THE SOURCES AND CAUSES OF SEDIMENTATION IN

SILVER CREEK, BLAINE CO., IDAHO

Final Report

by

C. Y. Manuel, J. S. Griffith, and G. W. Minshall

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ABSTRACT

The sources and causes of sediment in Silver Creek, Idaho were investigated in a 15 month study which began March 1979. The principal source of sediment was fluvial transport from the the major tributaries. Stalker Creek contributed 62% of the material, while Grove and Loving Creeks brought in 23% and 15% respectively. Estimates of windborne silt indicated that during the period of study this was not a major source of sediment.

Drainage basin surveys revealed the presence of channelization, drainage canals, and extensive areas of exposed fields in the Stalker Creek basin. Modification of other streams was less extensive.

Sediment depths in Silver Creek increased downstream, indicating the influence of the Purdy Dam which turned a part of Silver Creek into a settling basin.

Aquatic vegetation was identified as an important factor in the dynamics of sediment deposition and erosion.

The impact of ducks on Silver Creek appears to be relatively minor.

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INTRODUCTION

Over the past 15 to 20 years substantial changes in land use practices have occurred throughout the Silver Creek drainage system. These appear to have been paralleled by an increase in the amount of silt carried by and deposited in the stream. It has been suggested that the increased sediment load has had a detrimental effect on the productivity of Silver Creek and its value as a trout fishery.

The purpose of this study was to determine the sources and quantities of silt (sediment) entering Silver Creek, Blaine County, Idaho. The study is a prelude to a management program aimed at maintaining and/or restoring stream quality and fish and wildlife habitat and is aimed at documenting the origin and causes of high sediment transported in the stream.

BACKGROUND

Streams carry material in solution, in suspension, and along the bed of the channel (Morisawa 1968). The relative importance of each fraction varies with the stream but all three factors result from the erosive properties of flowing water.

The variability of the amount in solution depends in great part on the relative contributions of ground water and surface runoff to stream discharge. If stream flow is stable, resulting primarily from groundwater flow, concentration of dissolved salts is generally high. However, when surface runoff is the main contributor to stream flow, the concentration of dissolved salts is usually lower (Morisawa 1968). The solid load can be divided into the suspended <u>load</u> and the <u>bed load</u>. The bed load is composed of the grains moving along the channel bottom in the lower layers of laminar flow; these materials are not supported by the fluid. The suspended load is composed of finer particles than the bed load and involves those grains supported by the fluid and carried along above the layer of laminar flow.

Numerous changes in a stream ecosystem such as Silver Creek may result from the transport of suspended materials (turbidity) and from deposition in the streambed. The reduction in primary productivity that normally occurs from a reduction in light transmission due to turbidity and from a blanketing of aquatic plants with a layer of silt is well known (Ellis 1936).

Effects of turbidity and sedimentation on aquatic invertebrates and fishes range from those that are directly lethal to those that are extremely subtle. Turbidity of unusually high concentration may be directly toxic to fishes by clogging opercular cavities and gill filaments (Wallen 1951). More moderate concentrations reduce the visual feeding range of fish, enhance bacterial gill infections, and may cause lethal inflammation of gill membranes (Lynch et al. 1977). Abrasion by transported sediment has been suggested as a cause of increased drift rates in some aquatic insects (Pearson and Franklin 1968).

Excessive sedimentation destroys the habitat of both aquatic insects (Scott 1966) and fishes (Hunt 1969) by providing a uniform, unstable substrate devoid of shelter. The deposition of organic sediments undergoing decomposition reduces oxygen available for respiration of aquatic organisms. Most critical is the effect on salmonid embryos and fry. Sediments reduce the survival of salmonid embryos by decreasing their oxygen supply and inhibiting removal of waste products and impede the emergence of fry (Hall and Lantz 1969, Phillips et al. 1975, Hausle and Coble 1976). More subtly, salmonid fry incubated under low oxygen conditions have been shown to be less successful in competition
ı the stream with those incubated at higher oxygen levels (Mason 1969).

Attempts to gain information on the history of sedimentation in the Silver Creek drainage have been hampered by the lack of quantitative data. Fishermen and local landowners have been cooperative, but opinions vary; some report that there has always been a lot of sediment in Silver Creek, while others have observed a marked increase in deposited sediment in the past few years.

While it is impossible to document the change in sediment carried by and deposited in Silver Creek in the past, some information is available relative to drainage pattern modifications and climatic events that may have affected sediment transport.

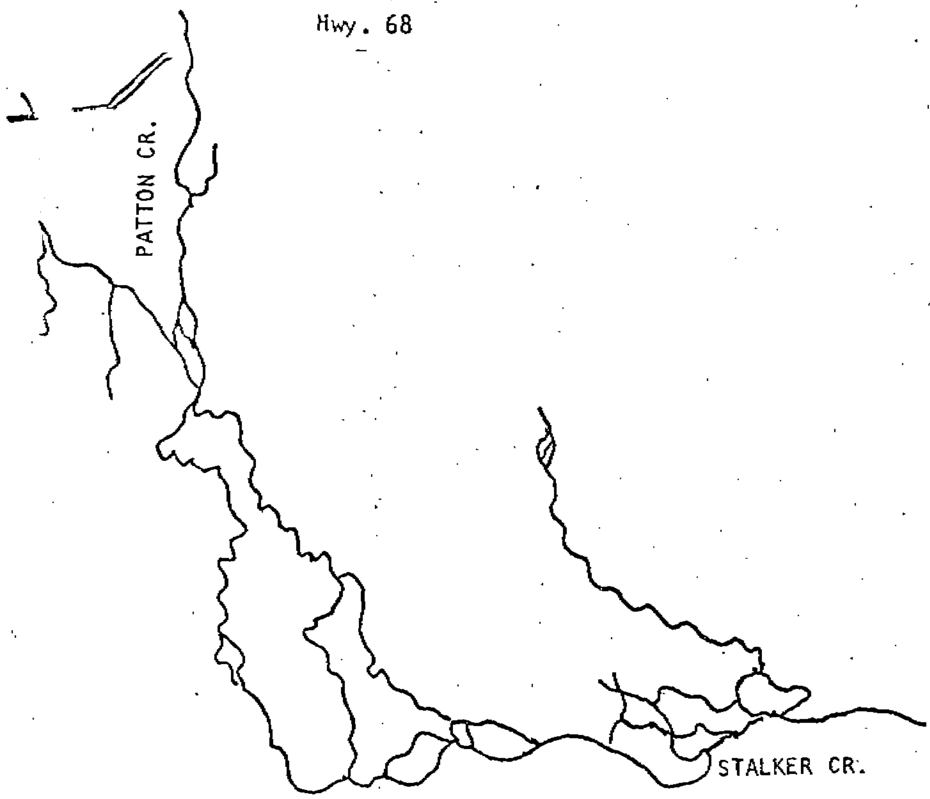
It is probable that the construction of the railroad caused some modification of Loving Creek and introduced sediment, especially at the bridges. In addition, there are several canals associated with Loving Creek which pre-date 1940, according to Gordon Beebe, TNC Manager at Silver Creek.

On Stalker Creek, the most significant changes resulted from the construction of the Patton Drain in 1952-1953. A comparison of recent arial photographs with one taken in 1950 indicates that the Patton Drain replaced the natural channel as the principal water carrier. The natural system was long and tortuous whereas the Patton Drain, coupled with canals feeding into it, constitute a more direct route to Lower Stalker Creek (Fig. 1).

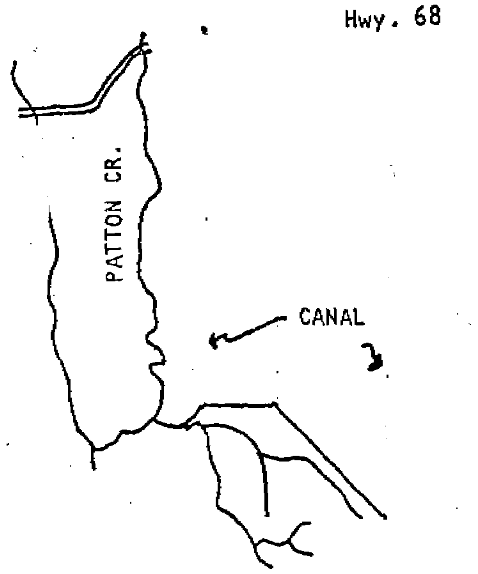
Other changes include the construction of the Patterson Drain in 1945 and the Daly Ditch in 1955-1956. The latter is an underground drain which carries into Loving Creek water that originally fed Thompson Creek, a tributary of Grove Creek.

Apparently wind erosion has, on at least one occasion, resulted in a significant input of silt. Based on information supplied by Harold Harris of Aberdeen, a long-time fisherman-observer of Silver Creek and a distinguished Idaho agronomist, and Hayspur Hatchery Superintendent Bud Batcholder, Gordon Beebe pieced together the following sequence of events: "In the spring of 1974,

Figure 1. Patton and Upper Stalker Creek: a comparison of present and pre-1952 drainage systems.



PRE-1952 DRAINAGE SYSTEM



PRESENT DRA

very strong winds persisted almost every day for the best part of a month during spring tillage and planting. Winds were 40-45 mph from May 25 through June 7, following a 60 day period of no precipitation. This was the beginning of an intolerable degree of siltation upstream in Loving Creek, which led to installation of a sediment basin above the hatchery in 1977."

Once silt has entered a stream the dynamics of sediment transport, deposition, and reentrainment are influenced by the interaction of several physical and biological factors. These include, but are not limited to, discharge, velocity, turbulence, ice, aquatic plants, fish, and water fowl. Of these factors, only discharge has been measured quantitatively over a period of several years. Table 1 shows monthly means of discharge at the United States Geological Survey Gauging Station near Picabo from March 1975 to April 1979. Each twelve month period begins in March to coincide with the beginning of spring runoff and the time of maximum discharge in Silver Creek. Since the aquifer is generally undercharged at this time, spring runoff is usually followed by a period of low flow. As the groundwater becomes recharged in late summer, flow again increases.

During runoff, snowmelt water carries silt into the stream and the rising waters of the tributaries entrain sediment that had been previously deposited. This sediment burden is then carried on into Silver Creek, where some may be deposited, or additional sediment entrained, depending on the conditions. High discharge, and accompaning high velocities promote scouring of sediment. It is unlikely that this occurred in Silver Creek the spring of 1977 since discharge was reduced as a result of abnormally low precipitation in the winter of 1976-1977. Maximum daily discharge in 1977 was only 5.0 m^3/sec and occurred on March 9 whereas in 1975 and 1976 the maximum daily values were 15.5 and 13.0 m^3/sec and occurred on April 21 and April 6, respectively. Most of the silt that had been deposited during the previous months probably remained in the streambed in the spring of 1977 and was augumented by additional deposition as the flow continued

Table 1. Discharge at the United States Geological Survey Gauging Station near Picabo, I means, March 1975 through April 1979. Values after September 1978 are based on provis Values are in m^3/sec.

	Month											
Year	M	A	M	J	J	A	S	O	N	D	J	F
1975-1976	5.3	8.9	5.4	4.6	6.3	6.3	6.1	7.2	6.7	5.9	5.0	4.
1976-1977	5.0	6.5	5.0	4.6	4.7	5.4	6.4	7.2	7.0	5.3	4.6	4.
1977-1978	4.5	3.7	3.0	2.6	2.2	2.2	2.5	3.3	3.9	4.2	3.8	3.
1978-1979	5.5	4.6	3.3	3.3	4.4	5.5	6.4	5.6	5.6	---[a]	---[a]	---
1979-	5.7	5.0										

[a]Ice interfered with stage height/discharge relationship.

to decrease during the summer. Since there was very little recharge of the underground aquifer, discharge remained low until the following spring (1978). The high turbidity that was observed in Silver Creek and its major tributaries in mid-March, 1978, just prior to the initiation of the present study, resulted in part, from the reentrainment of silt accumulated during this protracted period of low flow.

OBJECTIVES

In the present study emphasis has been placed on the measurement of suspended load and has concentrated on the role of the three major tributaries in contributing sediments to Silver Creek. Six routine collection stations were selected for sampling suspended sediment (hereafter referred to as 'sediment'). Of these, three were located on Silver Creek and one each on Stalker, Grove, and Loving Creeks near the confluence of each with Silver Creek. Samples were collected during spring runoff in both 1978 and 1979 and on ten intervening dates in order to provide a complete profile of annual sediment transport. The sediment load was separated into organic and inorganic components and analyzed so as to distinguish between those materials which settle out rather quickly from those which remain in suspension for relatively long times.

The second objective of the study was to determine the sources of silt borne by the tributaries, the proportions due to snowmelt and wind erosion, and the ultimate cases of these contributions. A survey of conditions on the Stalker-Patton drainage during snowmelt was made by walking the creek banks in March 1978 and again in February, 1979. Loving Creek was surveyed in April 1978 and February 1979. Silt entering the water from wind erosion was measured by placing wind-fall collection buckets at 15 sites.

The third objective of the study was to characterize deposited sediment with respect to depth, weight, particle size, and organic content. This information was gained by taking core samples and depth measurements.

The final objective of the study has been an attempt to intergrate the available information into a comprehensive analysis of sediment movement within the Silver Creek drainage system.

MATERIALS AND METHODS

Field Methods

Fifteen site visits were made between March 1978 and May 1979 and samples were collected on fourteen of these occasions. Types of samples collected and field data recorded are listed in Table 2.

Six routine sampling stations were established, three on Silver Creek and one each on Stalker, Grove, and Loving Creeks (Fig. 2, 1-6). Water was collected with a depth-integrating sampler (Rainwater and Thatcher 1960) for measurement of turbidity, total dissolved solids, and sediment. Current velocity was measured with either a Price Meter or an Ott Meter and morphometric parameters (stream width and depth) were recorded.

The depths of deposited sediment were measured at fourteen sites (Fig. 2, A-N). Sites A, M, and N are on Stalker Creek, Loving Creek, and Sullivan Slough, respectively; other sites are on Silver Creek. At each site ten depth measurements were taken equidistant apart along a cross-sectional transect.

During snowmelt in the spring of 1978 and again in 1979, a survey of the Stalker Creek drainage was made by walking along the banks of the creek from the Pumpkin Road bridge to Highway 20. A survey of Loving Creek during snowmelt in 1979 included the section of the stream between the Hayspur Fish Hatchery and the Gannet Highway. The purpose of these surveys was to gain general information on the morphology and hydrology of the drainages as well as to identify point sources of sediment. Photographs were taken and water samples collected. During the 1979 survey of Stalker Creek it was noted that its major tributary, Chaney Creek, had extensive sediment deposits. Therefore, in March 1979 Gordon Beebe made a survey of the Chaney-Cain Creek drainage and collected water samples

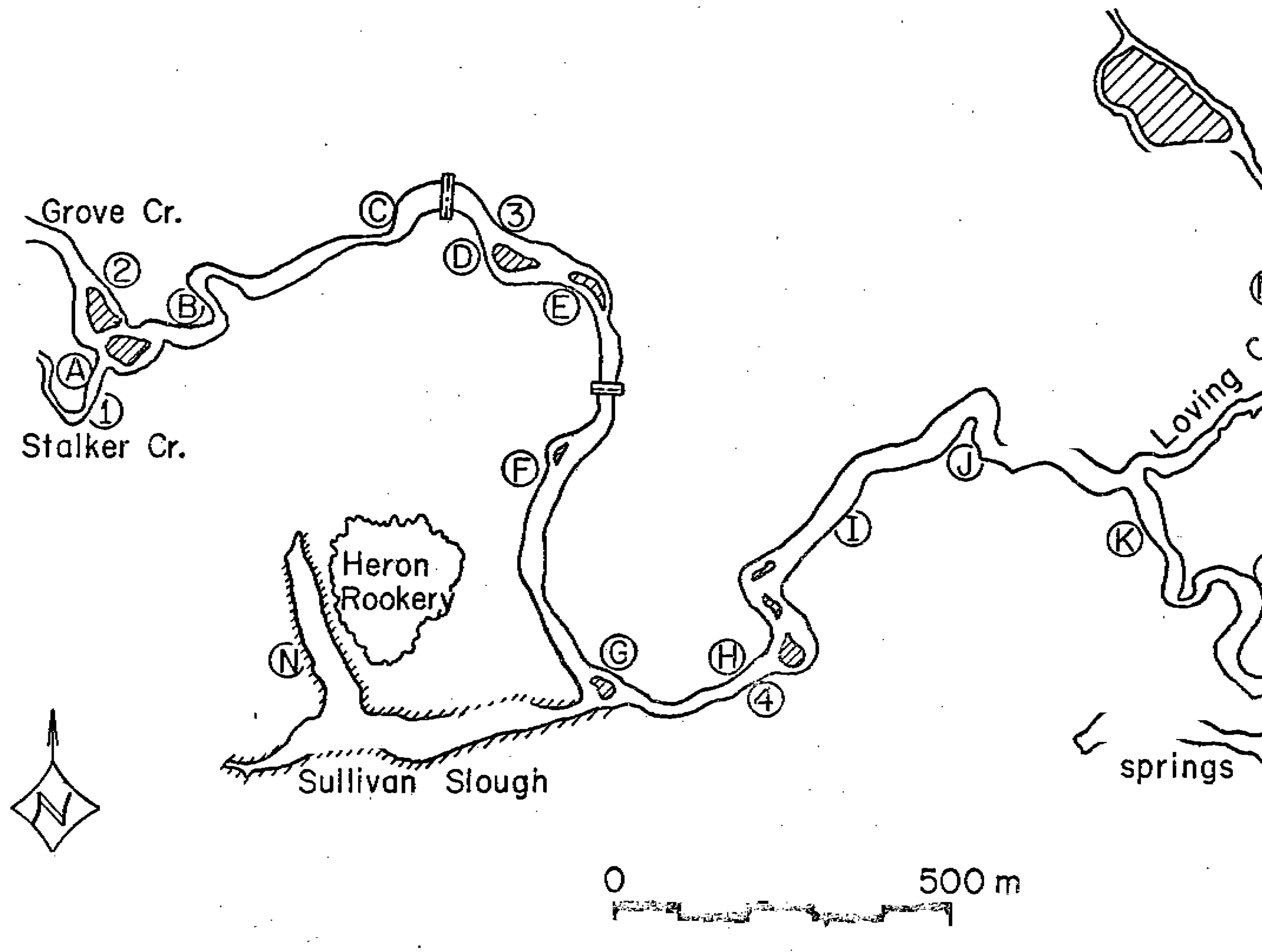
Table 2. Dates of site visits to Silver Creek, surveys, sample collection,and field data

	Suspended Sediment	Width Depth Velocity	Wind Borne Silt	Sediment Cores	Sediment Depths	Survey of Stalker Drainage	Survey of Loving Drainage	Su Ch Dr
March 1978	X	X				X		
April "	X[a]	X[a]	X				X	
May "	X	X	X	X	X			
June "	X	X	X		X (slough)			
July "	X	X	X	X				
Sept. "	X	X						
Nov. "	X	X	X		X			
Jan. 1979	X	X						
Feb. "	X	X				X	X	
March "	X[b]							X
April "	X	X	X					
May "	X	X	X					

[a]Samples collected at beginning, middle, and end of month.

[b]Field sampling by Gordon Beebe.

Figure 2. Location of suspended sediment sampling stations (1-6) and deposited sediment transects (A-N).



Grove Cr.
Stalker Cr.
A
B
C
D
E
F
G
H
I
J
K
N
1
2
3
4
Heron Rookery
Sullivan Slough
Loving C
springs
N
0
500 m

which were sent to the Idaho State University laboratory for processing.

Forty core samples were collected with a Welco sampler for dry weight determination. These data were coupled with depth measurements to develop a ratio of dry weight of deposited sediment to sediment depth. This ratio, together with the additional sediment depth measurements from the 11 sites on Silver Creek, was used to estimate the total amount of sediment deposited in the section of Silver Creek between the confluence of Stalker and Grove Creek and the Kilpatrick Bridge.

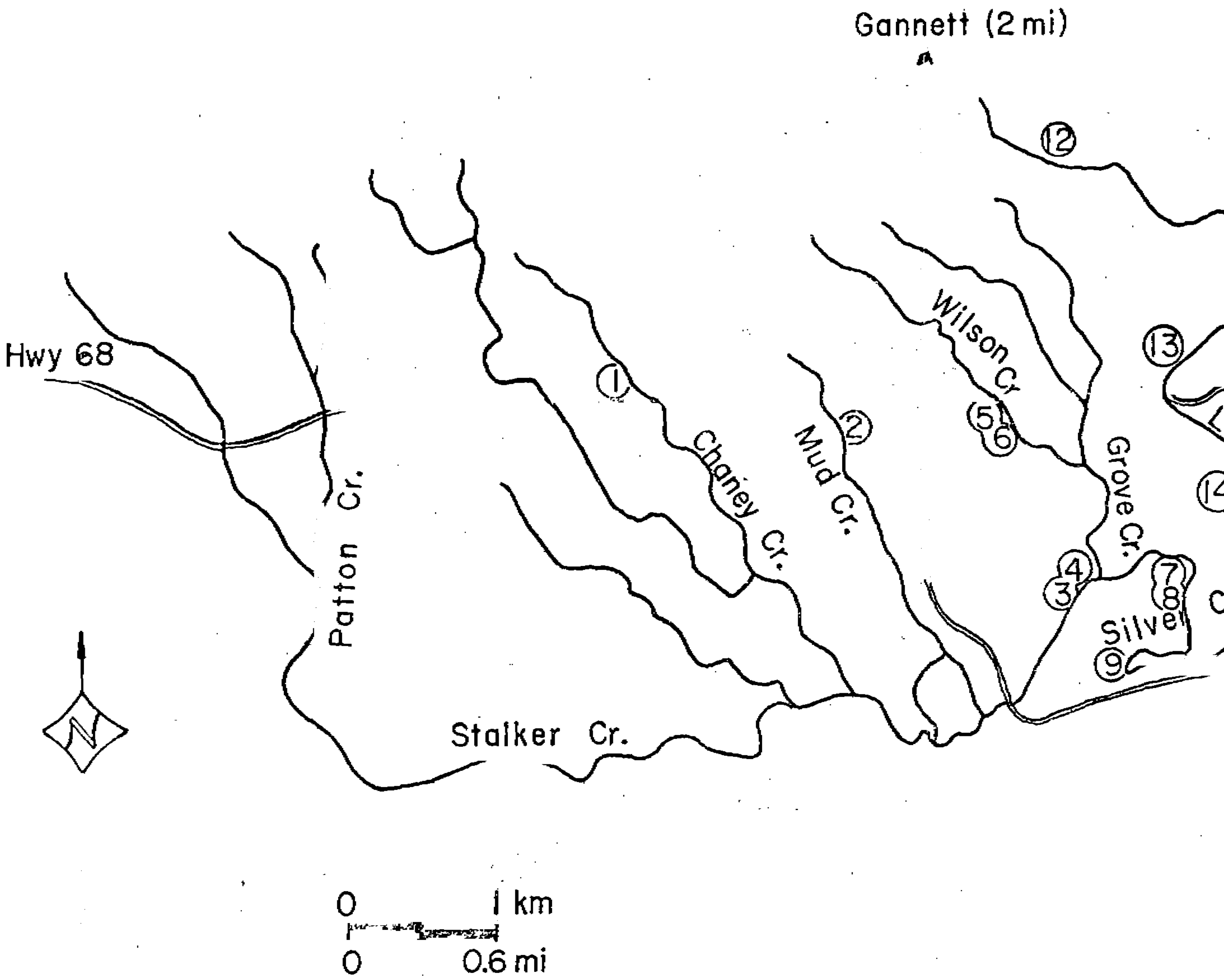
Additional core samples were taken on Stalker and Silver Creek to determine the relationships between particle size, organic content, and sediment depth.

Wind-borne silt was collected in 666-cm^2 traps located above the water surface approximately 1 meter from the bank at 15 locations (Fig. 3). A dilute formalin solution was added to the traps during the 1978 sampling period to prevent algal growth and preserve insects which entered. It was later decided that the formalin solution was unnecessary, therefore it was not used after November 1978.

From November 1978 through January 1979, thousands of ducks were present on the preserve, and were concentrated close to our Stations 3 and 4 on Silver Creek. Water samples collected in January were tested for phosphate, nitrate, and ammonia, to determine if there was a correlation between these nutrients and locations with high duck density.

Laboratory Procedures

Laboratory processing of water samples yielded measurements of turbidity, total dissolved solids (TDS), and sediment. Sediment was separated into settleable and non-settleable fractions and these were, in turn, separated into organic and inorganic fractions. Values for sediment concentration ($mg \cdot l^{-1}$) coupled with discharge data yielded estimates of total sediment transport. The initial step in processing water samples was measurement of turbidity (HACH, Model 2100 A Turbidimeter).



Gannett (2 mi)
Hwy 68
Patton Cr.
Chaney Cr.
Mud Cr.
Wilson Cr.
Grove Cr.
Silve
Stalker Cr.
1
2
3
4
5
6
7
8
9
12
13
0 1 km
0 0.6 mi

Next, a measured quantity of the sample was poured into an Imhoff cone and allowed to settle for 45 minutes. The water was then swirled with a glass stirring rod to resuspend material that had settled on the sides of the cone. Following an additional 15 minute settling, all but 5-15 ml of the water was decanted, separating settleable from non-settleable material. Both fractions were filtered through pre-ashed, tared, GF/F glass filters (pore size 0.8μ). To measure total dry weight, organic weight, and inorganic weight, the filters and residue were dried at 60 C for at least 24 h, cooled in a desiccator, weighed, ashed at 400 to 425 C for 4 h, returned to the 60 C drying oven for 24 h, cooled in a desiccator and reweighed.

Dry weight of wind-borne silt was determined either by filtering the sample through 0.8μ filters, or drying the entire sample including the dilute folmalin solution which added approximately 500 mg per sample. In the latter procedure, 500 mg was subtracted from the total weight of the dried sample. The amount of silt entering the creek was calculated by dividing the dry weight of the sample by the number of days the sampler had been in place, and the result expressed as $mg \cdot m^{-2}$ of stream surface area.

Dry weight of sediment deposited in the stream bed was estimated by drying the 40 core samples at 60 C and weighing to the nearest 0.0001 g. The relationship of particle size and organic content to sediment depth and location within the stream was tested by separating other core samples into four sections each 2.3 cm in depth (4 x 2.3 = 9.2 cm total depth). Because in the process of taking the core the sediment was compressed, this depth actually represented greater than 9.2 cm of sediment in the stream. Some of the cores were deeper than 9.2 cm even after compressed, but only the top four 2.3 cm sections were used in the analyses. Each section was then separated into seven size classes (>4mm, 1-4 mm, 0.5-1 mm, 0.25-0.5 mm, 0.106-025 mm, 0.052 mm, and <0.052 mm). Organic and inorganic weights of each size were obtained by ashing dried samples (see method for determining organic and inorganic weight of suspended sediment).

Concentrations of nutrients were determined colorimetrically using Hach reagents and a Bausch and Lomb Spectronic 20.

Conductivity was measured on filtered water. The relationship between total dissolved solids and conductivity, determined empirically (APHA, 1976) for Silver Creek, was used to calculate total dissolved solids. Calculations and data reduction were facilitated by the use of computer program designed specifically for this study.

RESULTS

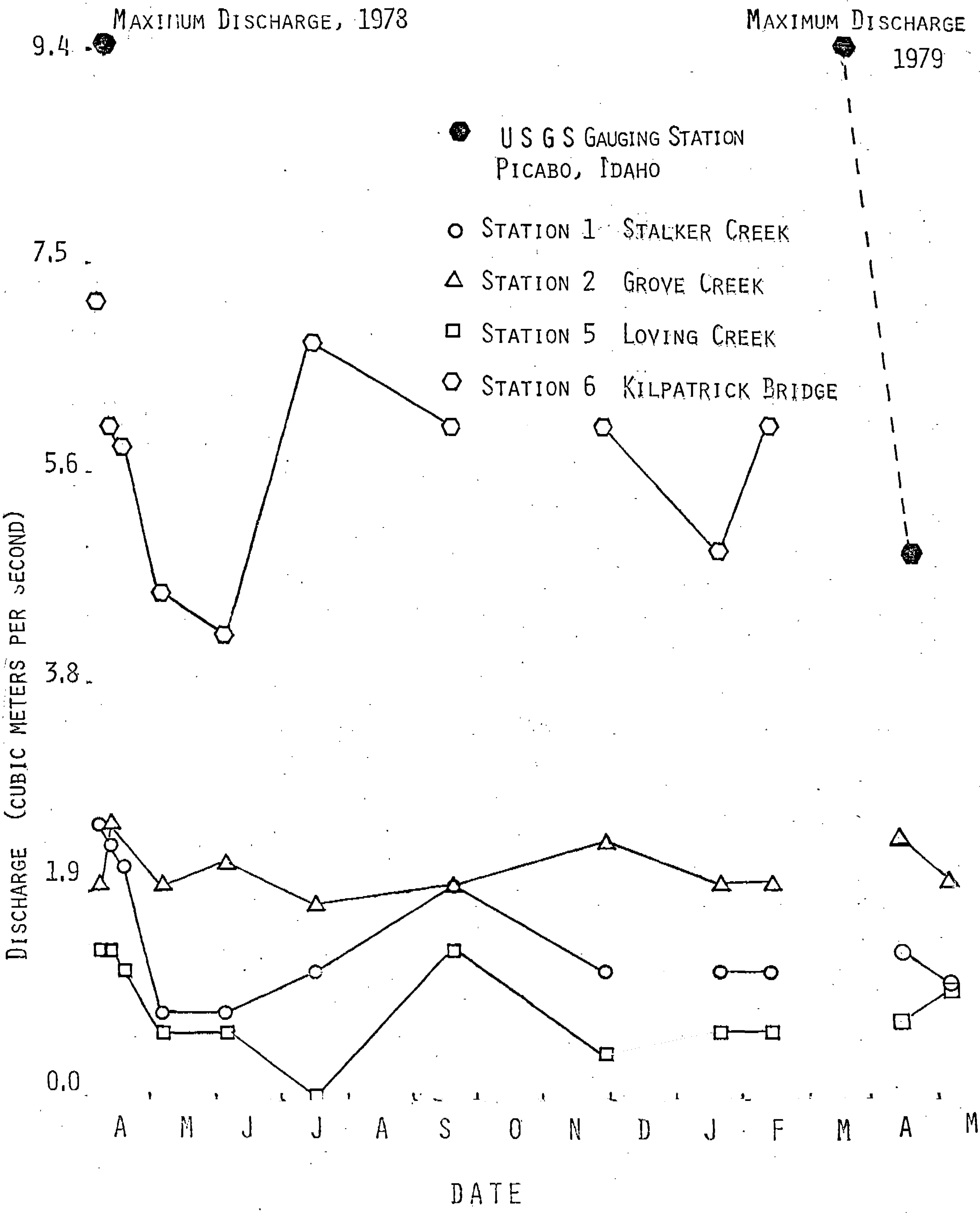
Transport of Suspended Sediment and Dissolved Matter

The concentration and quality (whether settleable or non-settleable, organic or inorganic) of sediment carried by Silver Creek and its tributaries varied with time and between sites. Sediment concentration, multiplied by discharge determines the total sediment load. These variables, together with data on dissolved material are addressed in this section of the report. Much of the information is presented in graphic form to facilitate rapid interpretation of data. Additional data are given in the nine appendices, which include some information that will not be discussed in detail in the report but may be of value at some future date.

Discharge

The primary source of water to Silver Creek is the underground aquifer system. Water emerges as springs which join to form the principal tributaries, Stalker, Grove, and Loving Creeks. Silver Creek also receives flow from springs upstream of Kilpatrick Bridge, from Sullivan Slough, and from numerous small seeps. Snowmelt contributes a significant but variable amount to the annual water budget. Additional sources are irrigation return and local storm events.

Of the three major tributaries, Grove Creek contributed the greatest volume of water to Silver Creek during the study period between 24 March 1978 and 3 May 1979 (Fig. 4). Rate of discharge was relatively uniform in Grove Creek, and ranged from a high of 2.46 m^3/sec on 1 May 1978 to a low of 1.86 m^3/sec on 7 July 1978.



Maximum Discharge, 1978
Maximum Discharge
1979
U S G S Gauging Station
Picabo, Idaho
Station 1 Stalker Creek
Station 2 Grove Creek
Station 5 Loving Creek
Station 6 Kilpatrick Bridge
9.4
7.5
5.6
3.8
1.9
0.0
Discharge (cubic meters per second)
A M J J A S O N D J F M A M
DATE

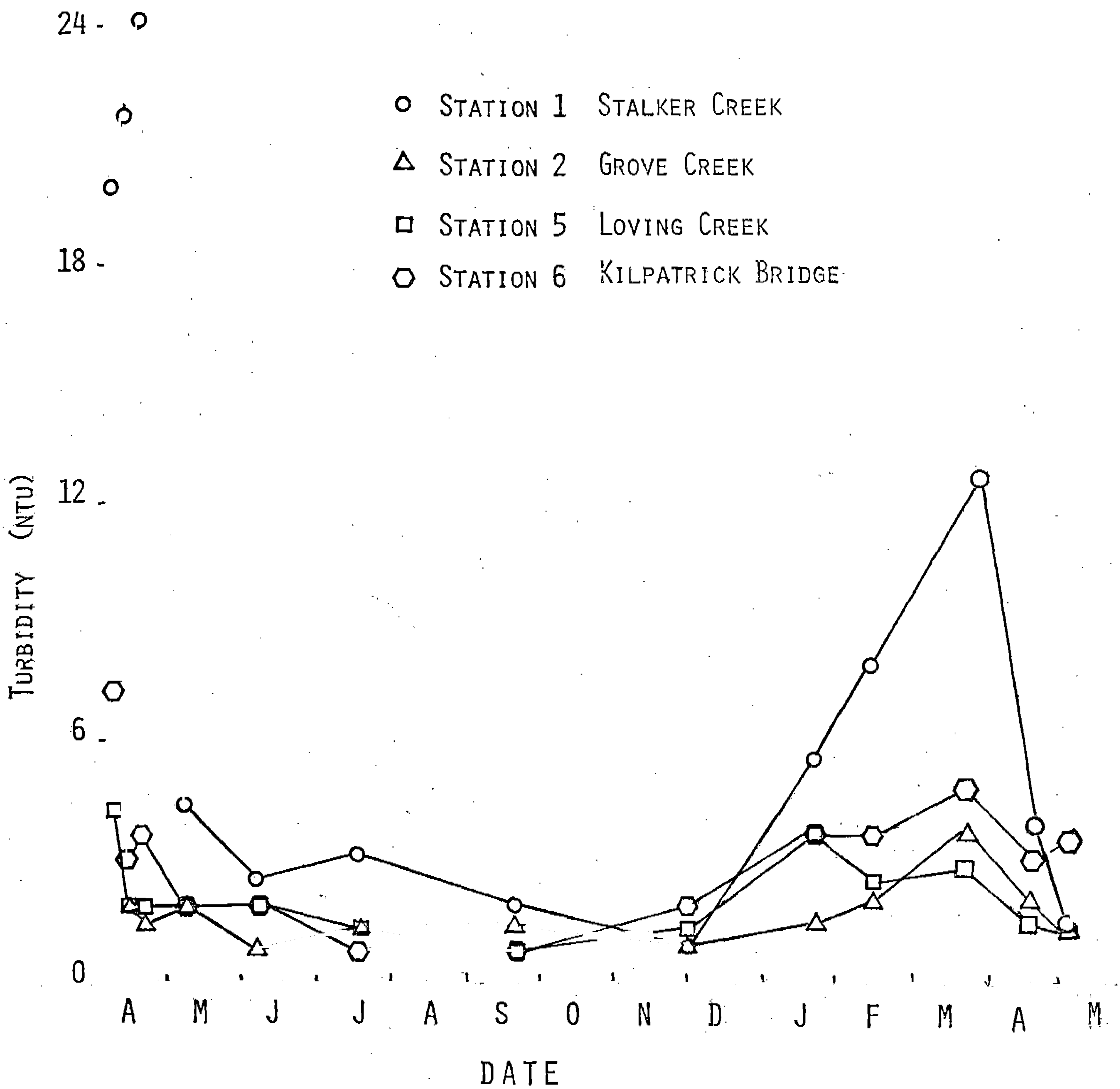
Although the highest discharge recorded for any of the three tributaries occurred on Stalker Creek (24 March 1978) discharge on Stalker Creek decreased significantly during summer and fall. Thus the total contribution of water from Stalker Creek during the study was only two-thirds as much as from Grove Creek. Discharge in Loving Creek ranged from 1.48 m^3/sec on 1 April 1978 to less than 0.25 m^3/sec on 10 July 1978.

The highest value recorded in this study was 7.21 m^3/sec at the Kilpatrick Bridge (Station 6) on 24 May 1978. Unfortunately, samples were not taken on the day of maximum discharge either in 1978 or in 1979. However, at this time of year water is not diverted for irrigation, therefore discharge at the USGS gauging station at Picabo is roughly equivalent to that at the Kilpatrick Bridge. USGS records indicate that in 1978 discharge peaked on 28 May at 9.48 m^3/sec. Maximum discharge in 1979 (9.43 m^3/sec) which occurred on March 16 was almost identical to the 1978 maximum. Although maximum discharge was about the same for the two years, the relative amounts contributed by snowmelt differed. This is because in 1978 an undercharged aquifer (which therefore contributed less than normal amount of flow, Table 1) was coupled with a high snowpack whereas in 1979 the aquifer was normally charged but the snowpack was less.

Turbidity

Turbidity, expressed as nephelometric turbidity units (NTU) is caused by the absorption and scattering of light by suspended matter, and changes in turbidity are generally associated with changes in suspended solids. Turbidity should not be confused with amber staining that results from high concentrations of humic acids, which occur occasionally in Silver Creek associated with flooding of the adjacent marsh.

Highest values for turbidity were found in Stalker Creek (Station 1) where the range was from 24.0 NTU on 7 April 1978 to 0.9 NTU on 26 November 1978 (Fig. 5). Turbidity was generally low in Grove Creek (Station 2) with a high



24
18
12
6
0
Turbidity (NTU)
Station 1 Stalker Creek
Station 2 Grove Creek
Station 5 Loving Creek
Station 6 Kilpatrick Bridge
A M J J A S O N D J F M A M
DATE

of only 3.7 NTU and a low of 0.7 NTU. Values for the other four stations were intermediate between that of Stalker and Grove Creeks. (See Appendix 11 for data on stations 3 and 4.)

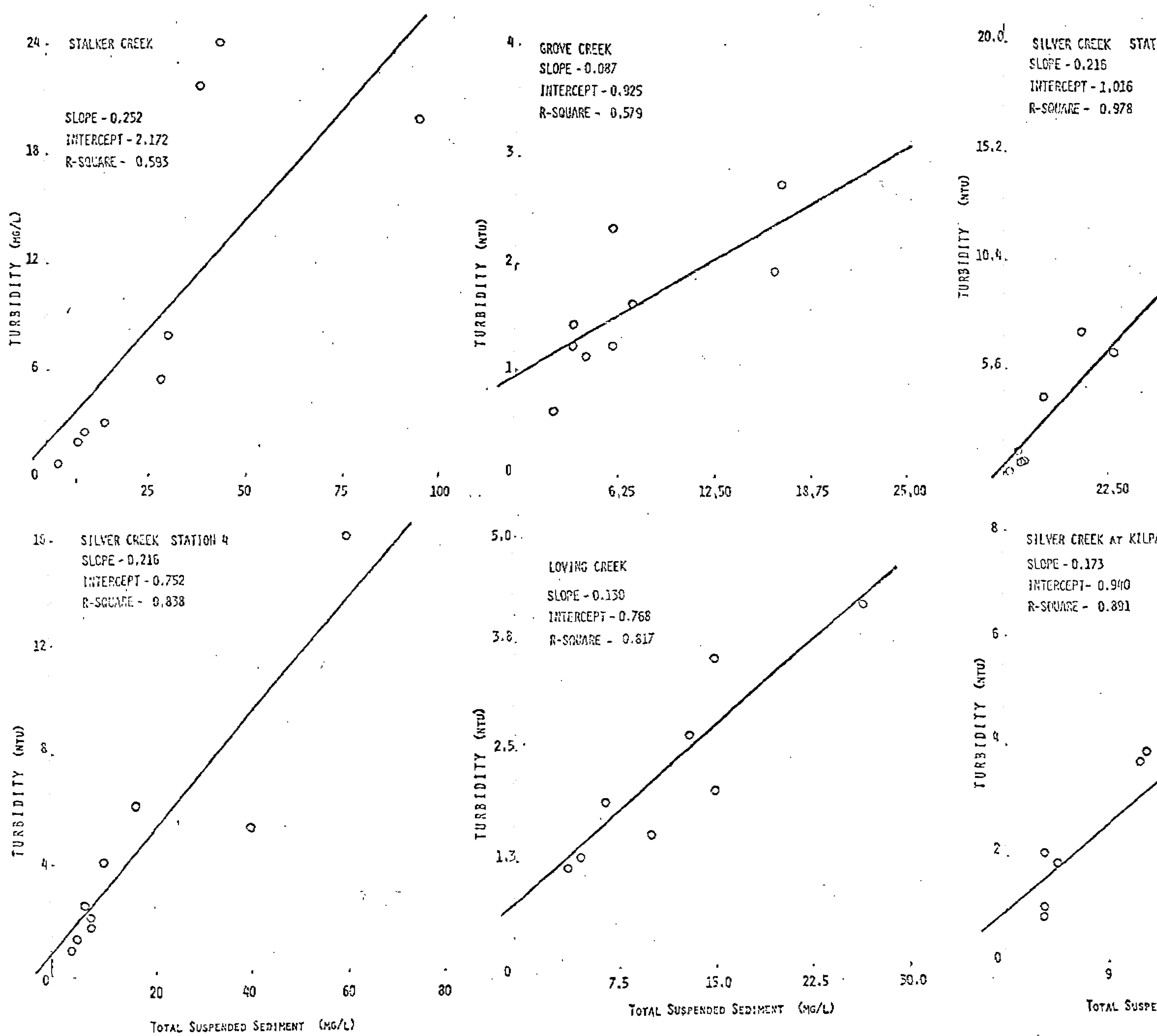
Turbidity was high at all stations during spring runoff then steadily declined through the remainder of 1978. Increase in discharge in the spring of 1979 was accompanied by increase in turbidity, with Stalker Creek again having the highest values.

Turbidity as an Index of Sediment Concentration

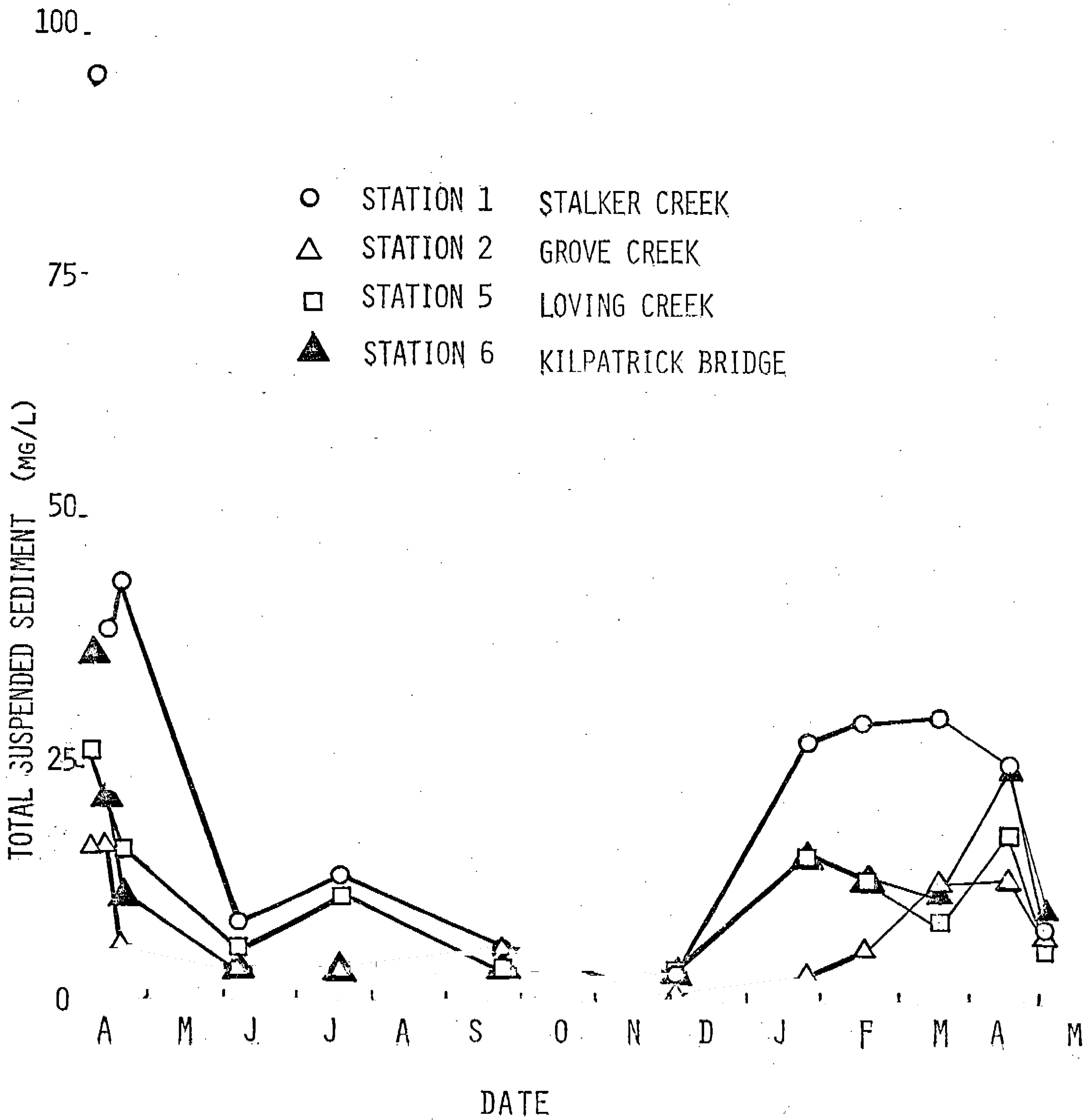
Measurement of turbidity is a quick and inexpensive method of monitoring changes in concentration of suspended sediment. However, the correlation of NTU to concentration of sediment varies among streams. The relationship between turbidity and sediment for the six sampling sites in this study was examined and values for the coefficient of determination (r^2) were calculated individually at each site (Fig. 6). They ranged from 0.579 for Station 2 to 0.978 for Station 3. The correlation between turbidity and sediment at the Kilpatrick Bridge ($r = 0.94$) is high enough that the use of turbidity measurements might be considered as a substitute for the more elaborate and expensive methods of sediment estimation that have been employed in this study.

Concentration of Sediment

Total sediment (settleable + non-settleable, organic + inorganic) concentrations were high in late March 1978 during snowmelt runoff (Fig. 7). Although values were relatively high for all sampling sites, there were large differences among the stations with concentrations ranging from 16.7 mg $\cdot$ l^{-1} at Station 2 (Grove Creek) to 96.4 mg$\cdot l^{-1}$ at Station 1 (Stalker Creek). Concentrations at all stations were reduced dramatically after runoff, and lowest values for Stations 1 and 2 occurred in November (2.9 and 1.6 mg$\cdot l^{-1}$ respectively). At this time there were thousands of ducks concentrated between Stations 3 and 6, and the increase in suspended sediment at these stations (see Appendix III for Stations 3 and 4) may have been



STALKER CREEK
SLOPE - 0.252
INTERCEPT - 2.172
R-SQUARE - 0.593
TURBIDITY (MG/L)
GROVE CREEK
SLOPE - 0.087
INTERCEPT - 0.925
R-SQUARE - 0.579
TURBIDITY (NTU)
SILVER CREEK STAT
SLOPE - 0.216
INTERCEPT - 1.016
R-SQUARE - 0.978
TURBIDITY (NTU)
SILVER CREEK STATION 4
SLOPE - 0.216
INTERCEPT - 0.752
R-SQUARE - 0.838
TURBIDITY (NTU)
TOTAL SUSPENDED SEDIMENT (MG/L)
LOVING CREEK
SLOPE - 0.130
INTERCEPT - 0.768
R-SQUARE - 0.817
TURBIDITY (NTU)
TOTAL SUSPENDED SEDIMENT (MG/L)
SILVER CREEK AT KILP
SLOPE - 0.173
INTERCEPT - 0.940
R-SQUARE - 0.891
TURBIDITY (NTU)
TOTAL SUSPE


100
75
50
25
0
STATION 1 STALKER CREEK
STATION 2 GROVE CREEK
STATION 5 LOVING CREEK
STATION 6 KILPATRICK BRIDGE
TOTAL SUSPENDED SEDIMENT (MG/L)
A M J J A S O N D J F M A M
DATE

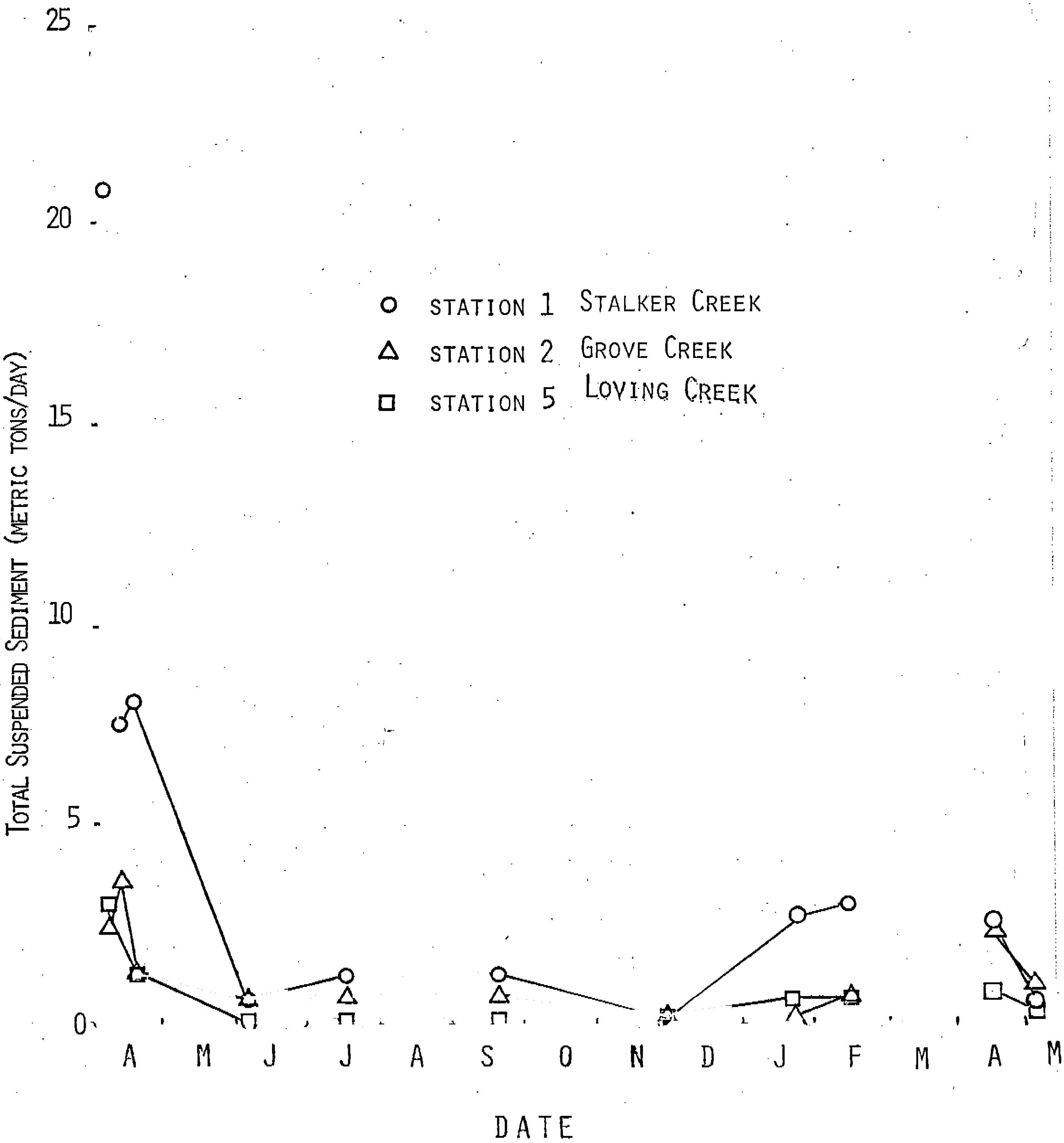
caused by their feeding activities. Ducks were observed cropping aquatic plants, and stirring up the deposited sediment.

Extremely cold weather in December and early January resulted in extensive ice-cover in Stalker and Silver Creeks. Plant mortality was high and when the ice thawed in late January deposited sediment, no longer protected by vegetation, became entrained in the water column. This resulted in increased sediment concentrations in Stalker and Silver Creeks prior to snowmelt runoff. Temperatures were higher in Grove Creek and high plant densities were maintained throughout the winter. Since plants tend to hold sediment, this may explain the low concentrations of suspended sediment entering Silver Creek from Grove Creek.

Even during runoff, sediment concentrations in 1979 did not reach 1978 levels at any station, and by May the levels had again dropped.

Total Sediment Load

The amount of sediment transported by a stream is a function of discharge as well as concentration and is expressed as a rate, i.e., metric tons per day (10^6 g/d). Estimates of sediment carried by Stalker, Grove, and Loving Creeks, are compared in Figure 8. During spring runoff sediment load was much higher in Stalker Creek (21 tons/day) than in Grove (2.8 tons/day) or Loving Creeks (3.1 tons/day). By late May sediment loads were reduced to 1.0 tons/day in each of the three tributaries. Sediment concentrations in Stalker Creek continued to exceed those of Grove Creek, but discharge in Stalker Creek dropped below that of Grove Creek and for the remainder of 1978 the two creeks transported about equal amounts of sediment into Silver Creek. Sediment load in Loving Creek was usually low. By November, values had dropped to 0.5 tons/day in each tributary. Then, in January 1979, there was a dramatic increase in sediment transported by Stalker Creek. Discharge remained low (Fig. 4) and the increase in sediment load resulting from higher sediment concentrations (Fig. 7). Although air



25
20
15
10
5
0
STATION 1 STALKER CREEK
STATION 2 GROVE CREEK
STATION 5 LOVING CREEK
TOTAL SUSPENDED SEDIMENT (METRIC TONS/DAY)
A M J J A S O N D J F M A M
DATE

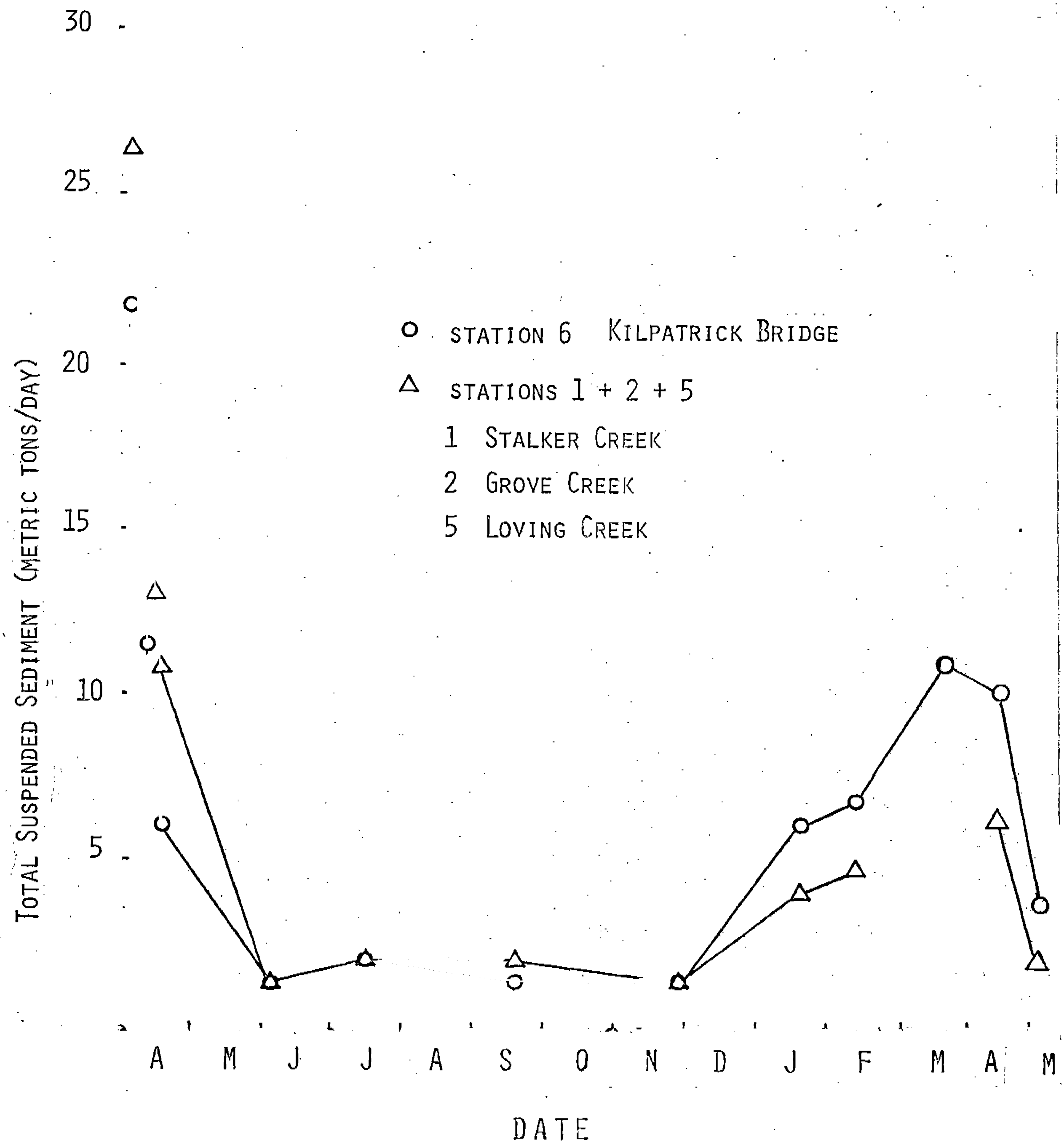
temperatures had increased and ice in the streams had melted, the snowpack remained on the fields. Therefore, the most likely source of sediment was Stalker Creek itself, that is, the re-entrainment of sediment that had been previously deposited.

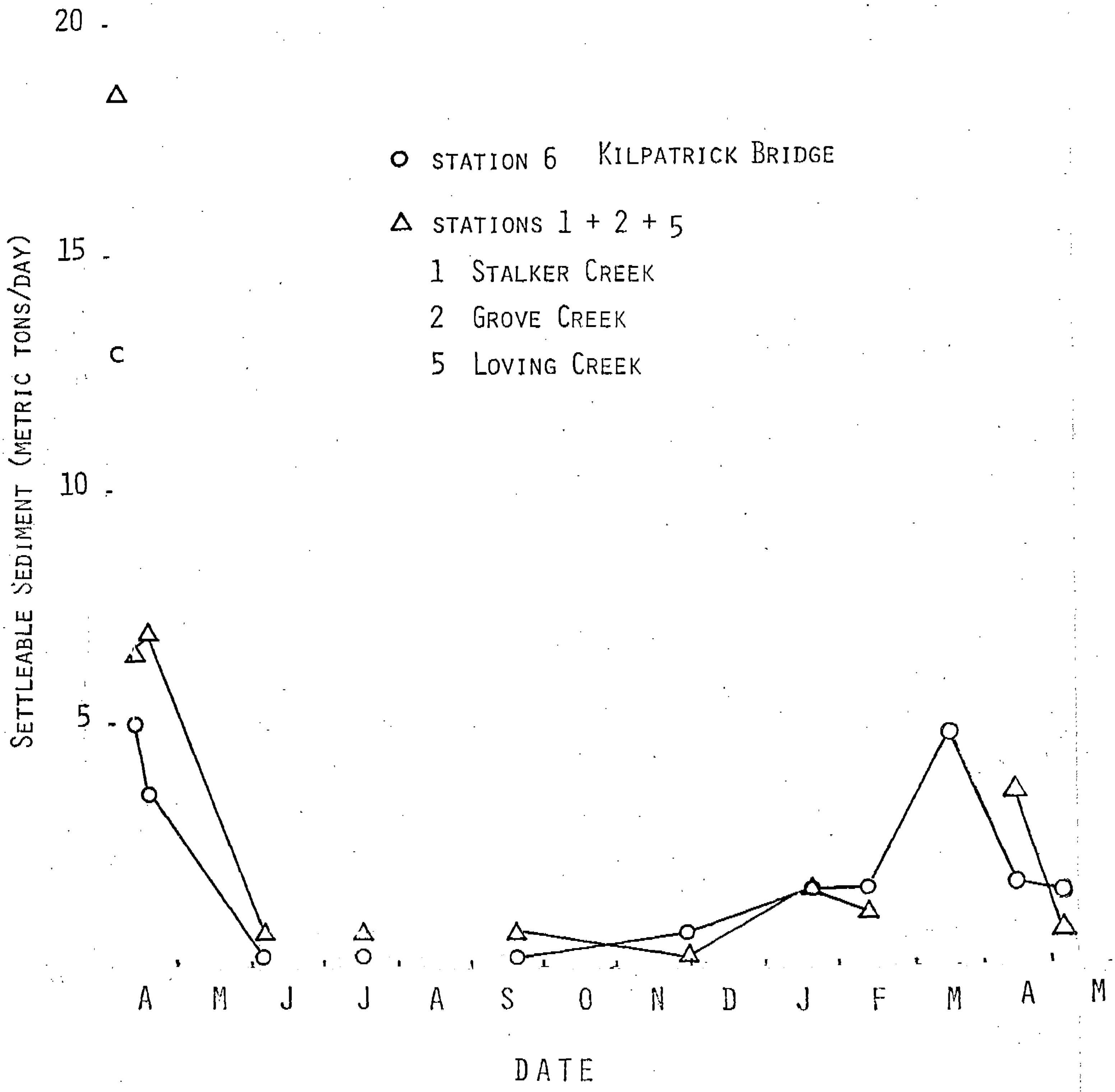
Since discharge data are not available for the tributaries for March 1979, peak values for sediment load during snowmelt runoff cannot be calculated. However, a comparison of sediment concentrations suggests that the total sediment load during 1979 runoff was less than in 1978.

The amount of sediment transported past the Kilpatrick Bridge (Station 6) is compared with the amount entering Silver Creek from Stalker, Grove, and Loving Creeks in Figure 9. Sediment entering from Sullivan Slough and other springs is considered negligible. During runoff in 1978 more sediment entered Silver Creek than was transported past Station 6, indicating a net accruel (deposition) of sediment in the stream. However, during the remainder of the year (late May through November 1978) sediment entering Silver Creek was balanced by the amount transported past Station 6. Sometime after the November sampling part of Purdy Dam was removed, lowering the water level in the stream. The increase in sediment transport at Station 6 may be the result of this change. Beginning with the sampling in January 1979 and continuing through May there was a net movement of sediment out of the section of Silver Creek that lies within the boundary of the Nature Conservancy Preserve.

Movement of settleable sediment (defined as that fraction of suspended sediment that will settle out within one hour in an Imhoff core) into and out of this section of Silver Creek followed a similar pattern (Fig. 10). Net losses were recorded in November (when ducks were stirring up the deposited sediment), February, and in May.

Sediment was also separated into organic and inorganic fractions. Percent inorganic matter was slightly lower in Grove Creek (62 $\pm$ 25) than in Stalker Creek (75 $\pm$ 9) but differences were not significant. Values for the other


30
25
20
15
10
5
STATION 6 KILPATRICK BRIDGE
STATIONS 1 + 2 + 5
1 STALKER CREEK
2 GROVE CREEK
5 LOVING CREEK
TOTAL SUSPENDED SEDIMENT (METRIC TONS/DAY)
A M J J A S O N D J F M A M
DATE



20
15
10
5
SETTLEABLE SEDIMENT (METRIC TONS/DAY)
O STATION 6 KILPATRICK BRIDGE
△ STATIONS 1 + 2 + 5
1 STALKER CREEK
2 GROVE CREEK
5 LOVING CREEK
A M J J A S O N D J F M A M
DATE

stations were intermediate between those of Stalker and Grove Creeks. The breakdown of data into total, settleable, non-settleable, and inorganic settleable material ($mg \cdot l^{-1}$) are given in Appendices III through VI but will not be discussed further in the text.

Dissolved Solids

Dissolved materials (TDS) accounted for about 90 percent of the material transported by Silver Creek. In contrast to suspended sediment, concentrations of TDS did not fluctuate seasonally, and there were no significant differences between stations. Mean concentrations at Stations 3, 4, and 6 on Silver Creek were 241, 238, and 264 $mg \cdot l^{-1}$. Loving Creek was intermediate with 255 $mg \cdot l^{-1}$ while Stalker and Grove Creek had slightly lower concentrations (225 and 227 $mg \cdot l^{-1}$). Under conditions where the CO_2 concentration is reduced, such as by photosynthesis or from diffusion into the air at riffles, dissolved material is precipitated out as calcium carbonate (marl or travertine). The process is especially conspicuous immediately below the bridge upstream of Sullivan Slough. In this section of the creek water runs swiftly over the more or less plantfree streambed, which is cemented by marl. By disturbing the streambed it was revealed that beneath this armour of marl lay the remains of extensive Chara beds. A possible sequence of events would be that Chara impeded the flow of water, forcing it above the plant beds in a more shallow, but swifter current. The increase in velocity (and also the photosynthetic activities of the plants) reduced the concentration of CO_2 which in turn caused the precipation of marl. The plants became heavily encrusted with marl and were not washed downstream but remained in place. This resulted in an elevation of the streambed and continued precipitation of calcium carbonate until the entire surface became sealed over. Loose sediment which had previously deposited in and around the Chara beds was entrapped in this process and no longer available for entrainment into the water column. Rates of calcium carbonate precipitation were not measured in this study, but they did not appear to be sufficiently great enough to cause a reduction in the concentration of TDS.

Impact of Ducks

In November 1978 thousands of ducks were observed on Silver Creek, concentrated between Stations 3 and 6, particularly just downstream of Station 4. They blanketed the stream banks with fecal material and cropped aquatic vegetations, particularly Chara. Plants became dislodged and floated downstream, and the disturbed sediment became entrained in the current. Concern about the impact of fecal material on water quality led to a decision to analyze water samples for plant nutrients. Samples were collected in January. By that date the duck population was considerable reduced, but still numbered in the hundreds.

Nitrate concentrations in Stalker and Grove Creeks were 0.04 and 0.1 $mg \cdot l^{-1}$, respectively, but increased to 0.22 $mg \cdot l^{-1}$ at Station 3 and 0.27 $mg \cdot l^{-1}$ at Station 4. However, at the Kilpatrick Bridge the concentration dropped back to 0.1 $mg \cdot l^{-1}$. Samples collected at Station 5 and immediately below the Purdy Dam also had only 0.1 $mg \cdot l^{-1}$ nitrate. Ammonia and phosphate levels were below the sensitivity of the methods used for analysis.

Wind-borne Sediment

Westerly winds predominate in the Silver Creek area. Data gathered in 1975 approximately 4 km from the Preserve indicate that for 70% of the records, winds were from the west, southest, or northwest. Highest velocities typically occur in May and June; in 1975, the average velocity for the 2-month period was about 7.5 mph.

Wind data were not available for 1978-1979, but estimates made by Gordon Beebe for April-May 1978 indicate roughly 40% of the time wind was 10-20 mph, 5% for 35-40 mph, and 1% for 45-50 mph. In 1979, wind speed was considerably less than in 1978, with little or no high wind occurring in April-May.

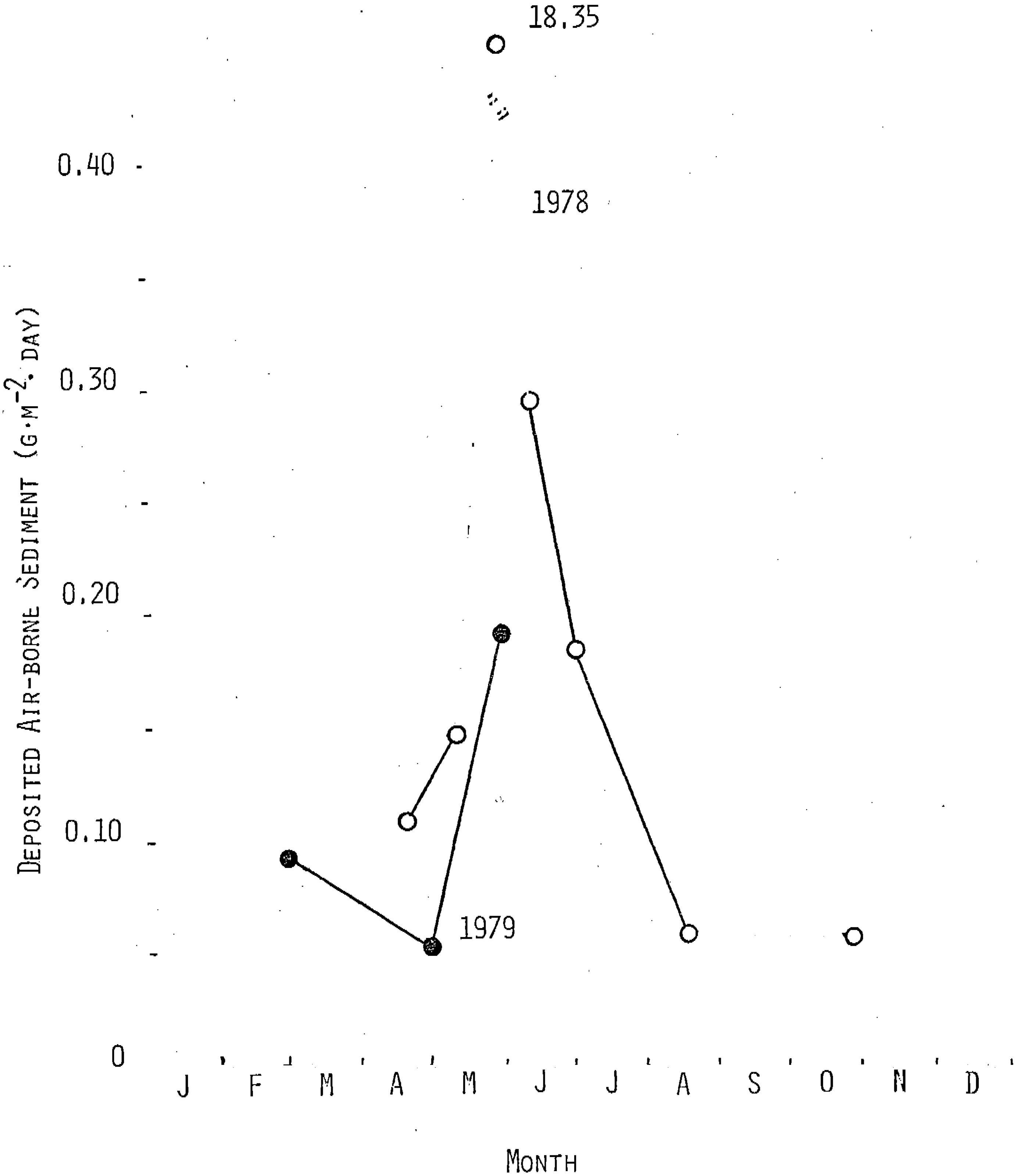
The stream acts as an effective "stilling basin" to trap air-borne material. Readings from a hand-held anemometer showed that wind velocities at the top of the samplers were 1/3 to 1/6 that at the surface of adjacent fields.

Data derived from the air-borne sediment traps should be regarded as minimal estimates of the amount of material actually being deposited in the stream because some material carried by horizontal air currents did not settle out in the containers.

Sediment deposition increased from a "background level" of approximately 0.10 g dry weight $\cdot m^{-2} \cdot day^{-1}$ in late summer, fall, and winter to maximum values in April-May in both 1978 and 1979 (Fig. 11). Values in April-May 1978 were about 1/3 those of 1978 if the sample from station 7A on 8-23 May 1978 is excluded and much less than this if that sample is included (Table 3). That sample was taken while bare field were being worked and winds over 20 mph were common. A special sample taken on 23 May 1978 for 2 hrs at station 15 downwind from the Preserve's field C contained the equivalent of 294 $g \cdot m^{-2} \cdot day^{-1}$.

Of the 114 samples collected during both years, 58% were 0.10 $g \cdot m^{-2} \cdot d^{-1}$ or less, 34% were 0.11-1.00 $g \cdot m^{-2} \cdot d^{-1}$, and 8% were greater than 1.00 $g \cdot m^{-2} \cdot day^{-1}$ (Table 3). During the 410-day sampling period, the total deposition of wind-borne sediment on to one square meter of stream surface would have been 315 g, averaging data from all stations. If the sample of 8-23 May 1978 from station 7A is excluded, this average would be about 51 g.

That portion of the Silver Creek drainage that is included on the Preserve has a surface area of approximately 100,000 m^2. A sediment accrual of 0.1 $g \cdot m^{-2} \cdot d^{-1}$ over the entire water surface would add a total of 10 kg of dry material per day. A 1 g rate would add 100 kg/day, and a 300-g rate would mean the deposition of



18.35
1978
1979
0.40
0.30
0.20
0.10
0
Deposited Air-borne Sediment (g·m⁻²·day)
J
F
M
A
M
J
J
A
S
O
N
D
Month

Table 3. e of deposition of sediment in wind-borne silt traps ($g \cdot m^{-2} \cdot d$. Sampling stations marked in pairs were selected to assess effects of various buffers.

Tributary	Station No.	Buffer Type and Width, m		SAMPLING PERIOD 4/8-23	4/24-5/7	5/8-23	5/24-6/9	6/10-7/10	7/10-9/15	9/15-11/28	1/21-4/19	4/17-5/3	5/5-6/6
Stalker Creek	1	rose	– 0.8	<0.01	0.27	2.37	0.04	0.06	---	---	---		
Stalker Creek	2	grass and rose	-27	<0.01	0.05	0.46	0.11	0.63	0.01	---	0.10		
Stalker Creek	3	willows	-61	<0.01	0.08	0.12	.01	0.21	<0.01	< .01	0.06	0.05	0.04
Stalker Creek	4	grass and rose	-16	<0.01	0.30	0.46	0.01	0.09	0.03	<0.01	0.05	0.04	0.08
Grove Creek	5	grass	-11	0.00	0.04	0.23	0.09	< .01	---	0.08	0.09	0.03	0.11
Grove Creek	6	grass	-67	1.35	0.29	0.35	0.17	< .01	---	---	0.06	0.05	0.06
Silver Creek	7A	grass	– 9	<0.01	0.11	265.31	1.57	0.29	0.26	0.16	0.05	0.04	0.36
Silver Creek	7B	opposite 7A	---	---	---	---	---	---	---	---	---	0.14	0.06
Silver Creek	8	willows	-35	---	---	0.40[a]	0.00	0.20	---	0.14	0.06	0.03	1.12
Silver Creek	9	grass and rose	-10	<0.01	0.12	1.11	0.03	0.19	---	---	---	---	---
Silver Creek	10A	grass	-14	<0.01	0.05	0.55	---	---	---	<0.01	---	0.07	0.14
Silver Creek	10B	opposite 10A	---	---	---	---	---	---	---	---	---	0.03	0.05
Silver Creek	11	grass and cattails	-45	<0.01	0.23	0.51	0.01	---	---	0.02	---		
Loving Creek	12	none		<0.01	0.13	0.19	1.35	0.24	0.06	---	0.12	0.05	0.16
Loving Creek	13	rose	– 1.5	---	---	1.57	.01	0.08	---	---	---		
Loving Creek	14	willows	-60	0.11	0.05	0.16	0.26	---	---	---	0.21	0.04	0.09
Loving Creek	15	grass and rose	-45	<0.01	0.08	1.64	0.46	---	0.01	<0.01	0.09	0.05	0.06

[a] Sampler 200 m downstream from station 7 until 8 May, when it was relocated 60 m away.

30,000 kg (a layer about 1mm thick) per day. During our study, the average rate of deposition was between 0.1 and 1.0 $g \cdot m^{-2} \cdot day^{-1}$.

We attempted to assess whether wind-borne material is deposited across the entire width of the stream or is concentrated in the windward side. Samplers situated on the bank opposite normal stations (Stations 7 and 10, Table 3) gave inconclusive results. On one occasion the windward sampler collected significantly more material than the leeward sampler, on two occasions slightly more, and on one occasion slightly less. It seems logical to speculate that when the wind is moderate and the source of material is restricted to a particular field, sediment is likely to be much heavier on the windward side of the stream. When wind velocity is higher and sediment chokes the entire valley, it is being deposited over the entire stream surface.

Samplers were located to enable evaluation of the effectiveness of vegetation (primarily grasses, wild rose and willows) in intercepting air-borne sediment before it could enter Silver Creek. Comparison between 2 pairs of samplers (Stations 3 vs. 4 and 7A vs. 8) assesses the effects of willows. For the former set of stations, deposited sediment was 47% lower in the sampler protected by willows and for the latter set, the reduction was 86%, suggesting willows are effective. Other types of vegetation appear to have much less effect, with Stations 6 and 11 showing no reduction in deposition over Station 5 and 10. Personal observations indicate that buffer zones composed of grasses and roses do trap some air-borne sediment, but at times of substantial sediment movement their effects are minimal.

Deposited Sediment Depth

Site locations for depth measurements of deposited sediment are shown in Figure 2 (A-N). Sites A, M, and N are on Stalker Creek, Loving Creek, and Sullivan Slough, respectively; other sites are on Silver Creek.

Sediment depth was variable in Stalker Creek and the upper portion of Silver Creek and there were large areas of streambed which were free of sediment (Table 4), indicating that the stream may be simultaneously eroding at one spot and depositing in another, sometimes in close proximity. Mean depths for each of the eight upstream sites ranged from 2.6 cm at site F to 11.1 cm at site H and the overall mean depth for lower Stalker Creek and the upstream section of Silver Creek was 7.0 cm. Downstream sites (I-L) had a mean depth of 25.4 cm, and closer to the Kilpatrick Bridge sediment occurs at depths greater than 1 meter.

Forty core samples were taken (together with depth measurements) and from these a ratio of dry weight/m^2 to depth was calculated. On this basis, and together with the 130 depth measurements, the mean weight of sediment in Silver Creek is estimated to be 0.05×10^6 g (metric tons/m^2) or 5000 metric tons of sediment (dry weight) in the section of Silver Creek between the confluence of Stalker and Grove Creeks and the Kilpatrick Bridge.

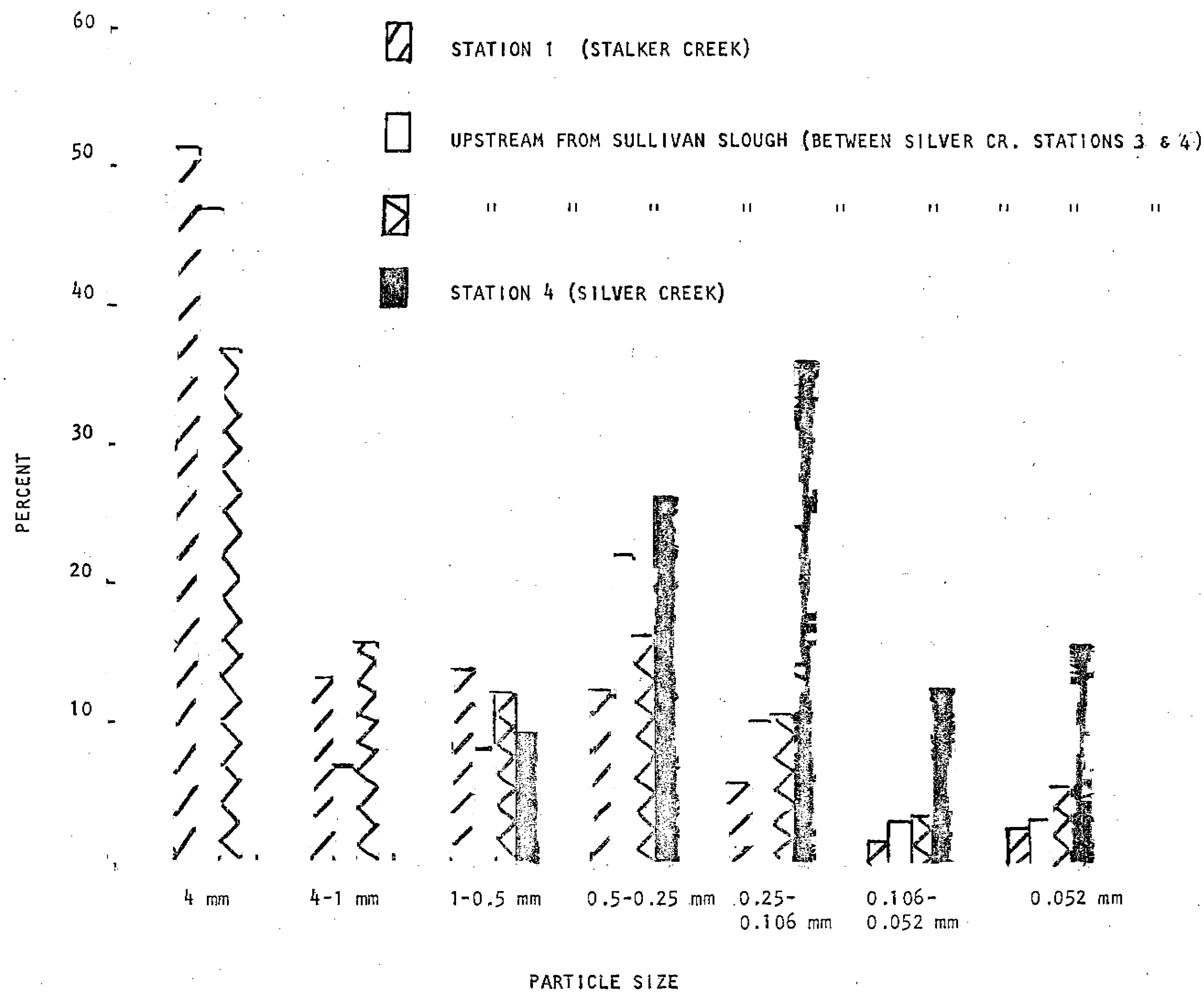
Measurements taken in November indicat that sediment had increased in Stalker Creek. The areas of deep sediment deposits were associated with dense plant beds. Upstream sites on Silver Creek showed a slight decrease in sediment depth. More significant changes occurred at Site 1 where mean depth decreased from 19.2 cm in May to 11.9 cm in November. This decrease may have resulted from the activities of ducks that fed on aquatic plants in this section of the Creek. There was an increase in turbidity im this section, presumably resulting from disturbance of the sediment. It is not known whether or not the effects of the ducks was sufficient to account for the observed differences in sediment depth.

Particle Size of Deposited Sediment

The relative amounts of material in each of seven size-classes for four core samples are shown in Figure 12. The largest size class (> 4 mm) predominates in the upstream sites (Stalker Creek, and Silver Creek upstream from Sullivan Slough) but at Station 4 over 60% of the material is less than 0.25 mm (middle diameter of

Table 4. Deposited sediment depths (cm) in Stalker, Silver and Loving Creek.

	SITE												
	(Stalker Creek) A	B	C	D	E	F	G	H	I	J	K	L	(Loving Creek) M
Individual Measurements May 1978													
1	40	0	7	1	3	0	18	9	22	24	46	12	15
2	0	10	0	9	10	0	19	0	21	19	0	7	25
3	0	0	0	0	1	0	0	3	23	17	40	25	28
4	0	0	3	7	5	0	1	0	20	18	39	22	28
5	0	0	0	4	17	0	2	0	14	14	0	15	18
6	0	7	7	0	12	0	23	7	23	17	10	8	18
7	14	5	0	0	0	1	18	13	17	14	17	8	24
8	10	13	9	0	0	6	17	18	21	13	0	3	31
9	12	11	33	5	6	4	12	23	14	0	13	8	32
10	11	7	41	4	0	15	1	23	17	0	9	4	32
$\bar{X}$ Depths May 1978	8.7	5.3	10.0	3.0	5.4	2.6	11.1	9.6	19.2	13.6	17.4	11.2	25.1
$\bar{X}$ Depths Nov 1978	16.0	5.9	6.5	1.1	-	-	-	8.0	11.9	-			


STATION 1 (STALKER CREEK)
UPSTREAM FROM SULLIVAN SLOUGH (BETWEEN SILVER CR. STATIONS 3 & 4)
" " " " " " " " "
STATION 4 (SILVER CREEK)
PERCENT
60
50
40
30
20
10
4 mm
4-1 mm
1-0.5 mm
0.5-0.25 mm
0.25-0.106 mm
0.106-0.052 mm
0.052 mm
PARTICLE SIZE

particle) and over 25% is less than 0.052 mm. There appears to be a trend toward downstream decrease in particle size, but since only four samples were analyzed, caution must be exercised in generalizing from these data. They are, however, consistent with the visual observation that fine sediment blankets much of the stream beyond Station 4.

Organic Matter in Deposited Sediment

Sediment cores were partitioned into four sections with respect to depth. Each section was then separated into seven particle size classes and organic matter was determined for each fraction. In one of the core samples collected upstream from Sullivan Slough particles less than 1 mm contained 4.0% organic matter (Table 5). When particles $>$1 mm were included the organic fraction was reduced to 3.6%. Organic matter was inversely related to particle size and for each size-class it was greatest close to the surface of the core, decreasing with depth below the streambed. Thus, organic matter ranged from 0.5% of the large particles most remote from the streambed to 12.8% for small articles near the surface.

Profile of Sediment Depth Across Sullivan Slough

Mean sediment depth in Sullivan Slough is 20.2 cm and varies from 2 to 40 cm as shown in the depth profile (Fig. 13). Since springs are the primary source of water into Sullivan Slough, and very little water comes in from overland drainage, a significant fraction of the sediment in the slough may be airborne in origin. However, analysis for percent organic matter may show that the sediment is derived largely from dead plants.

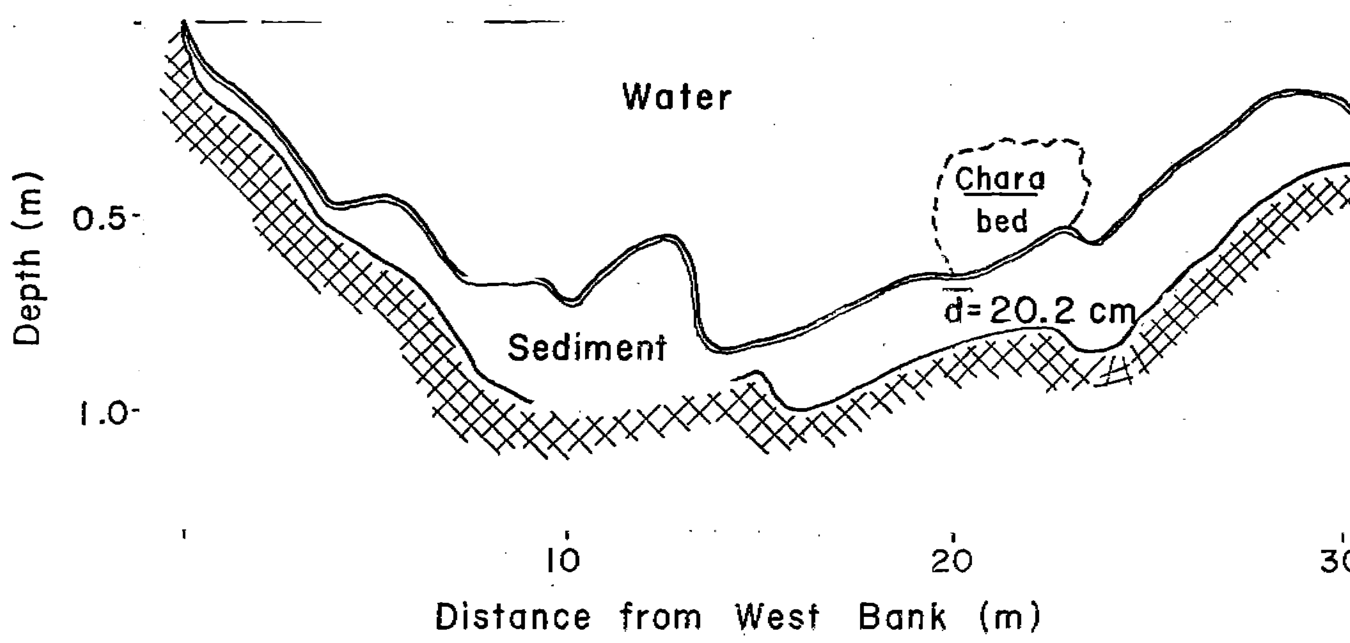
Special Sampling on Stalker Creek

Water samples were collected along Stalker and Patton Creeks and the lower Patton Drain in late March, 1978. Sampling stations and concentrations of sediment are shown in Figure 14. Values for turbidity and settleable and the inorganic settleable fractions of the sediment, total dissolved solids are given in Table 6. At the time of sampling, snowmelt was well underway and Stalker Creek

Table 5. Percent organic material in deposited sediment from a core sample collected upstream of Sullivan Slough.

Particle Size (mm)	Depth 0-2.3 cm	2.3-4.6 cm	4.6-6.9 cm	6.9-9.2 cm	Mean for all depths
0.5 - 1.0	6.8%	1.4%	0.9%	0.5%	2.4%
0.25 - 0.5	5.2	1.1	1.1	0.6	2.0
0.106 - 0.25	6.5	2.2	1.9	1.0	2.9
0.052 - 0.106	7.7	3.4	3.6	1.8	4.1
<0.052	12.8	9.8	6.9	4.2	8.4
Mean for all particle sizes	7.8	3.6	2.9	1.6	

Grand Mean for all depths and particle sizes = 4.0%



Water
Chara
bed
d̄= 20.2 cm
Sediment
Depth (m)
0.5
1.0
10
20
30
Distance from West Bank (m)

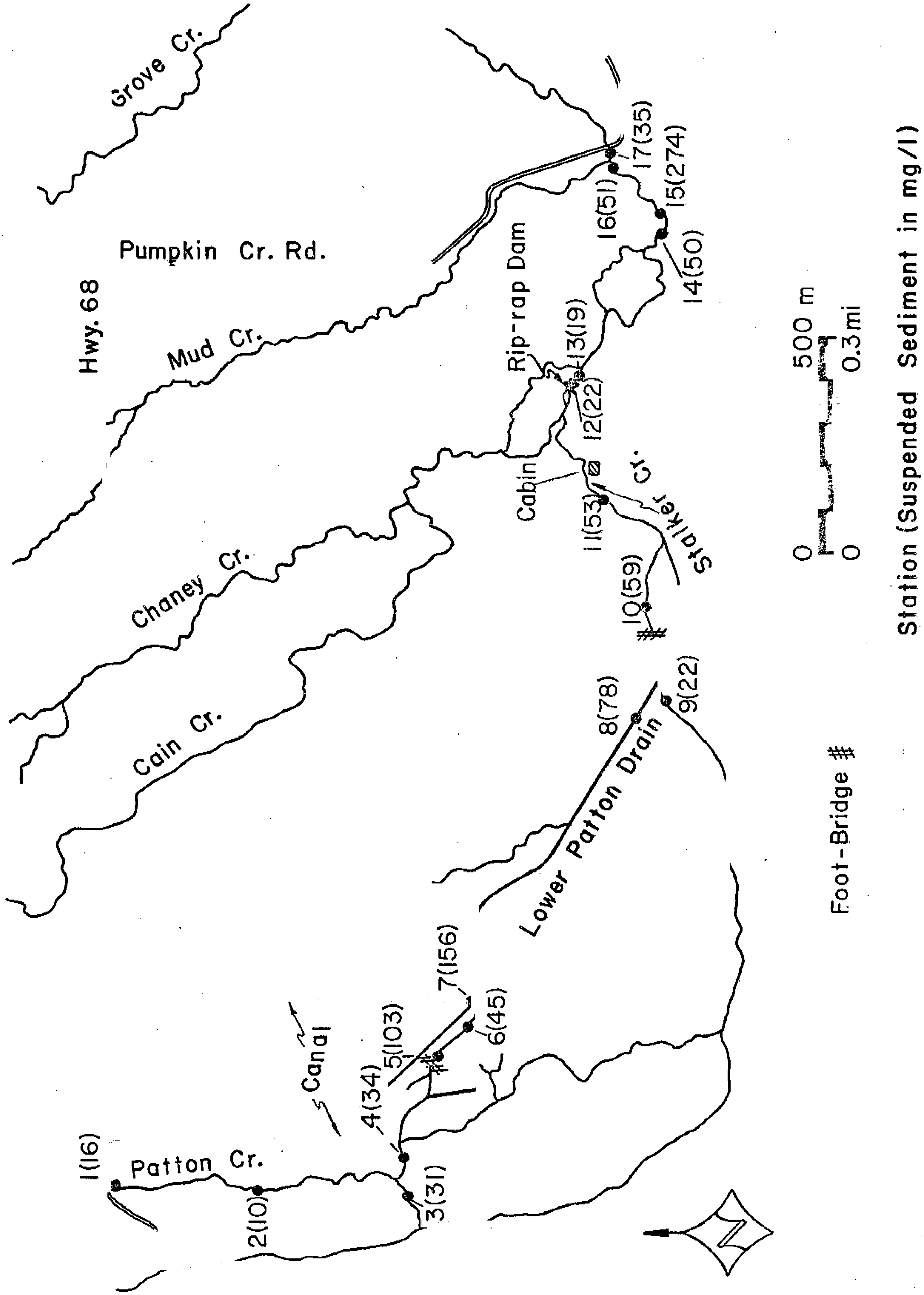

Grove Cr.
Pumpkin Cr. Rd.
Hwy. 68
Mud Cr.
Chaney Cr.
Cain Cr.
Rip-rap Dam
Cabin
Stalker Cr.
Lower Patton Drain
Canal
Patton Cr.
1(16)
2(10)
3(31)
4(34)
5(103)
6(45)
7(156)
8(78)
9(22)
10(59)
11(53)
12(22)
13(19)
14(50)
15(274)
16(51)
17(35)
0 500 m
0 0.3 mi
Foot-Bridge
Station (Suspended Sediment in mg/l)

Table 6. Sediment ($mg \cdot l^{-1}$), dissolved solids ($mg \cdot l^{-1}$), and turbidity (NTU) in water samples collected at 17 sites on the Stalker-Patton Drainage, March 25 and 26, 1978. Numbers in parentheses are values for samples collected February 17, 1979.

Site	SEDIMENT Total	settleable	inorganic settleable	dissolved solids	turbidity
1	16.1 (2.2)	7.8 (0.1)	6.7 (0.1)	228 (252)	0.8
2	10.5	4.6	3.3	275	1.0
3	30.8	18.0	12.0	256	3.0
4	33.7	28.7	28.1	305	2.0
5	103.5	91.8	84.5	241	4.7
6	45.4	33.5	27.1	306	9.5
7	156.8	122.2	97.4	396	24.0
8	79.0 (12.0)	61.4 (3.1)	53.8 (3.1)	294 (266)	19.0
9	22.4	15.3	10.9	234	5.5
10	59.1	41.7	37.4	292	65.0
11	52.6 (10.2)	40.6 (2.1)	35.4 (2.1)	286 (277)	8.0
12	22.3 (17.0)	17.2 (2.0)	13.5 (2.0)	277 (263)	3.6
13	19.4 (19.1)	16.3 (1.7)	13.2 (1.7)	260 (254)	4.1
14	49.9	30.5	24.5	107	5.4
15	273.2	248.0	223.9	255	110.0
16	50.9	41.0	38.3	273	8.7
17	34.2 (59.1)	18.8 (34.0)	13.5 (26.2)	302 (214)	7.8

was approaching peak runoff. Snow still covered much of the ground but in many areas, especially along drainages, the soil was free of snow but saturated with water (Fig. 15a).

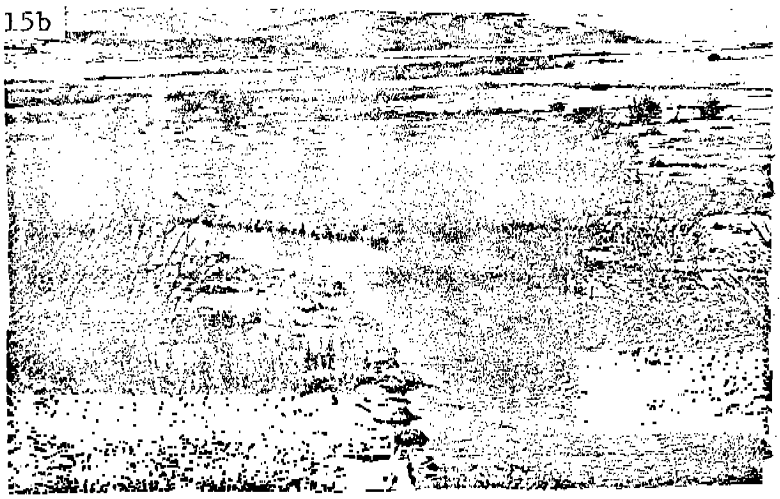
Sediment concentration at Station 1 on Patton Creek was 16 $mg \cdot l^{-1}$ and the general trend was toward a downstream increase. The creek is small at upstream sites, but increases downstream as the flow is augumented by springs, canals, and direct runoff from the fields. The stream banks have good cover of riparian vegetation (Fig 15b) in some places but elsewhere the banks are bare, sometimes steep, and vulnerable to erosion.

Immediately downstream from the confluence of Patton Creek with the Lower Patton Drain the drain is joined by waters of two canals (Station 7). Water flowing in from the canals was dark brown and contained 156 $mg \cdot l^{-1}$ sediment. Large piles of dirt line the banks along the drain (Fig. 15c) and constitute potential sources of sediment. The drain is relatively straight (Fig. 15d) and there is little natural impediment to the rush of water toward the confluence with Stalker Creek. Where they join, the concentration of sediment in the drain (Station 8, 78 $mg \cdot l^{-1}$) was much greater than in Stalker Creek (Station 9, 22 $mg \cdot l^{-1}$). Channelization continued downstream as far as Station 10 where sediment measured 59 $mg \cdot l^{-1}$. A dam at Station 12 has created a small lake that apparently serves as a settling basin, and sediment below the dam and at the next station was significantly reduced.

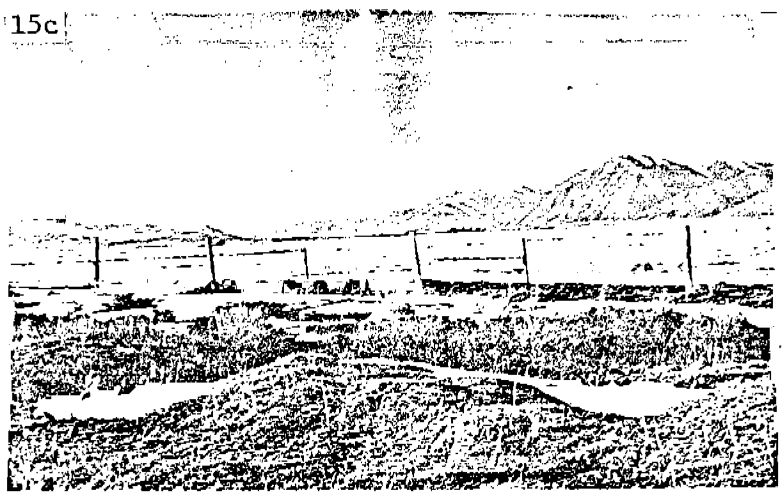
Sample 15 was taken from Stalker Creek just below the point where extremely muddy water drained into the creek from a bare, exposed slope (Fig. 15d). Sample 16 was taken just upstream from the confluence of Stalker Creek with Mud Creek, and Fig. 15f was taken on a sagebrush hillside above the sampling station. The final sample, taken immediately upstream from the Pumpkin Bridge had a sediment concentration of 35 $mg \cdot l^{-1}$.

15a

15b



15c



15d

15e

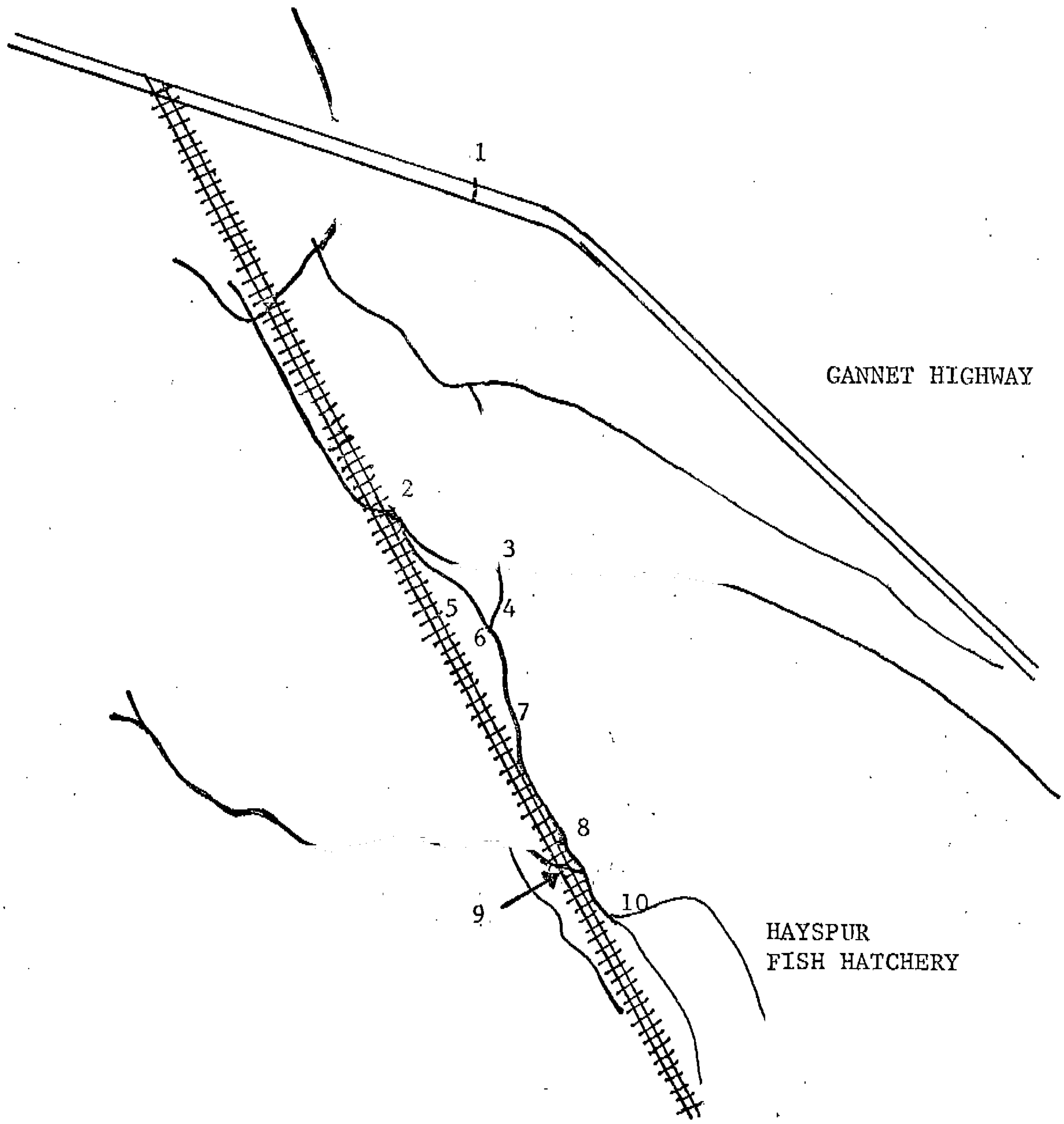
15f

A similar tour of the Stalker-Patton Drainage was undertaken in February 1979. Unseasonably warm weather had melted some of the snow, and peak runoff from this early melt had already passed (more snow accumulated later in the season, followed by melt and runoff in March). Samples were collected at several of the same sites as in 1978, and this additional data is included in Table 6. Sediment concentrations were much less than in 1978 and the relative amount in the 'settleable' fraction was only 4.5 to 58% compared to 44-91% in 1978.

Special Sampling on Loving Creek

The section of Loving Creek that lies within the Nature Conservancy Preserve is blanketed with silt. This condition is aesthetically unpleasing and provides poor fish habitat. Furthermore, during high flow some of the deposited sediment is re-entrained and carred into Silver Creek. At the time of the initial site visit in early March 1978, Loving Creek was extremely turbid and sediment concentrations appeared to be even greater than in Stalker Creek. In an attempt to locate the source of this sediment a limited survey was made of Loving Creek on April 1, 1978. Samples were taken at three locations, just above the diversion dam at the Hayspur Fish Hatchery, at Highway 68, and near the confluence with Silver Creek. Turbidity was low at each of these sites on this date. Peak discharge from snowmelt had passed and the reduced flow carried much less sediment than during March.

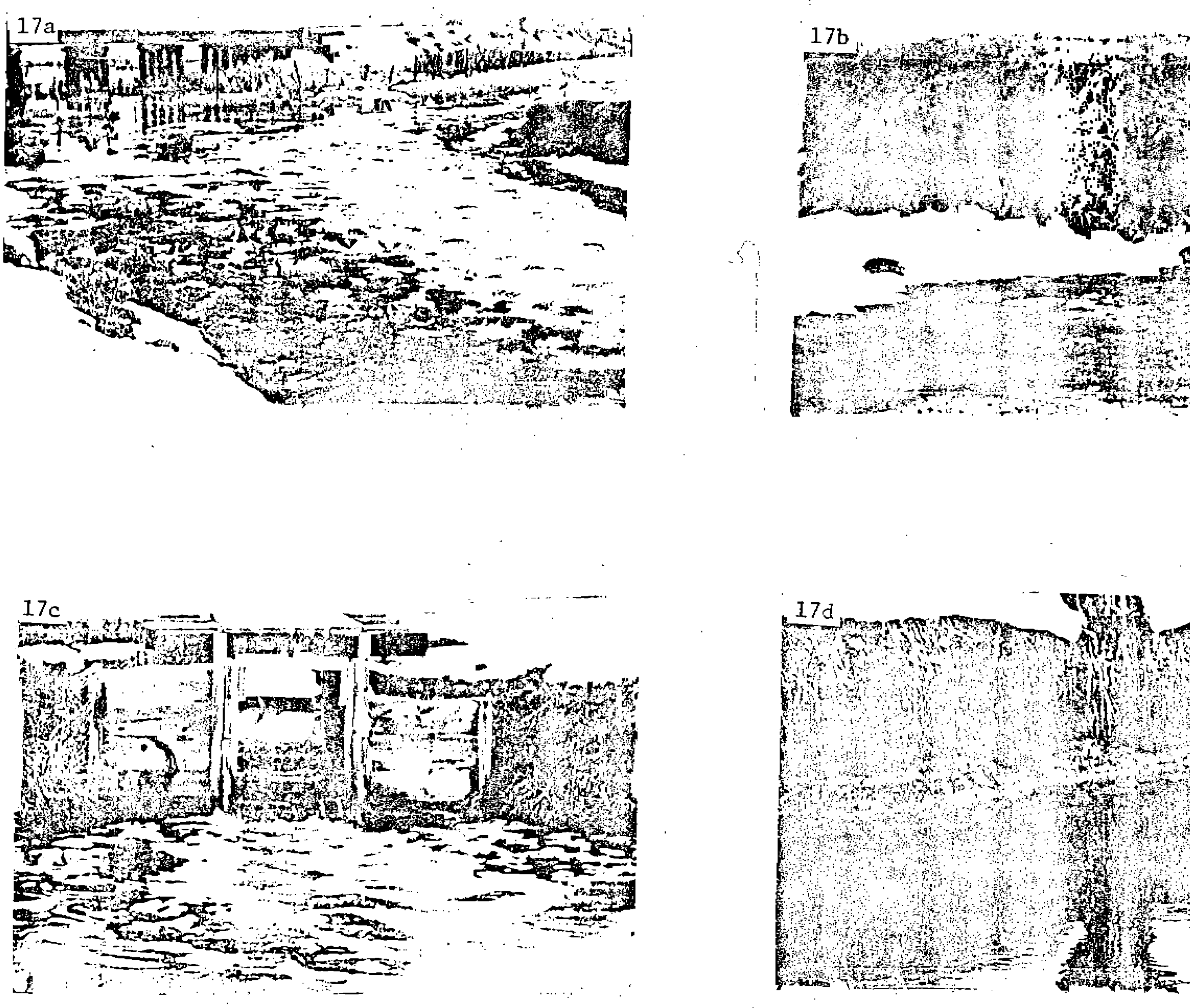
A more extensive survey of Loving Creek was made on 16 February 1979. This sampling followed a period of unseasonably warm weather which resulted in an early snowmelt. Sampling sites are shown in Figure 16. Site 1 is located at the point where the Gannet highway crosses Loving Creek. The water was stained amber and the concentration of sediment was 7.8 $mg \cdot l^{-1}$ (Table 7). Most of the land through which the stream flows between Site 1 and the fish hatchery is in pasture, and there appear to be no large areas under cultivation. The stream is intersected at several points by a network of canals. Photographs taken at Site 2 (Fig. 17a-b) show a canal in the upper right joined by a stream flowing under the railroad



LOVING CREEK DRAINAGE

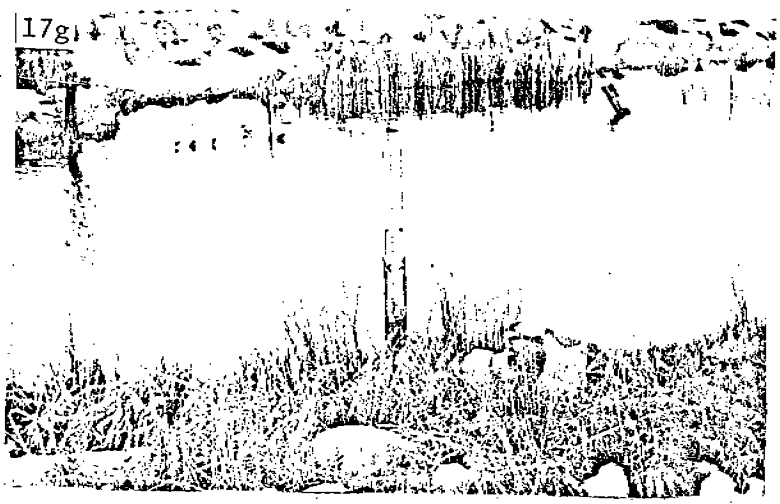
Table 7. Sediment (mg l^{-1}) and dissolved solids (mg·l^{-1}) from water samples collected in survey of Loving Creek 16 February, 1979. Photos at selected sites.

		SUSPENDED SEDIMENT				
Site	Total	Settleable	Non-Settleable	Inorganic Settleable	Dissolved Solids	Photos.
1	7.8	2.7	5.1	2.3	233	-
2	--	--	--	--	--	x
3	--	--	--	--	--	x
4	10.2	4.1	6.1	2.5	246	-
5	7.8	2.0	5.8	2.0	244	-
6	--	--	--	--	--	x
7	36.8	24.8	12.0	13.9	244	x
8	20.5	11.0	9.5	7.1	247	-
9	24.4	6.4	18.0	6.4	315	x
10	6.9	3.5	3.4	0.1	246	x
11	11.0	0.2	10.9	0.1	249	x
12	13.5	3.5	10.0	1.4	234	-


17a 17b 17c 17d


17e


17f


17g


17h

bridge. The canal continues on to the southeast, carrying part of the water. The canal is straight with steep baren banks, and there is nothing to hold back erosion during periods of high flow. The rest of the water at Site 2 flows south in the natural streambed. The photo in Figure 17c was taken at the intersection of this canal with Loving Creek, and is identified on the map as Site 3. The East Fork of Loving Creek was devoid of aquatic vegetation between Sites 3 and 4 (and for some distance upstream of Site 3) and silt covered much of the streambed. In contrast, vegetation was abundant in the West Fork. Silt, if present, was held in place by the plants. The differences between these two tributaries were very obvious at their confluence, and are reflected by the concentrations of suspended sediment at Sites 4 and 5 (Table 7). The eroding streambank shown in Figure 17d is located at Site 6, just below the confluence of the two tributaries. Roots from the pasture grass help bind the soil and probably retard the rate of erosion. Remains of vegetation caught on a fence give evidence of recent high water at Site 7 (Fig. 16, Fig. 17e) where suspended sediment concentration jumped to 36.8 mg l^{-1}. Although no source of sediment external to the stream was identified in the section between Sites 6 and 7, the streambed itself was covered with silt.

The concentration of suspended sediment at Site 8 was similar to that in the tributary (Site 9) which it confluenced with. Figure 17f shows the tributary passing under a railroad bridge about 50 m upstream of the confluence.

At Site 10 velocity decreased and the stream was almost lake-like (Fig. 17g). Silt deposits were deep and the amount of sediment in suspension dropped to 6.9 mg l^{-1}! Site 11 located at the downstream end of a culvert leading to a settling pond shows the hatchery, and Site 12 (identical with Station 5) had sediment concentrations of 11.0 and 13.5 mg l^{-1} respectively.

This survey failed to identify any point source of sediment into Loving Creek, although the canal system no doubt contributes some material during high flow.

The sediment in the streambed is no doubt a reservoir of silt which can become entrained by the water under certain conditions.

Special Sampling on Chaney-Cain Creeks

During the survey of Stalker and Patton Creeks in February 1979 it was noted that the streambed of Chaney Creek was silted in. Analysis of water samples collected from Chaney and Stalker Creeks above their confluence indicated that the sediment concentration in Chaney Creek (in February) was higher than in Stalker Creek. Discharge was about equal. These observations led to a survey of the Chaney-Cain Creek Drainage by Gordon Beebe of TNC.

On 22 March 1979 samples were collected from three sites in the Chaney-Cain Creek Drainage, from Stalker Creek above the confluence with Chaney Creek and at the Pumpkin Creek Road Bridge, and from Silver Creek at Kilpatrick Bridge (Fig. 18). Turibidty at Site 1 (Chaney Creek above confluence with Cain Creek) was very low (0.8 NTU) and total sediment only 5·mg 1^{-1}. In contrast, Cain Creek (Site 2) had a turbidity reading of 13 NTU and a much higher concentration of sediment (56 mg·1^{-1}). There was some evidence of stream alteration in Cain Creek, which may be the ultiment source of sediment.

Both Stalker and Chaney Creek were carried significantly more sediment in March than in February. Discharge measurements were not made in the March survey, but it is doubtful that at this time Chaney Creek contributed equally to the combined flows of Stalker and Chaney Creeks, since Stalker Creek receives water during snowmelt runoff from an extensive network of drainage canals. Although the amount of sediment contributed by the Chaney Creek-Cain Creek Drainage is significant, it is probably somewhat less than that transported by Stalker Creek above their confluence.

Table 8. Sediment ($mg \cdot l^{-1}$), dissolved solids ($mg \cdot l^{-1}$), and turbidity (NTU) in water samples from Cain, Chaney, Stalker, and Silver Creeks; collected by Gordon Beebe, March 22, 1979.

	Site	SEDIMENT Total	SEDIMENT settleable	SEDIMENT inorganic settleable	dissolved solids	turbidity
1	Chaney Creek 0.25 mile downstream from Highway 20	5.0	2.7	0.1	260	0.8
2	Cain Creek at confluence with Chaney Creek	56.0	43.6	30.8	246	13.0
3	Chaney Creek at confluence with Stalker Creek	29.6	18.6	13.0	214	7.7
4	Stalker Creek upstream of confluence with Chaney Creek	48.1	32.3	26.8	300	16.0
5	Stalker Creek at Pumpkin Road Bridge	31.1	19.6	15.2	275	9.8
6	Silver Creek at Kilpatrick Bridge	20.5	4.0	2.0	268	6.0

DISCUSSION

The emphasis of this study has been to identify the sources of sediment in Silver Creek and the factors that influence deposition and erosion of sediment in the stream channel, particularly in the section of Silver Creek that is within the boundary of The Nature Conservancy Preserve.

Results of 15 months sampling, which covered the period from March 1978 to June 1979, show that fluvial transport of suspended material by the three major tributaries, Stalker, Crove, and Loving Creeks, is the principal source of sediment. Our data indicate that Stalker Creek carried approximately 62% of the total sediment entering Silver Creek from these tributaries (Fig.18), while Grove and Loving Creeks contributed 23% and 15% respectively. The sediment transported by Loving Creek may have been slightly underestimated since in 1978 peak discharge occurred in the creek (but not in Stalker or Grove Creeks) prior to the initiation of the sampling program.

Stalker Creek carried a slightly greater sediment load in relation to drainage area than the other tributaries. Discharge was also not proportional to drainage area. This can be accounted for by the fact that a significant amount of water is derived from the aquifer rather than overland drainage. The result, however, is that Grove Creek transported only 23% of the sediment while contributing 49% of the discharge while Stalker transported 62% of the sediment and only 32% of the water. The differences are reflected in the concentrations of sediment in the respective streams. Grove Creek was almost always very clear while Stalker Creek was often turbid.

Unlike Grove and Stalker Creeks, the amount of sediment carried by Loving Creek was nearly proportional to the drainage area and the discharge.

Conclusions relative to the amount of sediment carried by the three tributaries are based on quantitative sampling and data are assumed to represent reasonably well

STALKER DRAINAGE

52 % of AREA

32 % of DISCHARGE

62 % of SEDIMENT LOAD

GROVE DRAINAGE

26 % of AREA

49 % of DISCHARGE

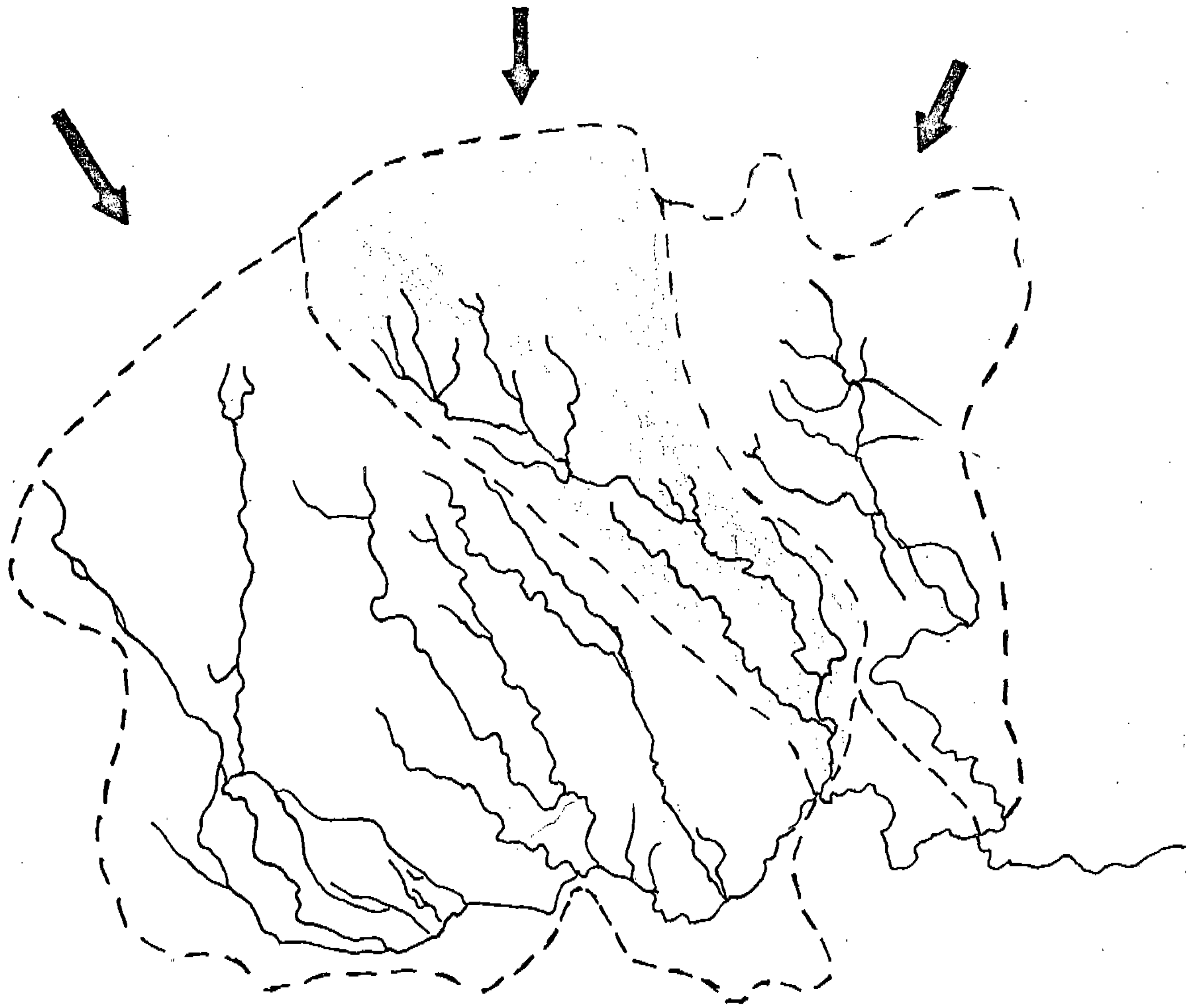
23 % of SEDIMENT LOAD

LOVING DRAINAGE

22 % of AREA

17 % of DISCHARGE

15 % of SEDIMENT LOAD



movement of sediment into Silver Creek. In contrast, identification of the ultimate sources of sediment in the tributaries is more difficult because quantitative data are not available, except for windborne material. To gain insight into the movement of sediment into and through the stream system, three drainages, Stalker-Patton Creek, Chaney-Cain Creek, and Loving Creek, were surveyed by walking along the stream banks and by analysing water samples collected at selected sites. A similar tour of Grove Creek was not made due to time constraints, and because sediment transport in Grove Creek did not appear to contribute significantly to the problems of Silver Creek. However, observations were made at several sites and some conclusions drawn relative to the interaction of aquatic plants, deposited sediment and sediment transport. This will be discussed later.

Extensive sediment deposits were found in the streambeds of each of the three creeks surveyed. During the summer and early fall the sediment probably remained relatively immobile, trapped and held in place by aquatic plants and the low water velocities. During snowmelt runoff, the absence of stablizing vegetation and the increased water velocities caused the sediment to be re-entrained and transported into Silver Creek. Measurement of the rate of entrainment of deposited sediment was beyond the scope of this study and although the amounts are probably significant there are no quantitative data relative to the percent of suspended sediment derived from this source. Furthermore, it begs the question. The real problem is to discover the mechanism by which silt enters the stream from the surrounding fields.

One of the objectives of the drainage basin surveys was to locate point sources of sediment if they existed. None were found in Loving Creek or in the Chaney-Cain Creek Drainage (unless Cain Creek itself is to be considered a point source). There were several sites in the Stalker-Patton Creek Drainage where very turbid water entered the creek, either from canals or directly off the hillslopes, but these inputs were not of sufficient magnitude to account for the high concentrations of sediment transported by Stalker Creek. It is reasonable to assume, however, that the combined effects of channelization and straightening of the stream, the network of drainage canals, and the extensive areas of exposed soil have resulted in the addition of significant amounts of silt to Stalker Creek. The process of water erosion continues at variable (but unmeasured) rates all along the drainage. The hydrological regime of Stalker Creek has apparently been modified by the rapid draining of the adjacent fields, resulting in higher discharge rates, and for a brief period of time increases the erosional and sediment carrying capacity of the stream. At the present time it is impossible to even speculate on the question of how much of the suspended sediment carried during spring runoff is silt newly added to the stream from bank erosion or runoff from fields and how much originate from the re-entrainment of sediment that had been deposited in the streambed at some earlier date.

Loving Creek also has an extensive network of canals, these these canals function principally as conduits for irrigation rather than to promote rapid draining of the fields during snowmelt. Another difference between Loving Creek and the Stalker drainage are that the fields surrounding Loving Creek are not in cultivation at the present time. There is a settling pond above the Hayspur Fish Hatchers, and in addition, water backs up from the Purdy Dam and this serves as a second settling basin. Then, in times of high discharge, the material that settled out near the mouth of Loving Creek is swept into Silver Creek. Deposited sediment is not confined to the settling basins, however, and is present in most areas of the stream, with the exception of the tributary sampled at site 5 (Fig. 16).

Windborne silt undoubtably contributes sediment to the streams. Although data from the present study indicate that in 1978 and 1979 this source did not add a significant amount of material at most sites, during one sampling period windborne silt was deposited at the rate of over 200 $g \cdot m^{-2} \cdot day^{-1}$ at one sampling station, illustrating the potential of wind erosion. It is possible that a large fraction of the silt that now lies on the streambeds was transported into the stream in this way (see page 3 of this report for a description of wind erosion in 1974).

Once silt enters the stream it is subject to the interacting forces of several variables. It is carried as suspended sediment until water velocity is sufficiently reduced for it to settle out. This occurs when the stream gradient is lower, in pools, behind dams, and in association with aquatic vegetation or other obstructions. Sediment will remain on the streambed until disturbed by the removal of protective vegetation, by increased water velocity, or by some other force. Under certain circumstances the silt associated with aquatic plants may be sealed off by deposits of marl (calcium carbonate) and no longer be vulnerable to re-entrainment, unless unusually great forces break the armour of marl.

The influence of aquatic plants on sediment transport has not been quantified, but there is some evidence that it may be very important. During the winter of 1978-1979 most of the aquatic plants in Stalker and Loving Creeks died out, presumably due to low water temperatures and/or ice cover. For reasons that are not yet clear Grove Creek maintains temperatures several degrees above those of Stalker and Loving Creeks during the winter. Although emergent parts of the plants froze in Grove Creek, the submersed parts remained alive and the streambed was not denuded as in the other creeks. Deposited sediment was present, but since it was protected by the plants very little became entrained in the current and transported into Silver Creek.

A similar condition appears to exist in the western tributary of Loving Creek (site 5, Fig. 16). It was observed during the survey of Loving Creek in February that there were large colonies of aquatic plants and low concentrations of suspended sediment in this tributary, whereas plants were absent from the eastern tributary (and most of the rest of the stream) and that sediment concentration was greater.

The persistance of aquatic plants during the winter in Silver Creek proper was variable. Potamogeton pectinatus (pondweed) breaks off at the interface between the sediment and the water. This is a part of the natural life history of this species and is not associated with extremely low water temperatures. Ducks grazed on Chara and in the process disturbed the sediment directly. Most of the Chara beds were gone by late winter, but this was probably not a result of the ducks but caused by the low temperatures.

Deposited sediment is present in all areas of Silver Creek that lie within the boundary of The Nature Conservancy Preserve but is deeper and more uniform in the lower reaches, especially between Station 4 and 6 of this study. The differences between upstream and downstream sections are the result of settling out of sediment when water backs up behind the Purdy Dam. The deep sediment deposits in the lower part of Loving Creek can also be attributed, in part, to the Purdy Dam. If the dam were not present silt would be carried downstream to be deposited at some other site. (This does not inplicate the Purdy Dam as a source of sediment, but rather that it functions to retain sediment which has entered the creek from tributaries or by wind erosion.)

Data from the first ten months of this study indicate that the stream above the Kilpatrick Bridge (Station 6) may have been in steady state with respect to sediment transport, i.e. as much sediment was leaving the system as was entering. It is possible that under the prevailing morphological and hydrological regime, goverened by the amount of sediment carried in by the tributaries and by the presence of the dam, the depth of sediment had reached a maximum and that in a normal water year would stay about the same. Then, in late December 1978 or early January 1979 the dam was lowered. Our data indicate that from this time until our last water samples were taken in May, more sediment passed the Kilpatrick Bridge than entered from Stalker, Loving and Grove Creeks, implying that some of the previously deposited sediment was being removed.

In conclusion, we have shown that during the 15 months of study the principal source of sediment to Silver Creek was suspended material carried in by the three major tributaries, and that of these Stalker Creek contributed 62%. We found that windborne silt played a minor role, but had the potential of contributing a significant amount of sediment to the stream under certain conditions. Changes in stream morphology that may have led to an increase in sediment carried by Stalker Creek were discussed and factors that influence deposition and erosion of sediment were identified.

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APPENDIX I

Discharge data for the six sampling sites on Silver Creek and the USGS gauging station at Access near Picabo, Idaho. Data in m^3/sec a = maximum discharge during spring runc values at gauging station may be due to diversion of water for irrigation.

Date	1 (Stalker Creek)	2 (Grove Creek)	3 (Silver Creek)	4 (Silver Creek)	5 (Loving Creek)	6 (Silver Creek)
3/24/78	2.53	1.93	5.50	4.47	1.34	7.21
3/28/78	-	-	-	-	-	-
4/ 1/78	2.26	2.46	4.53	3.81	1.48	6.14
4/ 7/78	2.09	2.06	4.28	3.59	1.24	5.83
4/23/78	0.87	2.01	2.58	3.23	0.69	4.50
5/23/78	0.85	2.16	2.56	2.57	0.68	4.14
7/10/78	1.24	1.86	5.58	4.31	0.25[c]	6.84
9/15/78	2.00	2.01	4.33	4.73	1.45	6.17
11/26/78	1.23	2.37	4.14	4.27	0.42	6.00
1/20/79	1.20	1.88	3.18	3.26	0.59	4.94
2/15/79	1.29	1.88	3.98	3.98	0.59	6.01
3/16/79	-	-	-	-	-	-
4/17/79	1.26	2.34	-	3.63	0.67	-
5/ 3/79	1.00	1.90	3.16	3.41	0.93	-

APPENDIX II

Turbidity as (NTU) of water samples collected from Silver Creek and tributaries, March 24, 1978 to May 3, 1979. [a] = samples collected by Gordon Beebe.

	STATION					
Date	1 (Stalker Creek)	2 (Grove Creek)	3 (Silver Creek)	4 (Silver Creek)	5 (Loving Creek)	6 (Silver Creek)
3/24/78	20.0	2.7	20.0	16.0	4.2	7.3
4/ 1/78	22.0	1.9	6.3	5.3	2.1	3.5
4/ 7/78	24.0	1.6	7.1	6.3	2.1	3.7
4/23/78	4.4	2.2	2.9	3.2	1.8	2.2
5/23/78	2.5	1.1	1.5	1.6	1.9	1.8
7/ 7/78[a]	-	-	-	-	-	8.0
7/ 8/78[a]	5.4	-	-	-	-	-
7/10/78	3.3	1.4	1.6	2.0	1.6	0.8
9/15/78	2.0	1.2	0.8	1.0	1.2	1.2
11/26/78	0.9	0.7	0.8	1.2	1.3	2.0
1/20/79	5.7	1.2	1.9	2.8	3.6	3.8
2/15/79	7.8	2.3	4.3	-	2.7	3.8
3/17/79[a]	12.5	-	-	-	-	3.5
3/28/79[a]	7.8	-	-	-	-	-
3/21/79[a]	7.6	3.7	-	-	2.8	4.8
3/22/79[a]	9.8	-	-	-	-	6.0
4/17/79	3.9	2.2	3.9	2.5	1.5	2.9
5/ 3/79	1.6	1.2	2.3	2.2	1.2	3.7

APPENDIX III

Total sediment (dry weight) from the six sampling stations on Silver Creek and its tributaries. Values in $mg \cdot l^{-1}$. a = samples collected by Gordon Beebe.

STATION

Date	1 (Stalker Creek)	2 (Grove Creek)	3 (Silver Creek)	4 (Silver Creek)	5 (Loving Creek)	6 (Silver Creek)
3/24/78	96.4	16.7	89.6	60.8	26.9	35.0
4/ 1/78	38.9	16.6	25.4	40.1	10.6	22.2
4/ 7/78	44.7	7.1	19.0	17.3	15.1	12.1
4/23/78	21.2	14.0	8.2	15.7	10.5	10.5
5/23/78	9.4	4.3	5.4	7.8	6.6	4.7
7/ 7/78[a]	-	-	-	-	-	46.6
7/ 8/78[a]	15.0	-	-	-	-	-
7/10/78	14.4	3.6	4.3	6.9	10.3	3.5
9/15/78	6.7	6.1	2.7	3.6	3.6	3.0
11/26/78	2.9	2.1	1.6	4.0	4.6	3.6
1/20/79	28.7	3.5	4.5	5.5	15.1	15.2
2/15/79	30.7	6.0	10.3	10.0	13.5	13.0
3/17/79[a]	37.0	-	-	-	-	10.3
3/20/79[a]	29.6	-	-	-	-	-
3/21/79[a]	29.1	11.8	-	-	7.7	10.5
3/22/79[a]	31.1	-	-	-	-	20.5
4/17/79	23.5	11.9	19.3	10.5	16.5	22.9
5/ 3/79	7.5	5.9	7.7	5.4	5.0	8.7

APPENDIX IV

Total settleable sediment from the six sampling stations on Silver Creek and its tributaries. Values in $mg \cdot l^{-1}$. a = samples collected by Gordon Beebe.

	STATION					
Date	1 (Stalker Creek)	2 (Grove Creek)	3 (Silver Creek)	4 (Silver Creek)	5 (Loving Creek)	6 (Silver Creek)
3/24/78	68.9	8.8	65.7	36.3	16.9	21.3
4/ 1/78	17.4	9.5	16.5	30.3	11.8	9.5
4/ 7/78	33.3	2.2	8.4	11.4	5.6	7.3
5/23/78	3.0	1.6	1.6	3.2	3.0	1.0
7/10/78	6.6	1.3	2.1	2.6	4.6	0.4
9/15/78	3.1	0.6	0.6	0.9	1.1	0.6
11/26/78	1.1	1.0	0.4	1.4	1.8	1.3
1/20/79	11.1	1.8	1.7	2.9	5.9	4.1
2/15/79	9.4	0.6	2.3	2.3	3.5	3.3
3/17/79[a]	27.6	-	-	-	-	6.0
3/20/79[a]	22.0	-	-	-	-	-
3/21/79[a]	21.0	5.3	-	-	6.3	8.6
3/22/79[a]	19.6	-	-	-	-	8.3
4/17/79	15.9	7.8	13.0	5.2	8.7	4.3
5/ 3/79	3.4	1.6	2.9	2.2	1.7	4.6

APPENDIX V

Non-settleable sediment ($mg \cdot l^{-1}$) from the six sampling stations on Silver Creek and its tributaries. a = samples collected by Gordon Beebe.

	STATION					
Date	1 (Stalker Creek)	2 (Grove Creek)	3 (Silver Creek)	4 (Silver Creek)	5 (Loving Creek)	6 (Silver Creek)
3/24/78	27.5	8.0	23.9	24.5	10.1	13.8
4/ 1/78	21.6	7.1	8.9	9.8	6.1	12.7
4/ 7/78	11.4	4.9	10.5	5.8	9.5	4.8
5/23/78	6.4	2.7	3.9	4.6	3.6	3.7
7/10/78	7.8	2.5	2.2	4.3	5.7	3.1
9/15/78	3.6	5.5	2.1	2.8	2.5	2.4
11/26/78	1.7	1.2	1.1	2.7	2.8	2.2
1/20/79	17.6	1.7	2.8	2.6	9.2	11.1
2/15/79	21.2	5.4	8.0	8.0	10.0	9.7
3/17/79[a]	9.5	-	-	-	-	4.3
3/20/79[a]	7.6	-	-	-	-	-
3/21/79[a]	8.1	6.5	-	-	1.4	6.8
2/22/79[a]	11.5	-	-	-	-	16.5
4/17/79	7.5	4.2	6.3	5.3	7.8	18.6
5/ 3/79	4.1	4.3	4.8	3.2	3.3	4.1

APPENDIX VI

Inorganic settleable sediment ($mg \cdot l^{-1}$) from the six sampling stations on Silver Creek and its tributaries. a = samples collected by Gordon Beebe.

STATION

Date	1 (Stalker Creek)	2 (Grove Creek)	3 (Silver Creek)	4 (Silver Creek)	5 (Loving Creek)	6 (Silver Creek)
3/24/78	59.8	6.6	57.1	31.3	13.1	14.1
4/ 1/78	12.4	7.1	11.2	20.9	7.7	6.6
4/ 7/78	26.0	2.2	7.6	9.2	3.6	45
5/23/78	2.3	1.3	1.2	2.2	2.5	0.7
7/10/78	unable to separate into inorganic and organic due to laboratory accident					
9/15/78	"		"			"
11/26/78	0.1	0.1	0.1	0.3	0.4	0.1
1/20/79	6.2	1.5	0.1	1.2	4.6	2.7
2/15/79	6.1	0.1	1.5	1.5	1.7	3.0
3/17/79[a]	27.6	-	-	-	-	6.0
3/20/79[a]	15.8	-	-	-	-	-
3/21/79[a]	13.1	0.2	-	-	2.0	4.4
3/22/79[a]	15.2	-	-	-	-	2.0
4/17/79	13.4	5.8	10.4	2.9	5.6	1.8
5/ 3/79	2.4	1.1	1.5	2.0	1.7	4.6

APPENDIX VII

Total sediment load for the six sampling sites on Silver Creek. Values given as metric tons per day (10^6g/d dry weight). [a] = Water sample collected by Gordon Beebe, discharge based on USGS records.

	STATION					
Date	1 (Stalker Creek)	2 (Grove Creek)	3 (Silver Creek)	4 (Silver Creek)	5 (Loving Creek)	6 (Silver Creek)
3/24/78	21.1	2.8	42.8	23.6	3.1	21.8
4/ 1/78	7.6	3.4	10.2	15.2	1.7	11.6
4/ 7/78	8.1	1.1	6.7	6.5	1.9	9.5
4/23/78	1.6	2.4	1.8	4.4	0.6	5.6
5/23/78	0.7	0.7	1.1	2.2	0.4	2.7
7/10/78	1.5	0.6	2.1	2.6	0.0	2.1
9/15/78	1.6	1.1	1.0	1.4	0.4	1.6
11/26/78	0.3	0.4	0.6	1.5	0.2	1.9
1/20/79	3.0	0.6	1.2	1.5	0.8	6.5
2/15/79	3.4	1.0	3.5	3.5	0.7	6.8
3/17/79	-	-	-	-	-	7.9[a]
3/21/79	-	-	-	-	-	8.7[a]
3/22/79	-	-	-	-	-	10.9[a]
4/17/79	2.6	2.4	6.0	3.3	0.9	9.6
5/ 3/79	0.6	0.9	2.0	1.6	0.4	3.3

APPENDIX VIII

Settable sediment load (Tons/day) from the six sampling stations on Silver Creek and its tributaries.

STATION

Date	1 (Stalker Creek)	2 (Grove Creek)	3 (Silver Creek)	4 (Silver Creek)	5 (Loving Creek)	6 (Silver Creek)
3/24/78	15.06	1.47	31.23	14.09	1.95	13.30
4/ 1/78	3.40	2.01	6.45	9.98	1.51	5.01
4/ 7/78	6.01	0.40	3.12	3.55	0.60	3.66
5/23/78	0.22	0.30	0.35	0.72	0.17	0.36
7/10/78	0.70	0.18	1.03	0.98	0.04	0.26
9/15/78	0.54	0.10	0.24	0.35	0.13	0.34
11/26/78	0.12	0.20	0.16	0.50	0.06	0.70
1/20/79	1.15	0.29	0.46	0.80	0.30	1.74
2/15/79	1.05	0.10	0.79	7.9	0.18	1.72
4/17/79	1.7	1.6	4.1	1.6	0.5	1.8
5/ 3/79	0.3	0.3	0.8	0.6	0.1	1.7

APPENDIX IX

Inorganic settleable load (Tons/day) from the six sampling stations on Silver Creek and its tributaries. a = samples collected by Gordon Beebe.

STATION

Date	1 (Stalker Creek)	2 (Grove Creek)	3 (Silver Creek)	4 (Silver Creek)	5 (Loving Creek)	6 (Silver Creek)
3/24/78	13.06	1.10	27.16	12.14	1.52	8.81
4/ 1/78	2.42	1.51	4.38	6.87	0.99	3.50
4/ 7/78	4.69	0.40	2.81	2.85	0.38	2.25
5/23/78	0.17	0.24	0.26	0.48	0.15	0.24
7/10/78	unable to separate into inorganic due to laboratory accident					
9/15/78	"		"			"
11/26/78	0.01	0.01	0.01	0.13	0.01	0.01
1/20/79	0.64	0.24	0.01	0.34	0.24	1.16
2/15/79	0.68	0.01	0.53	0.53	0.07	1.58
3/17/79[a]	-	-	-	-	-	4.6
3/21/79[a]	-	-	-	-	-	2.5
3/22/79[a]	-	-	-	-	-	1.1
4/17/79	1.5	1.2	3.3	0.9	0.3	0.8
5/ 3/79	0.2	0.2	0.4	0.6	0.1	1.7