STREAMFLOW AND WATER-QUALITY DATA FOR LAKE AND WETLAND INFLOWS AND OUTFLOWS IN THE TWIN CITIES METROPOLITAN AREA, MINNESOTA, 1981-82

By Luanne Nelson and R. G. Brown

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ERRATA

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INTERNATIONAL SYSTEM OF UNITS (SI)

For the convenience of readers who may want to use International System of Units (SI), the data may be converted by using the following factors:

Multiply inch-pound unit	By	To obtain SI (metric) unit
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)
acre	0.4047	hectare (ha)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second-day [(ft^3/s).d]	2447	cubic meter (m^3)

STREAMFLOW AND WATER-QUALITY DATA FOR LAKE AND WETLAND INFLOWS AND OUTFLOWS IN THE TWIN CITIES METROPOLITAN AREA, MINNESOTA, 1981-82

By Luanne Nelson and R. G. Brown

ABSTRACT

A study of runoff to selected lakes was done in the Twin Cities metropolitan area from July 1981 to December 1982. The purpose of the study was to determine differences in nutrient-loading characteristics for lakes with and without wetlands and settling ponds. The study also quantified nutrient loading to lakes on a storm, seasonal, and annual basis, complementing an in-lake water-quality study of these lakes done by the Metropolitan Council.

Discharge and water-quality data were collected periodically during 1981 and continuously during 1982 at 22 sites located in seven lake watersheds--Bryant Lake, Lake Elmo, Fish Lake, Lake George, Lake Riley, Spring Lake, and Square Lake. Basin characteristics and land use were determined for each watershed. Recording instruments provided continuous discharge records at 14 sites and continuous rainfall records at six sites. Automatic water-quality samplers were used at lake inlets. The automatic samplers collected samples at 1- to 2-hour intervals during storms. Lake-outlet samples were collected manually on a weekly basis during flow. Samples were analyzed for suspended solids and nutrients. Atmospheric-input data were collected at eight sites from September 23 to November 1, 1982. Discharge and water-quality data were used to calculate storm, seasonal, and annual loads of total suspended solids, volatile suspended solids, total phosphorus, dissolved phosphorus, nitrite-plus-nitrate nitrogen, ammonia nitrogen, and ammonia-plus-organic nitrogen.

All data collected during the study are documented in tables and graphs that contain (1) watershed characteristics and land use; (2) storm concentrations; (3) storm, seasonal, and annual loads; (4) storm hydrographs; (5) atmospheric-input concentrations and loads; (6) storm, seasonal, and annual precipitation totals; and (7) results of quality-assurance tests.

INTRODUCTION

Background

Studies throughout the United States indicate that materials carried in runoff from nonpoint sources contribute significantly to the degradation of stream- and lake-water quality (Federal Water Pollution Control Administration, 1969; Lager and Smith, 1974; Sliter, 1976; Bradford, 1977; Sonzogni and others, 1980). However, the amount of materials in runoff carried into lakes and streams differs among basins and storms (McElory and others, 1976; Sonzogni and others, 1980).

A survey of 60 metropolitan lakes by the Metropolitan Council of the Twin Cities in summer 1980 found 80 percent of the lakes to be eutrophic, 14 per cent mesotrophic, and 6 percent oligotrophic (Osgood, 1981). It was also evident from the 1980 survey that phosphorus loading from runoff contributed significantly to eutrophication of these lakes. Because phosphorus is the limiting constituent in the eutrophication process, its presence in high concentrations in runoff significantly accelerates eutrophication (Kirchner and Dillon, 1975). Control of nonpoint-source runoff is expensive and various alternatives for improving the quality of runoff entering lakes are being considered by local and State agencies (Oberts, 1982).

A common alternative is the use of wetlands and settling ponds to reduce runoff nutrient loading to lakes. Both natural wetlands and engineered settling ponds have been incorporated in the drainage systems of several lake shore developments and are used as filtering zones for primary inflows and storm-sewer discharges. The use of wetlands and settling ponds is increasing, but their effectiveness in reducing nutrient loading to lakes in the metropolitan area has not been documented quantitatively. The need for data on nutrient loadings in runoff to lakes and on the effects of wetlands on nutrient loading led to the development of a cooperative study between the U.S. Geological Survey and the Metropolitan Council. The U.S. Geological Survey monitored runoff to lakes with and without upstream wetlands and settling ponds while the Metropolitan Council monitored in-lake water quality. The combination of nutrient loading and in-lake water-quality data provided the basis for nutrient and hydrologic budgets of each lake. Wetlands and settling ponds were monitored in order to understand the effectiveness of these areas on reducing nutrient loads in runoff to lakes.

Objectives of the runoff study were to (1) quantify the surface-inflow volumes and nutrient loading on a storm, seasonal, and annual basis for each of the seven lakes; (2) determine the effects of wetlands and settling ponds on reducing the nutrient loading to lakes; (3) analyze the settling and flushing characteristics of the wetlands and settling ponds; and (4) determine the relationship between nonpoint-source nutrient loading and in-lake water quality.

The purpose of this report is to describe the approach and methods used for data acquisition and to document the data collected during the study. The in-lake water-quality data will be published by the Metropolitan Council.

Acknowledgments

The assistance of the following is gratefully acknowledged: Zack Hansen from the Metropolitan Council for the wetland inventory; Craig Skone from the Metropolitan Council for watershed characteristics; Gary and Judy Robinson for daily rainfall observations at Lake George; NOAA observers Floyd Cohoes, Toivo Kangas, and Milo Born for snow and rainfall data and for calling with storm warnings; and the Watershed Districts and County Park Directors for granting permission to install gages at the chosen locations.

METHODS AND APPROACH

Site Selection and Location

Seven lakes were selected on the basis of information from a 1980 survey of 60 metropolitan lakes done by the Metropolitan Council (fig. 1). The seven lakes are of regional interest because they are frequently used by the public for recreation. They represent a wide range of watershed areas, various land uses, and eutrophic levels (table 1). To calculate hydrologic and nutrient budgets, only primary lake inflows and outflows were chosen based on hydrologic characteristics and monitoring feasibility. Lakes with wetlands were selected to analyze the impact of wetlands on runoff quality and quantity. A total of 22 lake and wetland inflow and outflow sites were established (table 2, figs. 2-8). Rain gages and atmospheric-input collectors were also installed at each lake.

Tables 3-9 summarize watershed characteristics and land use within each lake watershed. Areas were planimetered and computed from U.S. Geological Survey topographic maps and aerial photographs. Land-use characteristics for urban watersheds were tabulated from land-use maps compiled by the Metropolitan Council of the Twin Cities. The maps were compared with 1980 aerial photographs and updated as necessary. The information on cropping practices, wetlands, and other basin characteristics was obtained from 1982 field surveys conducted in each watershed. Population estimates were determined using Metropolitan Council 1982 statistics.

Data Collection and Instrumentation

Sampling schemes for lake inflows (which included wetland inflows) differed from those used for lake outflows because inflows had a shorter response time to storms. Streamflow data collected during 1981 was periodic and both streamflow and water-quality data had to be estimated from both 1981 and 1982 data. Streamflow and water-quality were monitored continuously during 1982.

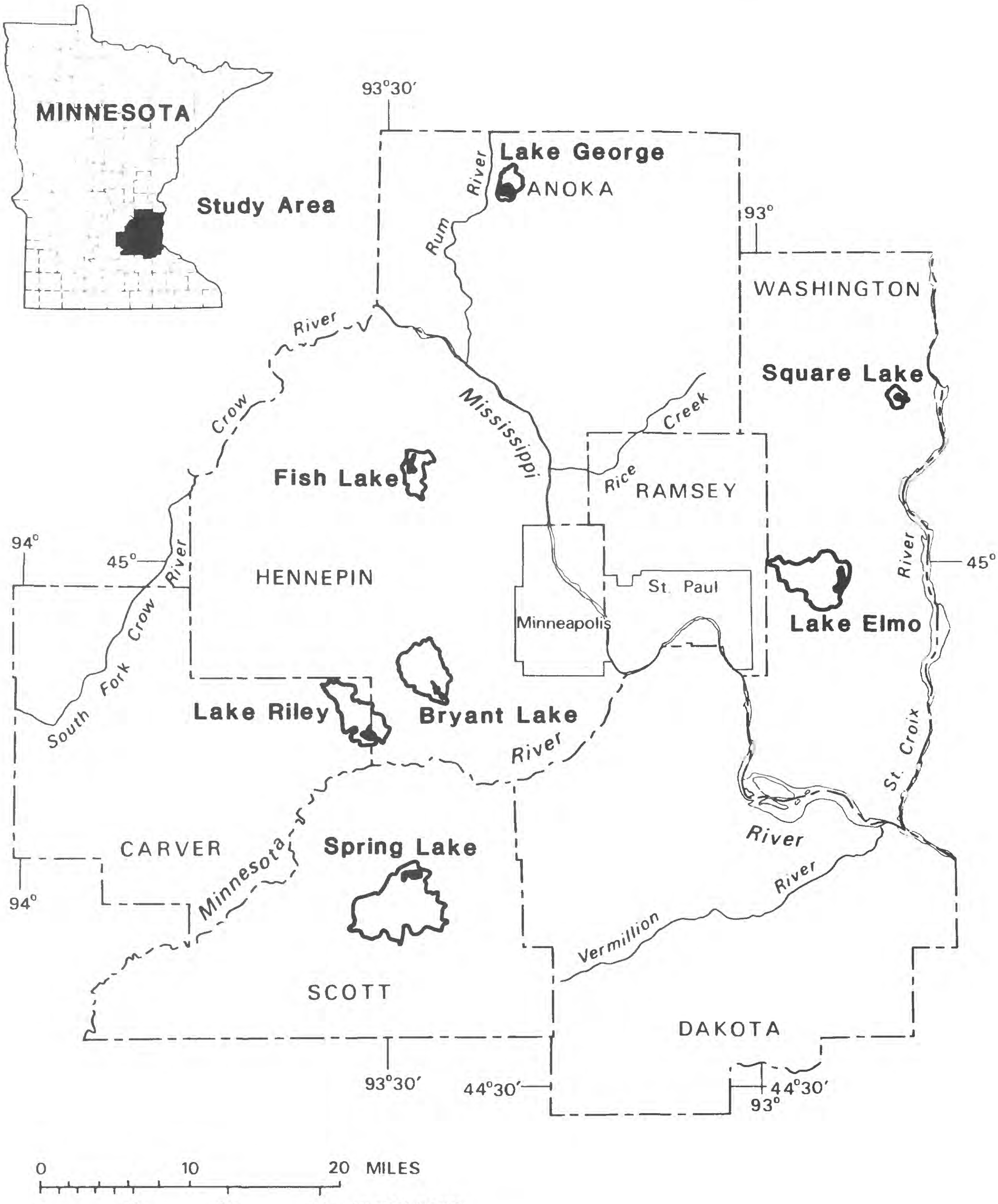


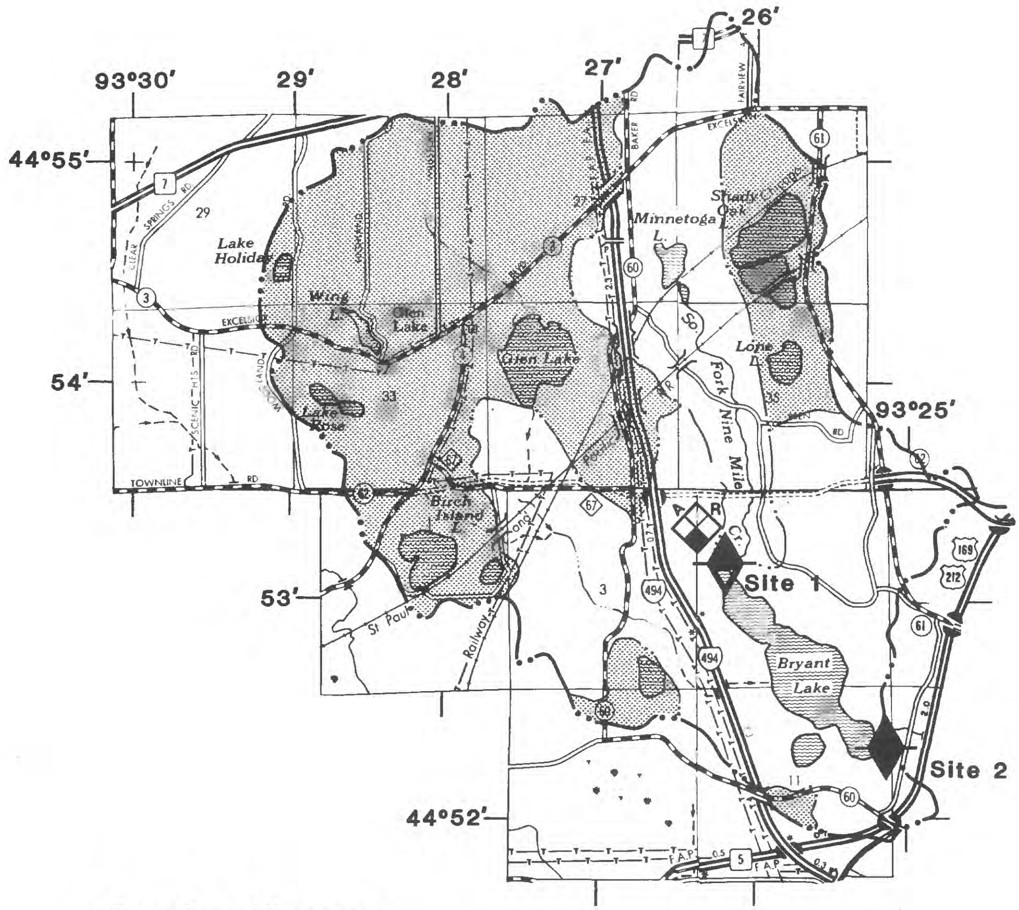
Figure 1.--Location of study lake watersheds in the Twin Cities Metropolitan Area

Table 1.--General description of watersheds

Lake	County	General watershed characteristics
Bryant Lake ($4.76\ mi^2$)	Hennepin	Watershed is 40 percent grassland or woodland, 22 percent residential (mostly single family), 18 percent wetlands or lakes, 8 percent commercial and 5 percent agricultural.
Lake Elmo ($7.54\ mi^2$)	Washington	Watershed is 32 percent agricultural, much of which is cash crops, 27 percent pastureland, 15 percent wetlands or lakes, and 8 percent woodland. Little commerical land use.
Fish Lake ($3.24\ mi^2$)	Hennepin	Watershed is 30 percent residential, (mostly single family), 29 percent grassland or woodland, 24 percent wetlands or lakes and 12 percent agricultural. Commercial land use is less than 1 percent.
Lake George ($2.90\ mi^2$)	Anoka	Watershed is 50 percent wetlands or lakes, 32 percent grassland or woodland, 13 percent agricultural, and 7 percent residential. Commercial land use is less than 1 percent.
Lake Riley ($7.96\ mi^2$)	Carver	Watershed is 30 percent agricultural, 29 percent grassland or woodland, 26 percent wetlands and lakes, 8 percent residential, and 2 percent commercial.
Spring Lake ($19.6\ mi^2$)	Scott	Watershed is 47 percent agricultural, 21 percent wetlands and lakes, 16 percent grassland or woodland, 5 percent residential, and less than 1 percent commercial.
Square Lake ($1.21\ mi^2$)	Washington	Watershed is 52 percent grassland or woodland, 28 percent wetlands or lakes, 6 percent residential, and 5 percent agricultural. There is no commercial land use.

Table 2.--Lake and wetland monitored sites

Site number	Description
	BRYANT LAKE
1	Bryant Lake inflow (South Fork Nine Mile Creek)
2	Bryant Lake outflow
	LAKE ELMO
1	Eagle Point Lake wetland area inflow--southern
2	Eagle Point Lake wetland area inflow--northern
3	Eagle Point Lake wetland area outflow and Lake Elmo inflow
4	Lake Elmo outflow
A1	Auxiliary site that was sampled periodically
	FISH LAKE
1	Wetland inflow--storm-sewered drainage
2	Wetland ouflow and lake inflow
3	Fish Lake outflow
A1-A3	Auxiliary sites that were sampled periodically
	LAKE GEORGE
1	Lake George inflow
2	Lake George outflow
	LAKE RILEY
1	Rice Marsh Lake wetland area inflow
2	Rice Marsh Lake wetland area outflow and Lake Riley inflow
3	Lake Riley outflow
	SPRING LAKE
1	Settling pond inflow
2	Settling pond outflow and Spring Lake inflow
3	Spring Lake outflow
	SQUARE LAKE
1	Square Lake outflow



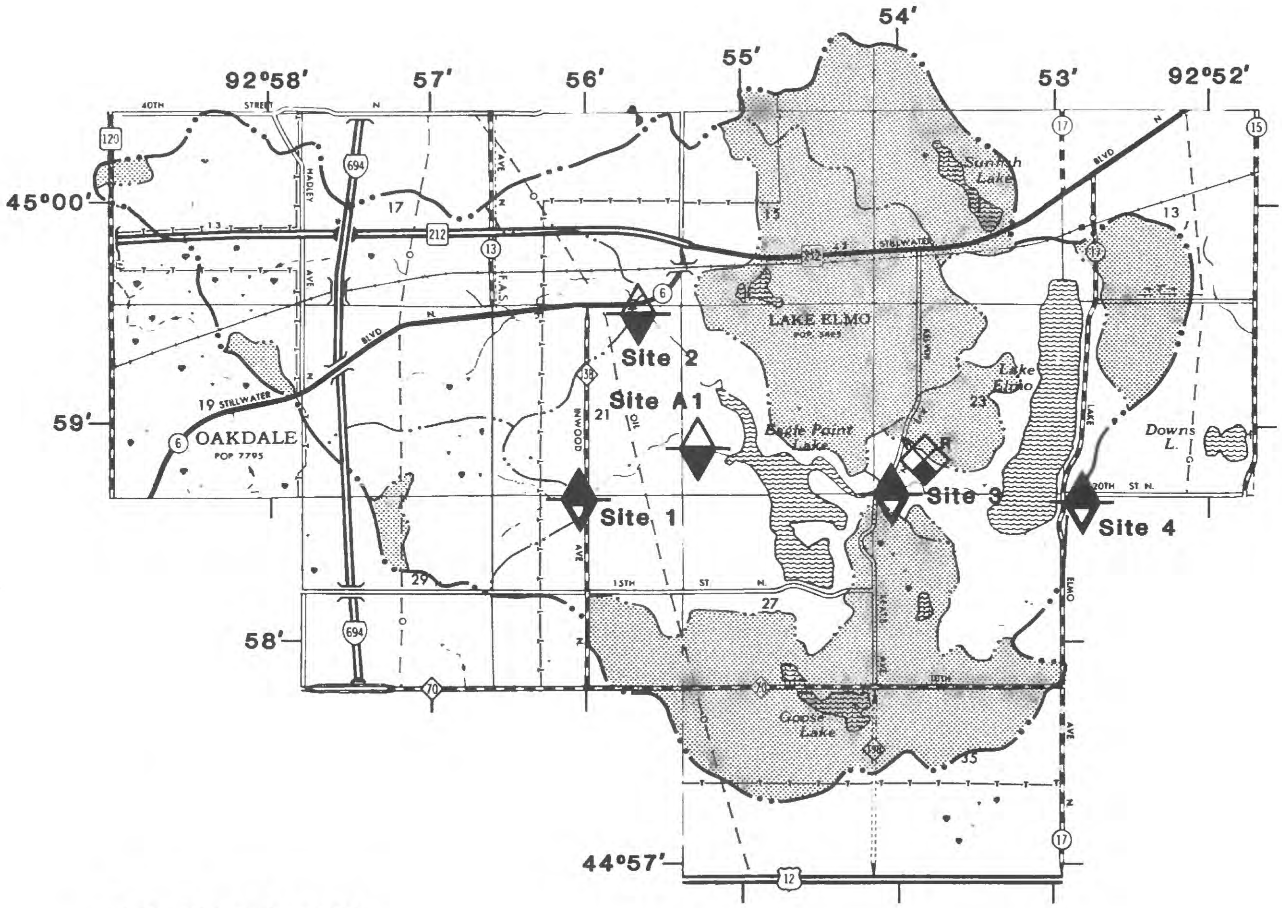
Base from Minnesota Department of Highways General Highway Map of Hennepin County, 1977

0 — 1 MILE
0 — 1 KILOMETER

EXPLANATION

- ▲ Continuous-record gaging station
- —— Biological/sediment-measurement site
- ▼ Active site
- ▽ Active site with monitor
- Weather station with recorder; atmospheric data collection
- Area not contributing to surface water drainage
- —··— Drainage basin divide

Figure 2.--Location of runoff monitoring sites in Bryant Lake watershed



EXPLANATION

- Continuous-record gaging station
- Measurement site without gage
- Biological/sediment-measurement site
- Active site
- Active site with monitor
- Weather station with recorder; atmospheric data collection
- Area not contributing to surface water drainage
- Drainage basin divide

Figure 3.--Location of runoff monitoring sites in Lake Elmo watershed

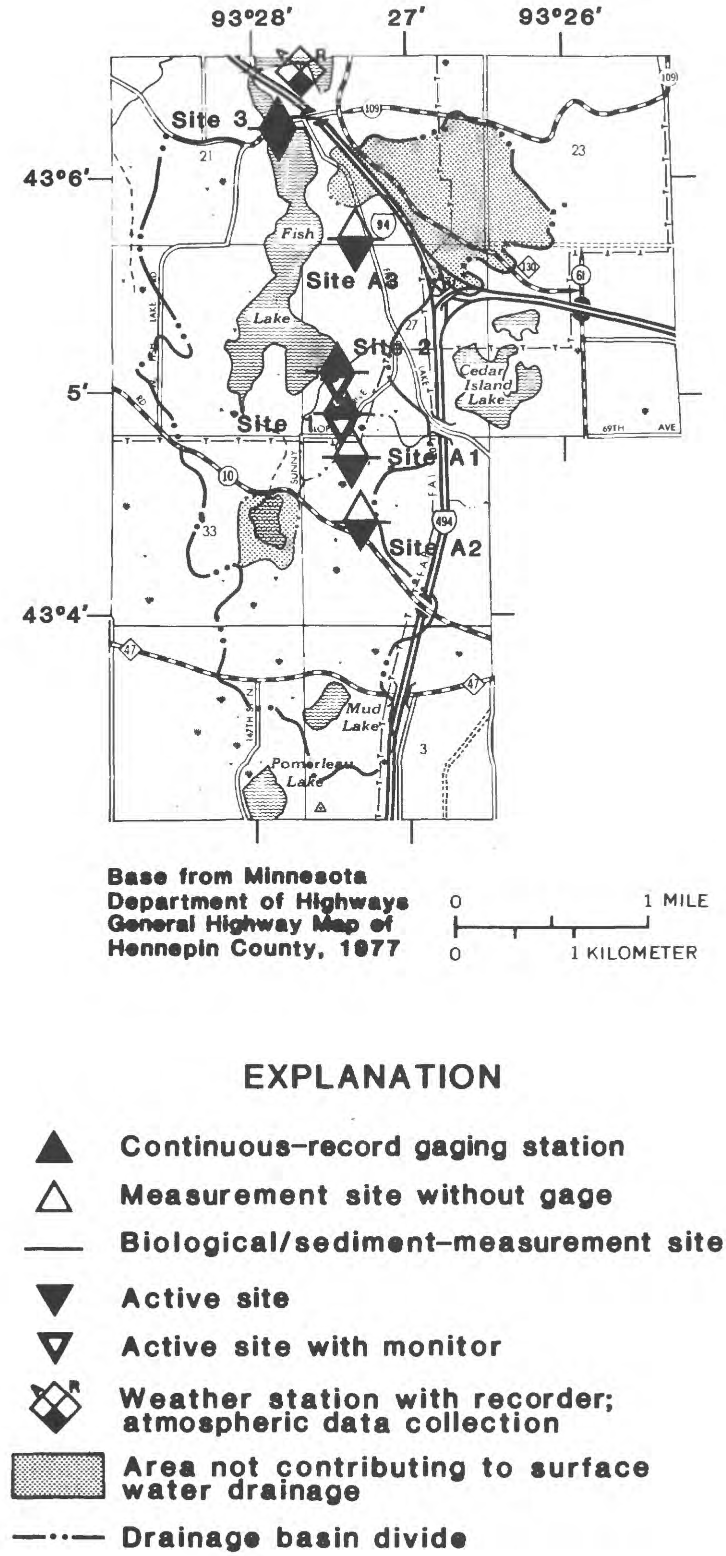
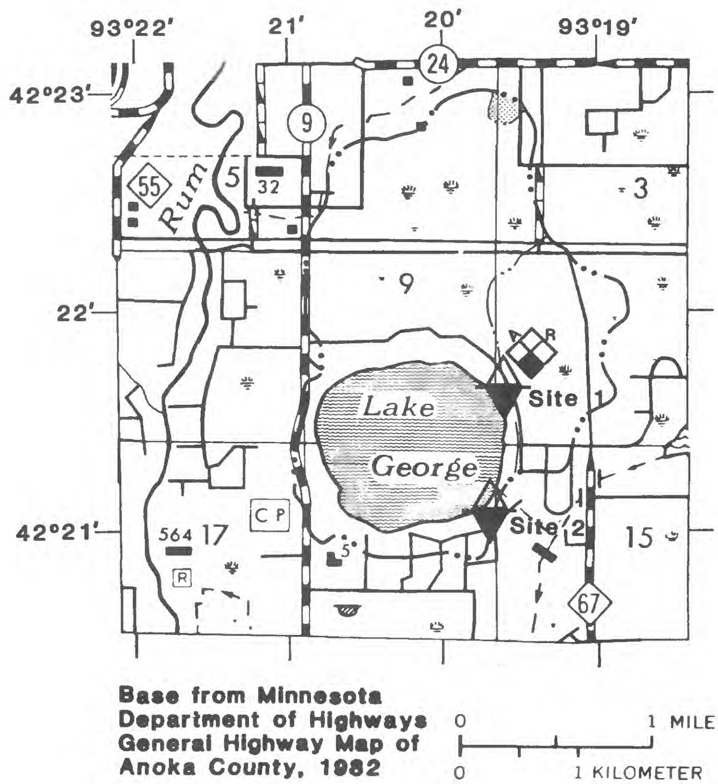


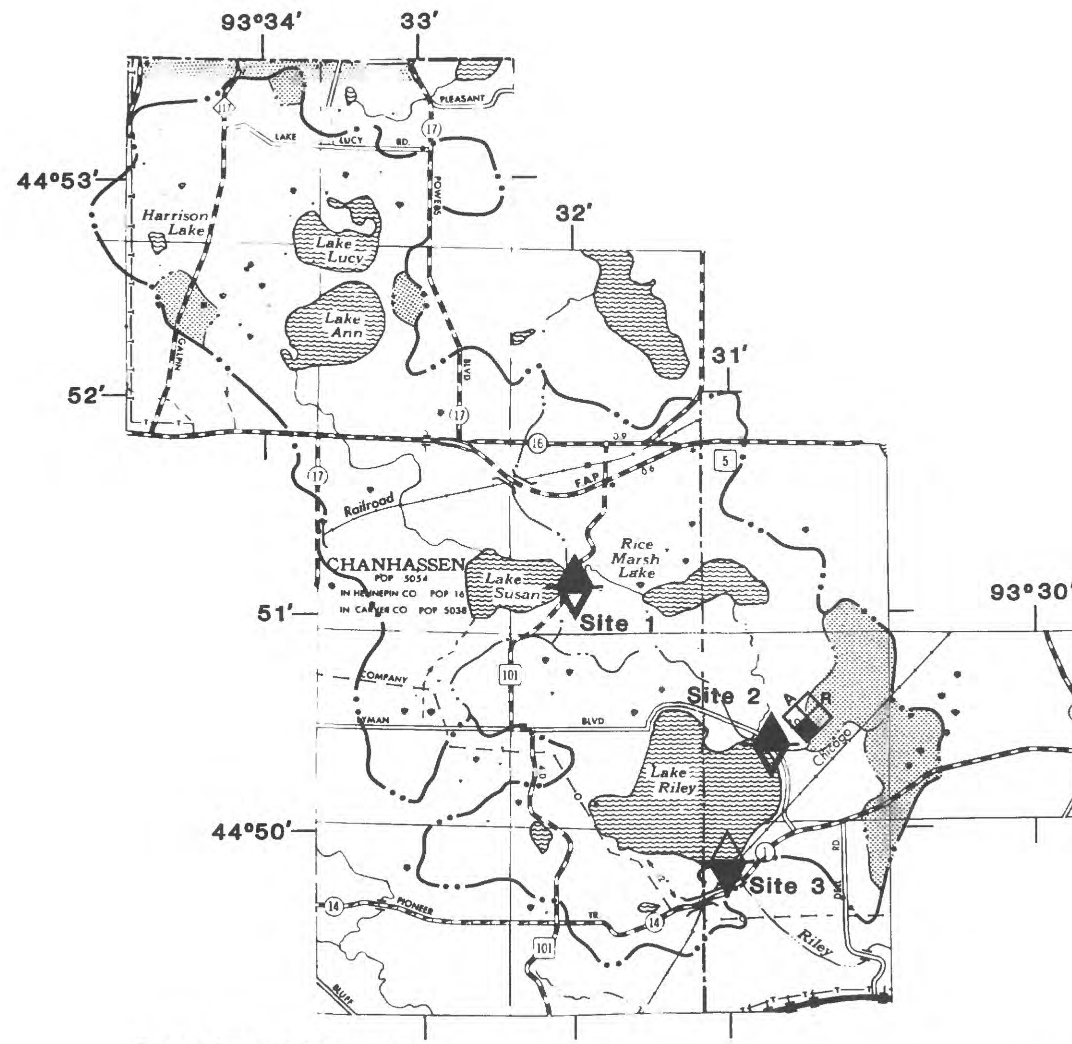
Figure 4.--Location of runoff monitoring sites in Fish Lake watershed



EXPLANATION

- △ Measurement site without gage
- —— Biological/sediment-measurement site
- ▼ Active site
- Weather station with recorder; atmospheric data collection
- Area not contributing to surface water drainage
- —··— Drainage basin divide

Figure 5.--Location of runoff monitoring sites in Lake George watershed



Base from Minnesota
Department of Highways
General Highway Map of
Carver and
Hennepin Counties, 1977

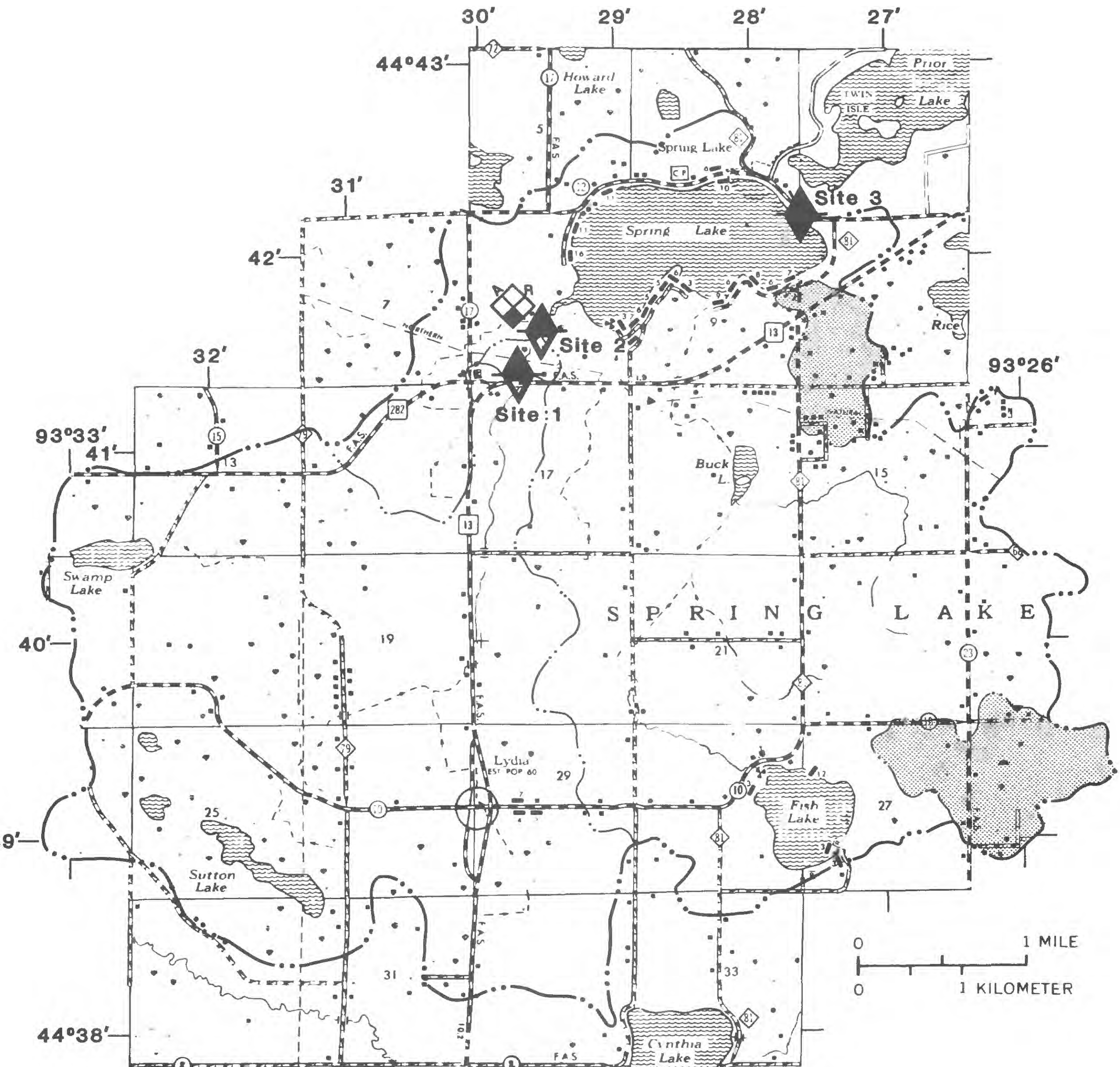
0 1 MILE

0 1 KILOMETER

EXPLANATION

- ▲ Continuous-record gaging station
- △ Measurement site without gage
- —— Biological/sediment-measurement site
- ▼ Active site
- ▽ Active site with monitor
- Weather station with recorder; atmospheric data collection
- Area not contributing to surface water drainage
- —·:·— Drainage basin divide

Figure 6.--Location of runoff monitoring sites in Lake Riley watershed

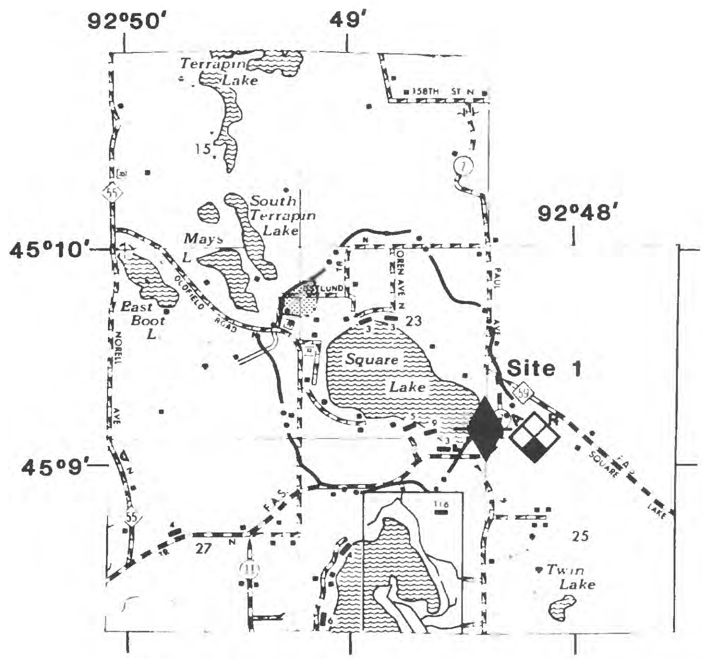


Base from Minnesota Department of Highways General Highway Map of Scott County, 1977

EXPLANATION

- ▲ Continuous-record gaging station
- —— Biological/sediment-measurement site
- ▼ Active site
- ▽ Active site with monitor
- Weather station with recorder; atmospheric data collection
- Area not contributing to surface water drainage
- —··— Drainage basin divide

Figure 7.--Location of runoff monitoring sites in Spring Lake watershed



Base from Minnesota
Department of Highways
General Highway Map of
Washington County, 1977

EXPLANATION

▲ Continuous-record gaging station

—— Biological/sediment-measurement site

▼ Active site

Weather station with recorder; atmospheric data collection

Area not contributing to surface water drainage

—··— Drainage basin divide

Figure 8.--Location of runoff monitoring site for Square Lake watershed

Table 3.--Watershed characteristics and land use at inflow and outflow sites at Bryant Lake

[All measurements in acres, unless noted]

Characteristic	Site 1 (lake inflow)	Lake and ungaged water-shed	Site 2 (lake outflow)
WATERSHED CHARACTERISTICS			
Total contributing area	944.0	2,099.2	3,043.2
Area under construction	8.8	129.6	138.4
Population density (persons/acre)	1.53	.58	.89
Relief (ft)	199	199	199
Drainage density (ft/acre)	17.88	13.01	14.60
Impervious area	105	177	282
Ditch density (ft/acre)	10.99	13.01	12.35
Ditch length (mi)	1.93	4.70	6.63
LAND USE			
Residential (2 units/acre)	237.8	145.2	383.0
Residential (3 to 8 units/acre)	118.1	150.5	268.6
Residential, multifamily	7.2	15.4	22.6
Wetlands	103.4	229.8	333.2
Open water	15.8	192.7	208.5
Parks, open space	11.9	35.3	47.2
Commercial, industrial, institutional	17.5	224.5	242.0
Cropland: total	13.1	51.8	64.9
Cropland: corn	0	.8	.8
Cropland: soybeans	0	0	0
Cropland: grasses	13.1	42.0	55.1
Cropland: small plots	0	6.2	6.2
Cropland: unknown	0	2.8	2.8
Pastureland	20.9	65.5	86.4
Grassland	116.3	582.4	698.7
Woodland	199.0	318.1	517.1

Table 4.--Watershed characteristics and land use at inflow and outflow sites at Lake Elmo
[All measurements in acres, unless noted]

Characteristic	Site 1 (wetland area inflow)	Site 2 (wetland area inflow)	Wetland area	Site 3 (wetland area outflow and lake inflow)	Lake and ungaged water-shed	Site 4 (lake out-flow)
WATERSHED CHARACTERISTICS						
Total contributing area	420.0	1,643.0	1,859.0	3,922.2	907.0	4,829.2
Area under construction	0	1.0	5.2	6.2	0	6.2
Population density (persons/acre)	.41	1.23	.21	.68	.47	.65
Relief (ft)	115	170	171	191	68	208
Drainage density (ft/acre)	13.33	15.95	6.67	11.45	5.97	10.70
Impervious area	7.0	158	38	203	17	220
Ditch density (ft/acre)	2.86	15.95	5.26	9.65	4.64	8.96
Ditch length (mi)	0.23	4.96	1.70	6.89	.53	7.42
LAND USE						
Residential (2 units/acre)	2.0	19.9	50.8	73.7	58.9	132.6
Residential (3 to 8 units/acre)	21.1	242.2	72.1	336.8	22.8	359.6
Residential, multifamiliy	0	42.4	0	42.4	0	42.4
Wetlands	39.3	160.8	25.2	225.3	46.1	271.4
Open water	0	0	149.5	149.5	304.2	453.7
Parks, open space	2.9	4.2	2.9	10.0	.7	10.7
Commercial, industrial, institutional	3.1	52.1	0	55.2	0	55.2
Cropland: total	157.2	451.7	638.3	1,247.2	284.2	1,531.4
Cropland: corn	130.4	327.1	425.6	883.1	172.3	1,055.4
Cropland: soybeans	13.7	31.9	69.2	114.8	0	114.8
Cropland: grasses	13.1	92.7	143.5	249.3	111.9	361.2
Pastureland	0	26.4	1.0	27.4	0	27.4
Grassland	80.0	400.7	734.7	1,215.4	84.0	1,299.4
Woodland	117.5	68.1	85.9	271.5	107.4	378.9

Table 5.--Watershed characteristics and land use at inflow and outflow sites at Fish Lake
[All measurements in acres, unless noted]

Characteristic	Site 1 (wetland inflow)	Wetland	Site 2 (wetland outflow and lake inflow)	Lake and ungaged water-shed	Site 3 (lake outflow)
WATERSHED CHARACTERISTICS					
Total contributing area	704.0	128.0	832.0	1,240.0	2,072.0
Area under construction	3.7	0	3.7	2.5	6.2
Population density (persons/acre)	1.70	4.40	2.10	3.20	2.70
Relief (ft)	144	75	149	99	153
Drainage density (ft/acre)	13.82	6.25	12.61	1.98	6.70
Impervious area	48	19	67	101	168
Ditch density (ft/acre)	13.82	6.25	12.61	1.98	6.70
Ditch length (mi)	1.78	.15	1.93	.38	2.31
LAND USE					
Residential (2 units/acre)	14.4	0	14.4	14.6	29.0
Residential (3 to 8 units/acre)	156.3	76.3	232.6	274.8	507.4
Residential, multifamiliy	0	0	0	61.8	61.8
Wetlands	112.7	15.7	128.4	113.0	241.4
Open water	24.0	0	24.0	227.6	251.6
Parks, open space	25.7	0	25.7	11.0	36.7
Commercial, industrial, institutional	2.5	0	2.5	2.5	5.0
Cropland: total	149.0	0	149.0	107.6	256.6
Cropland: corn	124.0	0	124.0	28.0	152.0
Cropland: soybeans	0	0	0	20.6	20.6
Cropland: grasses	25.0	0	25.0	59.0	84.0
Pastureland	21.3	0	21.3	0	21.3
Grassland	105.8	20.5	126.3	211.5	337.8
Woodland	81.3	18.0	99.3	204.5	303.8

Table 6.--Watershed characteristics and land use at inflow and outflow sites at Lake George
[All measurements in acres, unless noted]

Characteristic	Site 1 (lake inflow)	Lake and ungaged water-shed	Site 2 (lake outflow)
WATERSHED CHARACTERISTICS			
Total contributing area	336.0	1,518.0	1,854.0
Area under construction	0	0	0
Population density (persons/acre)	0.25	.53	.46
Relief (ft)	22	41	41
Drainage density (ft/acre)	13.5	5.5	7.4
Impervious area	3	16	19
Ditch density (ft/acre)	13.5	5.5	7.4
Ditch length (mi)	.85	1.07	1.92
LAND USE			
Residential (2 units/acre)	14.7	103.9	118.6
Residential (3 to 8 units/acre)	0	7.6	7.6
Residential, multifamiliy	0	0	0
Wetlands	79.8	182.7	262.5
Open water	3.0	487.2	490.2
Parks, open space	1.0	11.0	12.0
Commercial, industrial, institutional	1.0	1.5	2.5
Cropland: total	61.1	188.1	249.1
Cropland: corn	44.4	89.2	133.6
Cropland: soybeans	0	0	0
Cropland: grasses	10.8	78.0	88.8
Cropland: unknown	5.9	20.9	26.8
Pastureland	19.8	48.6	68.4
Grassland	40.8	53.0	93.8
Woodland	113.6	386.1	499.7

Table 7.--Watershed characteristics and land use at inflow and outflow sites at Lake Riley
[All measurements in acres, unless noted]

Characteristic	Site 1 (wetland area inflow)	Wetland area	Site 2 (wetland area outflow and lake inflow)	Lake and ungaged water-shed	Site 3 (lake outflow)
WATERSHED CHARACTERISTICS					
Total contributing area	2,477.0	1,168.0	3,645.0	1,448.0	5,093.0
Area under construction	25.7	5.7	31.4	0	31.4
Population density (persons/acre)	.20	1.01	.50	.72	.56
Relief (ft)	199	136	216	76	216
Drainage density (ft/acre)	12.34	14.65	13.16	6.154	11.27
Impervious area	82	97	179	31	210
Ditch density (ft/acre)	9.06	8.70	8.93	4.83	7.83
Ditch length (mi)	3.45	1.80	5.25	1.04	6.29
LAND USE					
Residential (2 units/acre)	155.7	13.7	169.4	102.2	271.6
Residential (3 to 8 units/acre)	11.5	82.1	93.6	0	93.6
Residential, multifamiliy	0	9.5	9.5	8.1	17.6
Wetlands	226.6	161.9	388.5	85.9	474.4
Open water	468.0	76.0	544.0	309.0	853.0
Parks, open space	54.9	17.5	72.4	10.3	82.7
Commercial, industrial, institutional	41.6	63.6	105.2	6.3	111.5
Cropland: total	671.0	265.7	936.7	569.4	1506.1
Cropland: corn	350.0	79.6	429.6	277.7	707.3
Cropland: soybeans	201.1	119.2	320.3	109.6	429.9
Cropland: grasses	99.3	19.8	119.1	122.1	241.2
Cropland: orchard	5.3	0	0	49.7	55.0
Cropland: unknown	15.3	47.1	62.4	10.3	72.7
Pastureland	102.7	3.5	106.2	50.6	156.8
Grassland	304.9	159.2	464.1	151.9	616.0
Woodland	504.5	248.8	753.3	135.5	888.8

Table 8.—Watershed characteristics and land use at inflow and outflow sites at Spring Lake
[All measurements in acres, unless noted]

Characteristic	Site 1 (settling pond inflow)	Settling pond	Site 2 (settling pond outflow and lake inflow)	Lake and ungaged watershed	Site 3 (lake outflow)
WATERSHED CHARACTERISTICS					
Total contributing area	5,574.4	60.8	5,635.2	6,928.0	12,563.2
Area under construction	0	0	0	26.1	26.1
Population density (persons/acre)	.06	.06	.06	.22	.15
Relief (ft)	85	35	85	189	189
Drainage density (ft/acre)	13.21	19.74	13.28	15.10	14.23
Impervious area	76	1	77	113	190
Ditch density (ft/acre)	12.33	19.74	12.41	14.57	13.54
Dtich length (mi)	12.84	.23	13.07	16.86	29.93
LAND USE					
Residential (2 units/acre)	140.6	1.2	141.8	446.1	587.9
Residential (3 to 8 units/acre)	21.0	0	21.0	55.0	76.0
Residential, multifamiliy	0	0	0	0	0
Wetlands	817.5	25.0	842.5	868.7	1,711.2
Open water	76.9	0	76.9	820.3	897.2
Parks, open space	1.8	0	1.8	23.2	25.0
Commercial, industrial, institutional	3.9	0	3.9	1.2	5.1
Cropland: total	3,139.5	21.4	3,160.9	2,736.4	5,897.3
Cropland: corn	1,297.5	21.4	1,318.9	1,305.6	2,624.5
Cropland: soybeans	570.9	0	570.9	267.7	835.6
Cropland: grasses	829.7	0	829.7	955.4	1,785.1
Cropland: unknown	340.3	0	340.3	207.7	548.0
Cropland: miscellaneous	101.1	0	101.1	0	101.1
Pastureland	355.3	0	355.3	442.7	798.0
Grassland	375.5	9.5	385.0	672.6	1,057.6
Woodland	300.1	4.1	304.2	613.7	917.9

Table 9.--Watershed characteristics and land use at inflow and outflow sites at Square Lake
[All measurements in acres, unless noted]

Characteristic	Site 1 (lake outflow)
WATERSHED CHARACTERISTICS	
Total contributing area	774.5
Area under construction	0
Population density (persons/acre)	.25
Relief (ft)	129
Drainage density (ft/acre)	n/a
Impervious area	9
Ditch density (ft/acre)	n/a
Ditch length (mi)	n/a
LAND USE	
Residential (2 units/acre)	50.3
Residential (3 to 8 units/acre)	0
Residential, multifamiliy	0
Wetlands	10.3
Open water	210.1
Parks, open space	10.3
Commercial, industrial, institutional	0
Cropland: total	36.6
Cropland: corn	1.0
Cropland: soybeans	15.8
Cropland: grasses	19.8
Pastureland	34.1
Grassland	139.0
Woodland	260.5

Lake Inflows

Inflows to five of the lakes (Bryant, Elmo, Fish, Riley, and Spring) were monitored for flow by continuous stage recorders (15-minute intervals) and for quality by automatic water-quality samplers (1- or 2-hour sampling intervals) during 1982. Inflows were periodically measured and sampled between July and December 1981. Four of these lakes (Elmo, Fish, Riley, and Spring) had primary inflows passing through either a settling pond or wetland, and stage recorders and automatic water-quality samplers were installed both above and below the settling pond or wetland. Figures 9, 10, and 11 show typical installations.

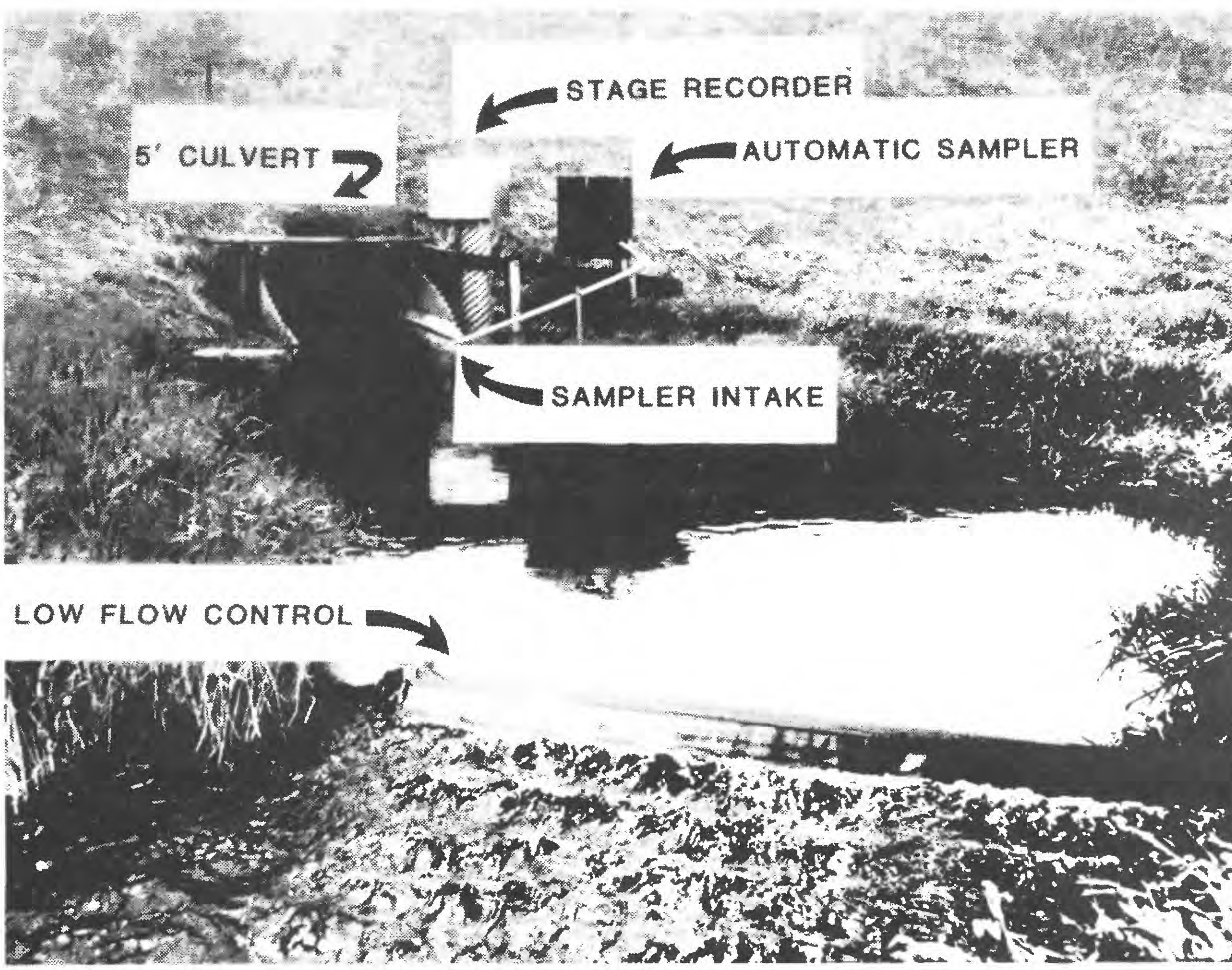


Figure 9.--Photograph showing Spring Lake 1 gage, typical of nine inlet installations automated for stage and water-sample collection

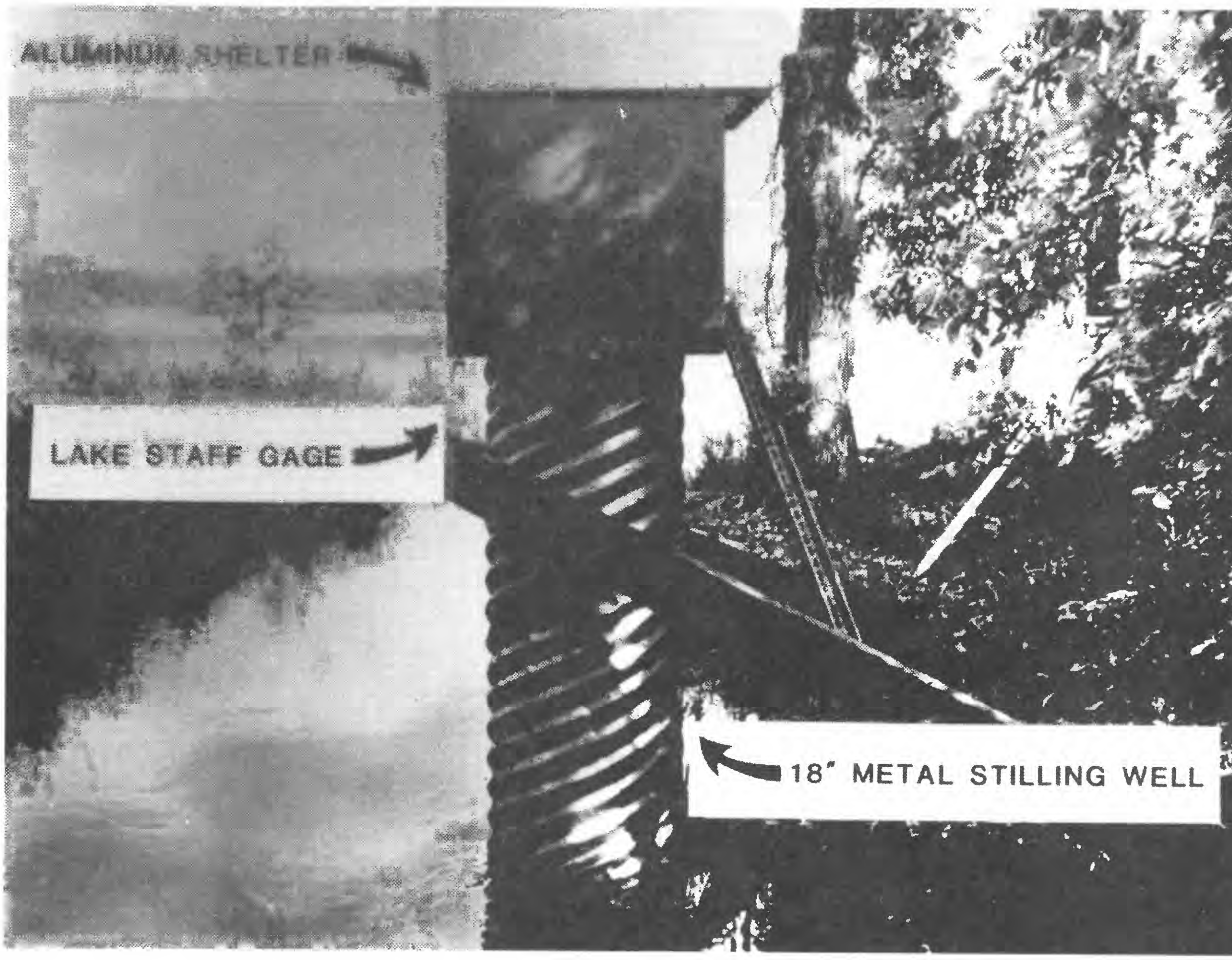


Figure 10.--Photograph showing Lake Elmo 4 gage, typical of six outlet installations automated for stage only

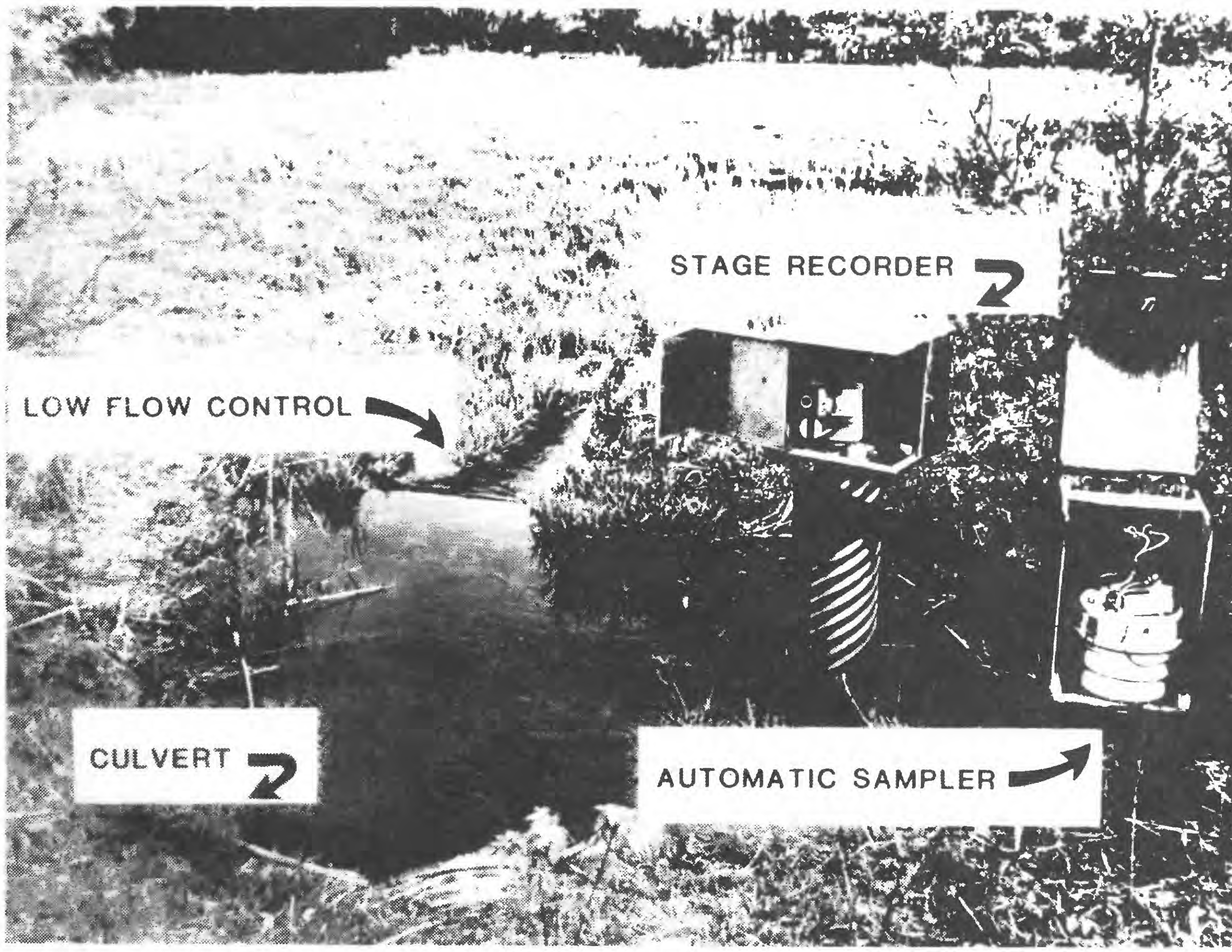


Figure 11.--Photograph showing Fish Lake 1 gage, interior view of a typical wetland inlet installation

Inflows were measured and sampled almost daily during 1982 snowmelt (table 10) and samples were composited as one storm. One 6-week set of base-flow samples was collected after 1982 snowmelt and composited as one storm sample to be used for estimating 1981 concentrations. The 1981 streamflow measurements were combined with the estimated 1981 concentrations for load calculation. After snowmelt, the automatic water-quality samplers were used to collect storm-runoff samples.

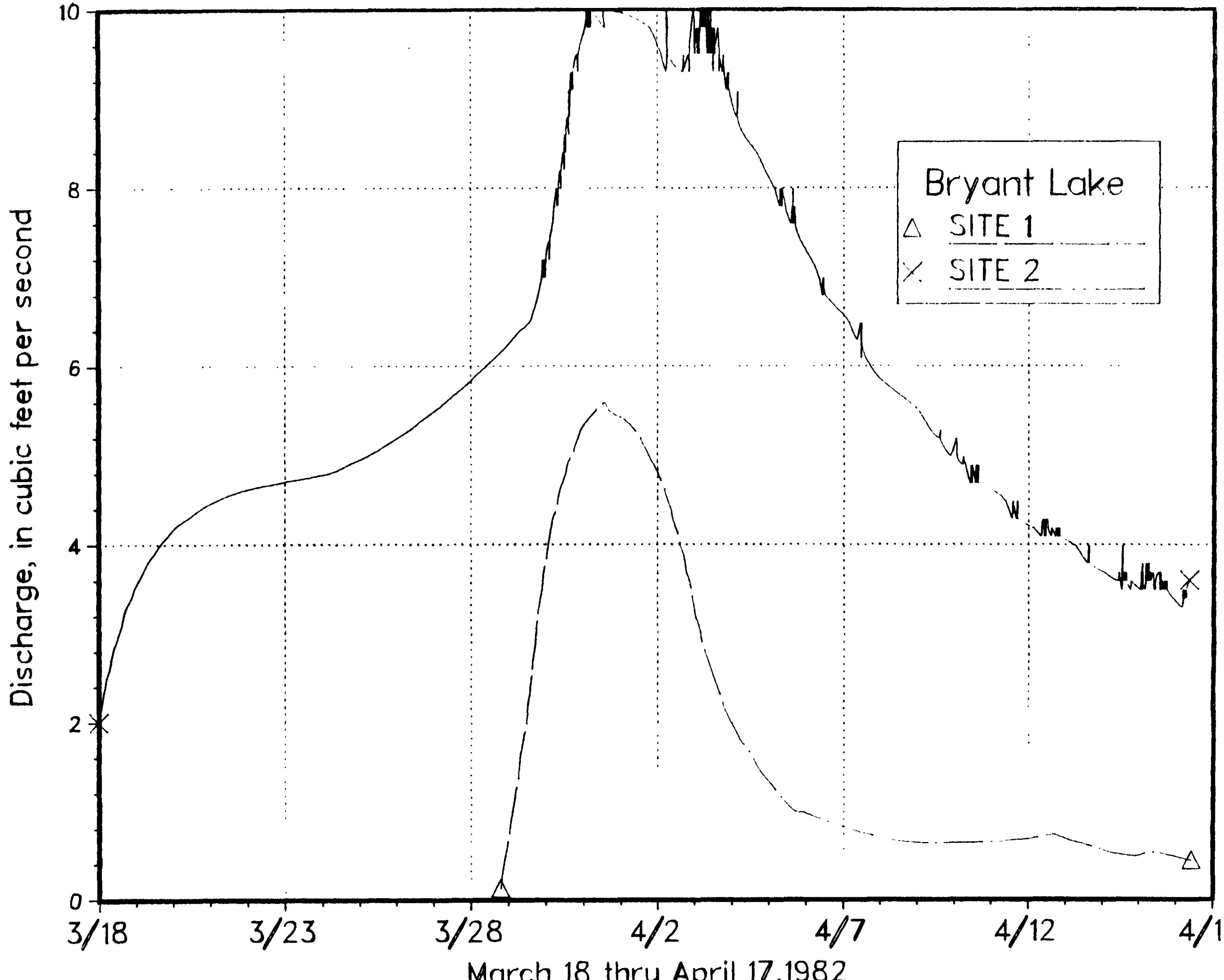


Figure 12.--Streamflow discharge for snowmelt at Bryant Lake, March 30, 1982

Table 10.--Storms sampled for each study site during 1982

Sites[1]	Bryant Lake		Fish Lake						Lake Elmo					Lake George	Lake Riley			Spring Lake			Square Lake
Storm	1	2	1	2	3	A1	A2	A3	1	2	3	4	A1	1	1	2	3	1	2	3	1
March 30	x	x	x	x	x	-	-	-	x	x	x	x	-	x	x	x	x	x	x	x	x
April 16	x	x	x	x	x	-	-	-	x	x	x	x	-	x	x	x	x	x	x	x	x
May 4	x	-	x	x	-	-	-	-	x	-	x	-	-	x	x	x	-	x	x	-	-
May 9	x	-	x	x	-	-	-	-	x	x	x	-	x	-	x	x	-	x	x	-	-
May 17	x	-	x	x	-	-	-	-	x	x	x	-	x	x	x	x	-	x	x	-	-
June 19	-	-	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
June 24	x	-	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	x	x	-	-
June 28	-	-	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	x	x	-	-
July 6	x	-	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
July 10	x	-	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	x	x	-	-
July 25	x	-	x	x	-	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-
August 16	-	-	x	x	-	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-
August 24	x	-	x	x	-	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-
August 26	x	-	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
August 31	x	-	x	x	-	-	-	-	x	-	-	-	-	-	-	-	-	x	x	-	-
September 4	-	-	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
September 10	x	-	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
September 30	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
October 1	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
October 19	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	x	-	-

[1]/Sites in downstream order; auxiliary sites noted by "A" (for example, A1).

Three ungaged inflows to Fish Lake (sites A1, A2, and A3) and one ungaged inflow to Lake Elmo (site A1) were sampled occasionally during 1982 and analyzed by storm for estimation of water quality for comparisons to other gaged sites. These sites were not sampled during 1981.

Square Lake has no channelized inflow so only the outflow was monitored with a continuous-stage recorder. Flow was intermittent at both Lake George site 1 and at Lake Elmo site 2 and did not warrant the use of a continuous-stage recorder.

Lake Outflows

All the lakes (except Lake George) had continuous-stage recorders (15-minute intervals) at their primary outflows. The lake outflows were measured and sampled manually almost daily during snowmelt. The samples were composited as one storm. Because of the longer time between storms and response of the lake outflows, outflows were sampled manually at weekly intervals, and composited every 6 weeks (table 11) using the same mean-discharge-weighted compositing method used for storm samples. The 6-week period of April 22 to June 1 was used to estimate the 1981 concentrations. Data from 1981 streamflow measurements were combined with the estimated 1981 concentrations for load calculations.

Streamflow and Water-Quality Calculations

Streamflow was determined by monitoring stage fluctuations and using stage-discharge relations. The stage-discharge relations were developed from discharge measurements at various stages throughout the collection period. Measurements of discharge were made with a current meter, using methods adopted by the U.S. Geological Survey (Buchanan and Somers, 1969). The accuracy of the stage-discharge relations was controlled by frequent discharge measurements (up to 45 per site during 1982), datum surveys, and control stabilization. The stage records, discharge measurements, and record interpretations were checked for accuracy. Based on periodic discharge measurements, flow hydrographs were estimated for all sites from July 1 to December 31, 1981, and for the ungaged sites for 1982.

Storm samples were collected as soon as possible after the storm. Advance warning of approaching storms was provided by local weather stations. When rain accumulation was predicted to be greater than 0.50 inch, personnel were sent to inspect equipment for malfunctions, start the automatic water-quality samplers, and make discharge measurements before, during, and after the storm. While at the site, temperature and pH of the first and last sample were measured for indications of chemistry changes. Bulk rain gages were inspected and amount of rainfall recorded. Gage heights corresponding to the time of each sample were obtained from the stage recorder. This procedure determined sample position on the storm hydrograph and helped determine which samples would be analyzed. Samples were packed in coolers and transported to the laboratory for further processing. Selected samples were flow composited by the mean-discharge-weighted compositing method so only one sample per site per storm was analyzed. This sample represented the flow-weighted mean concentration for the particular storm. These samples were then split into subsamples

Table 11.--Sites at which samples were collected weekly during periods in 1982

Sampling period, 1982	Sites																				
	Bryant Lake		Fish Lake						Lake Elmo					Lake George	Lake Riley			Spring Lake			Square Lake
	1	2	1	2	3	A1	A2	A3	1	2	3	4	A1	1	1	2	3	1	2	3	1
April 22-June 1	-	x	-	-	x	-	-	-	-	-	-	x	-	-	-	-	x	-	-	x	x
April 22-July 14	x	-	x	x	-	x	x	-	x	x	x	-	-	x	x	x	-	x	x	-	-
June 2-July 17	-	x	-	-	x	-	-	-	-	-	-	x	-	-	-	-	x	-	-	x	x
July 18-September 4	-	-	-	-	x	-	-	-	-	-	-	x	-	-	-	-	-	-	-	x	x
September 5-December 31	-	-	-	-	x	-	-	-	-	-	-	x	-	-	-	-	-	-	-	x	x

for the various constituent analyses, filtered (if required), and preserved. Subsampling was accomplished by shaking and pouring (fig. 12). Subsamples selected for nutrient analyses were preserved with sulfuric acid. All samples were stored at 4.0°C until analyzed.

Storm loads in kilograms of suspended solids, volatile suspended solids, phosphorus, dissolved phosphorus, nitrite-plus-nitrate nitrogen, ammonia nitrogen, and ammonia-plus-organic nitrogen were calculated from the flow-weighted mean concentration, in milligrams per liter, and total flow volume, in cubic meters, for each storm for each site. Loads were calculated with the equation

$$L = (F \times C)K$$

where

L = load of constituent for the storm, in kilograms;

F = total discharge for the storm, in cubic meters;

C = flow-weighted mean concentration of the constituent for the storm, in milligrams per liter; and

K = a constant to convert milligrams per liter to kilograms (10×10^{-3}).

Average seasonal storm flow-weighted mean concentrations were calculated using the following equation

$$C_s = (F_s/F_1)C_1 + (F_s/F_2)C_2 + \ldots(F_s/F_n)C_n$$

where

Cs = average seasonal flow-weighted mean concentrations of constituent,

Fs = total flow during the season,

Fl = total flow during the first storm or storm number 1 of the season, and

Cl = storm flow-weighted mean concentration of constituent for the first storm or storm number 1.

Average flow-weighted mean concentrations for 1982 were calculated using the following equation

$$C_a = (F_a/F_1)C_1 + (F_a/F_2)C_2 + \ldots(F_a/F_n)C_n$$

where

Ca = average flow-weighted mean concentration of constituent for 1982,

Fa = total flow during 1982,

Fl = total flow during the first storm or storm number 1 of 1982, and

Cl = storm flow-weighted mean concentration of constituent for the first storm or storm number 1.

Average seasonal storm loads were calculated by taking the arithmetic means of the storm loads for each season. Storm flow-weighted mean-concentration ratios were calculated for suspended solids (percentage of suspended solids in volatile form; volatile suspended solids/suspended solids), phosphorus (percent of phosphorus in dissolved form; dissolved phosphorus/total phosphorus), and nitrogen (percent of nitrogen in the form of ammonia; ammonia nitrogen/ammonia-plus-organic nitrogen).

Precipitation

Rainfall recorders (15-minute intervals) and bulk rain gages were installed at each lake except George. Lake George had a bulk rain gage read by an observer. All rainfall recorders except Lake Elmo's had continual mechanical failures and the data were not used. Totals from the bulk rain gages for each storm by lake are shown in table 12.

Three NOAA (National Oceanic and Atmospheric Administration) observers were hired to provide daily precipitation data. Table 13 compares 1982 total precipitation with median annual precipitation for these sites. The average annual precipitation for 1982 was 9 percent higher based on these data.

Table 12.--Precipitation totals by storm for the seven study lakes

[Values in millimeters]

Storm	Bryant Lake	Lake Elmo	Fish Lake	Lake George	Lake Riley	Spring Lake	Square Lake
March 30..........	104.1	109.7	108.4	114.0	103.9	99.6	119.9
April 16..........	29.0	27.4	24.9	20.6	37.1	34.5	30.2
May 4.............	5.8	33.0	26.2	31.8	27.2	36.3	39.6
May 9.............	39.6	52.3	39.4	31.0	52.1	61.2	47.0
May 17............	52.8	56.4	68.6	41.9	21.1	25.9	2.3
June 14...........	5.6	6.6	9.4	16.0	9.6	5.6	6.1
June 24...........	32.8	27.2	24.1	15.2	30.2	34.3	13.2
June 28...........	3.3	10.4	10.4	11.7	0.8	1.3	18.8
July 6............	15.2	9.1	18.5	33.0	19.0	11.2	8.9
July 10...........	13.7	8.1	25.4	2.8	19.8	33.5	17.8
July 25...........	22.6	17.0	36.1	24.6	24.6	22.6	20.1
August 16.........	7.6	3.3	29.5	7.4	8.1	9.9	4.8
August 24.........	35.6	23.9	19.6	9.6	33.8	48.5	21.8
August 26.........	12.2	22.6	17.8	17.0	12.2	14.2	15.5
August 31.........	38.1	69.1	42.2	47.0	43.4	70.9	34.8
September 4.......	7.1	14.0	15.0	0.0	6.6	11.9	8.6
September 10......	47.5	41.9	32.2	30.5	36.3	25.1	56.1
October 2.........	26.7	26.2	26.7	6.6	21.8	14.5	30.0
October 8.........	26.7	10.4	18.5	20.3	21.8	22.4	40.4
October 19........	35.6	40.4	35.6	18.8	35.3	33.3	34.3

Table 13.--Frequency statistics for three National Oceanographic and Atmospheric Administration weather stations for 1982 total rainfall

Site	Median annual precipitation (mm)	1982 precipitation (mm)	Deviation from median annual (percent)
Buffalo..........	711	885	20
Chaska...........	721	759	5
Forest Lake......	774	787	2
Average deviation from median annual precipitation in 1982............................			9

Atmospheric Data

Collectors were installed at each lake (including Eagle Point Lake) to obtain data on input from the atmosphere of selected chemical constituents and suspended solids. Data were collected from September 23 to November 1, 1982. Both wetfall and dryfall were collected as a composite sample. Table 14 shows concentration data and table 15 shows load data for each lake watershed. The loads were calculated using the following equation

$$L_a = [(RC_a)K](A_w/A_b)$$

where

L_a = atmospheric load of constituent for the collection period, in kilograms;

R = total rainfall during the collection period, in liters;

C_a = concentration of constituent, in milligrams per liter;

K = constant to convert milligrams per liter to kilograms (10×10^{-3});

A_w = area of watershed, in square meters; and

A_b = area of collection bucket, in square meters.

Table 14.--Atmospheric input concentrations for all study lakes, including Eagle Point Lake, for the collection period September 23 to November 1, 1982

Site	Total suspended solids (mg/L)	Volatile suspended solids (mg/L)	Total phosphorus (mg/L)	Dissolved phosphorus (mg/L)	Dissolved NO2+NO3 nitrogen (mg/L)	Total ammonia nitrogen (mg/L)	Total ammonia + organic nitrogen (mg/L)
Bryant Lake	50	12	0.06	0.02	0.25	0.22	1.2
Eagle Point Lake	10	10	.23	.12	.45	1.1	1.9
Fish Lake	25	16	.14	.04	.15	.06	1.1
Lake Elmo	10	10	.10	.04	.35	.50	1.4
Lake George	20	14	.14	.05	.30	.06	.88
Lake Riley	36	22	.19	.04	.15	.29	2.3
Spring Lake	24	17	.37	.10	.40	.94	5.0
Square Lake	6.0	6.0	.07	.04	.80	.06	.60

Table 15.--Atmospheric input, total precipitation, and loads for all study lakes, including Eagle Point Lake, for the collection period September 23 to November 1, 1982

Site	Total precip-itation (mm)	Total sus-pended solids (kg/ha)	Vola-tile sus-pended solids (kg/ha)	Total phos-phorus (kg/ha)	Dis-solved phos-phorus (kg/ha)	Dis-solved NO_2+NO_3 nitro-gen (kg/ha)	Total ammonia nitro-gen (kg/ha)	Total ammonia + organic nitro-gen (kg/ha)
Bryant Lake	104	8.2	2.0	0.01	<0.01	0.04	0.04	0.19
Eagle Point Lake	112	1.6	1.6	.04	.02	.07	.18	.32
Fish Lake	74	4.1	2.6	.02	.01	.02	.01	.18
Lake Elmo	112	1.6	1.6	.02	.01	.06	.08	.22
Lake George	67	3.3	2.3	.02	.01	.05	.01	.14
Lake Riley	94	5.9	3.6	.03	.01	.02	.05	.38
Spring Lake	80	3.9	2.8	.06	.02	.06	.15	.82
Square Lake	120	.98	.98	.01	.01	.13	.01	.10

Water-Quality Analyses

Both lake inflow and outflow samples were analyzed for (1) total suspended solids, (2) volatile suspended solids, (3) total phosphorus, (4) dissolved phosphorus, (5) nitrite-plus-nitrate nitrogen, (6) ammonia nitrogen, and (7) ammonia-plus-organic nitrogen. Atmospheric deposition samples were analyzed for the same constituents as the storm samples.

Samples were analyzed by the MWCC (Metropoltian Waste Control Commission) laboratory in St. Paul, Minn., according to methods described by the American Public Health Association (1976), Metropolitan Waste Control Commission (1979), U.S. Environmental Protection Agency (1978; 1979), and Skougstad and others (1979). Quality-assurance analysis of samples was split between the MWCC laboratory and the U.S. Geological Survey laboratory in Atlanta, Ga. The U.S. Geological Survey laboratory analyzed the samples according to methods described in Goerlitz and Brown (1972) and Skougstad and others (1979).

Quality Assurance

A quality-assurance program was undertaken to assess the precision of the sample-preparation techniques and the analytical accuracy of the laboratories. The program included submitting replicate and spiked samples to both MWCC and U.S. Geological Survey laboratories.

During preparation, samples were shaken and then poured into subsamples for analysis. To determine the adequacy of the shake-and-pour method, it was compared to the cone-splitter method devised by the U.S. Geological Survey. Three replicate subsamples were obtained by each method of splitting. Mean concentration values were then computed for the reported analytical results of each set of replicate subsamples. A t-table was used to compute confidence intervals of the means. Differences between the means of each splitting method were tested for significance (f-test) at the 0.05 alpha level. Precision between two methods was nearly the same, as none of the differences were significant (table 16). These results are similar to the conclusions made by Payne and others (1982) in an earlier quality-assurance analysis of these methods. However, it should be noted that the test was only performed once and the concentration levels were near the detection limits. The results of the test do agree with Payne and others (1982) but the significance of the test is limited.

Precision of composite versus discrete sampling is shown in table 17. Total suspended solids and total ammonia + organic nitrogen had a 5-percent difference in average confidence interval (because the average difference between method values exceeded the average confidence interval of the laboratory precision or error by 5 percent). Total volatile suspended solids and total phosphorus average difference was within the range of the average confidence interval for laboratory precision. The quality-assurance program was limited by small sample size (n = 3 replicates) and a small number of tests.

Precision of both the MWCC and U.S. Geological Survey laboratories was evaluated on the basis of quality-assurance data for replicate samples and was determined by evaluating the confidence intervals (CI) of the sample means for each constituent. Sending samples to both laboratories provided an opportunity to compare precision values at the MWCC laboratory to precision values at another laboratory. Results are shown in table 18. Three replicate sets of susbsamples were prepared for each laboratory three different times. Mean concentrations were computed from the results reported from each laboratory and confidence intervals were computed and compared. Each laboratory had higher confidence intervals for particular samples, but the overall confidence intervals were generally equal. These results indicate that there was little difference between the laboratories for precision, which agrees with previous MWCC quality-assurance tests (Payne and others, 1982).

Table 16.--Analytical results for two methods of sample splitting

[SD is standard deviation; CI is confidence interval (95 percent level)]

Site	Sample Identification	Method	Total suspended solids (mg/L)	Volatile suspended solids (mg/L)	Total ammonia + organic nitrogen (mg/L)	Total ammonia nitrogen (mg/L)	Dissolved $NO_2 + NO_3$ nitrogen (mg/L)	Total phosphorus (mg/L)	Dissolved phosphorus (mg/L)
QL	1	Poured	2	2	0.36	0.04	0.05	0.01	0.01
QL	2	Poured	2	2	.32	.03	.10	.01	.01
QL	3	Poured	3	2	.32	.04	.05	.02	.01
MEAN			2	2	.33	.04	.07	.01	.01
SD			1	0	.02	.01	.03	.01	.00
CI			2±1	2±1	.33±0.03	.04±0.01	.07±0.04	.01±0.01	.01±0
QL	1	Cone splitter	1	1	.68	.03	.05	.01	.01
QL	2	Cone splitter	2	2	.68	.04	.05	.02	.01
QL	3	Cone splitter	2	2	.26	.02	.05	.01	.01
MEAN			2	2	.54	.03	.05	.01	.01
SD			1	1	.24	.01	.00	.01	.00
CI			2±1	2±1	.54±0.36	.03±0.01	.05±0	.01±0.01	.01±0

Table 17.--Analytical results for comparing composite and discrete sampling methods

Site	Method	Total suspended solids (mg/L)	Volatile suspended solids (mg/L)	Total phosphorus (mg/L)	Total ammonia + organic nitrogen (mg/L)
SL3	Discrete	5	3	0.43	1.8
	compositing	6	4	.43	1.8
FL1	Discrete	21	5	.25	1.2
	compositing	14	6	.22	1.1
FL2	Discrete	5	3	.26	1.6
	compositing	4	4	.19	1.2
Average difference between method values, in percent		21	21	13	12
*Average confidence interval found in replicate quality assurance, in percent (precision error)		16	27	18	7
Difference between methods excluding precision error		5	0	0	5

*Data based on the quality-assurance analysis of replicate samples at both the MWCC and USGS labs (table 18).

Table 18.--Analytical results for replicate samples

[SD is standard deviation; CI is confidence interval (95 percent level); * denotes significant difference in means at 0.05 alpha level]

Site	Sample identification	Laboratory	Total suspended solids (mg/L)	Volatile suspended solids (mg/L)	Total ammonia + organic nitrogen (mg/L)	Total ammonia nitrogen (mg/L)	Dissolved $NO_2 + NO_3$ nitrogen (mg/L)	Total phosphorus (mg/L)	Dissolved phosphorus (mg/L)
					Precision Test 1				
LG3	1	MWCC	7	7	1.5	0.08	0.10	0.07	0.03
	2	MWCC	6	6	1.3	.07	.10	.06	.04
	3	MWCC	6	6	1.4	.08	.10	.06	.04
MEAN			6	6	1.4	.08	.10	.06	.04
SD			1	1	.2	.00	.00	.00	.00
CI			6±1	6±1	1.4±0.2	.08±0.01	.10±0.00	.06±0.01	.04±0.01
LG3	1	USGS	4	2	1.5	.08	.10	.07	.04
	2	USGS	5	2	1.3	.08	.10	.09	.04
	3	USGS	4	2	1.4	.05	.10	.06	.04
MEAN			4	2	1.4	.07	.10	.07	.04
SD			1	0	.1	.01	.00	.01	.00
CI			4±1	2±0	1.4±0.2	.07±0.02	.10±0	.07±0.02	0.04±0
					Precision Test 2				
FL4	1	MWCC	10	5	2.1	.07	.15	.21	.17
	2	MWCC	8	5	2.2	.09	.15	.17	.20
	3	MWCC	10	4	2.1	.09	.15	.14	.13
MEAN			*9	*5	*2.1	.08	* .15	.17	.17
SD			1	1	.1	.01	.00	.04	.04
CI			9±2	5±1	2.1±0.1	.08±0.02	.15±0	.17±0.05	0.17±0.05

Table 18.--Analytical results for replicate samples--Continued

Site	Sample identi-fication	Labor-atory	Total sus-pended solids (mg/L)	Volatile sus-pended solids (mg/L)	Total ammonia + organic nitrogen (mg/L)	Total ammonia nitrogen (mg/L)	Dis-solved $NO_2 + NO_3$ nitrogen (mg/L)	Total phosphorus (mg/L)	Dissolved phosphorus (mg/L)
					Precision Test 2--Continued				
FL4	1	USGS	14	10	1.5	0.08	0.10	0.21	0.14
	2	USGS	16	10	1.3	.09	.10	.20	.14
	3	USGS	15	10	1.5	.08	.10	.21	.15
MEAN			*15	*10	*1.4	.08	* .10	.21	.14
SD			1	0	.1	.00	.00	.01	.01
CI			15±2	10±0	1.4±0.2	.08±0.01	.10±0	.21±0.01	.14±0.01
					Precision Test 3				
FL4	1	MWCC	6	2	1.5	.18	*1.8	.34	.27
	2	MWCC	5	1	1.4	.16	1.8	.31	.26
	3	MWCC	6	2	1.5	.32	1.8	.35	.28
MEAN			6	2	1.5	.22	1.8	.33	* .27
SD			1	1	.1	.09	<.1	.02	.01
CI			6±1	2±1	1.5±0.1	.22±0.13	1.8±<0.1	.33±0.03	.27±0.01
FL4	1	USGS	4	3	1.0	.19	1.5	.37	.30
	2	USGS	6	5	1.1	.18	1.4	.34	.29
	3	USGS	2	1	1.4	.18	1.5	.33	.29
MEAN			4	3	1.2	.18	*1.5	.35	* .29
SD			2	2	.2	.01	.1	.02	.01
CI			4±3	3±3	1.2±0.3	.18±0.01	1.5±0.1	.35±0.03	.29±0.01

Accuracy of the analyses was another objective of the quality-assurance program. Accuracy was determined by sending spiked samples to both the MWCC and U.S. Geological Survey laboratories, because sending samples to only one laboratory would not provide enough information to determine accuracy. Spiked samples can be expected to have errors associated with subsampling and spike preparation. Therefore, the results of using only one laboratory would include errors in sample preparation and laboratory analytical error with no differentiation. Sending samples to both laboratories provided an opportunity to compare values and evaluate the accuracy of each. Six sets of spiked and unspiked subsamples were analyzed by each laboratory three times. Half were spiked with measured volumes of known concentrations supplied by the U.S. Environmental Protection Agency. In order to evaluate the accuracy of the laboratory, the mean concentrations determined for the unspiked subsamples were subtracted from the mean concentrations determined for the spiked sub samples. The resulting values were compared with the known concentrations of the spikes and to the other laboratory (table 19). Accuracy of the MWCC laboratory, as determined by the results of the three spiked sample tests, ranged from 0 to 44 percent. The results between MWCC and U.S. Geological Survey laboratories were generally equal. However, concentrations of ammonia nitrogen were consistently different between the laboratories. The accuracy of the MWCC laboratory was consistent with that of the U.S. Geological Survey laboratory and the differences between calculated and known spikes were probably the result of spike preparation.

Table 19.--Analytical results for spiked samples

[SD is standard deviation; CI is confidence interval (95 percent level); * denotes significant difference in means at 0.05 alpha level; spike calculated is the mean concentration of spiked samples minus the mean concentration of unspiked samples; spike known is the actual concentration of spike]

Site	Sample Identification	Laboratory	Total suspended solids (mg/L)	Volatile suspended solids (mg/L)	Total ammonia + organic nitrogen (mg/L)	Total ammonia nitrogen (mg/L)	Dissolved $NO_2 + NO_3$ nitrogen (mg/L)	Total phosphorus (mg/L)	Dissolved phosphorus (mg/L)
					Accuracy Test 1				
LG3	1	MWCC	530	294	4.8	0.16	0.45	0.89	0.34
	2	MWCC	510	294	4.9	.19	.45	.92	.34
	3	MWCC	520	294	5.3	.28	.45	1.0	.34
	MEAN		520	294	5.0	* .21	* .45	.94	.34
	SD		10	0	.3	.06	.00	.06	.00
	CI		520±15	294±0	5.0±.4	0.21±.09	0.45±0	0.94±.09	0.34±0
	Spike calculated		514	288	.6	.13	.35	.88	.30
	Spike known		530	294	4.2	.19	.31	.95	unknown
	Percent difference		-3	-2	-14	-32	+13	-7	---
LG3	1	USGS	500	296	5.0	1.8	.29	.95	.32
	2	USGS	528	303	4.9	1.8	.27	.94	.32
	3	USGS	514	300	4.7	1.8	.28	.95	.33
	MEAN		514	299	4.9	*1.8	* .28	.95	.32
	SD		14	3.5	.2	0	.01	.01	.01
	CI		514±21	299±15	4.9±0.2	1.8±0	.28±0.1	.95±0.1	.32±.01
	Spike calculated		510	297	3.5	1.7	.18	.88	.28
	Spike known		530	294	4.2	.19	.31	.95	unknown
	Percent difference		-4	+<1	-17	+850	-42	-7	---

Table 19.--Analytical results for spiked samples--Continued

Site	Sample Identi-fication	Labor-atory	Total sus-pended solids (mg/L)	Volatile sus-pended solids (mg/L)	Total ammonia + organic nitrogen (mg/L)	Total ammonia nitrogen (mg/L)	Dis-solved $NO_2 + NO_3$ nitrogen (mg/L)	Total phosphorus (mg/L)	Dissolved phosphorus (mg/L)
					Accuracy Test 2				
FL4	1	MWCC	290	156	4.6	0.68	1.6	0.80	1.3
	2	MWCC	252	166	4.0	.66	1.6	.82	1.4
	3	MWCC	309	160	5.1	.65	1.7	.86	1.3
MEAN			284	*161	4.6	* .66	1.7	.83	1.3
SD			29	5	.1	.02	< .1	.03	.1
CI			284±43	161±7	4.6±0.1	0.66±.02	1.7±<.01	0.83±.04	1.3±.1
Spike calculated			275	156	2.5	.58	1.6	.66	1.1
Spike known			343	190	2.3	.72	1.6	.50	unknown
Percent difference			-20	-18	+8	-20	0	+32	---
FL4	1	USGS	338	204	3.7	1.5	1.6	.79	1.6
	2	USGS	320	200	3.9	1.5	1.6	.81	1.6
	3	USGS	330	209	4.0	1.5	1.6	.80	1.6
MEAN			329	*204	3.9	*1.5	1.6	.80	1.6
SD			9.0	4	.1	.0	0	.01	0
CI			329±13	204±7	3.9±.2	1.5±0	1.6±0	.80±0	16±0
Spike calculated			314	194	2.5	1.4	1.5	.59	1.5
Spike known			343	190	2.3	.72	1.6	.50	unknown
Percent difference			-8	+2	+8	+97	-6	+18	---

Table 19.--Analytical results for spiked samples--Continued

Site	Sample Identi- fication	Labor- atory	Total sus- pended solids (mg/L)	Volatile sus- pended solids (mg/L)	Total ammonia + organic nitrogen (mg/L)	Total ammonia nitrogen (mg/L)	Dis- solved $NO_2 + NO_3$ nitrogen (mg/L)	Total phosphorus (mg/L)	Dissolved phosphorus (mg/L)
					Accuracy Test 3				
FL4	1	MWCC	34	3	6.0	0.28	3.7	1.2	0.56
	2	MWCC	34	3	6.0	.24	3.6	1.2	.54
	3	MWCC	32	1	7.8	.22	3.6	1.1	.64
MEAN			33	2	6.6	* .25	3.6	1.2	.58
SD			1	1	1.0	.03	.1	.1	.06
CI			33±7	2±2	6.6±1.5	.25±.04	3.6±.1	1.2±.1	.58±.08
Spike calculated			27	.00	5.1	.03	1.8	.87	.31
Spike known			30	.00	4.8	unknown	3.2	1.0	unknown
Percent difference			-10	0	+6	---	-44	-13	---
FL4	1	USGS	38	8	4.5	2.2	3.0	1.7	.56
	2	USGS	21	4	4.1	2.2	3.0	1.7	.56
	3	USGS	33	1	4.6	2.1	3.0	1.7	.56
MEAN			31	4	4.4	*2.1	3.0	1.7	.56
SD			9	4	.3	.1	0.0	0	0
CI			31±13	4±5	4.4±.4	2.1±.1	3.0±0	1.7±0	.56±0
Spike calculated			27	1	3.2	1.9	1.5	1.4	.27
Spike known			30	0.00	4.8	unknown	3.2	1.0	unknown
Percent difference			-10	+<100	-33	---	-53	+40	---

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DATA TABLES AND HYDROGRAPHS

The following tables and figures contain data collected during the study. Statistical Analysis System computer programs were used to compile and tabulate some of the tables. Site-identification numbers for each lake are in downstream order. All data were rounded to two significant figures.

Mean daily discharge, instantaneous discharge, rainfall data, and water-quality data are stored in the U.S. Geological Survey WATSTORE system. Water-quality data are also stored in the U.S. Environmental Protection Agency STORET system.

The data are divided into four sections: the first contains storm quantity and quality data for lake-inflow sites, organized by lake; the second includes the weekly quantity and quality data for the lake outflows; the third contains seasonal-load data, arranged by lake; and the fourth contains estimated flow hydrographs for 1981 and annual load data for both 1981 and 1982.

Inflows

This section contains storm-inflow hydrographs, concentration tables, and load tables, organized by lake. Snowmelt and the first subsequent storm include outflow data, composited as storms. There are four types of concentration tables for each lake (1) mean storm concentrations, (2) mean storm concentration ratios, (3) average storm concentrations for each season, and (4) seasonal average storm concentration ratios.

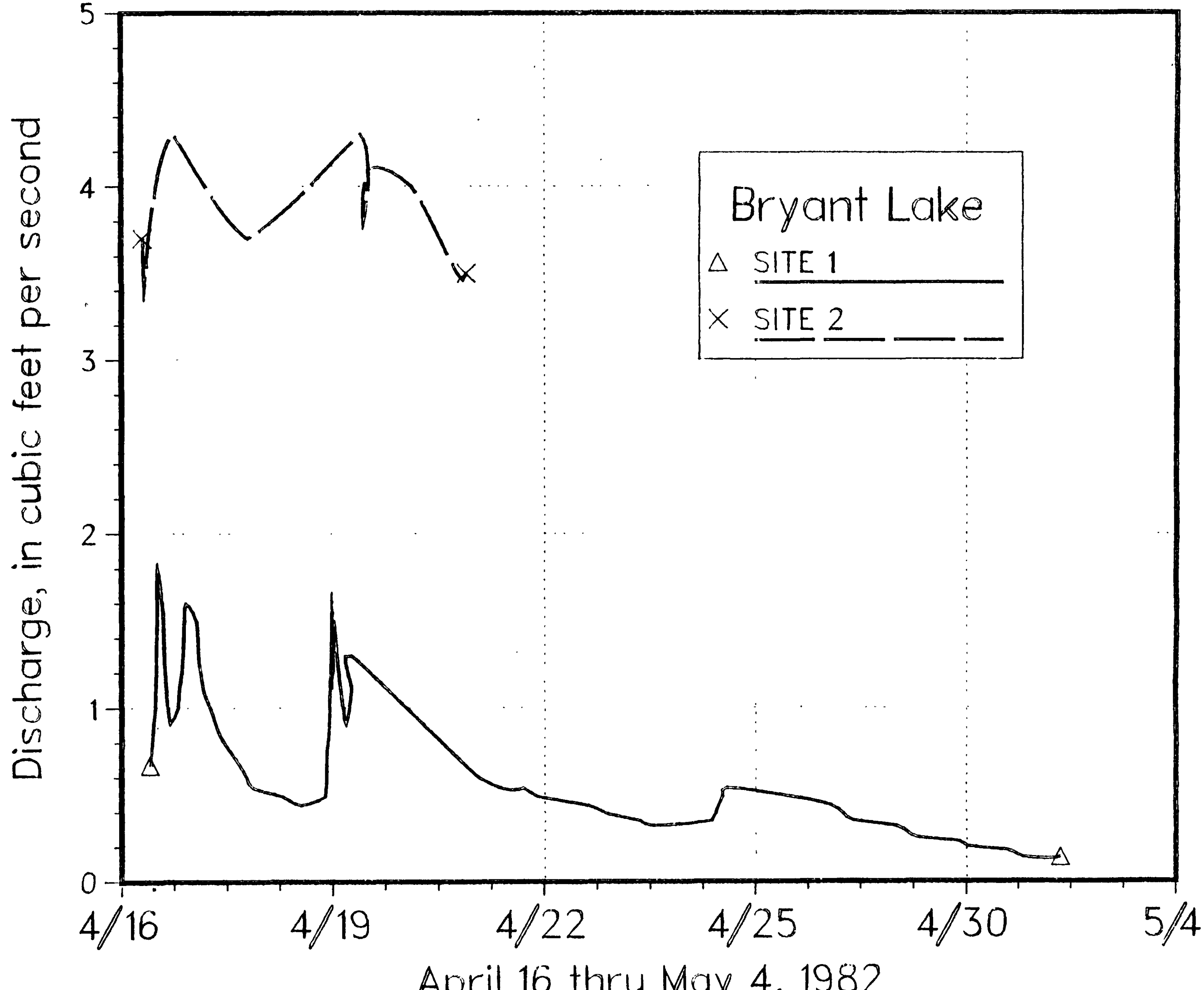

Figure 13.--Streamflow discharge for Bryant Lake, storm of April 16, 1982

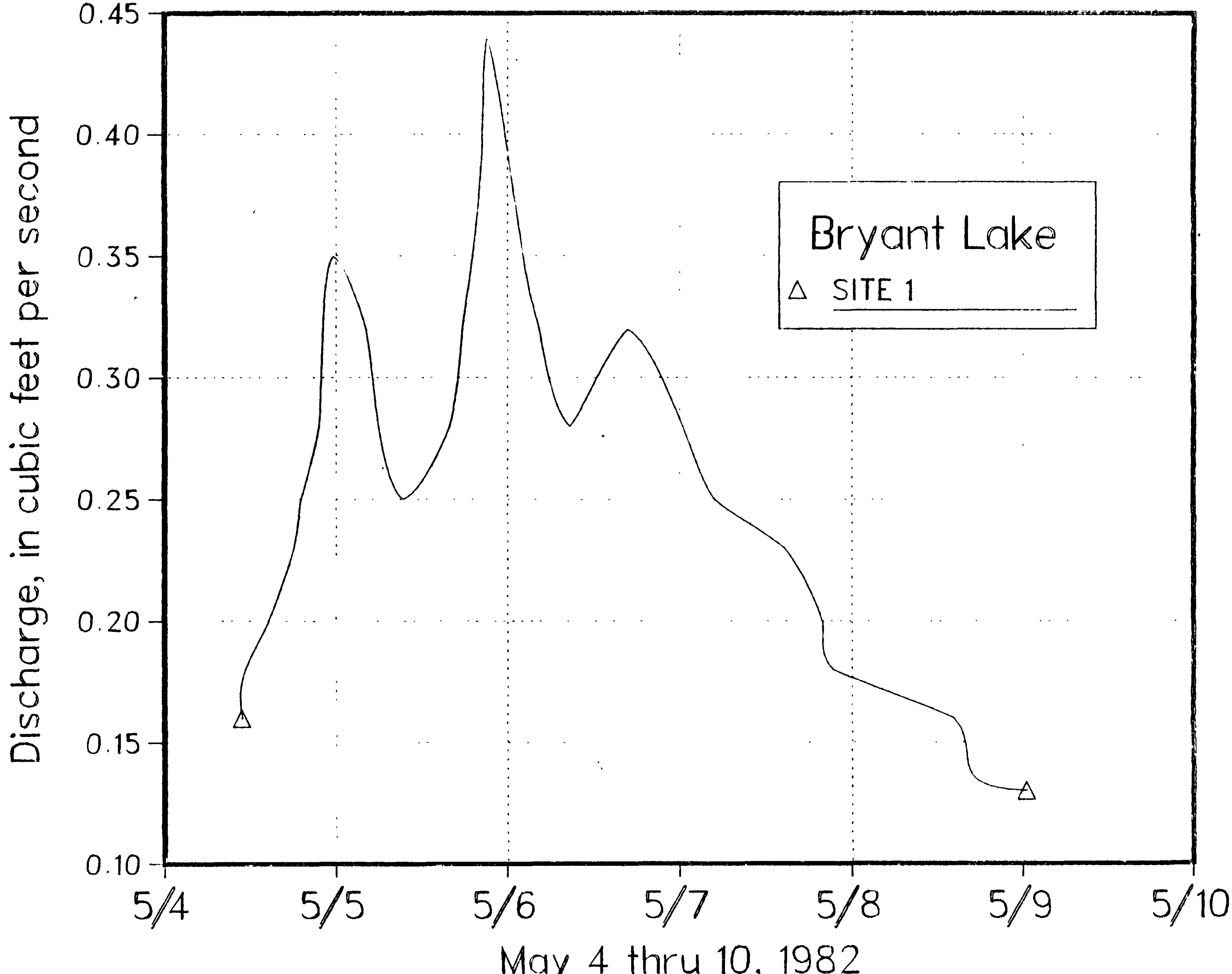

Figure 14.--Streamflow discharge for Bryant Lake, storm of May 4, 1982

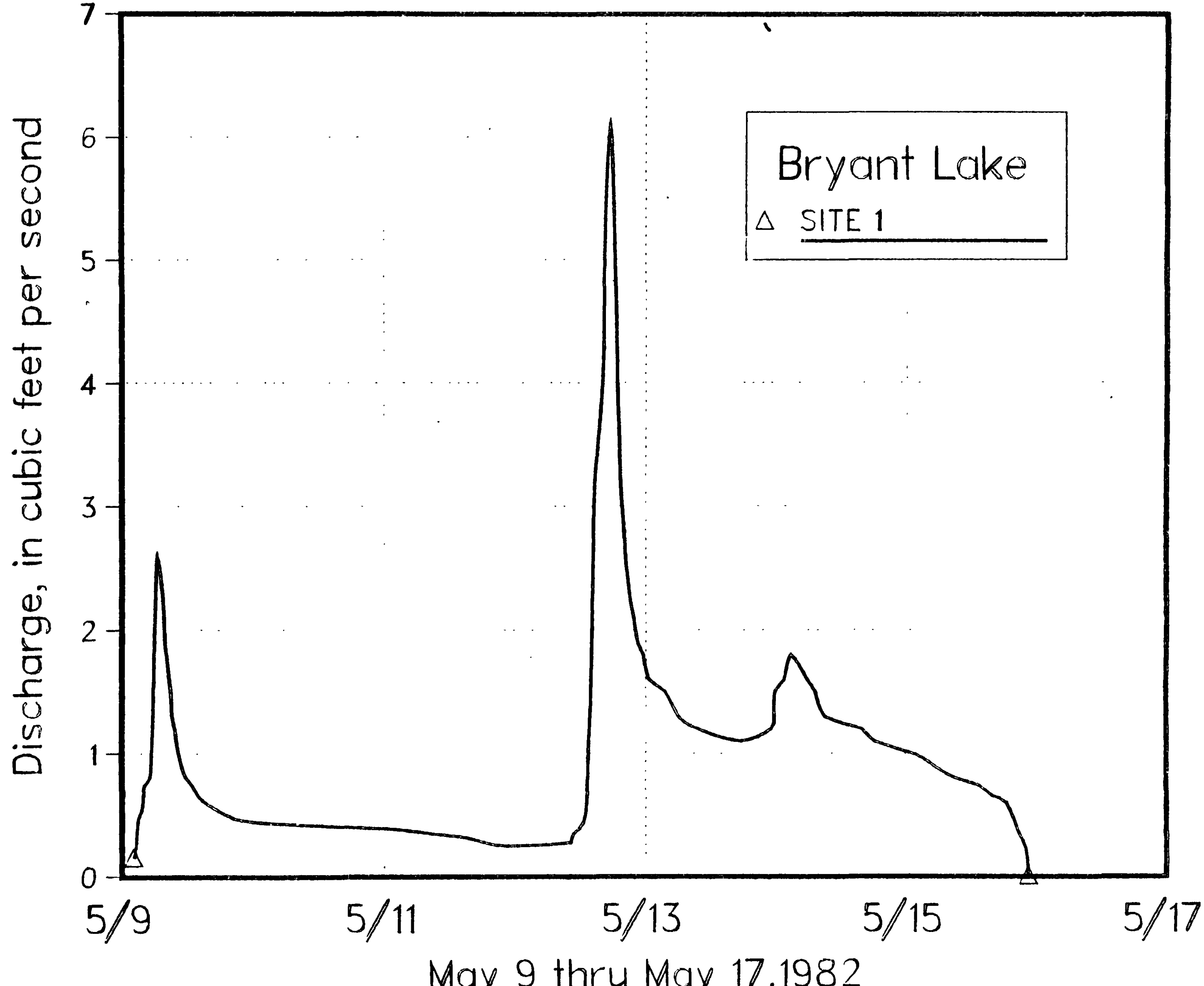

Figure 15.--Streamflow discharge for Bryant Lake, storm of May 9, 1982

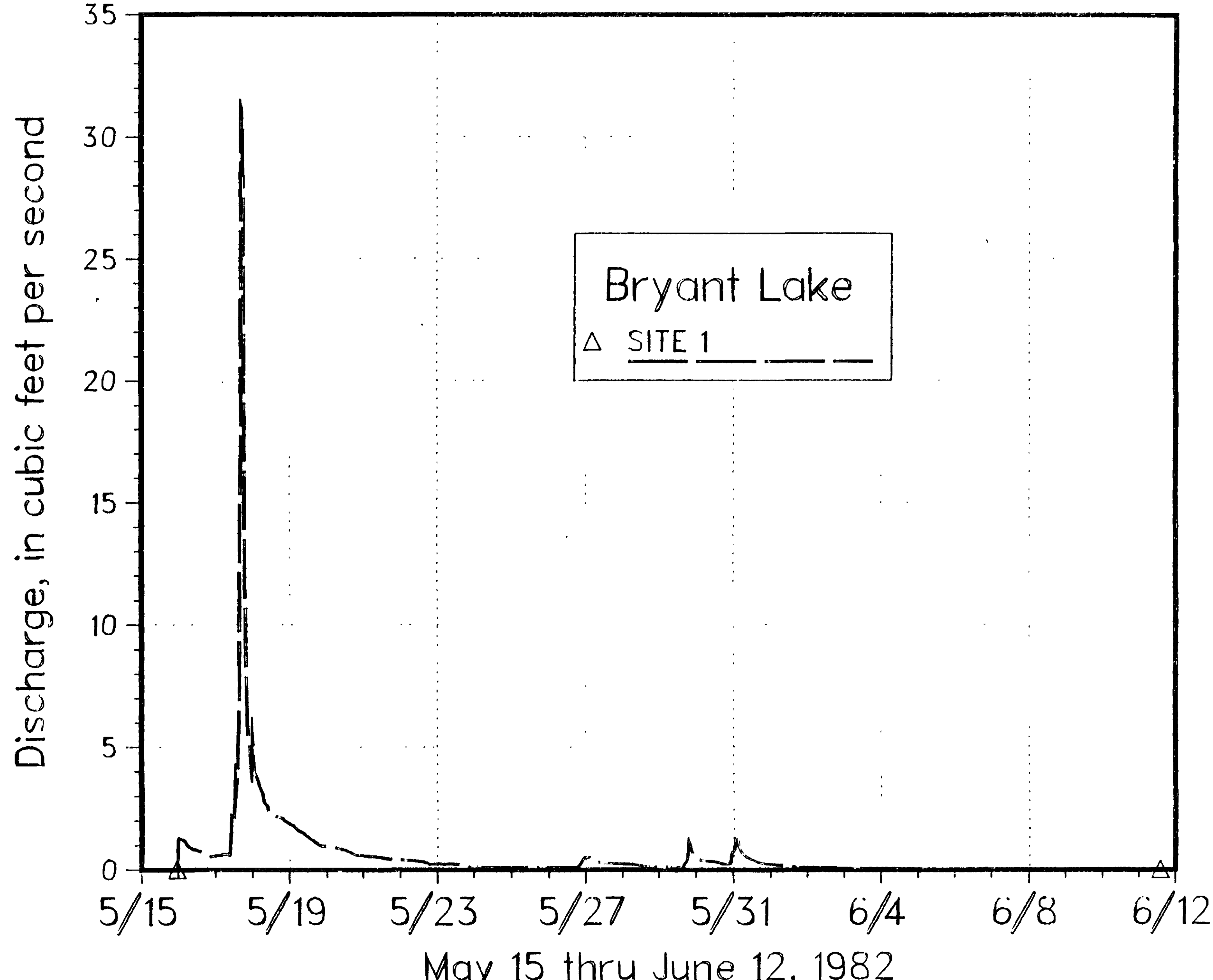

Figure 16.--Streamflow discharge for Bryant Lake, storm of May 17, 1982

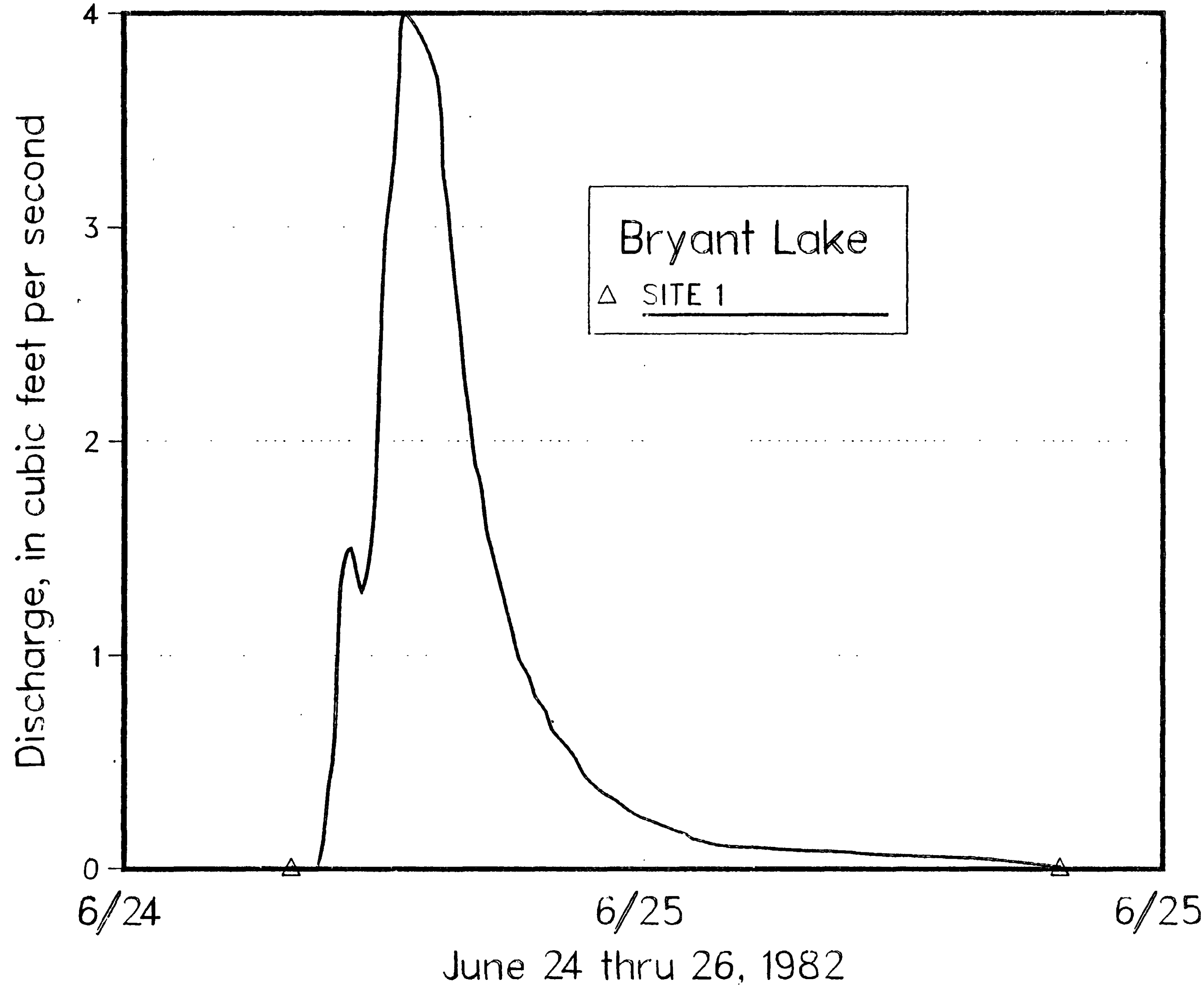

Figure 17.--Streamflow discharge for Bryant Lake, storm of June 24, 1982

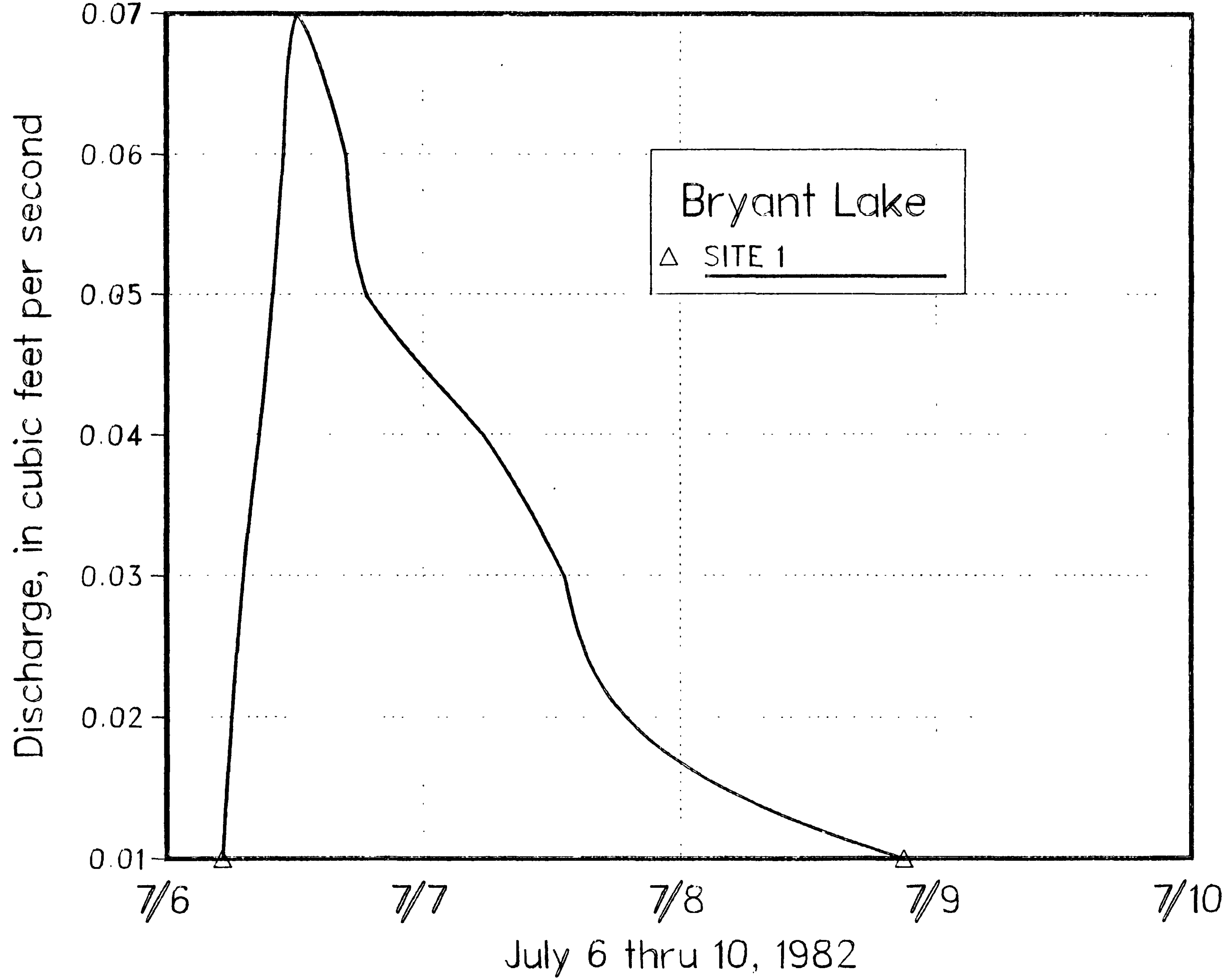

Figure 18.--Streamflow discharge for Bryant Lake, storm of July 6, 1982

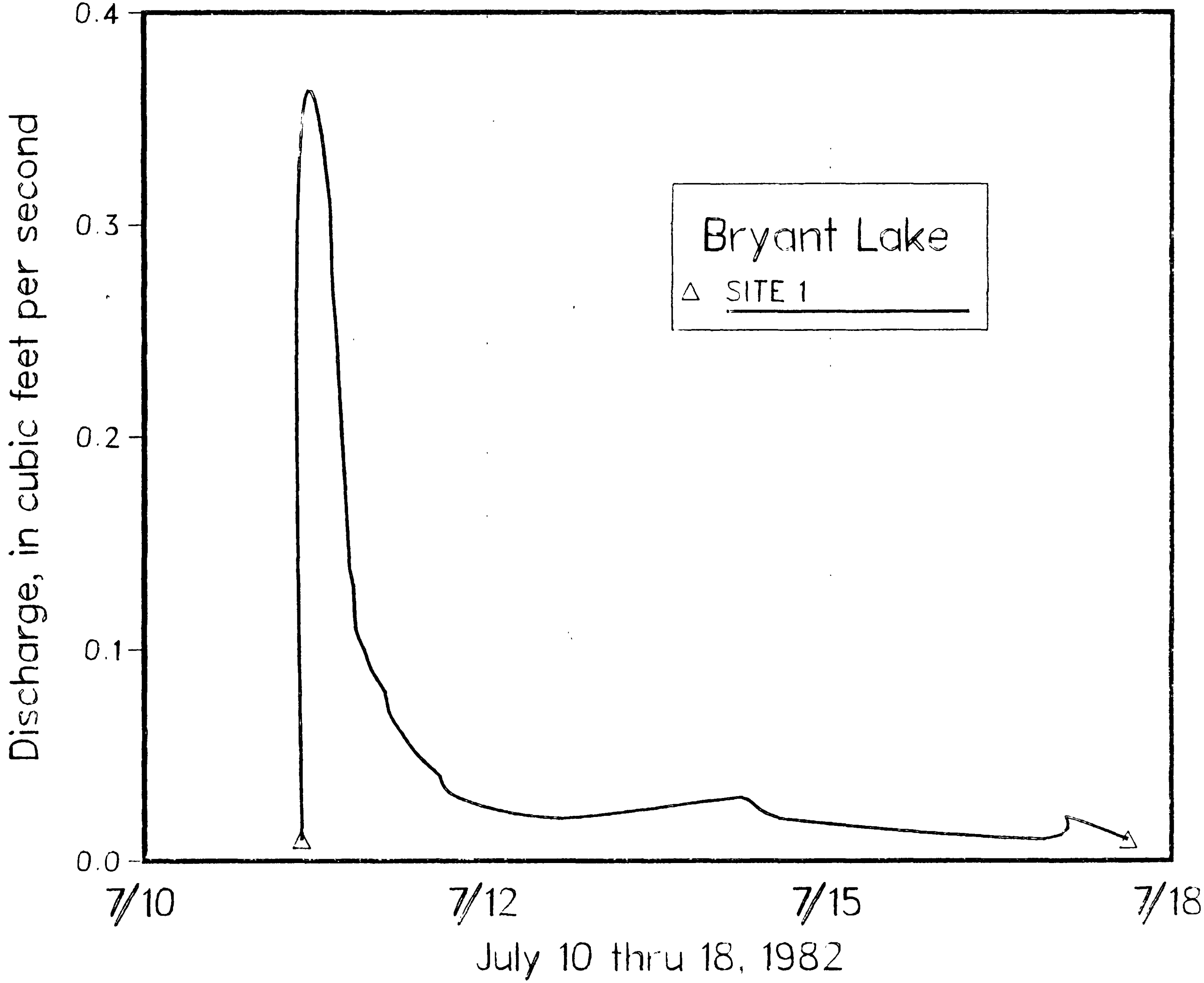

Figure 19.--Streamflow discharge for Bryant Lake, storm of July 10, 1982

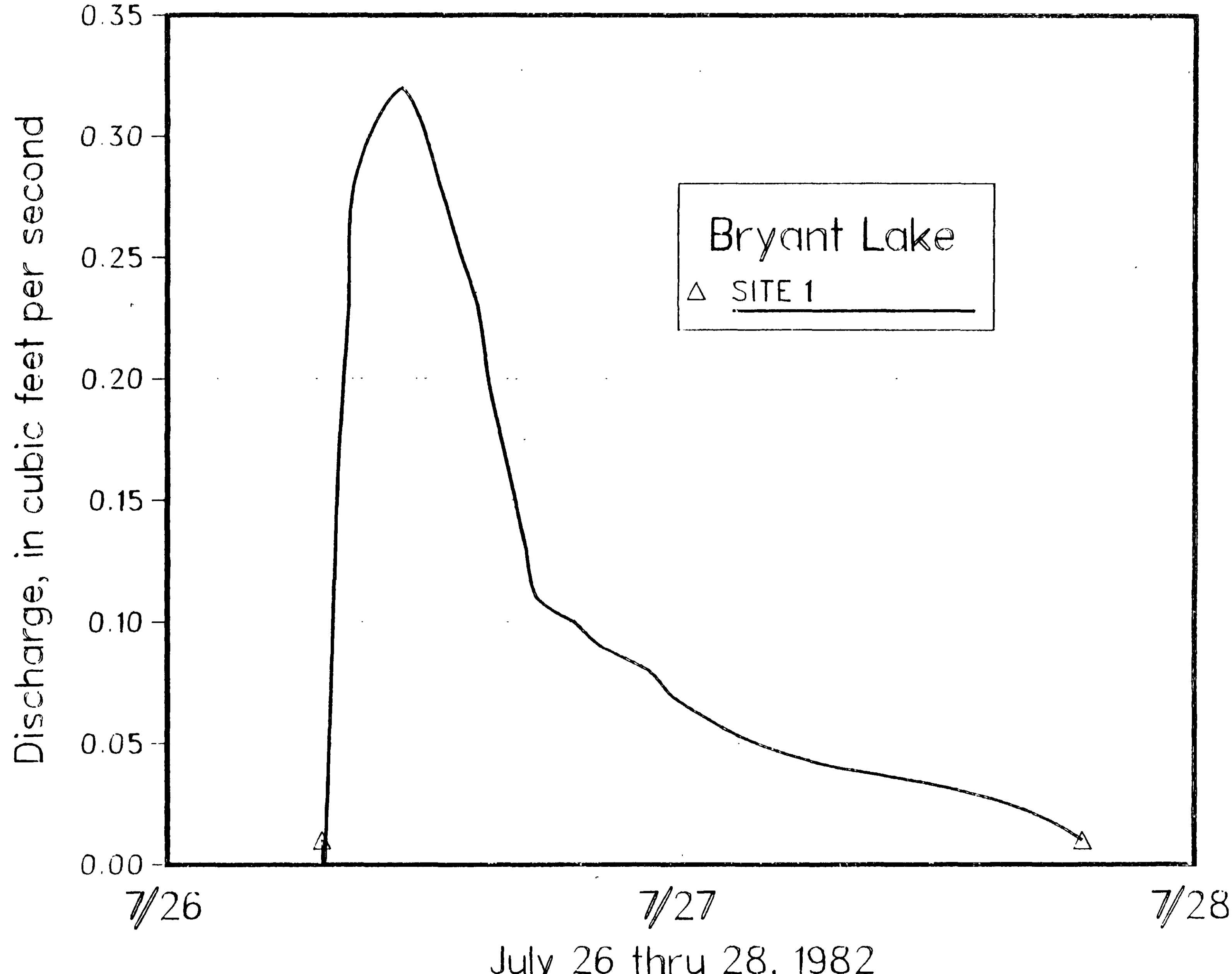

Figure 20.--Streamflow discharge for Bryant Lake, storm of July 25, 1982

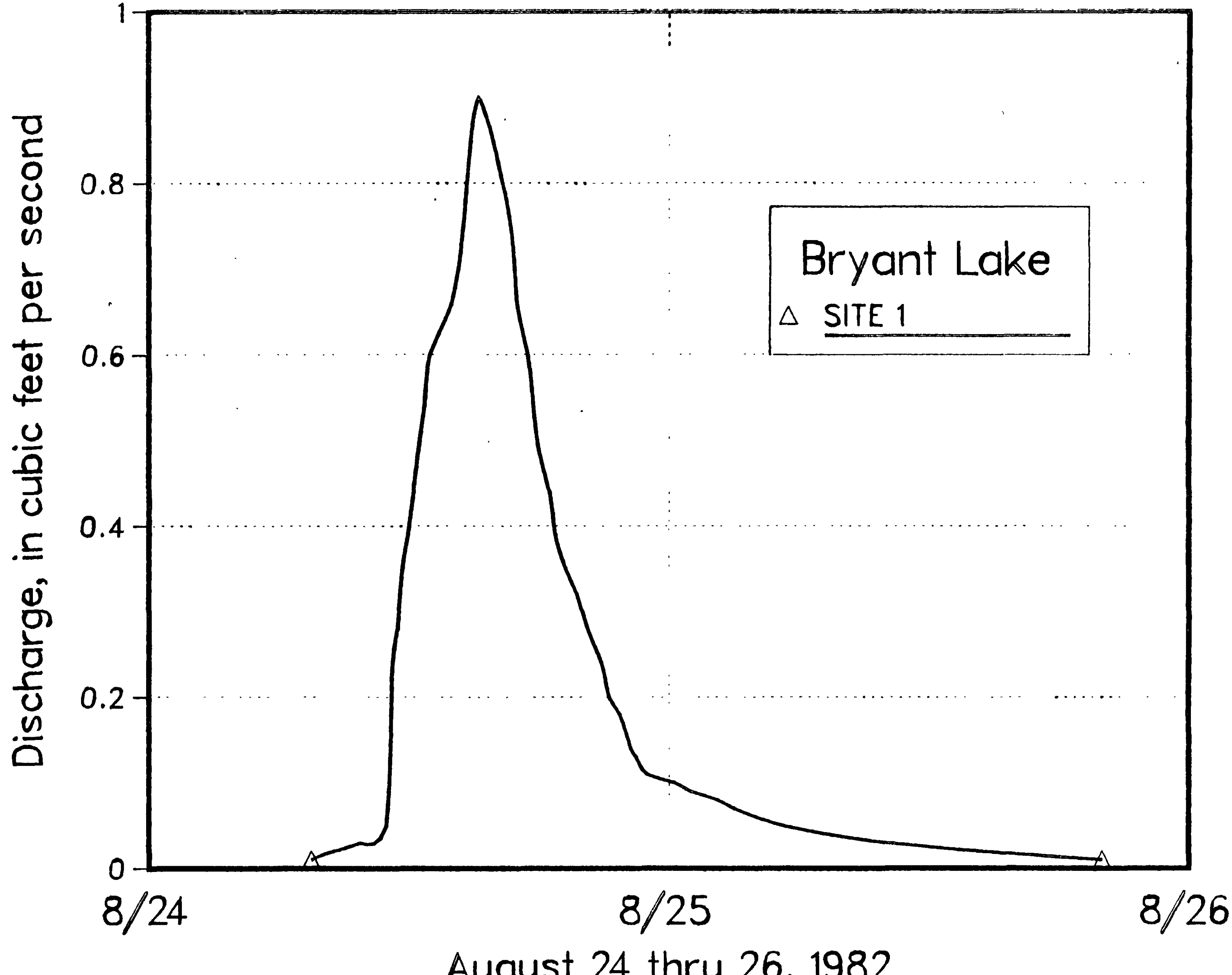

Figure 21.--Streamflow discharge for Bryant Lake, storm of August 24, 1982

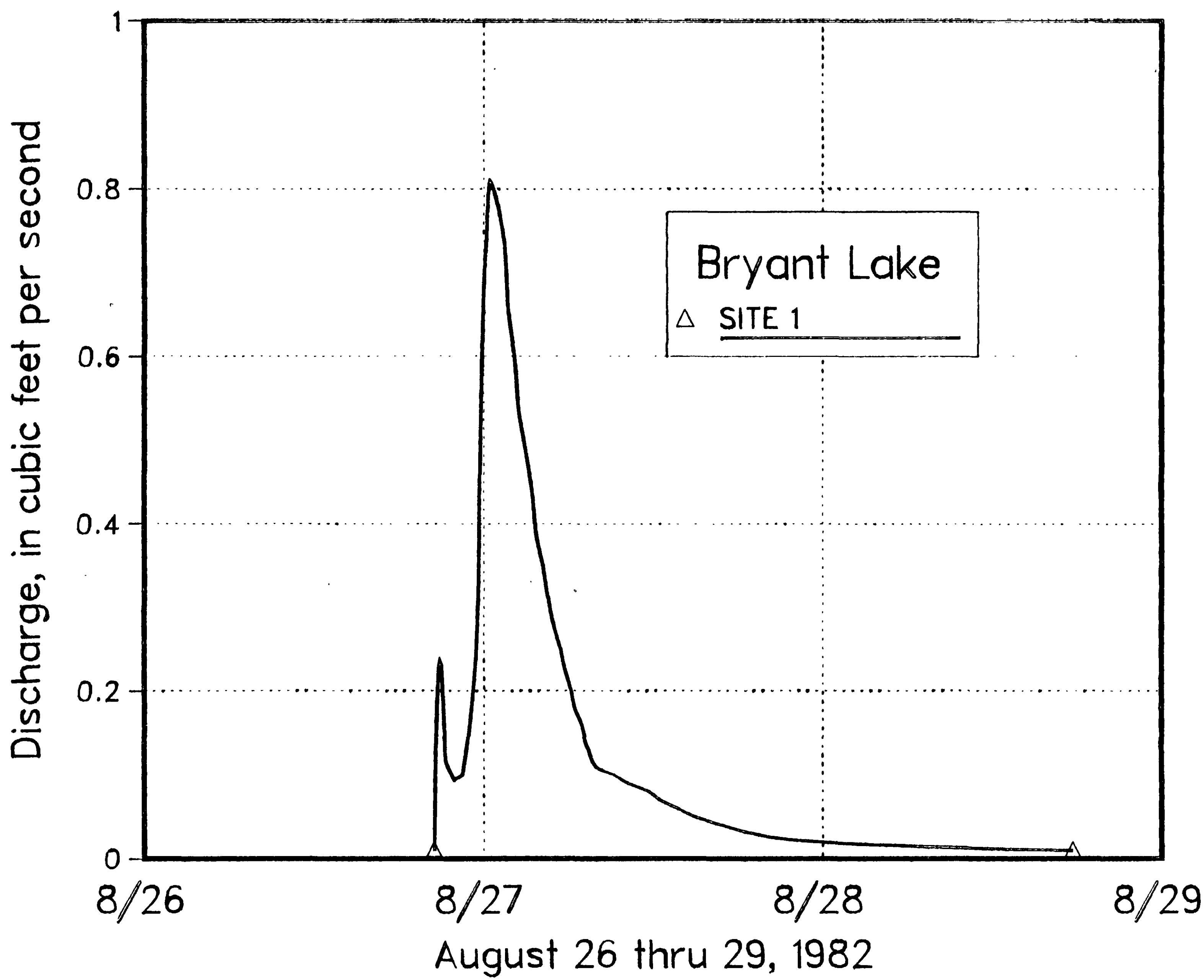

Figure 22.--Streamflow discharge for Bryant Lake, storm of August 26, 1982

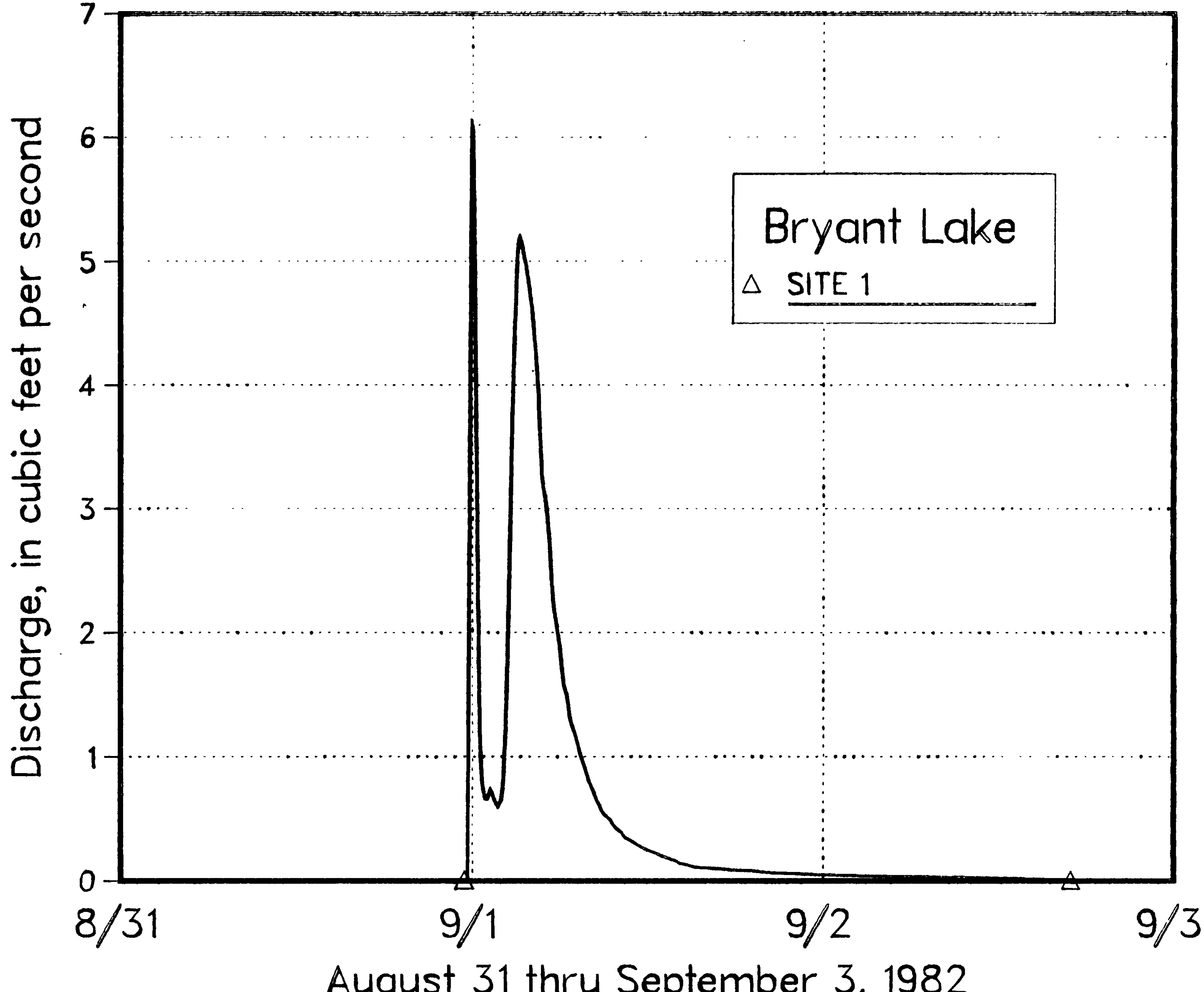

Figure 23.--Streamflow discharge for Bryant Lake, storm of August 31, 1982

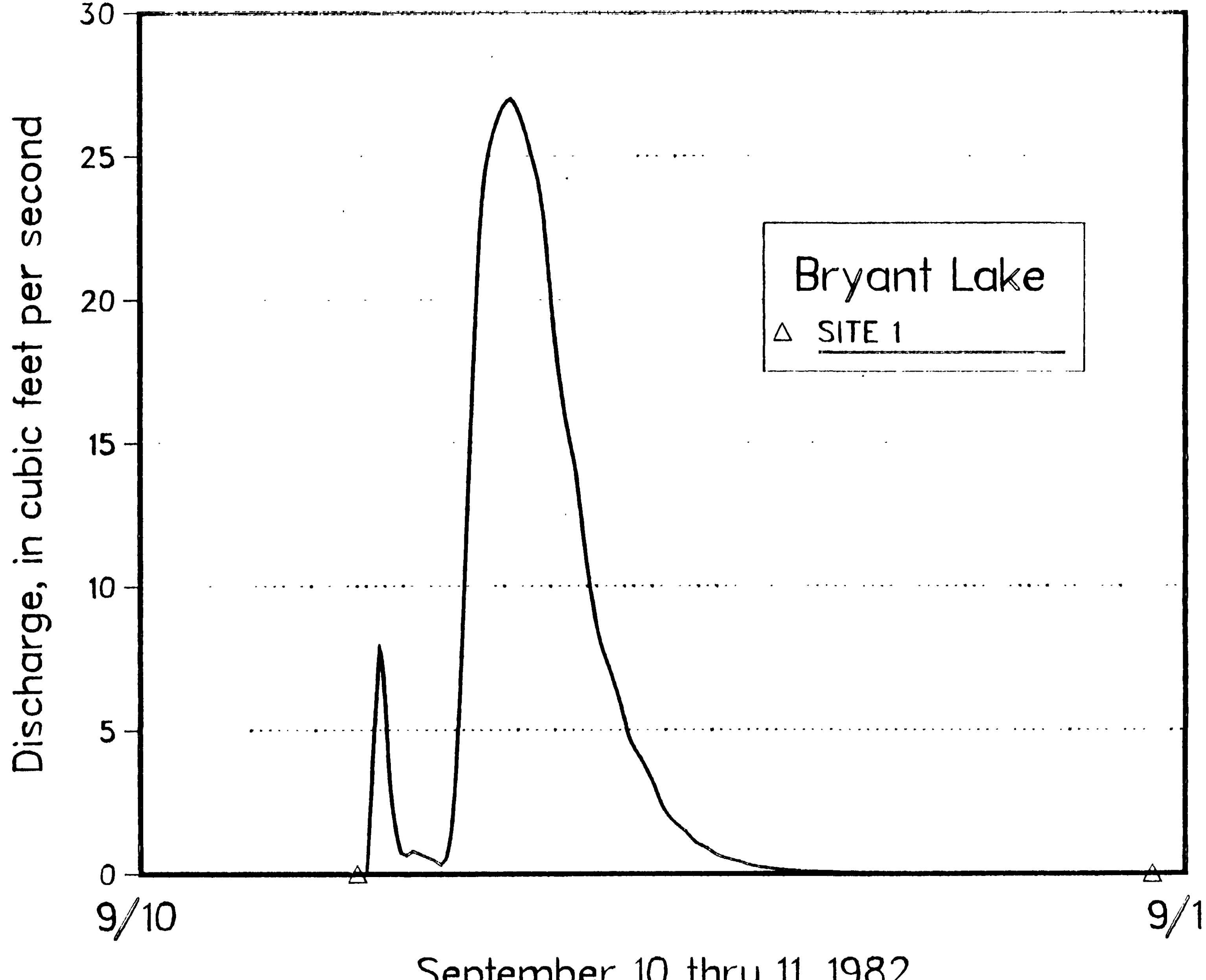

Figure 24.--Streamflow discharge for Bryant Lake, storm of September 10, 1982

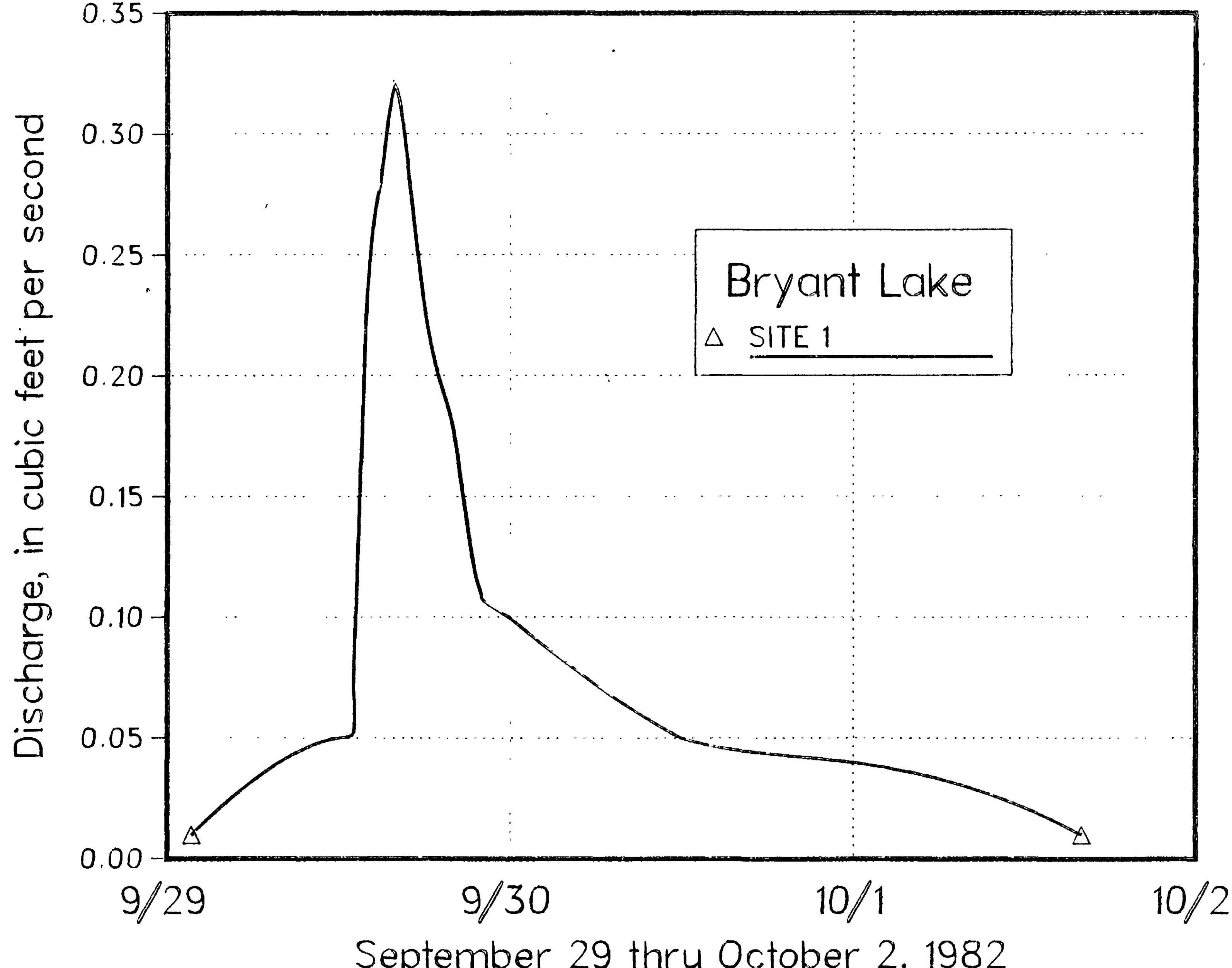

Figure 25.--Streamflow discharge for Bryant Lake, storm of September 30, 1982

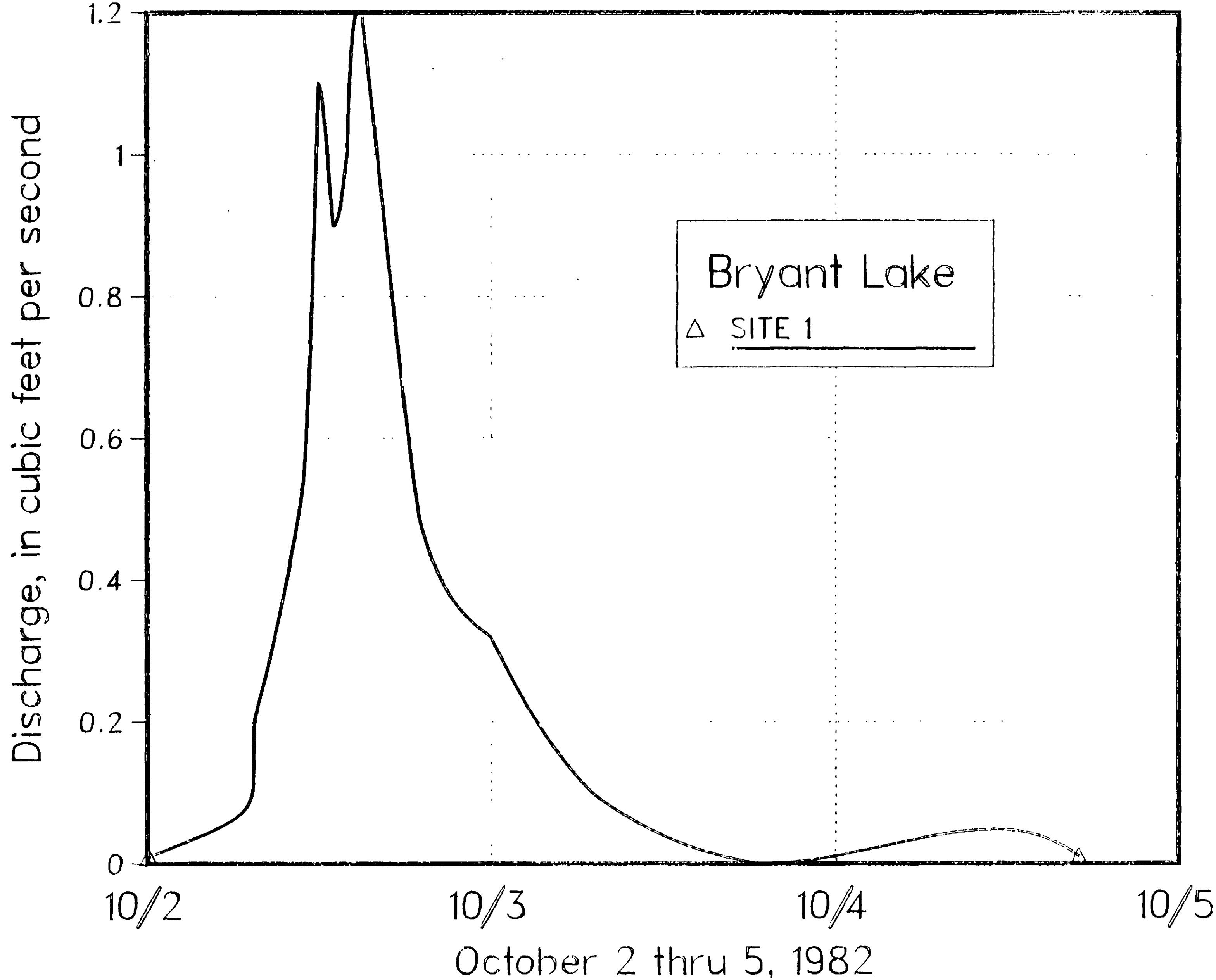

Figure 26.--Streamflow discharge for Bryant Lake, storm of October 12, 1982

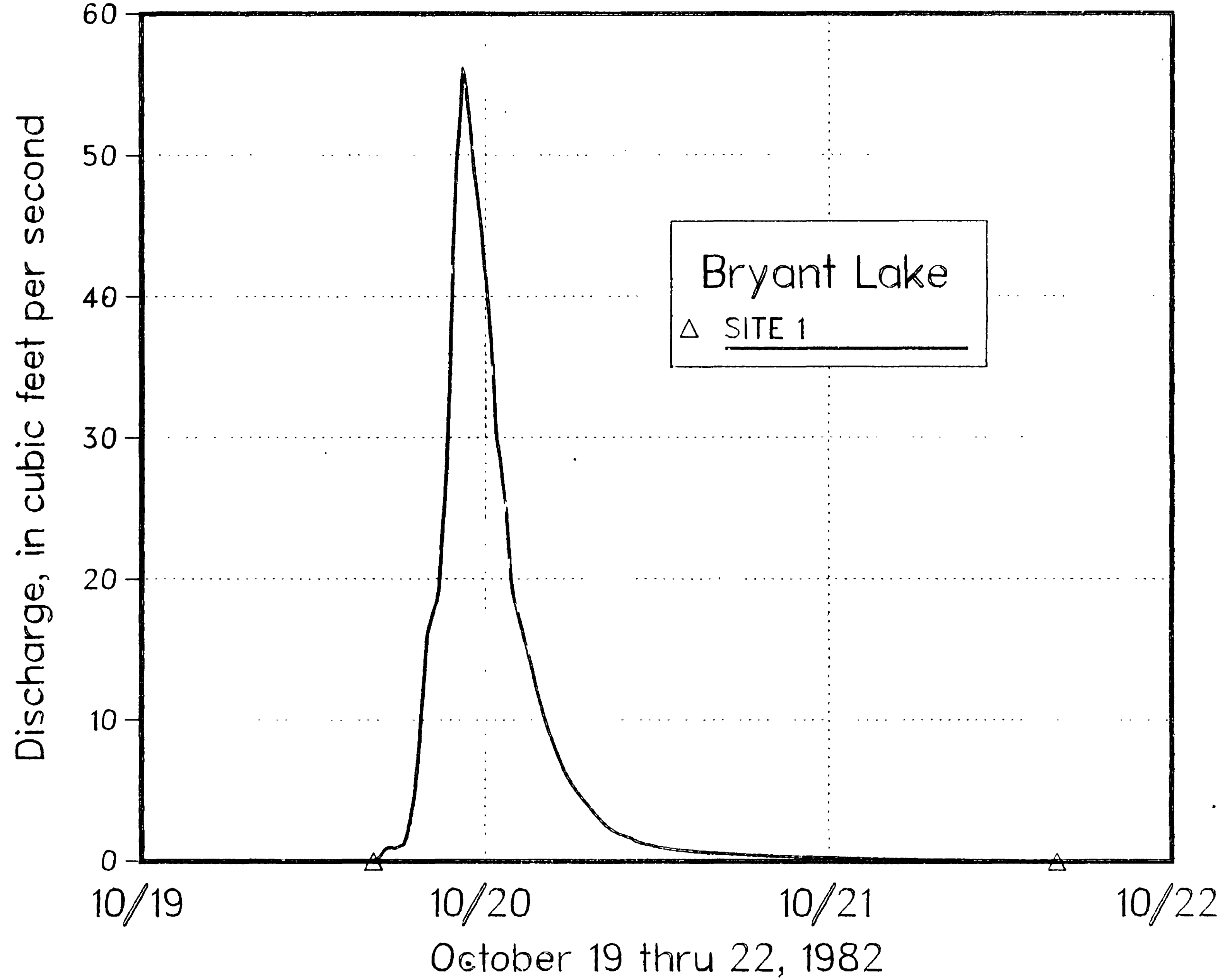

Figure 27.--Streamflow discharge for Bryant Lake, storm of October 19, 1982

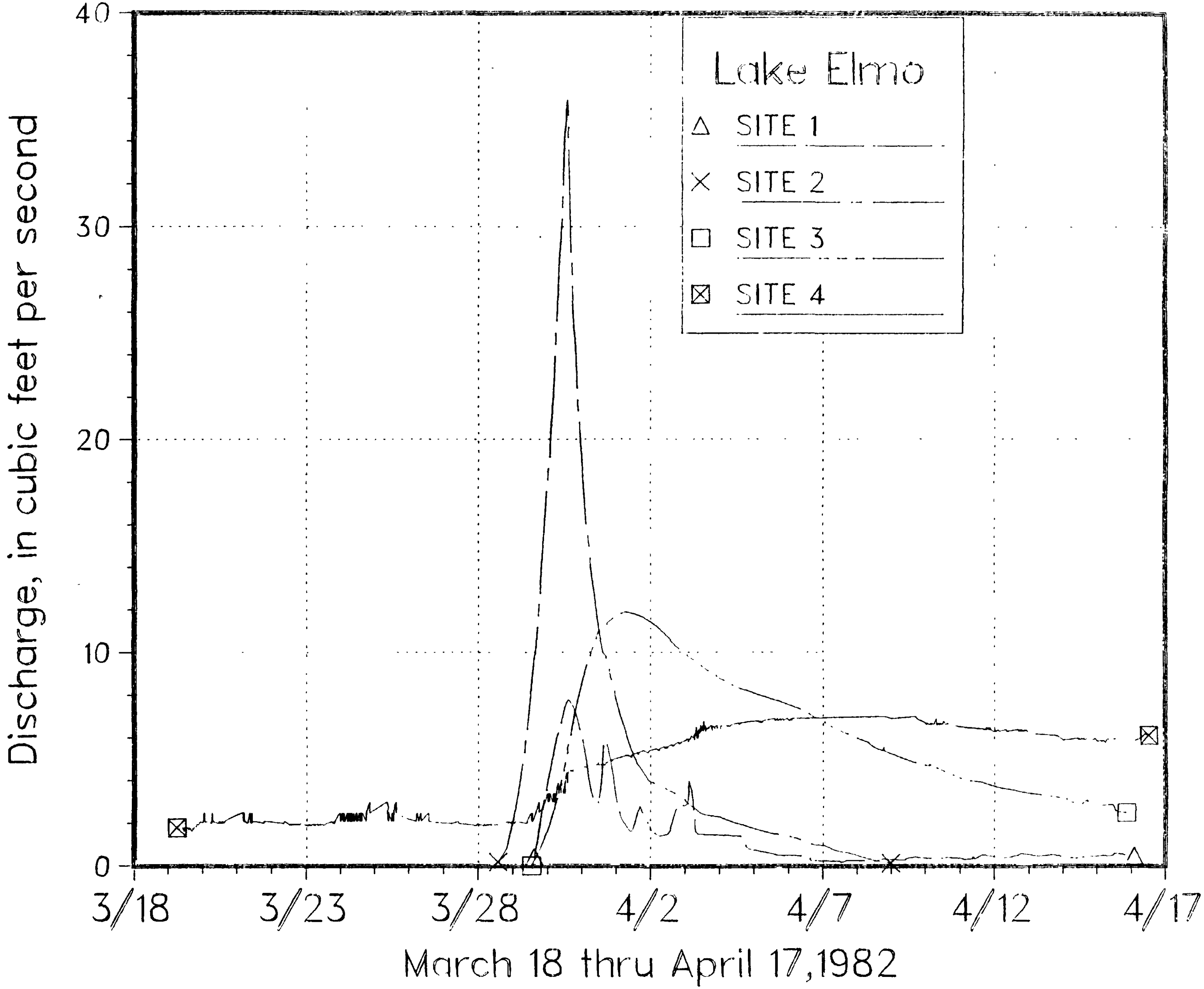

Figure 28.--Streamflow discharge for snowmelt at Lake Elmo, March 30, 1982

Table 20.--Storm beginning time, ending time, and flow-weighted mean concentrations at Bryant Lake sites

Site	Beginning time[1]		Ending time		Storm duration (hours)	Total suspended solids (mg/L)	Volatile suspended solids (mg/L)	Total phosphorus (mg/L)	Dissolved phosphorus (mg/L)	Dissolved NO_2+NO_3 nitrogen (mg/L)	Total ammonia nitrogen (mg/L)	Total ammonia + organic nitrogen (mg/L)
1	3-28-82	18:00	4-16-82	12:45	451	2.0	2.0	0.07	0.04	3.8	0.34	1.1
1	4-16-82	13:00	5-04-82	10:45	430	2.0	2.0	.03	.02	1.5	.09	1.1
1	5-04-82	11:00	5-09-82	2:30	112	1.0	1.0	.05	.03	.10	.08	.92
1	5-09-82	2:45	5-15-82	23:15	165	1.0	1.0	.05	.05	.20	.09	.90
1	5-15-82	23:30	6-14-82	14:15	711	14	5.0	.11	.06	.15	.10	.92
1	6-24-82	7:45	6-25-82	19:15	36	28	4.0	.12	.05	.15	.07	.84
1	7-06-82	4:00	7-09-82	2:00	70	13	1.0	.12	.09	.10	.07	.40
1	7-09-82	2:15	7-17-82	20:45	211	14	1.0	.16	.16	.20	.16	.58
1	7-26-82	7:15	7-27-82	18:45	36	12	6	.25	.16	.25	.06	.92
1	8-24-82	7:30	8-25-82	20:15	37	4.9	4.2	.19	.12	.14	.04	.61
1	8-26-82	20:30	8-28-82	20:45	48	15	3.0	.14	.12	.20	.06	.60
1	8-31-82	23:30	9-02-82	17:30	42	23	3.0	.21	.21	.20	.06	1.10
1	9-10-82	5:00	9-10-82	23:15	18	36	6.0	.19	.09	.20	.08	1.10
1	9-29-82	3:30	10-01-82	16:00	61	2	2	.15	.13	.15	.06	.40
1	10-02-82	0:30	10-04-82	22:00	70	2	1	.14	.09	.15	.05	.48
1	10-19-82	16:15	10-21-82	16:00	49	1	1	.07	.05	.10	.06	.38
2	3-17-82	14:00	4-16-82	8:45	715	2.0	2.0	.04	.01	.50	.78	1.4
2	4-16-82	9:00	4-22-82	12:45	148	4.0	4.0	.04	.03	.60	.32	1.6

[1]/If beginning and ending time are the same, then concentration was a grab sample; if time is 0:00, then exact time is unknown.

Table 21.--Storm flow-weighted mean concentration ratios for suspended solids, phosphorus, and nitrogen at Bryant Lake sites

Site	Beginning time[1]		Ending time		Percentage of suspended solids in the volatile form	Percentage of phosphorus in the dissolved state	Percentage of nitrogen in the form of ammonia
1	3-28-82	18:00	4-16-82	12:45	100	57	31
1	4-16-82	13:00	5-04-82	10:45	100	67	8
1	5-04-82	11:00	5-09-82	2:30	100	60	9
1	5-09-82	2:45	5-15-82	23:15	100	100	10
1	5-15-82	23:30	6-14-82	14:15	36	54	11
1	6-24-82	7:45	6-25-82	19:15	14	42	8
1	7-06-82	4:00	7-09-82	2:00	8	75	18
1	7-09-82	2:15	7-17-82	20:45	7	100	28
1	7-26-82	7:15	7-27-82	18:45	50	64	6
1	8-24-82	7:30	8-25-82	20:15	86	63	7
1	8-26-82	20:30	8-28-82	20:45	20	86	10
1	8-31-82	23:30	9-02-82	17:30	13	100	6
1	9-10-82	5:00	9-10-82	23:15	17	47	7
1	9-29-82	3:30	10-01-82	16:00	100	87	15
1	10-02-82	0:30	10-04-82	22:00	50	64	10
1	10-19-82	16:15	10-21-82	16:00	100	71	16
2	3-17-82	14:00	4-16-82	8:45	100	25	57
2	4-16-82	9:00	4-22-82	12:45	100	75	20

[1]/If beginning and ending time are the same, then concentration was a grab

Table 22.--Average storm flow-weighted mean concentrations for each season at Bryant Lake sites, 1982

[Seasons are: snowmelt - beginning of flow to April 22; spring - April 23 to June 1; early summer - June 2 to July 17; late summer - July 18 to September 4; autumn - September 5 to end of flow]

Site	Season	Total suspended solids (mg/L)	Volatile suspended solids (mg/L)	Total phosphorus (mg/L)	Dissolved phosphorus (mg/L)	Dissolved NO_2+NO_3 nitrogen (mg/L)	Total ammonia nitrogen (mg/L)	Total ammonia + organic nitrogen (mg/L)
1	Snowmelt	2.0	2.0	0.07	0.04	3.8	0.34	1.1
1	Spring	6.8	3.1	.04	.03	.90	.09	1.0
1	Early summer	2.2	4.9	.11	.05	.15	.09	.90
1	Late summer	17	3.3	.19	.17	.17	.05	.88
1	Autumn	38	17	.27	.13	.29	.13	1.5
2	Snowmelt	2.3	2.3	.04	.01	.51	.69	1.42
2	Spring	4.1	4.1	.04	.02	.20	.07	1.6
2	Early summer	.99	.99	.03	.02	.05	.06	1.5

Table 23.--Seasonal average storm flow-weighted mean concentration ratios for suspended solids, phosphorus, and nitrogen at Bryant Lake sites

[Seasons are: snowmelt - beginning of flow to April 22; spring - April 23 to June 1; early summer - June 2 to July 17; late summer - July 18 to September 4; autumn - September 5 to end of flow]

Site	Season	Percentage of suspended solids in the dissolved state	Percentage of phosphorus in the dissolved state	Percentage of nitrogen in the form of ammonia
1	Snowmelt	100	57	30
1	Spring	46	75	9
1	Early summer	100	45	10
1	Late summer	19	89	6
1	Autumn	45	48	9
2	Snowmelt	100	25	48
2	Spring	100	50	4
2	Early summer	100	67	4

Table 24.--Storm beginning time, ending time, flow, and loads at Bryant Lake sites

Site	Beginning time[1]		Ending time		Storm flow (m^3)	Total suspended solids (kg)	Volatile suspended solids (kg)	Total phosphorus (kg)	Dissolved phosphorus (kg)	Dissolved NO_2+NO_3 nitrogen (kg)	Total ammonia nitrogen (kg)	Total ammonia + organic nitrogen (kg)
1	3-28-82	18:00	4-16-82	12:45	83,000	170	170	5.9	3.4	310	28	92
1	4-16-82	13:00	5-04-82	10:45	22,000	44	44	0.67	0.44	33	2.0	25
1	5-04-82	11:00	5-09-82	2:30	2,800	2.9	2.9	.14	.14	0.58	0.26	2.6
1	5-09-82	2:45	5-15-82	23:15	16,000	230	81	1.8	.97	2.4	1.6	15
1	5-15-82	23:30	6-14-82	14:15	36,000	1,100	147	3.7	1.8	7.4	2.6	48
1	6-24-82	7:45	6-25-82	19:15	2,600	72	10	.31	.13	.39	.18	2.2
1	7-06-82	7:45	7-09-82	2:00	230	3.0	0.23	.03	.02	.02	.02	0.09
1	7-09-82	2:15	7-17-82	20:45	780	11.0	.79	.13	.13	.16	.13	.46
1	7-26-82	7:15	7-27-82	18:45	380	4.6	2.3	.10	.06	.10	.02	.35
1	8-24-82	7:30	8-25-82	20:15	690	4.9	4.2	.19	.12	.14	.04	.61
1	8-26-82	20:30	8-28-82	20:45	540	8.1	1.6	.08	.07	.11	.03	.33
1	8-31-82	23:30	9-02-82	17:30	2,400	56	7.4	.52	.52	.49	.15	2.6
1	9-10-82	5:00	9-10-82	23:15	7,800	280	47	1.5	.71	1.6	.63	8.7
1	9-29-82	3:30	10-01-82	16:00	780	1.6	1.6	.12	.10	.12	.05	.32
1	10-02-82	00:30	10-04-82	22:00	2,700	5.4	2.7	.38	.24	.40	.13	1.3
1	10-19-82	16:15	10-21-82	16:00	50,000	51	51	3.6	2.3	5.1	3.1	19
2	3-17-82	14:00	4-16-82	8:45	420,000	850	850	17	4.2	210	330	575
2	4-16-82	9:00	4-22-82	12:45	57,000	230	230	2.3	1.7	35	18	92

[1]/If beginning and ending times are the same, then concentration was a grab sample; if time is 0:00, then exact time is unknown.

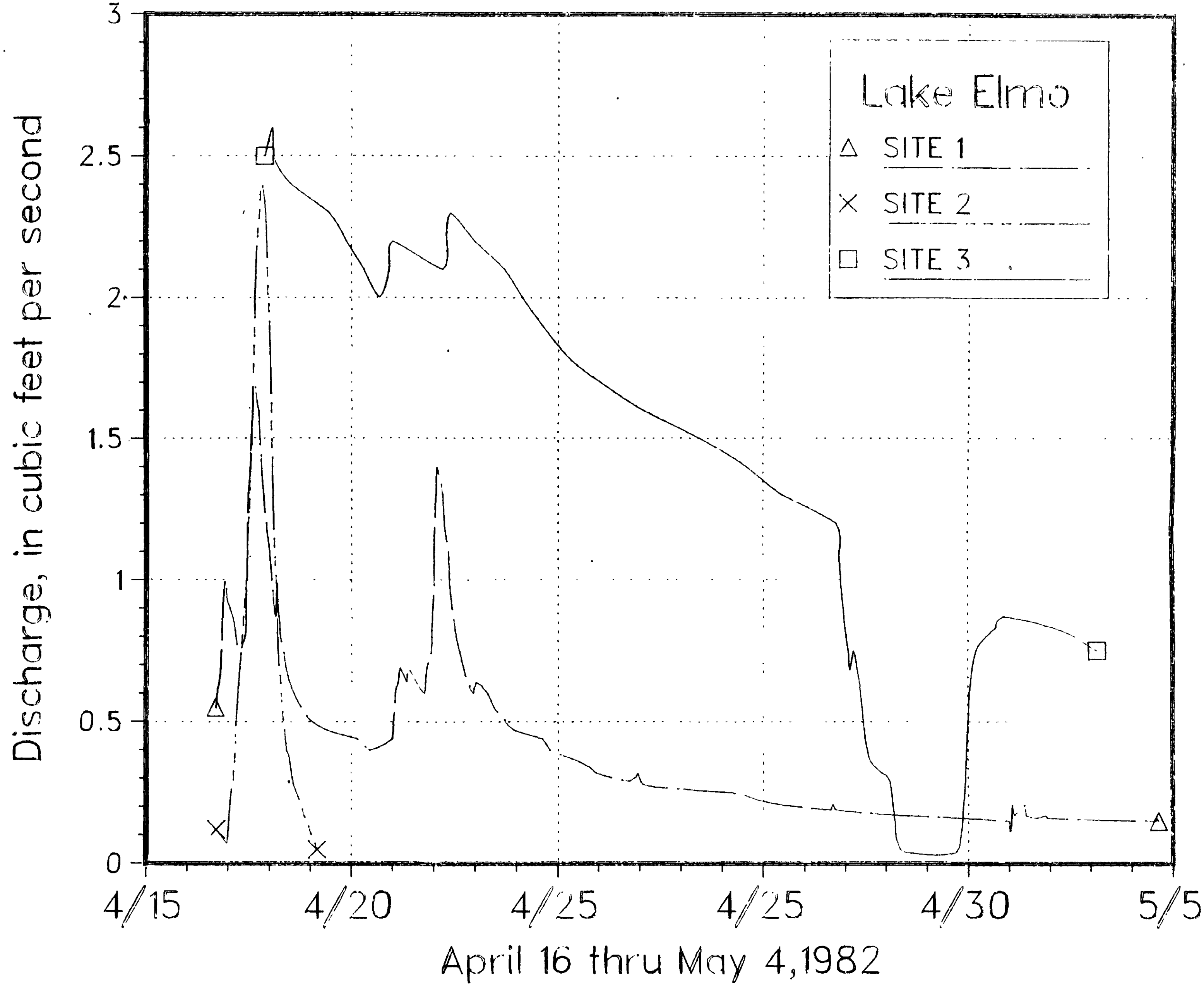

Figure 29.--Streamflow discharge for Lake Elmo, storm of April 16, 1982

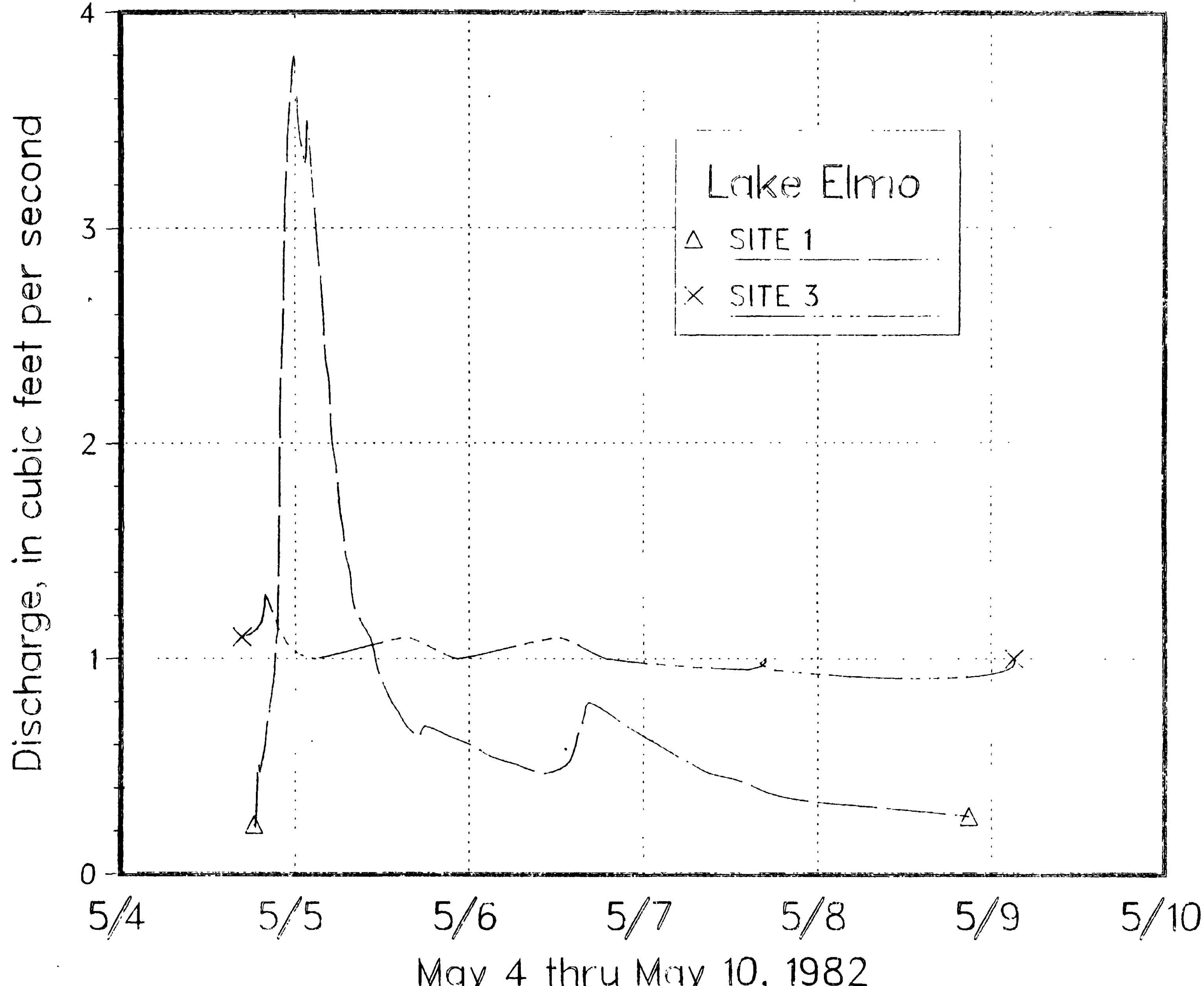

Figure 30.--Streamflow discharge for Lake Elmo, storm of May 4, 1982

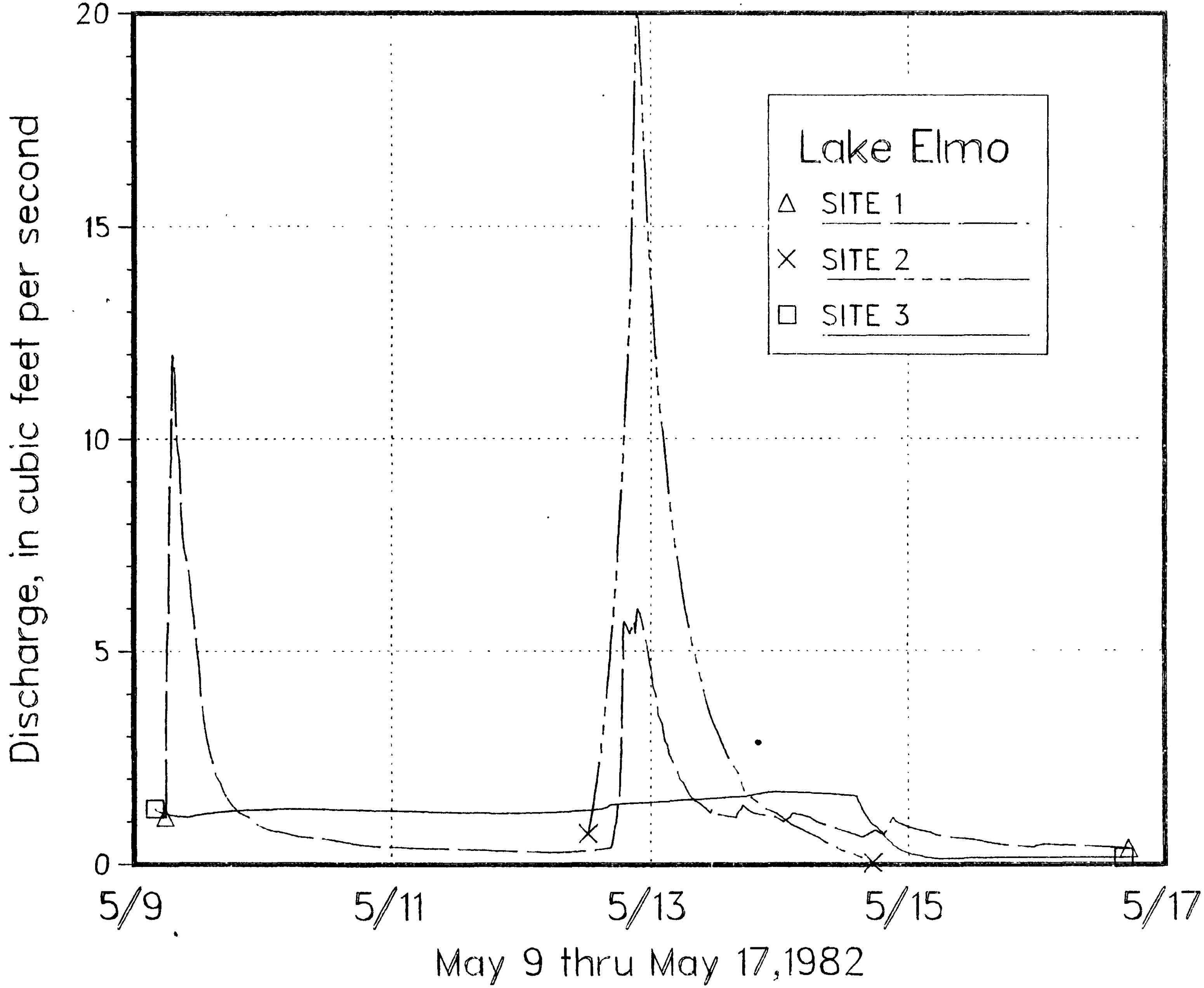

Figure 31.--Streamflow discharge for Lake Elmo, storm of May 9, 1982

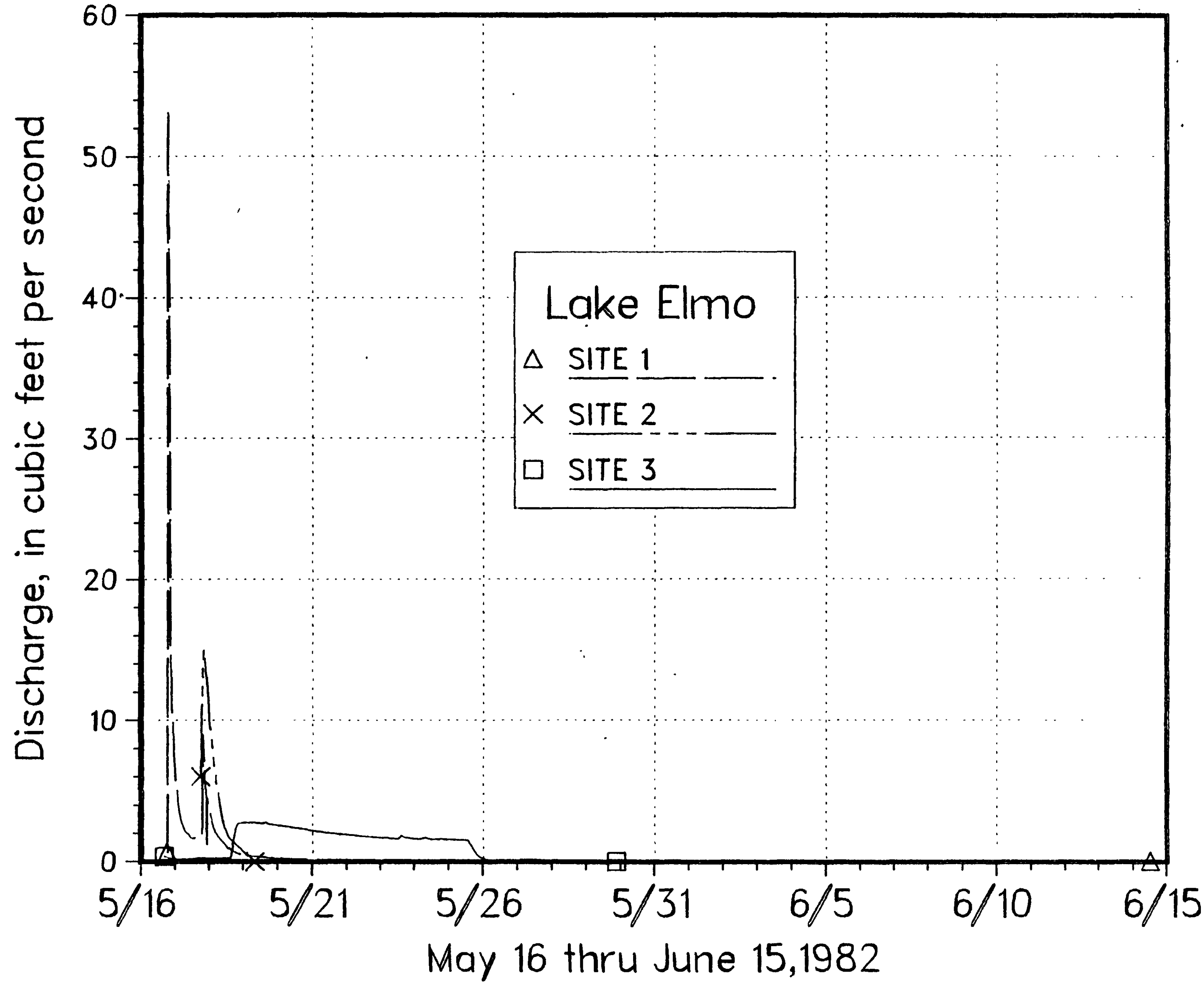

Figure 32.--Streamflow discharge for Lake Elmo, storm of May 17, 1982

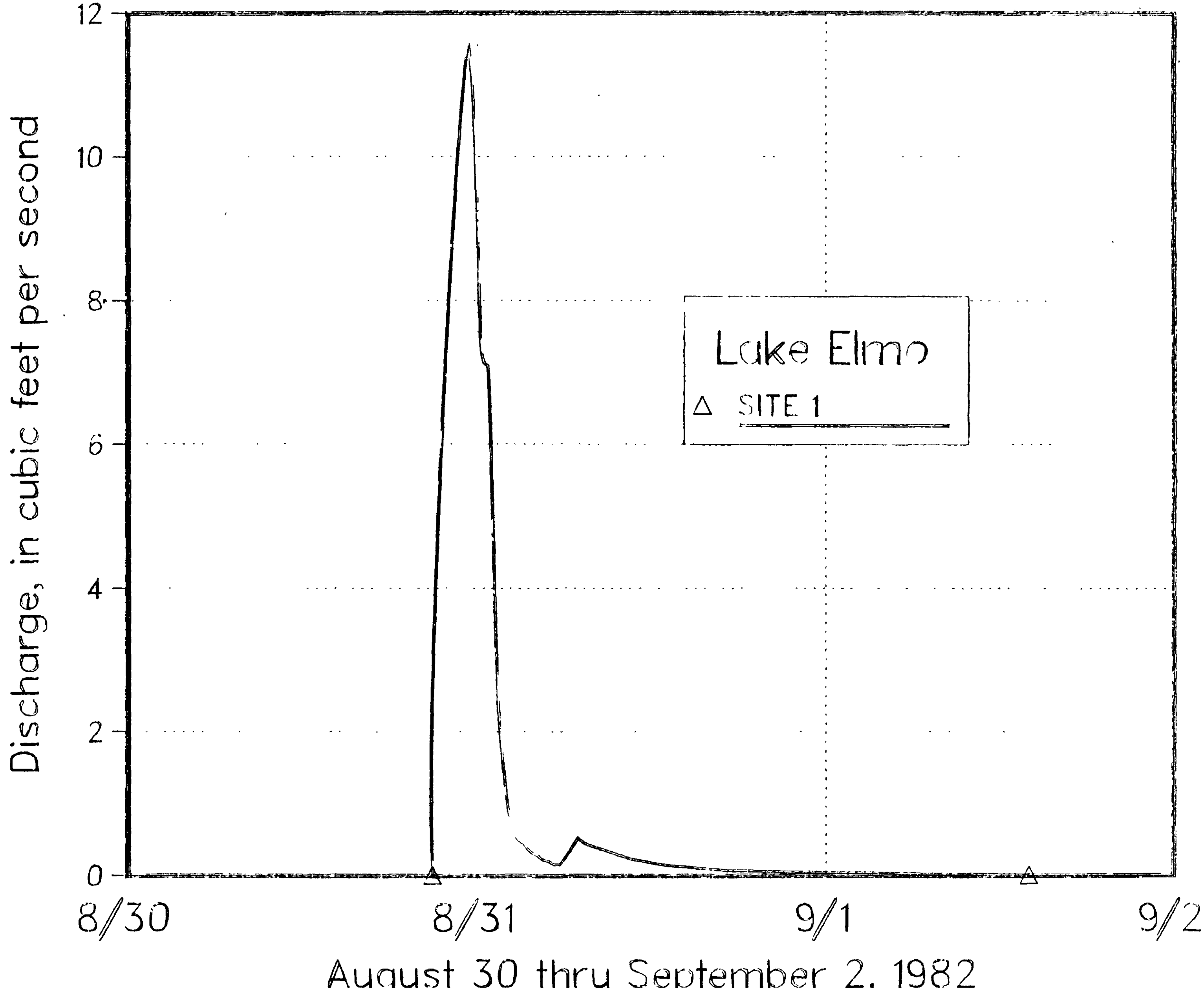

Figure 33.--Streamflow discharge for Lake Elmo, storm of August 31, 1982

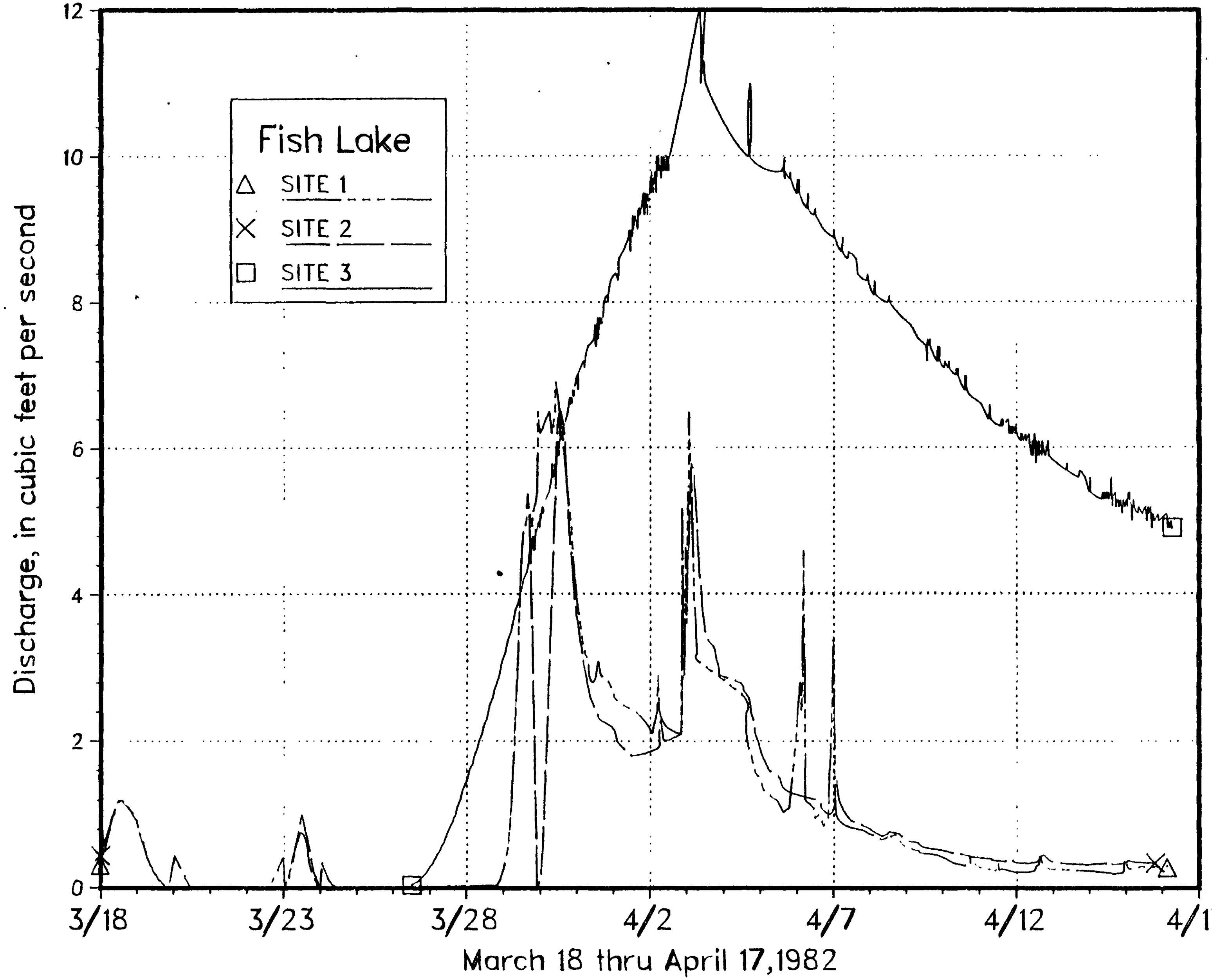

Figure 34.--Streamflow discharge for snowmelt at Fish Lake, March 30, 1982

Table 25.--Storm beginning time, ending time, and flow-weighted mean concentrations at Lake Elmo sites

Site	Beginning time[1]		Ending time		Storm duration (hours)	Total suspended solids (mg/L)	Volatile suspended solids (mg/L)	Total phosphorus (mg/L)	Dissolved phosphorus (mg/L)	Dissolved NO_2+NO_3 nitrogen (mg/L)	Total ammonia nitrogen (mg/L)	Total ammonia + organic nitrogen (mg/L)
1	3-29-82	14:00	4-16-82	7:45	426	361	31.0	0.50	0.07	1.4	0.20	1.5
1	4-16-82	8:00	5-04-82	18:30	443	108	15.0	.18	.04	1.2	.10	1.0
1	5-04-82	18:45	5-09-82	6:00	107	42.0	21.0	.27	.08	1.0	1.5	1.7
1	5-09-82	6:15	5-16-82	19:00	181	148	22.0	.21	.06	.70	.70	1.5
1	5-16-82	19:15	6-14-82	13:00	690	460	40	.48	.10	.80	.15	2.4
1	8-30-82	22:30	9-01-82	16:00	42	145	6.0	.15	.08	.35	.06	.82
2	3-28-82	13:00	4-09-82	0:00	275	33.0	4.0	.14	.08	.60	.82	1.5
2	4-16-82	8:00	4-18-82	8:00	48	7.0	1.0	.05	.05	.10	.05	.80
2	5-12-82	12:00	5-14-82	18:00	54	10.0	4.0	.10	.05	.10	.06	.90
2	5-17-82	18:00	5-19-82	9:00	39	8.0	2.0	.07	.05	.05	.09	1.0
3	3-29-82	12:00	4-16-82	21:30	442	5.0	2.0	.16	.05	.50	.32	1.4
3	4-16-82	21:45	5-04-82	16:45	427	11.0	6.0	.16	.03	.20	.11	1.3
3	5-04-82	17:00	5-09-82	3:45	107	13.0	11.0	.10	.04	.15	.23	1.6
3	5-09-82	4:00	5-16-82	16:45	181	6.0	6.0	.11	.04	.10	.24	1.6
3	5-16-82	17:00	5-31-82	15:30	359	12.0	6.0	.18	.10	.10	.46	1.9
4	3-18-82	0:15	4-16-82	14:30	710	1.0	1.0	.05	.02	.30	.12	.84
4	4-16-82	14:45	4-22-82	8:15	138	10.0	10.0	.05	.02	.10	.15	.80
A1	5-13-82	8:15	5-13-82	8:15	0	44.0	6.0	.12	.03	.30	.10	.86
A1	5-18-82	10:15	5-18-82	10:15	0	122.0	15.0	.28	.06	.45	.11	1.3

[1]/If beginning and ending time are the same, then concentration was a grab sample; if time is 0:00, then exact time is unknown.

Table 26.--Storm flow-weighted mean concentration ratios for suspended solids, phosphorus, and nitrogen at Lake Elmo sites

Site	Beginning time[1]		Ending time		Percentage of suspended solids in the volatile form	Percentage of phosphorus in the dissolved state	Percentage of nitrogen in the form of ammonia
1	3-29-82	14:00	4-16-82	7:45	8	14	13
1	4-16-82	8:00	5-04-82	18:30	14	22	10
1	5-04-82	18:45	5-09-82	6:00	50	30	88
1	5-09-82	6:15	5-16-82	19:00	15	28	47
1	5-16-82	19:15	6-14-82	13:00	9	21	6
1	8-30-82	23:30	9-01-82	16:00	4	53	7
2	3-28-82	13:00	4-09-82	0:00	12	57	55
2	4-16-82	8:00	4-18-82	8:00	14	100	6
2	5-12-82	12:00	5-14-82	18:00	40	50	7
2	5-17-82	18:00	5-19-82	9:00	25	71	9
3	3-29-82	12:00	4-16-82	21:30	40	31	22
3	4-16-82	21:45	5-04-82	16:45	54	19	8
3	5-04-82	17:00	5-09-82	3:45	85	40	14
3	5-09-82	4:00	5-16-82	16:45	100	36	15
3	5-16-82	17:00	5-31-82	15:30	50	56	24
4	3-18-82	0:15	4-16-82	14:30	100	40	14
4	4-16-82	14:45	4-22-82	8:15	100	40	19

[1]/If beginning and ending time are the same, then concentration was a grab sample; if time is 0:00, then exact time is unknown.

Table 27.--Average storm flow-weighted mean concentrations for each season at Lake Elmo, 1982

[Seasons are: snowmelt - beginning of flow to April 22; spring - April 23 to June 1; early summer - June 2 to July 17; late summer - July 18 to September 4; autumn - September 5 to end of flow]

Site	Season	Total suspended solids (mg/L)	Volatile suspended solids (mg/L)	Total phosphorus (mg/L)	Dissolved phosphorus (mg/L)	Dissolved NO_2+NO_3 nitrogen (mg/L)	Total ammonia nitrogen (mg/L)	Total ammonia + organic nitrogen (mg/L)
1	Snowmelt	360	31	0.50	0.07	1.4	0.20	1.5
1	Spring	116	19	.11	.02	0.93	.63	1.3
1	Early summer	460	40	.48	.10	.80	.15	2.4
1	Late summer	140	6.0	.15	.08	.35	.06	.82
2	Snowmelt	32	4.1	.14	.08	.59	.80	1.5
2	Spring	9.2	3.1	.09	.05	.08	.07	.94
3	Snowmelt	5.0	2.0	.16	.05	.50	.32	1.4
3	Spring	11	6.4	.16	.05	.16	.24	1.5
4	Snowmelt	1.0	1.0	.05	.02	.28	.12	.83
4	Spring	0.99	0.99	.03	.02	.05	.11	1.0
4	Early summer	1.0	1.0	.04	.01	.05	.06	.80
4	Late summer	5.0	5.0	.09	.01	.05	.05	1.6
4	Autumn	6.0	6.0	.02	.01	.10	.02	.92

Table 28.--Seasonal average storm flow-weighted mean concentration ratios for suspended solids, phosphorus, and nitrogen at Lake Elmo sites

[Seasons are: snowmelt - beginning of flow to April 22; spring - April 23 to June 1; early summer - June 2 to July 17; late summer - July 18 to September 4; autumn - September 5 to end of flow]

Site	Season	Percentage of suspended solids in the dissolved state	Percentage of phosphorus in the dissolved state	Percentage of nitrogen in the form of ammonia
1	Snowmelt	9	14	13
1	Spring	16	18	48
1	Early summer	9	21	6
1	Late summer	4	53	7
2	Snowmelt	13	57	53
2	Spring	34	56	7
3	Snowmelt	40	31	23
3	Spring	58	33	16
4	Snowmelt	100	40	14
4	Spring	100	67	0
4	Early summer	100	25	8
4	Later summer	100	11	3
4	Autumn	100	50	2

Table 29.--Storm beginning time, ending time, flow, and loads at Lake Elmo sites

Site	Beginning time[1]		Ending time		Storm flow (m^3)	Total suspended solids (kg)	Volatile suspended solids (kg)	Total phosphorus (kg)	Dissolved phosphorus (kg)	Dissolved NO_2+NO_3 nitrogen (kg)	Total ammonia nitrogen (kg)	Total ammonia + organic nitrogen (kg)
1	3-29-82	14:00	4-16-82	7:45	58,000	21,000	1,800	29	4.1	82	12	87
1	4-16-82	8:00	5-04-82	18:30	17,000	1,900	260	3.1	0.70	20	1.7	17
1	5-04-82	18:45	5-09-82	6:00	7,800	330	170	2.1	.63	8.3	12	13
1	5-09-82	6:15	5-16-82	19:00	22,000	3,200	480	4.6	1.3	15	15	32
1	5-16-82	19:15	6-14-82	13:00	26,000	12,000	1,100	13	2.7	21	4.0	65
1	8-30-82	22:30	9-01-82	16:00	1,700	250	10	0.26	.14	0.60	0.10	1.4
2	3-28-82	13:00	4-09-82	0:00	160,000	5,200	630	22	13	95	130	230
2	4-16-82	8:00	4-18-82	8:00	3,700	26	3.7	.19	.19	.37	.19	3.0
2	5-12-82	12:00	5-14-82	18:00	22,000	230	91	2.3	1.1	2.3	1.4	20
2	5-17-82	18:00	5-19-82	9:00	16,000	130	33	1.1	.82	.82	1.5	16
3	3-29-82	12:00	4-16-82	21:30	270,000	1,400	547	44	14	137	88	390
3	4-16-82	21:45	5-04-82	16:45	63,000	700	380	10	1.9	13	7.0	84
3	5-04-82	17:00	5-09-82	3:45	11,000	140	120	1.1	.44	1.6	2.5	18
3	5-09-82	4:00	5-16-82	16:45	19,000	120	120	2.1	.78	2.0	4.7	32
3	5-16-82	17:00	5-31-82	15:30	37,000	440	220	6.6	3.7	3.7	17	72
4	3-18-82	00:15	4-16-82	14:30	320,000	320	320	16	6.5	97	39	270
4	4-16-82	14:45	4-22-82	8:15	30,000	300	300	1.5	.60	3.0	4.5	24

[1]/If beginning and ending times are the same, then concentration was a grab sample; if time is 0:00, then exact time is unknown.

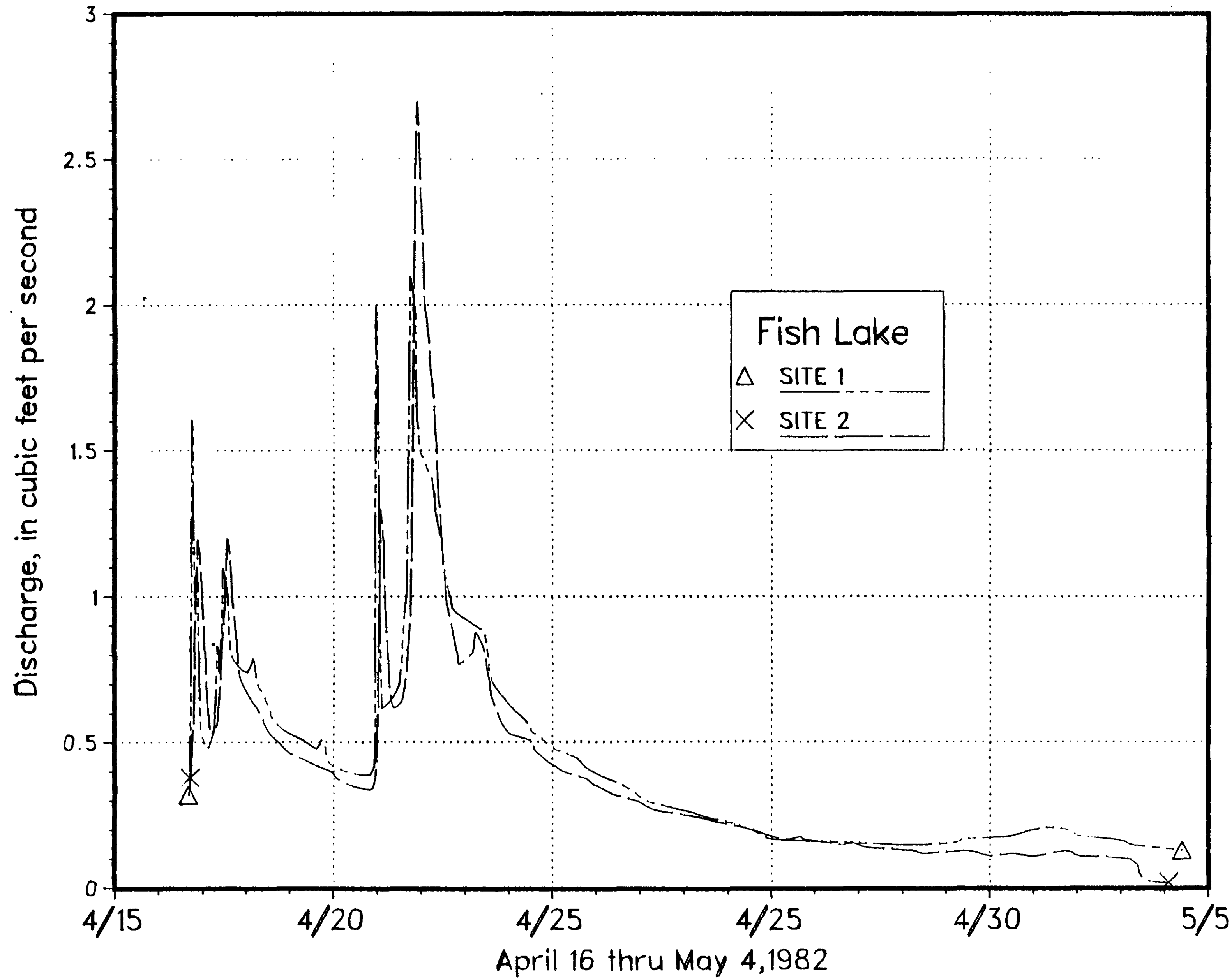

Figure 35.--Streamflow discharge for Fish Lake, storm of April 16, 1982

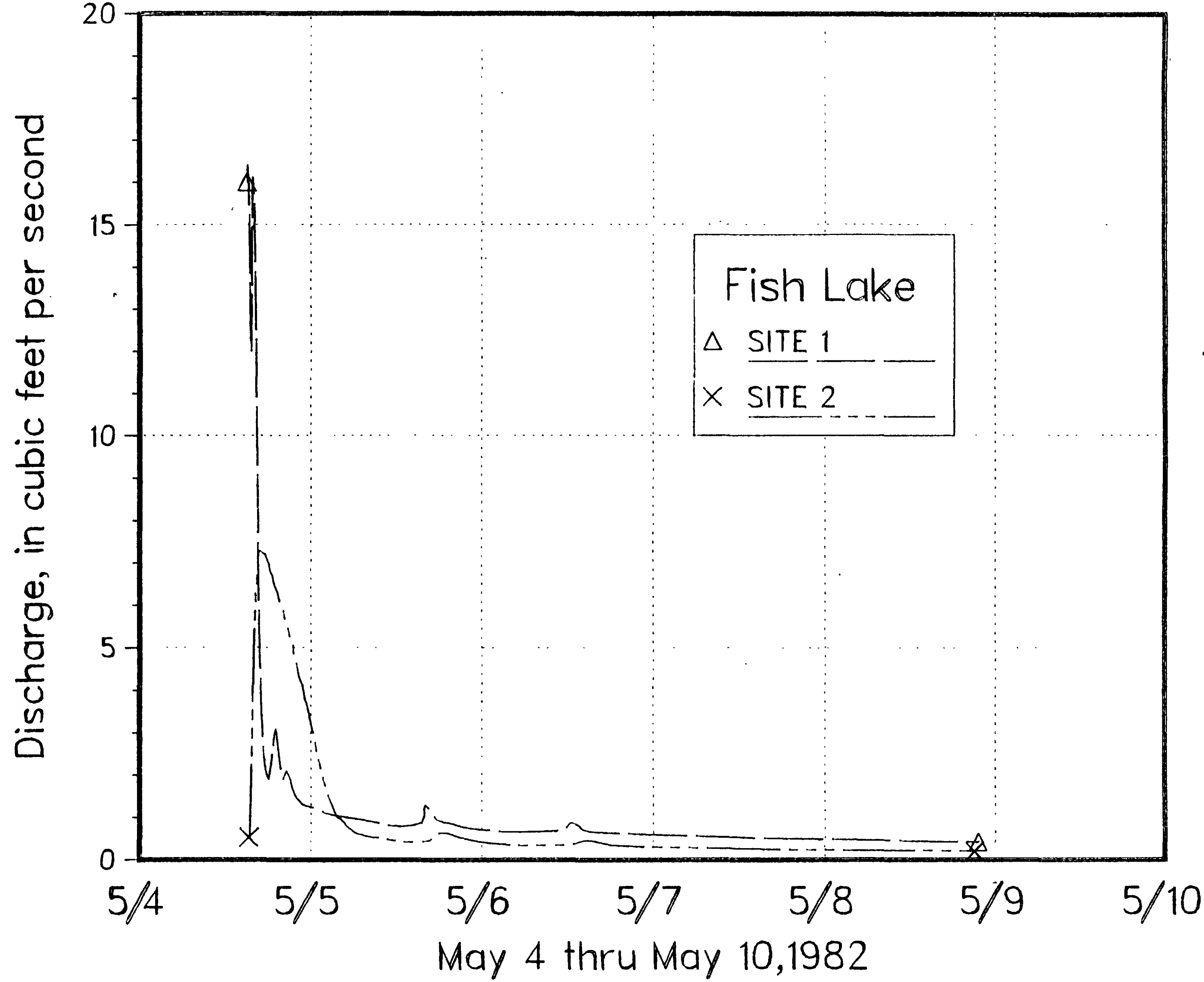

Figure 36.--Streamflow discharge for Fish Lake, storm of May 4, 1982

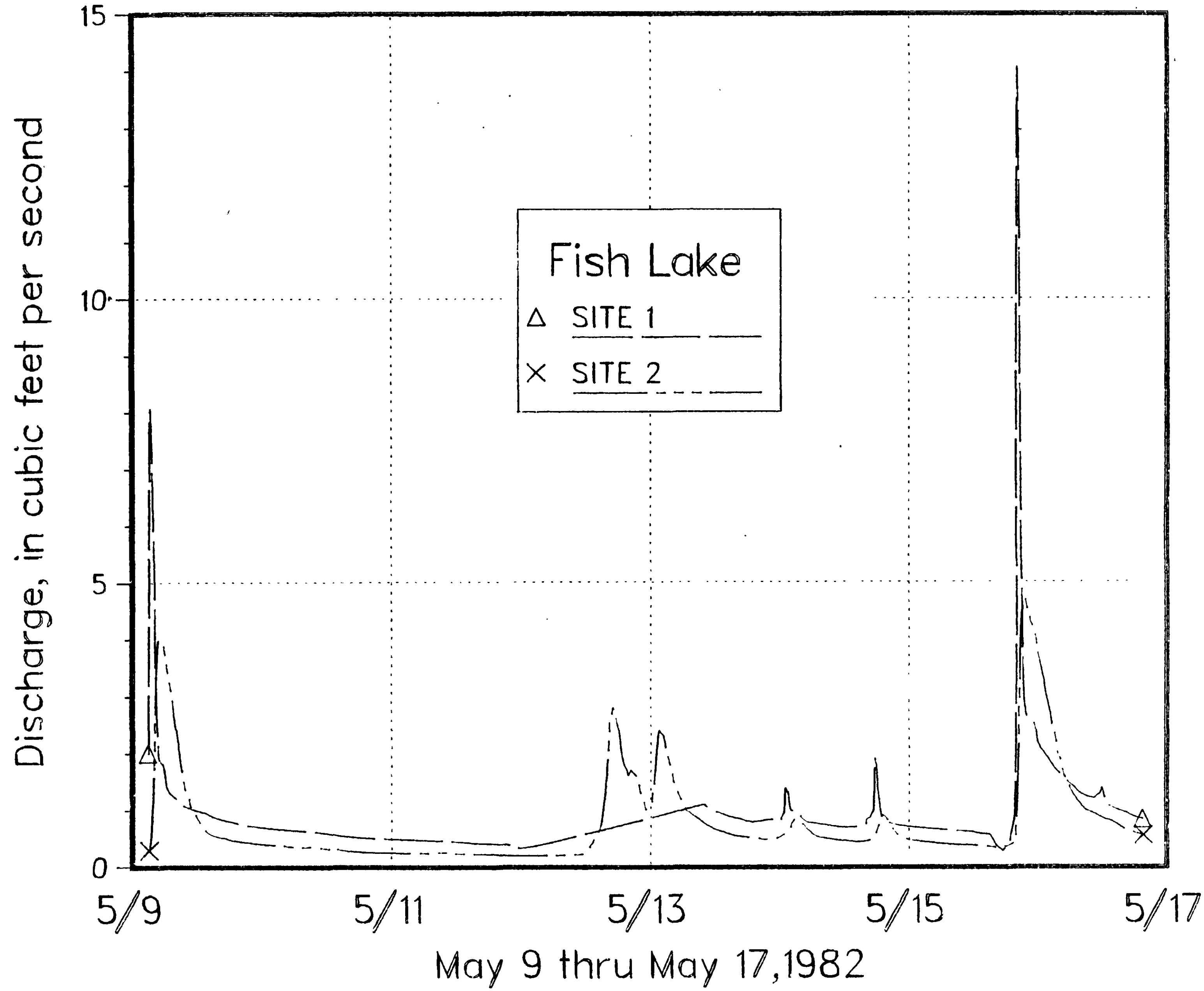

Figure 37.--Streamflow discharge for Fish Lake, storm of May 9, 1982

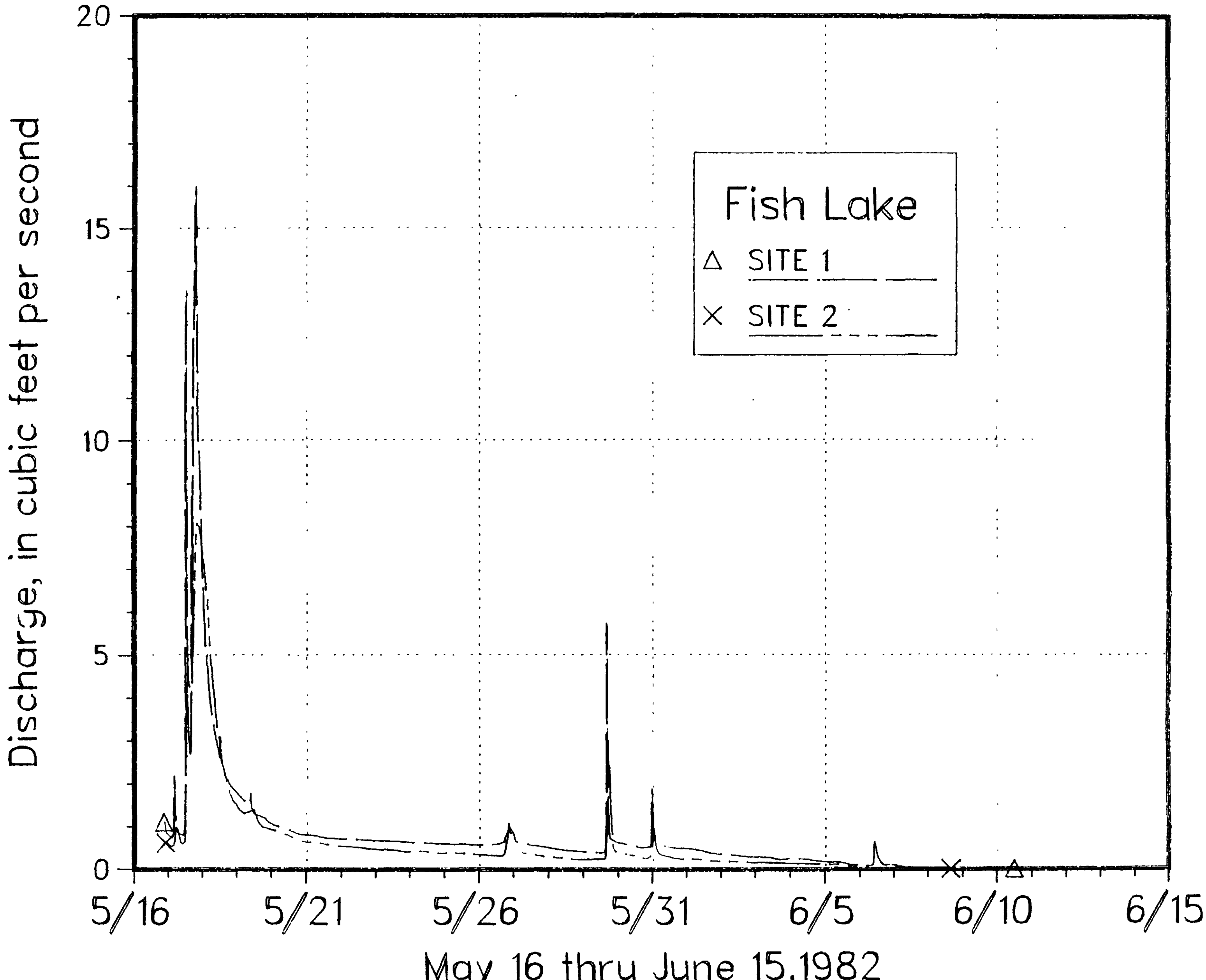

Figure 38.--Streamflow discharge for Fish Lake, storm of May 17, 1982

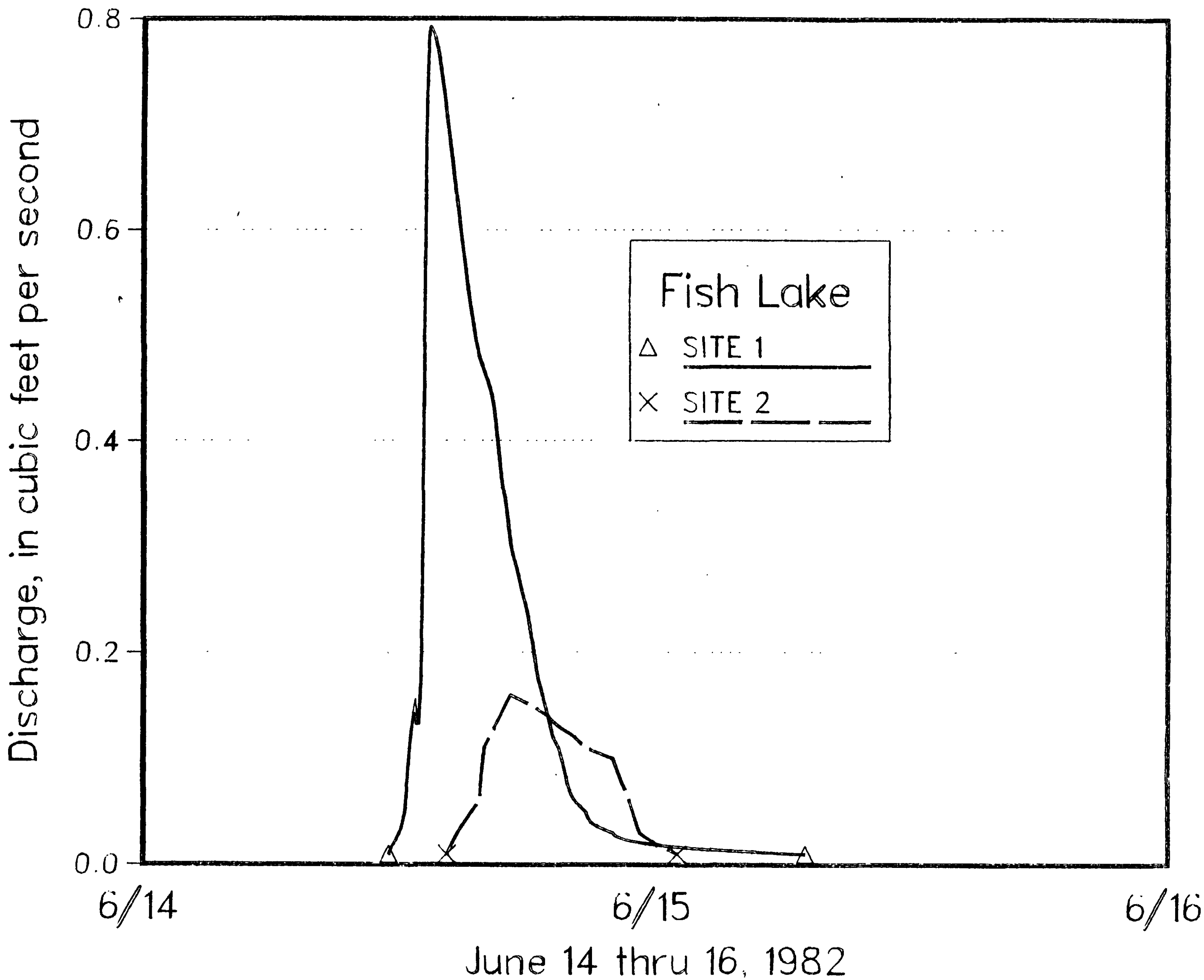

Figure 39.--Streamflow discharge for Fish Lake, storm of June 14, 1982

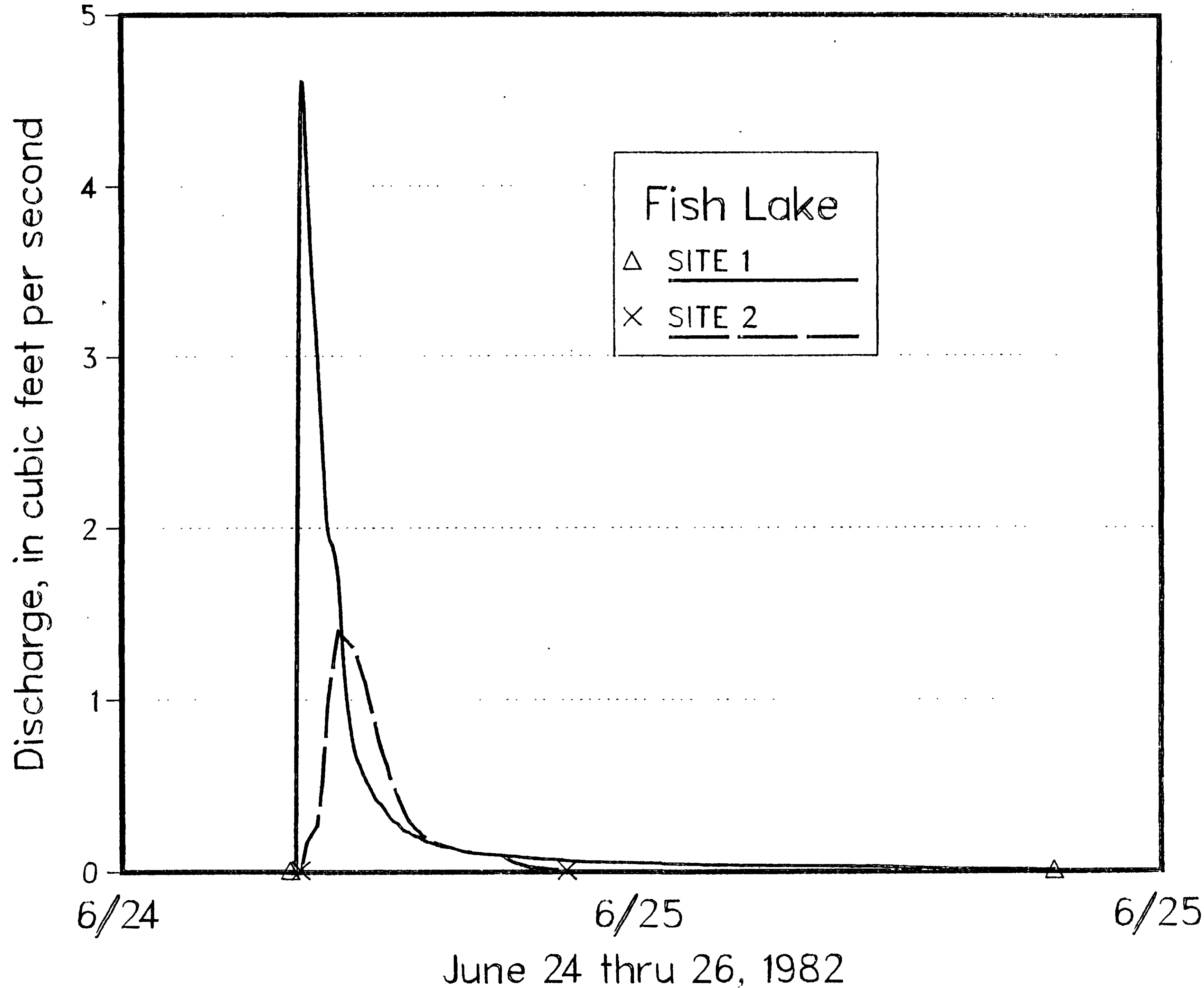

Figure 40.--Streamflow discharge for Fish Lake, storm of June 24, 1982

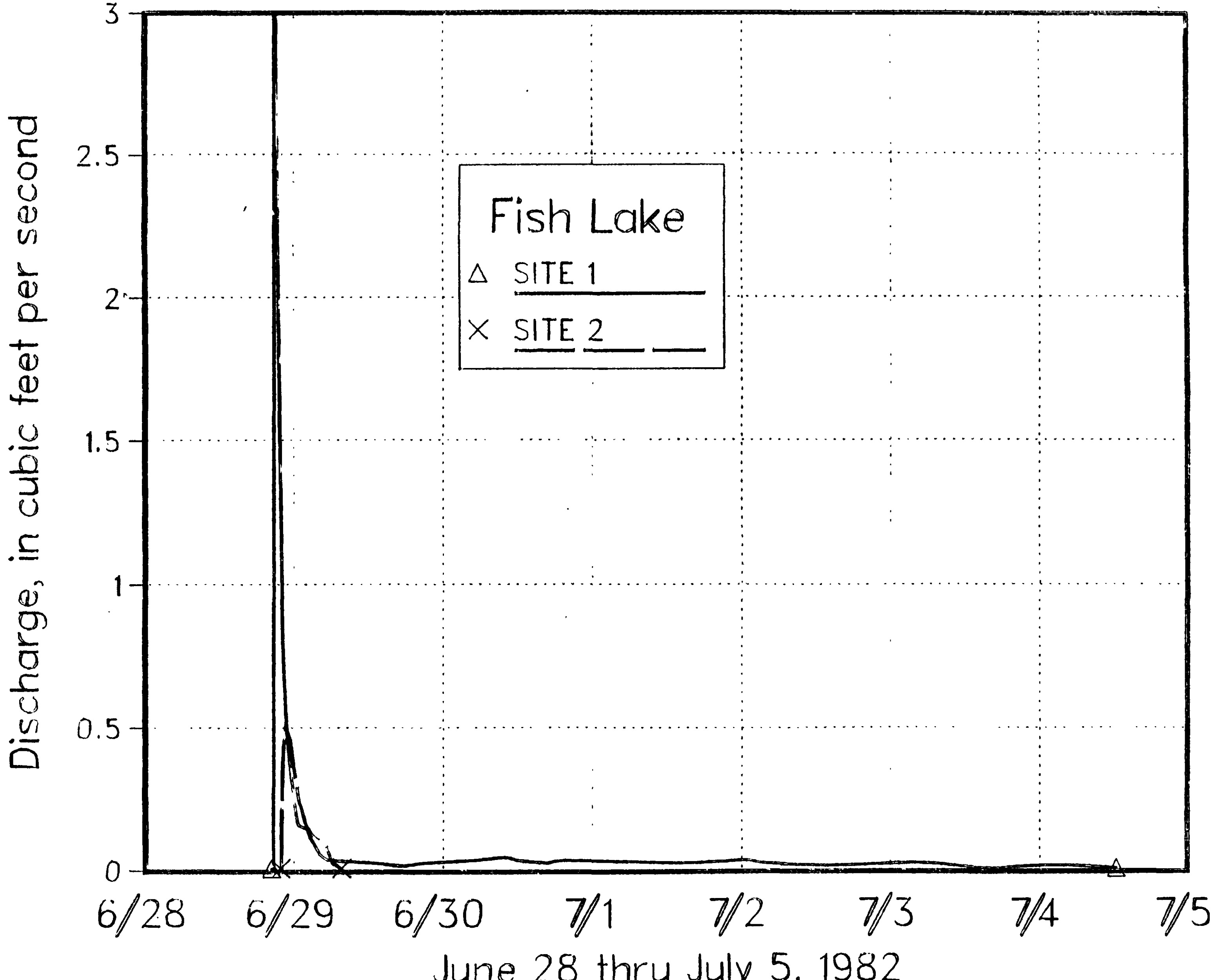

Figure 41.--Streamflow discharge for Fish Lake, storm of June 28, 1982

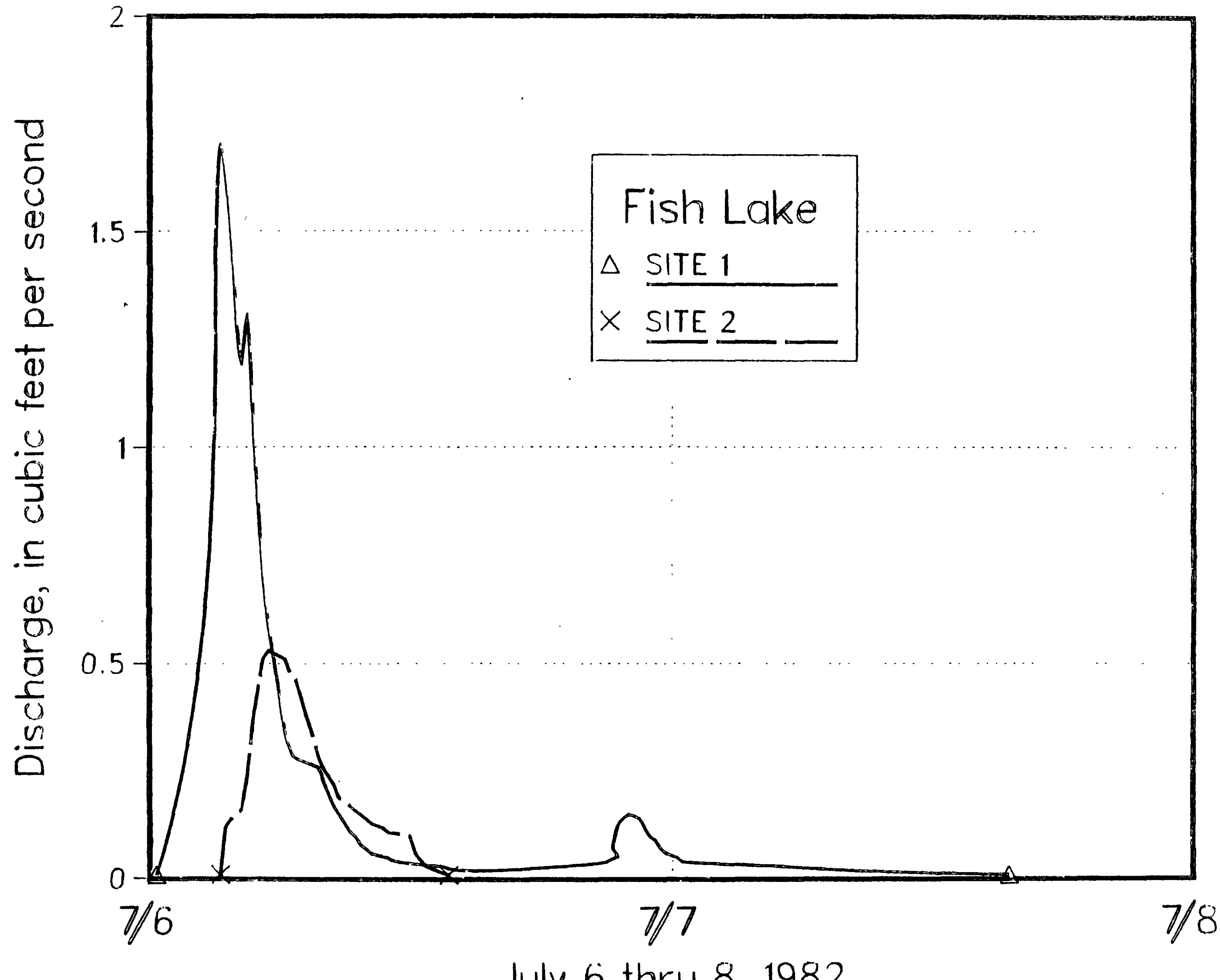

Figure 42.--Streamflow discharge for Fish Lake, storm of July 6, 1982

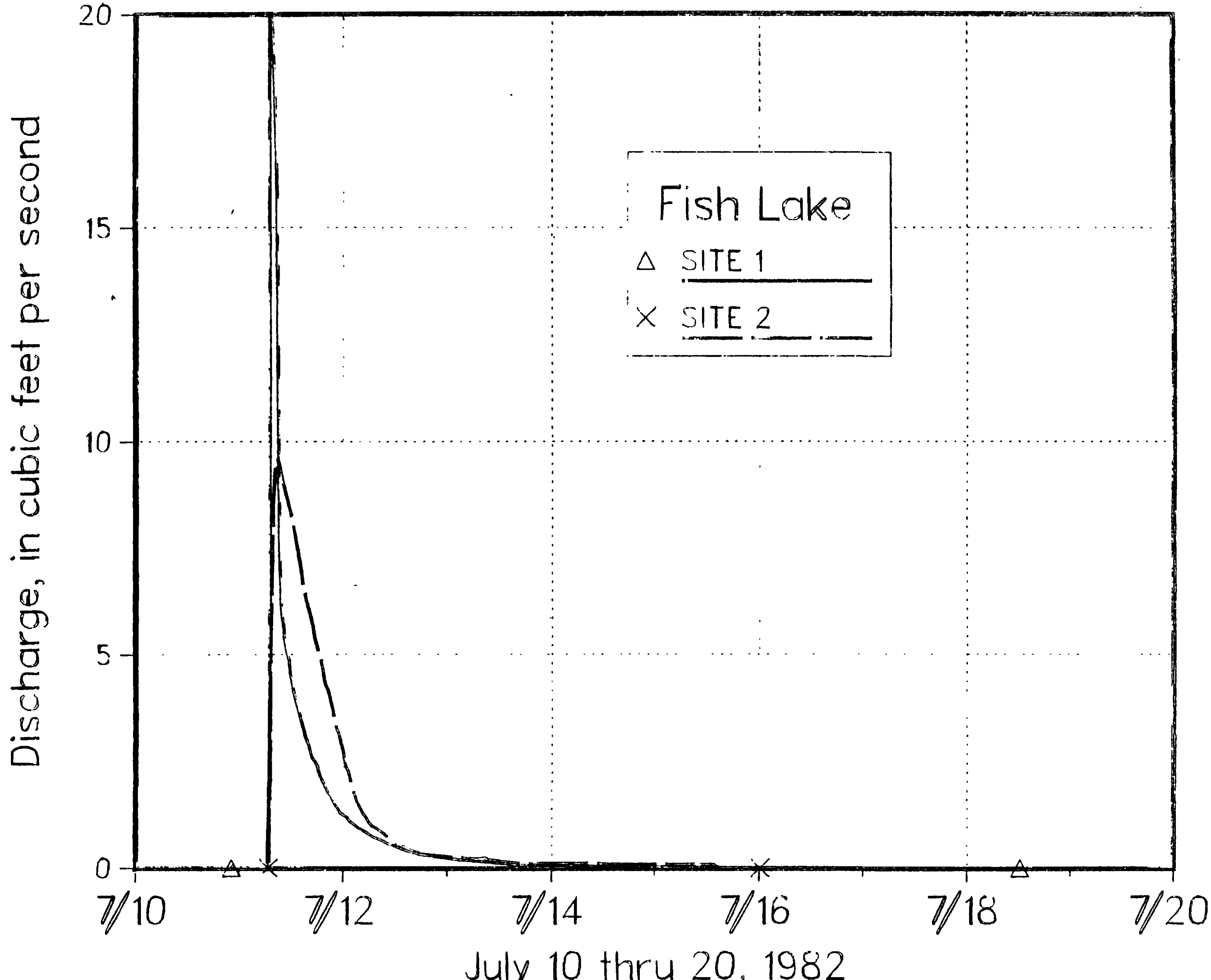

Figure 43.--Streamflow discharge for Fish Lake, storm of July 10, 1982

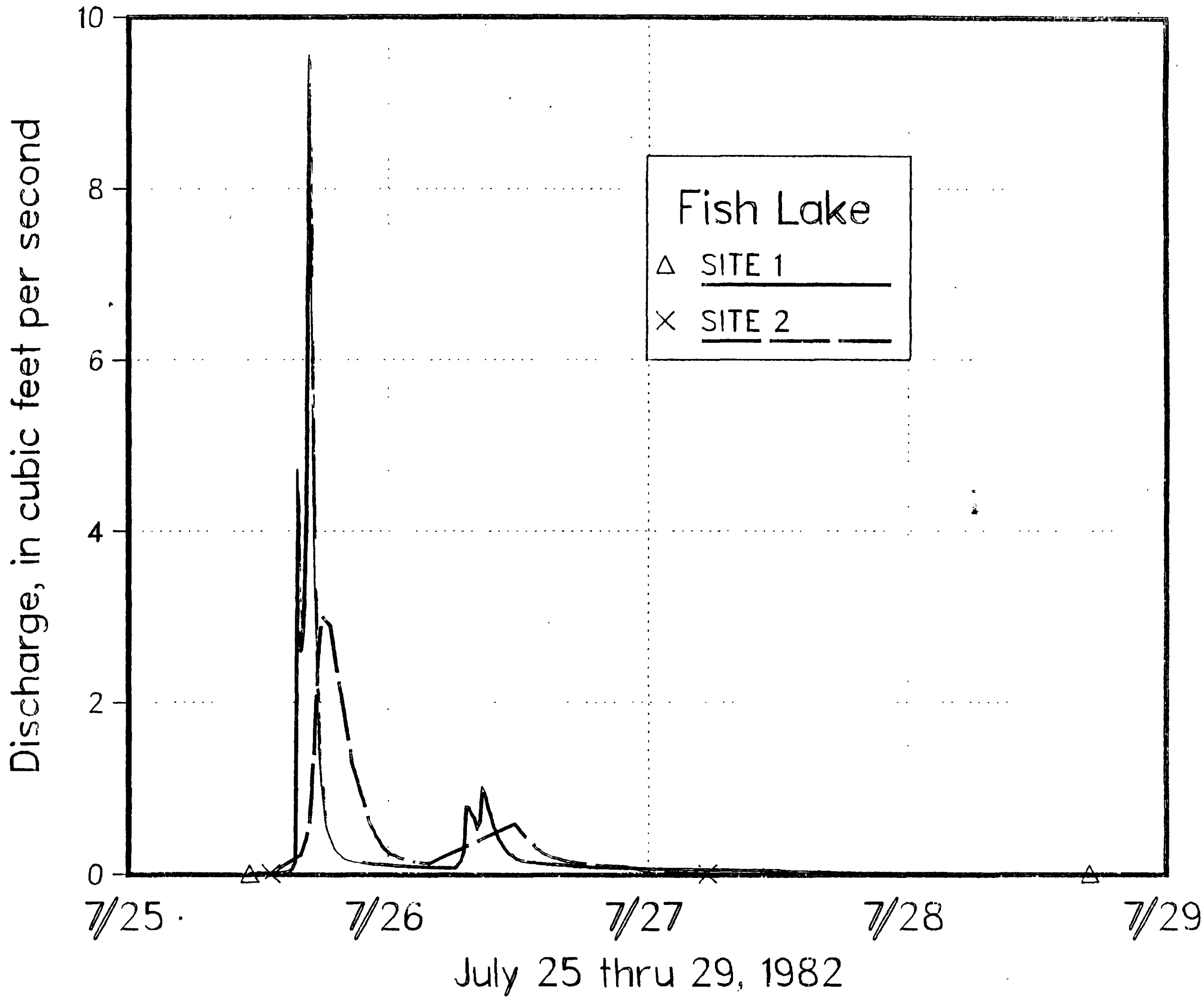

Figure 44.--Streamflow discharge for Fish Lake, storm of July 25, 1982

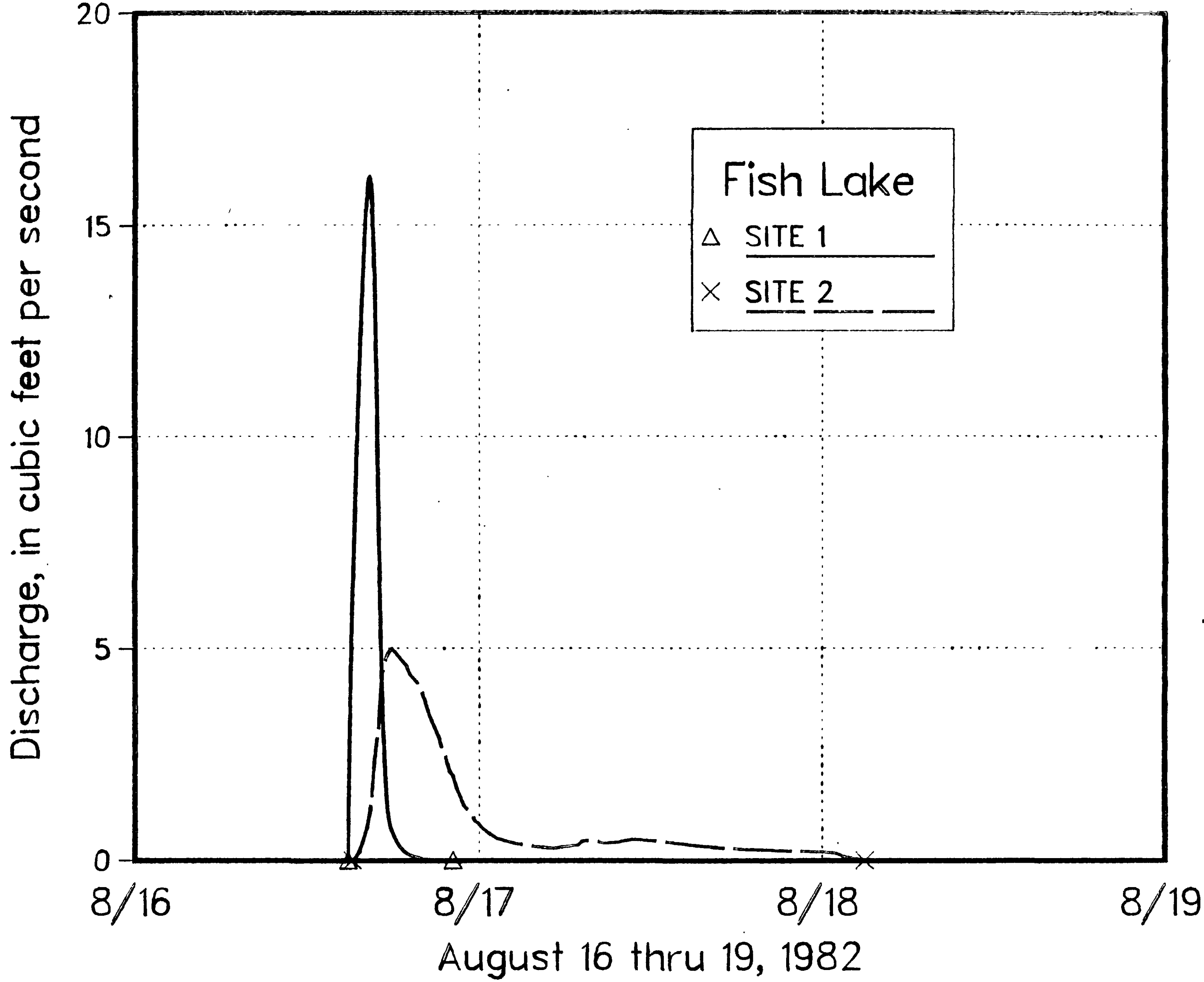

Figure 45.--Streamflow discharge for Fish Lake, storm of August 16, 1982

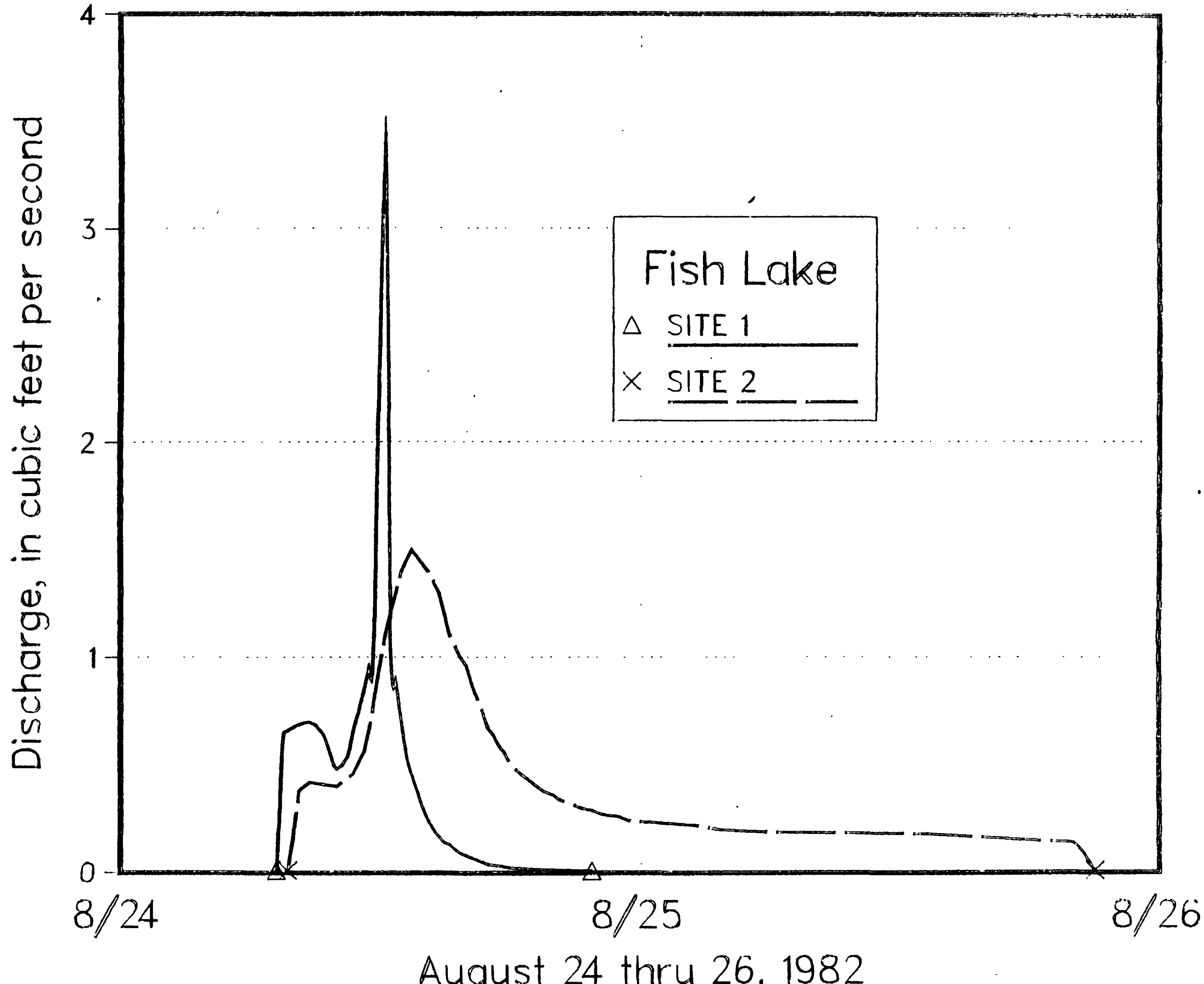

Figure 46.--Streamflow discharge for Fish Lake, storm of August 24, 1982

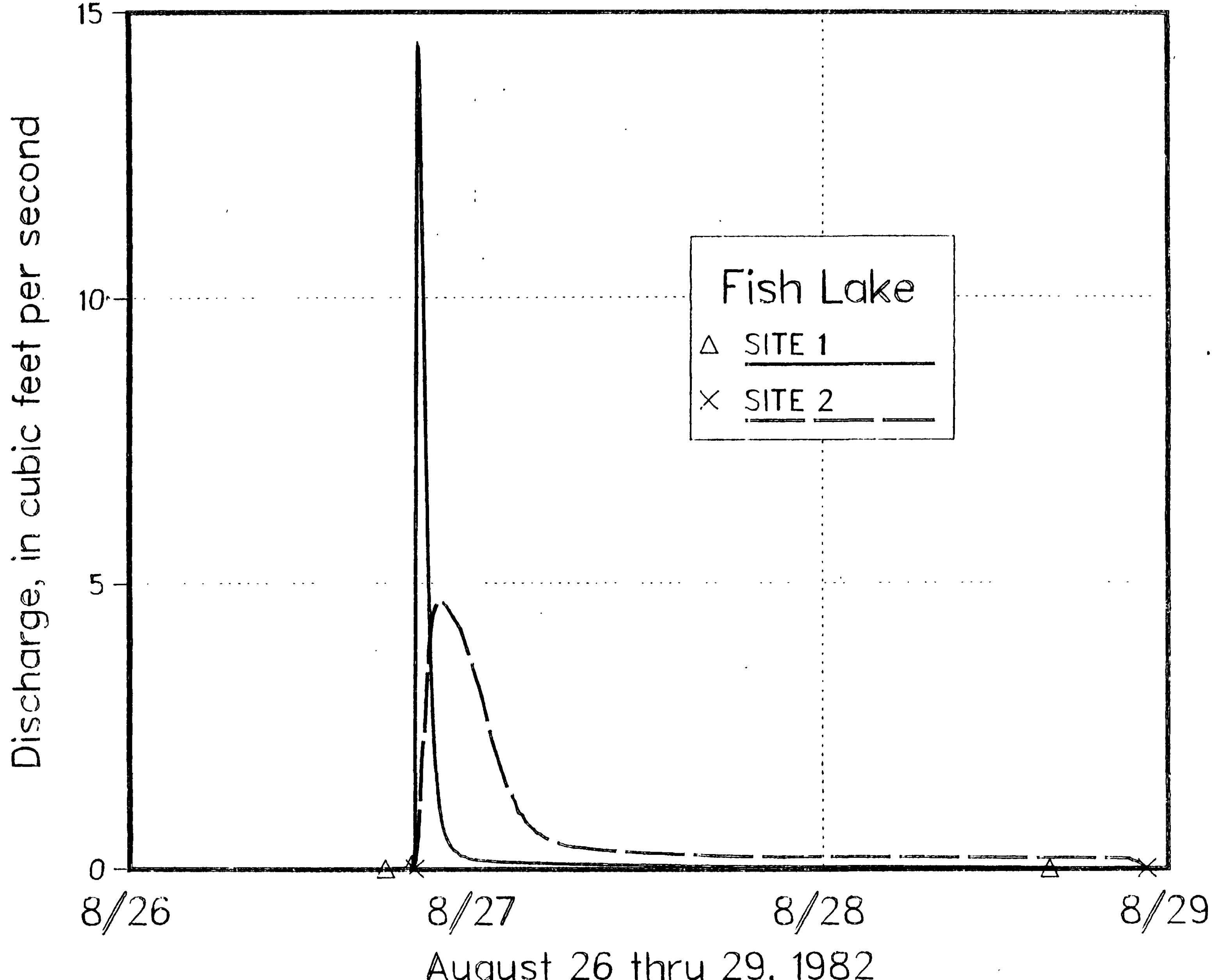

Figure 47.--Streamflow discharge for Fish Lake, storm of August 26, 1982

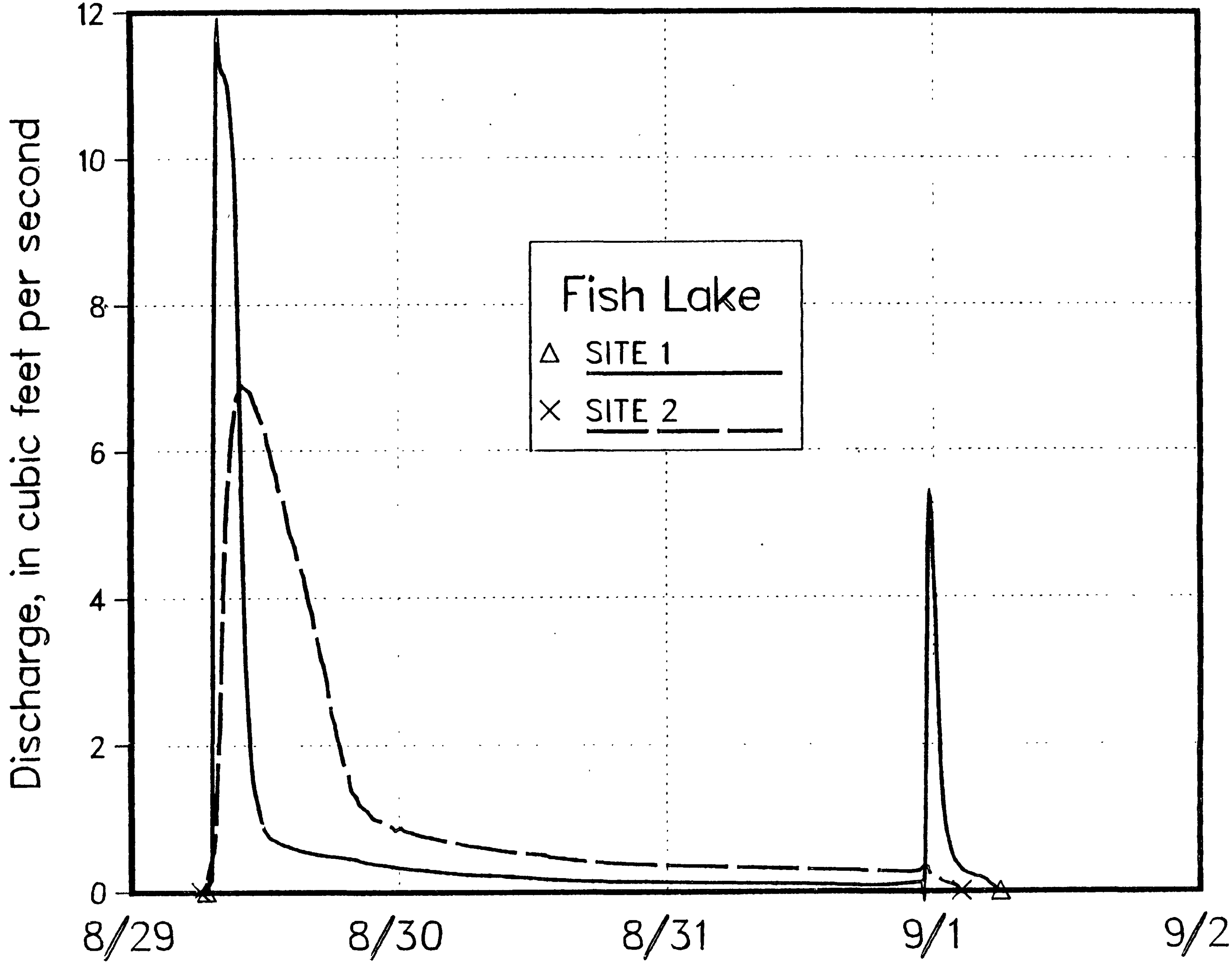

Figure 48.--Streamflow discharge for Fish Lake, storm of August 31, 1982

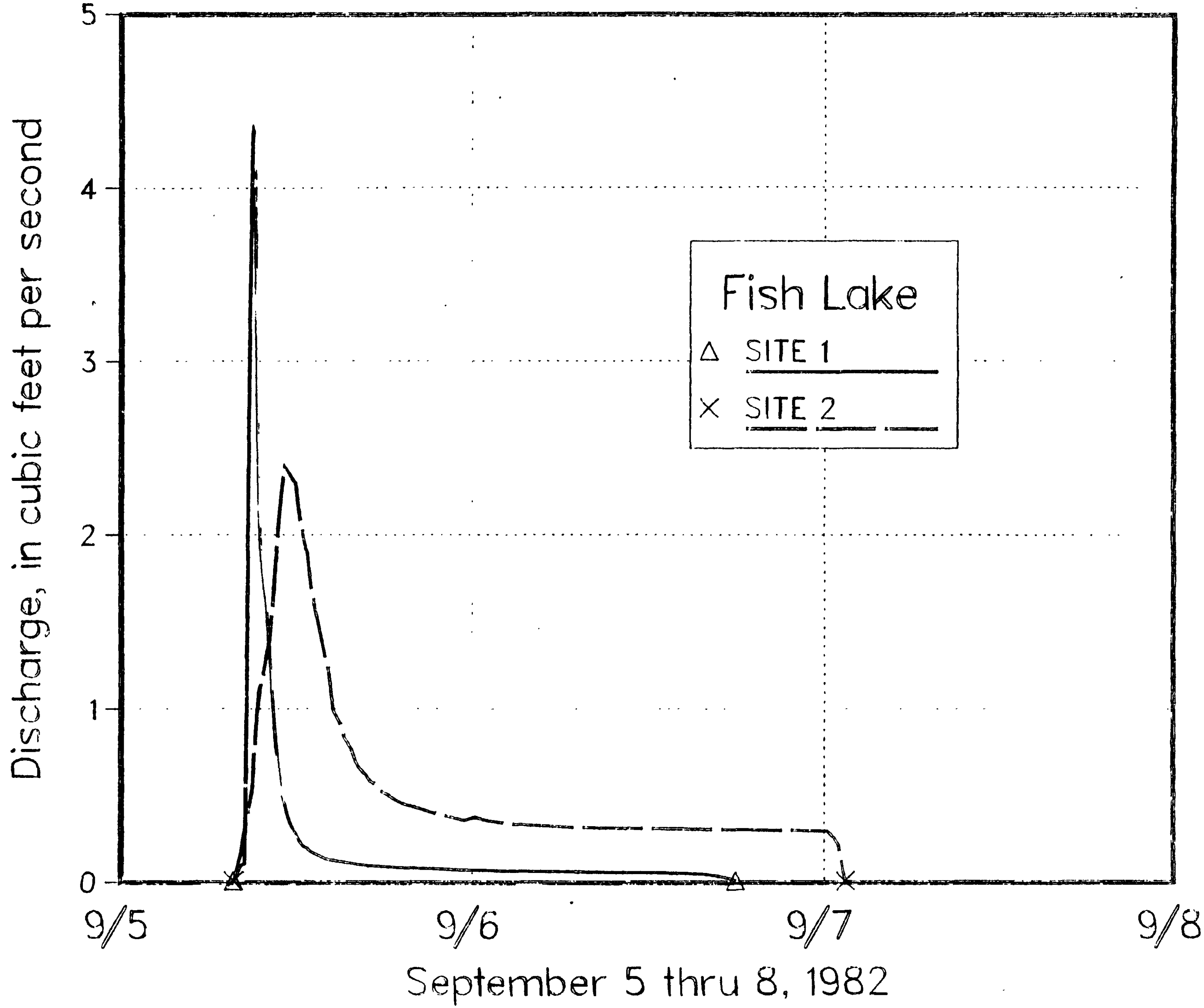

Figure 49.--Streamflow discharge for Fish Lake, storm of September 4, 1982

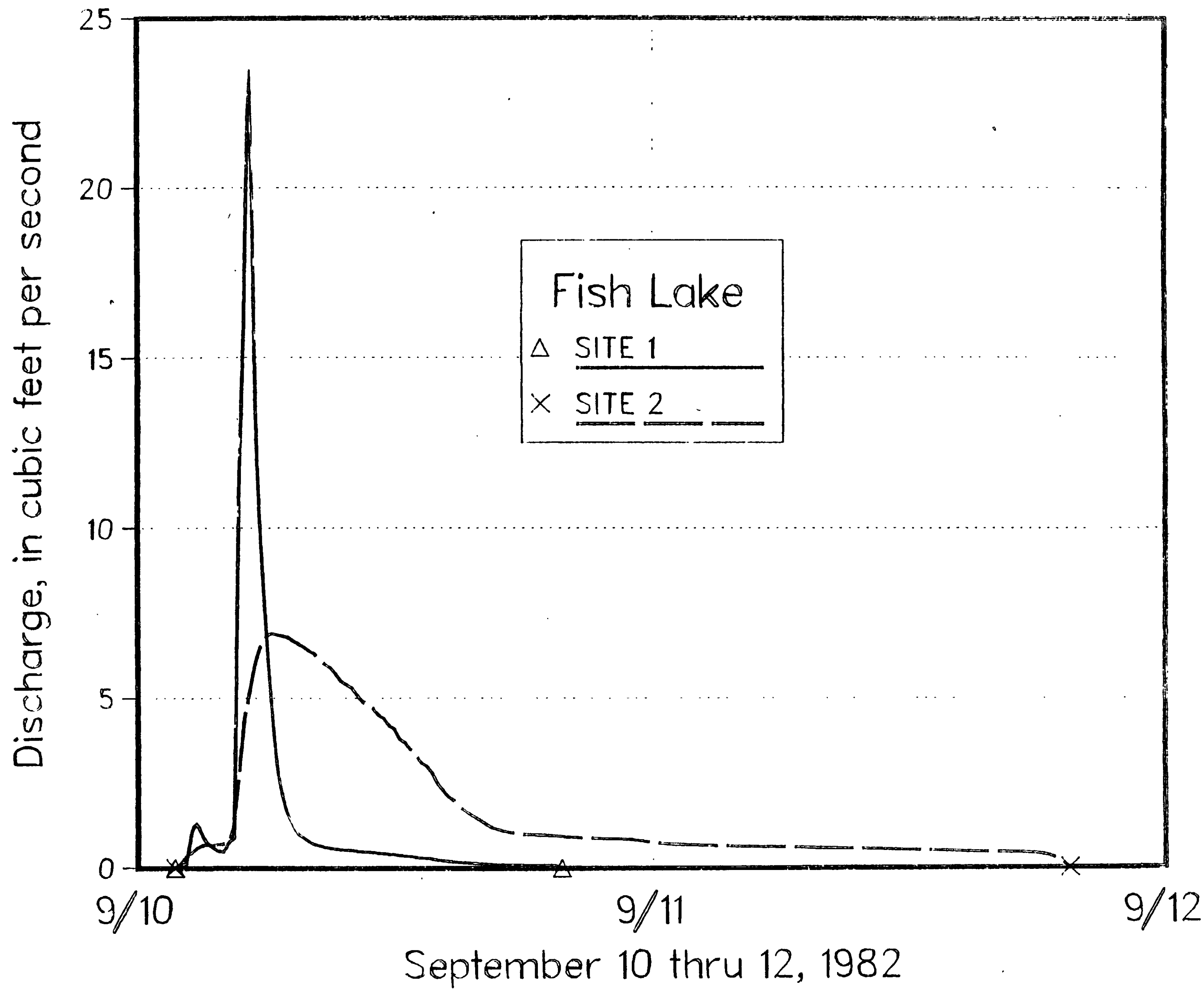

Figure 50.--Streamflow discharge for Fish Lake, storm of September 10, 1982

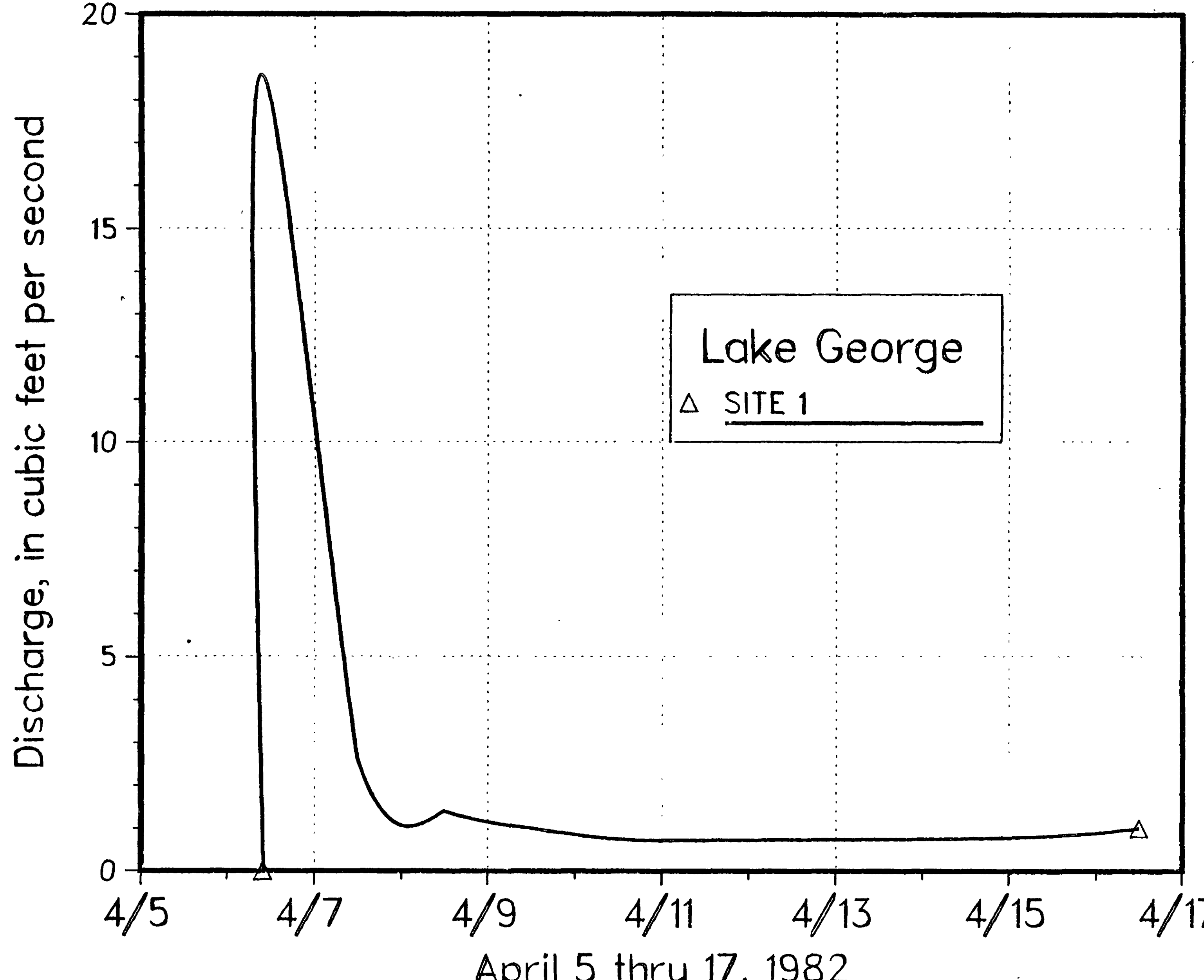

Figure 51.--Streamflow discharge for snowmelt at Lake George, March 30, 1982

Table 30.--Storm beginning time, ending time, and flow-weighted mean concentrations at Fish Lake sites

Site	Beginning time[1]/		Ending time		Storm duration (hours)	Total suspended solids (mg/L)	Volatile suspended solids (mg/L)	Total phosphorus (mg/L)	Dissolved phosphorus (mg/L)	Dissolved NO_2+NO_3 nitrogen (mg/L)	Total ammonia nitrogen (mg/L)	Total ammonia + organic nitrogen (mg/L)
1	3-17-82	17:00	4-16-82	6:45	710	2.0	2.0	.25	.18	2.80	.95	1.60
1	4-16-82	7:00	5-04-82	15:15	440	1.0	1.0	.08	.06	.65	.10	1.00
1	5-04-82	15:30	5-09-82	3:00	108	1200	170	2.2	.21	.85	1.3	7.2
1	5-09-82	3:15	5-16-82	21:00	186	1.0	1.0	.10	.08	.20	.08	1.4
1	5-16-82	21:15	6-14-82	11:15	686	20.0	4.0	.22	.17	.35	.09	1.6
1	6-14-82	11:30	6-15-82	15:15	28	4.0	4.0	.16	.03	.20	.20	1.6
1	6-24-82	7:45	6-26-82	15:45	56	6.0	2.0	.21	.10	.30	.14	1.3
1	6-28-82	20:30	7-04-82	17:30	141	10.0	5.0	.22	.10	.30	.14	1.5
1	7-05-82	4:00	7-08-82	17:15	85	18.0	1.0	.24	.18	.15	.32	1.3
1	7-09-82	22:15	7-17-82	17:30	187	180	140	.45	.14	.35	.09	1.8
1	7-25-82	11:15	7-29-82	17:00	102	14.0	6.0	.22	.16	1.00	.09	1.1
1	8-16-82	16:00	8-16-82	22:15	6	9.0	1.0	.40	.20	.75	.16	1.6
1	8-24-82	7:15	8-24-82	21:45	15	4.0	4.0	.20	.18	.10	.06	.74
1	8-26-82	17:45	8-28-82	15:45	46	8.0	2.0	.21	.12	.35	.06	.84
1	8-29-82	6:45	9-01-82	6:00	71	8.0	2.0	.22	.10	.35	.06	.88
1	9-05-82	7:45	9-06-82	18:00	34	5.0	4.0	.17	.06	.55	.09	.84
1	9-10-82	1:45	9-10-82	19:45	18	2.0	2.0	.22	.12	.35	.10	1.2
2	3-17-82	12:00	4-16-82	8:45	717	2.0	2.0	.21	.15	2.6	.78	1.5
2	4-16-82	9:00	5-04-82	15:30	439	1.0	1.0	.08	.07	.55	.08	1.4
2	5-04-82	15:45	5-09-82	3:15	108	4.0	4.0	.14	.06	.20	.18	2.0
2	5-09-82	3:30	5-16-82	22:00	187	1.0	1.0	.07	.06	.05	.37	1.4
2	5-16-82	22:15	6-14-82	14:00	688	2.0	2.0	.16	.11	.20	.31	1.4
2	6-14-82	14:15	6-15-82	2:00	12	25.0	13.0	.20	.02	.10	.12	1.7
2	6-24-82	8:15	6-24-82	21:45	14	4.0	3.0	.30	.17	.35	.10	1.2

Table 30.--Storm beginning time, ending time, and flow-weighted mean concentrations at Fish Lake sites--Continued

Site	Beginning time[1]		Ending time		Storm duration (hours)	Total suspended solids (mg/L)	Volatile suspended solids (mg/L)	Total phosphorus (mg/L)	Dissolved phosphorus (mg/L)	Dissolved NO_2+NO_3 nitrogen (mg/L)	Total ammonia nitrogen (mg/L)	Total ammonia + organic nitrogen (mg/L)
2	6-28-82	22:00	6-29-82	8:45	12	10.0	6.0	0.18	0.06	0.05	0.05	0.96
2	7-06-82	3:15	7-06-82	14:15	11	11.0	1.0	.21	.12	.05	.06	1.6
2	7-10-82	6:45	7-15-82	14:45	128	64.0	40.0	.30	.14	.30	.52	1.3
2	7-25-82	15:45	7-27-82	10:00	42	4.0	4.0	.19	.11	.35	.66	1.2
2	8-16-82	15:15	8-18-82	3:00	36	9.0	3.0	.27	.16	.40	.12	1.3
2	8-24-82	7:45	8-25-82	21:15	38	4.0	4.0	.23	.18	.15	.07	1.2
2	8-26-82	19:45	8-28-82	22:30	51	6.0	3.0	.17	.13	.05	.09	.8
2	8-29-82	6:15	9-01-82	2:30	68	1.0	1.0	.11	.09	.20	.08	.76
2	9-05-82	7:45	9-07-82	1:30	42	2.0	1.0	.10	.06	.20	.07	.72
2	9-10-82	1:45	9-11-82	19:30	42	2.0	2.0	.13	.11	.25	.08	.72
3	3-27-82	17:00	4-16-82	8:30	472	3.0	3.0	.08	.03	.25	.52	1.2
3	4-16-82	8:45	4-22-82	12:30	148	4.0	4.0	.07	.03	.35	.27	1.5
A1	7-25-82	17:45	7-25-82	17:45	0	20.0	10.0	.19	.18	.95	.26	1.0
A1	8-16-82	17:30	8-16-82	17:30	0	6.0	2.0	.34	.27	1.8	.18	1.5
A1	8-24-82	10:00	8-24-82	10:00	0	6.0	4.0	.12	.09	.40	.06	.48
A2	7-25-82	17:20	7-25-82	17:20	0	46.0	12.0	.42	.37	2.2	.50	2.5
A2	8-16-82	17:40	8-16-82	17:40	0	10.0	2.0	.50	.29	1.6	.16	1.6
A2	8-24-82	9:20	8-24-82	9:20	0	93.0	20.0	.22	.10	.35	.07	.90
A3	7-25-82	17:05	7-25-82	17:05	0	189.0	18.0	.35	.26	.80	.43	2.0
A3	8-16-82	17:55	8-16-82	17:55	0	40.0	8.0	.92	.49	.35	.25	3.3
A3	8-24-82	10:20	8-24-82	10:20	0	10.0	5.0	.19	.15	.20	.10	.72

[1]/If beginning and ending time are the same, then concentration was a grab sample; if time is 0:00, then exact time is unknown.

Table 31.--Storm flow-weighted mean concentration ratios for suspended solids, phosphorus, and nitrogen at Fish Lake sites

Site	Beginning time[1]		Ending time		Percentage of suspended solids in the volatile form	Percentage of phosphorus in the dissolved state	Percentage of nitrogen in the form of ammonia
1	3-17-82	17:00	4-16-82	6:45	100	72	59
1	4-16-82	7:00	5-04-82	15:15	100	75	10
1	5-04-82	15:30	5-09-82	3:00	14	10	18
1	5-09-82	3:15	5-16-82	21:00	100	80	6
1	5-16-82	21:15	6-14-82	11:15	20	77	5
1	6-14-82	11:30	6-15-82	15:15	100	19	12
1	6-24-82	7:45	6-26-82	15:45	33	48	11
1	6-28-82	20:30	7-04-82	17:30	50	45	9
1	7-05-82	4:00	7-08-82	17:15	6	75	25
1	7-09-82	22:15	7-17-82	17:30	78	31	5
1	7-25-82	11:15	7-29-82	17:00	43	73	8
1	8-16-82	16:00	8-16-82	22:15	11	50	10
1	8-24-82	7:15	8-24-82	21:45	100	90	8
1	8-26-82	17:45	8-28-82	15:45	25	57	7
1	8-29-82	6:45	9-01-82	6:00	25	45	7
1	9-05-82	7:45	9-06-82	18:00	80	35	11
1	9-10-82	1:45	9-10-82	19:45	100	54	8
2	3-17-82	12:00	4-16-82	8:45	100	71	53
2	4-16-82	9:00	5-04-82	15:30	100	88	6
2	5-04-82	15:45	5-09-82	3:15	100	43	9
2	5-09-82	3:30	5-16-82	22:00	100	86	26
2	5-16-82	22:15	6-14-82	14:00	100	69	22
2	6-14-82	14:15	6-15-82	2:00	52	10	7
2	6-24-82	8:15	6-24-82	21:45	75	57	8
2	6-28-82	20:45	6-29-82	8:45	60	33	5
2	7-06-82	3:15	7-06-82	14:15	9	57	4
2	7-10-82	6:45	7-15-82	14:45	62	47	41
2	7-25-82	15:45	7-27-82	10:00	100	58	54
2	8-16-82	15:15	8-18-82	3:00	33	59	9
2	8-24-82	7:45	8-25-82	21:15	100	78	6
2	8-26-82	19:45	8-28-82	22:30	50	76	11
2	8-29-82	6:15	9-01-82	2:30	100	82	10

Table 31.--Storm flow-weighted mean concentration ratios for suspended solids, phosphorus, and nitrogen at Fish Lake sites--Continued

Site	Beginning time[1]		Ending time		Percentage of suspended solids in the volatile form	Percentage of phosphorus in the dissolved state	Percentage of nitrogen in the form of ammonia
2	9-05-82	7:45	9-07-82	1:30	50	60	10
2	9-10-82	1:45	9-11-82	19:30	100	85	11
3	3-27-82	17:00	4-16-82	8:30	100	38	43
3	4-16-82	8:45	4-22-82	12:30	100	43	18
A1	7-25-82	17:45	7-25-82	17:45	50	95	26
A1	8-16-82	17:30	8-16-82	17:30	33	79	12
A1	8-24-82	10:00	8-24-82	10:00	67	75	12
A2	7-25-82	17:20	7-25-82	17:20	26	88	20
A2	8-16-82	17:40	8-16-82	17:40	20	58	10
A2	8-24-82	9:20	8-24-82	9:20	22	45	8
A3	7-25-82	17:05	7-25-82	17:05	10	74	21
A3	8-16-82	17:55	8-16-82	17:55	20	53	8
A3	8-24-82	10:20	8-24-82	10:20	50	79	14

1/If beginning and ending time are the same, then concentration was a grab sample; if time is 0:00, then exact time is unknown.

Table 32.--Average storm flow-weighted mean concentrations for each season at Fish Lake, 1982

[Seasons are: snowmelt - beginning of flow to April 22; spring - April 23 to June 1; early summer - June 2 to July 17; late summer - July 18 to September 4; autumn - September 5 to end of flow]

Site	Season	Total suspended solids (mg/L)	Volatile suspended solids (mg/L)	Total phosphorus (mg/L)	Dissolved phosphorus (mg/L)	Dissolved NO_2+NO_3 nitrogen (mg/L)	Total ammonia nitrogen (mg/L)	Total ammonia + organic nitrogen (mg/L)
1	Snowmelt	1.9	1.9	0.24	0.18	2.7	0.95	1.5
1	Spring	265	38	.56	.10	.52	.36	2.5
1	Early summer	48	28	.25	.16	.33	.09	1.6
1	Late summer	8.9	2.6	.25	.14	.49	.08	1.0
1	Autumn	2.6	2.4	.21	.11	.38	.10	1.1
2	Snowmelt	2.0	2.0	.21	.15	2.5	.77	1.4
2	Spring	1.6	1.6	.09	.06	.29	.21	1.5
2	Early summer	19	12	.19	.12	.23	.35	1.4
2	Late summer	3.9	2.2	.17	.12	.22	.15	0.94
2	Autumn	2.0	1.8	.12	.10	.24	.08	.72
3	Snowmelt	3.1	3.1	.08	.03	.25	.52	1.2
3	Spring	17	10	.07	.03	.11	.14	1.4
3	Early summer	9.0	7.0	.03	.01	.05	.10	1.2
3	Late summer	4.0	4.0	.02	.01	.05	.05	1.2
3	Autumn	1.0	1.0	.08	.03	850	.04	1.8

Table 33.--Seasonal average storm flow-weighted mean concentration ratios for suspended solids, phosphorus, and nitrogen at Fish Lake sites

[Seasons are: snowmelt - beginning of flow to April 22; spring - April 23 to June 1; early summer - June 2 to July 17; late summer - July 18 to September 4; autumn - September 5 to end of flow]

Site	Season	Percentage of suspended solids in the dissolved state	Percentage of phosphorus in the dissolved state	Percentage of nitrogen in the form of ammonia
1	Snowmelt	100	75	63
1	Spring	3	18	14
1	Early summer	58	64	6
1	Later summer	29	56	8
1	Autumn	92	52	9
2	Snowmelt	100	71	55
2	Spring	100	67	14
2	Early summer	63	63	25
2	Late summer	56	70	16
2	Autumn	90	83	11
3	Snowmelt	100	38	43
3	Spring	59	43	10
3	Early summer	78	33	8
3	Late summer	100	50	4
3	Autumn	100	38	2

Table 34.--Storm beginning time, ending time, flow, and loads at Fish Lake sites

Site	Beginning time[1]		Ending time		Storm flow (m^3)	Total suspended solids (kg)	Volatile suspended solids (kg)	Total phosphorus (kg)	Dissolved phosphorus (kg)	Dissolved NO_2+NO_3 nitrogen (kg)	Total ammonia nitrogen (kg)	Total ammonia + organic nitrogen (kg)
1	3-17-82	17:00	4-16-82	6:45	77,000	150	150	19	14	210	74	120
1	4-16-82	7:00	5-04-82	15:15	18,000	19	19	1.5	1.1	12	1.9	19
1	5-04-82	15:30	5-09-82	3:00	10,000	13,000	1,800	23	2.2	8.9	14	76
1	5-09-82	3:15	5-16-82	21:00	18,000	18	18	1.8	1.5	3.7	1.5	26
1	5-16-82	21:15	6-14-82	11:15	46,000	935	187	10	7.9	16	4.2	77
1	6-14-82	11:30	6-15-82	15:15	340	1.4	1.4	0.05	0.01	0.07	0.07	0.56
1	6-24-82	7:45	6-26-82	15:45	950	5.8	1.9	.20	.10	.29	.14	1.2
1	6-28-82	20:30	7-04-82	17:30	830	8.4	4.2	.18	.08	.25	.12	1.3
1	7-05-82	4:00	7-08-82	17:15	619	11	0.63	.15	.11	.09	.20	.79
1	7-09-82	22:15	7-17-82	17:30	11,000	2,000	1,600	5.0	1.6	3.9	1.0	20
1	7-25-82	11:15	7-29-82	17:00	1,800	26	11	.40	.29	1.8	.16	2.0
1	8-16-82	16:00	8-16-82	22:15	1,500	13	1.5	.59	.30	1.1	.24	2.3
1	8-24-82	7:15	8-24-82	21:45	520	2.1	2.1	.11	.09	.05	.03	.39
1	8-26-82	17:45	8-28-82	15:45	1,500	12	3.1	.32	.18	.54	.09	1.3
1	8-29-82	6:45	9-01-82	6:00	5,200	42	10	1.2	.52	1.8	.31	4.6
1	9-05-82	7:45	9-06-82	18:00	720	3.7	3.9	.12	.04	.40	.07	.62
1	9-10-82	1:45	9-10-82	19:45	3,000	6.0	6.0	.67	.36	1.1	.30	3.8

Table 34.--Storm beginning time, ending time, flow, and loads at Fish Lake sites--Continued

Site	Beginning time[1]		Ending time		Storm flow (m^3)	Total suspended solids (kg)	Volatile suspended solids (kg)	Total phosphorus (kg)	Dissolved phosphorus (kg)	Dissolved NO_2+NO_3 nitrogen (kg)	Total ammonia nitrogen (kg)	Total ammonia + organic nitrogen (kg)
2	3-17-82	12:00	4-16-82	8:45	83,000	170	170	18	13	210	66	120
2	4-16-82	9:00	5-04-82	15:30	17,000	17	17	1.4	1.2	9.4	1.4	24
2	5-04-82	15:45	5-09-82	3:15	8,700	35	35	1.2	0.53	1.8	1.6	18
2	5-09-82	3:30	5-16-82	22:00	15,000	15	15	1.0	.90	0.75	5.6	22
2	5-16-82	22:15	6-14-82	14:00	36,000	72	72	6.8	3.9	7.2	11	51
2	6-14-82	14:15	6-15-82	2:00	100	2.6	1.4	0.02	.00	.01	0.01	0.17
2	6-24-82	8:15	6-24-82	21:45	480	2.0	1.5	.15	.08	.17	.05	.59
2	6-28-82	20:45	6-29-82	8:45	210	2.2	1.3	.04	.01	.01	.01	.21
2	7-06-82	3:15	7-06-82	14:15	240	2.7	0.25	.05	.03	.01	.01	.40
2	7-10-82	6:45	7-15-82	14:45	14,000	890	560	4.2	2.0	4.2	7.3	18
2	7-25-82	15:45	7-27-82	10:00	1,900	7.8	7.8	.37	.21	.68	1.3	2.4
2	8-16-82	15:15	8-18-82	3:00	3,400	31	10	.93	.55	1.4	.41	4.5
2	8-24-82	7:45	8-25-82	21:15	1,500	5.9	5.9	.34	.26	.22	.10	1.7
2	8-26-82	19:45	8-28-82	22:30	3,400	21	10	.58	.45	.17	.31	2.7
2	8-29-82	6:15	9-01-82	2:30	9,000	9.2	9.2	1.0	.82	1.8	.73	7.0
2	9-05-82	7:45	9-07-82	1:30	2,300	4.6	2.3	.23	.14	.46	.16	1.7
2	9-10-82	1:45	9-11-82	19:30	7,300	15	15	.96	.81	1.8	.59	5.3
3	3-27-82	17:00	4-16-82	8:30	340,000	1,042	1,042	28	10	86	180	400
3	4-16-82	8:45	4-22-82	12:30	75,000	300	300	5.3	2.3	27	20	114

[1]/If beginning and ending times are the same, then concentration was a grab sample; if time is 0:00, then exact time is unknown.

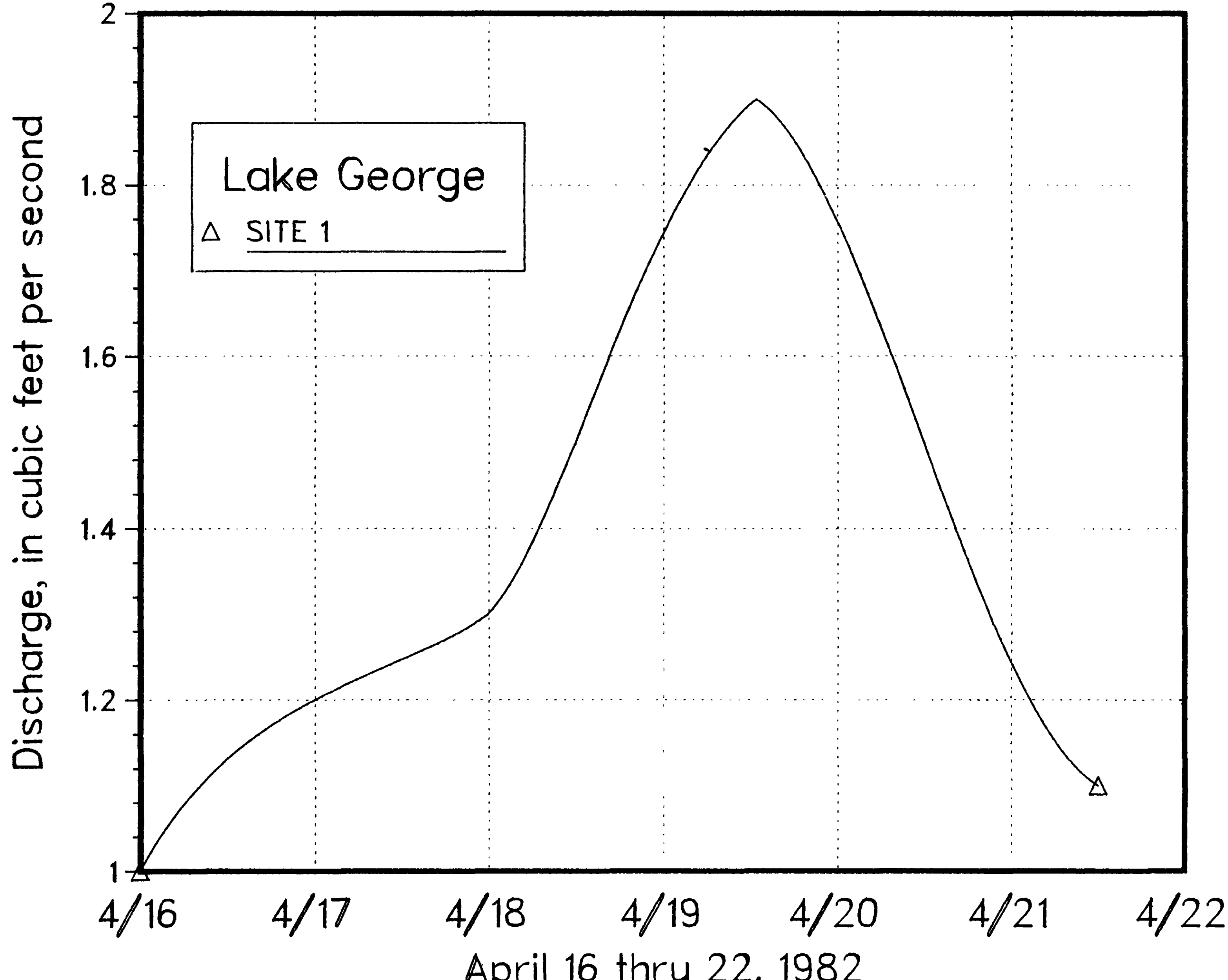

Figure 52.--Streamflow discharge for Lake George, storm of April 16, 1982

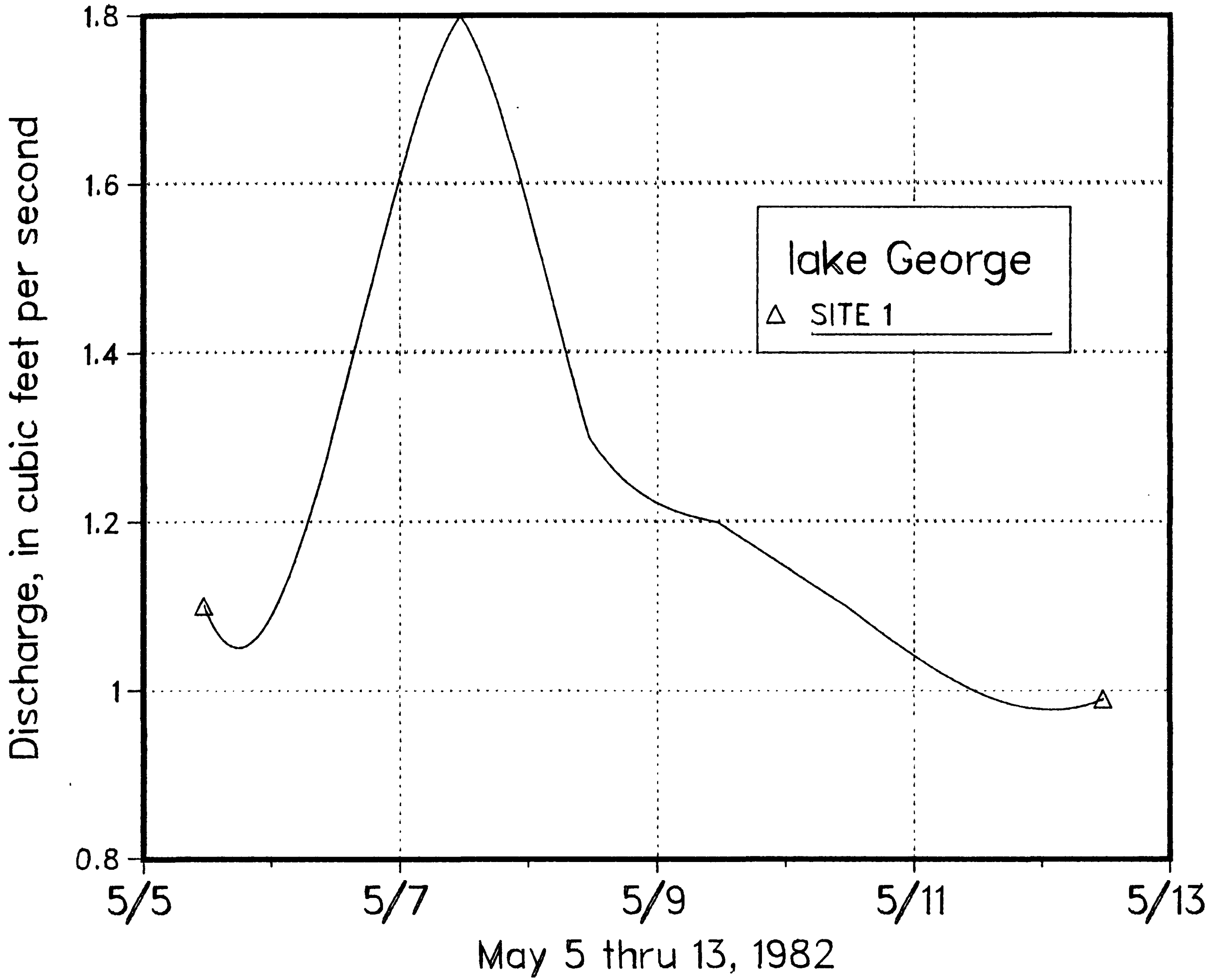

Figure 53.--Streamflow discharge for Lake George, storm of May 4, 1982

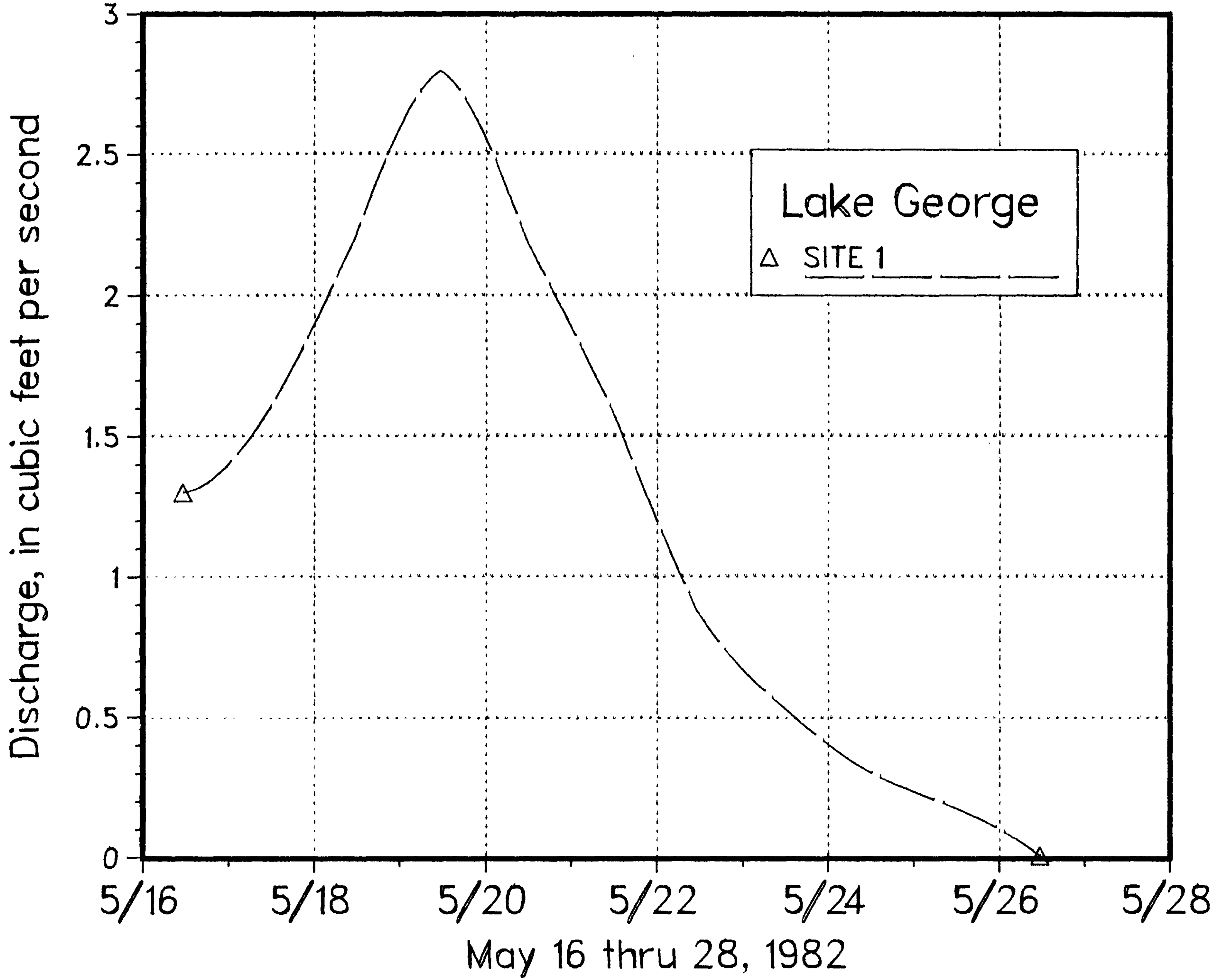

Figure 54.--Streamflow discharge for Lake George, storm of May 17, 1982

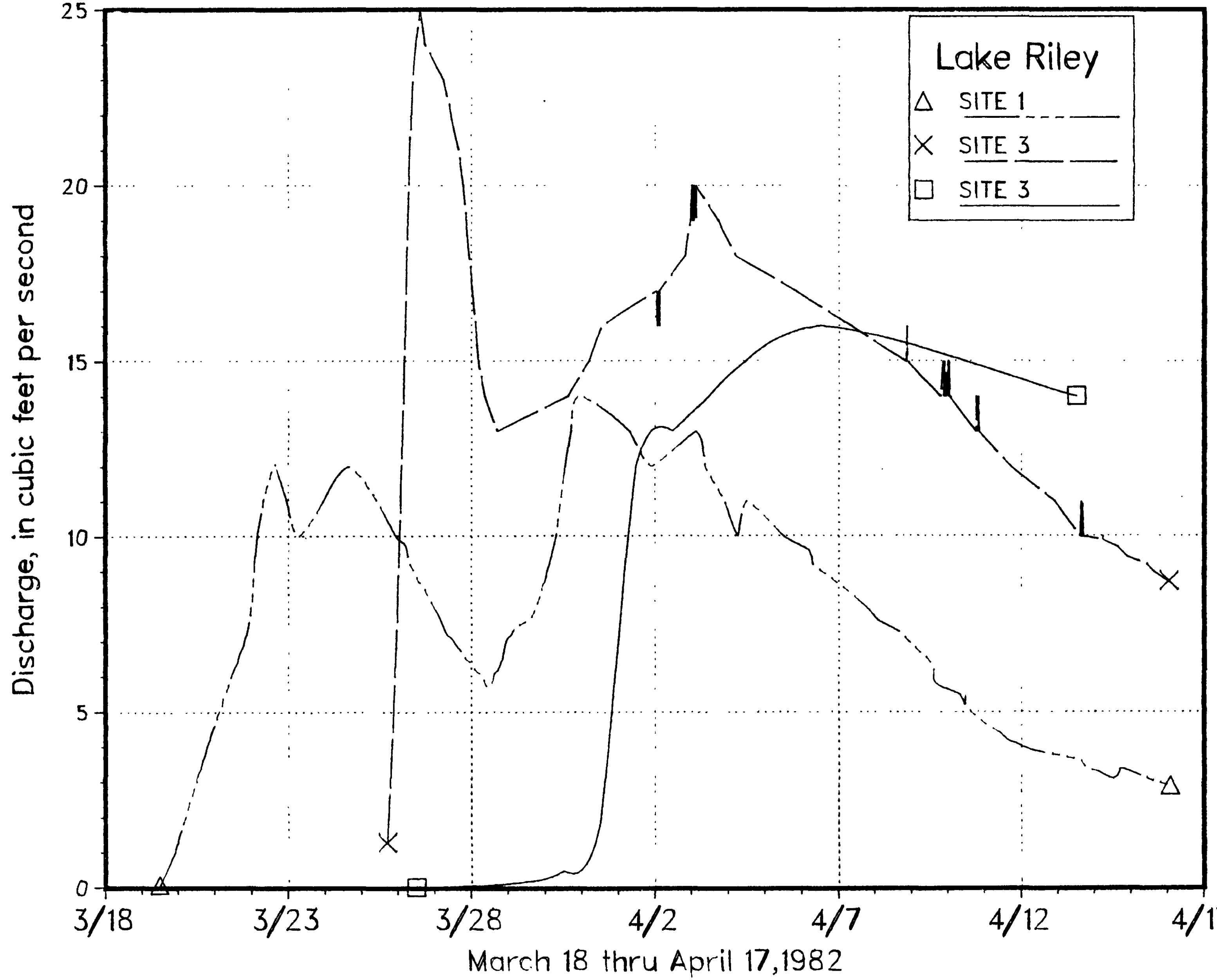

Figure 55.--Streamflow discharge for snowmelt at Lake Riley, March 30, 1982

Table 35.--Storm beginning time, ending time, and flow-weighted mean concentrations at Lake George

Site	Beginning time[1]		Ending time		Storm duration (hours)	Total suspended solids (mg/L)	Volatile suspended solids (mg/L)	Total phosphorus (mg/L)	Dissolved phosphorus (mg/L)	Dissolved NO_2+NO_3 nitrogen (mg/L)	Total ammonia nitrogen (mg/L)	Total ammonia + organic nitrogen (mg/L)
1	4-05-82	0:00	4-16-82	0:00	264	2.0	2.0	0.22	0.12	0.10	0.29	1.2
1	4-16-82	0:00	5-04-82	0:00	432	6.0	6.0	.09	.04	.15	.33	1.0
1	5-04-82	0:00	5-14-82	0:00	240	6.5	6.5	1.0	.34	.45	.28	5.3
1	5-14-82	0:00	5-26-82	0:00	288	2.0	2.0	.07	.04	.05	.08	1.6

[1]/If beginning and ending time are the same, then concentration was a grab sample; if time is 0:00, then exact time is unknown.

Table 36.--Storm flow-weighted mean concentration ratios for suspended solids, phosphorus, and nitrogen at Lake George

Site	Beginning time[1]		Ending time		Percentage of suspended solids in the volatile form	Percentage of phosphorus in the dissolved state	Percentage of nitrogen in the form of ammonia
1	4-05-82	0:00	4-16-82	0:00	100	54	24
1	4-16-82	0:00	5-04-82	0:00	100	44	33
1	5-04-82	0:00	5-14-82	0:00	100	34	5
1	5-14-82	0:00	5-26-82	0:00	100	57	5

[1]/If beginning and ending time are the same, then concentration was a grab sample; if time is 0:00, then exact time is unknown.

Table 37.--Average storm flow-weighted mean concentrations for each season at Lake George, 1982

[Seasons are: snowmelt - beginning of flow to April 22; spring - April 23 to June 1; early summer - June 2 to July 17; late summer - July 18 to September 4; autumn - September 5 to end of flow]

Site	Season	Total suspended solids (mg/L)	Volatile suspended solids (mg/L)	Total phosphorus (mg/L)	Dissolved phosphorus (mg/L)	Dissolved NO_2+NO_3 nitrogen (mg/L)	Total ammonia nitrogen (mg/L)	Total ammonia + organic nitrogen (mg/L)
1	Snowmelt	2.0	2.0	0.21	0.12	0.10	0.29	1.2
1	Spring	6.0	6.0	.09	.04	.15	.33	1.0

Table 38.--Seasonal average storm flow-weighted mean concentration ratios for suspended solids, phosphorus, and nitrogen at Lake George

[Seasons are: snowmelt - beginning of flow to April 22; spring - April 23 to June 1; early summer - June 2 to July 17; late summer - July 18 to September 4; autumn - September 5 to end of flow]

Site	Season	Percentage of suspended solids in the dissolved state	Percentage of phosphorus in the dissolved state	Percentage of nitrogen in the form of ammonia
1	Snowmelt	100	57	24
1	Spring	100	44	33

Table 39.--Storm beginning time, ending time, flow, and loads at Lake George

Site	Beginning time[1]		Ending time		Storm flow (m^3)	Total suspended solids (kg)	Volatile suspended solids (kg)	Total phosphorus (kg)	Dissolved phosphorus (kg)	Dissolved NO_2+NO_3 nitrogen (kg)	Total ammonia nitrogen (kg)	Total ammonia + organic nitrogen (kg)
1	4-05-82	0:00	4-16-82	0:00	69,000	140	140	15	8.4	7.0	20	84
1	4-16-82	0:00	5-04-82	0:00	16,000	98	98	1.5	0.66	2.5	5.4	16
1	5-04-82	0:00	5-14-82	0:00	28,000	170	170	2.5	1.1	4.2	9.2	28
1	5-14-82	0:00	5-26-82	0:00	34,000	200	200	3.1	1.4	5.1	11	34

[1]/If beginning and ending times are the same, then concentration was a grab sample; if time is 0:00, then exact time is unknown.

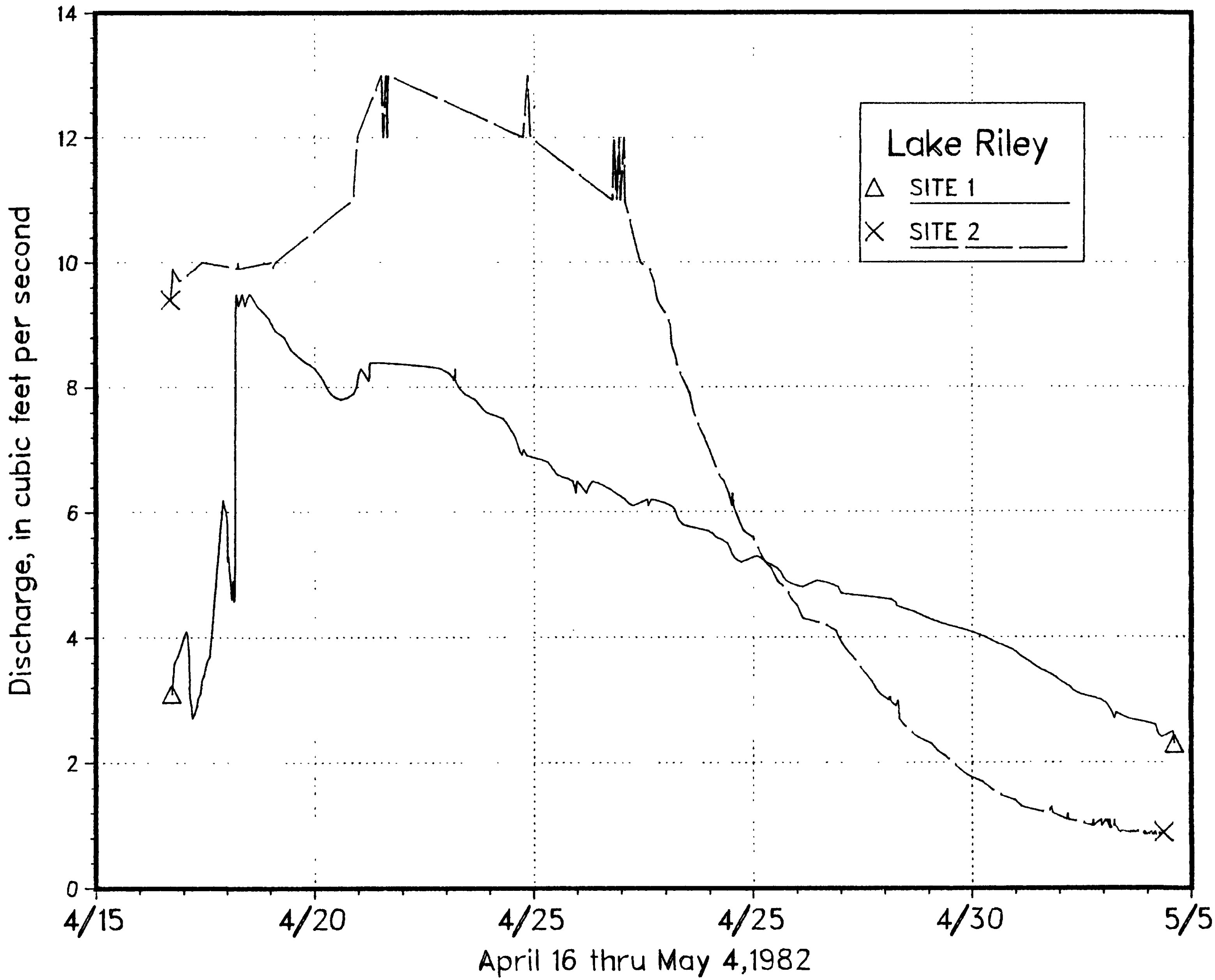

Figure 56.--Streamflow discharge for Lake Riley, storm of April 16.--1982

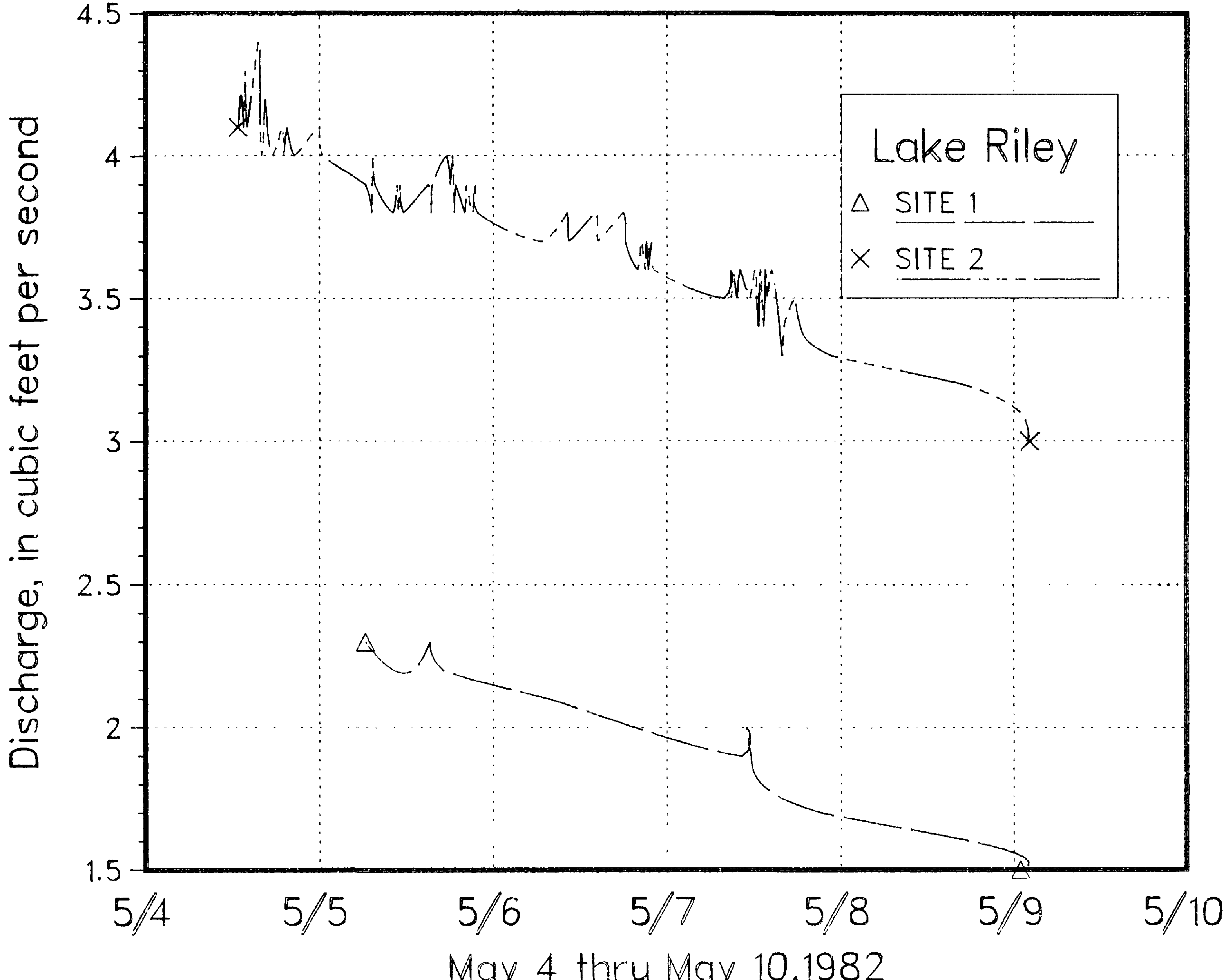

Figure 57.--Streamflow discharge for Lake Riley, storm of May 4, 1982

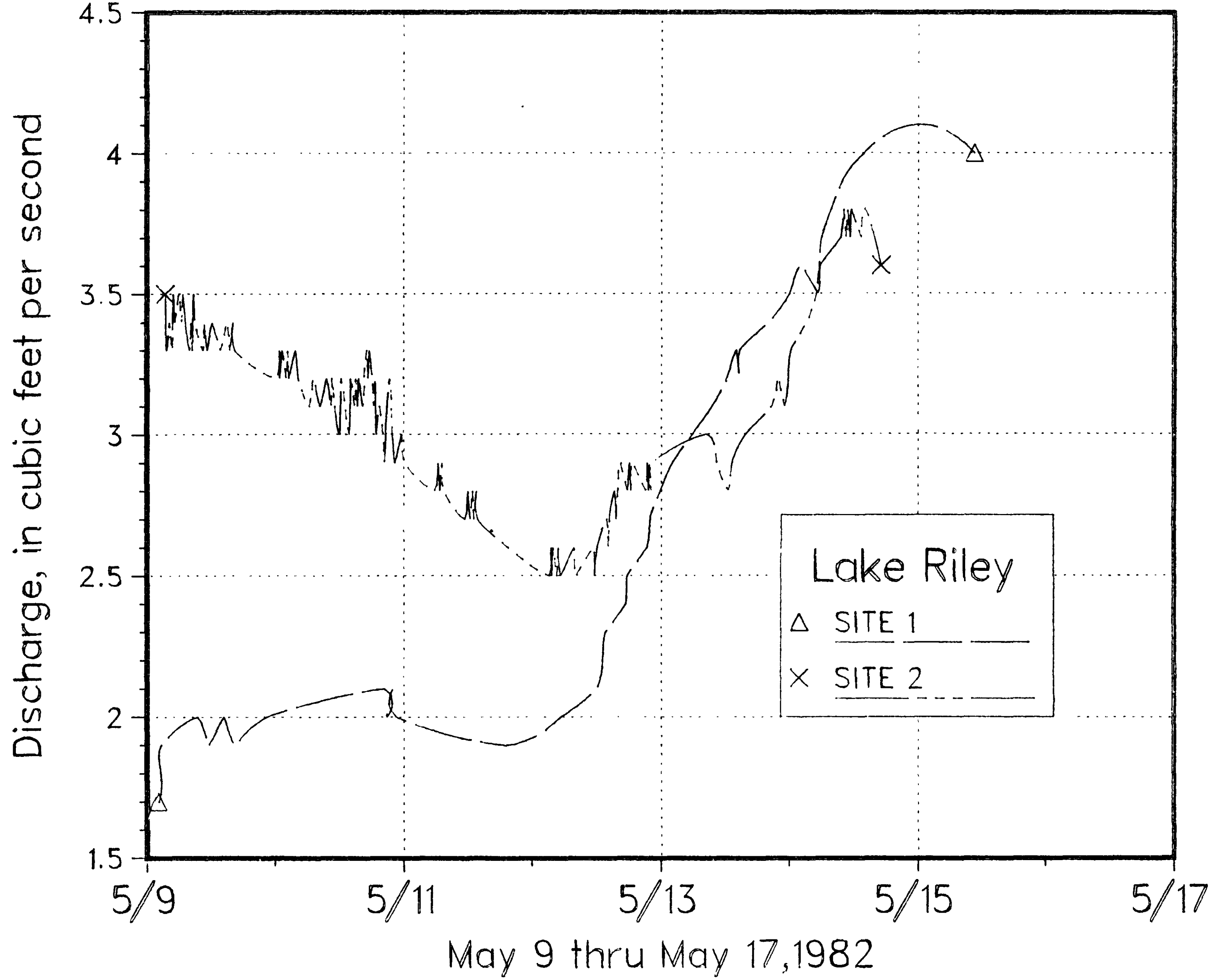

Figure 58.--Streamflow discharge for Lake Riley, storm of May 9, 1982

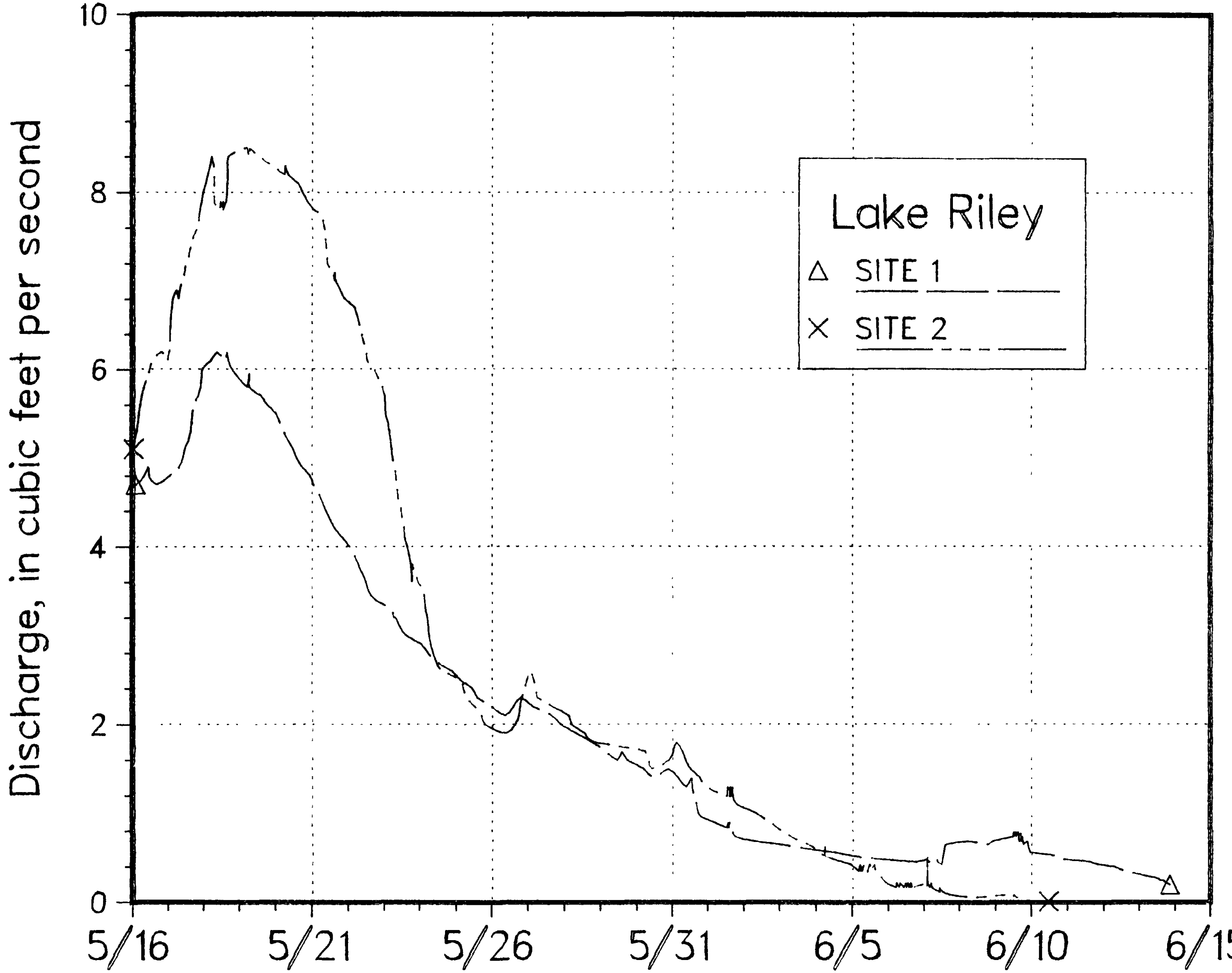

Figure 59.--Streamflow discharge for Lake Riley, storm of May 17, 1982

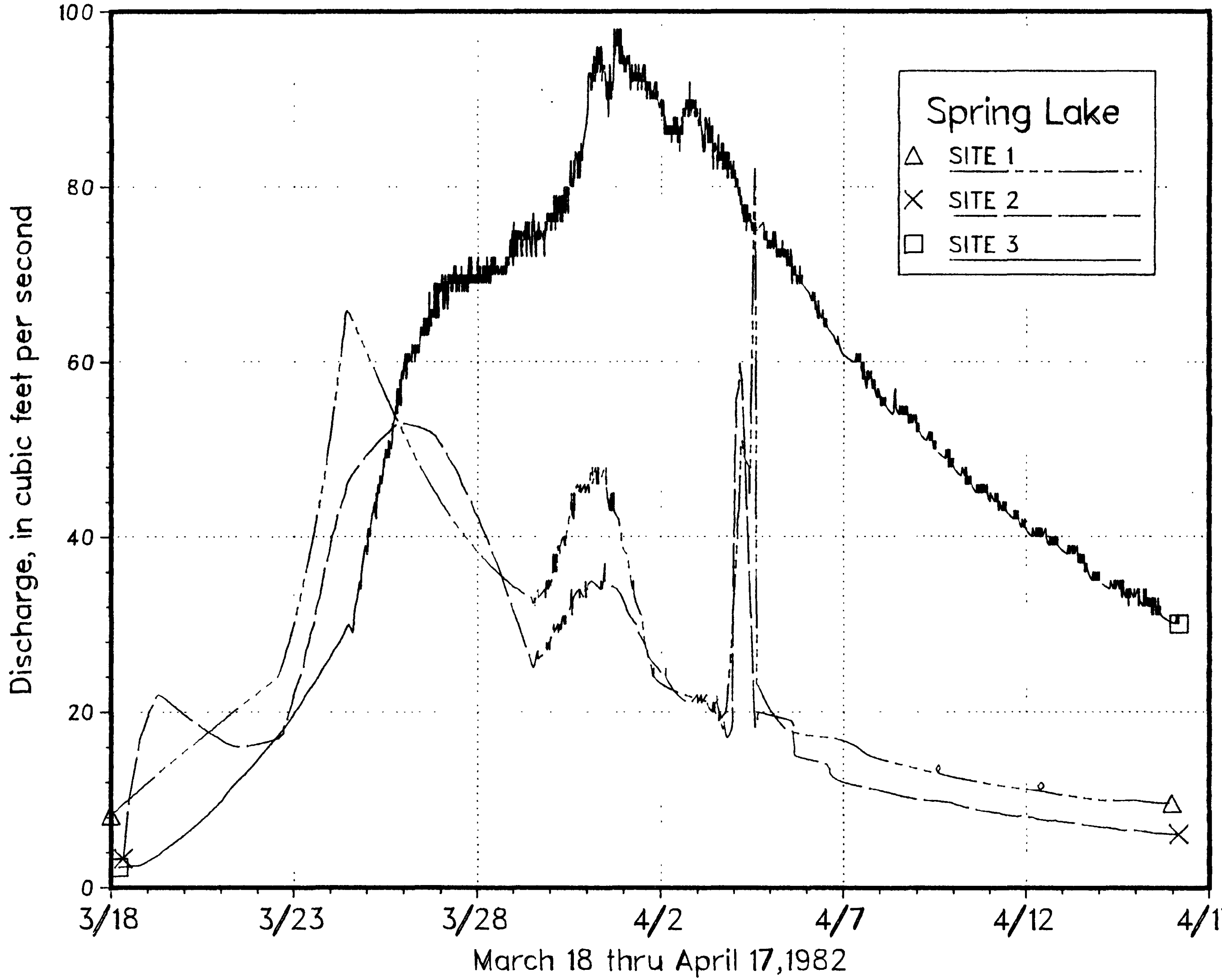

Figure 60.--Streamflow discharge for snowmelt at Spring Lake, March 30, 1982

Table 40.--Storm beginning time, ending time, and flow-weighted mean concentrations at Lake Riley sites

Site	Beginning time[1]		Ending time		Storm duration (hours)	Total suspended solids (mg/L)	Volatile suspended solids (mg/L)	Total phosphorus (mg/L)	Dissolved phosphorus (mg/L)	Dissolved NO_2+NO_3 nitrogen (mg/L)	Total ammonia nitrogen (mg/L)	Total ammonia + organic nitrogen (mg/L)
1	3-19-82	11:00	4-16-82	8:15	520	3.0	2.0	0.11	0.06	1.0	0.72	1.8
1	4-16-82	8:30	5-04-82	19:00	436	1.5	1.0	.09	.07	.90	.25	1.6
1	5-04-82	19:15	5-09-82	2:15	111	12.0	8.0	.06	.05	.05	.10	1.6
1	5-09-82	2:30	5-15-82	17:30	144	6.0	4.0	.06	.03	.15	.21	1.5
1	5-15-82	17:45	6-14-82	3:15	666	6.0	4.0	.05	.04	.15	.12	1.5
2	3-25-82	16:00	4-16-82	8:15	669	2.0	2.0	.25	.11	.75	.70	2.2
2	4-16-82	8:30	5-04-82	12:00	443	1.0	1.0	.14	.10	.85	.19	1.7
2	5-04-82	12:15	5-09-82	3:00	103	1.0	1.0	.13	.08	.81	.17	1.6
2	5-09-82	3:15	5-15-82	3:00	159	8.0	4.0	.34	.20	1.0	.15	1.5
2	5-15-82	3:15	6-11-82	21:00	706	8.0	3.0	.16	.13	.85	.10	1.4
3	3-25-82	0:00	4-16-82	0:00	528	2.0	2.0	.11	.06	.50	.20	1.4
3	4-16-82	0:00	4-22-82	0:00	144	1.0	1.0	.08	.02	.35	.10	1.4

[1]/If beginning and ending time are the same, then concentration was a grab sample; if time is 0:00, then exact time is unknown.

Table 41.--Storm flow-weighted mean concentration ratios for suspended solids, phosphorus, and nitrogen at Lake Riley sites

Site	Beginning time[1]		Ending time		Percentage of suspended solids in the volatile form	Percentage of phosphorus in the dissolved state	Percentage of nitrogen in the form of ammonia
1	3-19-82	11:00	4-16-82	8:15	67	54	39
1	4-16-82	8:30	5-04-82	19:00	67	78	16
1	5-04-82	19:15	5-09-82	2:15	67	83	6
1	5-09-82	2:30	5-15-82	17:30	67	50	14
1	5-15-82	17:45	6-14-82	3:15	67	80	8
2	3-25-82	16:00	4-16-82	8:15	100	44	32
2	4-16-82	8:30	5-04-82	12:00	100	71	11
2	5-04-82	12:15	5-09-82	3:00	100	62	11
2	5-09-82	3:15	5-15-82	3:00	50	59	10
2	5-15-82	3:15	6-11-82	21:00	38	81	7
3	3-25-82	0:00	4-16-82	0:00	100	54	14
3	4-16-82	0:00	4-22-82	0:00	100	25	7

[1]/If beginning and ending time are the same, then concentration was a grab sample; if time is 0:00, then exact time is unknown.

Table 42.--Average storm flow-weighted mean concentrations for each season at Lake Riley, 1982

[Seasons are: snowmelt - beginning of flow to April 22; spring - April 23 to June 1; early summer - June 2 to July 17; late summer - July 18 to September 4; autumn - September 5 to end of flow]

Site	Season	Total suspended solids (mg/L)	Volatile suspended solids (mg/L)	Total phosphorus (mg/L)	Dissolved phosphorus (mg/L)	Dissolved NO_2+NO_3 nitrogen (mg/L)	Total ammonia nitrogen (mg/L)	Total ammonia + organic nitrogen (mg/L)
1	Snowmelt	2.9	2.0	0.11	0.06	1.0	0.73	1.8
1	Spring	2.6	1.7	.08	.06	0.74	.23	1.5
1	Early summer	6.0	4.0	.05	.04	.20	.12	1.6
2	Snowmelt	2.0	2.0	.25	.11	.76	.71	2.2
2	Spring	1.8	1.3	.16	.11	.87	.18	1.6
2	Early summer	8.0	3.0	.16	.14	.85	.10	1.4
3	Snowmelt	2.0	2.0	.10	.05	.50	.20	1.4
3	Spring	8.0	8.0	.08	.03	.15	.10	1.6
3	Early summer	3.9	3.9	.06	.01	.05	.09	1.7

Table 43.--Seasonal average storm flow-weighted mean concentration ratios for suspended solids, phosphorus, and nitrogen at Lake Riley sites

[Seasons are: snowmelt - beginning of flow to April 22; spring - April 23 to June 1; early summer - June 2 to July 17; late summer - July 18 to September 4; autumn - September 5 to end of flow]

Site	Season	Percentage of suspended solids in the dissolved state	Percentage of phosphorus in the dissolved state	Percentage of nitrogen in the form of ammonia
1	Snowmelt	69	54	40
1	Spring	65	75	15
1	Early summer	67	80	8
2	Snowmelt	100	44	32
2	Spring	72	69	11
2	Early summer	38	88	7
3	Snowmelt	100	50	14
3	Spring	100	38	6
3	Early summer	100	17	5

Table 44.--Storm beginning time, ending time, flow, and loads at Lake Riley sites

Site	Beginning time[1]		Ending time		Storm flow (m^3)	Total suspended solids (kg)	Volatile suspended solids (kg)	Total phosphorus (kg)	Dissolved phosphorus (kg)	Dissolved NO_2+NO_3 nitrogen (kg)	Total ammonia nitrogen (kg)	Total ammonia + organic nitrogen (kg)
1	3-19-82	11:00	4-16-82	8:15	540,000	1,600	1,100	60	33	550	400	1,000
1	4-16-82	8:30	5-04-82	19:00	250,000	390	260	23	18	232	64	400
1	5-04-82	19:15	5-09-82	2:15	21,000	250	169	1.3	1.1	1.1	2.1	34
1	5-09-84	2:30	5-15-82	17:30	43,000	260	170	2.6	1.3	6.5	9.2	64
1	5-15-82	17:45	6-14-82	3:15	150,000	920	610	7.7	6.1	23	18	230
2	3-25-82	16:00	4-16-82	8:15	780,000	1,600	1,600	200	87	600	560	1,700
2	4-16-82	8:30	5-04-82	12:00	320,000	320	320	45	32	276	62	540
2	5-04-82	12:15	5-09-82	3:00	41,000	41	41	5.8	4.1	35	7.8	69
2	5-09-82	3:15	5-15-82	3:00	45,000	360	180	15	9.1	48	6.8	70
2	5-15-82	3:15	6-11-82	21:00	190,000	1,600	590	31	26	167	20	280
3	3-25-82	0:00	4-16-82	0:00	540,000	1,100	1,100	60	33	270	110	760
3	4-16-82	0:00	4-22-82	0:00	150,000	150	150	12	3.1	54	15.3	210

[1]/If beginning and ending times are the same, then concentration was a grab sample; if time is 0:00, then exact time is unknown.

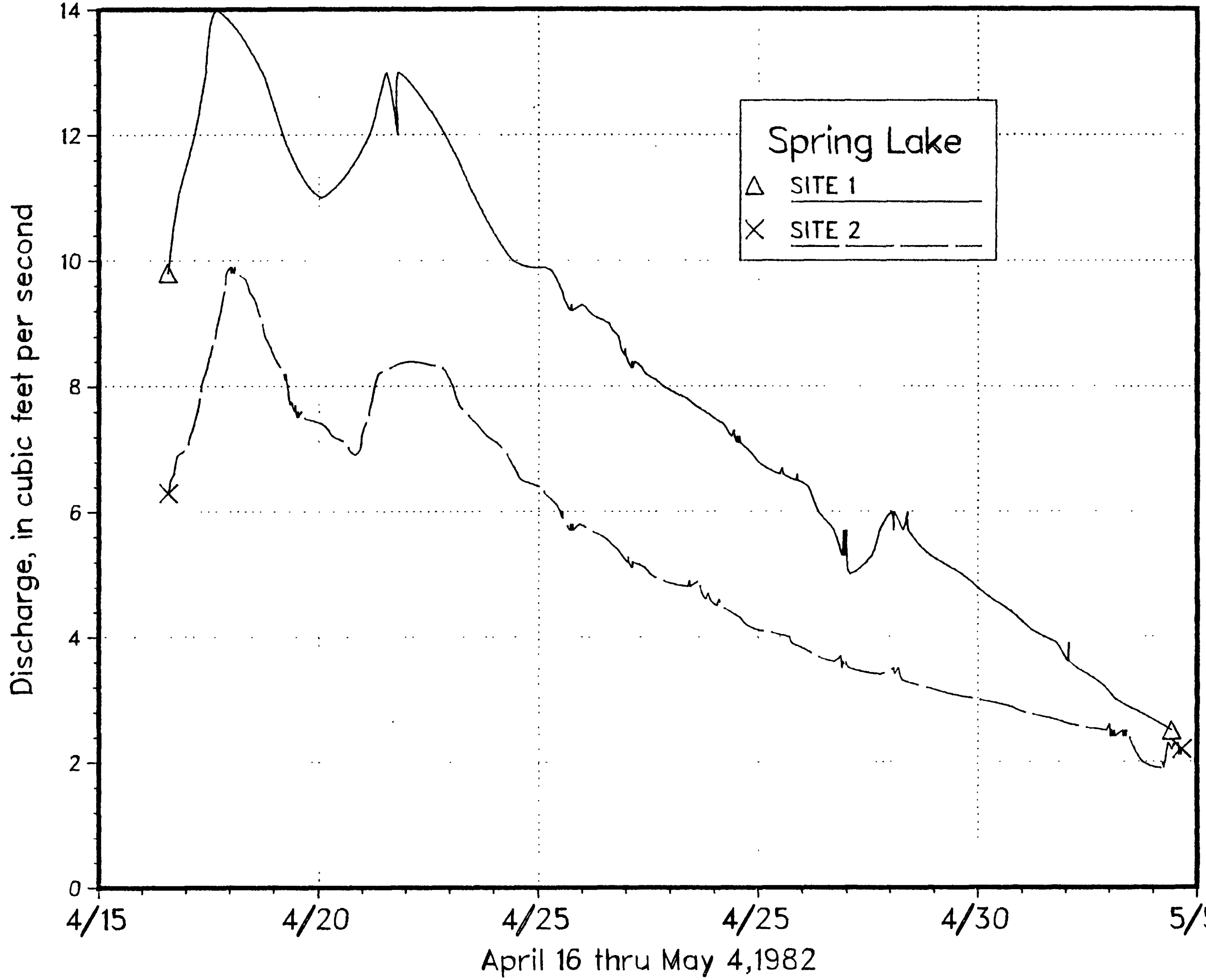

Figure 61.--Streamflow discharge for Spring Lake, storm of April 16, 1982

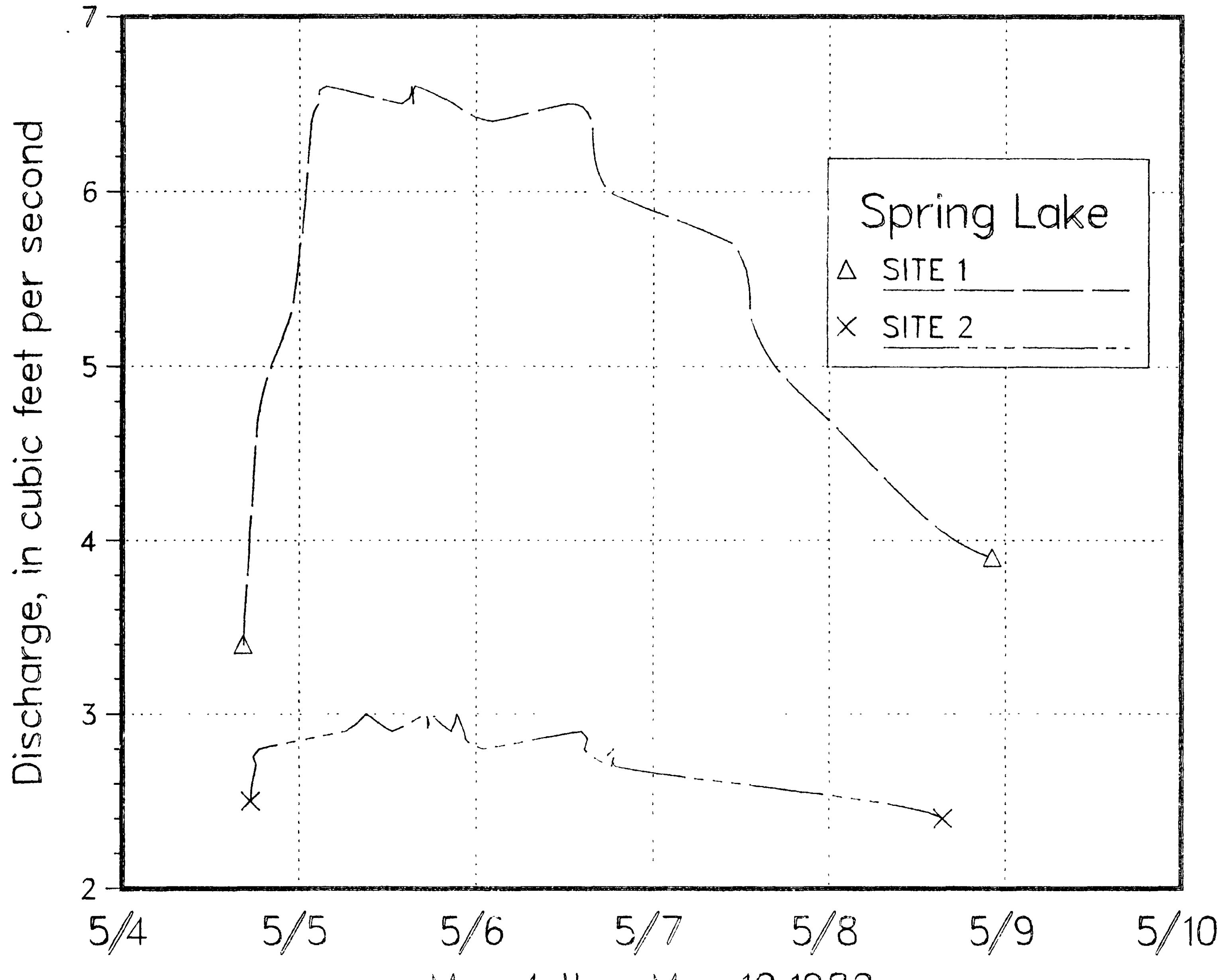

Figure 62.--Streamflow discharge for Spring Lake Lake, storm of May 4, 1982

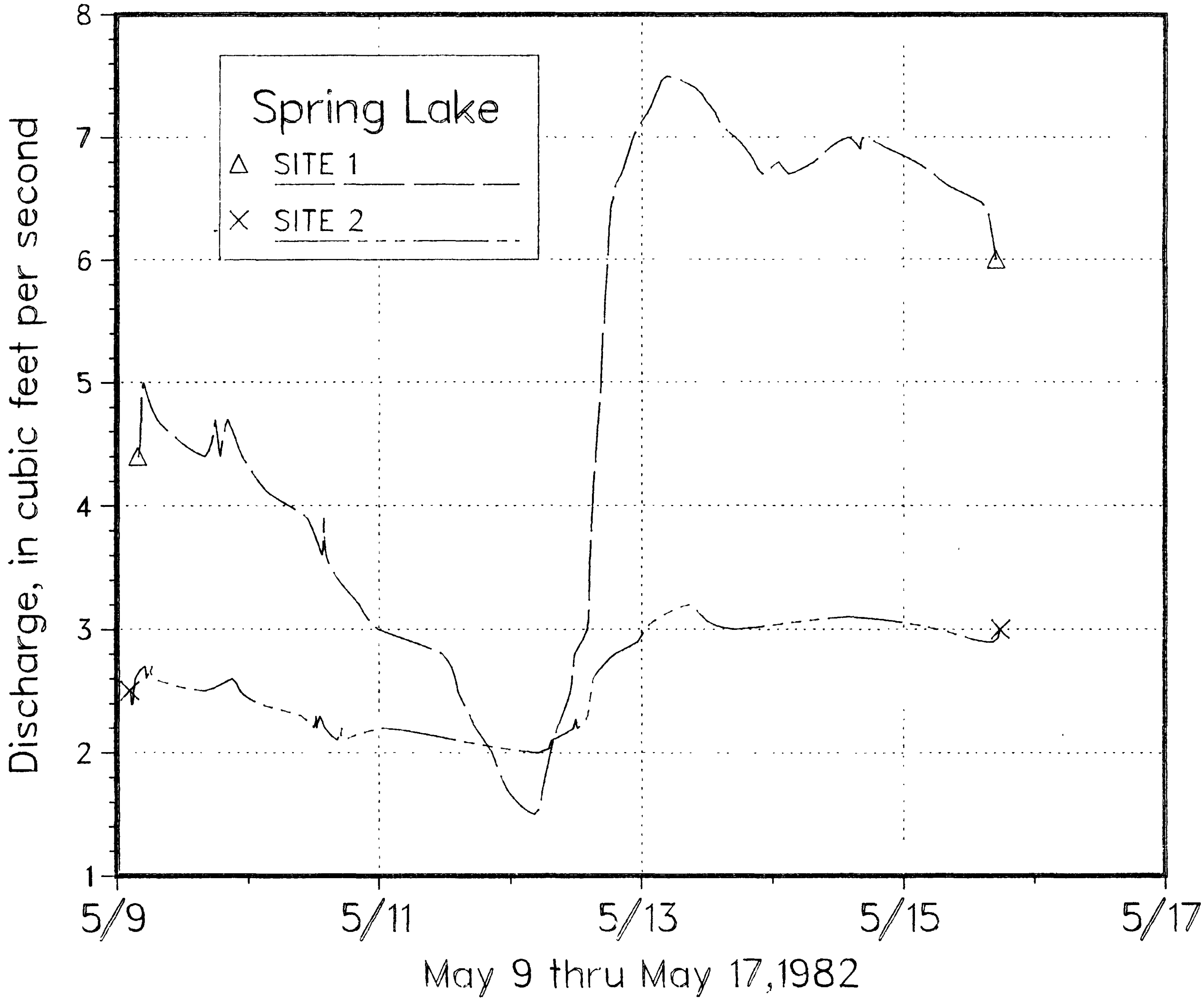

Figure 63.--Streamflow discharge for Spring Lake, storm of May 9, 1982

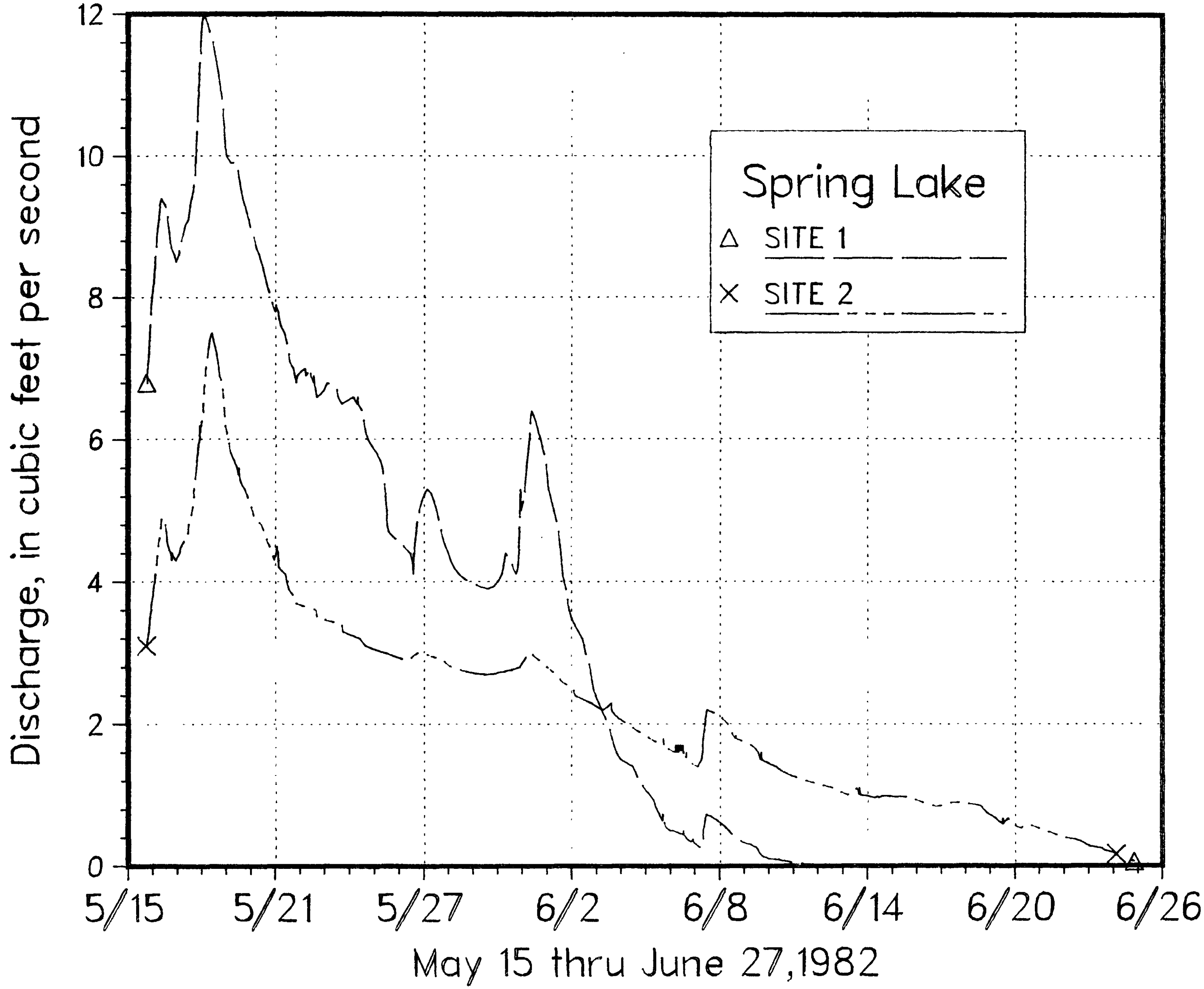

Figure 64.--Streamflow discharge for Spring Lake, storm of May 17, 1982

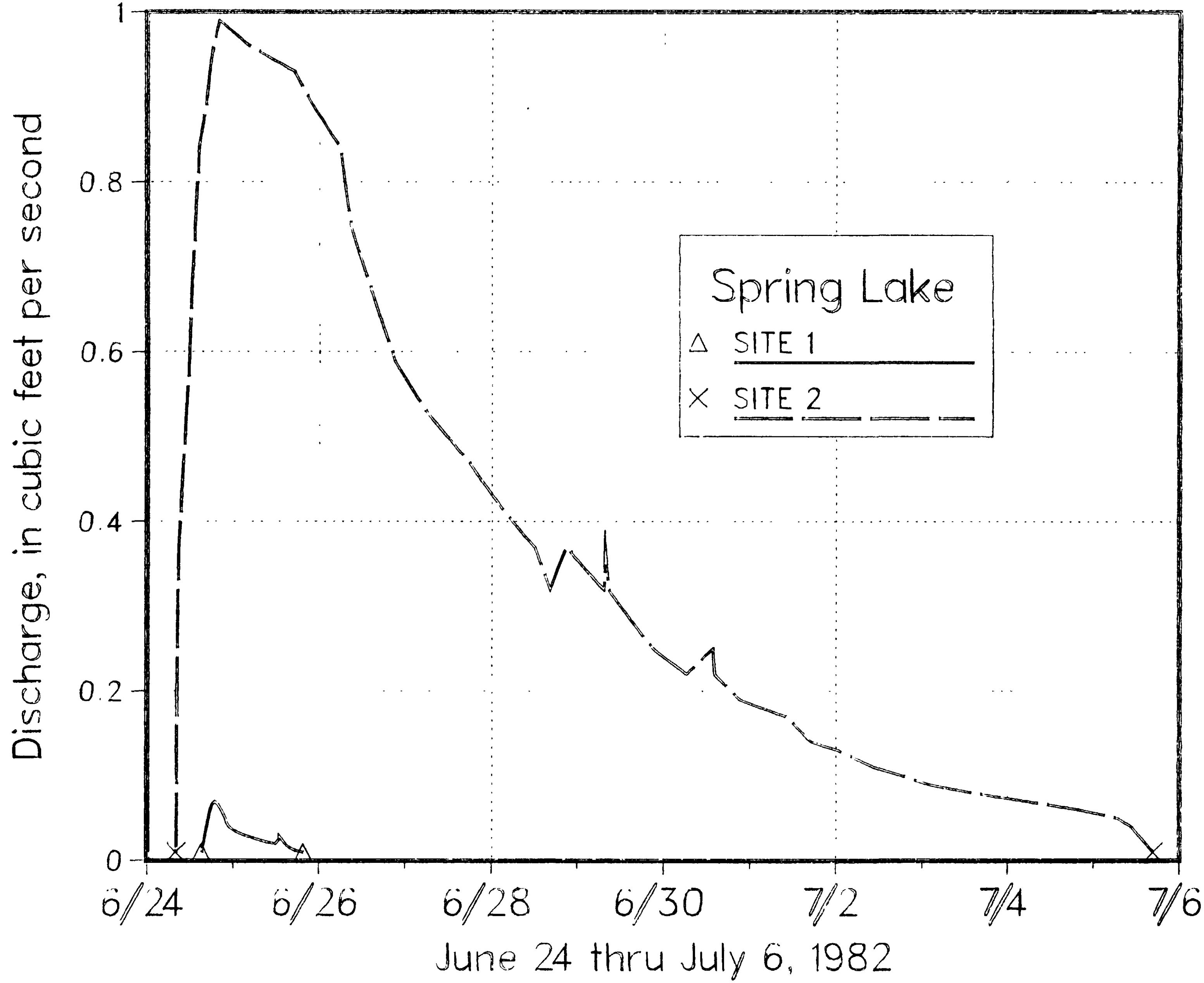

Figure 65.-- Streamflow discharge for Spring Lake, storm of June 24, 1982

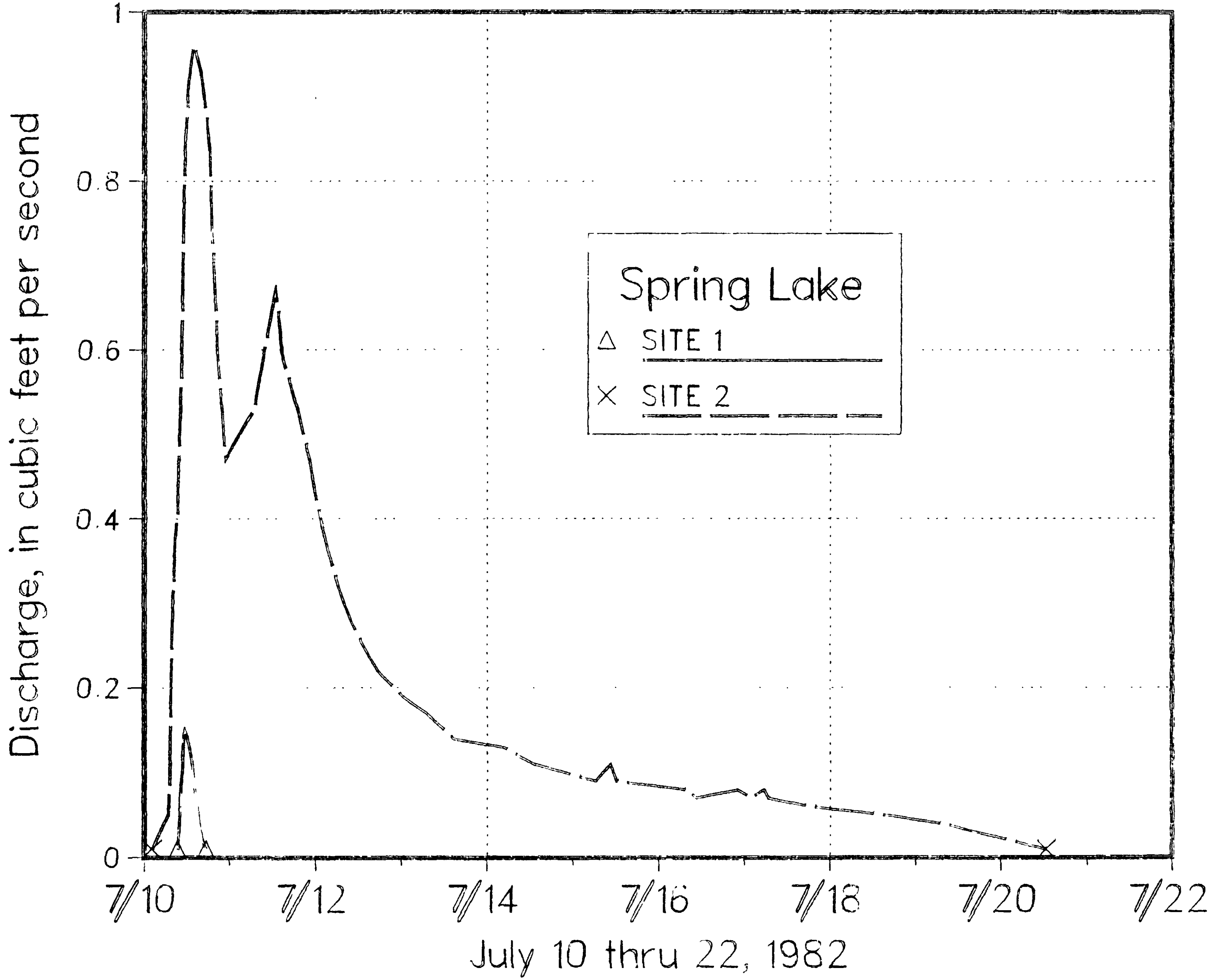

Figure 66.--Streamflow discharge for Spring Lake, storm of July 10, 1982

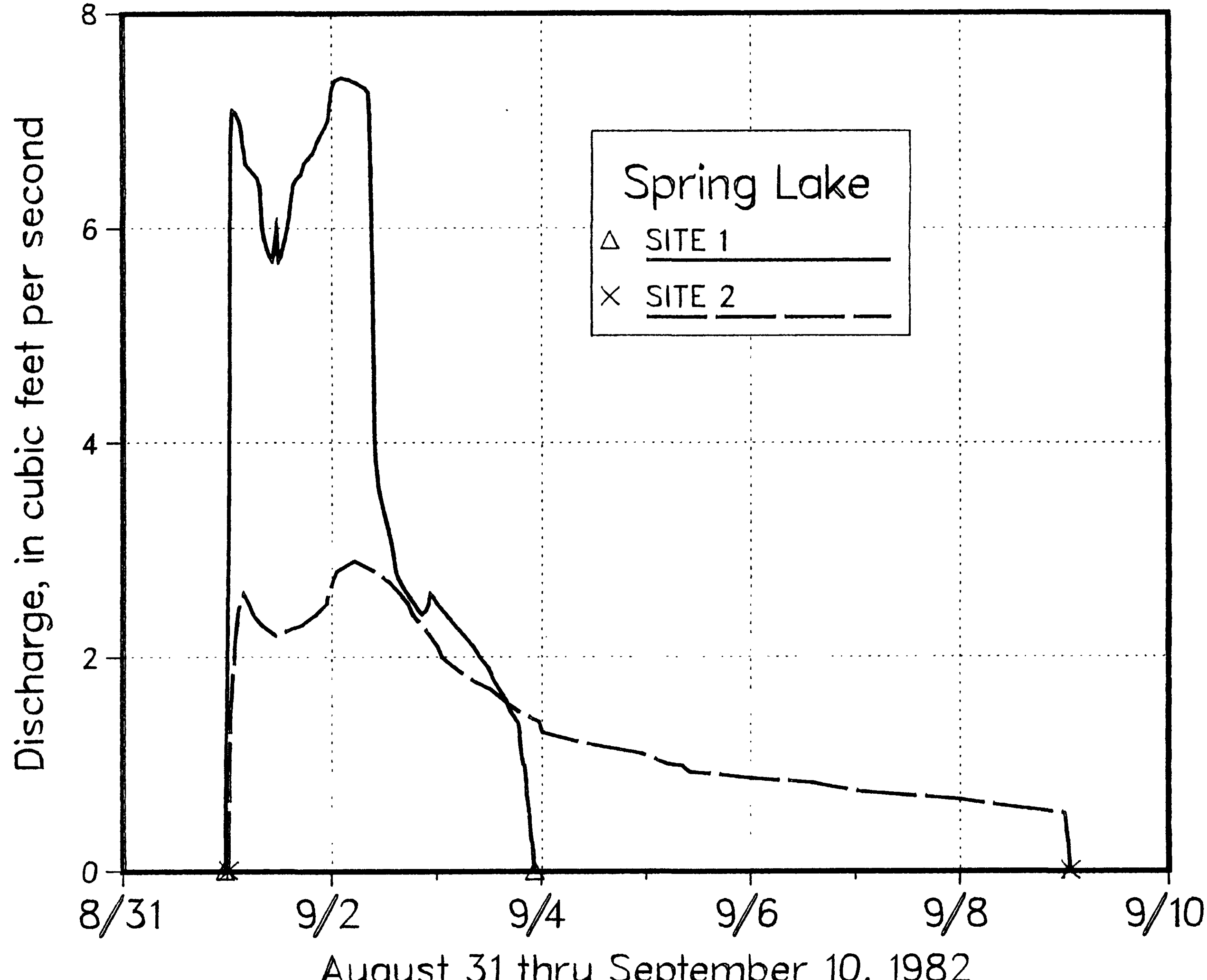

Figure 67.--Streamflow discharge for Spring Lake,storm of August 31, 1982

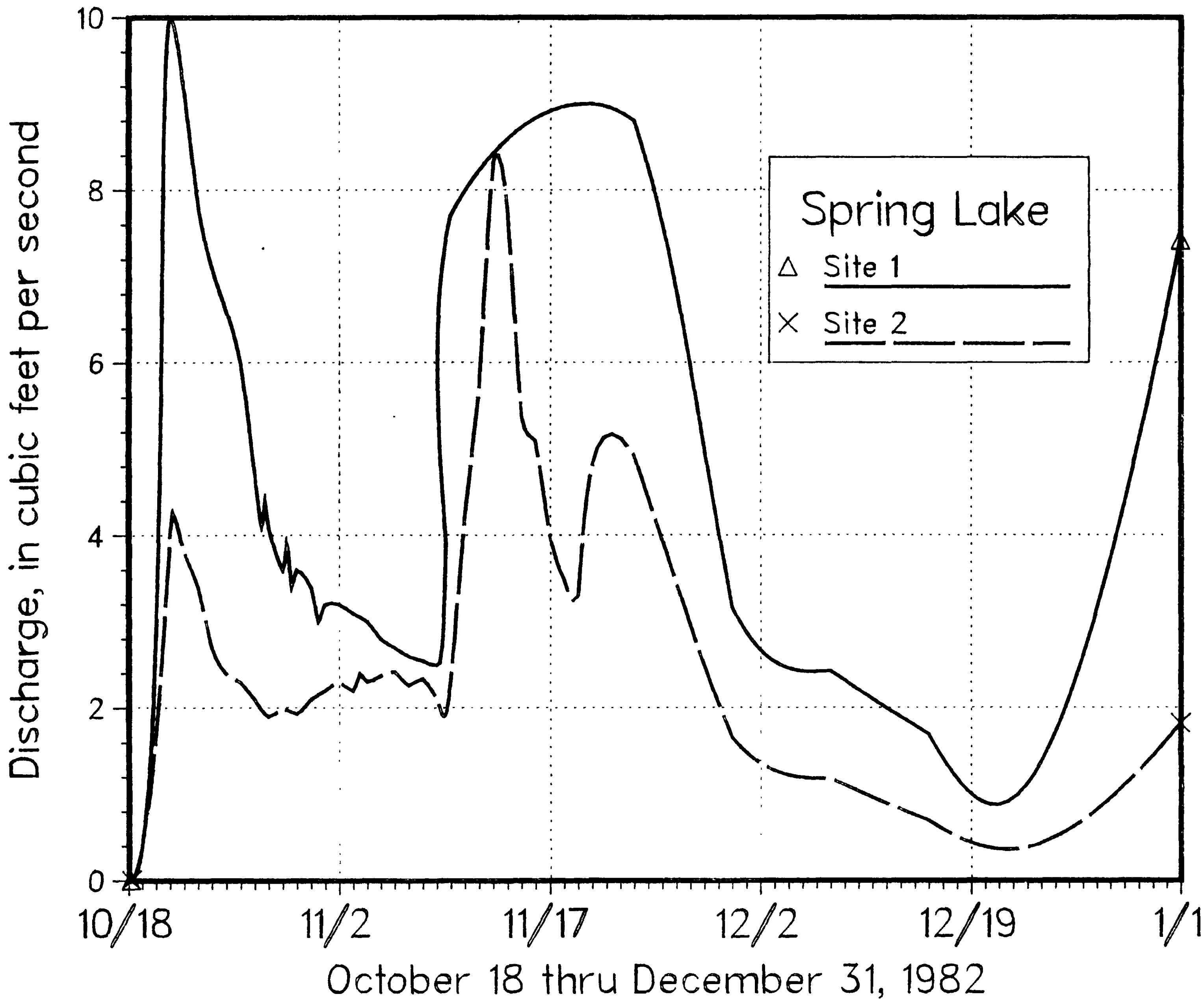

Figure 68.--Streamflow discharge for Spring Lake, storm of October 19, 1982

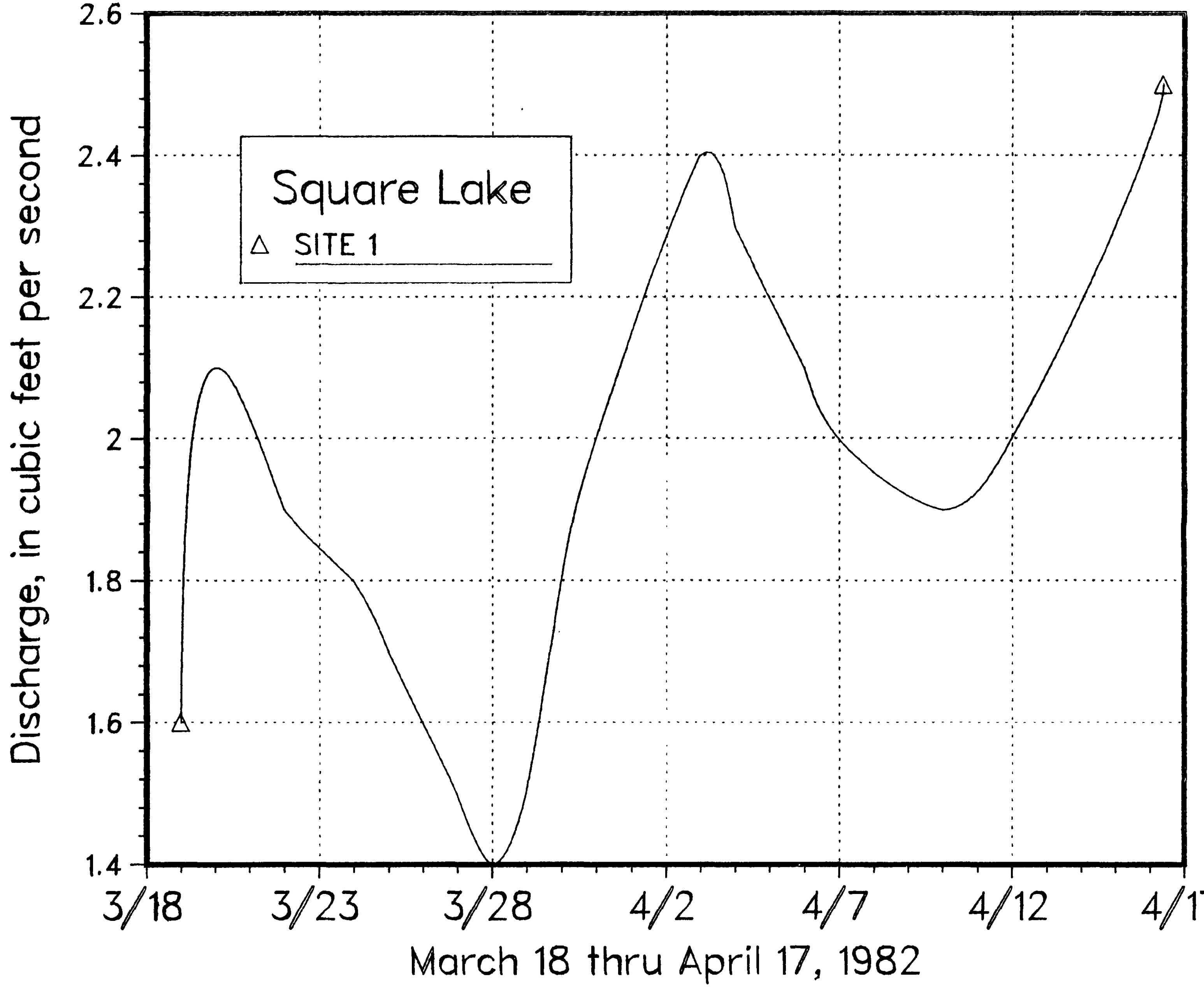

Figure 69.--Streamflow discharge for snowmelt at Square Lake, March 30, 1982

Table 45.--Storm beginning time, ending time, and flow-weighted mean concentrations at Spring Lake sites

Site	Beginning time[1]		Ending time		Storm duration (hours)	Total suspended solids (mg/L)	Volatile suspended solids (mg/L)	Total phosphorus (mg/L)	Dissolved phosphorus (mg/L)	Dissolved NO_2+NO_3 nitrogen (mg/L)	Total ammonia nitrogen (mg/L)	Total ammonia + organic nitrogen (mg/L)
1	3-16-82	5:00	4-16-82	5:45	745	2.0	1.0	0.31	0.23	14	0.48	2.3
1	4-16-82	6:00	5-04-82	16:30	443	2.0	1.0	.13	.09	7.5	.09	2.0
1	5-04-82	16:45	5-09-82	3:45	107	3.0	3.0	.14	.07	2.6	.15	2.5
1	5-09-82	4:00	5-15-82	18:00	158	34.0	9.0	.29	.12	3.1	.18	2.7
1	5-15-82	18:15	6-24-82	21:00	963	52.0	13.0	.45	.21	5.4	.16	3.6
1	6-24-82	15:15	6-26-82	15:45	49	10.0	1.0	.37	.23	2.4	.21	1.8
1	7-10-82	9:30	7-11-82	19:00	34	17.0	1.0	.60	.37	1.5	.24	2.3
1	8-31-82	23:30	9-09-82	1:30	71	7.0	3.0	.69	.40	.75	.11	1.8
1	10-19-82	13:45	12-31-82	23:59	1962	1.0	1.0	.36	.36	1.2	.04	2.2
2	3-18-82	7:00	4-16-82	5:30	695	44.0	4.0	.32	.25	14	.93	2.5
2	4-16-82	5:45	5-04-82	17:30	444	11.0	1.0	.14	.09	7.5	.12	2.1
2	5-04-82	17:45	5-09-82	2:15	105	71.0	25.0	.17	.05	2.9	.19	2.7
2	5-09-82	2:30	5-15-82	18:15	160	32.0	10.0	.19	.09	2.9	.24	2.5
2	5-15-82	18:30	6-24-82	8:00	950	16.0	8.0	.29	.21	4.5	.33	3.0
2	6-24-82	8:15	7-05-82	19:00	275	17.0	8.0	.24	.12	.15	.57	2.1
2	7-09-82	18:00	7-21-82	11:15	281	64.0	37.0	.59	.36	.20	1.4	2.2
2	9-01-82	0:15	9-09-82	1:30	193	14.0	5.0	.71	.45	.95	.10	1.7
2	10-19-82	14:15	12-31-82	23:59	1762	1.0	1.0	.44	.38	1.0	.06	1.9
3	3-18-82	1:00	4-16-82	5:45	701	2.0	2.0	.11	.07	2.0	.15	1.2
3	4-16-82	6:00	4-22-82	10:45	149	6.0	6.0	.10	.04	1.8	.11	1.4

[1]/If beginning and ending time are the same, then concentration was a grab sample; if time is 0:00, then exact time is unknown.

Table 46.--Storm flow-weighted mean concentration ratios for suspended solids, phosphorus, and nitrogen at Spring Lake sites

Site	Beginning time[1]		Ending time		Percentage of suspended solids in the volatile form	Percentage of phosphorus in the dissolved state	Percentage of nitrogen in the form of ammonia
1	3-16-82	5:00	4-16-82	5:45	50	74	21
1	4-16-82	6:00	5-04-82	16:30	50	69	4
1	5-04-82	16:45	5-09-82	3:45	100	50	6
1	5-09-82	4:00	5-15-82	18:00	26	41	7
1	5-15-82	18:15	6-24-82	10:00	25	47	4
1	6-24-82	10:15	6-26-82	15:45	10	62	11
1	7-10-82	9:30	7-11-82	19:00	59	62	10
1	8-31-82	23:30	9-09-82	22:30	43	58	6
1	10-19-82	13:45	12-31-82	23:59	100	100	2
2	3-18-82	7:00	4-16-82	5:30	9	78	38
2	4-16-82	5:45	5-04-82	17:30	9	64	6
2	5-04-82	17:45	5-09-82	2:15	35	29	7
2	5-09-82	2:30	5-15-82	18:15	31	47	9
2	5-15-82	18:30	6-24-82	8:00	50	72	11
2	6-24-82	8:15	7-05-82	19:00	47	50	27
2	7-09-82	18:00	7-21-82	11:15	58	61	65
2	10-19-82	14:15	12-31-82	23:59	100	86	3
3	3-18-82	1:00	4-16-82	5:45	100	64	12
3	4-16-82	6:00	4-22-82	10:45	100	40	8

[1]/If beginning and ending time are the same, then concentration was a grab sample; if time is 0:00, then exact time is unknown.

Table 47.--Average storm flow-weighted mean concentrations for each season at Spring Lake, 1982

[Seasons are: snowmelt - beginning of flow to April 22; spring - April 23 to June 1; early summer - June 2 to July 17; late summer - July 18 to September 4; autumn - September 5 to end of flow]

Site	Season	Total suspended solids (mg/L)	Volatile suspended solids (mg/L)	Total phosphorus (mg/L)	Dissolved phosphorus (mg/L)	Dissolved NO_2+NO_3 nitrogen (mg/L)	Total ammonia nitrogen (mg/L)	Total ammonia + organic nitrogen (mg/L)
1	Snowmelt	2.0	1.0	0.32	0.24	14.0	0.49	2.3
1	Spring	7.2	2.5	.16	.09	6.2	.11	2.1
1	Early summer	53	13	.46	.21	5.3	.16	3.6
1	Late summer	7.0	3.0	.69	.40	0.75	.11	1.8
1	Autumn	4.0	2.0	.52	.38	.96	.08	2.0
2	Snowmelt	44	4.0	.32	.25	14.0	.93	2.5
2	Spring	19	4.5	.15	.09	6.4	.14	2.2
2	Early summer	16	8.0	.29	.21	4.3	.34	3.0
2	Late summer	21	9.6	.70	.44	.84	.29	1.8
2	Autumn	7.5	3.0	.58	.42	.98	.08	1.8
3	Snowmelt	2.0	2.0	.11	.06	2.0	.14	1.2
3	Spring	6.0	6.0	.10	.03	1.80	.11	1.5
3	Early summer	0.99	0.99	.16	.10	.15	1.7	2.3
3	Late summer	9.9	9.9	.09	.09	.10	.15	2.0
3	Autumn	1.0	1.0	.62	.13	.10	.08	10

Table 48.--Seasonal average storm flow-weighted mean concentration ratios for suspended solids, phosphorus, and nitrogen at Spring Lake sites

[Seasons are: snowmelt - beginning of flow to April 22; spring - April 23 to June 1; early summer - June 2 to July 17; late summer - July 18 to September 4; autumn - September 5 to end of flow]

Site	Season	Percentage of suspended solids in the dissolved state	Percentage of phosphorus in the dissolved state	Percentage of nitrogen in the form of ammonia
1	Snowmelt	50	75	21
1	Spring	35	56	5
1	Early summer	24	46	4
1	Late summer	43	58	6
1	Autumn	50	73	4
2	Snowmelt	9	78	37
2	Spring	24	60	6
2	Early summer	50	72	11
2	Late summer	46	63	16
2	Autumn	40	72	4
3	Snowmelt	100	54	12
3	Spring	100	30	7
3	Early summer	100	62	74
3	Late summer	100	100	8
3	Autumn	100	21	1

Table 49.--Storm beginning time, ending time, flow, and loads at Spring Lake sites

Site	Beginning time[1]		Ending time		Storm flow (m^3)	Total suspended solids (kg)	Volatile suspended solids (kg)	Total phosphorus (kg)	Dissolved phosphorus (kg)	Dissolved NO_2+NO_3 nitrogen (kg)	Total ammonia nitrogen (kg)	Total ammonia + organic nitrogen (kg)
1	3-16-82	5:00	4-16-82	5:45	1,800,000	3,700	1,900	580	430	27,000	890	4,200
1	4-16-82	6:00	5-04-82	16:30	370,000	740	370	48	33	2,800	33	730
1	5-04-82	16:45	5-09-82	3:45	60,000	180	180	8.5	4.3	160	9.1	150
1	5-09-82	4:00	5-15-82	18:00	80,000	2,700	730	23	9.7	250	15	220
1	5-16-82	18:15	6-24-82	10:00	300,000	16,000	4,000	140	64	1,600	49	1,100
1	6-24-82	10:15	7-10-82	9:15	120	1.2	0.12	0.05	0.03	0.29	0.03	0.23
1	7-10-82	9:30	7-11-82	19:00	92	1.6	.09	.06	.03	.14	.02	.22
1	8-31-82	23:30	9-03-82	22:30	31,000	220	93	21	12	23	3.4	55
1	10-19-82	13:45	12-31-82	23:59	730,000	740	740	270	270	890	30	1,600
2	3-18-82	7:00	4-16-82	5:30	1,600,000	72,000	6,500	520	410	24,000	1,500	4,000
2	4-16-82	5:45	5-04-82	17:30	240,000	2,600	240	33	22	1,800	29	510
2	5-04-82	17:45	5-09-82	2:15	29,000	2,000	720	4.9	1.5	84	5.5	79
2	5-09-82	2:30	5-15-82	18:15	42,000	1,400	430	8.2	3.9	120	10	110
2	5-15-82	18:30	6-24-82	8:00	220,000	3,600	1,800	65	47	1,000	74	670
2	6-24-82	8:15	7-05-82	19:00	10,000	170	81	2.4	1.2	1.5	5.8	22
2	7-09-82	18:00	7-21-82	11:15	4,900	320	180	2.9	1.8	1.0	7.0	11
2	9-01-82	0:15	9-09-82	1:30	29,000	420	150	21	13	28	3.0	50
2	10-19-82	14:15	12-31-82	23:59	370,000	370	370	160	140	370	22	700
3	3-18-82	1:00	4-16-82	5:45	3,600,000	7,200	7,200	400	250	7,400	540	4,500
3	4-16-82	6:00	4-22-82	10:45	520,000	3,100	3,100	52	21	940	57	750

[1]/If beginning and ending times are the same, then concentration was a grab sample; if time is 0:00, then exact time is unknown.

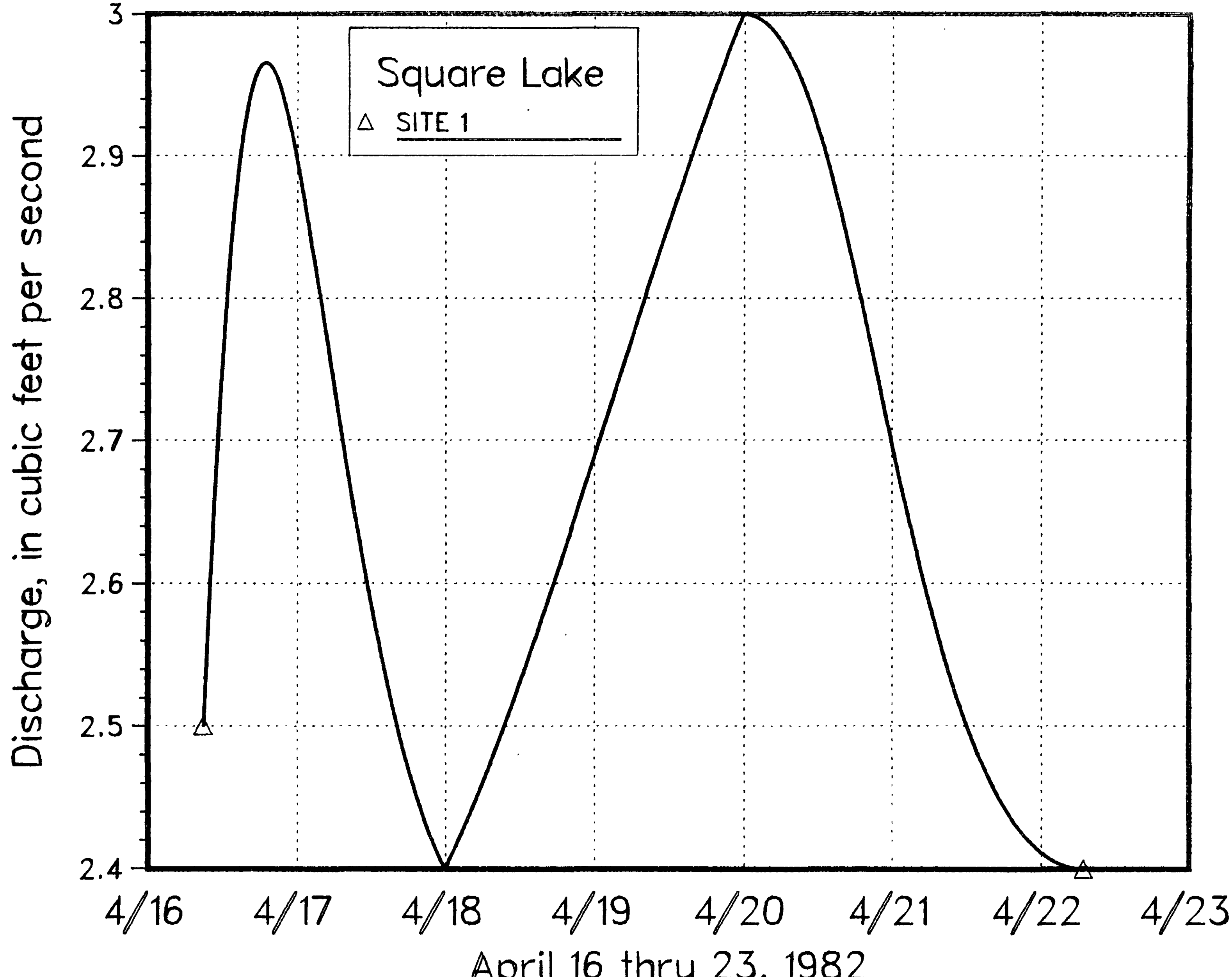

Figure 70.--Streamflow discharge for Square Lake, storm of April 16, 1982

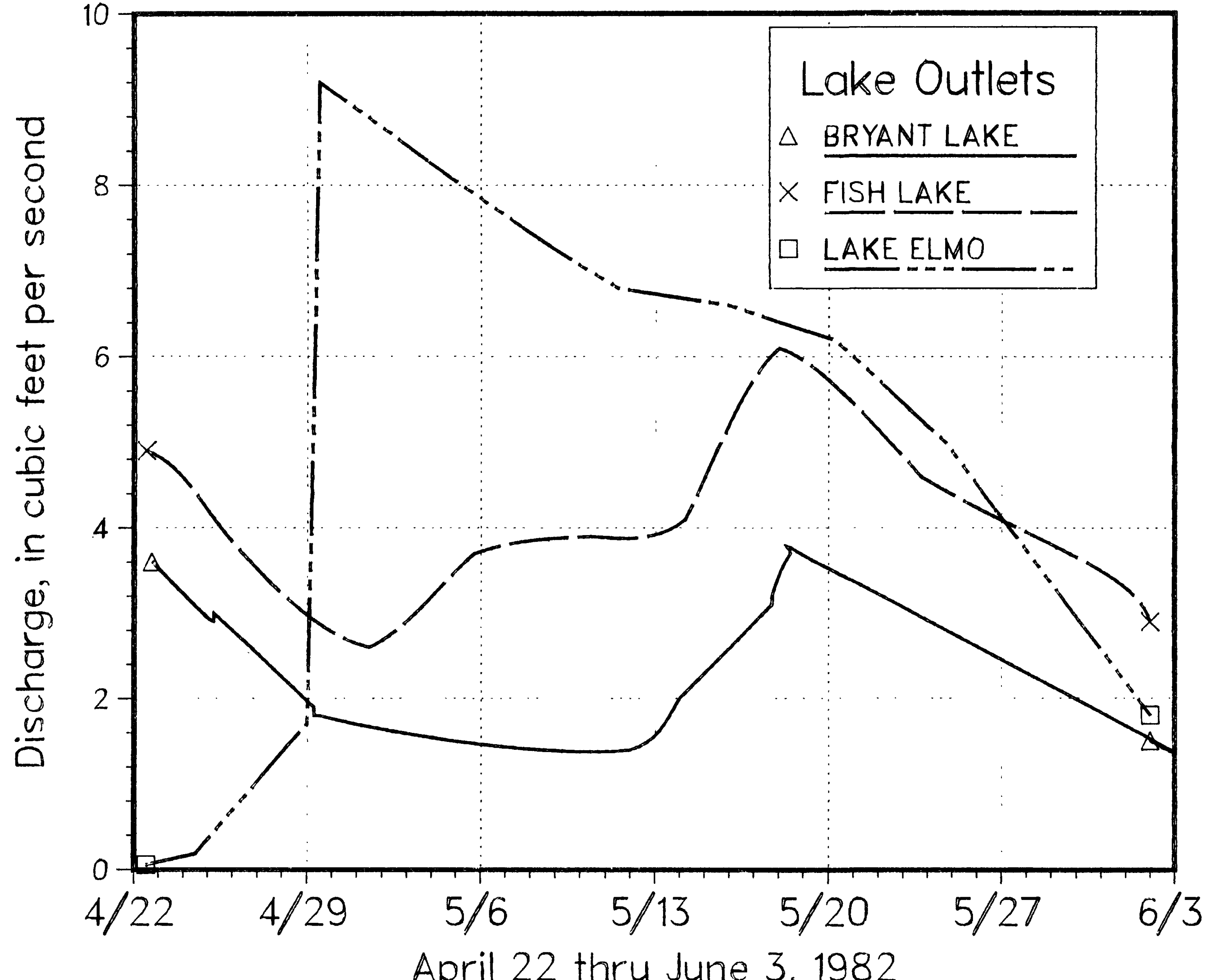

Figure 71.--Streamflow discharge for outflows during weekly sampling at Bryant Lake, Fish Lake, and Lake Elmo for the period of April 22 through June 3, 1982

Table 50.--Storm beginning time, ending time, and flow-weighted mean concentrations at Square Lake

Site	Beginning time[1]		Ending time		Storm duration (hours)	Total suspended solids (mg/L)	Volatile suspended solids (mg/L)	Total phosphorus (mg/L)	Dissolved phosphorus (mg/L)	Dissolved NO_2+NO_3 nitrogen (mg/L)	Total ammonia nitrogen (mg/L)	Total ammonia + organic nitrogen (mg/L)
1	3-19-82	0:15	4-16-82	9:15	681	3.0	3.0	0.01	0.01	0.25	0.12	0.24
1	4-16-82	9:30	4-22-82	7:15	142	1.0	1.0	.04	.01	.25	.11	.28

[1]/If beginning and ending time are the same, then concentration was a grab sample; if time is 0:00, then exact time is unknown.

Table 51.--Storm flow-weighted mean concentration ratios for suspended solids, phosphorus, and nitrogen at Square Lake

Site	Beginning time[1]		Ending time		Percentage of suspended solids in the volatile form	Percentage of phosphorus in the dissolved state	Percentage of nitrogen in the form of ammonia
1	3-19-82	0:15	4-16-82	9:15	100	100	50
1	4-16-82	9:30	4-22-82	7:15	100	25	39

[1]/If beginning and ending time are the same, then concentration was a grab sample; if time is 0:00, then exact time is unknown.

Table 52.--Average storm flow-weighted mean concentrations for each season at Square Lake, 1982

[Seasons are: snowmelt - beginning of flow to April 22; spring - April 23 to June 1; early summer - June 2 to July 17; late summer - July 18 to September 4; autumn - September 5 to end of flow]

Site	Season	Total suspended solids (mg/L)	Volatile suspended solids (mg/L)	Total phosphorus (mg/L)	Dissolved phosphorus (mg/L)	Dissolved NO_2+NO_3 nitrogen (mg/L)	Total ammonia nitrogen (mg/L)	Total ammonia + organic nitrogen (mg/L)
1	Snowmelt	3.0	3.0	0.01	0.01	0.25	0.12	0.25
1	Spring	1.0	1.0	.01	.01	.10	.11	.20
1	Early summer	1.0	1.0	.04	.01	.05	.58	.20
1	Late summer	2.0	2.0	.01	.01	.05	.04	.36
1	Autumn	1.0	1.0	.01	.01	.10	.06	.26

Table 53.--Seasonal average storm flow-weighted mean concentration ratios for suspended solids, phosphorus, and nitrogen at Square Lake

[Seasons are: snowmelt - beginning of flow to April 22; spring - April 23 to June 1; early summer - June 2 to July 17; late summer - July 18 to September 4; autumn - September 5 to end of flow]

Site	Season	Percentage of suspended solids in the dissolved state	Percentage of phosphorus in the dissolved state	Percentage of nitrogen in the form of ammonia
1	Snowmelt	100	100	48
1	Spring	100	100	55
1	Early summer	100	25	34
1	Late summer	100	100	11
1	Autumn	100	100	23

Table 54.--Storm beginning time, ending time, flow, and loads at Square Lake

Site	Beginning time[1]		Ending time		Storm flow (m^3)	Total suspended solids (kg)	Volatile suspended solids (kg)	Total phosphorus (kg)	Dissolved phosphorus (kg)	Dissolved NO_2+NO_3 nitrogen (kg)	Total ammonia nitrogen (kg)	Total ammonia + organic nitrogen (kg)
1	3-19-82	00:15	4-16-82	9:15	130,000	400	400	1.3	1.3	33	16.0	32
1	4-16-82	9:30	4-22-82	7:15	38,000	39	39	1.6	0.39	9.7	4.3	11

1/If beginning and ending times are the same, then concentration was a grab sample; if time is 0:00, then exact time is unknown.

Outflows

This section contains outflow hydrographs divided into 6-week sampling periods. There are two hydrographs for each 6-week sampling period and each hydrograph contains three lake outflows. Also included are mean concentration tables and mean concentration ratio tables.

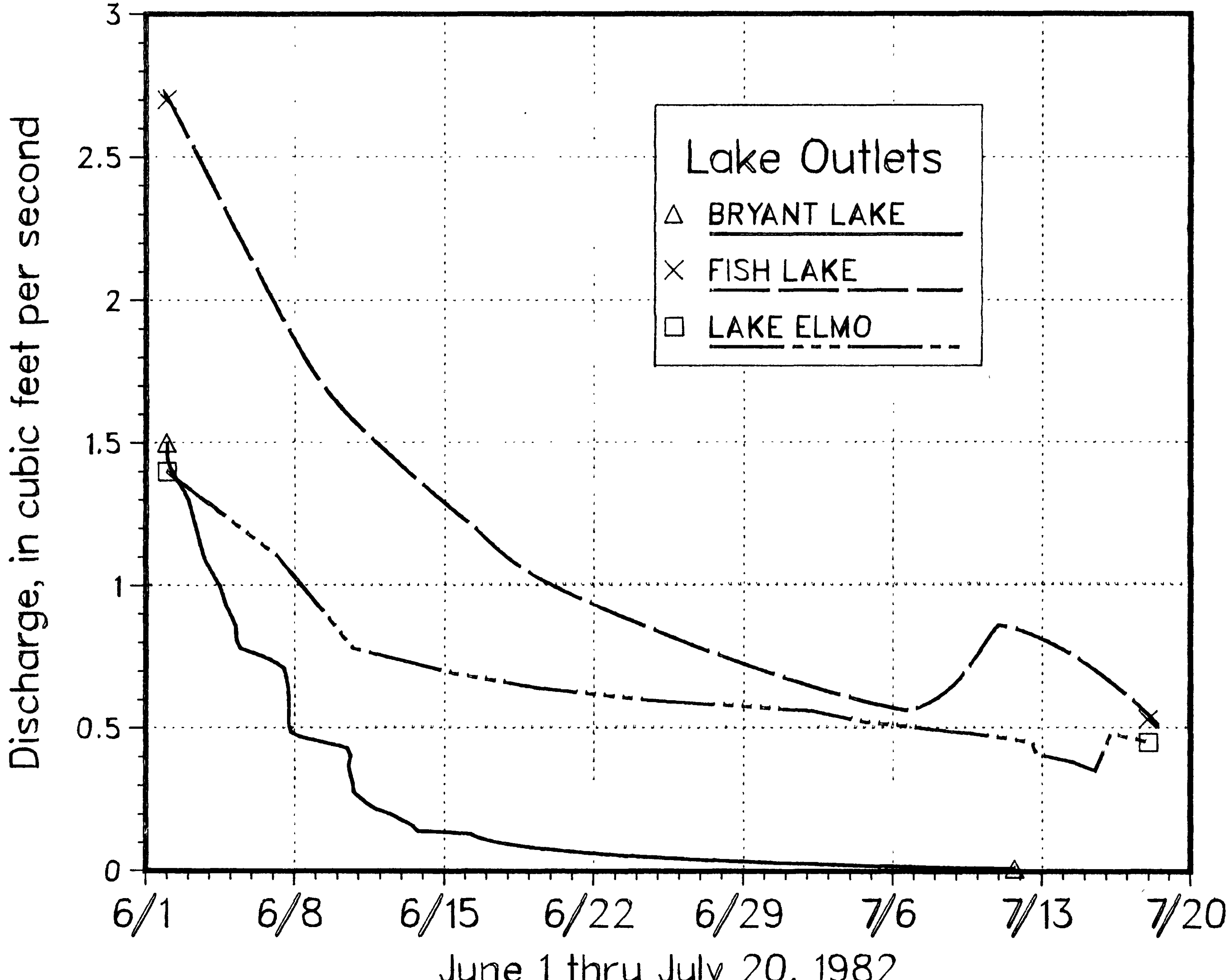

Figure 72.--Streamflow discharge for outflows during weekly sampling at Bryant Lake, Fish Lake, and Lake Elmo for the period of June 2 through July 17, 1982

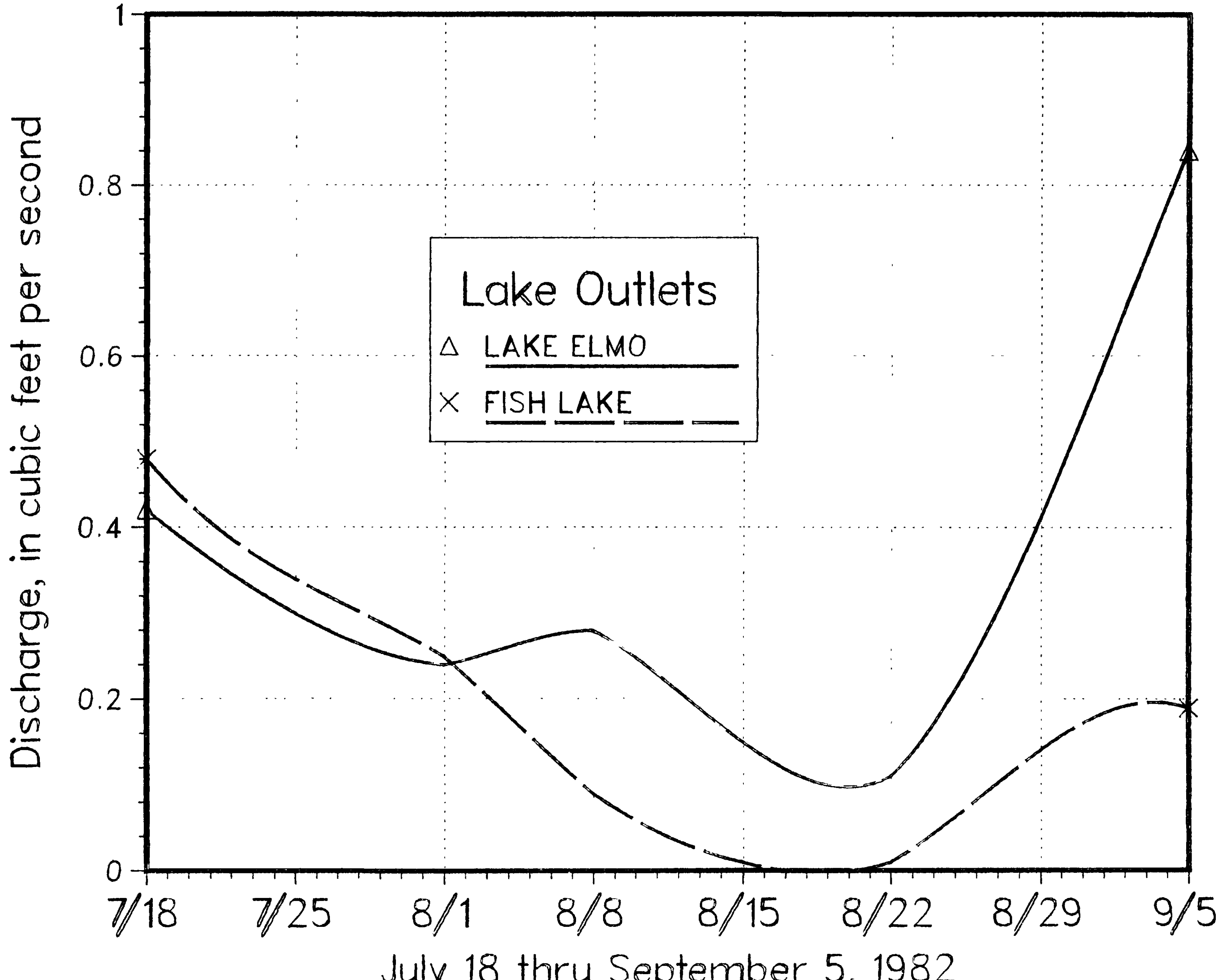

Figure 73.--Streamflow discharge for outflow during weekly sampling at Bryant Lake, Fish Lake, and Lake Elmo for the period July 18 through September 4, 1982 (Bryant Lake outflow did not have discharge during this period)

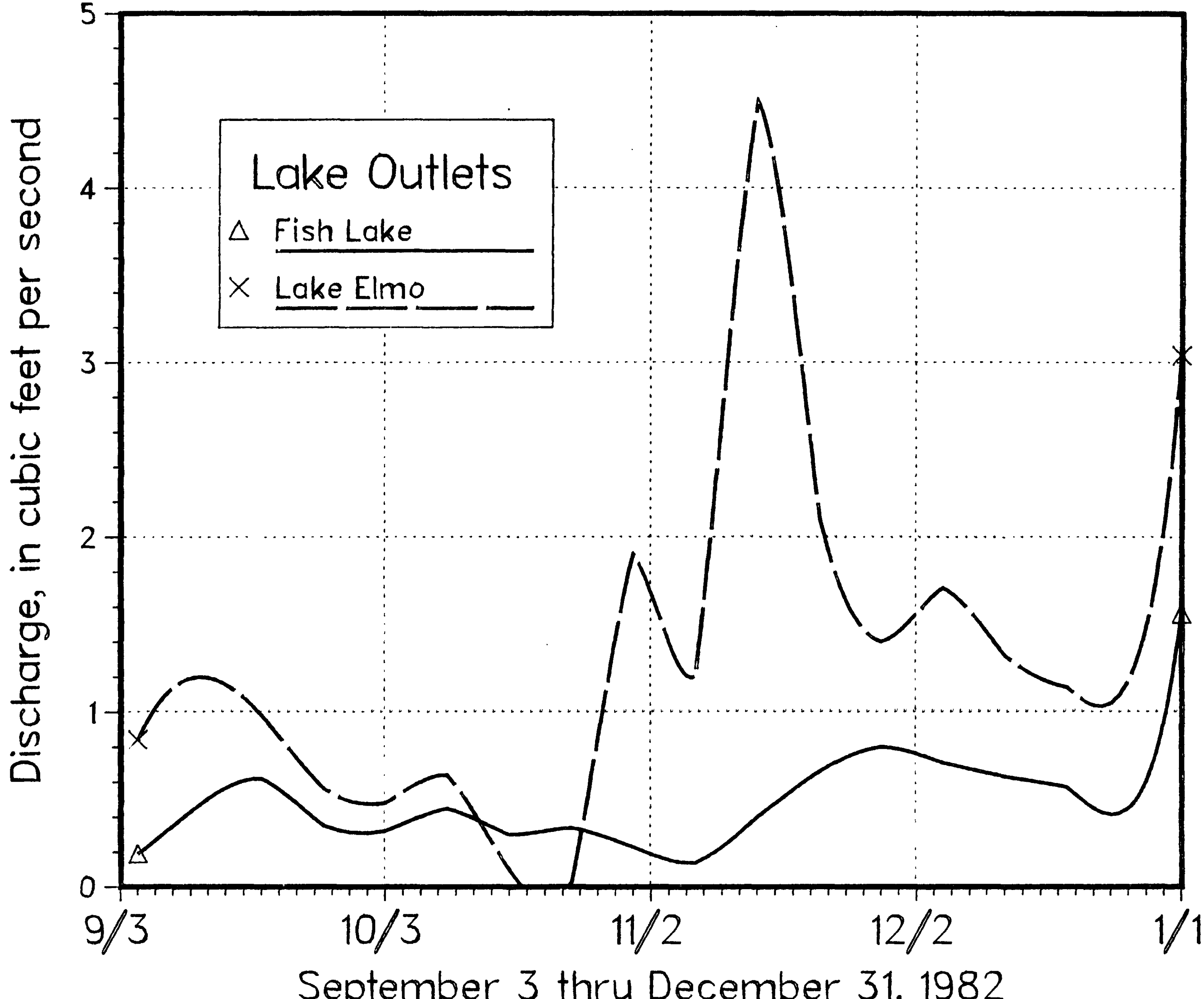

Figure 74.--Streamflow discharge for outflows during sampling at Bryant Lake, Fish Lake, and Lake Elmo for the period September 5 through December 31, 1982 (Bryant Lake outflow did not discharge during this period)

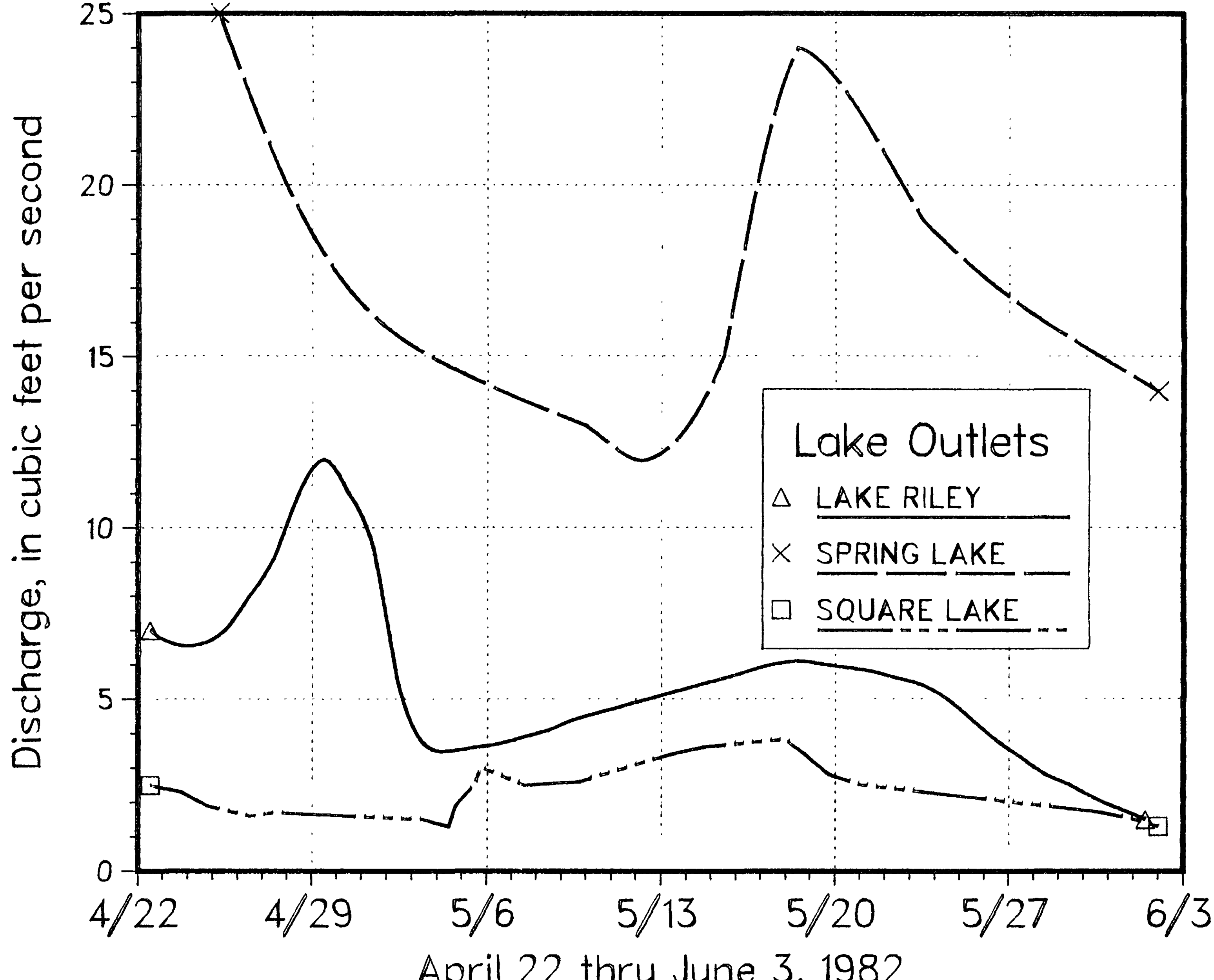

Figure 75.--Streamflow discharge for outflow during sampling at Lake Riley, Spring Lake, and Square Lake during the period April 22 through June 3, 1982

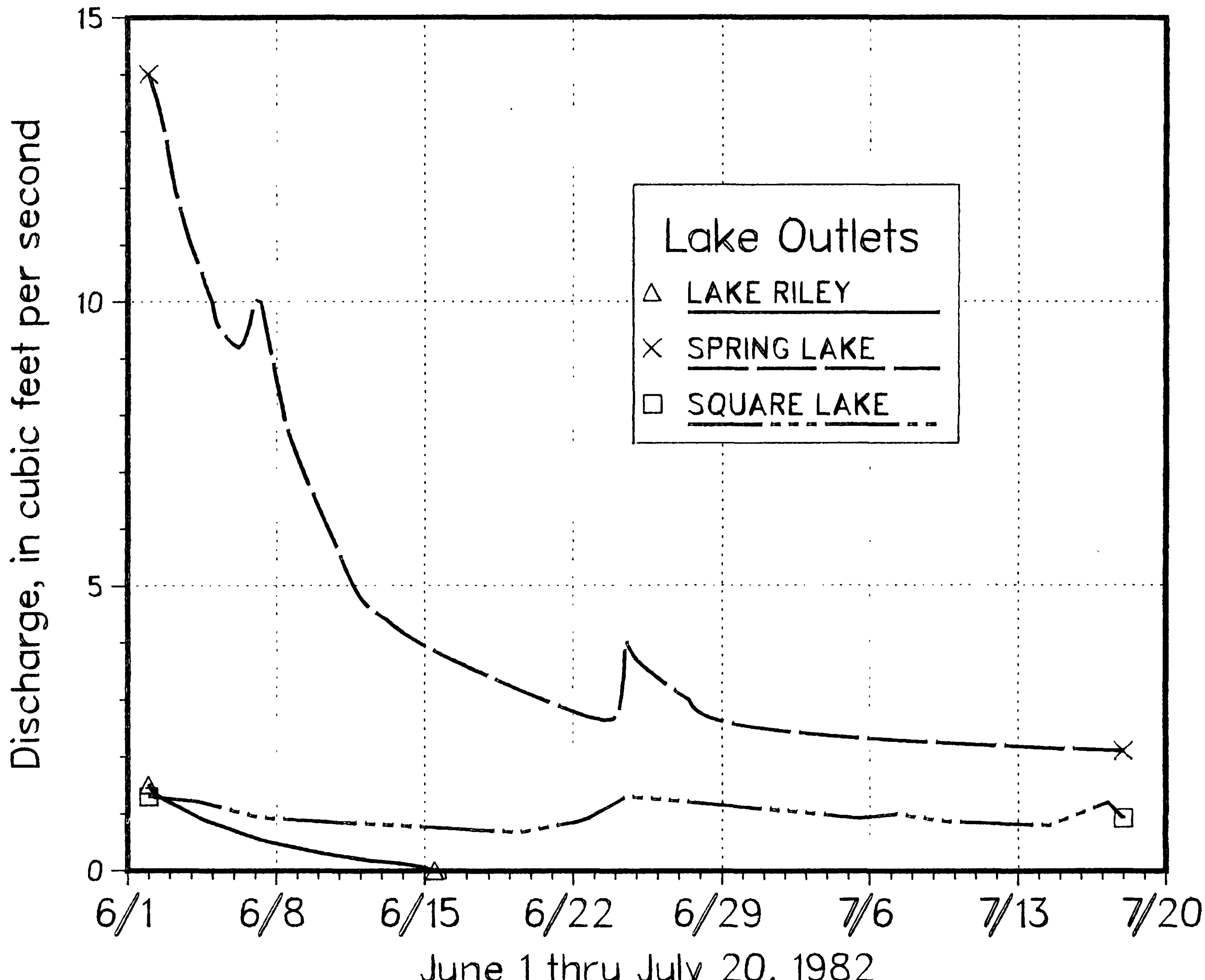

Figure 76.--Streamflow discharge for outflows during sampling at Lake Riley, Spring Lake, and Square Lake during the period June 2 through July 17, 1982

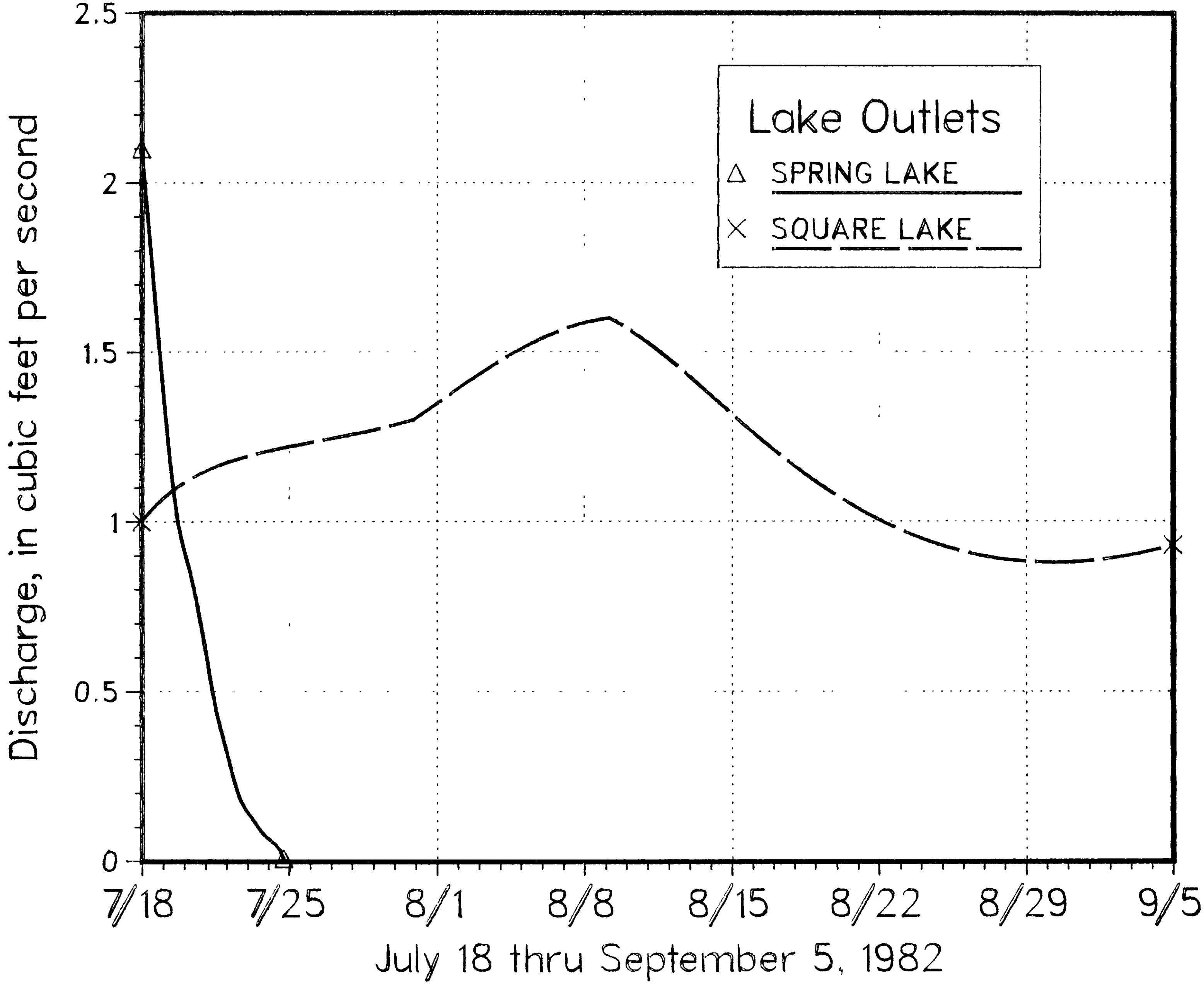

Figure 77.--Streamflow discharge for outflows during weekly sampling at Lake Riley, Spring Lake, and Square Lake for the period July 18 through September 4, 1982 (Lake Riley outflow did not discharge during this period)

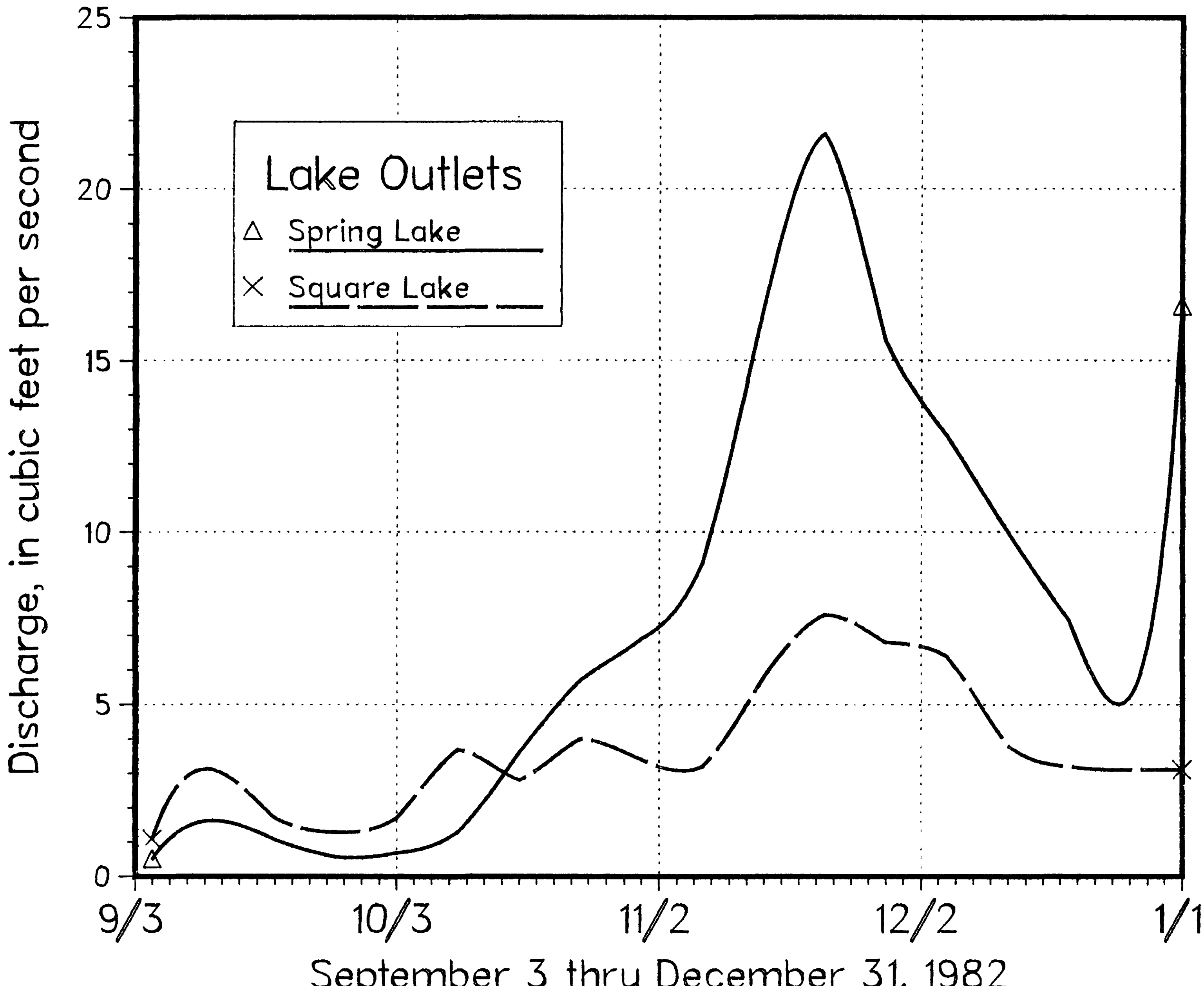

Figure 78.--Streamflow discharge for outflows during weekly sampling at Lake Riley, Spring Lake, and Square Lake during the period September 5 through December 31, 1982 (Lake Riley outflow did not discharge during this period)

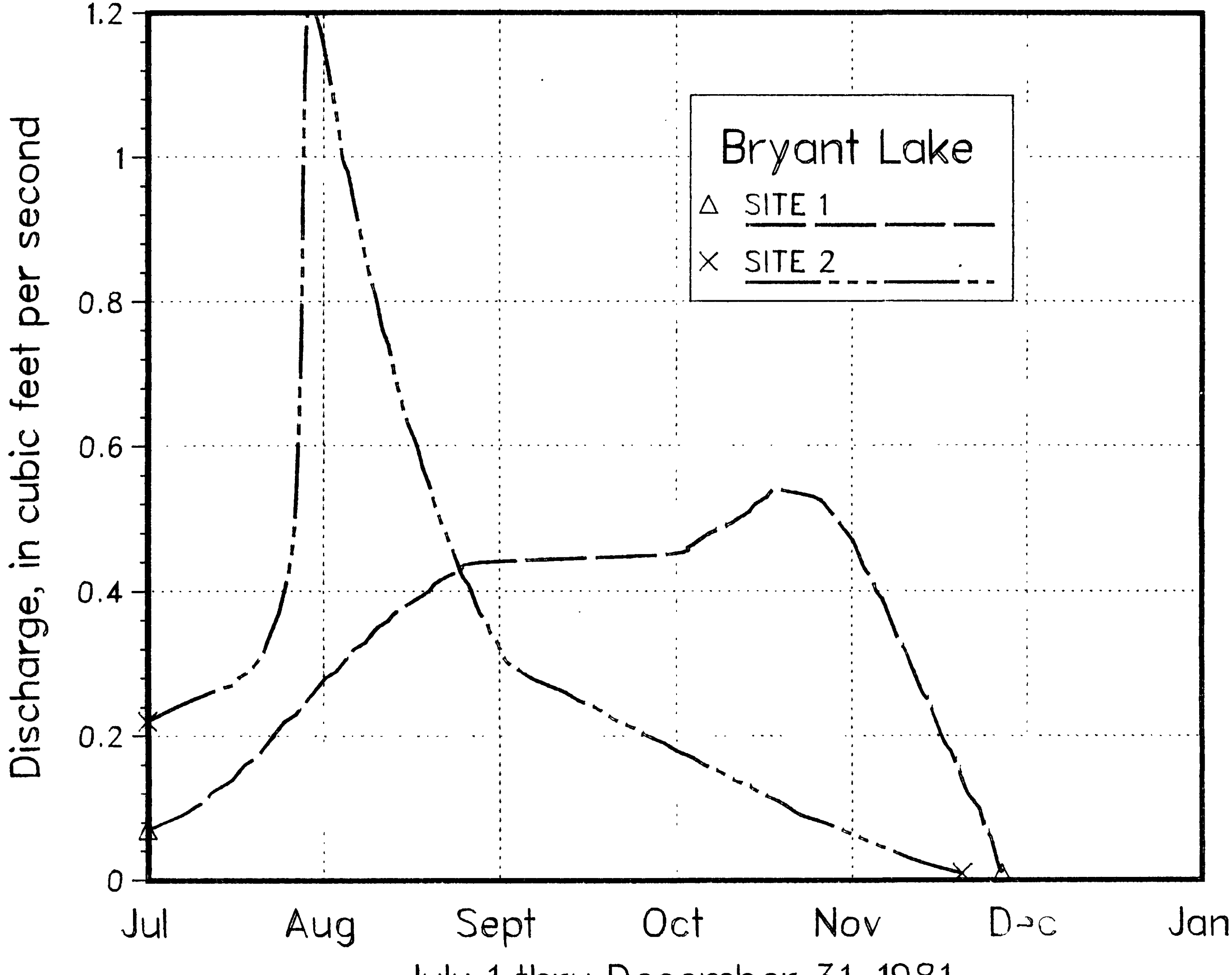

Figure 79.--1981 estimated flow for Bryant Lake

Table 55.--Weekly sampling period beginning time, ending time, and flow-weighted mean concentrations at study sites during 1982

Site	Beginning time[1]		Ending time		Storm duration (hours)	Total suspended solids (mg/L)	Volatile suspended solids (mg/L)	Total phosphorus (mg/L)	Dissolved phosphorus (mg/L)	Dissolved NO_2+NO_3 nitrogen (mg/L)	Total ammonia nitrogen (mg/L)	Total ammonia + organic nitrogen (mg/L)
						BRYANT LAKE						
1	4-22-82	0:00	7-14-82	23:59	2064	1.0	1.0	0.05	0.03	0.10	0.08	0.92
2	4-22-82	13:00	6-01-82	23:59	971	4.0	4.0	.04	.02	.20	.07	1.5
2	6-02-82	0:00	7-13-82	13:00	997	1.0	1.0	.03	.02	.05	.06	1.5
						LAKE ELMO						
1	4-22-82	0:00	7-14-82	23:59	2064	1.0	1.0	0.02	0.02	0.40	0.04	0.40
3	4-22-82	0:00	7-14-82	23:59	2064	1.0	1.0	.08	.04	.05	.07	1.6
4	4-22-82	8:30	6-01-82	23:59	976	1.0	1.0	.03	.02	.05	.11	1.0
4	6-02-82	0:00	7-17-82	23:59	1104	1.0	1.0	.04	.01	.05	.06	.80
4	7-18-82	0:00	9-04-82	23:59	1176	5.0	5.0	.09	.01	.05	.05	1.6
4	9-05-82	0:00	12-31-82	23:59	2832	6.0	6.0	.02	.01	.10	.02	.92
						FISH LAKE						
1	4-22-82	0:00	7-14-82	23:59	2064	1.0	1.0	0.10	0.10	0.05	0.04	2.0
2	4-22-82	0:00	7-14-82	23:59	2064	1.0	1.0	.07	.02	.05	.03	1.7
A1	4-22-82	0:00	7-14-82	23:59	2064	2.0	2.0	.23	.16	.10	.01	1.3
A2	4-22-82	0:00	7-14-82	23:59	2064	1.0	1.0	.15	.11	.10	.03	2.2
3	4-22-82	12:45	6-01-82	23:59	971	20.0	12.0	.07	.03	.05	.11	1.4
3	6-02-82	0:00	7-17-82	23:59	1104	9.0	7.0	.03	.01	.05	.10	1.1
3	7-18-82	0:00	9-04-82	23:59	1176	4.0	4.0	.02	.01	.05	.05	1.2
3	9-05-82	0:00	12-31-82	23:59	2832	1.0	1.0	.08	.03	.05	.04	1.8

Table 55.--Weekly sampling period beginning time, ending time, and flow-weighted mean concentrations at study sites during 1982--Continued

Site	Beginning time[1]		Ending time		Storm duration (hours)	Total suspended solids (mg/L)	Volatile suspended solids (mg/L)	Total phosphorus (mg/L)	Dissolved phosphorus (mg/L)	Dissolved NO_2+NO_3 nitrogen (mg/L)	Total ammonia nitrogen (mg/L)	Total ammonia + organic nitrogen (mg/L)
LAKE RILEY												
1	4-22-82	0:00	7-14-82	23:59	2064	3.0	3.0	0.08	0.05	0.40	0.08	2.3
2	4-22-82	0:00	7-14-82	23:59	2064	1.0	1.0	.04	.04	.15	.13	1.1
3	4-22-82	12:15	6-01-82	23:59	984	8.0	8.0	.08	.03	.15	.10	1.6
3	6-02-82	0:00	6-15-82	12:00	336	4.0	4.0	.06	.01	.05	.09	1.8
SPRING LAKE												
1	4-22-82	0:00	7-14-82	23:59	2064	1.0	1.0	0.12	0.11	5.4	0.12	2.4
2	4-22-82	0.00	7-14-82	23:59	2064	35	12	.13	.35	6.0	.09	2.6
3	4-22-82	11:00	6-01-82	23:59	973	6.0	6.0	.08	.03	.80	.18	1.5
3	6-02-82	0:00	7-17-82	23:59	1104	1.0	1.0	.16	.10	.15	1.7	2.4
3	7-18-82	0:00	9-04-82	23:59	1176	10	10	.09	.09	.10	.15	2.0
3	9-05-82	0:00	12-31-82	23:59	2832	1.0	1.0	.62	.13	.10	.08	10
SQUARE LAKE												
1	4-22-82	7:30	6-01-82	23:59	977	1.0	1.0	0.01	0.01	0.10	0.11	0.20
1	6-02-82	0:00	7-17-82	23:59	1104	1.0	1.0	.04	.01	.05	.59	.20
1	7-18-82	0:00	9-04-82	23:59	1176	2.0	2.0	.01	.01	.05	.04	.36
1	9-05-82	0:00	12-31-82	23:59	2832	1.0	1.0	.01	.01	.10	.06	.26

[1]/If beginning and ending time are the same, then concentration was a grab sample; if time is 0:00, then exact time is unknown.

Table 56.--Weekly flow-weighted mean concentration ratios for suspended solids, phosphorus, and nitrogen at study sites

Site	Beginning time[1]		Ending time		Percentage of suspended solids in the volatile form	Percentage of phosphorus in the dissolved state	Percentage of nitrogen in the form of ammonia
				BRYANT LAKE			
1	4-22-82	0:00	7-14-82	23:59	100	60	9
2	4-22-82	0:00	6-01-82	23:59	100	50	5
2	6-02-82	0:00	7-13-82	13:00	100	67	4
				LAKE ELMO			
1	4-22-82	0:00	7-14-82	23:59	100	100	10
3	4-22-82	0:00	7-14-82	23:59	100	50	4
4	4-22-82	8:30	6-01-82	23:59	100	67	11
4	6-02-82	0:00	7-17-82	23:59	100	25	8
4	7-18-82	0:00	9-04-82	23:59	100	11	3
4	9-05-82	0:00	12-31-82	23:59	100	50	2
				FISH LAKE			
1	4-22-82	0:00	7-14-82	23:59	100	100	2
2	4-22-82	13:00	7-14-82	23:59	100	28	2
A1	4-22-82	0:00	7-14-82	23:59	100	70	1
A2	4-22-82	0:00	7-14-82	23:59	100	73	1
3	4-22-82	12:45	6-01-82	23:59	60	43	8
3	1-02-82	0:00	7-17-82	23:59	78	33	9
3	7-18-82	0:00	9-04-82	23:59	100	50	4
3	9-05-82	0:00	12-31-82	23:59	100	38	2
				LAKE RILEY			
1	4-22-82	0:00	7-14-82	23:59	100	62	3
2	4-22-82	0:00	7-14-82	23:59	100	100	12
3	4-22-82	12:15	6-01-82	23:59	100	38	6
3	6-02-82	0:00	6-15-82	12:00	100	17	5

Table 56.--Weekly flow-weighted mean concentration ratios for suspended solids, phosphorus, and nitrogen at study sites--Continued

Site	Beginning time		Ending time		Percentage of suspended solids in the volatile form	Percentage of phosphorus in the dissolved state	Percentage of nitrogen in the form of ammonia
				SPRING LAKE			
1	4-22-82	0:00	7-14-82	23:59	100	92	5
2	4-22-82	0:00	7-14-82	23:59	34	100	3
3	4-22-82	11:00	6-01-82	23:59	100	38	12
3	6-02-82	0:00	7-17-82	23:59	100	62	71
3	7-18-82	0:00	9-04-82	23:59	100	100	8
3	9-05-82	0:00	12-31-82	23:59	100	21	1
				SQUARE LAKE			
1	4-22-82	7:30	6-01-82	23:59	100	100	55
1	6-02-82	0:00	7-17-82	23:59	100	25	100
1	7-18-82	0:00	9-04-82	23:59	100	100	11
1	9-05-82	0:00	12-31-82	23:59	100	100	23

1/If beginning and ending time are the same, then concentration was a grab sample; if time is 0:00, then exact time is unknown.

Seasonal Loads

Contained in this section are total seasonal load and average seasonal load tables, organized by lake. Zero's in a column indicate no flow during the period.

Table 57.--Seasonal total precipitation, flow, and loads at Bryant Lake sites for 1982

[Seasons are: snowmelt - beginning of flow to April 22; spring - April 22 to June 1; early summer - June 2 to July 17; late summer - July 17 to September 4; autumn - September 4 to end of flow]

Site	Season	Total precip-itation (cm)	Total flow (m^3)	Total suspended solids (kg)	Volatile suspended solids (kg)	Total phos-phorus (kg)	Dis-solved phos-phorus (kg)	Dis-solved NO_2+NO_3 nitrogen (kg)	Total ammonia nitrogen (kg)	Total ammonia + organic nitrogen (kg)
1	Snowmelt	43.3	83,000	170	170	5.9	3.4	310	28	92
1	Spring	7.4	41,000	280	130	2.6	1.6	36	3.9	43
1	Early Summer	9.5	40,000	1200	160	4.2	2.1	8.0	2.9	51
1	Late Summer	11.6	4,000	74	16	0.89	0.77	0.84	0.24	3.9
1	Autumn	25.8	61,000	340	100	5.6	3.4	7.2	3.9	29
2	Snowmelt	13.3	480,000	1100	1100	19	5.9	240	350	670
2	Spring	7.4	200,000	830	830	8.3	4.1	41	15	320
2	Early summer	9.5	23,000	23	23	.69	.46	1.2	1.4	34
2	Late summer	11.6	0	0	0	0	0	0	0	0
2	Autumn	25.8	0	0	0	0	0	0	0	0

Table 58.--Average seasonal storm loads at Bryant Lake sites, 1982

[Seasons are: snowmelt - beginning of flow to April 22; spring - April 23 to June 1; early summer - June 2 to July 17; late summer - July 18 to September 4; autumn - September 5 to end of flow]

Site	Season	Total suspended solids (kg)	Volatile suspended solids (kg)	Total phosphorus (kg)	Dissolved phosphorus (kg)	Dissolved NO_2+NO_3 nitrogen (kg)	Total ammonia nitrogen (kg)	Total ammonia + organic nitrogen (kg)
1	Snowmelt	170	170	5.9	3.4	310	28	92
1	Spring	93	43	0.87	0.53	12	1.3	14
1	Early summer	300	40	1.0	.52	2.0	0.72	13
1	Late summer	18	4.0	.22	.19	0.21	.06	0.97
1	Autumn	85	25	1.4	.85	1.8	.98	7.3
2	Snowmelt	850	850	17	4.2	210	330	575
2	Spring	230	230	2.3	1.7	35	18	92

Table 59.--Seasonal total precipitation, flow, and loads at Lake Elmo sites for 1982

[Seasons are: snowmelt - beginning of flow to April 22; spring - April 22 to June 1; early summer - June 2 to July 17; late summer - July 17 to September 4; autumn - September 4 to end of flow]

Site	Season	Total precipitation (cm)	Total flow (m^3)	Total suspended solids (kg)	Volatile suspended solids (kg)	Total phosphorus (kg)	Dissolved phosphorus (kg)	Dissolved NO_2+NO_3 nitrogen (kg)	Total ammonia nitrogen (kg)	Total ammonia + organic nitrogen (kg)
1	Snowmelt	13.0	58,000	21,000	1,800	29	4.1	82	12	87
1	Spring	13.1	47,000	5,400	910	9.8	2.6	43	29	62
1	Early summer	8.0	26,000	12,000	1,100	13	2.7	21	4.0	65
1	Late summer	13.6	1,700	250	10	0.26	0.14	0.60	0.10	1.4
1	Autumn	30.2	0	0	0	0	0	0	0	0
2	Snowmelt	13.0	160,000	5,200	630	22	13	95	130	230
2	Spring	13.1	38,000	360	120	3.4	1.9	3.1	2.9	36
2	Early summer	8.0	0	0	0	0	0	0	0	0
2	Late summer	13.6	0	0	0	0	0	0	0	0
2	Autumn	30.2	0	0	0	0	0	0	0	0
3	Snowmelt	13.0	270,000	1,400	550	44	14	140	88	390
3	Spring	13.1	130,000	1,400	840	20	6.8	20	31	210
3	Early summer	8.0	0	0	0	0	0	0	0	0
3	Late summer	13.6	0	0	0	0	0	0	0	0
3	Autumn	30.2	0	0	0	0	0	0	0	0
4	Snowmelt	13.0	540,000	800	800	26	9.0	110	55	440
4	Spring	13.1	530,000	530	530	16	11	27	1.4	20
4	Early summer	8.0	79,000	80	80	3.2	.80	4.0	4.8	64
4	Late summer	13.6	36,000	180	180	3.3	.37	1.8	1.8	60
4	Autumn	30.2	260,000	1,600	1,600	5.3	2.6	2.6	5.3	240

Table 60.--Average seasonal storm loads at Lake Elmo sites, 1982

[Seasons are: snowmelt - beginning of flow to April 22; spring - April 23 to June 1; early summer - June 2 to July 17; late summer - July 18 to September 4; autumn - September 5 to end of flow]

Site	Season	Total suspended solids (kg)	Volatile suspended solids (kg)	Total phosphorus (kg)	Dissolved phosphorus (kg)	Dissolved NO_2+NO_3 nitrogen (kg)	Total ammonia nitrogen (kg)	Total ammonia + organic nitrogen (kg)
1	Snowmelt	21,000	1,800	29	4.1	82	12	87
1	Spring	1,800	300	3.3	0.87	14	9.7	21
1	Early summer	12,000	1,100	13	2.7	21	4.0	65
1	Late summer	250	10	0.26	.14	0.60	0.10	1.4
2	Snowmelt	5,200	630	22	13	95	130	230
2	Spring	130	42	1.2	.70	1.2	1.0	13
3	Snowmelt	1,400	550	44	14	140	88	390
3	Spring	350	210	5.0	1.7	5.0	7.8	52
4	Snowmelt	311	311	8.8	3.5	50	22	148
4	Spring	530	530	16	11	27	59	53

Table 61.--Seasonal total precipitation, flow, and loads at Fish Lake sites for 1982

[Seasons are: snowmelt - beginning of flow to April 22; spring - April 22 to June 1; early summer - June 2 to July 17; late summer - July 17 to September 4; autumn - September 4 to end of flow]

Site	Season	Total precipitation (cm)	Total flow (m^3)	Total suspended solids (kg)	Volatile suspended solids (kg)	Total phosphorus (kg)	Dissolved phosphorus (kg)	Dissolved NO_2+NO_3 nitrogen (kg)	Total ammonia nitrogen (kg)	Total ammonia + organic nitrogen (kg)
1	Snowmelt	13.3	77,000	150	150	19	14	210	74	120
1	Spring	10.9	46,000	13,000	1,800	26	4.8	25	17	120
1	Early summer	11.3	60,000	3,000	1,800	16	9.8	21	5.7	100
1	Late summer	14.5	10,000	95	28	2.6	1.4	5.3	0.83	11
1	Autumn	25.3	3,700	9.7	8.9	0.79	0.40	1.5	.37	4.4
2	Snowmelt	13.3	83,000	170	170	18	13	210	65	120
2	Spring	10.9	41,000	67	67	3.6	2.6	12	8.6	64
2	Early summer	11.3	51,000	970	640	11	6.0	12	18	70
2	Late summer	14.5	19,000	75	43	3.2	2.3	4.3	2.9	18
2	Autumn	25.3	9,600	20	17	1.2	.95	2.3	.75	7.0
3	Snowmelt	13.3	420,000	1300	1300	33	13	113	200	520
3	Spring	10.9	390,000	7800	4700	27	12	20	43	560
3	Early summer	11.3	120,000	31	24	3.6	1.2	6.1	12	140
3	Late summer	14.5	19,000	78	78	.39	.19	0.98	.98	23
3	Autumn	25.3	150,000	147	147	12	4.4	7.6	5.9	260

Table 62.--Average seasonal storm loads at Fish Lake sites, 1982

[Seasons are: snowmelt - beginning of flow to April 22; spring - April 23 to June 1; early summer - June 2 to July 17; late summer - July 18 to September 4; autumn - September 5 to end of flow]

Site	Season	Total suspended solids (kg)	Volatile suspended solids (kg)	Total phosphorus (kg)	Dissolved phosphorus (kg)	Dissolved NO_2+NO_3 nitrogen (kg)	Total ammonia nitrogen (kg)	Total ammonia + organic nitrogen (kg)
1	Snowmelt	150	150	19	14	210	74	120
1	Spring	4,300	610	8.8	1.6	8.2	5.8	40
1	Early summer	500	300	2.7	1.6	3.5	0.95	17
1	Late summer	19	5.6	0.52	0.28	1.1	.17	2.2
1	Autumn	4.8	4.4	.40	.20	0.75	.18	2.2
2	Snowmelt	170	170	18	13	210	65	120
2	Spring	22	22	1.2	.87	4.0	2.9	21
2	Early summer	160	110	1.8	1.0	2.0	3.0	12
2	Late summer	15	8.6	.64	.46	.86	.58	3.6
2	Autumn	9.8	8.6	.60	.48	1.2	.38	3.5
3	Snowmelt	670	670	16	6.4	57	100	258
3	Spring	7800	4700	27	12	20	43	560

Table 63.--Seasonal total precipitation, flow, and loads at Lake George for 1982

[Seasons are: snowmelt - beginning of flow to April 22; spring - April 22 to June 1; early summer - June 2 to July 17; late summer - July 17 to September 4; autumn - September 4 to end of flow]

Site	Season	Total precipitation (cm)	Total flow (m^3)	Total suspended solids (kg)	Volatile suspended solids (kg)	Total phosphorus (kg)	Dissolved phosphorus (kg)	Dissolved NO_2+NO_3 nitrogen (kg)	Total ammonia nitrogen (kg)	Total ammonia + organic nitrogen (kg)
1	Snowmelt	11.4	69,000	140	140	15	8.4	7.0	20	84
1	Spring	11.3	78,000	470	470	7.1	3.2	12	26	78
1	Early summer	10.3	0	0	0	0	0	0	0	0
1	Late summer	16.5	0	0	0	0	0	0	0	0
1	Autumn	16.9	0	0	0	0	0	0	0	0

Table 64.--Average seasonal storm loads at Lake George, 1982

[Seasons are: snowmelt - beginning of flow to April 22; spring - April 23 to June 1; early summer - June 2 to July 17; late summer - July 18 to September 4; autumn - September 5 to end of flow]

Site	Season	Total suspended solids (kg)	Volatile suspended solids (kg)	Total phosphorus (kg)	Dissolved phosphorus (kg)	Dissolved NO_2+NO_3 nitrogen (kg)	Total ammonia nitrogen (kg)	Total ammonia + organic nitrogen (kg)
1	Snowmelt	140	140	15	8.4	7.0	20	84
1	Spring	160	160	2.4	1.0	3.9	8.6	26

Table 65.--Seasonal total precipitation, flow, and loads at Lake Riley sites for 1982

[Seasons are: snowmelt - beginning of flow to April 22; spring - April 22 to June 1; early summer - June 2 to July 17; late summer - July 17 to September 4; autumn - September 4 to end of flow]

Site	Season	Total precip-itation (cm)	Total flow (m^3)	Total suspended solids (kg)	Volatile suspended solids (kg)	Total phos-phorus (kg)	Dis-solved phos-phorus (kg)	Dis-solved NO_2+NO_3 nitrogen (kg)	Total ammonia nitrogen (kg)	Total ammonia + organic nitrogen (kg)
1	Snowmelt	14.1	540,000	1,600	1,100	60	33	550	400	1,000
1	Spring	8.5	310,000	900	600	27	20	240	76	500
1	Early summer	10.0	150,000	960	650	8.0	6.5	24	19	240
1	Late summer	12.1	0	0	0	0	0	0	0	0
1	Autumn	25.0	0	0	0	0	0	0	0	0
2	Snowmelt	14.1	780,000	1,600	1,600	200	87	600	560	1,700
2	Spring	8.5	410,000	730	550	67	46	360	76	680
2	Early summer	14.1	190,000	1,600	590	31	26	170	20	280
2	Late summer	12.1	0	0	0	0	0	0	0	0
2	Autumn	25.0	0	0	0	0	0	0	0	0
3	Snowmelt	14.1	690,000	1,200	1,200	72	36	330	120	970
3	Spring	8.5	540,000	4,400	4,400	44	16	82	55	900
3	Early summer	10.0	21,000	83	83	1.2	0.21	1.0	1.9	37
3	Late summer	12.1	0	0	0	0	0	0	0	0
3	Autumn	25.0	0	0	0	0	0	0	0	0

Table 66.--Average seasonal storm loads at Lake Riley sites, 1982

[Seasons are: snowmelt - beginning of flow to April 22; spring - April 23 to June 1; early summer - June 2 to July 17; late summer - July 18 to September 4; autumn - September 5 to end of flow]

Site	Season	Total suspended solids (kg)	Volatile suspended solids (kg)	Total phosphorus (kg)	Dissolved phosphorus (kg)	Dissolved NO_2+NO_3 nitrogen (kg)	Total ammonia nitrogen (kg)	Total ammonia + organic nitrogen (kg)
1	Snowmelt	1,600	1,100	60	33	550	400	1,000
1	Spring	300	200	9.0	6.7	80	25	170
1	Early summer	960	650	8.0	6.5	24	19	240
2	Snowmelt	1,600	1,600	200	87	600	560	1,700
2	Spring	240	180	22	15	120	25	230
2	Early summer	1,600	590	31	26	170	20	280
3	Snowmelt	620	620	36	18	160	62	490
3	Spring	4,400	4,400	44	16	82	55	900

Table 67.--Seasonal total precipitation, flow, and loads at Spring Lake sites for 1982

[Seasons are: snowmelt - beginning of flow to April 22; spring - April 22 to June 1; early summer - June 2 to July 17; late summer - July 17 to September 4; autumn - September 4 to end of flow]

Site	Season	Total precip-itation (cm)	Total flow (m^3)	Total suspended solids (kg)	Volatile suspended solids (kg)	Total phos-phorus (kg)	Dis-solved phos-phorus (kg)	Dis-solved NO_2+NO_3 nitrogen (kg)	Total ammonia nitrogen (kg)	Total ammonia + organic nitrogen (kg)
1	Snowmelt	13.4	1,800,000	3,700	1,900	580	430	27,000	890	4,200
1	Spring	10.2	510,000	3,600	1,300	80	47	3,200	57	1,100
1	Early summer	10.7	300,000	16,000	4,000	140	64	1,600	49	1,100
1	Late summer	17.3	31,000	220	93	21	12	23	3.4	55
1	Autumn	22.9	730,000	740	740	270	270	890	30	1,600
2	Snowmelt	13.4	1,600,000	72,000	6,500	520	410	24,000	1,500	4,000
2	Spring	10.2	310,000	6,000	1,400	46	27	2,000	44	700
2	Early summer	10.7	230,000	3,800	1,900	67	48	1,000	80	690
2	Late summer	17.3	34,000	730	330	24	15	29	10	61
2	Autumn	22.9	370,000	370	370	160	140	370	22	700
3	Snowmelt	13.4	4,400,000	10,000	10,000	500	300	8,300	1,100	6,000
3	Spring	10.2	1,800,000	11,000	11,000	150	55	1,500	330	2,700
3	Early summer	10.7	470,000	470	470	76	47	71	820	1,100
3	Late summer	17.3	43,000	43	43	3.9	3.9	4.3	6.4	85
3	Autumn	22.9	2,200,000	2,200	2,200	1,400	280	220	180	22,000

Table 68.--Average seasonal storm loads at Spring Lake sites, 1982

[Seasons are: snowmelt - beginning of flow to April 22; spring - April 23 to June 1; early summer - June 2 to July 17; late summer - July 18 to September 4; autumn - September 5 to end of flow]

Site	Season	Total suspended solids (kg)	Volatile suspended solids (kg)	Total phosphorus (kg)	Dissolved phosphorus (kg)	Dissolved NO_2+NO_3 nitrogen (kg)	Total ammonia nitrogen (kg)	Total ammonia + organic nitrogen (kg)
1	Snowmelt	3,700	1,900	580	430	27,000	890	4,200
1	Spring	1,200	430	26	16	1,100	19	370
1	Early summer	5,300	1,300	46	21	550	16	370
1	Late summer	220	93	21	12	23	3.4	55
1	Autumn	740	740	270	270	890	30	1,600
2	Snowmelt	72,000	6,500	520	410	24,000	1,500	4,000
2	Spring	2,000	460	15	9.1	670	15	230
2	Early summer	1,900	940	34	24	500	40	350
2	Late summer	320	180	2.9	1.8	1.0	7.0	10.7
2	Autumn	370	370	160	140	370	22	700
3	Snowmelt	7,200	7,200	400	250	7,400	540	4,500
3	Spring	3,100	3,100	52	21	940	57	750

Table 69.--Seasonal total precipitation, flow, and loads at Square Lake for 1982

[Seasons are: snowmelt - beginning of flow to April 22; spring - April 22 to June 1; early summer - June 2 to July 17; late summer - July 17 to September 4; autumn - September 4 to end of flow]

Site	Season	Total precip-itation (cm)	Total flow (m^3)	Total suspended solids (kg)	Volatile suspended solids (kg)	Total phos-phorus (kg)	Dis-solved phos-phorus (kg)	Dis-solved NO_2+NO_3 nitrogen (kg)	Total ammonia nitrogen (kg)	Total ammonia + organic nitrogen (kg)
1	Snowmelt	14.1	530,000	800	800	18	5.4	61	240	120
1	Spring	9.5	210,000	210	210	2.1	2.1	21	23	42
1	Early summer	5.1	110,000	110	110	4.4	1.1	5.5	64	22
1	Late summer	11.3	89,000	180	180	0.90	0.90	4.5	3.6	32
1	Autumn	29.7	1,000,000	1,100	1,100	1.1	1.1	11	6.3	270

Table 70.--Average seasonal storm loads at Square Lake, 1982

[Seasons are: snowmelt - beginning of flow to April 22; spring - April 23 to June 1; early summer - June 2 to July 17; late summer - July 18 to September 4; autumn - September 5 to end of flow]

Site	Season	Total suspended solids (kg)	Volatile suspended solids (kg)	Total phosphorus (kg)	Dissolved phosphorus (kg)	Dissolved NO_2+NO_3 nitrogen (kg)	Total ammonia nitrogen (kg)	Total ammonia + organic nitrogen (kg)
1	Snowmelt	400	400	1.3	1.3	33	16	32
1	Spring	39	39	1.6	.39	9.7	4.3	11

Annual Concentrations and Loads

This section contains estimated flow hydrographs for each lake from July 1 through December 31, 1981. Tables for average concentrations at inflow sites for 1982, average concentration ratios at inflow sites for 1982, average storm loads at inflow sites for 1982, and total loads at all sites for 1981 and 1982 are also included in this section.

Table 71.--Average storm flow-weighted mean concentrations at all inflow sites for 1982

Site	Season	Total suspended solids (mg/L)	Volatile suspended solids (mg/L)	Total phosphorus (mg/L)	Dissolved phosphorus (mg/L)	Dissolved NO_2+NO_3 nitrogen (mg/L)	Total ammonia nitrogen (mg/L)	Total ammonia + organic nitrogen (mg/L)
BRYANT LAKE								
1	2.6	1.4	0.03	0.01	0.34	0.04	0.24	
LAKE ELMO								
1	73	7.2	0.09	0.02	0.28	0.08	0.40	
2	14	1.9	.06	.04	.25	.33	.69	
3	3.4	1.7	.08	.02	.20	.15	.72	
FISH LAKE								
1	16	3.7	0.06	0.03	0.26	0.10	0.34	
2	6.4	4.4	.19	.11	1.7	.55	1.3	
LAKE GEORGE								
1	2.1	2.1	0.08	0.04	0.06	0.16	0.54	
LAKE RILEY								
1	1.1	0.74	0.03	0.02	0.27	0.16	0.56	
2	0.93	.65	.07	.04	.27	.15	.64	
SPRING LAKE								
1	1.6	0.51	0.07	0.05	1.8	0.06	0.46	
2	6.6	.86	.07	.05	2.0	.13	.48	

Table 72.--Average storm flow-weighted mean concentration ratios for suspended solids, phosphorus, and nitrogen at all inflow sites for 1982

Site	Percentage of suspended solids in the dissolved state	Percentage of phosphorus in the dissolved state	Percentage of nitrogen in the form of ammonia
		BRYANT LAKE	
1	54	33	17
		LAKE ELMO	
1	10	22	20
2	14	67	48
3	50	25	21
		FISH LAKE	
1	23	50	29
2	69	58	42
		LAKE GEORGE	
1	100	50	30
		LAKE RILEY	
1	67	67	29
2	70	57	23
		SPRING LAKE	
1	32	71	13
2	13	71	27

Table 73.--Average storm loads for 1982 at all sites

Site	Season	Total suspended solids (kg)	Volatile suspended solids (kg)	Total phosphorus (kg)	Dissolved phosphorus (kg)	Dissolved NO_2+NO_3 nitrogen (kg)	Total ammonia nitrogen (kg)	Total ammonia + organic nitrogen (kg)
				BRYANT LAKE				
1	130	36	1.2	0.70	23	2.4	14	
2	650	650	9.3	3.5	94	120	340	
				LAKE ELMO				
1	6,500	640	8.7	1.6	25	7.5	37	
2	1,400	190	6.2	3.8	25	33	67	
3	560	280	13	4.2	32	24	120	
				FISH LAKE				
1	960	220	3.8	1.8	15	5.8	21	
2	76	55	2.2	1.5	14	5.6	16	
3	2,000	1,200	15	6.2	30	52	300	
				LAKE GEORGE				
1	150	150	5.5	2.9	4.7	11	40	
				LAKE RILEY				
1	680	460	19	12	160	99	350	
2	780	550	59	32	220	130	530	
3	1,900	1,900	39	17	140	59	640	
				SPRING LAKE				
1	2,700	890	121	91	3,600	110	900	
2	9,200	1,200	91	71	3,000	180	80	
3	4,700	4,700	430	140	2,000	490	6,400	
				SQUARE LAKE				
1	480	480	5.3	2.1	21	67	97	

Table 74.--Annual precipitation, flow, and loads at all study sites for 1981 and 1982

[1981 total is from July 1 to December 31, 1981 only; rainfall was not collected during 1981]

Site	Year	Total precip-itation (cm)	Total flow (m^3)	Total suspended solids (kg)	Volatile sus-pended solids (kg)	Total phos-phorus (kg)	Dis-solved phos-phorus (kg)	Dis-solved NO_2+NO_3 nitrogen (kg)	Total ammonia nitrogen (kg)	Total ammonia + organic nitrogen (kg)
BRYANT LAKE										
1	1981	---	130,000	130	130	6.5	3.9	13	10	120
1	1982	57.84	230,000	2,100	570	19	11	360	39	218
2	1981	---	130,000	130	130	3.8	2.5	6.4	7.6	190
2	1982	57.84	700,000	2,000	2,000	28	10	280	370	1,000
LAKE ELMO										
1	1981	---	22,000	22	22	0.44	0.44	8.7	0.87	8.7
1	1982	67.56	130,000	42,000	3,800	52	9.5	150	45	220
2	1981	---	0	0	0	0	0	0	0	0
2	1982	67.56	200,000	5,600	750	25	15	98	130	270
3	1981	---	847	0.86	0.86	.07	.03	0.04	.06	1.34
3	1982	67.56	400,000	2,800	1,400	64	21	160	120	600
4	1981	---	550,000	560	560	22	5.6	28	34	450
4	1982	67.56	1,400,000	3,200	3,200	54	24	150	68	820

Table 74.--Annual precipitation, flow, and loads at all study sites for 1981 and 1982--Continued

Site	Year	Total precip-itation (cm)	Total flow (m^3)	Total suspended solids (kg)	Volatile sus-pended solids (kg)	Total phos-phorus (kg)	Dis-solved phos-phorus (kg)	Dis-solved NO_2+NO_3 nitrogen (kg)	Total ammonia nitrogen (kg)	Total ammonia + organic nitrogen (kg)
FISH LAKE										
1	1981	---	70,000	71	71	7.1	7.1	3.6	2.8	140
1	1982	66.32	197,000	16,000	3800	64	30	263	98	360
2	1981	---	42,000	42	42	2.9	0.84	2.1	1.3	72
2	1982	66.32	204,000	1300	940	37	25	240	95	280
3	1981	---	10,000	2.7	2.1	0.32	.11	0.53	1.06	12
3	1982	66.32	1,100,000	9,400	6,200	2,700	31	148	260	1,500
LAKE GEORGE										
1	1981	---	0	0	0	0	0	0	0	0
1	1982	68.80	150,000	610	610	22	12	19	46	160
LAKE RILEY										
1	1981	---	200,000	610	610	16	10	81	16	460
1	1982	59.61	1,000,000	3,400	2,300	95	60	810	490	1,700
2	1981	---	330,000	330	330	13	13	50	43	370
2	1982	59.61	1,400,000	3,900	2,700	300	160	1,100	660	2,700
3	1981	---	0	0	0	0	0	0	0	0
3	1982	59.61	1,300,000	5,700	5,700	120	52	410	177	1,900

Table 74.--Annual precipitation, flow, and loads at all study sites for 1981 and 1982--Continued

Site	Year	Total precip-itation (cm)	Total flow (m^3)	Total suspended solids (kg)	Volatile sus-pended solids (kg)	Total phos-phorus (kg)	Dis-solved phos-phorus (kg)	Dis-solved NO_2+NO_3 nitrogen (kg)	Total ammonia nitrogen (kg)	Total ammonia + organic nitrogen (kg)
SPRING LAKE										
1	1981	---	780,000	790	790	95	87	4,300	95	1,900
1	1982	65.28	3,400,000	24,000	8,000	1,100	820	33,000	1,000	8,100
2	1981	---	900,000	32,000	11,000	120	320	5,500	83	2,400
2	1982	65.28	2,500,000	83,000	10,000	820	640	2,700	1,700	6,200
3	1981	---	2,500,000	2,500	2,500	400	250	380	4,400	6,000
3	1982	65.28	8,900,000	24,000	24,000	21,000	690	10,000	2,400	32,000
SQUARE LAKE										
1	1981	---	1,400,000	1,390	1,390	56	14	69	820	280
1	1982	59.26	1,900,000	2,400	2,400	26	11	100	340	490

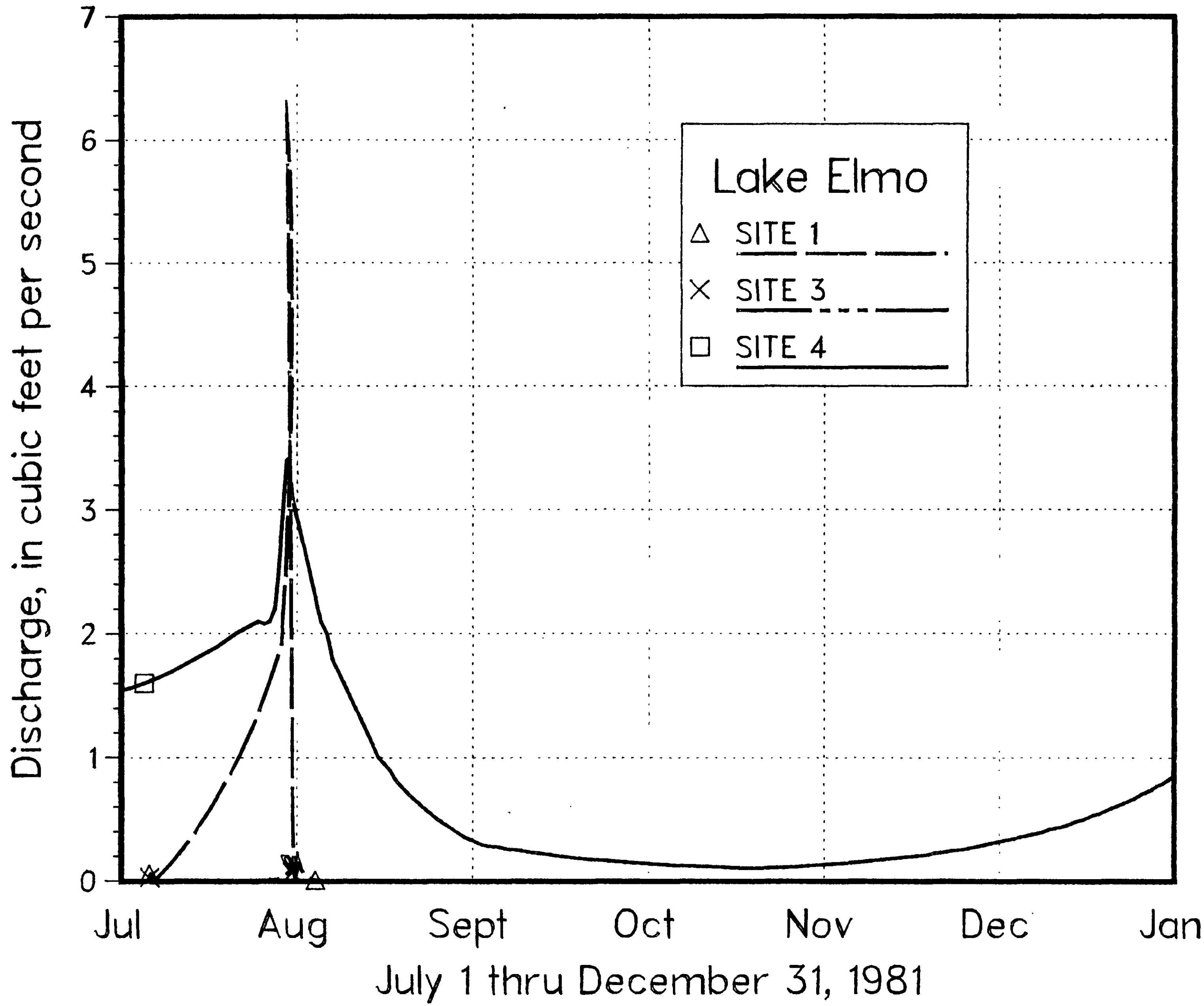

Figure 80.--1981 estimated flow for Lake Elmo

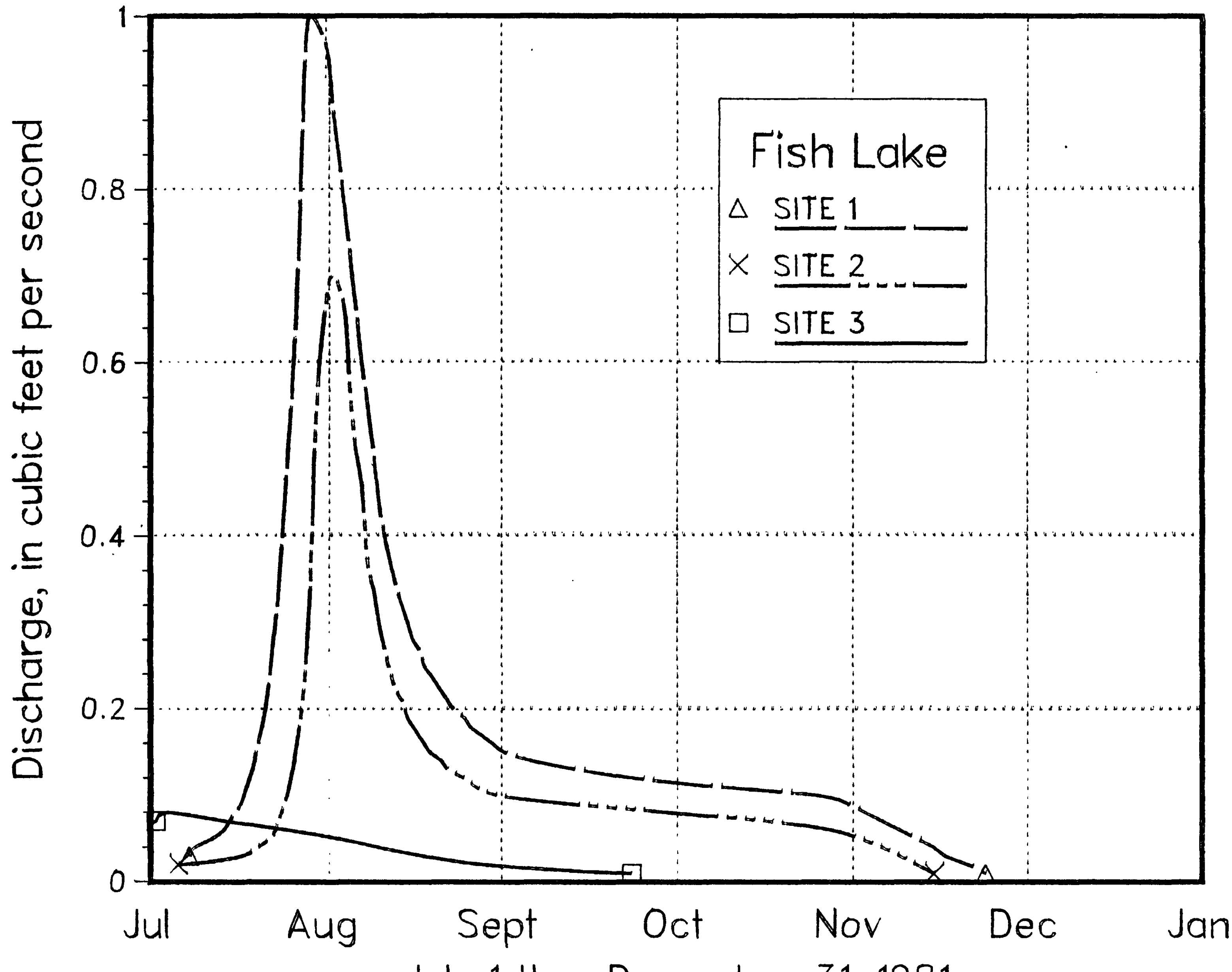

Figure 81.--1981 estimated flow for Fish Lake

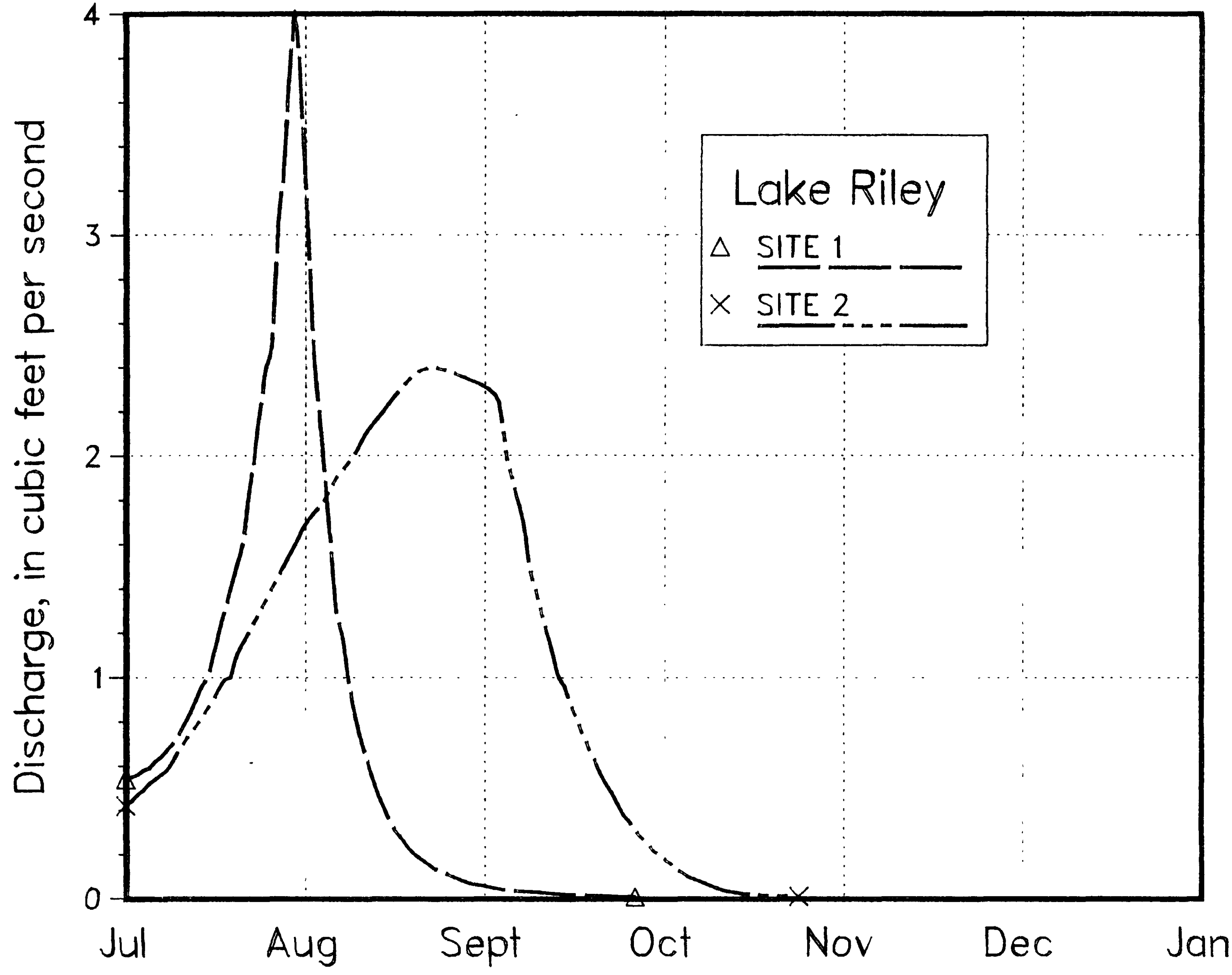

Figure 82.--1981 estimated flow for Lake Riley

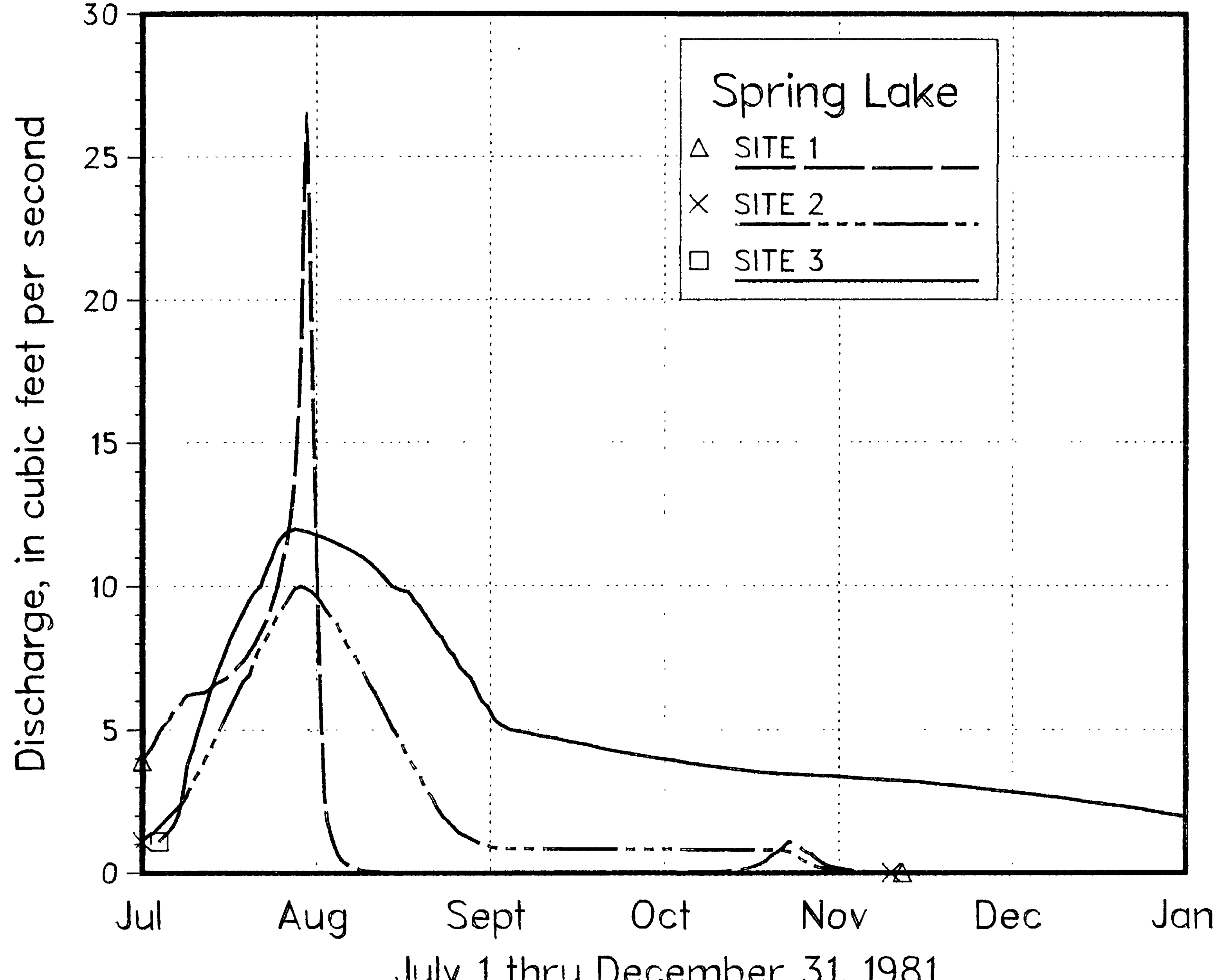

Figure 83.--1981 estimated flow for Spring Lake

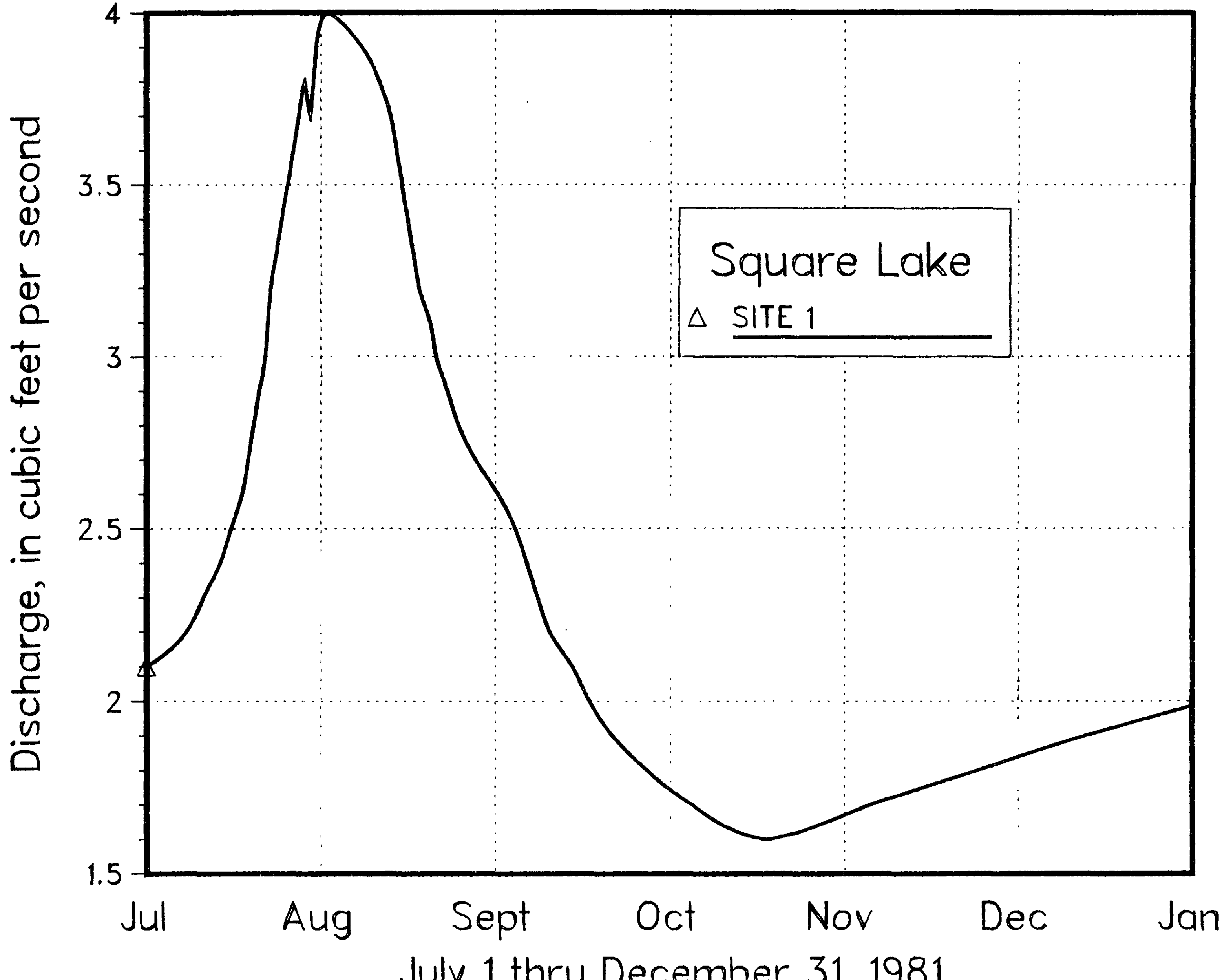

Figure 84.--1981 estimated flow for Square Lake