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SEDIMENT LOADS IN CANALS 18, 23, AND 24 IN SOUTHEASTERN FLORIDA

By

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ABSTRACT

Suspended-sediment concentrations and suspended-sediment discharges were determined in selected canals in St. Lucie, Martin, and Palm Beach Counties, in southeastern Florida. Sediment rating curves were developed to relate water discharge to sediment concentration at the three sites sampled. An evaluation of the concentration and sediment loads shows that larger amounts of suspended sediment were being carried into the St. Lucie River estuary than were being carried into the Loxahatchee River estuary.

Peat and muck soils in areas drained for agricultural planting and citrus cultivation are readily carried by runoff waters into the major canals that traverse the region.

INTRODUCTION

The amounts of sediment discharged into tidal estuaries have been the subject of increasing concern to those interested in the changes in the economic, natural, and esthetic conditions of estuarine environments. Although relatively detailed studies have been made in other coastal areas, little or no information has been obtained in south Florida.

The purpose of this report is to present the results of an investigation on suspended sediment loads carried by three canals in southeastern Florida. Sediment, discharge, and stage data were collected during a normally high discharge period, July to November, 1969, from Canals 23 and 24, which discharge into the St. Lucie River estuary, and from Canal 18, which discharges into the Loxahatchee River estuary.

The investigation was made by the U.S. Geological Survey in cooperation with the Central and Southern Florida Flood Control District. The daily discharges for the three canals during the investigation, as well as the instantaneous discharges at the time the sediment samples were collected, were furnished by the Flood Control District.

PURPOSE AND SCOPE

The primary objective of the investigation was to provide data on the particle size and volume of the suspended sediment transported by three major canals that discharge into the estuarine environments of the St. Lucie River and the Loxahatchee River.

A secondary objective was to determine what percentage of the total yearly suspended sediment load could be expected to have been discharged during the period studied. The 20 weeks of the investigation represent 38 percent of the year, during which time more than 60 percent of the total yearly discharge of water was recorded.

The project also provided the opportunity to relate sediment tonnage discharged to unit area drained and to volume of water discharged from that area.

AREA OF INVESTIGATION

The area investigated includes parts of St. Lucie, Martin and Palm Beach Counties along the southeast coast of Florida, as shown in figure 1.

Fig. 1 near here

The area is drained by four major canals that discharge into the St. Lucie River and the Loxahatchee River, which enter tidal estuaries near Stuart and Jupiter, respectively. Canal 18 drains the south part of the area, and Canals 23 and 24 drain the north part. Figures 2, 3, and 4 show the boundaries of the basins drained by the three canals and the land use in the basins. The investigation did not include St. Lucie Canal, which carries drainage from its basin and inflow from Lake Okeechobee.

Figs. 2, 3, & 4 near he

The average annual rainfall ranges from 65 inches in the south part of the area to about 53 inches in the north part. Rainfall usually occurs in short intense afternoon showers during the summer and as a slow drizzle of longer duration during the rest of the year.

Rainfall records for Stuart show that the average monthly rainfall from December through June is 3.8 inches and from July through November, 6.2 inches.

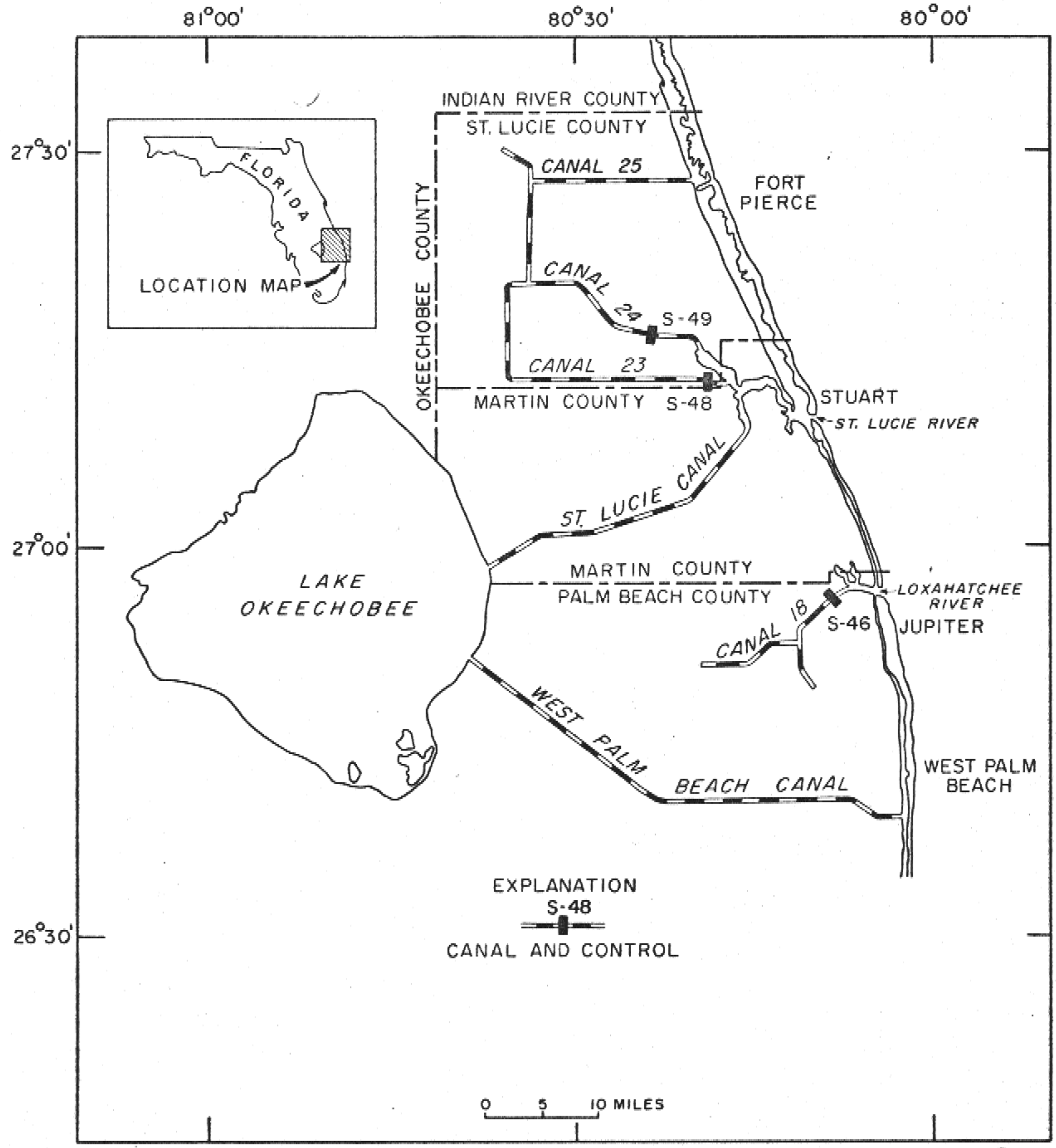

Figure 1.--Map of southeastern Florida showing the area of investigation.

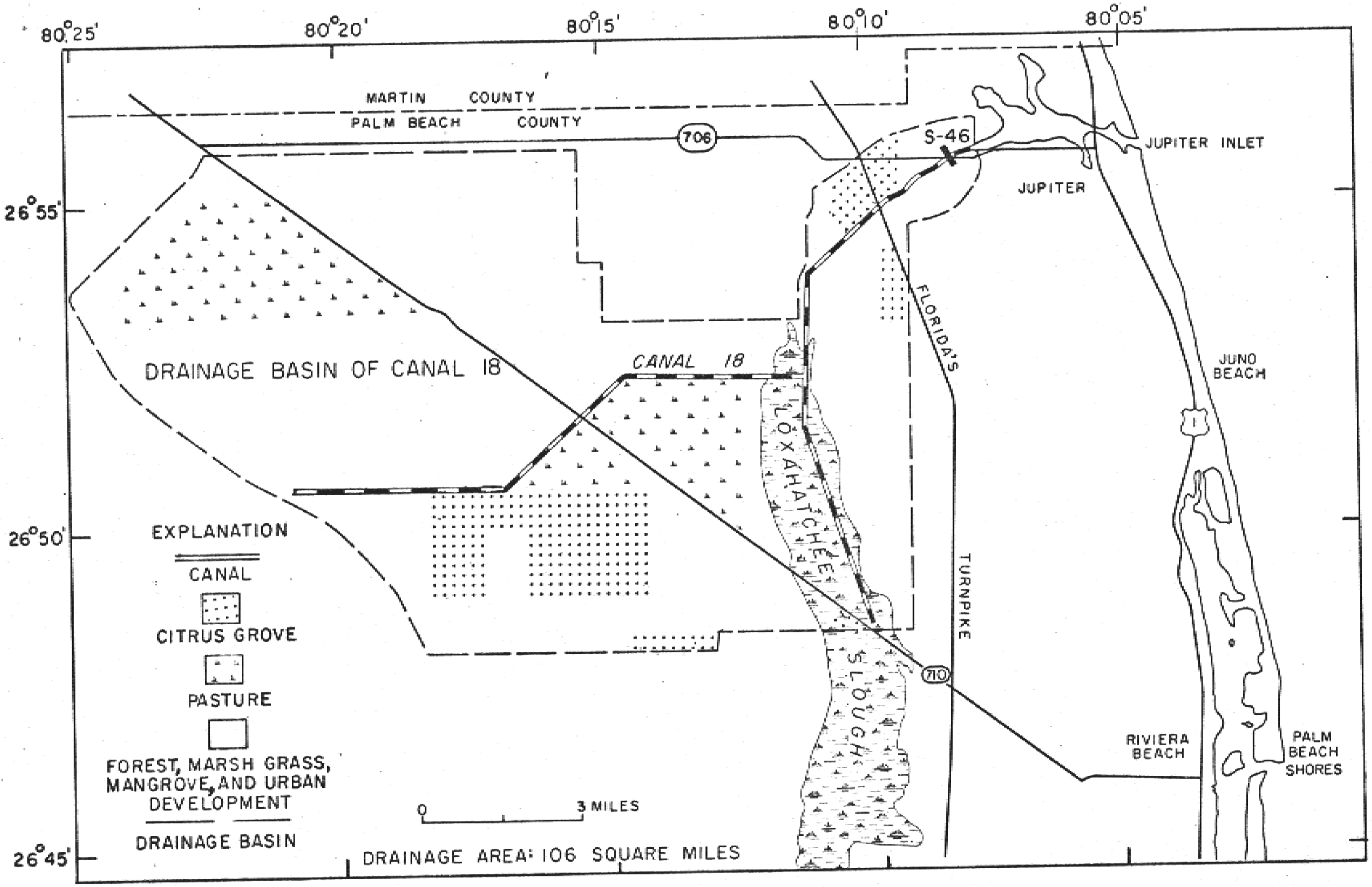

Figure 2.--Map of the drainage basin of Canal 18 showing the land use

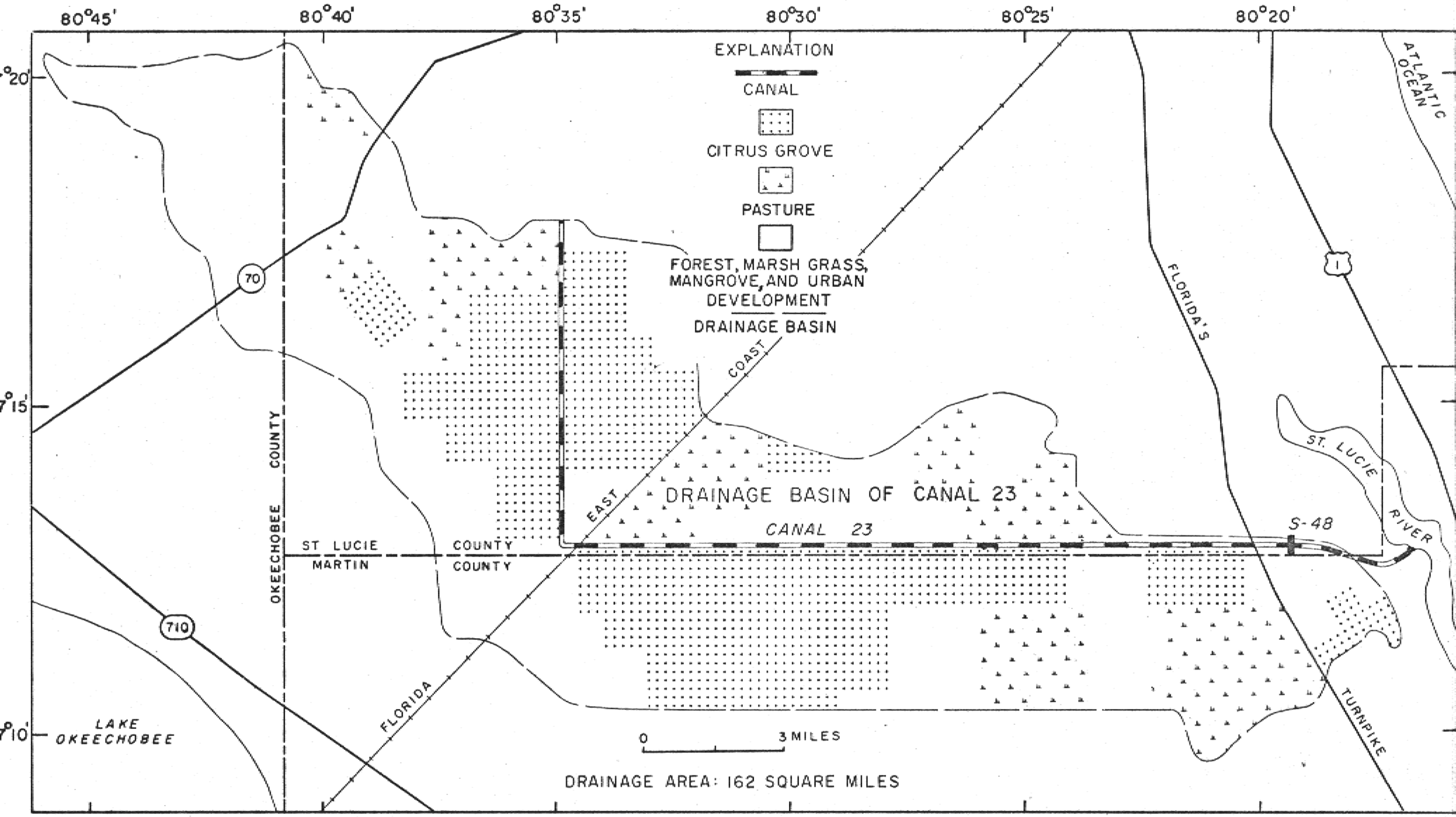

Figure 3.--Map of the drainage basin of Canal 23 showing the land use

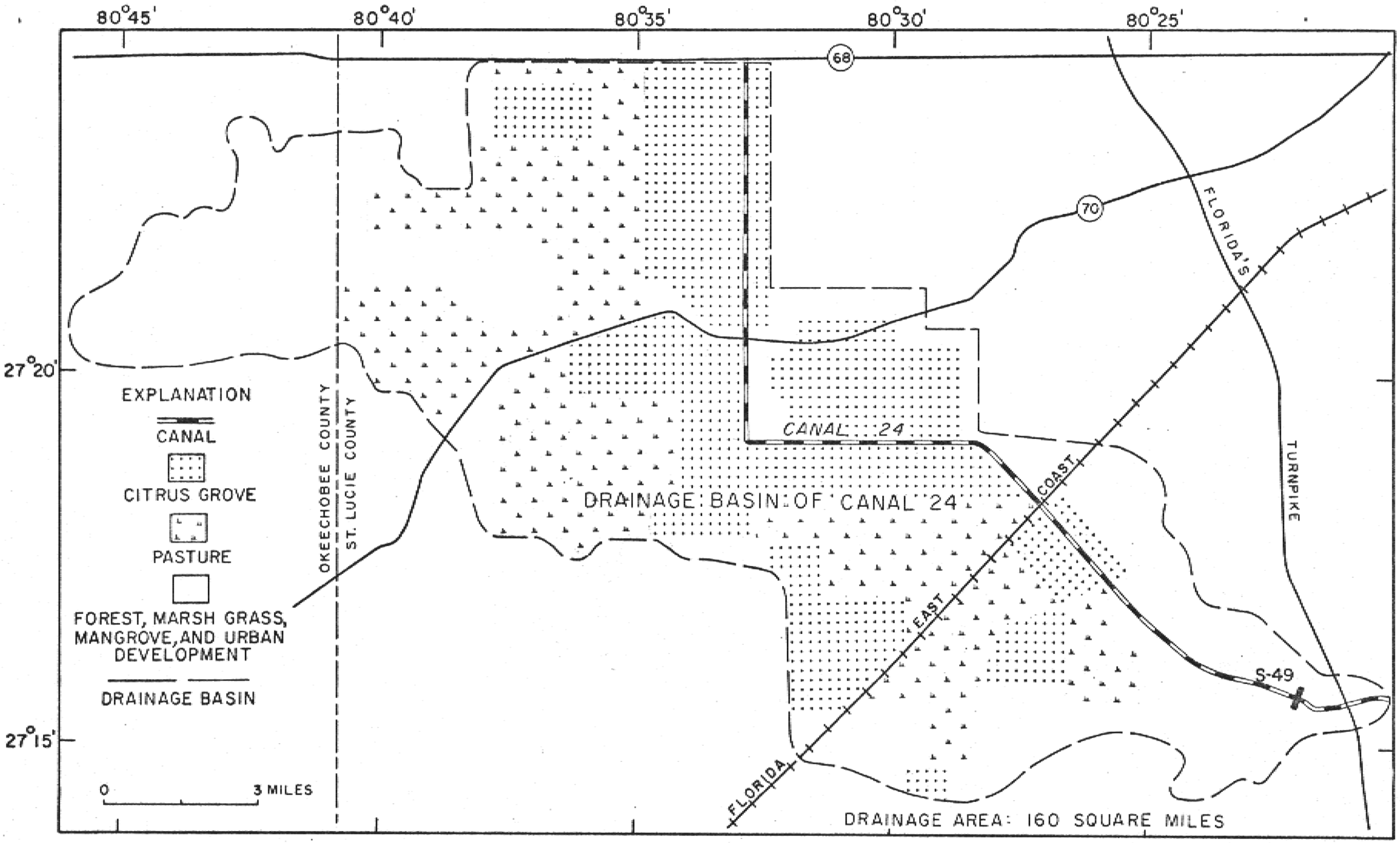

Figure 4.--Map of the drainage basin of Canal 24 showing the land use

The elevation of the land surface ranges from a few feet above mean sea level along the coast to 57 feet at the southwest corner of St. Lucie County. The entire area is of low relief, with the exception of an area of rolling terrain north of Jupiter.

Thirty to 35 percent of the land is presently (1970) used for pasture and 20 to 25 percent for citrus groves and truck farming. About 30 percent of the total area is forest and marsh grass, and the remainder is occupied by urban development and coastal mangroves. (See figs. 2-4).

Natural vegetation consists of cypress trees, pond grass, and sawgrass in the flatwoods and grass in the area of higher elevation. The soils are poorly drained sands or loamy sands that overlie limestone; the soils are covered with the characteristic peat and muck present throughout much of the area. This organic deposit is thickest in the north reaches of the area investigated and near Lake Okeechobee.

The natural drainage pattern has been changed considerably by the construction of hundreds of small flood control and drainage canals. These canals crisscross the area and finally empty into the major drainage canals shown in figure 1. The canals cut into the upper layers of a shallow water-table aquifer consisting mostly of sand and shell beds of the Pamlico Sand that overlie layers of sandy limestone of the Anastasia Formation. These upper layers are of low permeability, when considered as a water-yielding zone, but they are permeable enough to absorb most of the rainfall, thus reducing surface runoff. The canals are generally fed by ground water discharged directly into them and by whatever surface runoff reaches them.

Operation of the canal system is solely for the purpose of flood control and drainage during the wet season and for water management during the dry season. The canal system has made possible the development of extensive agricultural areas.

Increasing water requirements have brought about a plan to backpump water from the canals into Lake Okeechobee during high water levels for later release to agricultural lands during dry periods.

SAMPLING SITES AND PROCEDURES

Depth-integrated samples of canal water were obtained weekly at each of three stations on random days from the first week in July 1969 to the second week in November 1969. Canal 18 was sampled at the center and the downstream side of the bridge on State Road 706 approximately 300 feet upstream from Control Structure 46. (see fig. 2.) The sampler was lowered and raised at a constant rate with a crane-mounted sounding reel. Canal 23 was sampled near the middle of the canal at the protective cable about 500 feet upstream from Control Structure 48 (see fig. 3). The sampler was lowered and raised from a boat using a sounding reel. Canal 24 also was sampled from a boat at the protective cable approximately 600 feet upstream from Control Structure 49 (see fig. 4).

Samples were collected with a depth-integrating U.S.D.H. 59 suspended sediment sampler with a quarter-inch diameter nozzle. This nozzle allowed an intake velocity to the sampler that was approximately equal to the velocity in the canal, and, as a pint bottle was used, the horizontal length of sample filament was almost 50 feet.

Early in the investigation, samples were collected at one-third, one-half, and two-thirds of the width of each canal, but the analyses of these samples showed that the sediment concentration was the same for each sampled point of the cross section at all three sites. Therefore, for the remainder of the investigation, samples were collected at the center of the canals only.

Samples were analyzed by the U.S. Geological Survey laboratory in Ocala, Florida. The gravimetric method was used for the determination of sediment concentration, and the bottom withdrawal tube method together with sieve analyses were used for the particle-size determinations. Detailed explanations of the laboratory techniques used in water quality, sediment concentration, and particle-size determinations may be found in the references listed at the end of this report.

RESULTS OF INVESTIGATION

Graphs of weekly measurements of gage height, discharge, and sediment concentration for Canal 18 are shown in figure 5. Except from August 24 to September 4 and September 17 to 24, there is a direct relationship between discharge and sediment concentration for Canal 18. This relationship, however, is variable, as indicated by different sediment concentrations for the same discharge at different times. No relationship between gage height and sediment concentration is apparent from figure 5, probably because gate operations at Structure 46 prevented any direct relationship between gage height and discharge.

Fig. 5 near here

Structure 48 on Canal 23 is a fixed crest dam with no gates. Water levels were above the crest of Structure 48 during July 1 to November 15, 1969.

The graphs for Canal 23 (fig. 6) show in general a direct relationship between sediment concentration, gage height, and discharge. The sediment concentration deviates slightly from the general relationship during July 29 to August 4, August 30 to September 4, and September 29 to October 7.

Fig. 6 near here

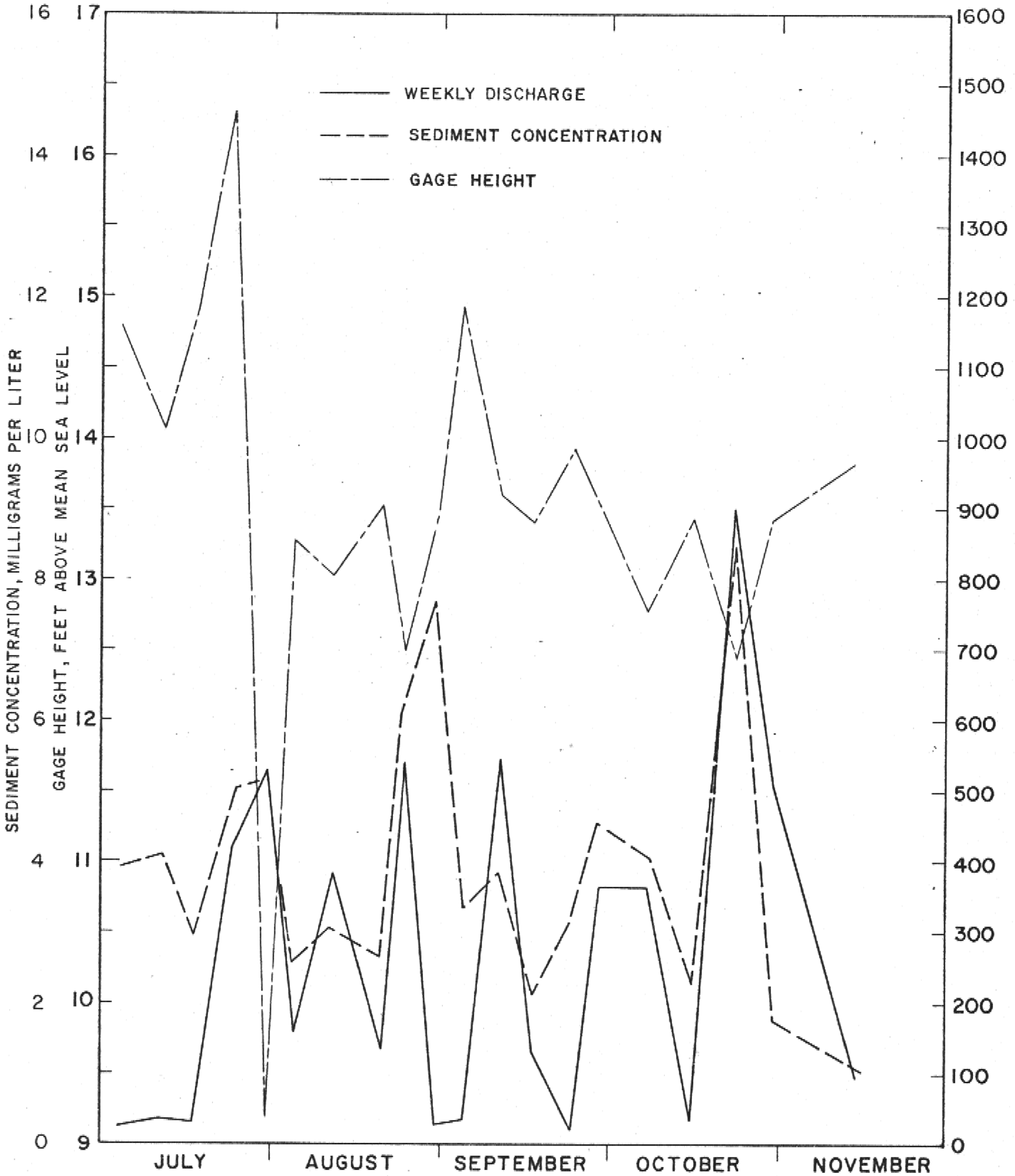

Figure 5.--Graphs of weekly discharge, gage height, and sediment concentration for Canal 18 near Structure 46.

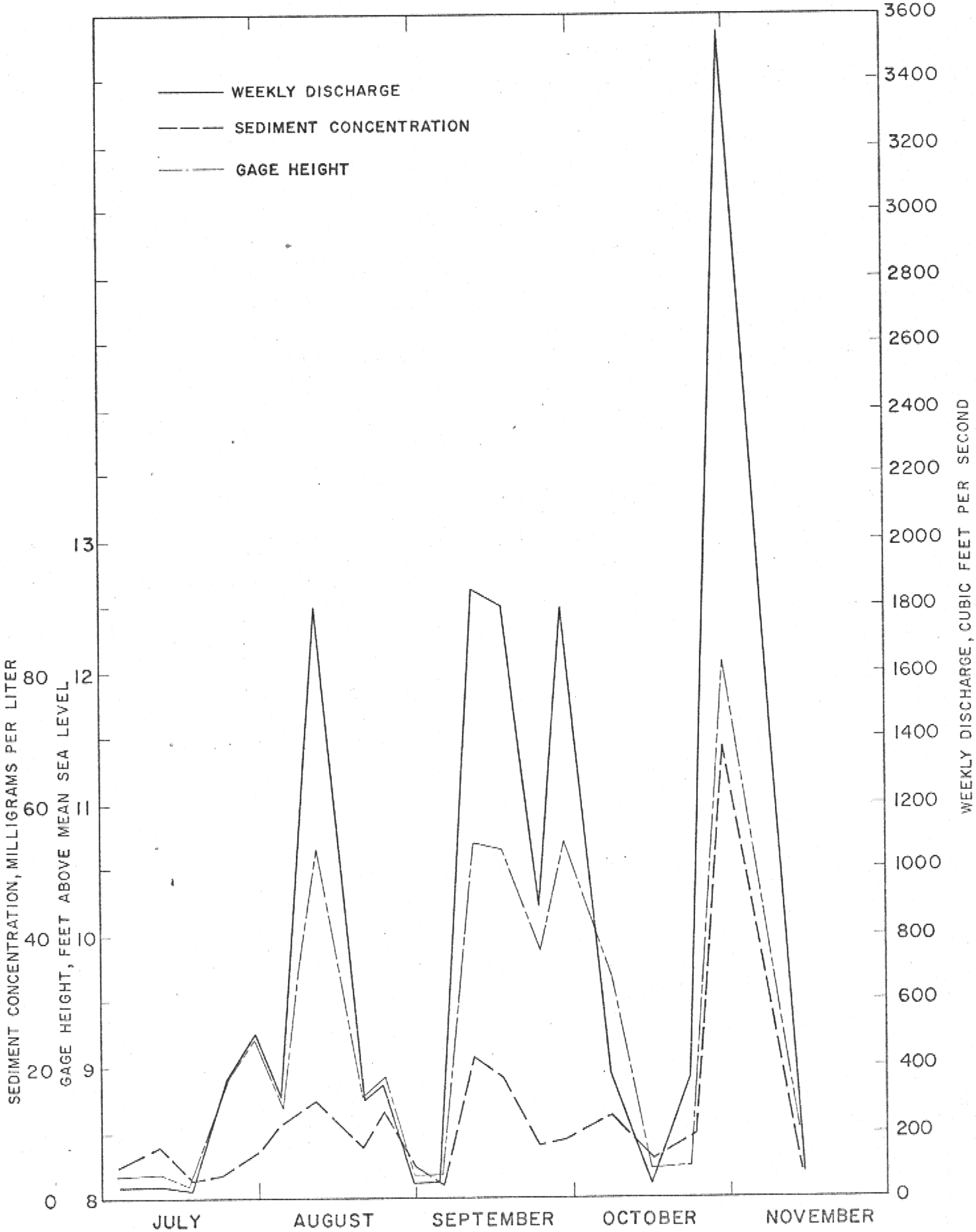

Figure 6.--Graphs of weekly discharge, gage height, and sediment concentration for Canal 23 near Structure 48.

The graphs for Canal 24 are shown in figure 7. At Canal 24 a direct relationship exists between discharge and sediment concentration, except for July 3-11 and July 17-24. The operations of the gate at Structure 49 also prevent a direct relationship between gage height and discharge.

Fig. 7 near here

Curves of sediment concentration versus discharge were developed for all three canals. (See figs. 8-10.) These curves show the maximum, minimum, and median sediment concentration that may be expected for a given discharge. Particle-size analyses were run on two samples collected at each site. One sample was collected during low flow and the other during high flow.

Figs. 8, 9 & 10 near here

The results of the particle-size analysis for a sample from Canal 18 are shown in figures 11 and 12, from Canal 23 in figures 13 and 14, and from Canal 24 in figures 15 and 16.

Figs. 11 & 12 near here

Figs. 13 & 14 near here

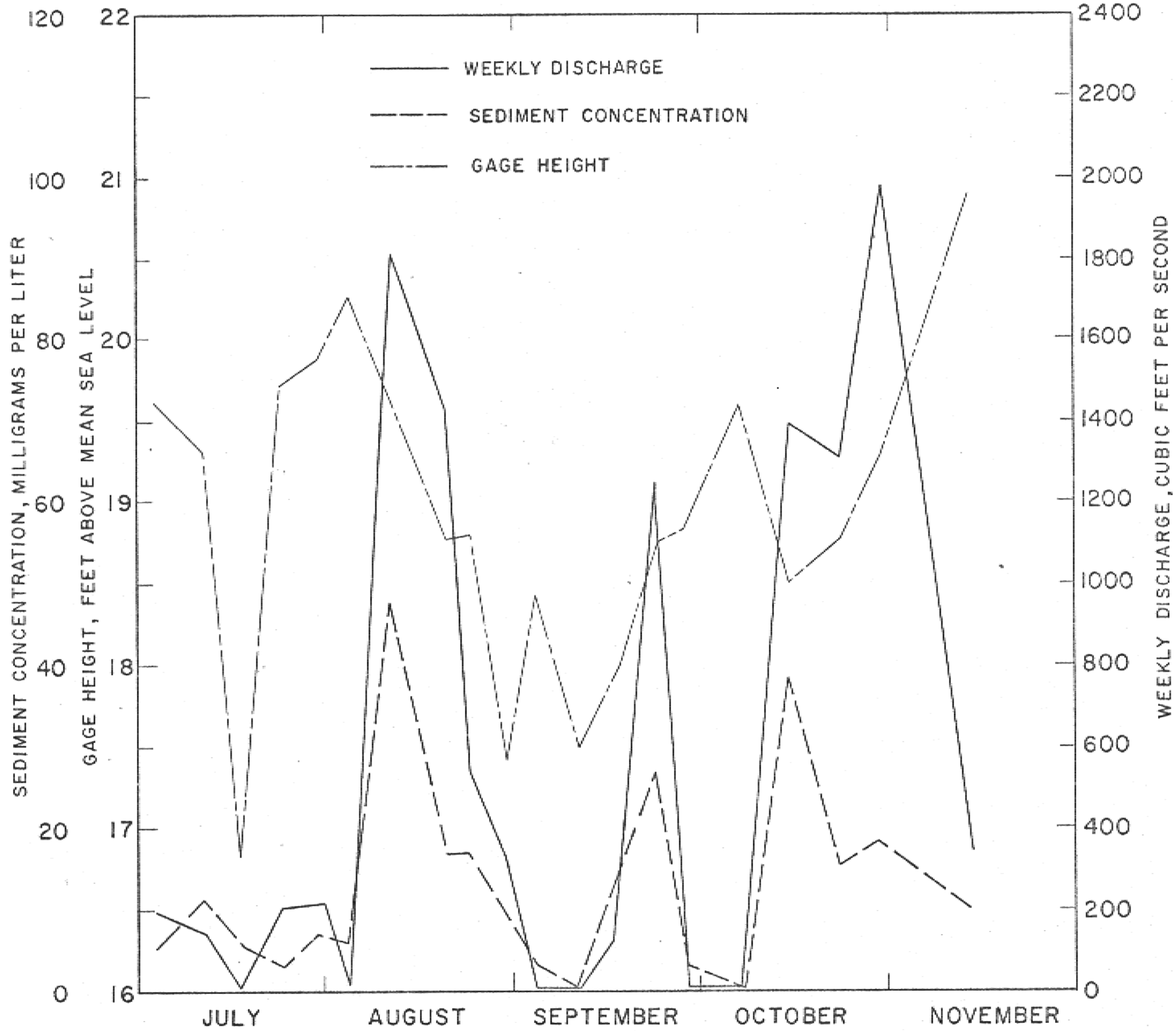

Figure 7.--Graphs of weekly discharge, gage height, and sediment concentration for Canal 24 near Structure 49

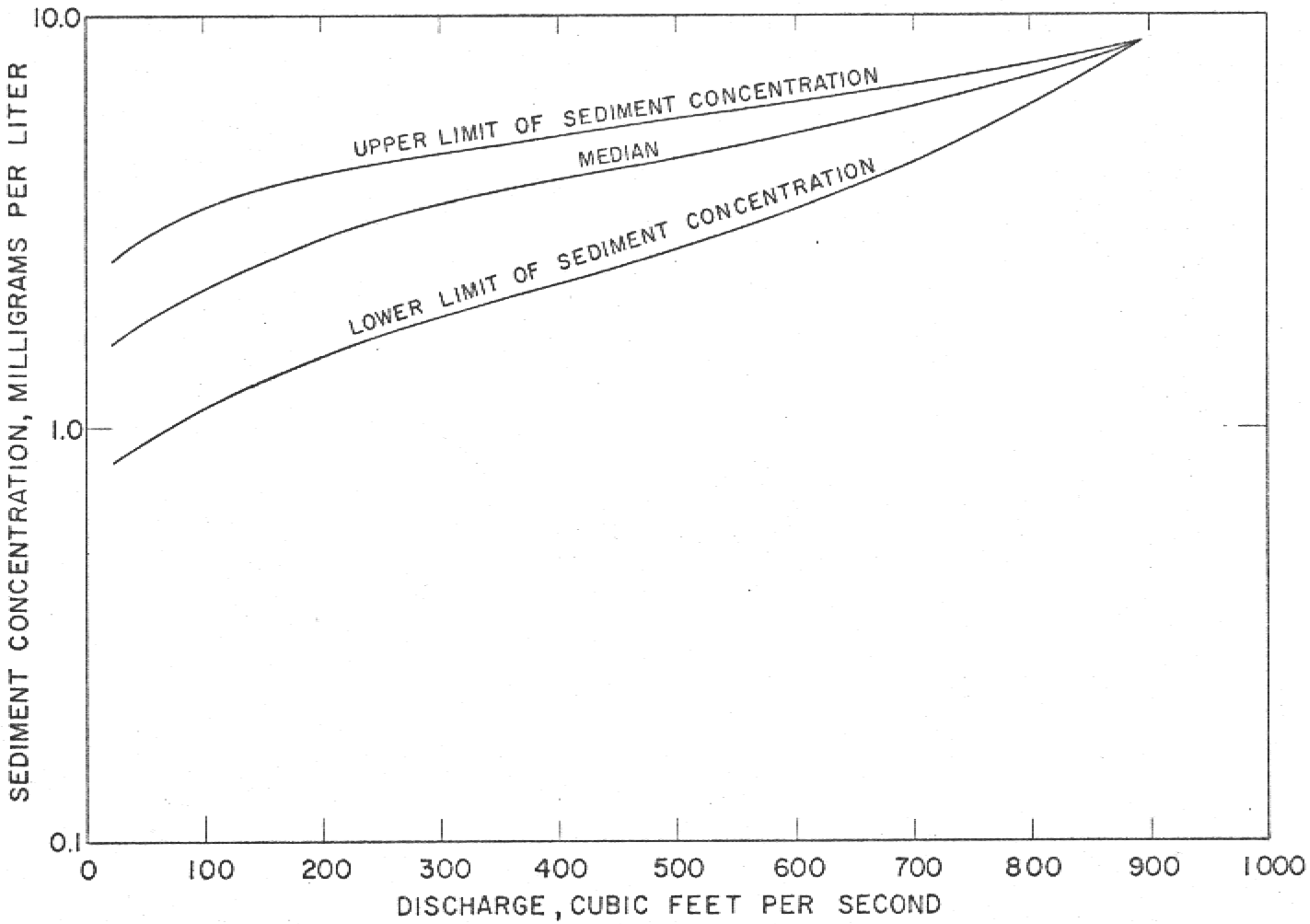

Figure 8.--Suspended sediment transport curve for Canal 18 near Structure 46.

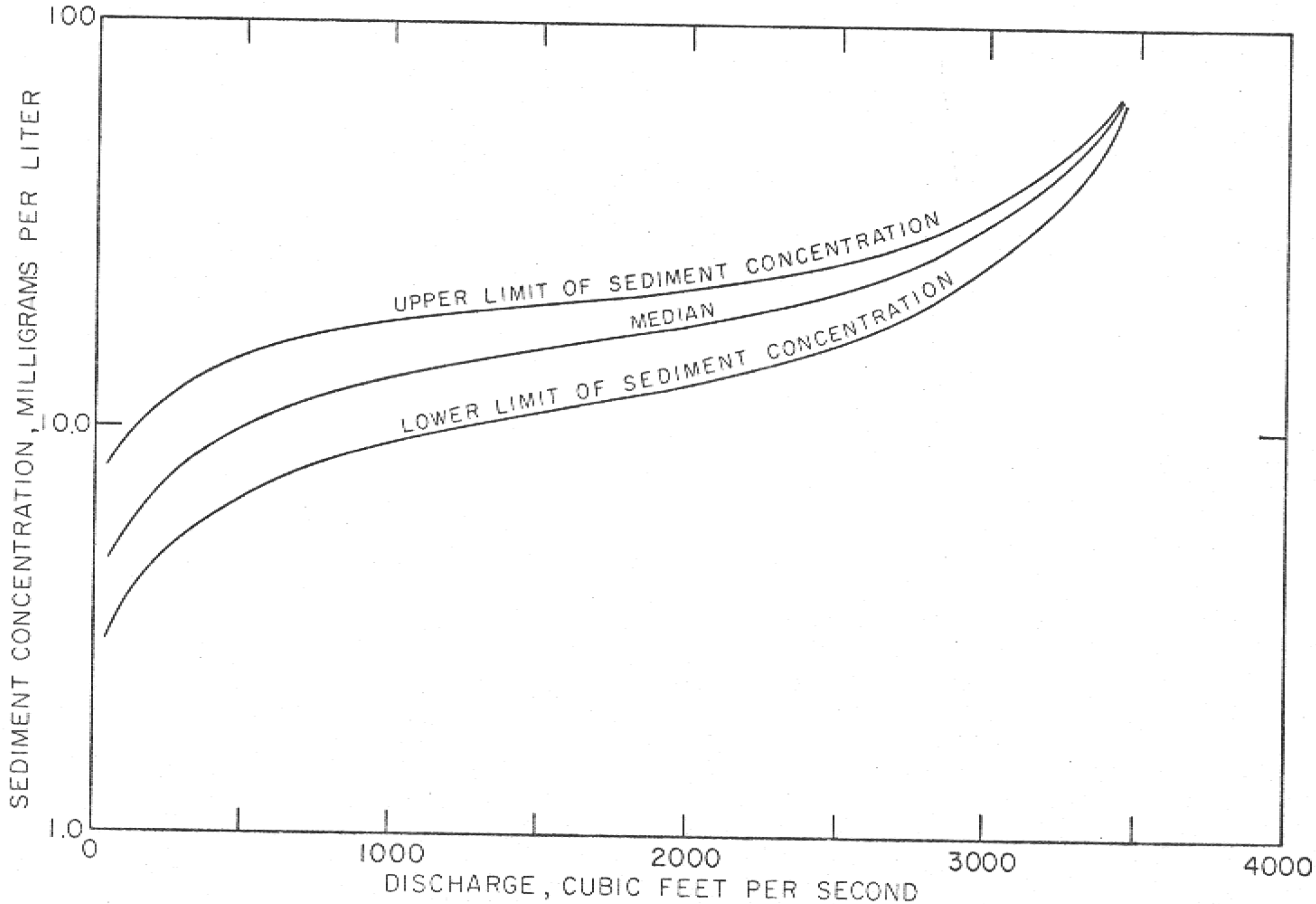

Figure 9.--Suspended sediment transport curve for Canal 23 near Structure 49.

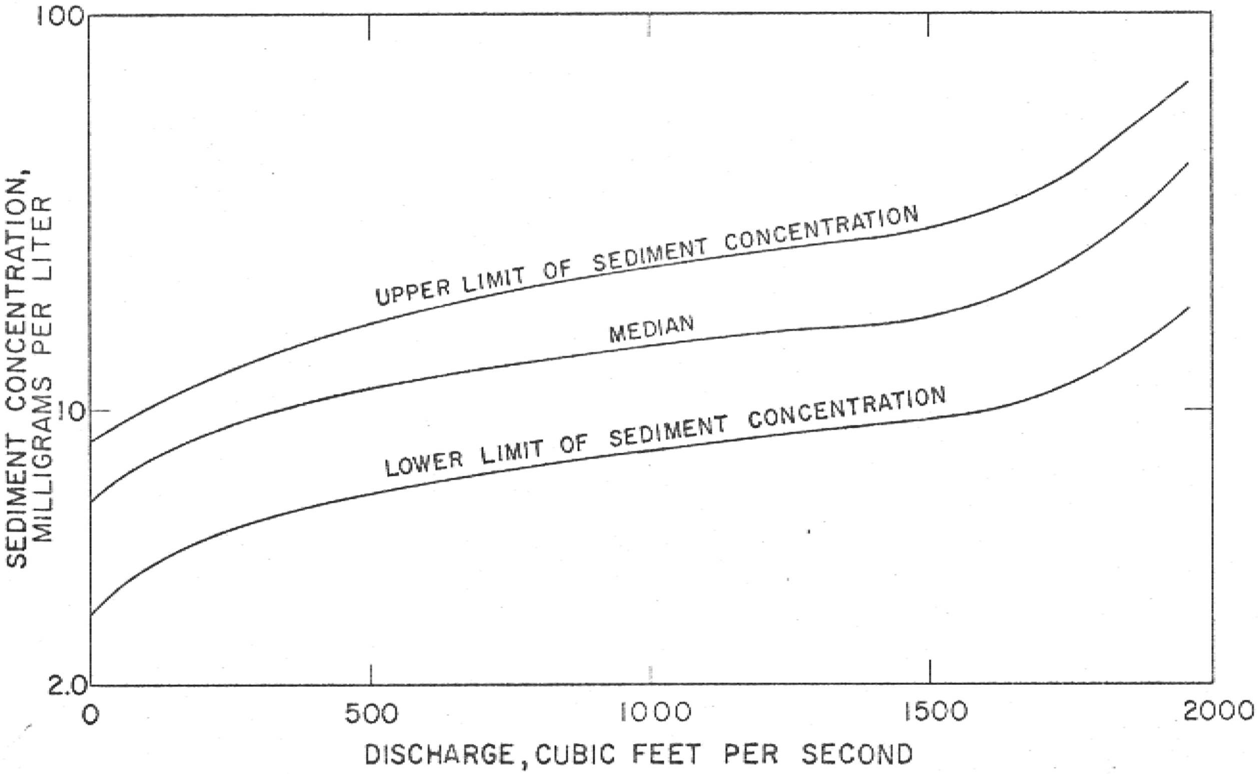

Figure 10.--Suspended sediment transport curve for Canal 24 near

Structure 49.

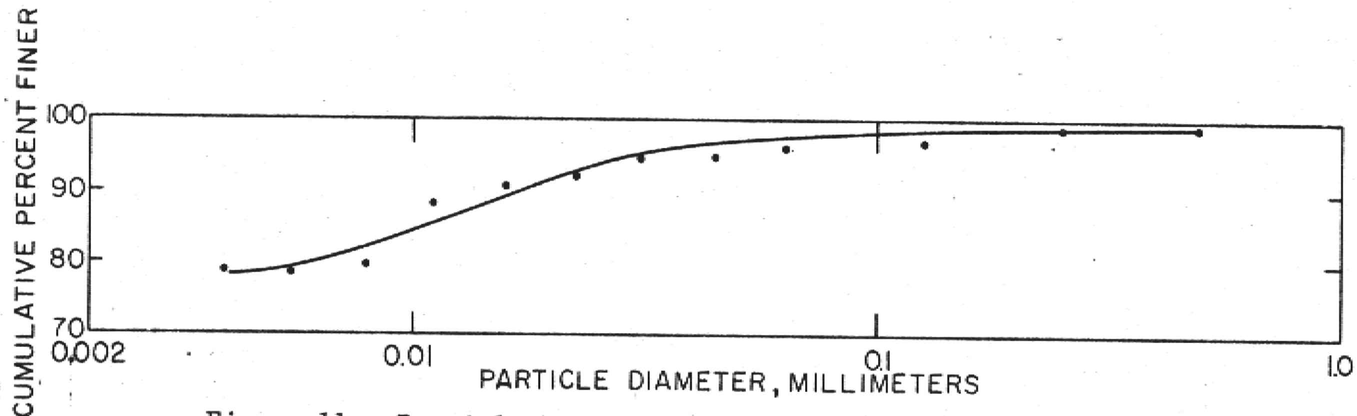

Figure 11.--Particle size distribution for a sediment sample from Canal 18 near Structure 46 during a low flow period.

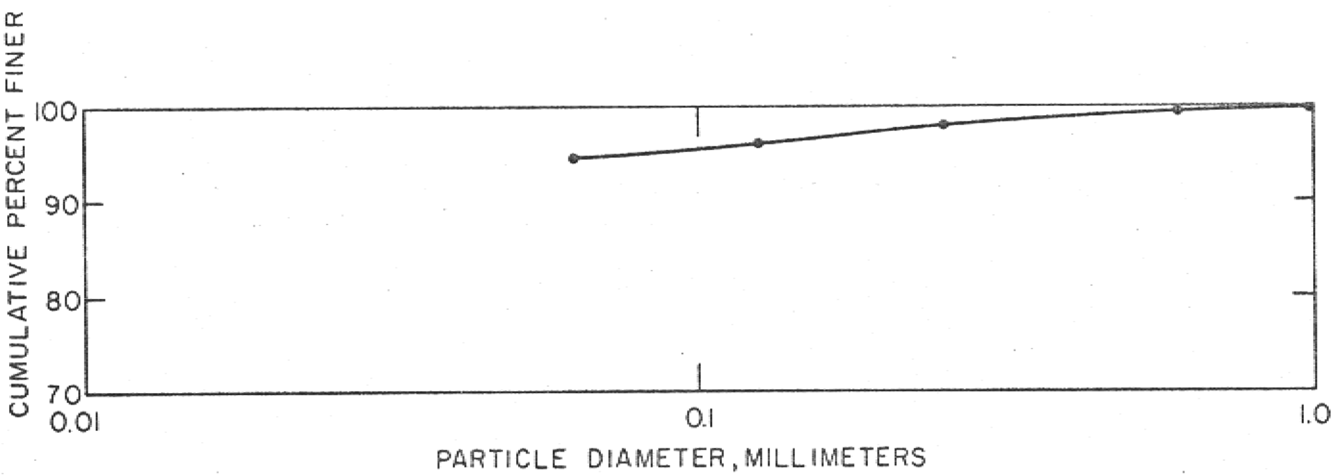

Figure 12.--Particle size distribution for a sediment sample from Canal 18 near Structure 46 during a high flow period.

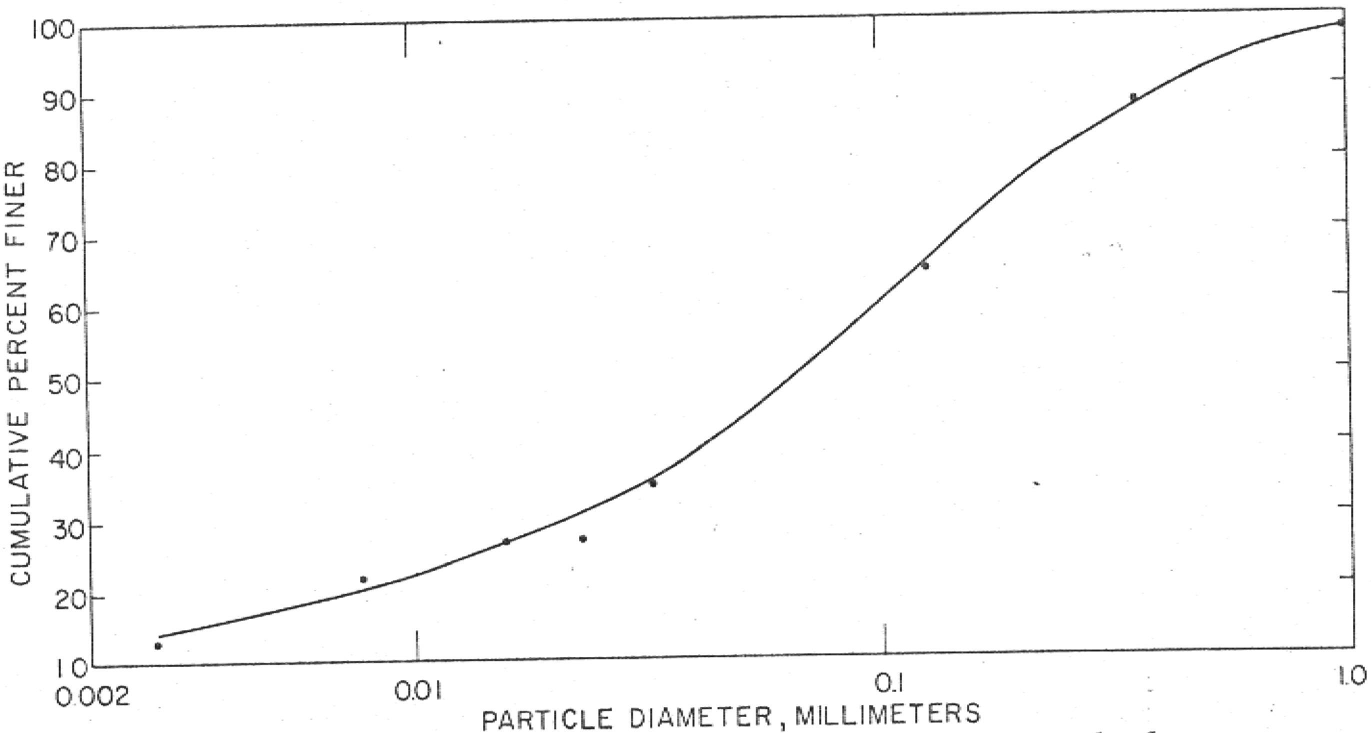

Figure 13.--Particle size distribution for a sediment sample from Canal 23 near Structure 48 during a low flow period.

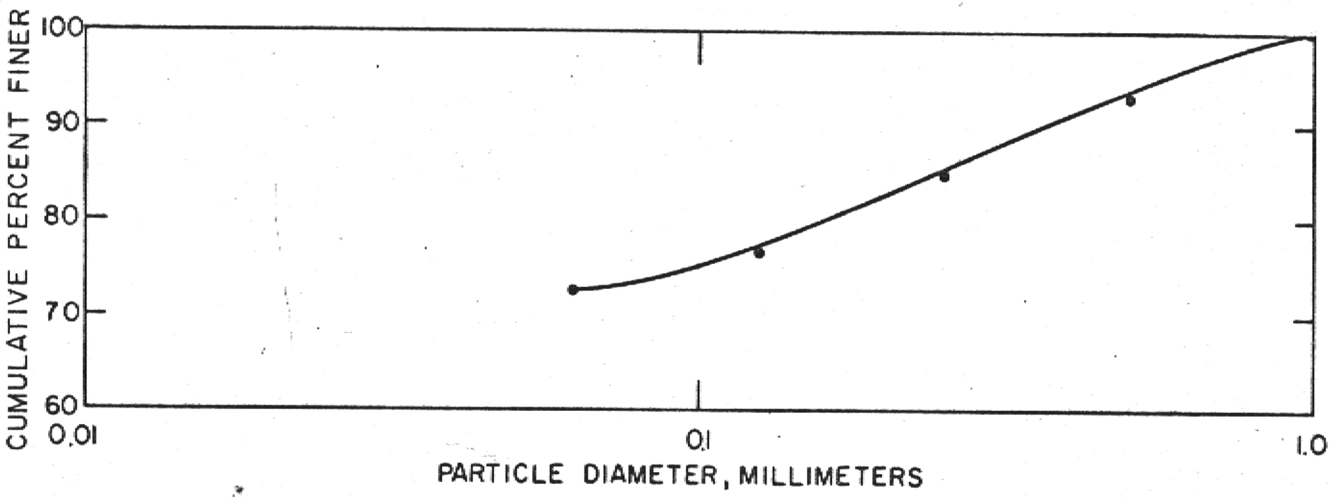

Figure 14.--Particle size distribution for a sediment sample from Canal 23 near Structure 48 during a high flow period.

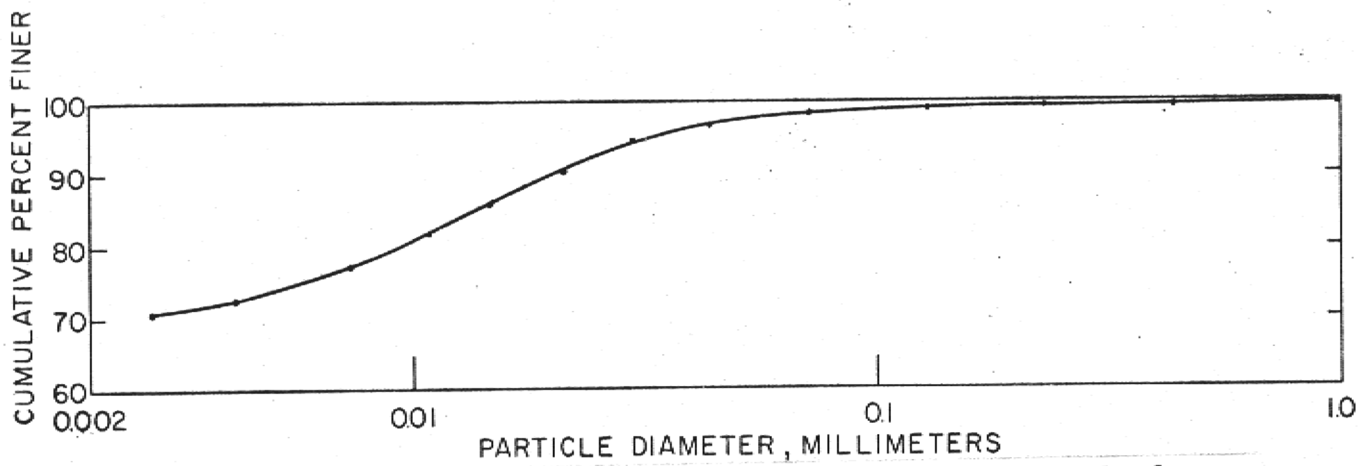

Figure 15.--Particle size distribution for a sediment sample from Canal 24 near Structure 49 during a low flow period.

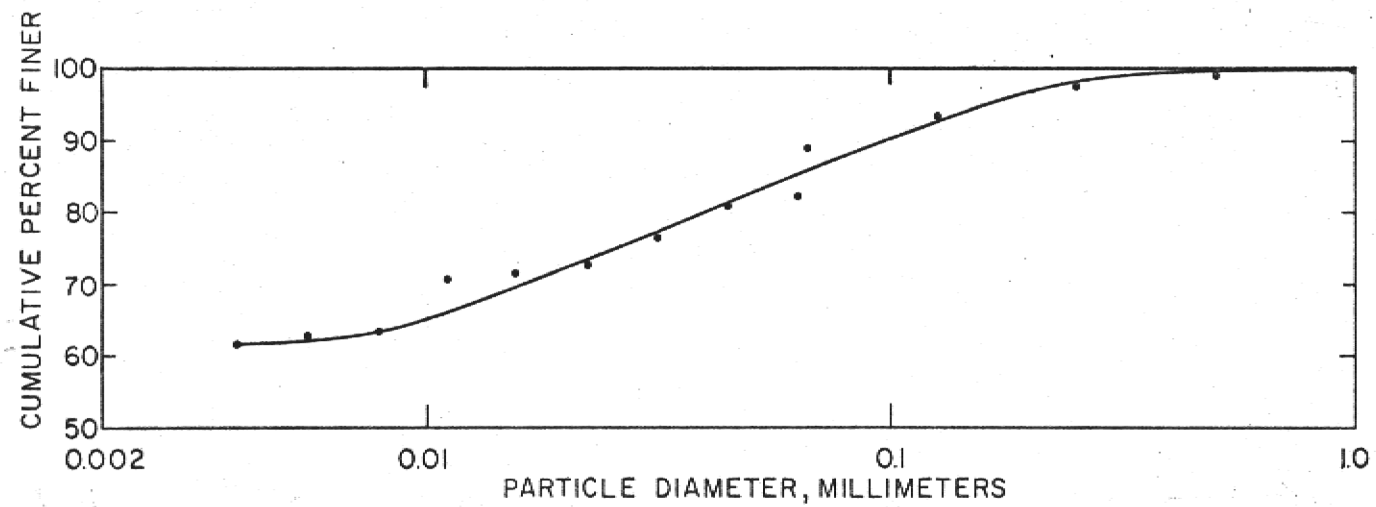

Figure 16.--Particle size distribution for a sediment sample from Canal 24 near Structure 49 during a high flow period.

The Subcommittee on Sedimentation Terminology of the American Geophysical Union (Lane and others, 1947, p. 337) classifies sediment by particle size as follows:

Clay Size:	Smaller than 0.004 mm
Silt Size:	Between 0.004 and 0.062 mm
Sand Size:	Between 0.062 and 2.0 mm

The table below lists the particle-size distributions of the suspended sediment collected from the three canals.

The similarity in size distribution of suspended particles at low and high discharges and, consequently, at different velocities, indicates a uniform vertical distribution of sediments in the canals. This is because the whole suite of sediment sizes must be in suspension even at low velocities for that similarity to exist when the velocities are high.

Sampling Site	Date	Instantaneous Sediment Concentration (milligrams per liter)	Discharge (cubic feet per second)	Particle Size (percent finer than)					
				1mm	0.5mm	0.25mm	0.125mm	0.0625mm	0.004 mm
anal 18 near S-46	July 11, 1969	0.2	Leakage	100	100	99	97	96	79
anal 18 near S-46	Oct. 15, 1969	4	170	100	100	98	96	95	86
anal 23 near S-48	July 11, 1969	6	40	100	93	85	77	73	66
anal 23 near S-48	*Oct. 15, 1969	8	170	95	91	75	64	48	16
Canal 24 near S-49	July 11, 1969	11	140	100	100	99	99	98	72
Canal 24 near S-49	Oct. 15, 1969	38	1,380	100	99	98	94	82	61

* Data incomplete; sediment would not settle.

Except for the particle-size data listed for the sample collected October 15, 1969, from Canal 23 at S-48, the table shows that the sediment concentration and discharge have little to do with particle-size (mostly clay-size) of the sediment. The particle-size data for this sample are anomalous because the sediment would not settle during analysis; the weight of the segment withdrawn from the bottom of the sedimentation tube was deficient by the amount remaining in suspension.

A study of the chemical analyses of these samples shows that there is no apparent relationship between sediment concentration and most chemical constituents.

Low iron concentrations and high color units, suggest the presence of organic compounds in the water. This is further indicated by the appearance of the samples at the time of collection and during analysis in the laboratory. Of the three sets of samples, only the set taken from Canal 23 showed an increase in nitrate with increase in suspended sediment. Two of the three sets of samples showed an increase in sulfate with increases in sediment concentration. Nitrate and sulfate are end products of decomposition of organic plant protein. No tests were made of the sediment to determine its nature, but the fragmentary evidence strongly suggests its organic composition.

Table 1 shows the results of chemical analyses of water samples taken from Canals 18, 23 and 24 at the sites of the control structures.

Table 1 near here

Tables 2, 3, and 4 show the daily mean discharge, sediment concentration, and tons per day of sediment for Canals 18, 23, and 24 respectively.

Tables 2, 3 & 4 near here

The monthly and annual water discharge for Canals 18, 23 and 24 for 1963-69 are shown in table 5. The discharge during July 1 to November 15 represents, on the average, about 70 percent of the total yearly discharge of Canal 18. During the 1969 calendar year the same period represented nearly 70 percent of the total. Similarly, for Canal 23, the discharge for July 1 to November 15 represents, on the average, approximately 60 percent of the yearly discharge, and for 1969 the discharge for the same period represented about 60 percent of the total flow for the calendar year. In Canal 24 the approximate percentages are 50 percent of the discharge on the average and 60 percent of the total flow for the 1969 calendar year.

Table 5 near here

Table 1.--Chemical analyses of water from Canals 18, 23, and 24.

Station	Date of collection	Discharge (cfs)	Silica (SiO_2)	Iron (Fe) ug/l	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved solids: Residue at 180°C	Dissolved solids: Calculated	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Temperature (°C)	Alkalinity as HCO_3	Alkalinity as CO_3	Alkalinity as $CaCO_3$	Sediment Concentration
C-18 at S-46	7-11-69	39	6.0	-	-	46	3.1	-	36	0.8	128	-	33	24	0.3	0.6	-	198	173	128	23	316	8.0	40	32	128	63	105	4
C-18 at S-46	10-15-69	37	4	70	-	29	3.8	-	12	0.8	88	0	4.8	19	0.2	0.6	-	154	117	88	16	225	7.2	40	27	88	43	72	3
C-23 at S-48	7-11-69	40	8.4	-	-	52	7.3	-	33	2.6	136	-	42	33	0.3	2.1	-	317	268	160	48	470	8.2	120	32	136	67	112	8
C-23 at S-48	10-15-69	50	7.8	260	-	46	5.7	-	24	1.9	116	0	30	43	0.3	0.6	-	283	217	139	44	418	7.4	160	27	116	57	95	6
C-24 at S-49	7-11-68	143	7.6	-	-	48	11	-	36	2.6	108	-	43	106	1.0	1.3	-	416	329	165	77	630	7.3	200	19.7	108	53	89	11
C-24 at S-49	10-15-69	1,360	1.0	250	-	40	6.0	-	28	1.6	92	0	31	56	0.5	1.1	-	267	211	125	48	402	7.5	120	27	92	45	75	38

Table 2.-- Daily mean discharge, sediment concentration, and tons per day of sediment for Canal 18.

Day	JULY			AUGUST			SEPTEMBER			OCTOBER			NOVEMBER		
	Discharge (cfs)	Sediment concen-tration (mg/l)	Sediment discharge (tons per day)	Discharge (cfs)	Sediment concen-tration (mg/l)	Sediment discharge (tons per day)	Discharge (cfs)	Sediment concen-tration (mg/l)	Sediment discharge (tons per day)	Discharge (cfs)	Sediment concen-tration (mg/l)	Sediment discharge (tons per day)	Discharge (cfs)	Sediment concen-tration (mg/l)	Sediment discharge (tons per day)
1	64	4	0.72	141	3	1.1	128	4	1.4	178	3	1.6	271	3	2.3
2	64	4	.72	152	3	1.1	142	4	1.6	267	4	2.8	300	3	2.6
3	67	4	.76	0	0	0	130	4	1.4	193	3	1.7	227	3	1.6
4	63	4	.71	212	3	1.7	131	4	1.4	262	4	2.6	315	3	2.6
5	63	4	.71	218	3	1.7	20	3	0.15	104	3	0.73	285	3	2.3
6	59	4	.67	186	3	1.4	166	4	1.6	233	4	2.2	300	3	2.4
7	59	4	.66	591	5	7.7	142	3	1.2	214	3	1.8	271	3	1.9
8	0	0	0	220	2	1.5	132	3	.93	259	4	2.4	391	3	3.5
9	59	4	.66	119	2	0.55	130	2	.77	198	3	1.7	292	3	2.1
10	0	0	0	111	2	.45	131	2	.67	214	3	1.9	300	3	2.1
11	0	0	0	240	2	1.5	130	2	.53	167	3	1.4	314	3	2.2
12	0	0	0	7.8	1	.01	140	2	.6	220	4	2.1	329	3	2.3
13	0	0	0	10	1	.01	135	2	.62	123	3	.93	334	3	2.4
14	0	0	0	246	3	1.7	100	2	.43	170	3	1.5	425	3	3.4
15	0	0	0	155	2	.88	252	3	1.9	173	3	1.5	395	3	3.1
16	0	0	0	140	2	.79	138	2	.78	146	3	1.2			
17	18	3	.14	142	2	.92	284	3	2.4	106	3	.74			
18	0	0	0	142	2	.96	154	2	1.0	43	2	.26			
19	0	0	0	140	2	.94	241	3	2.2	166	3	1.3			
20	59	3	.48	130	3	.91	129	3	1.0	202	3	1.7			
21	0	0	0	0	0	0	238	4	2.5	271	4	2.6			
22	0	0	0	100	3	.81	128	3	1.1	220	3	1.8			
23	0	0	0	100	3	.86	210	4	2.4	220	3	1.8			
24	400	5	5.3	98	4	.93	158	4	1.7	150	2	1.0			
25	0	0	0	45	3	.37	159	4	1.6	123	2	.76			
26	0	0	0	142	4	1.5	267	4	3.2	281	3	2.6			
27	0	0	0	138	4	1.4	170	4	1.8	226	3	1.8			
28	0	0	0	132	4	1.4	236	4	2.6	195	3	1.5			
29	881	9	21	61	3	.56	103	3	.61	168	3	1.2			
30	699	7	12	67	5	.62	238	4	2.4	99	2	.56			
31	235	4	2.3	142	4	1.6				159	2	1.0			
TOTAL	4,790		47	4,327		36	4,862		42	5,750		49	4,749		37

Underlined values show that an actual sample was collected that day.

Table 3.-- Daily mean discharge, sediment concentration, and tons per day of sediment for Canal 23.

Day	JULY			AUGUST			SEPTEMBER			OCTOBER			NOVEMBER		
	Discharge (cfs)	Sediment concen-tration (mg/1)	Sediment discharge (tons per day)	Discharge (cfs)	Sediment concen-tration (mg/1)	Sediment discharge (tons per day)	Discharge (cfs)	Sediment concen-tration (mg/1)	Sediment discharge (tons per day)	Discharge (cfs)	Sediment concen-tration (mg/1)	Sediment discharge (tons per day)	Discharge (cfs)	Sediment concen-tration (mg/1)	Sediment discharge (tons per day)
1	29	4	0.31	134	6	2.1	343	7	6.8	494	6	7.6	2460	21	139
2	438	9	11	308	9	7.5	259	6	4.5	772	9	19	1,700	16	74
3	263	7	5.3	532	12	17	156	4	1.8	1,230	12	40	962	13	34
4	263	7	5.3	1,470	18	72	37	2	0.20	659	11	20	372	9	8.7
5	427	10	12	918	14	35	424	8	9.3	949	15	38	525	10	14
6	530	11	16	545	12	18	44	4	.53	752	15	30	618	11	18
7	77	7	1.5	532	11	16	437	10	12	479	14	18	479	9	11
8	420	11	12	639	11	19	406	11	12	605	14	23	396	8	8.4
9	34	6	.55	1,180	14	44	98	8	2.0	236	10	6.4	38	3	0.31
10	407	12	13	724	10	20	1,120	17	51	269	10	7.0	309	7	5.9
11	37	7	.70	614	9	15	569	14	22	444	11	13	269	7	4.7
12	32	6	.52	549	8	12	731	15	33	280	10	7.3	30	2	.16
13	23	5	.31	447	7	8.8	413	12	14	192	8	4.0	477	9	11
14	15	5	.20	1,040	12	34	628	13	22	153	7	3.0	1,170	13	41
15	398	10	11	1,440	14	54	568	12	18	227	9	6.8	701	11	21
16	23	3	.19	1,031	12	33	341	9	8.6	39	5	0.53			
17	19	2	.10	1,650	15	67	604	11	18	384	10	10			
18	16	1	.04	1,190	14	45	492	9	12	48	6	.73			
19	22	2	.12	1,230	14	47	470	8	11	1,140	15	46			
20	30	1	.08	1,070	13	37	432	7	8.4	649	11	19			
21	26	1	.07	588	12	19	392	7	7.2	619	11	18			
22	127	3	.96	737	14	28	401	7	7.5	942	13	33			
23	335	4	3.8	622	15	25	496	7	9.1	478	10	12			
24	327	4	3.6	330	13	12	527	7	10	1,760	17	81			
25	167	2	.90	704	15	29	404	5	5.4	1,440	15	58			
26	71	1	.21	342	11	10	373	4	3.6	979	13	34			
27	77	1	.25	316	11	9.4	70	1	.19	881	12	29			
28	535	7	10	400	11	12	412	2	2.1	500	10	13			
29	548	7	10	253	8	5.7	558	2	3.0	2690	23	167			
30	514	7	9.7	363	8	8.3	589	4	6.4	3610	75	730			
31	304	5	4.1	41	4	.50				2880	27	210			
TOTAL	6,534		134	21,939		762	12799		319	25,640		1,700	10506		391

Underlined values show that an actual sample was collected that day.

Table 4.-- Daily mean discharge, sediment concentration, and tons per day of sediment for Canal 24.

Day	JULY			AUGUST			SEPTEMBER			OCTOBER			NOVEMBER		
	Discharge (cfs)	Sediment concen-tration (mg/l)	Sediment discharge (tons per day)	Discharge (cfs)	Sediment concen-tration (mg/l)	Sediment discharge (tons per day)	Discharge (cfs)	Sediment concen-tration (mg/l)	Sediment discharge (tons per day)	Discharge (cfs)	Sediment concen-tration (mg/l)	Sediment discharge (tons per day)	Discharge (cfs)	Sediment concen-tration (mg/l)	Sediment discharge (tons per day)
1	135	4	1.4	669	12	22	391	8	8.5	402	7	7.6	1,642	31	154
2	113	4	1.1	412	11	12	350	8	7.6	459	8	9.9	1,265	18	61
3	158	4	1.7	770	13	27	390	7	7.4	767	10	21	1,273	18	62
4	160	5	2.2	1,093	15	44	374	7	7.1	851	11	25	1,122	17	52
5	178	6	3.1	1,203	15	49	374	7	7.1	850	11	25	945	17	43
6	507	10	14	668	12	22	265	7	5.0	662	9	16	1,323	19	68
7	174	8	3.9	750	13	26	452	9	11	352	7	6.7	1,082	18	53
8	187	10	4.8	779	13	27	536	10	14	396	8	8.6	1,063	19	55
9	161	10	4.4	1,455	17	67	578	11	17	337	8	7.3	622	16	27
10	122	11	3.6	265	9	6.4	649	12	21	384	8	8.3	671	16	29
11	105	10	2.8	277	10	7.5	1,170	15	47	345	8	7.5	677	16	29
12	73	10	2.0	272	9	6.6	803	13	28	437	9	11	668	17	31
13	70	9	1.7	705	13	25	844	14	32	94	5	1.3	358	15	15
14	59	9	1.4	1,379	16	60	1,574	19	81	189	6	3.1	1,148	20	62
15	43	8	0.88	1,229	15	50	1,698	22	101	242	8	5.3	1,031	20	55
16	22	7	.43	1,254	15	51	1,029	16	44	202	8	4.4			
17	0	0	0	1,640	20	89	459	13	16	130	5	1.7			
18	0	0	0	1,443	17	66	625	14	24	275	8	6.3			
19	20	5	.27	1,148	15	46	510	14	19	652	11	19			
20	73	5	.99	1,161	15	47	270	12	8.8	350	9	8.5			
21	145	5	2.0	835	14	32	254	12	8.2	520	10	14			
22	261	5	3.7	963	16	42	353	14	13	611	11	18			
23	208	4	2.1	1,052	19	54	822	17	38	519	11	15			
24	170	2	1.1	333	15	13	472	16	20	2,208	84	500			
25	167	2	.89	214	13	7.5	323	13	11	1,438	16	62			
26	195	4	1.9	1,014	19	47	482	13	17	980	15	40			
27	220	5	2.9	1,114	17	51	251	10	6.8	952	15	39			
28	712	10	19	1,072	18	52	156	7	3.0	653	13	23			
29	743	11	22	658	13	23	120	5	1.6	1,949	41	216			
30	276	7	5.5	320	10	8.6	290	7	5.2	2,170	78	460			
31	1,079	13	38	408	9	9.9				4,650	360	4,550			
TOTAL	4,576		151	26,571		1,090	15,864		630	26,982		6,140	15,690		797

Underlined values show that an actual sample was collected that day.

Table 5.--Monthly and annual discharge, in acre-feet for Canal 18 at Structure 46, Canal 23 at Structure 48, and Canal 24 at Structure 49.

CANAL 18 NEAR STRUCTURE 46

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	ANNUAL	JULY 1 to NOV. 15
1963	0	303	0	0	0	950	684	2,400	9,980	18,920	2,760	1,880	37,880	34,030
1964	13,920	4,410	789	50	1,490	7,370	3,180	9,560	13,300	24,600	17,880	5,650	102,200	61,140
1965	1,080	2,900	1,500	77	0	2,660	2,730	6,190	5,800	14,440	11,650	1,680	50,690	39,670
1966	11,420	8,620	4,550	1,110	5,150	23,950	24,240	11,550	9,390	11,220	2,950	1,730	115,880	58,110
1967	305	784	206	0	0	3,500	11,700	10,850	8,750	28,410	6,640	916	72,060	65,110
1968	0	175	0	0	578	14,900	13,900	10,140	8,570	13,360	4,150	0	65,770	49,200
1969	290	0	2,030	0	3,810	4,930	5,530	8,580	9,640	11,400	14,210	3,950	64,370	44,570
AVG.	3,860	2,460	1,300	1,300	1,580	8,320	8,850	8,470	9,350	17,480	8,610	2,260	74,690	50,260

CANAL 23 NEAR STRUCTURE 48

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	ANNUAL	JULY 1 to NOV. 15
1963	-	-	-	-	-	-	-	770	3,710	7,540	2,650	5,570	-	-
1964	-	-	2,720	1,880	2,320	1,700	11,590	27,080	29,040	16,780	6,910	2,340	-	90,890
1965	600	7,980	4,740	1,730	270	1,370	7,270	8,090	11,380	23,160	11,740	1,280	79,610	58,890
1966	31,700	20,100	7,580	2,750	4,140	27,140	45,710	29,850	18,770	45,470	5,990	2,590	241,790	143,050
1967	1,800	2,870	2,560	8,920	480	5,470	17,680	11,530	3,030	15,730	1,790	540	72,400	49,260
1968	420	390	330	330	5,630	58,400	59,200	12,370	4,230	6,060	7,500	1,740	156,600	86,870
1969	2,000	1,870	14,650	2,660	15,330	23,210	12,950	43,500	25,380	53,220	29,410	22,970	247,150	155,890
AVG.	7,300	6,640	5,430	3,050	4,700	19,550	25,730	19,130	13,650	23,990	9,430	5,290	159,510	97,480

CANAL 24 NEAR STRUCTURE 49

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	ANNUAL	JULY 1 to NOV. 15
1963	0	0	0	0	1,590	60	3,310	0	15,910	10,310	11,410	16,400	58,990	33,500
1964	16,020	18,980	4,380	5,530	13,660	8,390	16,360	36,840	28,850	15,490	16,470	16,690	197,660	105,190
1965	16,160	13,170	12,580	3,690	150	8,740	18,150	12,900	19,410	22,560	16,280	16,560	160,620	83,110
1966	25,860	19,430	12,460	8,950	16,390	27,670	30,420	24,030	15,690	35,890	12,020	11,580	240,390	111,490
1967	0	1,170	0	0	0	9,690	20,170	12,090	12,290	11,580	790	0	67,780	56,920
1968	0	0	0	0	12,050	84,120	32,510	7,110	7,760	12,470	3,550	0	159,570	62,420
1969	3,400	0	18,760	760	18,380	21,240	13,040	52,690	32,450	45,560	47,070	34,660	288,010	173,670
AVG.	8,780	7,540	6,880	2,700	8,890	22,840	19,140	20,810	18,910	21,980	15,370	13,700	167,570	89,470

Table 5 also shows that during February and April 1969 there was no flow in Canal 18 and, therefore, no sediment discharge. In January the sediment load must have been small, as the discharge was very low that month. March, May, June, and December were the only months (other than the months during which samples were collected) during which any significant amount of sediment could have been discharged; however, figure 8 shows that the sediment concentration will generally be below 3 mg/1 at discharges below 220 cfs. Examination of the daily discharges for the period not sampled shows that 3 days in late November and 2 days in early May were the only days in which a discharge of 220 cfs was reached. It seems that at no other time could the sediment discharge have exceeded 1 ton per day, and, therefore, the conclusion can be made that the annual suspended sediment discharged by Canal 18 in 1969 could not have been more than 350 tons, of which 211 was discharged during July 1 to November 15.

Analysis of the daily discharge data, comparison of these data with other discharge data for which sediment concentrations are known, and the sediment-transport curves of figure 9 were used in a similar manner to obtain an estimate of annual suspended sediment discharge for Canal 23. On that basis, it was estimated that the load carried by Canal 23 during 1969 did not exceed 4,500 tons, of which 3,310 tons was discharged during July 1 to November 15.

A similar examination of data for Canal 24 discloses that the total suspended sediment load discharged by it during 1969 was about 9,000 tons, of which 6,810 was discharged during July to November 15.

The relationships between sediment yield and drainage area, annual discharge, and length of canal are shown in table 6 for all three canals. Table 6 near here

Table 6.--Relationships of sediment yield with drainage area, annual discharge, and length of canal for Canals 18, 23, and 24.

Canal	Length (miles)	Drainage Area (sq. miles)	Annual Discharge (acre-feet)	Annual Sediment yield (tons)	Tons per sq.mile	Tons per thousand acre-feet
18	17	106	74,690	350	3.3	4.7
23	24	162	159,510	4,500	27.8	28.2
24	20	160	167,570	9,000	56.2	53.7

CONCLUSIONS

In contrast to Canal 18, Canals 23 and 24 carry relatively large quantities of suspended sediment into the St. Lucie River estuary at Stuart during high discharge. Maximum sediment-discharge rates of 730 and 2,550 tons per day and average rates of 23 and 42 tons per day during July 1 to November 15 were computed for Canal 23 and Canal 24, respectively, while Canal 18 carried little sediment, a maximum of 21 tons per day and an average of 1.5 tons per day during the same period.

Chemical analyses show that the water from Canals 23 and 24 are of similar chemical quality, but that of Canal 18 has considerably lower concentrations of most constituents.

The preponderance of citrus groves in the area drained by Canals 23 and 24 may partly explain the differences in sediment discharge rates and in water quality.

Most of the sediment in the canals originates in the cultivated areas; some of it comes from the decomposition of the vegetal matter in the canals. The sediment consists predominantly of particles that remain in suspension at low velocities.

Clearing of virgin land and preparation of the land for farming or pasture results in an increase per unit area of the amount of sediment in runoff water. This is indicated by comparing the data for Canal 18, which drain a relatively virgin area, with data for Canals 23 and 24, which drain an area that is extensively developed for agricultural use and pasture.

Increasing agricultural activity in the area will probably increase the amount of suspended sediment discharged into the canals and estuaries in future years.

GLOSSARY

Flatwoods: A vegetal environment characterized by clusters of cypress tress towering above the pond grasses and marshes and separated by sawgrass.

Muck: A soil of extremely soft consistency. The term is applied herein to soils that are predominantly an organic silt.

Peat: An extremely compressible, but loose soil that is very dark in color and which contains much fibrous organic material. When dry, it floats and can be easily transported with surface runoff.

Sediment: Solid material that originates mostly from soils and is transported by, suspended in, or deposited by water; it includes chemical and biochemical precipitates and decomposed organic matter, such as humus.

Sediment discharge: The rate at which dry weight of sediment passes a section of a stream, or is the quantity of sediment, as measured by dry weight or by volume, that is discharged in a given time.

Suspended sediment: The sediment that at any given time is maintained in suspension by the upward components of turbulent currents or that exists in suspension as a colloid.

Tons per day: The quantity of materials in solution or suspension that passes a stream section during a 24-hour period.

Transit velocity: The velocity at which the sampler is lowered and raised. The velocity should be uniform and slow enough to allow the air in the sampler to be compressed by the inflowing water proportionally to the hydrostatic head.

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