, but concurrent, research project in the same basin. Upstream data were collected for the 9.73 mi^2 North Branch Rock Creek near Norbeck basin (station 01647720) and the 1.01 mi^2 Manor Run near Norbeck basin (station 01647725) (fig. 1).

The investigation was designed to measure suspended-sediment loads leaving the impoundment and to collect the data necessary to estimate sediment inflow to the impoundment accurately.

The period of recorded data available at each of the streamflow and recording-precipitation gaging stations is given in table 1. Additional data were collected on the particle-size distribution of fluvial sediments, land use and land cover, and storm precipitation distribution.

Similar investigations of trap efficiency have been made in Colorado (Mundorff, 1968), Kentucky (Anttila, 1970), Ohio (Flint, 1972a), and West Virginia (Flint, 1972b). Sedimentation studies have also been made on Loch Raven and Prettyboy Reservoirs in Baltimore County, Md. (Holeman, 1965).

ACKNOWLEDGMENTS

This report was prepared by the U.S. Geological Survey in cooperation with the U.S. Soil Conservation Service. The author expresses his gratitude to the following: G. T. Munkittrick, State Conservationist, U.S. Soil Conservation Service; G. T. Stem, District Conservationist, U.S. Soil Conservation Service; and E. R.

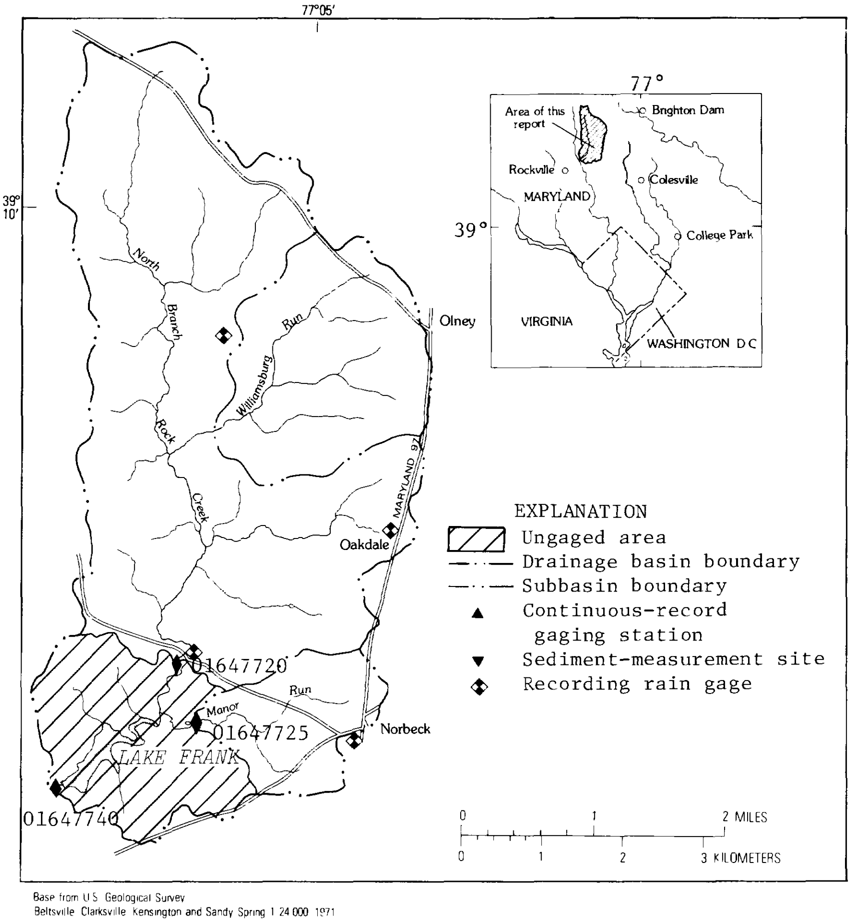


FIGURE 1.—Location of North Branch Rock Creek basin.

Keil, former State Conservationist, U.S. Soil Conservation Service for their encouragement and strong support during the project; and Ronald Dorsey, Maryland-National Capital Park and Planning Commission, for providing insight into the day-to-day operation of Lake Frank and data on flood levels in the impoundment.

BASIN CHARACTERISTICS AFFECTING SEDIMENT YIELDS

The four primary basin characteristics affecting sediment yields in the North Branch Rock Creek basin are climate, geology and soils, physiography and topography, and land use and land cover.

TABLE 1.—*Summary of recorded data at gaging stations in the North Branch Rock Creek basin*

Streamflow and suspended-sediment stations

Station	Station No.	Drainage area (mi^2)	Streamflow		Suspended sediment		Automatic sampling equipment
			Period of record	Type of record	Period of record	Type of record	
North Branch Rock Creek near Norbeck	01647720	9.73	Oct. 1966–Sept. 1976	Daily	Nov. 1966–Sept. 1975	Storm only	Pumping and single stage.
Manor Run near Norbeck	01647725	1.01	Oct. 1966–Sept. 1974	Daily	Nov. 1966–Aug. 1974	Storm only	Single stage.
North Branch Rock Creek near Rockville	01647740	12.5	Aug. 1967–Sept. 1977	Daily	Sept. 1967–Sept. 1977	Daily	Pumping and single stage.

Recording precipitation stations

Station	Station No.	Period of record	Recording frequency
Olney West	01647679	Nov. 1966–Sept. 1974	5-minute punch interval before Oct. 1968, 15-min. thereafter.
Oakdale	01647689	Mar. 1967–Sept. 1974	5-minute punch interval before Oct. 1968, 15-min. thereafter.
Norbeck Northwest	01647719	Dec. 1966–Sept. 1974	15-minute punch interval.
Norbeck	01650419	Nov. 1966–Sept. 1974	5-minute punch interval.

CLIMATE

The climate is rather humid and temperate, with a mean annual temperture of 13°C. Calculations based on the Environmental Data Service 1926-76 record of precipitation at nearby College Park, Md., indicate an average annual precipitation of 42.55 in. Average annual precipitation for water years 1968-76, for stations near the study area, ranges from 43.74 in. at Wheaton Regional Park to 47.02 in. at College Park. Precipitation averaged from four nearby rain gages ranged from 34.61 to 55.76 inches in 1968 and 1972, respectively. The driest month during the study was February 1968, precipitation 0.47 inch, and the wettest was June 1972, precipitation 14.11 inches. Herb and Yorke (1976) found no significant trends in the magnitude of rainstorms during 1968-74.

The long-term average monthly precipitation is highest in August, 4.89 in., and lowest in February, 2.77 in. During the 1968-76 water years, average monthly precipitation was at a minimum in January and at a maximum in June. The June maximum reflects the large amounts of rainfall associated with Hurricane Agnes in 1972. Figure 2 shows the average monthly precipitation at nearby stations during 1968-76. Summer precipitation is generally high-intensity rainfall associated with convective storms, and winter precipitation is generally rainfall from long-duration frontal storms.

Sediment yields are generally highest in the summer, when intense rainfall from convective storms provides sufficient energy for soil erosion. Herb and Yorke (1976) found that rainfall intensity was a statistically significant factor determining sediment yields in urban construction areas. They also found that the amount and intensity of storm runoff, which are closely correlated with the amount and intensity of rainfall, were also significant factors.

GEOLOGY AND SOILS

Soils of the eastern division of the Piedmont plateau are found in the study basin. These soils are developed in materials weathered from igneous and metamorphic rocks. The predominant soils are in the Manor-Chester-Glenelg association, which has a soft micaceous schist as parent material. The soils are primarily silt loams with a mixture of silty clay loams and channery silt loams. The silt loams and silty clay loams have about 30-percent sand or larger particles, and the channery silt loams have about 40-percent sand or larger particles. Most of the upland soils are in the Manor, Chester, Glenelg, Glenville, and Elioak series; and the stream valleys contain Worsham and Wehadkee silt loams.

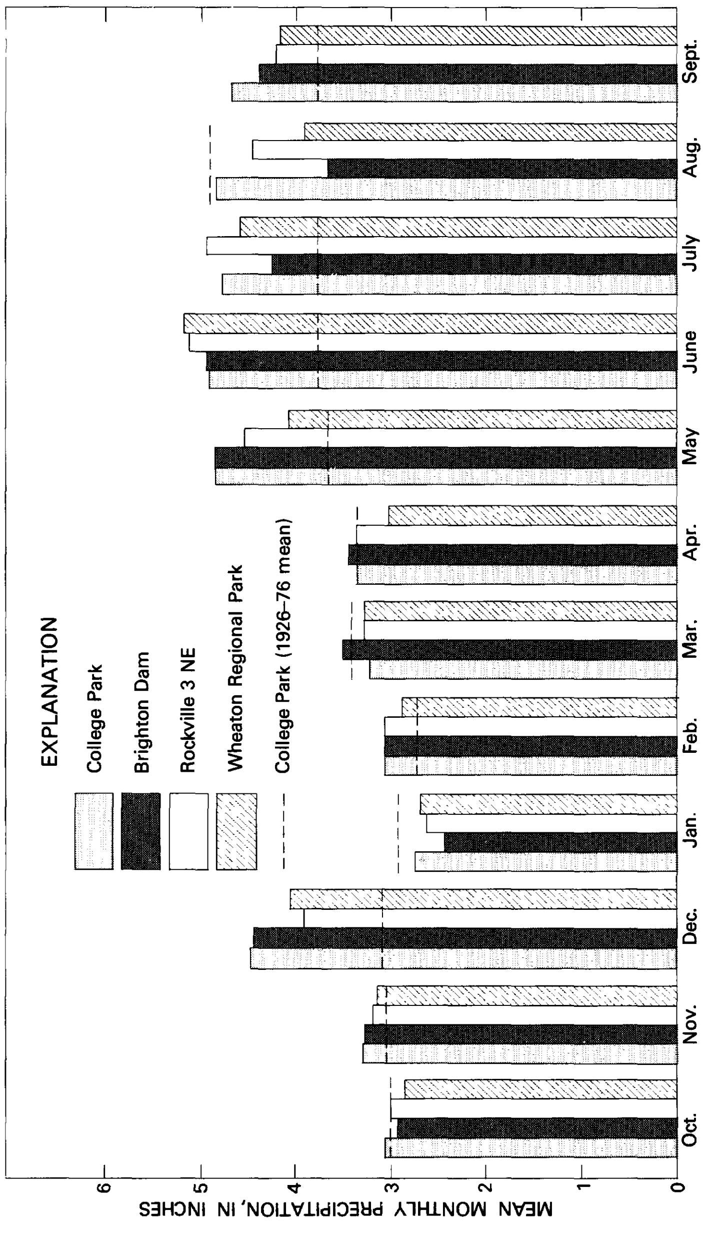


FIGURE 2.—Mean monthly precipitation at locations near the study area, October 1967 to September 1976.

The soils are generally uniform; however, the subsoils in the Manor and Glenville series have a weak structure, which makes them extremely susceptible to erosion when the surface soils are removed during construction (Yorke and Herb, 1978).

PHYSIOGRAPHY AND TOPOGRAPHY

The study area is in the eastern division of the Piedmont physiographic province. Altitudes in the North Branch Rock Creek basin range from about 570 ft in the headwaters of Williamsburg Run to about 270 ft at the North Branch Rock Creek near Rockville gaging station. Slopes of the stream valleys generally range from zero to 3 percent. Areas adjacent to the stream valleys generally have slopes greater than 8 percent and commonly in the 15- to 25-percent range. Slopes farther from the stream valleys are flatter and tend to range from zero to 8 percent near the drainage divides. Yorke and Herb (1978) present a detailed slope map of the North Branch Rock Creek basin and the adjacent Northwest Branch Anacostia River basin.

LAND USE AND LAND COVER

Owing to the fact that Lake Frank is in an urbanizing basin, land use and land cover changed almost continuously during the study period. Yorke and Herb (1978) determined that land use and land cover can be the major factor determining a basin's sediment yield in this area. Mansue and Anderson (1974) show similar results in New Jersey. As part of their study, Yorke and Herb obtained annual aerial photographs of the North Branch Rock Creek basin from 1966 through 1974. These aerial photographs were analyzed for land use and land cover by a dot-grid sampling procedure, and the land use and land cover in the basin was classified into 13 categories under the five general headings of farmland and parks, rural residential, urban residential, public and commercial, and construction. Acreage for each land use and land cover category is listed in table 2 for three subbasins and the total drainage basin of North Branch Rock Creek above the dam at Lake Frank. The three subbasins are North Branch Rock Creek near Norbeck, Manor Run near Norbeck, and the ungaged basin area. Land use and land cover for 1975 and 1976 was interpolated from the 1974 aerial photographs and data from a field inspection in March 1977. Because construction in 1975 and 1976 was minimal, these estimates are considered representative of actual land use and land cover during this period.

Figure 3 illustrates annual changes in three land use and land cover categories during 1968-76. Land use and land cover changes

TABLE 2.—*Land use and land cover, in acres, in the North Branch Rock Creek basin, 1968-76*

Year	Farmland and parks					Rural residential			Urban residential		Public and commercial		
	Crops	Grass	Forest	Water	Impervious	Grass	Forest	Impervious	Grass	Impervious	Grass	Impervious	Construction
North Branch Rock Creek near Norbeck (6,228 acres)													
1968	1789	2063	1560	10	101	281	118	56	72	23	14	15	126
1969	1789	2037	1556	10	102	281	118	56	98	37	27	23	94
1970	1698	2065	1582	11	101	256	113	50	128	49	33	26	116
1971	1543	2105	1588	12	97	264	114	52	184	73	33	26	137
1972	1543	2035	1572	12	98	264	114	52	227	95	33	26	157
1973	1542	1998	1552	12	98	265	114	53	281	120	34	32	127
1974	1534	1992	1545	12	95	275	115	55	352	159	34	31	29
1975[1]	1534	1992	1545	12	95	275	115	55	358	162	34	31	20
1976[1]	1534	1992	1545	12	95	275	115	55	364	165	34	31	11
Manor Run near Norbeck (646 acres)													
1968	12	205	200	0	13	58	30	15	19	5	6	7	76
1969	22	152	182	0	9	50	55	23	39	22	18	12	62
1970	22	134	171	0	9	57	53	25	67	29	19	12	48
1971	22	122	171	0	9	58	53	25	89	31	19	12	35
1972	22	115	171	0	9	58	53	25	102	35	19	12	25
1973	22	119	171	0	9	58	53	25	113	40	19	12	5
1974	22	115	171	0	9	58	53	25	115	41	19	12	6
1975[1]	22	115	171	0	11	58	53	25	115	41	19	12	4
1976[1]	22	115	171	0	13	58	53	25	115	41	19	12	2

TABLE 2.—*Land use and land cover, in acres, in the North Branch Rock Creek basin, 1968-76*—Continued

Year	Farmland and parks					Rural residential			Urban residential		Public and commercial		
	Crops	Grass	Forest	Water	Impervious	Grass	Forest	Impervious	Grass	Impervious	Grass	Impervious	Construction
Ungaged basin area (1,141 acres)													
1968	140	428	284	53	9	0	8	2	75	25	3	1	113
1969	139	389	259	55	9	0	9	2	104	48	4	3	120
1970	136	340	258	55	14	0	4	2	171	65	22	6	68
1971	138	338	258	56	14	0	11	1	190	93	18	6	18
1972	139	322	258	56	15	0	7	1	204	103	17	6	13
1973	139	323	258	56	15	0	7	1	205	103	17	6	11
1974	139	320	258	59	16	1	7	1	204	103	17	5	11
1975[1]	139	320	258	59	16	1	7	1	206	104	17	5	8
1976[1]	139	320	258	59	16	1	7	1	208	106	17	5	4
North Branch Rock Creek near Rockville, Md. (8,015 acres)													
1968	1941	2696	2044	63	123	339	156	73	166	53	23	23	315
1969	1950	2578	1997	65	120	331	182	81	241	107	49	38	276
1970	1856	2539	2011	66	124	313	170	77	366	143	74	44	232
1971	1703	2565	2017	68	120	322	178	78	463	197	70	44	190
1972	1704	2472	2001	68	122	322	174	78	533	233	69	44	195
1973	1703	2440	1981	68	122	323	174	79	599	263	70	50	143
1974	1695	2427	1974	71	120	334	175	81	671	303	70	48	46
1975[1]	1695	2427	1974	71	122	334	175	81	679	307	70	48	32
1976[1]	1695	2427	1974	71	124	334	175	81	687	312	70	48	17

[1]Land use and land cover estimated from 1974 aerial photos and field inspection in March 1977.

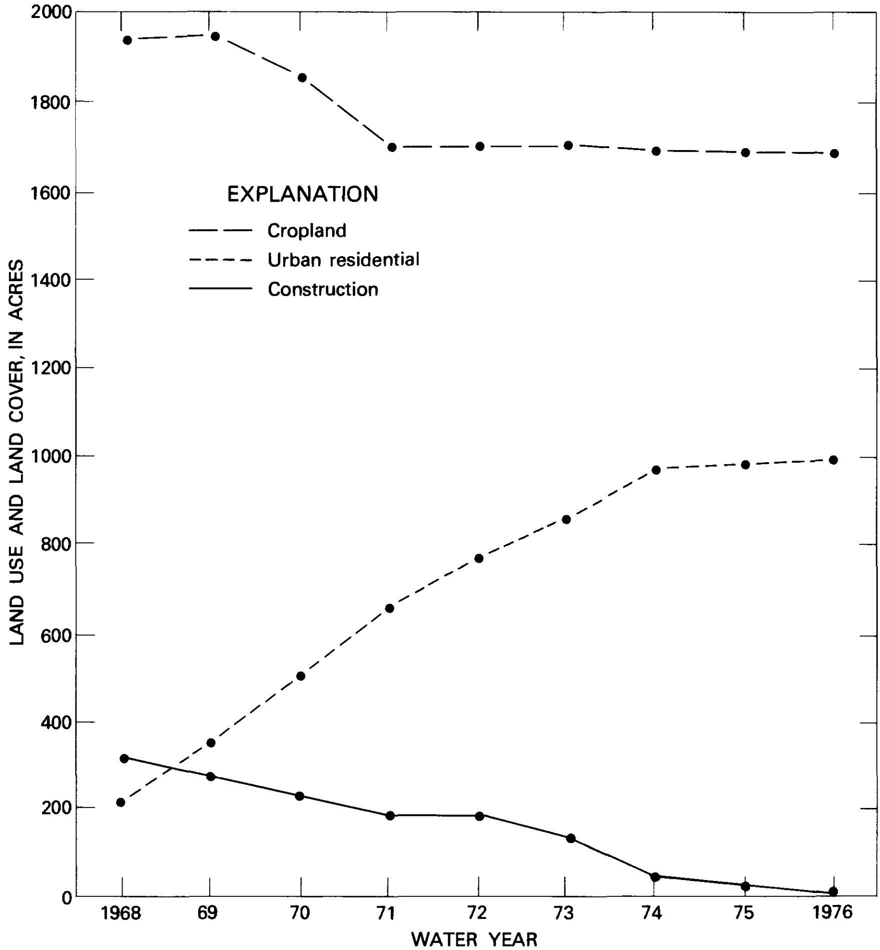


FIGURE 3.—Annual variations in basin land use and land cover, North Branch Rock Creek near Rockville, 1968–76.

during this period were characterized by a decline in cropland and construction area and a dramatic increase in the urban residential area. The percentage of construction in a basin can be a significant factor affecting storm-period suspended-sediment loads (Herb and Yorke, 1976). Even those urban areas without active construction sites provide a source of downstream sediment as stream channels adjust to accommodate an urbanized runoff regime (Yorke and Herb, 1978).

HYDRAULIC STRUCTURE

Lake Bernard Frank is impounded by a rolled-earth dam 576 ft wide and 78 ft high (fig. 4*A*). A grassed emergency spillway, 198 ft wide, at the top-of-dam elevation (fig. 4*B*), brings the total width to 774 ft.

Normal releases of water from the impoundment are through a 24-in. x 30-in. orifice that has a crest elevation of 299.25 ft, in a concrete riser in the lake's pool (fig. 4*C*). A gate-operated 24-in. x 30-in. cold-water release orifice that has a crest elevation of 267.5 ft, and three 24-in.-diameter sluice gates at approximate elevations of 275, 282.5, and 291.5 ft are available for additional releases through the riser. The cold-water-release orifice and sluice gates are normally used only to lower the lake level for maintenance.

The principal spillway is a 42-in.-inside diameter reinforced concrete conduit, which extends 460 ft from the base of the concrete riser to an impact basin (fig. 4*D*) at the downstream face of the dam.

The impoundment is oriented northeast-southwest and is rather sinous, as determined by the area's topography. The permanent pool is 5,700 ft long, and the maximum design high-water pool is 9,400 ft. The impoundment has a design sediment-pool area of 35 acres and a sediment-pool capacity of 261 acre-ft. The permanent-pool area is 56 acres and has a capacity of 780 acre-ft. Floodwater detention at the crest of the emergency spillway is 3,894 acre-ft, for a total capacity of 4,576 acre-ft. Altitude-capacity and altitude-surface area relations for Lake Frank are presented in table 3.

STREAMFLOW

Daily streamflow data were collected at three sites (fig. 1) by standard stream-gaging procedures described by Carter and Davidian (1968). Data were gathered at station 01647740 (fig. 5) immediately downstream from Lake Frank from August 1967 through September 1977. Daily streamflow data were collected at stations 01647720 (fig. 5) and 01647725 (fig. 7) from October 1966 through September 1974, except during October and November 1966, when no data were collected at 01647725.

If the severe storms of June 1972 and September 1975 are excluded, the mean monthly discharge is highest from February to April and lowest in September or October. This distribution of runoff is almost exactly opposite the distribution of precipitation. The difference is probably caused by the differences in potential evapotranspiration between early spring and early fall. If the two large storms are included, mean monthly runoff is lowest in October and highest in June.

Average annual discharge at North Branch Rock Creek near Rockville ranged from 3,152 to 11,886 ft^3/s-d (table 4) and includes the effect of the drought at the beginning of the study and the wetter years near the end of the study.

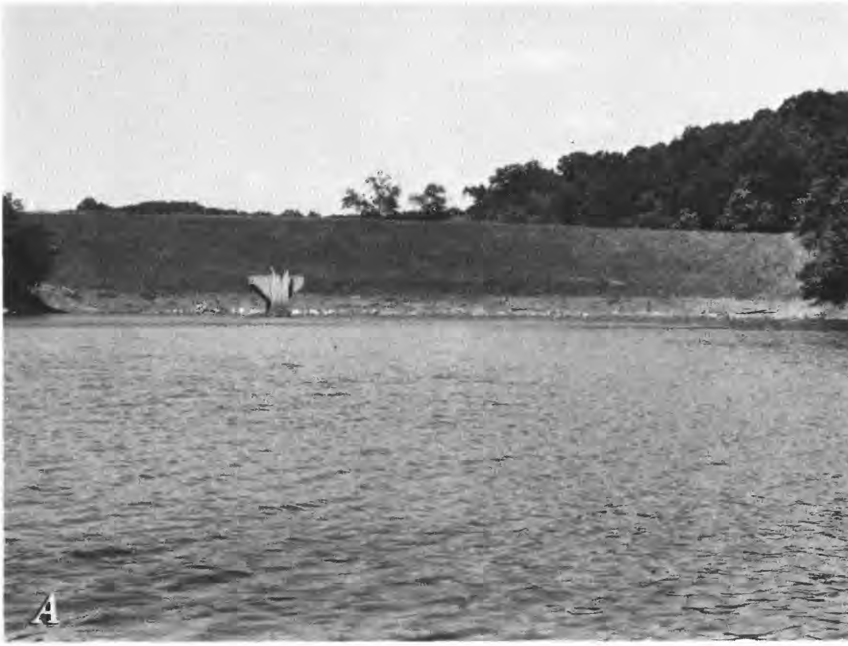


FIGURE 4.—Lake Bernard Frank (*A*) earth-fill dam (view from upstream), left bank), and (*D*) concrete impact

(*B*) emergency spillway (view from upstream), (*C*) concrete riser (view from basin (view from downstream).

TABLE 3.—*Altitude, capacity, and surface-area relationships of Lake Bernard Frank (as designed)*

[Modified from data furnished by Soil Conservation Service]

Altitude (feet above NGVD of 1929)[3]	Approximate capacity (acre-ft)	Approximate surface area (acres)	Altitude (feet above NGVD of 1929)[3]	Approximate capacity (acre-ft)	Approximate surface area (acres)
268	0	0.0	308	1,450	75.0
270	0.7	.7	310	1,598	79.0
272	5.5	2.4	312	1,750	84.0
274	10	4.1	314	1,937	89.0
276	26	6.8	316	2,110	95.0
278	50	12.0	318	2,320	102.0
280	81	19.5	320	2,536	110.0
282	123	25.5	322	2,750	118.0
284	180	30.5	324	3,014	129.0
286	245	34.5	326	3,250	140.0
288	320	39.0	328	3,500	150.0
290	399	43.0	330	3,883	163.0
292	480	46.0	332	4,200	175.0
294	581	49.5	334[2]	4,576	187.0
296	680	53.0	336	4,900	199.0
298[1]	780	56.0	338	5,300	214.0
300	904	60.0	340	5,812	225.0
302	1,020	63.0	342	6,300	240.0
304	1,157	67.0	344	6,772	255.0
306	1,300	71.0			

[1]Normal pool.
[2]Crest of emergency spillway.
[3]National geodetic vertical datum of 1929.

FIGURE 5.—Gaging station (arrow), North Branch Rock Creek near Rockville (view looking downstream from top of dam).

FIGURE 6.—Gaging station, North Branch Rock Creek near Norbeck (view from upstream).

FIGURE 7.—Gaging station, Manor Run near Norbeck (view from upstream).

TABLE 4.—*Annual discharges, in cubic feet per second-days, for gages in the North Branch Rock Creek basin, 1968-76*

Water year	Gaging Stations		
	North Branch Rock Creek near Norbeck	Manor Run near Norbeck	North Branch Rock Creek near Rockville
1968	2,757	361	3,378
1969	2,330	315	3,152
1970	3,646	399	4,954
1971	5,018	571	6,967
1972	8,508	844	11,886
1973	6,320	733	8,160
1974	3,650	397	4,492
1975	5,646	[1]618	7,570
1976	4,294	[1]431	5,382

[1]Estimated by correlation with North Branch Rock Creek near Norbeck.

SEDIMENT

METHODOLOGY

The sediment load of a stream consists of suspended-sediment load and bedload. Suspended load is defined as that part of the load transported while distributed throughout the flowing water by upward components of turbulence or colloidal forces. Bedload consists of sediment that moves by sliding, rolling, or skipping along the steambed; it generally remains in contact with the bed. Standard sediment-sampling equipment samples only that part of the suspended-sediment load in transport more than 0.3 ft above the bed. No direct bedload measurements were attempted.

Concurrent daily streamflow records are available for North Branch Rock Creek near Norbeck and at the outlet of Lake Frank for the 1968-76 water years. Daily streamflow records are available for Manor Run for the 1968-74 water years. The two upstream gages measure inflow to Lake Frank from 86 percent of the contributing drainage area. The mean discharge at the North Branch Rock Creek near Rockville gage was 17.0 ft^3/s, or 12,300 acre-ft per year during 1968-76. Disregarding losses to evaporation and leakage and gains from precipitation on the lake, the mean annual outflow is assumed to be equivalant to the total mean annual inflow to Lake Frank during 1968-76.

Storm-period suspended-sediment loads were determined by collecting samples manually or automatically during storm runoff, determining the concentration in a laboratory, and computing sediment loads by the subdivided-day method (Guy and Norman, 1970; Guy, 1973; Porterfield, 1972).

Peak suspended-sediment concentrations generally preceeded peak water discharges of North Branch Rock Creek near Norbeck. The same pattern was observed on Manor Run for most storms, but there was a slight tendency toward simultaneous concentration and discharge peaks. Anttila and Tobin (1978) believe that advanced concentration peaks reflect a basinwide abundance of sediment readily available for transport. The continuous construction activity in the North Branch Rock Creek basin would provide such a ready source of new sediment.

SEDIMENT INFLOW

SUSPENDED SEDIMENT

Storm-period suspended-sediment loads were determined at the two gaging stations upstream from Lake Frank. Suspended-sediment samples were collected at the Manor Run station with single-stage samplers located at preset flow elevations. These samplers can obtain samples only when the stream stage is rising. The single-stage samples were supplemented with numerous depth-integrated cross-section samples taken by hand to define suspended-sediment concentrations on both rising and falling stages. Single-stage samplers were used at North Branch Rock Creek near Norbeck, but the primary sampling was done by an automatic pumping suspended-sediment sampler, which sampled at preset elevations on rising and falling stages. Depth-integrated cross-section samples were also taken by hand at this site to verify the automatic samplers.

Daily suspended-sediment loads for unmeasured storm days during the partial-record and post-data collection periods were estimated from records of daily discharge and daily suspended-sediment transport curves. A suspended-sediment transport curve relates daily streamflow to daily suspended-sediment load. A series of transport curves was used from 1968 through 1976 because the streamflow-sediment transport relations changed as land use and land cover within the basin changed (Yorke and Herb, 1978). Figures 8 and 9 show suspended-sediment transport curves for North Branch Rock Creek and Manor Run.

Five suspended-sediment transport curves were developed for Manor Run and seven for North Branch Rock Creek near Norbeck. Each curve applies to a period during which land use and land cover was relatively constant. The transport curves were based on data collected during storm runoff that had adequate streamflow and sediment load definition.

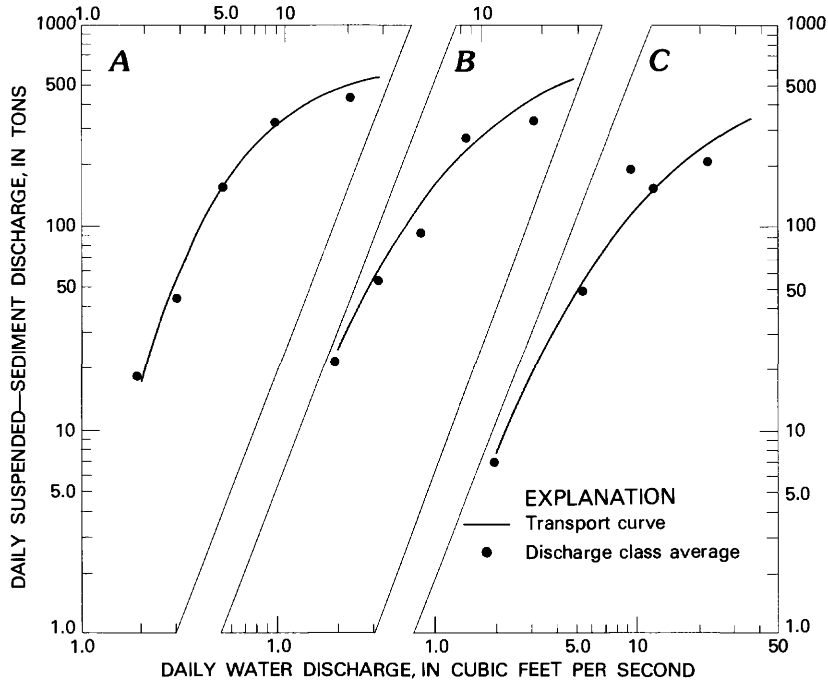
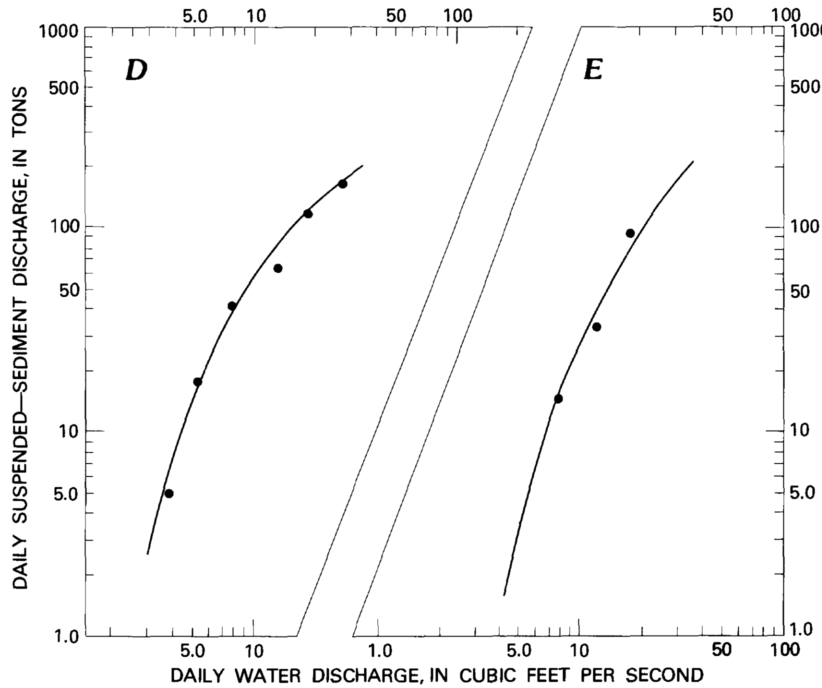


FIGURE 8.—Suspended-sediment transport curves (*A*) Oct. 1967-Sept. 1968, (*B*) 1973-Sept. 1976; Manor

Daily streamflow and sediment-load data collected during the 1973-74 water years were used to develop transport curves for the 1975-76 water years for Manor Run but not for North Branch Rock Creek near Norbeck. There were major changes in land use and cover, primarily due to construction, between the 1973-74 and 1975-76 periods in North Branch Rock Creek basin, but only minimal changes between the two periods in Manor Run basin. Accordingly, streamflow and sediment-load data collected in the 1975 water year were used to develop the 1975-76 transport curve for North Branch Rock Creek.

Owing to the fact that the transport curves were based on storm-day data, suspended-sediment loads were estimated only for storm-runoff days. Storm runoff occurred on 14 percent of the days in Manor Run and North Branch Rock Creek near Norbeck during 1968-76. Yorke and Herb (1978) found that in the adjacent Anacostia River basin, 94 percent of the suspended-sediment load was transported during high runoff. This high runoff occurred during fewer than 6 percent of the days. Therefore, suspended-sediment loads measured or estimated for storm-runoff during 14 percent of the days probably account for at least 95 percent of the



Oct. 1968-Mar. 1970, (*C*) Apr. 1970-Dec. 1970, (*D*) Jan. 1971-Mar. 1973, (*E*) Apr.
Run near Norbeck.

total suspended-sediment load, and are assumed to be representative of the total suspended load.

Days defined as having storm runoff were determined by examining daily streamflow records and choosing those days during which the previous day's discharge was at least doubled. The storm period was considered to continue until the recession in water discharge became fairly constant. This procedure usually resulted in storm periods of 1 or 2 days. As most of the suspended sediment in this area is transported on the rising stage, as indicated by concentration peaks preceding water discharge peaks, total storm suspended-sediment loads should be adequately estimated by this procedure.

Although the daily discharge and sediment-transport curve technique provides adequate estimates of suspended-sediment loads when daily streamflow is known, a modified technique was needed for Manor Run for 1975-76, when no daily discharges were available. The modified technique required estimates of daily discharges for Manor Run followed by the daily discharge and sediment-transport procedures discussed earlier.

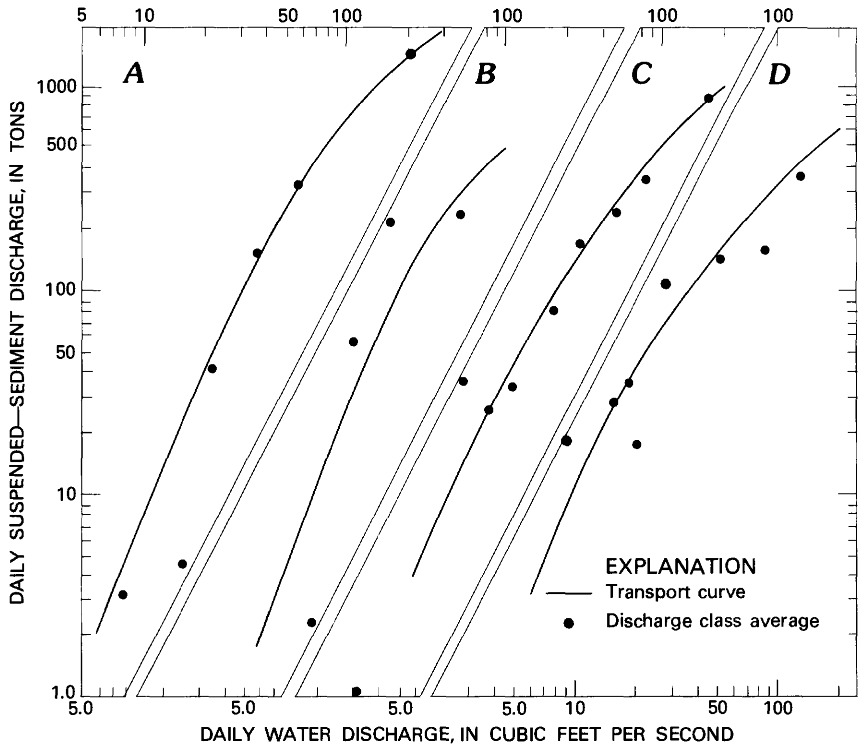


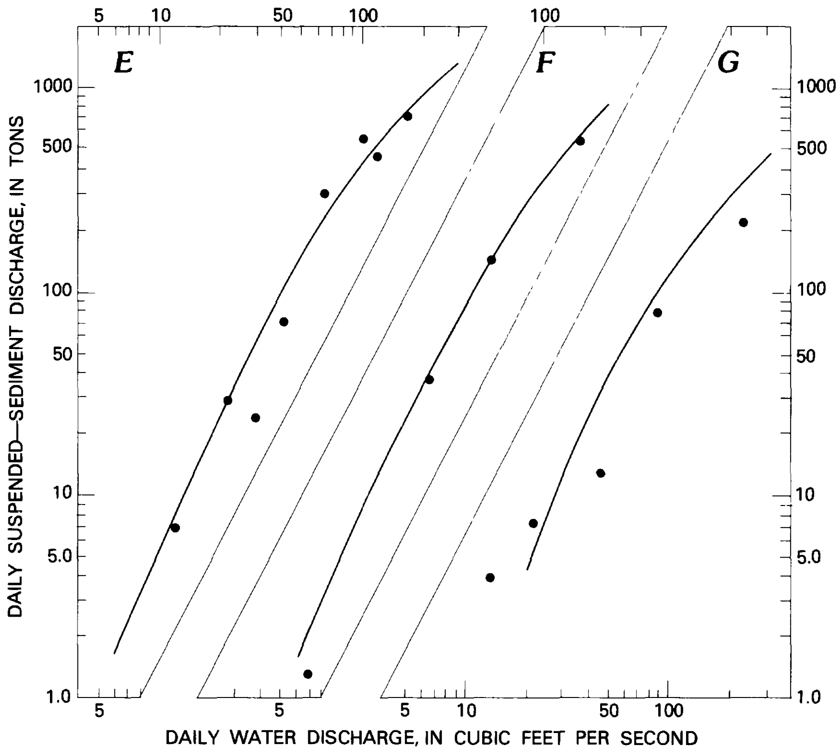
FIGURE 9.—Suspended-sediment transport curves (*A*) Oct. 1967-Mar. 1968, (*B*) Apr. Dec. 1973, (*F*) Jan. 1974-Sept. 1974, (*G*) Oct. 1974-

A regression equation using concurrent daily discharges at North Branch Rock Creek near Norbeck was used to estimate discharges for Manor Run. Discharges on the 1st, 6th, 11th, 16th, 21st, and 26th of each month during the 1973 and 1974 water years, or 144 sets of data, were used to develop the equation. This pseudorandom procedure should provide a data set with no bias toward days with low or high discharges.

An initial, graphical solution indicated that the relation between concurrent daily discharges for Manor Run and North Branch Rock Creek near Norbeck could be described by two straight lines. One line, based on 57 data points, defined the relationship for North Branch Rock Creek daily discharges less than 7.0 ft^3/s. A second line, based on 87 data pairs, defined the relationship for North Branch Rock Creek daily discharges equal to or greater than 7.0 ft^3/s.

The linear regression model used in the analysis was of the form:

$$\log M = b_0 + b_1(\log N)$$



1968-Mar. 1969, (*C*) Apr. 1969-Mar. 1971, (*D*) Apr. 1971-Dec. 1971, (*E*) Jan. 1972-Sept. 1976; North Branch Rock Creek near Norbeck.

where

log M = logarithm (base 10) of Manor Run daily discharge, in cubic feet per second;

log N = logarithm (base 10) of North Branch Rock Creek near Norbeck daily discharge, in cubic feet per second;

b_0 = regression constant; and

b_1 = regression coefficient.

It was found that the logarithmic (base 10) transformation was useful to achieve homoscedasticity, or equal variance about the regression line. The linear regression analysis developed the following equations:

$$\log M = -0.74 + 0.65 (\log N) \quad (1)$$
$$\log M = -1.13 + 1.09 (\log N) \quad (2)$$

Equation 1 applies when the average daily discharge at North

Branch Rock Creek near Norbeck was less than 7.0 ft^3/s, and equation 2 applies when the daily discharge was equal to or greater than 7.0 ft^3/s.

The validity of the regression equations was tested by estimating daily discharges for Manor Run using daily discharges at North Branch Rock Creek for the 1972 water year. The estimated discharges were then compared with those measured on Manor Run. As no 1972 data were used in the regression model calibration, the 1972 synthetic discharges for Manor Run are considered to be an unbiased estimate of an independent data set. Table 5 shows the monthly and yearly totals of the synthetic and measured daily discharges for Manor Run.

Although table 5 indicates that estimates of monthly discharges depart widely from measured monthly discharges, the annual estimate is closer to the measured, due to the compensating nature of the monthly departures. If the month of June, containing data from Hurricane Agnes, is eliminated, the estimated 11-month discharge is 595.1 ft^3/s-d as compared with a measured 11-month total discharge of 608.5 ft^3/s-d. June can be dropped from the comparison because the maximum daily discharge during Hurricane Agnes was more than 15 times greater than the maximum daily discharge used to calibrate the regression model.

As only storm days were used to estimate annual sediment inflows, the relation between estimated and measured discharge was tested on 57 storm days in the 1972 water year. All storm-day discharges were estimated using equation 2 which is applicable for all North Branch Rock Creek daily discharges above 50 percent duration. If the runoff associated with Hurricane Agnes is excluded, the regression equation underestimates the 1972 storm-day discharges by about 15 percent. An error of this magnitude would probably not cause a significant underestimate of the total sediment load. None of the daily discharges of the North Branch Rock Creek near Norbeck in the 1975 and 1976 water years greatly exceeded the range of data used in the regression model calibration, so the estimates of daily discharge for Manor Run are acceptable.

Daily storm suspended-sediment loads for the 1975–76 water years were estimated from the sediment-transport curve by applying the daily water discharges determined from equation 2. Although the daily and monthly estimates may be in error, the yearly totals shown in table 6 are relatively accurate.

TABLE 5.—*Estimated monthly discharge totals for 1972 water year compared to measured monthly discharges for Manor Run near Norbeck*

	Monthly discharge ($ft^3/s\text{-}d$)		Percentage error
	Estimated	Measured	
1971:			
October	62.8	63.2	- 1
November	64.4	67.0	- 4
December	35.1	31.3	+12
1972:			
January	40.0	36.1	×11
February	108	81.1	-25
March	57.0	55.2	+ 3
April	73.1	68.3	+ 7
May	80.6	59.3	+36
June	346	235	+47
July	68.9	83.1	-17
August	19.9	25.6	-22
September	12.2	11.4	+ 7
Total	941.1	843.5	+12

TABLE 6.—*Annual storm suspended-sediment inflows[1] to Lake Bernard Frank from Manor Run and North Branch Rock Creek*

Water year	Storm suspended-sediment inflow, in tons per year	
	Manor Run	North Branch Rock Creek
1968	4,209	3,113
1969	3,454	4,504
1970	3,508	7,302
1971	2,352	9,465
1972	2,408	14,867
1973	1,702	11,062
1974	512	4,354
1975	806	3,986
1976	587	1,830

[1]Measured and estimated.

BEDLOAD

Bedload was not measured directly, but was estimated by empirical equations, as described by Yorke and Herb (1978). Thus, the Meyer-Peter and Muller equation (Sheppard, 1960) and the Schoklitsch equation (Shulits, 1935) were used to compute the bedload. A bed material sample from the channel (fig. 10) and discharge measurements from 19 to 338 ft^3/s for North Branch Rock Creek near Norbeck were used in the computations. Bedload-transport curves determined from the Schoklitsch and Meyer-Peter and Muller formulas were then used with a flow-duration curve to compute average annual bedload transport for North Branch Rock Creek near Norbeck.

Average annual bedloads for 1968–76 of 1,370 tons and 1,290 tons were computed from the Meyer-Peter and Muller and the Schoklitsch equations, respectively. These computed bedloads accounted for 13.7 and 16.1 percent of the total average annual sediment yield for the same period. Yorke and Herb (1978) computed bedloads of 6 and 13 percent for the adjacent Northwest Branch Anacostia River basin. These four estimates of bedload were averaged, giving double weight to the North Branch Rock Creek data, to obtain a bedload contribution of 13 percent of the total load. The 13 percent value was assumed to be applicable to both North Branch Rock Creek and Manor Run. The bedload contribution was combined with the suspended-sediment load estimate for the upstream stations to estimate yearly total sediment inflow to Lake Frank. Bedload from the ungaged area was assumed minimal because most of the area is adjacent to the impoundment and lacks well-defined stream channels.

UNGAGED SEDIMENT YIELD

The gaging stations on Manor Run and North Branch Rock Creek near Norbeck monitored flow and sediment from only 10.74 mi^2 of the 12.5 mi^2 drainage area above station 01647740. Therefore, the sediment contribution of the ungaged 14 percent of the basin was estimated to determine trap efficiency.

Yorke and Herb (1978) estimated average annual sediment yields under different land use and land cover conditions in the Northwest Branch Anacostia River and North Branch Rock Creek basins (table 7).

The land use and land cover categories given in table 6 are generally the same as those in table 2. However, impervious area in the farmland category was assigned to the crop category because most of the impervious area consists of dirt roads and unimproved

FIGURE 10.—Channel of North Branch Rock Creek near Norbeck in vicinity of bed-material sampling point (view from upstream).

TABLE 7.—*Annual suspended-sediment yields for land use and land cover categories for Northwest Branch Anacostia River and North Branch Rock Creek basins (Yorke and Herb, 1978)*

Land use and land cover category	Annual sediment yield (tons/acre)
Forest	0.03
Grass	.2
Crops	2.7
Rural residential	.5
Urban residential	3.75
Public and commercial	0.3
Construction[1]	85.3

[1]Construction-area weighted average yield computed using ungaged subbasin construction area and four sediment yields for the Manor Run basin (Yorke and Herb, 1978).

roadside ditches (Yorke and Herb, 1978). In addition to the sediment yields shown in table 7, the obvious yearly sediment yield of 0 tons per acre per year was used for lake and pond areas.

When the acres in each category of land use and land cover are multiplied by the appropriate annual sediment yield, the annual sediment yields shown in table 8 are obtained.

TABLE 8.—*Annual suspended-sediment yields, in tons, for land use and land cover categories, and total annual sediment yields, in tons, for ungaged portion of North Branch Rock basin, 1968-76*

Water year	Land use and land cover categories								
	Forest	Grass	Crops	Rural residential	Urban residential	Public and commercial	Construction	Water	Total
1968	8.52	85.6	402.3	5.0	375.0	1.2	9638.9	0	10516.52
1969	7.77	77.8	399.6	5.5	570.0	2.1	10236.0	0	11298.77
1970	7.74	68.0	394.2	3.0	885.0	9.6	5800.4	0	7167.94
1971	7.74	67.6	402.3	6.0	1061.3	8.1	1535.4	0	3088.44
1972	7.74	64.4	405.0	4.0	1151.3	8.1	1108.9	0	2749.44
1973	7.74	64.6	405.0	4.0	1155.0	8.1	938.3	0	2582.74
1974	7.74	64.0	405.0	4.5	1151.3	8.1	938.3	0	2578.94
1975	7.74	64.0	405.0	4.5	1162.5	8.1	682.4	0	2334.24
1976	7.74	64.0	405.0	4.5	1177.5	8.1	341.2	0	2008.04

SEDIMENT OUTFLOW

Daily suspended-sediment loads were determined at station 01647740, immediately downstream from Lake Frank (fig. 1). An automatic pumping suspended-sediment sampler took one or more daily samples. The intake orifice for the sampler was mounted on a concrete pier (fig. 11) on the left bank of the outflow channel. The daily automatic samples were supplemented with depth-integrated samples collected by hand on routine visits to the gaging station and during storm runoff. Bedload outflow from Lake Frank was considered to be negligible because the bulk of the material passing through the impoundment is sufficiently fine to be in suspension at the downstream gaging station.

EFFECTS OF IMPOUNDMENT

STORM RUNOFF AND SEDIMENT DISCHARGE

Flood frequency analyses for Manor Run near Norbeck (Yorke and Herb, 1978), 1967-74, show peak discharges of 310, 590, and 990 ft^3/s at exceedance probabilities of 50, 20, and 10 percent, respectively. A flood having an exceedance probability of 50 percent has a 50 percent chance of being exceeded in any given year; other exceedance probabilities are similarly defined. Flood frequency analyses for North Branch Rock Creek near Norbeck, 1967-77, indicate peak discharges of 910; 2,120; and 3,510 ft^3/s at exceedance probabilities of 50, 20, and 10 percent, respectively. Below Lake Frank, the average annual maximum peak for the 1968-76 water years was approximately 150 ft^3/s, and a maximum peak of 420 ft^3/s occurred in 1972.

Examination of upstream and downstream flood peaks on North Branch Rock Creek and Manor Run show that the Lake Frank

FIGURE 11.—Channel of North Branch Rock Creek near Rockville. Intake for automatic pumping suspended-sediment sampler is located on concrete pier (arrow) (view from downstream).

impoundment reduces downstream flood peaks. During May 13-14, 1971, the basin received 2.15 in. of rainfall. This precipitation was evenly distributed across the basin, but the maximum 15-minute intensity was 1.98 in./h (inches per hour) in the Manor Run basin and 1.32 in./h in the North Branch Rock Creek basin near Norbeck. Runoff hydrographs, shown in figure 12 for the upstream and downstream stations, clearly show the effects of the impoundment. The peak discharges, expressed as $(ft^3/s)/mi^2$, of Manor Run and North Branch Rock Creek near Norbeck were 207 and 51.2, respectively. The exceedance probability of such peaks is 95 to 99 percent. Below Lake Frank the peak was measured at 7.0 $(ft^3/s)/mi^2$ during the same runoff.

Another example of the attenuating effect of Lake Frank was observed during Hurricane Agnes. On June 21-22, 1972, 11.25 in. of precipitation from Hurricane Agnes was measured at nearby Wheaton Regional Park (Bailey and others, 1975). Peak discharges of Manor Run and North Branch Rock Creek near Norbeck were 900 $(ft^3/s)/mi^2$ and 1,040 $(ft^3/s)/mi^2$. Below Lake Frank, the peak discharge was 33.6 $(ft^3/s)/mi^2$. The maximum elevation of the water surface reached in the lake during the runoff after Hurricane Agnes was 329 ft (Ronald Dorsey, oral commun., 1978). This is equivalent to 2,850 acre-ft of flood storage.

Lake Frank not only exerts a major effect on flood peaks, but it also significantly affects suspended-sediment loads during storm runoff. Figure 13 is a plot of instantaneous suspended-sediment loads at the three gaging stations in the study area for May 13-14, 1971. Precipitation and streamflow data during this storm are given in the section on streamflow.

Peak instantaneous suspended-sediment loads at the upstream stations were 15,000 tons/d and 4,880 tons/d for Manor Run and North Branch Rock Creek, respectively. During the same two-day event, the maximum instantaneous suspended-sediment load downstream from Lake Frank was 33 tons/d. The total suspended-sediment load measured at Manor Run and North Branch Rock Creek near Norbeck was 991 tons on May 13 and 14; whereas the total measured load below the lake was 31 tons.

During the June 21-23, 1972, period of Hurricane Agnes, a suspended-sediment load of 3,270 tons was measured at North Branch Rock Creek near Norbeck. Downstream from the impoundment, 593 tons of suspended sediment were measured over the same period, and another 332 tons of suspended sediment were measured over the 5 succeeding days.

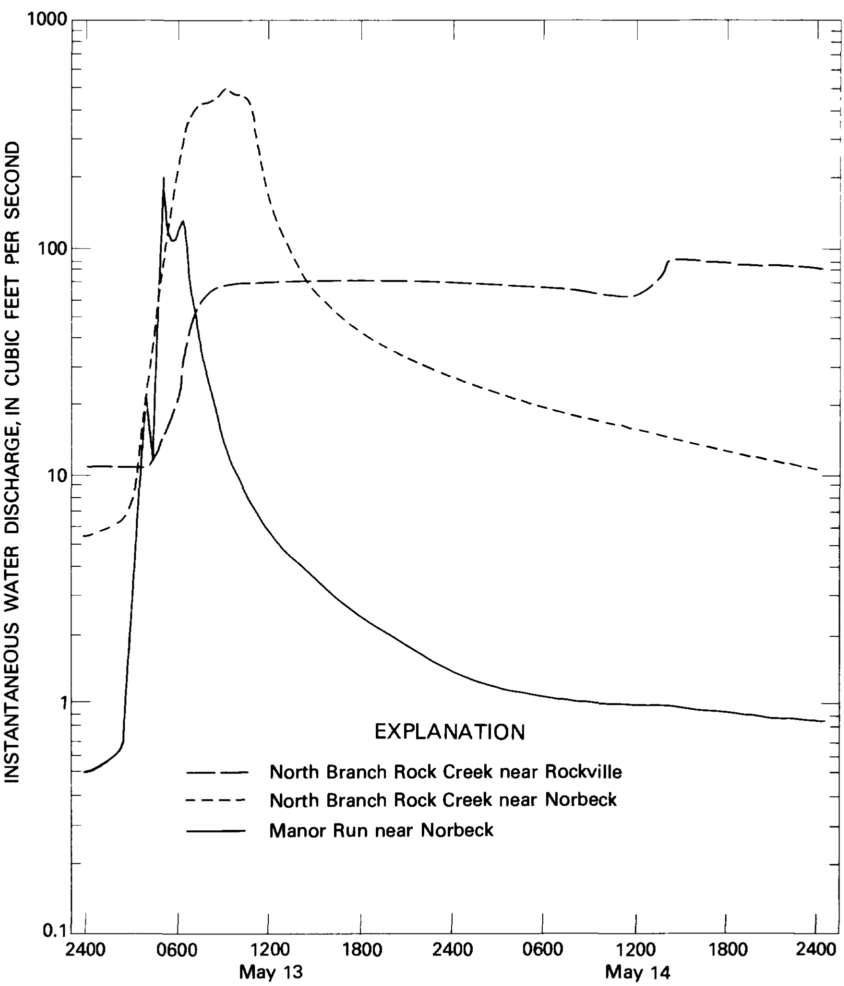


FIGURE 12.—Hydrograph for three locations in the North Branch Rock Creek basin, storm of May 13-14, 1971.

PARTICLE SIZE

Table 9 summarizes the results of particle-size analyses of suspended-sediment samples taken at the three sediment-monitoring stations in the North Branch Rock Creek basin. Sediment discharge-weighted percentages of sand-sized particles were 13 and 19 at the upstream stations and zero at the station below the impoundment. Silt percentages were 45 and 54 upstream

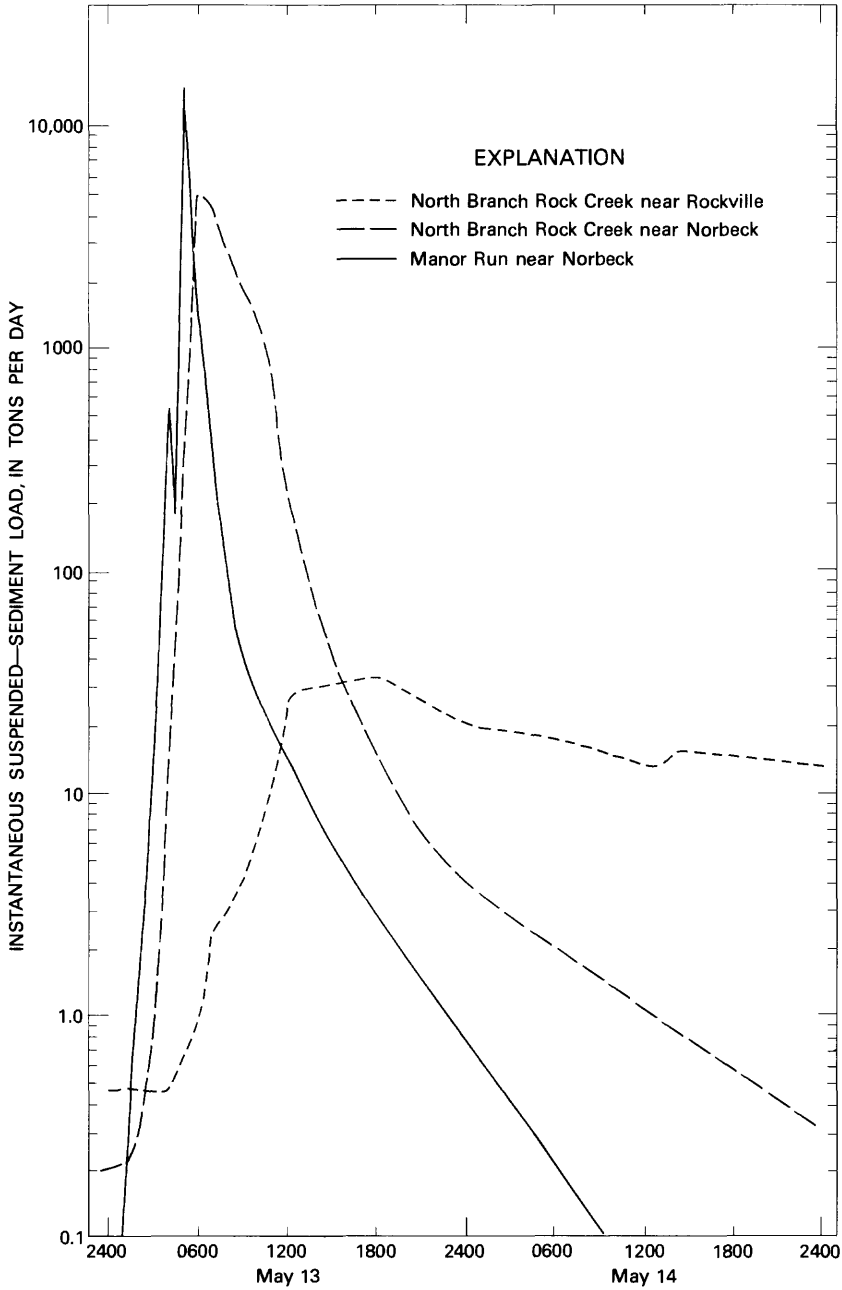


FIGURE 13.—Instantaneous suspended-sediment load for storm of May 13-14, 1971.

TABLE 9.—*Particle-size distribution of suspended sediment in the North Branch Rock Creek basin*

Date	Water discharge (ft^3/s)	Suspended-sediment concentration (mg/L)	Suspended-sediment discharge (tons/d)	Percent suspended sediment in size class: Sand	Silt	Clay
North Branch Rock Creek near Norbeck, Md. 1969-75						
June 18, 1969	90	4,090	994	5	58	37
Apr. 2, 1970	143	2,840	1,100	12	56	32
Feb. 2, 1973	342	2,400	2,220	13	54	33
Apr. 4, 1973	380	1,460	1,500	23	46	31
June 2, 1974	151	344	140	3	50	47
Sept. 24, 1975	194	464	243	4	62	34
Sediment discharge-weighted average	—	—	—	13	54	33
Manor Run near Norbeck, Md. 1967-70						
May 7, 1967	53	10,000	1,430	23	46	31
June 22, 1967	18	28,400	1,380	8	50	42
Mar. 18, 1968	6.3	2,780	47	4	48	48
June 19, 1968	97	9,890	2,590	25	39	36
July 22, 1969	30	22,500	1,822	12	52	36
July 22, 1969	2.6	2,610	18	1	41	58
Sept. 10, 1970	77	6,380	1,330	25	43	32
Sediment discharge-weighted average	—	—	—	19	45	36
North Branch Rock Creek near Rockville, Md. 1972-76						
June 1, 1972	44	213	25	0	7	93
June 22, 1972	404	415	453	0	17	83
Jan. 28, 1976	28	46	3.5	2	18	80
Sediment discharge-weighted average	—	—	—	0	16	84

and 16 downstream. Below Lake Frank, 84 percent of the suspended-sediment load was clay size, while upstream the percentages were 33 and 36.

A relation exists between the percentages of sand, silt, and clay transported as suspended sediment, and water discharge of North Branch Rock Creek near Norbeck. The sand percentage is proportional to the logarithm of water discharge, while the silt and clay percentages are inversely proportional to the logarithm of water discharge as shown in figure 14. These relations can be explained by the fact that the stream becomes more competent to transport larger particles at higher discharges, while the amount of finer material in transport remains a relatively constant function of availability. Although the relation between the percentage of suspended sediment in a size class and the logarithm of water discharge seems to be linear on North Branch Rock Creek, this is not true in Manor Run (fig. 15). The distribution of data in figure 15 indicates a nonlinear relation; although additional data could produce a linear relation similar to that of North Branch Rock Creek near Norbeck.

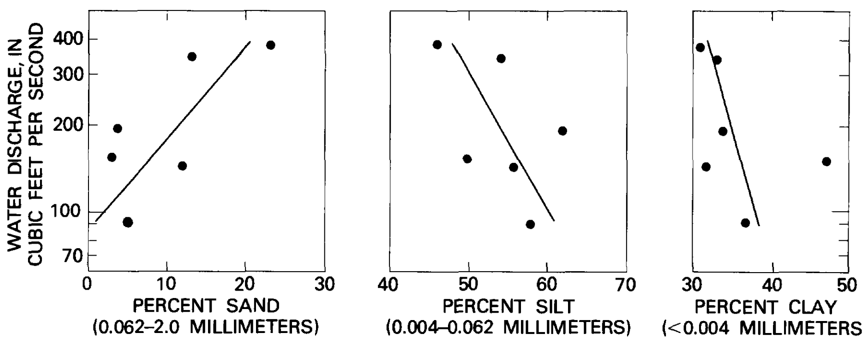


FIGURE 14.—Relation of sand, silt, and clay content of suspended sediment to water discharge, North Branch Rock Creek near Norbeck, 1969-75.

TRAP EFFICIENCY

Table 10 summarizes the estimated and measured sediment loads entering Lake Frank and the measured loads leaving Lake Frank, 1968-76. Figures 16 and 17 present the same data graphically and show that sediment inflow greatly exceeded sediment outflow.

Estimated annual sediment contributions to Lake Frank from all sources ranged from 0.57 to 2.83 tons/acre during 1968-76 (table 11). Maximum yield occurred during 1969-72 and averaged 2.48 tons/acre. The annual yield in tons per acre per inch of runoff decreases consistently (fig. 18) from a high of 0.272 in 1969 to 0.037 in 1976. Yorke and Herb (1978) attribute much of this decrease to the decline in construction area within the basin, as shown in figure 3, and an increase in the use of on site sediment controls in urban construction areas.

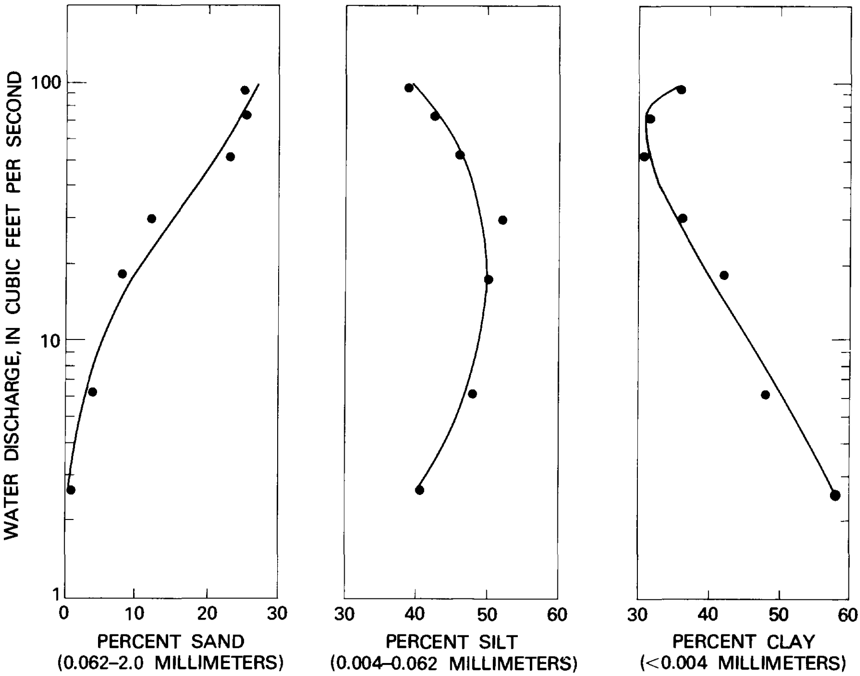


FIGURE 15.—Relation of sand, silt, and clay content of suspended sediment to water discharge, Manor Run near Norbeck, 1967-72.

The trap efficiency of an impoundment is the ratio of the amount of sediment trapped to the total amount of sediment entering. Trap efficiency can be computed by the formulas:

$$TE = 100 \frac{A}{A + B} \quad (3)$$

or

$$TE = 100 \frac{C-B}{C} \quad (4)$$

where

TE = trap efficiency of the impoundment, in percent;

A = weight of sediment deposited in impoundment, in tons;

B = weight of sediment discharged from the impoundment, in tons; and

C = weight of sediment entering the impoundment, in tons.

TABLE 10.—*Annual sediment inflow and outflow, in tons, Lake Bernard Frank, 1968-76*

Water year	Inflow						Outflow
	Manor Run		North Branch Rock Creek		Ungaged	Total Load	
	Suspended sediment	Bedload	Suspended sediment	Bedload	Total load	from all sources	Suspended sediment
1968	4,209	629	3,113	465	10,517	18,933	511
1969	3,454	516	4,504	673	11,299	20,446	226
1970	3,508	524	7,302	1,090	7,168	19,592	504
1971	2,352	351	9,465	1,410	3,088	16,666	979
1972	2,408	365	14,867	2,220	2,749	22,604	1,820
1973	1,702	254	11,062	1,650	2,583	17,251	720
1974	512	76	4,354	651	2,579	8,172	258
1975	806	120	3,986	596	2,334	7,842	569
1976	587	88	1,830	273	2,008	4,786	320
Total	19,538	2,918	60,483	9,028	44,325	136,292	5,905

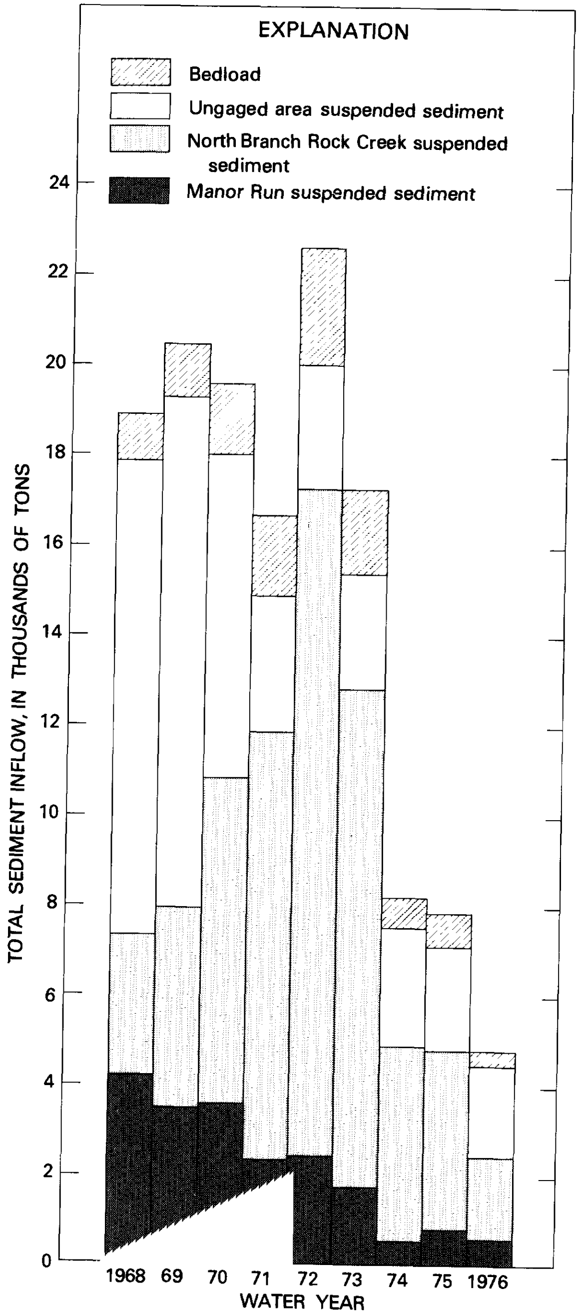


FIGURE 16.—Annual sediment inflow, Lake Bernard Frank, by water year.

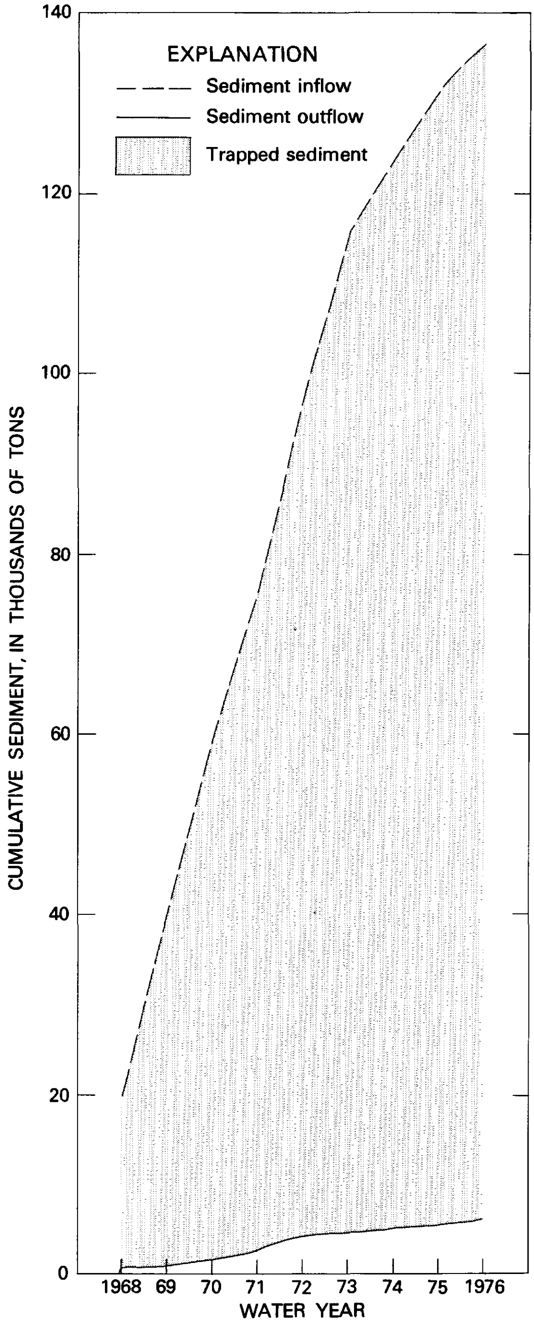


FIGURE 17.—Cumulative sediment inflow and outflow, Lake Bernard Frank, by water year.

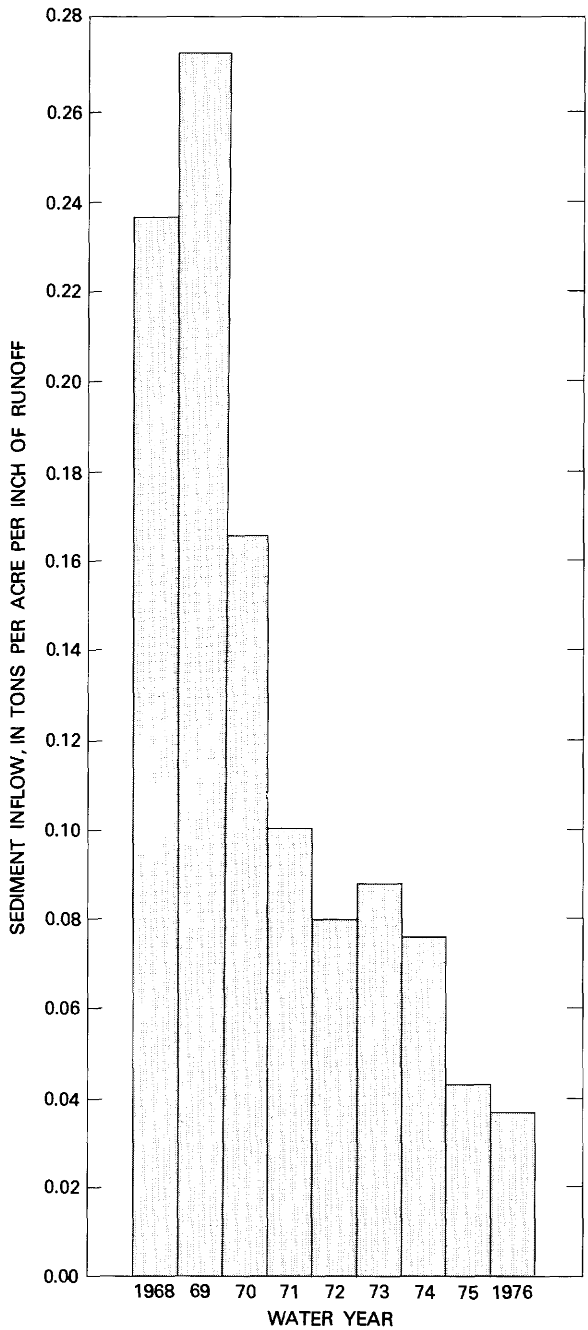


FIGURE 18.—Annual sediment inflow to Lake Bernard Frank per inch of runoff.

TABLE 11.—*Annual sediment yields from total drainage basin of Lake Frank, 1968-76*

Water year	Sediment yield		
	(tons/mi²)	(tons/acre)	(tons/acre/inch of runoff)
1968	1,510	2.36	0.236
1969	1,640	2.56	.272
1970	1,570	2.45	.165
1971	1,330	2.08	.100
1972	1,810	2.83	.080
1973	1,380	2.16	.088
1974	654	1.02	.076
1975	627	.98	.043
1976	383	.57	.037

Table 9 shows that 136,292 tons of sediment entered the impoundment and 5,905 tons of sediment left the impoundment during 1968-76. Trap efficiency, computed from equation 4, is 96 percent.

Estimates of the theoretical trap efficiency of an impoundment are often obtained by the relation between the capacity-inflow (C/I) ratio and trap efficiency as developed by Brune (1953) for normal ponded reservoirs. Normal ponded reservoirs are conventional reservoirs, as contrasted with desilting basins and dry reservoirs.

Average annual inflow to Lake Frank is assumed to equal the 12,300 acre-ft of the average annual outflow for 1968-76. As Lake Frank's capacity is 4,576 acre-ft at the crest of the emergency spillway, the C/I ratio for Lake Frank is 0.37. This gives an estimated trap efficiency of 95 percent from Brune's curve (fig. 19). In this particular instance the measured and theoretical trap efficiencies are almost the same.

Approximately 130,000 tons of sediment is estimated to have accumulated in Lake Bernard Frank during 1968-76. On the basis of a specific dry weight of 59 lb/ft³ (pounds per cubic foot) for the deposits, the total sediment accumulation for the 9-year period was 4,410,000 ft³, or 101 acre-ft. The specific dry weight of the sediment was estimated by procedures outlined by Lara and Pemberton (1963) for Type I reservoir operation and sediment-discharge weighted inflow percentages of 34, 50, and 16 for clay, silt, and sand.

The original sediment-pool capacity (as designed) of the impoundment was 261 acre ft or 11,400,000 ft³. In the 9 year period, 39 percent of the original sediment-pool capacity was lost. This is an average rate of capacity loss of 4.3 percent per year. Assuming

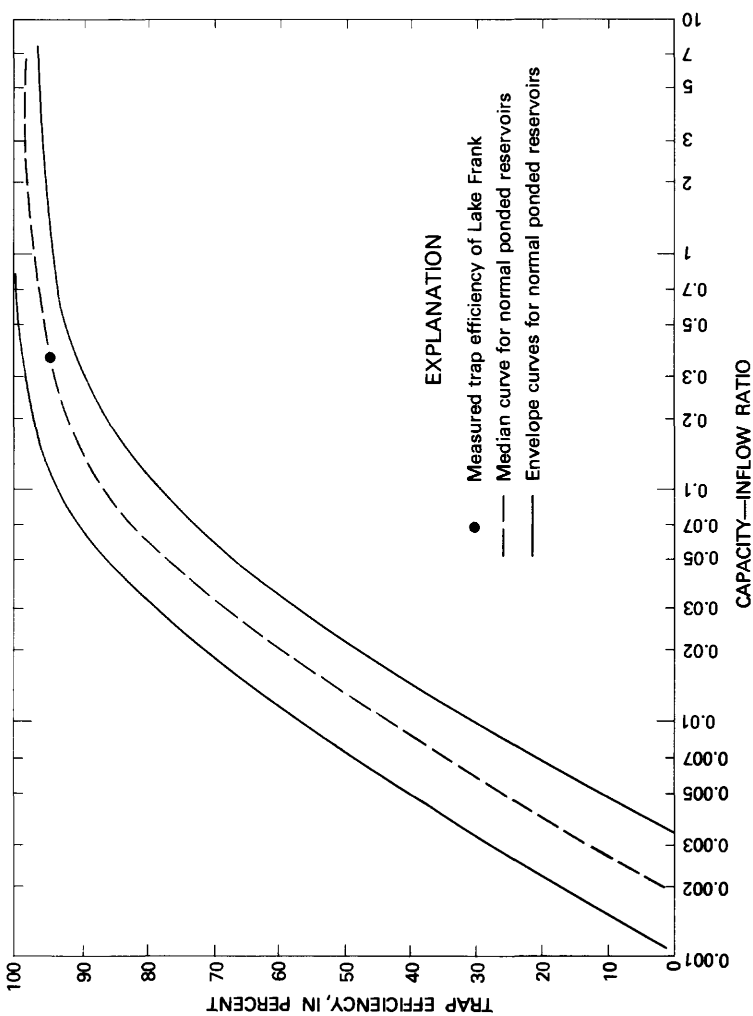


FIGURE 19.—Trap efficiency as related to capacity-inflow ratio for normal ponded reservoirs and Lake Frank (Brune, 1953).

this annual rate of capacity loss, average watershed conditions, and no loss of trap efficiency with a declining *C/I* ratio, the remaining 61 percent of sediment storage would be utilized in about 14 years. However, table 10 and figure 18 indicate that the annual sediment inflow and annual capacity loss varied from year to year and seemed to be declining in the last several years of the study.

Sediment yield to Lake Frank averaged 0.052 tons per acre per in. of runoff during the 1974-76 water years. This average is considered to be representative of future as well as current yields if no major land use and land cover changes occur in the basin. Mean annual runoff during the 1968-76 water years averaged 18.5 in. The 8,015-acre basin can be expected to yield about 7710 tons (6.0 acre-ft) of sediment annually under average runoff and present land use and land cover conditions. Under such conditions, the remaining 160 acre-ft of the sediment pool will not be fully utilized for 27 years.

SUMMARY AND CONCLUSIONS

Total sediment inflow to Lake Bernard Frank was estimated to be 136,000 tons for the 1968-76 water years. The estimate is based upon measured storm suspended-sediment loads, storm suspended-sediment loads determined from daily sediment-transport curves, suspended-sediment loads based upon land use and land cover in the ungaged part of the study area, and a bedload contribution computed by empirical transport equations. Total sediment inflow was related to land use and land cover changes associated with urbanization in the North Branch Rock Creek basin.

Total sediment outflow from Lake Frank was 5,910 tons during 1968-76. The entire outflow was considered to consist of suspended load with no bedload contribution.

Computations based upon total estimated sediment inflow and measured total sediment outflow indicated a trap efficiency of 96 percent. This agrees closely with the trap efficiency of other impoundments having similar capacity-inflow ratios.

Approximately 39 percent of Lake Frank's sediment-pool capacity has been lost since the dam was closed in 1967. On the basis of recent trends in sediment inflow and average runoff conditions, the sediment pool will be filled in about 27 years.

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