CONTRIBUTIONS OF SUSPENDED SEDIMENT FROM HIGHWAY CONSTRUCTION AND OTHER LAND USES TO THE OLENTANGY RIVER, COLUMBUS, OHIO

By Dennis R. Helsel

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CONVERSION FACTORS

For the convenience of readers who prefer to use the International System of units (SI), conversion factors for terms in this report are listed below:

Multiply inch-pound units	By	To obtain SI units
inch (in.)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
cubic foot per second	28.32	liter per second (L/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
ton, short	0.9072	megagram (Mg)
ton per square mile (ton/mi^2)	0.3503	megagram per square kilometer (Mg/km^2)

Temperature in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) as follows:

$$°F = 1.8°C + 32$$

CONTRIBUTIONS OF SUSPENDED SEDIMENT FROM HIGHWAY CONSTRUCTION AND OTHER LAND USES TO THE OLENTANGY RIVER, COLUMBUS, OHIO

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ABSTRACT

Highway construction within the Olentangy River flood plain in Columbus, Ohio, was projected to be a large source of suspended sediment to the river system. A monitoring program was begun by the U.S. Geological Survey in 1978 to quantify the impacts of the construction process. Sediment information was collected daily at six gaging stations located above, below, and within the construction area. Yields of suspended sediment from the active construction area ranged from 9,580 to 15,700 tons per square mile per year. Surrounding suburban terrain yielded 428 to 754 tons per square mile per year. However, the size of the construction project was small in comparison to the surrounding suburbs contributing sediment. No more than 4 percent of the yearly downstream suspended-sediment loads were produced by highway construction during the monitoring period.

INTRODUCTION

Suspended sediment is a major contaminant of our nation's rivers. Rivers draining the conterminous United States discharge an average of 491,449,600 tons per year, or 185 tons per square mile per year, to the oceans (Curtis and others, 1973). Major localized sources of suspended sediment are exposed land surfaces that lack vegetative cover, such as tilled fields, surface mines, and construction sites.

State highway departments have been concerned about the potential impacts of highway construction sites on suspended-sediment discharges. One such site is Ohio State Route (SR) 315, which lies within the Olentangy River floodplain in Columbus, Ohio. Construction of this highway would be in close proximity to the stream channel, and possibly would result in higher suspended sediment inputs to the river. In turn, this sediment might adversely affect stream-channel characteristics, biological communities, and water quality.

Purpose and Scope

This report describes the sediment contributions of the SR 315 highway construction site and other land uses (residential and commercial) to the Olentangy River. The report presents the results of analyses of suspended sediment and streamflow data collected at six sites in the drainage basin.

The U.S. Geological Survey (USGS), in cooperation with the Ohio Department of Transportation (ODOT), began a 3-year monitoring program along the Olentangy River and its tributaries in August 1978 in an effort to quantify the impacts of the SR 315 construction.

Two gaging stations were established on the Olentangy River (one above and one below the highway-construction area), three stations were established on tributaries draining suburban land surrounding the highway-construction site, and one was located on the highway-construction site itself. A seventh location, also at the construction site, was occasionally sampled for instantaneous suspended sediment and streamflow. Using daily discharge and sediment-concentration data from these six stations, the amount of sediment contributed to this reach of the Olentangy River by the SR 315 construction could be quantified and compared to that from the surrounding suburban land.

Previous Studies

Wolman and Schick (1967) were among the first to quantify large suspended-sediment yields from urban construction sites and evaluate their effects on stream channels. Vice and others (1969) monitored suspended sediment from highway construction in northern Virginia; 85 percent of the sediment delivered downstream resulted from that construction. Reed (1980)evaluated suspended-sediment control measures during interstate highway construction near Harrisburg, Pennsylvania. Ponds trapped from 70 to 80 percent of the suspended sediment; seeding and mulching decreased yields by 20 percent; and rock dams and hay trapped 5 percent. Yorke and Herb (1978) found that controls reduced suspended-sediment loads by 60 to 80 percent downstream of construction sites in suburban Maryland. They also showed that suspended-sediment yields increased with the proximity of construction to the stream channel.

Bullard (1963) surveyed sediment problems associated with highway constuction, and presented guidelines for their avoidance. Many of these guidelines have become standard practice today. Richards and Middleton (1978) more recently described various traps, fences, and other procedures for reducing sediment losses during highway construction.

Table 1 presents data from previous studies. Suspended-sediment yields from basins with various land uses, including those undergoing construction, are presented. Variations in yields from the construction sites can be attributed to (1) drainage area of the basin (smaller basins having greater percentages of disturbed land produce higher yields per acre), (2) proximity of construction to stream channels, and (3) use of sediment-control practices. On the basis of these data, suspended-sediment yields during highway construction would be expected to be 2 to 20 times the yields from undisturbed urban residential land.

Physical Setting

Columbus, Ohio is a city of over half a million people (U.S. Department of Commerce, 1981). The total population of Columbus and surrounding areas in Franklin County is more than 850,000. The mean annual temperature is 52°F; the mean minimum temperature (in January) is 23°F, and the mean maximum temperature (in July) is 88°F (U.S. Department of Commerce, 1959).

The Olentangy River basin is located in the till plains section of the Central Lowlands physiographic province (Fenneman, 1938). Clayey and silty glacial till, the predominant surficial material, is underlain by Devonian shales and limestones (Ohio Department of Natural Resources, 1958). Soils are of the Miamian series, are well-drained and highly permeable, and have moderate erosion potential (U.S. Department of Agriculture, 1980). Texture classes are silt loams, loams, silty clay loams, or clay loams. Thus, the soils consist primarily of silt-sized particles, with clays the secondary component.

Precipitation averages 36.7 inches per year; April to July is the wettest period, and October and February generally are the driest months (U.S. Department of Agriculture, 1980). Average annual streamflow for the Olentangy River near Worthington, Ohio is 13.1 inches (U.S. Geological Survey, 1982). Flow in the river is regulated by a water-supply reservoir located 21 miles upstream of the project area.

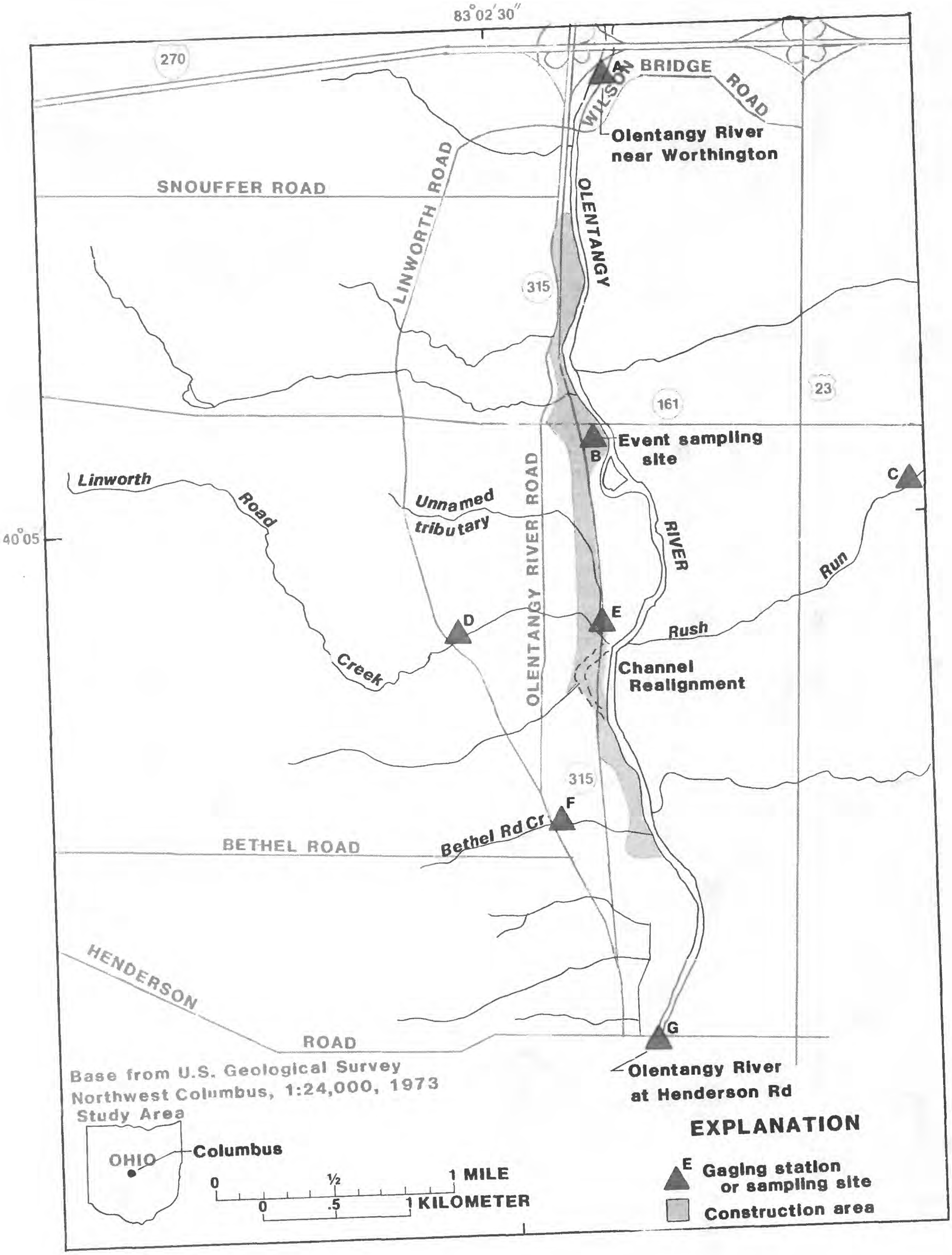
Highway Construction and Other Land Uses

Construction of SR 315 began on June 7, 1978, with the clearing and removal of vegetation. Earthwork began later that month. Trenching the new section of river channel began on September 5, 1978, with completion and opening of the channel on November 17 of that year. Earthwork was largely completed by autumn, 1980, and permanent vegetation was established before the spring of 1981.

On November 27, 1978, the Olentangy River was permanently diverted through a 0.2-mile-long manmade section of channel to the east of the river's natural channel (fig. 1). Highway construction was then begun in the vicinity of the natural channel.

Table 1.--Suspended-sediment yield from various land uses

Land use	Sediment yield in $(\text{tons/mi}^2)/\text{yr}$	Reference
Highway construction-----	3,800- 6,000	Reed (1980)
Highway construction-----	40,000	Vice and others (1969)
Building construction----	21,000	Yorke and Herb (1978)
Building construction----	25,000	Guy and Ferguson (1962)
Urban residential--------	2,300- 2,500	Yorke and Herb (1978)
Cropland-----------------	416- 2,750	Yorke and Herb (1978)
Cropland-----------------	3,200	Vice and others (1969)
Rural--------------------	200- 500	Wolman and Schick (1967)
Forest-------------------	110	Reed (1980)
Forest-------------------	19	Williams and George (1968)
Forest-------------------	15	Wolman and Schick (1967)



Base from U.S. Geological Survey Northwest Columbus, 1:24,000, 1973

Figure 1.--Location of study area and gaging stations.

During the construction, several sediment-control measures were used on the project. Temporary seeding and mulching, and straw or hay bales reduced entrainment of sediment from overland runoff. Benches, dikes, dams, and sediment basins diverted and held back waters from the Olentangy until sediment could settle out. Channels were lined with rock fill and concrete riprap to prevent scour during high-flow events. Other measures such as jute and excelsion matting also were used.

Surrounding the 0.19-mi^2 construction site is 21 mi^2 of suburban land, which drains to the Olentangy River between the upstream and downstream gaging stations. Much of this area is residential, but there are also small shopping areas and office buildings. A part of a small private airport also is within the watershed.

Site Locations

Six stations were operated along the Olentangy River and its tributaries in Columbus, Ohio for this study. Their locations are shown in figure 1 and described in table 2. Upstream of all construction activity, the Olentangy River near Worthington (site A) monitored water and sediment entering the study reach. The Olentangy River at Henderson Road at Columbus (site G) was located at the study area's downstream end, and provided information on outputs of water and sediment discharge. Three representative tributaries to the river, Rush Run at Worthington (site C), Linworth Road Creek at Columbus (site D), and Bethel Road Creek at Columbus (site F) provided daily information on sediment derived from suburban land surrounding the SR 315 construction.

Daily water and sediment records for the construction site itself were difficult to obtain. Because of the close proximity of construction to the river channel, gaging stations downstream of the construction site could be flooded by backwater from the Olentangy River during all medium and high flows. After encountering backwater problems at several sites, one station was established on the construction site (unnamed tributary to the Olentangy River at Columbus, site E) in July 1979. It was as free from backwater as was possible on site. In addition to this station, a second location within the construction area (site B) was sampled during occasional storm events (fig. 1).

On November 27, 1978, water began flowing through a new section of the channel of the Olentangy River created during the SR 315 construction. Discharge measurements and suspended-sediment samples were obtained in this new section on November 27 and 28.

Table 2.--Descriptions of gaging stations

Site	Station number	Station name	Drainage area (mi^2)	Description
A	03226800	Olentangy River near Worthington	497	Upstream of project; rural and residential
C	03226865	Rush Run at Worthington	1.65	Suburban residential
D	03226870	Linworth Road Creek at Columbus	2.03	Suburban residential
E	03226872	Unnamed Tributary to Olentangy River at Columbus	2.50	Suburban residential plus 0.05 mi^2 highway construction
F	03226875	Bethel Road Creek Columbus	0.22	Suburban residential and commercial
G	03226885	Olentangy River at Henderson Road, Columbus	518	Downstream of project area
		Drainage area between upstream and downstream gages	21.0	
		Suburban drainage between gages	20.81	
		Total area undergoing SR 315 construction	.19	

METHODS

Data Collection

Water discharge at each site was determined by a digital stage recorder, which recorded values every 5 minutes. Stage data were converted to discharge data by means of a rating curve based on numerous discharge measurements over the range of stage (Carter and Davidian, 1968). Suspended-sediment samples were collected periodically with DH-48, DH-59, and D-49 samplers using the equal-width-increment method (Guy and Norman, 1970). In addition, automatic pumping (PS-69 or Manning[1]) samplers collected daily and storm-event samples. From 500 to 1,000 samples per station were collected each water year. No data were collected on bedload (particles too large to be suspended), as sediment of this size was not expected to result from soil erosion at the construction site.

Figure 2 displays coverage by a pumping sampler during one storm event. These were point samples representing only one depth and width position of the stream's cross section, and may not represent the concentration obtained if all points in the cross section were sampled. To relate these point samples to discharge-weighted samples representing the entire cross-section, concurrent point and standard manual samples were collected intermittently throughout the study over a range of discharges. Table 3 presents the weighting coefficients used to adjust point-sample concentrations to best match discharge-weighted concentrations for each station. These coefficients were determined by the slope of a least-squares linear regression relating the concentrations of concurrent discharge-weighted and point samples. Coefficients of 1.0 for the Olentangy River stations indicated that samples from a single point were not different from those representing the entire stream cross section at these sites. For the smaller streams, large differences between the sample types were found, indicating that automatic pump samples were not representative of small-stream discharge-weighted concentrations. Where two coefficients are presented, the slope of the relationship changed enough to warrant representation by two straight lines. This is attributed to the fixed intake point being at greater flow depths for large-discharge storms.

Rainfall was recorded at 5-minute intervals at all but one of the gaging stations. Tipping-bucket rain gages (one tip equal to 0.01 inch of rain) were used.

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[1] Use of trade names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

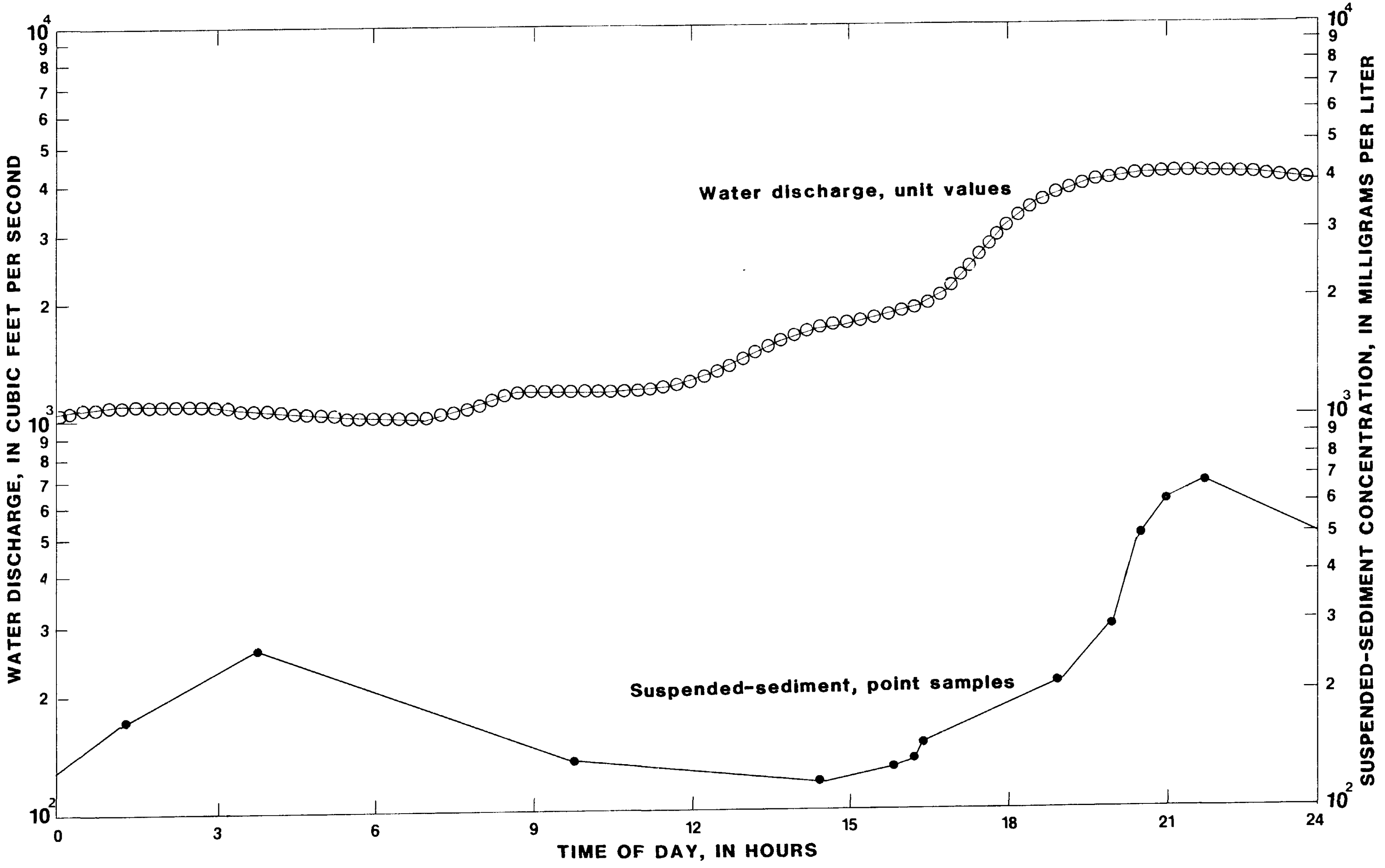

Figure 2.--Storm-event data for water discharge and suspended-sediment concentration, site G, January 1, 1979.

Table 3.--Point-sample weighting coefficients

[mg/L, milligrams per liter]

Site	Coefficient(s)
A	1.0
C	0.87 below 300 mg/L 0.40 above 300 mg/L
D	0.55
E	1.0
F	0.73 below 400 mg/L 0.43 above 400 mg/L
G	1.0

Data Analysis

Daily suspended-sediment discharges were calculated for all stations from suspended-sediment concentration and streamflow data. For the construction-site station (site E), a sediment rating curve was developed for each water year. These logarithmic regression equations are given in table 4. Daily streamflow data were then input to the equation to produce daily suspended-sediment discharges.

For the other five stations, daily suspended-sediment discharges were calculated by multiplying the daily sample concentrations by the water discharge for each day without storm events. Computations for storm-event days used the mid-interval method of subdivision (Porterfield, 1972) using 5-minute intervals (Helsel, 1983).

CONTRIBUTIONS OF SUSPENDED SEDIMENT

Suspended Sediment at Sites A-G

Daily mean discharges for sites A, C, D, F, and G have previously been reported in annual water-data reports for Ohio (U.S. Geological Survey, 1982, 1983). Monthly totals of suspended-sediment load (tons), suspended-sediment yield (tons per square mile), streamflow (cubic feet per second-days), and discharge-weighted suspended-sediment concentration (milligrams per liter) for the study sites are given in tables 5 through 8. Yearly totals are given in table 9.

The columns G through A in tables 5 through 9 report the net amounts contributed by the 21 mi^2 between the upstream (site A) and downstream (site G) gaging stations on the Olentangy River. Net streamflow (table 7) and net suspended-sediment load (table 5) were calculated as the difference between daily values (site G minus site A). Net suspended-sediment yield (table 6) was not calculated as a simple subtraction of daily values between the two sites, as the drainage areas of the two gaging stations are different. Table 6 presents net suspended-sediment yields calculated as:

$$\frac{\text{Sediment load (site G)} - \text{Sediment load (site A)}}{\text{21 square miles.}}$$

Discharge-weighted concentrations were calculated by dividing the suspended-sediment load by its corresponding water discharge, and then dividing by 0.0027 (for units conversion).

Table 4.--Annual suspended-sediment rating curve regression equations for site E

[Suspended-sediment discharge (L) in tons per day; water discharge (Q) in cubic feet per second]

Water year	Equation	n	r	Standard error of estimate
1979	$L = 0.146\ Q^{1.546}$	48	0.80	0.48 log units (156 percent)
1980	$L = 0.166\ Q^{1.681}$	166	0.82	0.45 log units (139 percent)
1981	$L = 0.068\ Q^{1.687}$	102	0.82	0.40 log units (116 percent)

Table 5.--Monthly suspended-sediment loads at selected sites in the Olentangy River basin, water years 1979-81

[All values are in tons]

	Site					
Month	A	C	D	E	F	G	G-A
OCT 78	31	9.4	4.9	--	0.6	64	32
NOV 78	42	7.8	2.7	--	.2	99	56
DEC 78	1838	31.4	21.3	--	7.4	3112	1274
JAN 79	3935	53.8	50.9	--	1.1	5374	1439
FEB 79	4503	68.8	133.4	--	37.2	4670	167
MAR 79	12096	13.2	18.7	--	1.8	12654	558
APR 79	7285	50.1	129.7	--	17.5	20912	13627
MAY 79	627	7.2	8.7	--	3.5	1212	585
JUNE 79	1147	52.5	9.6	--	7.8	1677	530
JULY 79	962	31.6	3.9	16.0	16.3	1424	462
AUG 79	7953	336.4	114.5	283.9	34.6	10833	2880
SEPT 79	8309	712.6	297.9	558.6	643.0	20075	11766
OCT 79	453	4.3	0.6	20.7	1.4	849	396
NOV 79	6544	154.2	36.1	278.3	11.6	18642	12097
DEC 79	7270	42.3	20.9	148.5	11.5	4183	-3087
JAN 80	4055	64.0	24.9	172.8	1.8	3637	-417
FEB 80	3307	68.1	2.3	67.0	1.8	3054	-253
MAR 80	22702	92.0	27.7	128.3	8.9	31842	9140
APR 80	7835	72.8	8.4	4.2	2.6	32939	25104
MAY 80	1243	144.9	15.0	18.6	57.7	4777	3534
JUNE 80	24876	203.4	40.0	153.6	79.3	29912	5036
JULY 80	3336	136.0	9.6	10.2	67.2	19998	16662
AUG 80	11198	169.7	32.9	48.8	48.9	15450	4252
SEPT 80	135	4.7	.4	0.1	.4	202	67
OCT 80	166	13.6	2.3	.6	1.3	381	215
NOV 80	158	8.4	11.8	.4	.7	270	112
DEC 80	817	2.1	7.3	.8	.4	426	-391
JAN 81	1632	0.7	.9	.1	1.0	1391	-241
FEB 81	11874	97.5	251.5	151.0	7.7	17487	5613
MAR 81	562	9.3	1.9	.6	.6	1447	885
APR 81	7623	166.0	402.3	121.0	29.5	49250	41627
MAY 81	7633	252.4	202.4	127.8	62.0	57601	49968
JUNE 81	28961	207.2	370.2	152.6	74.1	93219	64258
JULY 81	240	81.3	6.0	.1	1.0	728	489
AUG 81	67	16.8	.0	.0	.1	204	137
SEPT 81	1819	68.4	.1	.0	4.5	4105	2286

Table 6.--Monthly suspended-sediment yields at selected sites in the Olentangy River basin, water years 1979-81

[All values are in tons per square mile]

	Site						
Month	A	C	D	E	F	G	G-A*
OCT 78	0.1	5.7	2.4	--	2.9	0.1	1.5
NOV 78	.1	4.7	1.3	--	0.7	.2	2.7
DEC 78	3.7	19.0	10.5	--	33.5	6.0	60.7
JAN 79	7.9	32.6	25.1	--	5.2	10.4	68.5
FEB 79	9.1	41.7	65.7	--	168.4	9.0	8.0
MAR 79	24.3	8.0	9.2	--	8.1	24.4	26.6
APR 79	14.7	30.3	63.9	--	79.0	40.4	648.9
MAY 79	1.3	4.3	4.3	--	15.8	2.3	27.9
JUNE 79	2.3	31.8	4.7	--	35.1	3.2	25.2
JULY 79	1.9	19.1	1.9	6.4	73.8	2.7	22.0
AUG 79	16.0	203.7	56.4	113.6	156.5	20.9	137.1
SEPT 79	16.7	431.6	146.7	223.4	2909.3	38.8	560.3
OCT 79	.9	2.6	0.3	8.3	6.1	1.6	18.9
NOV 79	13.2	93.4	17.8	111.3	52.4	36.0	576.1
DEC 79	14.6	25.6	10.3	59.4	51.9	8.1	-147.0
JAN 80	8.2	38.8	12.3	69.1	8.2	7.0	-19.9
FEB 80	6.7	41.3	1.1	26.8	8.0	5.9	-12.0
MAR 80	45.7	55.7	13.6	51.3	40.2	61.5	435.2
APR 80	15.8	44.1	4.1	1.7	11.9	63.6	1195.4
MAY 80	2.5	87.8	7.4	7.4	261.1	9.2	168.3
JUNE 80	50.1	123.2	19.7	61.5	358.8	57.7	239.8
JULY 80	6.7	82.4	4.7	4.1	303.8	38.6	793.4
AUG 80	22.5	102.8	16.2	19.5	221.2	29.8	202.5
SEPT 80	.3	2.9	.2	0.0	2.0	.4	3.2
OCT 80	.3	8.3	1.1	.2	5.7	.7	10.2
NOV 80	.3	5.1	5.8	.2	3.3	.5	5.3
DEC 80	1.6	1.3	3.6	.3	1.9	.8	-18.6
JAN 81	3.3	0.4	.4	.1	4.6	2.7	-11.5
FEB 81	23.9	59.0	123.8	60.4	34.8	33.8	267.3
MAR 81	1.1	5.6	.9	.2	2.6	2.8	42.1
APR 81	15.3	100.6	198.1	48.4	133.6	95.1	1982.3
MAY 81	15.4	152.9	99.6	51.1	280.5	111.2	2379.4
JUNE 81	58.3	125.5	182.3	61.0	335.1	180.0	3059.9
JULY 81	.5	49.2	3.0	.0	4.3	1.4	23.3
AUG 81	.1	10.2	.0	.0	.5	.4	6.5
SEPT 81	3.7	41.4	.0	.0	20.5	7.9	108.9

*Adjusted for drainage area. See text.

Table 7.--Streamflow at selected sites in the Olentangy River basin, water years 1979-81

[All values are in cubic feet per second-days]

Month	Site A	C	D	E	F	G	G-A
OCT 78	918	120.3	17.0	--	5.1	1018	100
NOV 78	1487	132.6	19.9	--	8.8	1754	267
DEC 78	9712	261.3	52.0	--	23.4	10533	821
JAN 79	21994	272.8	165.6	--	8.2	26358	4364
FEB 79	10245	170.4	154.0	--	32.9	10051	-194
MAR 79	57553	157.2	93.7	--	21.6	58640	1087
APR 79	44353	97.9	133.7	--	30.7	48596	4243
MAY 79	6903	32.7	31.1	--	17.3	7029	126
JUNE 79	6306	60.5	44.6	--	19.6	7069	763
JULY 79	7340	44.8	29.5	35.6	19.8	8626	1286
AUG 79	17679	153.8	97.3	291.5	27.0	19610	1931
SEPT 79	24282	193.2	146.2	321.1	86.7	27035	2753
OCT 79	10355	34.4	12.7	57.1	16.3	9739	-616
NOV 79	27794	90.1	100.8	232.0	18.3	28360	566
DEC 79	30303	110.3	51.5	193.2	27.6	32069	1766
JAN 80	15554	138.0	50.9	162.6	14.5	17748	2194
FEB 80	10369	69.8	19.6	122.2	5.9	11539	1170
MAR 80	41553	83.3	112.9	178.5	16.0	44008	2455
APR 80	26331	65.8	54.1	13.0	6.8	30495	4164
MAY 80	7945	119.6	57.5	46.9	15.0	9199	1254
JUNE 80	37613	70.2	56.7	90.1	10.2	42832	5219
JULY 80	5966	90.9	45.9	33.7	4.0	7420	1454
AUG 80	24845	279.6	100.9	76.2	16.4	30384	5539
SEPT 80	1730	22.4	4.2	1.6	1.4	2181	451
OCT 80	1841	27.4	8.0	11.3	5.1	2310	469
NOV 80	3856	16.9	15.1	9.7	5.1	4657	801
DEC 80	7431	20.6	32.4	14.6	6.4	8253	822
JAN 81	5125	8.4	30.8	2.6	6.6	7182	2057
FEB 81	36457	115.7	167.4	160.8	20.3	51806	15349
MAR 81	6563	28.4	31.3	12.2	5.1	8629	2066
APR 81	17155	131.2	88.8	131.8	29.5	21678	4523
MAY 81	26549	262.7	144.4	216.8	21.0	32862	6313
JUNE 81	38915	227.7	162.6	222.2	40.2	46703	7788
JULY 81	2130	118.1	13.6	3.1	4.1	3423	1293
AUG 81	1199	100.9	0.1	0.9	1.0	1717	518
SEPT 81	9233	168.2	.6	.8	4.9	11081	1848

Table 8.--Discharge-weighted sediment concentrations at selected sites in the Olentangy River basin, water years 1979-81

[All values are in milligrams per liter]

Month	Site A	C	D	E	F	G
OCT 78	13	29	106	--	45	23
NOV 78	11	22	50	--	6	21
DEC 78	70	45	152	--	117	109
JAN 79	66	73	114	--	52	76
FEB 79	163	149	321	--	419	172
MAR 79	78	31	74	--	31	80
APR 79	61	190	359	--	211	159
MAY 79	34	81	104	--	75	64
JUNE 79	67	321	79	--	146	88
JULY 79	49	262	49	167	304	61
AUG 79	167	810	436	361	475	205
SEPT 79	127	1367	755	644	2748	275
OCT 79	16	46	17	134	31	32
NOV 79	87	634	133	444	235	243
DEC 79	89	142	150	285	154	48
JAN 80	97	172	181	394	46	76
FEB 80	118	362	43	203	111	98
MAR 80	202	409	91	266	206	268
APR 80	110	410	57	120	144	400
MAY 80	58	449	97	147	1423	192
JUNE 80	245	1074	261	632	2879	259
JULY 80	207	554	77	112	6265	998
AUG 80	167	225	121	237	1106	188
SEPT 80	29	78	35	17	113	34
OCT 80	33	184	107	18	91	61
NOV 80	15	184	290	15	54	21
DEC 80	41	38	83	19	25	19
JAN 81	118	32	11	19	57	72
FEB 81	121	312	556	348	140	125
MAR 81	32	121	22	18	42	62
APR 81	165	469	1678	340	371	841
MAY 81	106	356	519	218	1094	649
JUNE 81	276	337	843	254	682	739
JULY 81	42	255	165	11	86	79
AUG 81	21	62	0	3	44	44
SEPT 81	73	151	30	10	344	137

Table 9.--Yearly summaries of suspended-sediment and streamflow data for selected sites in the Olentangy River basin, water years 1979-81

	Site					
Water year	A	C	D	E	F	G	G-A
			Suspended-sediment load [tons]				
WY1979	48730	1375	796	859	771	82106	33376
WY1980	92953	1156	219	1051	293	165485	72532
WY1981	61551	924	1257	555	183	226509	164958
			Suspended-sediment yield [tons per square mile]				
WY1979	98	833	392	343	3488	159	1589
WY1980	187	700	108	420	1326	319	3454
WY1981	124	560	619	222	828	437	7855
			Streamflow [cubic feet per second-days]				
WY1979	208772	1697	984	648	301	226319	17547
WY1980	240358	1174	668	1207	152	265974	25616
WY1981	156454	1226	695	787	149	200301	43847
			Discharge-weighted suspended-sediment concentrations [milligrams per liter]				
WY1979	86	300	300	491	948	134	
WY1980	143	365	121	323	713	230	
WY1981	146	279	670	261	454	419	

In order to determine the amount of suspended sediment contributed by each land-use source, mass balances of monthly suspended-sediment loads (tons) were calculated as follows.

1.--Suspended-sediment loads at site D (upstream of construction) were multiplied by the ratio of the undisturbed drainage area at site E (below highway construction) to the drainage area of site D, to approximate the sediment load at site E due to sources other than construction. Because site E is actually downstream from site D, the undisturbed 0.42 square mile below site D is assumed to be similar to the 2.03 square miles above the site:

Undisturbed load at Site E = Site D load X 2.45/2.03

2.--This undisturbed load was subtracted from the measured load at site E to give the amount due to highway construction within the watershed:

Site E construction load = Site E load - Undisturbed load

3.--To estimate sediment load from the entire construction area, the site E construction load was multiplied by the ratio of total construction area to site E construction area. This assumes that the site E highway-construction yields are representative of the entire construction area:

Construction = Site E construction load X 0.19/0.05

4.--Average suburban suspended-sediment load was calculated by summing the loads from the three suburban watersheds, and multiplying by the ratio of total suburban drainage area between sites A and G to the total drainage area of the three watersheds. This assumes that these three watersheds are typical of the entire suburban area:

Suburban load = (loads from Sites C + D + F) X 20.81/3.90

5.--The net suspended-sediment load between sites A and G, minus suburban and construction runoff loads, was attributed to erosion of the channel. Any other unknown sources would be included in this term:

Erosion load = Net load - Construction load - Suburban load.

Net Suspended Sediment Between Sites G and A

Differences in sediment load between the site G (downstream) and site A (upstream) gaging stations were calculated for each day of the 3-year project. Streamflow and sediment load on any given day are not independent of those for the previous day. All statistical tests used in this report require such independence; for this reason, monthly sums were calculated and used in all subsequent statistical tests.

Table 5 presents the monthly net suspended-sediment loads between sites G and A. The maximum monthly net load of 64,258 tons occurred in June 1981, and the minimum of -3,087 tons in December 1979. A typical monthly net load for the 3-year period is 2,733 tons. This is not the mean value, but the Hodges-Lehmann estimate (Hollander and Wolfe, 1973, p. 33), which provides a more "central" value than the mean when the data are not normally distributed and are skewed.

A negative net sediment load signifies that deposition within the study reach exceeds the amount being added by tributaries and overland runoff within the reach. Negative net loads occurred for 5 months, all of which were in the period December through February. These were months of low precipitation and low storm intensities (light rain and snow). As most suspended sediment is transported during large storm events, it is not surprising that deposition, rather than transport, dominates during these months. The sediment deposited is available for later transport during higher streamflow events.

Net sediment yields, in tons per the 21-mi^2 study-reach drainage area, are reported as "G-A" in table 6. Monthly streamflow contributed by tributaries within the study reach is listed in table 7, also as "G-A." Yearly totals for each are reported in table 9.

A Wilcoxon signed-rank test also was performed to determine whether the monthly differences in streamflow and sediment load between sites G and A differed significantly from zero (that is, did they increase going downstream). The null hypothesis was that there was no increase. Sediment load and streamflow both significantly increased going downstream at greater than a 99.9-percent confidence level (table 10).

In summary, significant amounts of streamflow and sediment load were being added by tributaries draining to the Olentangy River within the study reach. These additions varied widely from month to month; the typical difference in sediment load between sites G and A was 2,733 tons per month, or 130 tons per square mile per month.

Table 10.--Wilcoxon signed-rank test

[Z statistic: approximates a normal N (0,1) distribution. Critical probability (P): probability that differences between sites G and A are due solely to chance.]

Type of data	Z (n = 36)	P
Sediment, tons	4.26	0.0001
Sediment, tons per square mile	4.26	0.0001
Streamflow, cubic feet per second	4.21	0.0001

Comparisons of Yields Among Sites A-G

Monthly net suspended sediment yields, in tons per square mile, were compared for the six stations. Ranks of the monthly yields (1 = lowest, 216 = highest) rather than the yields themselves were input to an analysis of variance (ANOVA) test (Conover and Iman, 1976). Ranks were used because the differences between data points and their station mean were not normally distributed as required by ANOVA. ANOVA's null hypothesis is that all yields are identical. The results, given in table 11, disprove this. Differences in sediment yields exist between the sites at greater than the 99.9-percent confidence level (P = 0.0001).

ANOVA does not indicate which yields differ from others. To do this, a Duncan's multiple range test was employed. Three groups of stations were found to be significantly different (95-percent confidence level), as shown in table 11. Stations within each group are not significantly different from each other. Two of the urban residential watersheds (C and F) produced the highest suspended-sediment yields. A second group of lower yields (sites D, E, G) follows, which includes the drainage from the construction site. Finally, the lowest sediment yields were found at site A, the upstream point of the study reach.

One notable result is that drainage below the construction area (site E) delivered no more suspended sediment per square mile than did drainage upstream of the construction area (site D). This is not surprising, however, if one considers that the SR 315 construction disturbed only 2 percent of site E's drainage area. Yields from the construction activity itself are discussed in a later section.

Effects of Highway Construction and Other Land Uses

Table 12 lists all net suspended-sediment loads and their three constituents -- suburban, construction, and erosional and other sources. Negative values for erosion are again interpreted as deposition within the channel. The 1979 water-year total for site E was estimated using the 3 months of data collected (table 9) divided by the fraction of yearly sediment discharged by suburban runoff for those 3 months in the other 2 years. Essentially no sediment was contributed by the SR 315 construction in the final year of monitoring.

Table 13 presents loads attributed to each source (from table 13) divided by the net difference between upstream and downstream loads; the loads in table 13 are expressed as percentages.

Table 11.--Duncan's multiple range test comparisons--ranks of sediment yields per square mile

[Analysis of variance: F = 18.11; P = 0.0001; degrees of freedom = 166]

Group	Site	Tons per square mile per month
I	C	24.7
	F	20.9
II	E	8.2
	G	8.1
	D	8.0
III	A	5.7

Table 12.--Suspended-sediment load, by source, water years 1979-81

[All values are in tons]

	Source			
Month	Construction	Suburban	Erosion + other	G-A
OCT 78	--	80	--	32
NOV 78	--	57	--	56
DEC 78	--	321	--	1274
JAN 79	--	565	--	1439
FEB 79	--	1277	--	167
MAR 79	--	180	--	558
APR 79	--	1052	--	13627
MAY 79	--	103	--	585
JUNE 79	--	372	--	530
JULY 79	43	277	143	462
AUG 79	554	2591	-264	2880
SEPT 79	756	8823	2187	11766
OCT 79	76	33	287	396
NOV 79	892	1077	10128	12097
DEC 79	469	398	-3954	-3087
JAN 80	542	484	-1444	-417
FEB 80	244	385	-882	-253
MAR 80	360	686	8093	9140
APR 80	0	447	24657	25104
MAY 80	2	1161	2371	3534
JUNE 80	400	1722	2914	5036
JULY 80	0	1135	15527	16662
AUG 80	35	1342	2876	4252
SEPT 80	0	30	37	67
OCT 80	0	92	123	215
NOV 80	0	112	0	112
DEC 80	0	52	-443	-391
JAN 81	0	14	-255	-241
FEB 81	0	1903	3710	5613
MAR 81	0	63	823	885
APR 81	0	3190	38437	41627
MAY 81	0	2757	47211	49968
JUNE 81	0	3476	60781	64258
JULY 81	0	471	18	489
AUG 81	0	90	46	137
SEPT 81	0	390	1897	2286
Water year				
WY1979	1820	15697	15859	33376
WY1980	2991	8901	60640	72532
WY1981	0	12611	152348	164958

Table 13.--Net suspended-sediment loads by source (in percent)

[x indicates negative net sediment load for the month]

Month	Construction/NET	Suburban/NET	Erosion/NET
Oct. 1978	--	247	--
Nov.	--	101	--
Dec.	--	25	--
Jan. 1979	--	39	--
Feb.	--	763	--
Mar.	--	32	--
Apr.	--	8	--
May	--	18	--
June	--	70	--
July	9	60	31
Aug	19	90	-9
Sept	6	75	19
Oct	19	8	72
Nov	7	9	84
Dec	x	x	-128
Jan. 1980	x	x	-346
Feb.	x	x	-349
Mar.	4	8	89
Apr.	0	2	98
May	0	33	67
June	8	34	58
July	0	7	93
Aug.	1	32	68
Sept.	0	45	55
Oct.	0	43	57
Nov.	0	100	0
Dec.	0	x	-113
Jan. 1981	0	x	-106
Feb.	0	34	66
Mar.	0	7	93
Apr.	0	8	92
May	0	6	94
June	0	5	95
July	0	96	4
Aug.	0	66	34
Sept.	0	17	83
Water year			
1979	4	47	49
1980	4	12	84
1981	0	8	92

Several intense thunderstorms during March through June 1981 produced flows that scoured the Olentangy streambed, as shown by the percentage attributed to erosion. These storms picked up sediment deposited in the channel between sites A and G during and prior to the monitoring period. Monthly sediment loads would have been from 0 to 19 percent lower had the SR 315 construction not taken place; there would have been 0 to 4 percent less suspended sediment on a yearly basis.

Suspended-sediment yields are shown in table 14. Highway-construction yields for this study fall within the range of yields cited in table 1. Suburban residential yields for this study are lower than the urban yield cited in table 1. This may be due to the suburban, rather than urban character of the lower Olentangy drainage basin. Overall net suspended-sediment yields between sites A and G are on the same magnitude of those for urban residential areas cited previously.

Effects of Channel Realignment

On November 27, 1978, the Olentangy River was permanently diverted through a 0.2-mile-long manmade section of channel to the east of the river's natural channel (fig. 1). Highway construction was then begun near the natural channel. Discharge measurements and discharge-weighted sediment samples were obtained 300 feet below the new channel section, as well as at both ends of the study reach (sites A and G). In figure 3, these data for site G are shown.

Table 15 presents the daily totals of suspended-sediment load at the three sites for November 27 through 29. No storm event occurred during this time, therefore, any sudden changes in streamflow or sediment concentration at the downstream site (G) are due to the channel-opening process. Streamflow and sediment concentrations at the upstream site (A) did not change during this time.

The daily suspended-sediment yield reported in table 15 for the Worthington gage was multiplied by 518 mi^2 to estimate the background sediment load expected at site G, had the new channel section not been opened (table 15). At site G, 25.8 tons of sediment passed as a result of the channel realignment. This began at 1000 hours on November 27, 1978, and ended by 0200 hours on November 29, 1978, when concentrations returned to pre-opening levels. The load due to the channel realignment was 85 percent of site G's suspended load for that time period, and 26 percent of the suspended-sediment load for November 1978, a month low in sediment. It comprised 0.03 percent (or three ten-thousandths) of the sediment load at site G that water year, and 0.08 percent of the net yearly load between sites A and G.

Table 14.--Suspended-sediment yield by source, water years 1979-81

[All values are in tons per square mile]

	Source			
Month	Construction	Suburban	Erosion + other	G-A
OCT 78	--	4	--	2
NOV 78	--	3	--	3
DEC 78	--	15	--	61
JAN 79	--	27	--	69
FEB 79	--	61	--	8
MAR 79	--	9	--	27
APR 79	--	51	--	649
MAY 79	--	5	--	28
JUNE 79	--	18	--	25
JULY 79	226	13	7	22
AUG 79	2914	124	-13	137
SEPT 79	3981	424	104	560
OCT 79	400	2	14	19
NOV 79	4694	52	482	576
DEC 79	2466	19	-188	-147
JAN 80	2855	23	-69	-20
FEB 80	1285	19	-42	-12
MAR 80	1897	33	385	435
APR 80	0	21	1174	1195
MAY 80	10	56	113	168
JUNE 80	2107	83	139	240
JULY 80	0	55	739	793
AUG 80	182	64	137	202
SEPT 80	0	1	2	3
OCT 80	0	4	6	10
NOV 80	0	5	0	5
DEC 80	0	3	-21	-19
JAN 81	0	1	-12	-11
FEB 81	0	91	177	267
MAR 81	0	3	39	42
APR 81	0	153	1830	1982
MAY 81	0	133	2248	2379
JUNE 81	0	167	2894	3060
JULY 81	0	23	1	23
AUG 81	0	4	2	7
SEPT 81	0	19	90	109
Water year				
WY1979	9579	754	755	1589
WY1980	15743	428	2888	3454
WY1981	0	606	7255	7855

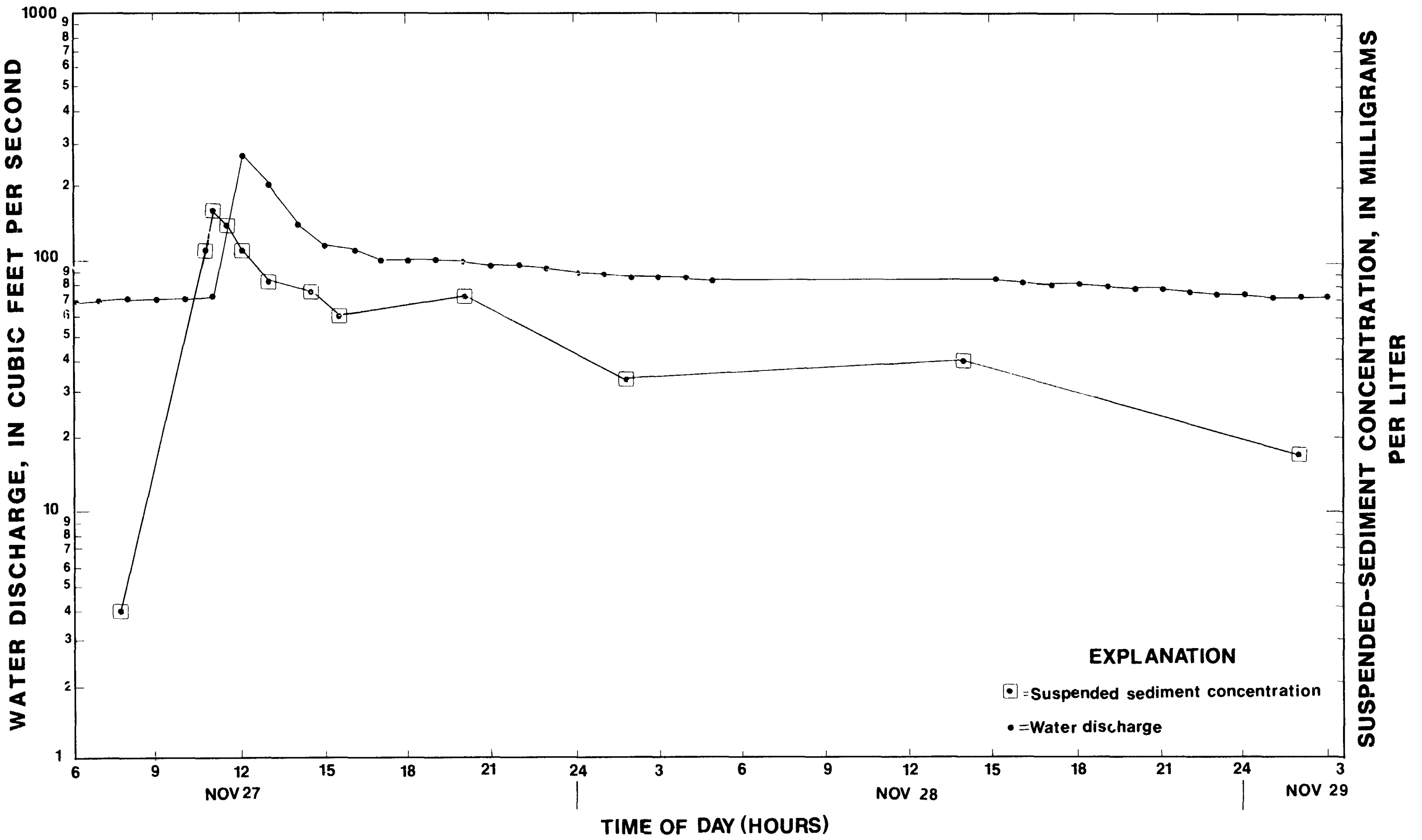

Figure 3.--Water discharge and sediment concentration at site G during channel opening.

Table 15.--Suspended-sediment load during channel realignment (in tons)

[Total due to new channel = 25.8 tons]

Data-collection site or type of data	11/27	11/28	11/29
Site A	2.8	1.8	1.8
300 feet below new channel	29.6	16.6	--
Site G	20.0	8.4	4.1
Site G background load	2.9	1.9	1.9
Tons due to new channel	17.1	6.5	2.2

SUMMARY AND CONCLUSIONS

1.--Suspended-sediment loads were greater downstream of the project area than upstream. A typical monthly net difference was 2,733 tons, or 130 tons per square mile per month. This is much higher than the 185 tons per square mile per year calculated as a national average for higher-order streams (Curtis and others, 1973). It is similar to yields from urban residential areas cited in previous reports. Yields (tons per square mile) from the highway construction site were within the range of those found in previous studies. Suburban residential yields were lower than yields from urban residential areas studied previously.

2.--The net suspended-sediment load was low in months of low precipitation and streamflow. Highest loads were carried during months of high streamflow.

3.--Three distinct groups of stations were differentiated on the basis of suspended-sediment yields per square mile per month. Lowest was the station upstream of Columbus (site A). Yields were intermediate at the downstream station (site G), for the suburban drainage above the construction site (site D), and at drainage below the highway construction (site E). Only the lower 2 percent of the drainage basin at site E underwent construction. Highest yields were from two suburban drainage basins (site C and F).

4.--Monthly suspended-sediment loads at site G would have been 0 to 19 percent lower, had no highway construction taken place. The SR 315 construction added 0 to 4 percent of the yearly suspended sediment at site G compared with 8 to 47 percent at site G from suburban residential runoff.

5.--Realignment of the Olentangy River channel produced 25.8 tons of suspended sediment over a 48-hour period. This was equivalent to 85 percent of the suspended load at site G for that 48 hours, but only 0.03 percent of the suspended sediment carried past site G in water year 1979, or 0.08 percent of the net load added within the study reach for that water year.

6.--Suspended sediment produced by the SR 315 construction during the project period, although high on a per-drainage-area basis, was small in comparison to the amounts received by the Olentangy River from nonpoint suburban runoff and other sources.

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