HYDROLOGICAL INVESTIGATION OF GLACIAL RUNOFF COMPONENTS AND THEIR SEPARATION THROUGH HYDROCHEMICAL ANALYSIS

A THESIS

SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES

OF

THE UNIVERSITY OF OTTAWA

BY

STEVEN CHARLES BIGRAS, B.A.

IN PARTIAL FULFILMENT OF REQUIREMENTS

FOR THE DEGREE OF

MASTER OF ARTS

JANUARY, 1981

ABSTRACT

This study examines and explains the hydrological regime of Grizzly Creek Glacier (61°03'; 139°06'), Yukon Territory over a six week period (June 8th to July 15th, 1979).

Through the use of hydrological measurement techniques and hydrochemical analysis subglacial and supraglacial flows were separated, and their relative contributions to the total discharge over the study period were assessed.

Subglacial flows accounted for 41.5 to 84.0 percent of the total discharge at the beginning of the field season. Towards the end of June beginning of July, supraglacial streams gained in importance as the major runoff component contributing fourty-eight percent of the total discharge compared to ten percent by the subglacial component. This transition was linked to climatological conditions.

The hydrochemical analysis of the three main runoff components also provided a useful and reliable means of determining hydrological process inputs. By measuring pH, electrical conductivity and ionic concentrations of magnesium, calcium, chloride, phosphate and silica in ice, snow and glacial meltwater samples throughout the field season, the analysis revealed that at the beginning of the summer the diluted character

of the meltwaters provokes rapid cation exchange and water enrichment as they came into contact with the winter's accumulation of weathered materials. As the summer progressed, the general trend in water quality characteristics was one of decreasing electrical conductivity and ion concentration, with pH levels tending to be basic.

Spatial, temporal and diurnal variations in the meltwater's solute concentrations was shown to depend on the various hydrological environments, routing, climatic and melt conditions.

Suspended sediment analysis has shown that sorption of major cations (Na^+, K^+, Ca^{++} and Mg^{++}) on suspended particles is of greater importance for glacial meltwaters running through morainic deposits than for subglacial meltwaters.

This study also contributes to the understanding of the complex linkages which exist between climatological variables, the discharge regime and the chemical composition of glacial meltwaters.

RESUME

Cette étude a comme but d'examiner et d'expliquer le régime hydrologique du glacier Grizzly Creek ($61^{\circ}03'$; $139^{\circ}06'$) Territoire du Yukon, à partir d'observations qui ont été effectuées pendant six semaines (du 8 juin au 15 juillet, 1979).

En se servant des techniques de mesures hydrologiques et d'analyses hydrochimiques, nous avons réussi à séparer les écoulements intraglaciaires et supraglaciaires et à calculer leurs contributions relatives au débit total.

Des valeurs quotidiennes de 41.5 à 84.0 pour-cent du débit total par le réseau interne d'écoulement ont été enrégistrés au commencement de la saison de terrain. Vers la fin de juin début de juillet, les ruisseaux superficiels ont contribué quarante-huit pour-cent au débit total, comparé à dix pour-cent par le réseau interne. Cette transition est attribuable aux conditions climatologiques.

L'analyse hydrochimique des échantillons d'eau provenant des trois principaux constituants d'écoulement (neige, glace et eau de fonte) nous ont permis de determiner quels environments sont relatives aux caractéristiques des eaux de ruisellement. En se servant des données de pH, de conductivité électrique ainsi que les concentrations

ionique de magnésium, chlorure, calcium, de phosphate et silice, cette investigation a révélé qu'au début de l'été les eaux glaciaires étaient trés aggressives ce qui résulte d'un contact insuffisament long entre l'eau et l'accumulation de matériel altéré au cours de l'hiver.

Au cours de l'été une dimunition de la concentration des éléments chimiques caractérisent l'eau glaciére. Une réduction dans la conductivité électrique et dans les concentrations ioniques accompagnées d'un pH basique sont observé pour les échantillons d'eau glaciaire.

Les variations spatiales, saisonniérés et diurnes dans la concentration des solides dissous dans l'eau montrent que ces concentrations dépendent du milieu, du parcour des eaux, des condition de fonte et des conditions météorologiques.

L'analyse des sédiments en suspension indique que l'adsorbtion des cations principaux (Na^+, K^+, Ca^{++} et Mg^{++}) par ces sédiments est plus importante pour les eaux supraglaciaires qui traversent des dépôts morainiques que pour les eaux intraglaciéres.

Cette étude a aussi essayé d'identifier les liens complexes qui existent entre les variables climatiques, le régime du débit et les propriétés chimiques des eaux de fonte glaciaires.

ACKNOWLEDGEMENTS

I would like to extend my sincerest thanks and appreciation to Dr. P.G. Johnson, not only for his indispensible supervision and support of my research, but for providing me with the opportunity of conducting my field research in the Yukon.

I deeply appreciate the logistical support provided by Dr. Gordon Young, Glaciology Division, Environment Canada, but I'm especially grateful for his advice and continued interest in my research throughout my academic career.

Special thanks are due to all the members of the 1979 Grizzly Creek field expedition, and in particular to Marthe Belliveau for her assistance in the collection of field data.

I would also like to thank the Northern Research Group for their monetary award.

Finally I would like to thank Judv Lonsdale for her expert typing of this thesis.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER I

INTRODUCTION

A large volume of literature exists on the mass balance and hydrologic regimes of temperate glaciers in southern areas as a result of the involvement of Canada and other countries in the International Hydrological Decade Program. Thanks to this program and the researchers involved, improved measurement techniques and new methods of glacial investigation were developed. By applying these new investigative techniques in the field, significant steps have been made towards understanding the hydraulics and hydrology of glaciers. This in turn should lead to a better understanding of the complex geomorphological processes active within glaciers.

This study sought to investigate the processes taking place at the frontal and marginal zones of Grizzly Creek Glacier, Yukon Territory (Figure 1). Over a six week period during the summer of 1979, widely accepted and proven hydrochemical analysis and hydrological measurement techniques were employed in order to seperate the various runoff components and determine their relative contribution to the glacier's hydrological system.

The actual measurement of glacial runoff was divided into

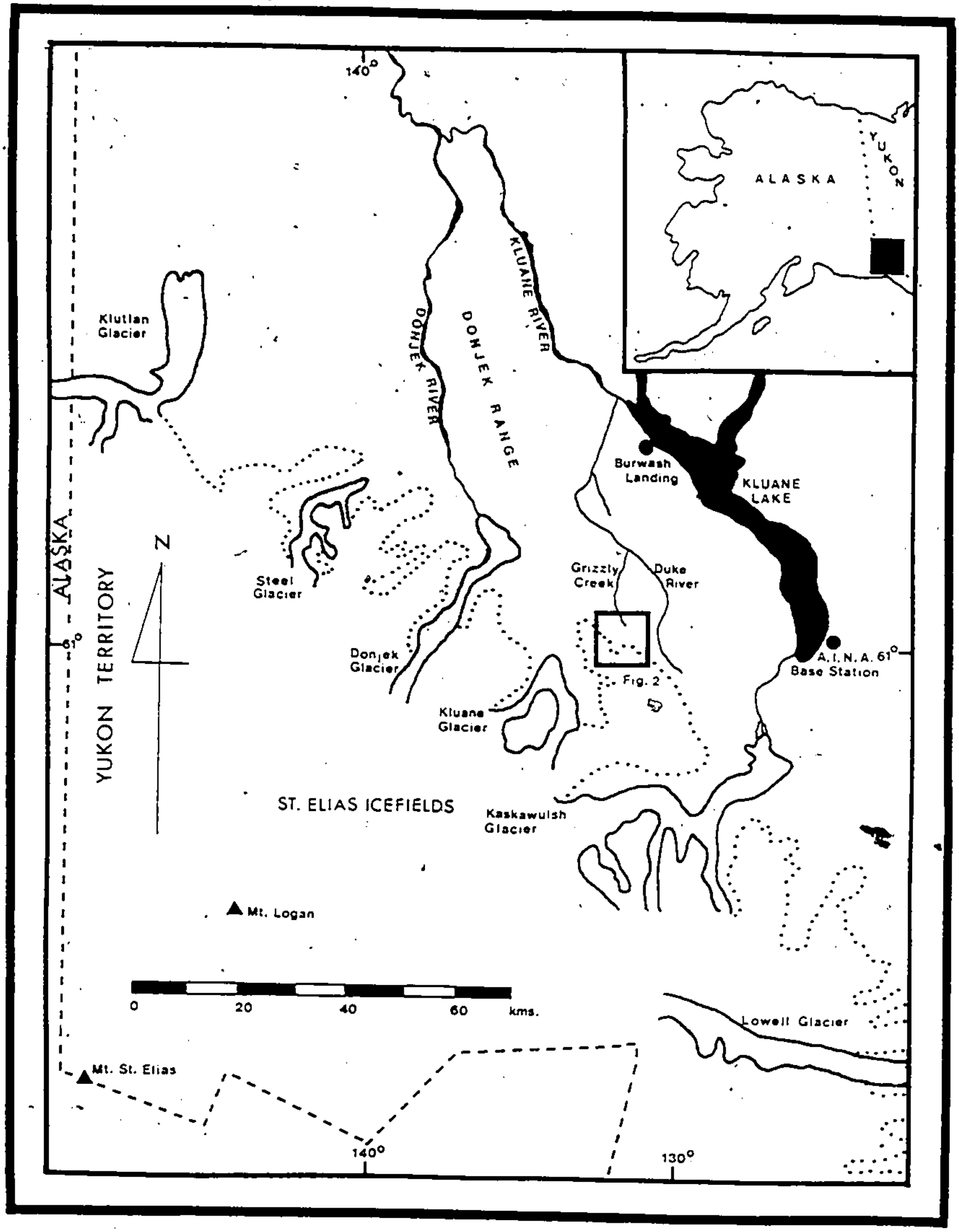


FIGURE 1
Location Map

(Johnson, 1975)

three parts. The first, consisted of a stage recorder network that continuously measured discharge of the glacier's main stream and two of its tributaries. Hydrological investigations of this type have been carried out successfully by Mathews (1964), Tangborn (1967), Faber (1968), Loijens (1974), Rasmussen and Tangborn (1976), Collins (1977d), and Young (1977).

Hydrograph recordings of diurnal fluctuations in the glacier's discharge regime are explained, and attributed to physical relationships which exist between the important meteorological parameters and daily discharge. Much attention has been focused on the complex linkages which constitute this relationship (Østrem, et. al. 1967, Derikx 1968, Gudmundsson 1969, Lang 1969, Campbell and Rasmussen 1969, Stenborg 1969, Derikx and Loijens 1971, Goodison 1972, Jacobs, et. al. 1972, Krimmel and Tangborn 1974, Gray 1972; Sugden and John 1976, Tangborn and Rasmussen 1976, Young, 1977, and Bigras 1978).

In the second part, the relative contribution of the smaller glacial streams discharge was measured by a currentmeter on days with no precipitation.

Finally, supraglacial and subglacial flows were measured by either dye or brine solutions on days with no precipitation. In this manner, it was possible to determine just how much water was contributed by the various supraglacial and intraglacial components of the runoff system to the total discharge. Previous work (Østrem 1964, Golubev 1969, Stenborg 1969; 1970, Behrens, et. al. 1971, Shreve 1972, Krimmel, et. al. 1972, Moser and Ambach 1975, Behrens, et. al. 1975) in this area has proven very useful in gathering information on intraglacial water movement, and clarifying some of the problems of time delay and storage mechanisms of water within a glacier.

Glacial meltwaters are characteristically low in solute content and acquire most of their ionic concentration as they flow across the glacier's surface and through the internal hydrological system. Consequently, hydrochemical analysis of these meltwaters has proven to be a highly accurate and consistant method of measuring changes in water quality parameters. This method allowed Rainwater and Guy (1958) to subdivide total flow into components of water from ground environment and water from glacial meltwater and precipitation. Subsequent investigations (Slatt 1972, Church 1974, Zeman and Slaymaker 1975, Collins 1977a ; 1977b, Collins and Young 1978) on the chemical characteristics of glacial meltwaters lead to the successful separation of surface flow from subglacial flow, and revealed that ionic concentrations vary as a function of temporal and spatial fluctuations of runoff and source areas.

Ek (1966) and Ricq-de Bouard (1973), using pH and hardness and pH and resistivity measurements respectively found that glacial meltwaters tended to be alkaline and would become more so as mineralization increased. On the other hand, Ricq-de Bouard measured acidic values for snow samples taken from the Chartreuse mountains, which decreased as soluble material increased.

In addition to the hydrochemical analysis of snow, ice and meltwaters, this study includes an analysis of the suspended sediment load. By analysing the suspended sediment in glacial meltwater samples, a complete record of water quality characteristics is obtained. Concerted efforts by Lorrain and Souchez (1972), and Lemmens and Roger (1978) have, through the use of atomic absorption spectrophotometry, found that sorption of major cations on suspended particles is more important in the waters resulting from percolation through morainic deposits than in subglacial waters which in turn offers some indication of the rate and characteristics of water enrichment in the frontal and marginal zones of glaciers.

This thesis describes results of the investigation into the hydrological regime of Grizzly Creek Glacier throughout the 1979 field season (June 8 to July 15). By combining the aforementioned hydrological, hydrochemical and sedimentary analysis techniques this study seeks to:

- determine the relative contribution of supraglacial and subglacial flows to the total discharge,
- explain long term and diurnal fluctuations in the discharge regime,
- explore the linkages which exist between climatological variables in Grizzly Creek Valley and the daily discharge regime of the glacier,
- analyse spacial, temporal and diurnal variations in the chemical composition of glacial meltwaters,
- analyse the effects of routing on the chemical composition of glacial meltwaters,
- investigate the effects of the discharge regime on water quality parameters,
- analyse the effect of suspended sediment on water quality parameters,
- determine the source areas of the chemical elements associated with glacial meltwaters.

1.1 Location and Description of Study Area

1.1 a) Regional Setting

One of many geometrically complex ice streams in the St. Elias Icefields, Grizzly Creek Glacier ($61^{\circ}03'$; $139^{\circ}06'$), Yukon Territory lies in the southwest portion of the Donjek Mountain Range, (Figure 1). At 2700m above sea level, it flows a little less than 5km to a terminus at 1890m and has a total area of approximately $14.9km^2$. There are two other glaciers occupying the same valley at the present time; one an ice cap on the west side at approximately 2550m elevation and covering $6.5km^2$, the other a small cirque glacier 2550m above sea level extending over $2.6km^2$, (Figure 2).

1.1 b) Local Area

This site, provides a unique opportunity to investigate the effects of avalanche contributions from the ice cap to the discharge and water quality of the west side stream "A1" (Figure 2), and the effects of a small cirque glacier's contribution to the east side stream's ("A2", Figure 2) discharge and water quality. A third stream "A3" (Figure 2) fed entirely by meltwater from the main glacier was used as a control stream to monitor the changes which occured in the water quality characteristics of "A1" and "A2".

Grizzly Creek Glacier's accumulation zone is made up of a two tier system. The upper basin (Figure 2) between 2700m and 2400m contributes to the mass of Grizzly Creek Glacier via an icefall which joins the lower basin at 2250m.

The upper accumulation zone ($5.8km^2$) has an average gradient of 0.19m/m, and the lower accumulation zone ($5.2km^2$) has an average gradient of 0.18m/m. The ablation zone extends from 2100m to 1890m , and covers

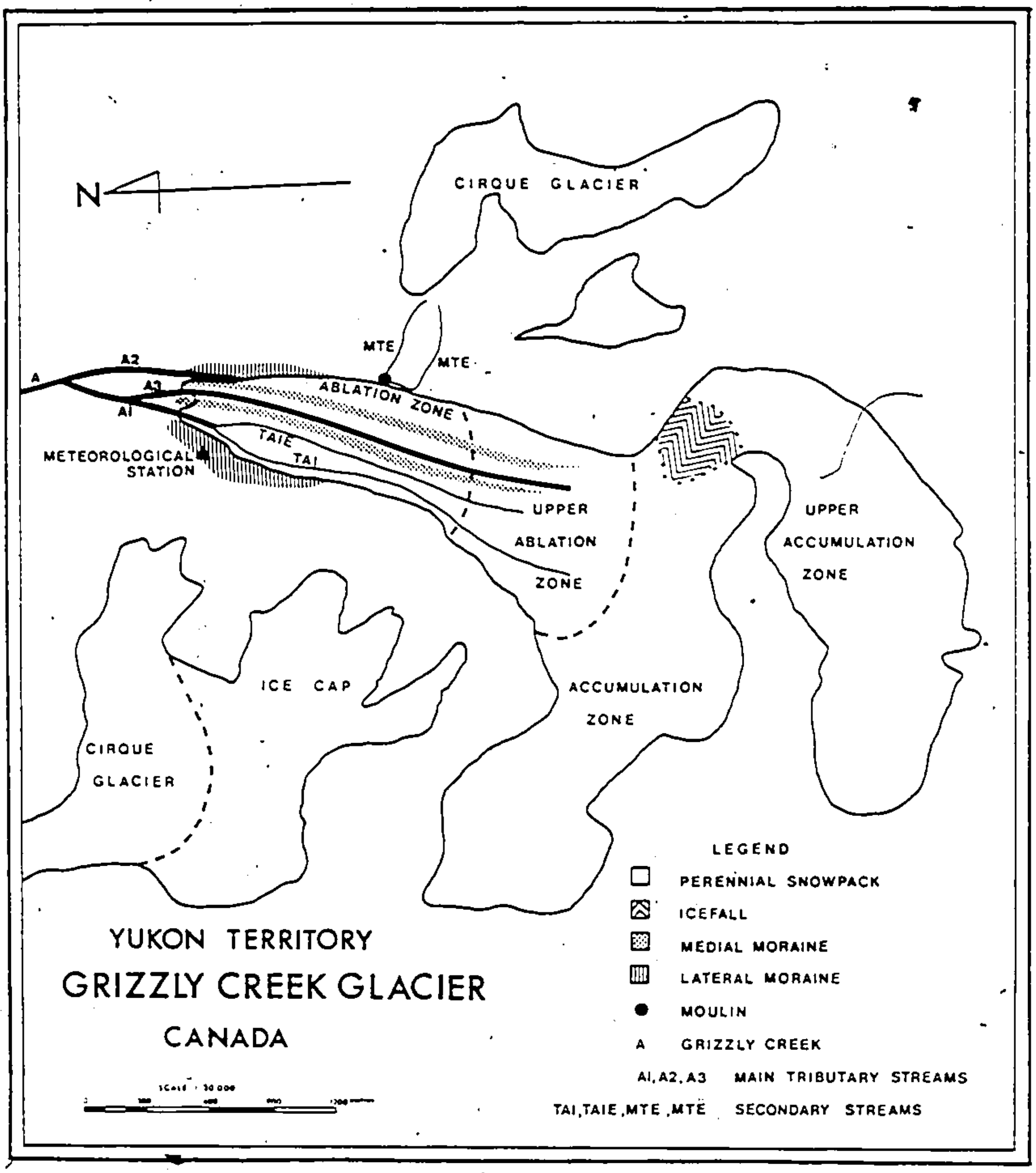

N
CIRQUE GLACIER
MTE
MTE
A2
A
A3
AI
ABLATION ZONE
TAIE
TAI
METEOROLOGICAL STATION
UPPER ABLATION ZONE
UPPER ACCUMULATION ZONE
ICE CAP
ACCUMULATION ZONE
CIRQUE GLACIER
YUKON TERRITORY
GRIZZLY CREEK GLACIER
CANADA
LEGEND
PERENNIAL SNOWPACK
ICEFALL
MEDIAL MORAINE
LATERAL MORAINE
MOULIN
A GRIZZLY CREEK
AI, A2, A3 MAIN TRIBUTARY STREAMS
TAI, TAIE, MTE, MTE SECONDARY STREAMS

FIGURE 2

an area of approximately $3.9km^2$, with an average gradient of 0.08m/m. The surficial area comprising the accumulation and ablation zones varies from year to year depending on climate conditions.

In addition several small cirque glaciers and perennial snow patches, located on either side of the glacial basin, contribute to the mass and discharge of Grizzly Creek Glacier.

The walls of the basin have been cut into Devonian-Mississippian slate. During the ablation season, the high cliffs of the basin walls are continually the source of avalanches. Schists and greenstones can also be found in the area on the surface of the medial and lateral moraine systems (Figure 2). On the east side, near the icefall, there is a small area of exposed quartz, and it may underly much of the ice.

1.1 c) Climate and Weather during the Summer-Season

The St. Elias Mountain Ranges' weather is influenced by two major air masses, and generally conforms to regional patterns described by Kendrew and Kerr (1955). During winter, migration of the deep Aleutian Low into the Gulf of Alaska brings heavy precipitation and clouds to the marine slope. While the extremely cold and dry Mackenzie High influences the continental slope front range.

Summer patterns are more complicated with the Northern cell being very active in the spring (May-June) and is the major source of storms which track the interior valleys past Kluane Lake. Northward migrations of the Pacific High brings warm, dry weather to the region. (Marcus 1974, Taylor-Barge 1969).

Severe summer storms at Kluane Lake and along the continental front are associated with easterly flow, an unusual phenomenon in the area.

The source of these storms is usually in the southerly flow off deep lows that move into the Gulf of Alaska. Moist air is funnelled into the interior, particularly through such openings in the mountain barrier as the Alsek and Chilwat valleys. Once past the divide, the flow swings eastward and eventually makes contact with the western ranges of the St. Elias Mountains. (Marcus 1974).

Since the St. Elias Mountain Range lies almost perpendicular to the normal atmospheric flow, it has a considerable effect on local climate. In fact, the weather is orographically induced, and variations in weather phenomena and processes vary over short distances from valley to valley. In Grizzly Creek Basin mean daily temperatures range between -0.8^{o} and 13.8^{o}C. The lowest temperatures occured during wet, snowy conditions, at which time the entire basin may be shrouded in thick Stratus and Stratocumulus clouds with a base between 1500m and 2500m.

On Grizzly Creek Glacier, daily summer temperatures range between -1.1^{o} and 15.5^{o}C but decrease rapidly at sunset when nocturnal temperatures range between -2.2^{o} and 10.5^{o}C. Wind speed and direction were faily uniform over the glacier, with a mean montly velocity of 7.21 km/s blowing from the south-southwest (i.e. up glacier). Occasionally the wind shifted and blew from the north- northwest (i.e. katabatic winds).

Warm air in Grizzly Creek Valley was forced up-glacier where it mixed with the cold glacier air and caused orographic precipitation. During such unstable periods, the wind velocity was greatly reduced and calms dominated, while snow or drizzle fell. Precipitation was mainly in the form of snow during June and changed to mixed snow or drizzle in July. Moderate to heavy rainfall was very infrequent, usually occuring at night, and accounted for very little of the total precipitation over the course of the field season. The maximum amount of precipitation, which fell in the form of rain, was 24.3mm on June 22. A detailed record of daily meteorological observations for Grizzly Creek Glacier are presented in Appendix A.

CHAPTER II

HYDROLOGICAL INVESTIGATION

Because of accessibility problems and mountainous terrain, use of conventional densified networks of permanent gauging stations for discharge measurements was not possible. In order to obtain reliable flow measurements of the runoff system of Grizzly Creek Glacier, emphasis was directed towards an optimized hydrometric network which would be flexible enough to measure discharge from the various runoff components and maintain a certain degree of accuracy thus allowing meaningful conclusions to be drawn from the data. In this respect, a combination of roving, short-term stream gauging stations and one permanent installation offered the best possible solution.

2.1 Equipment and Methodology

Total discharge for Grizzly Creek Glacier was recorded on an A Ott Kempen stage recorder with a seven day recording capacity. The two tributary streams were monitored by a Leopold and Stevens F type stage recorder, which also has a seven day recording capacity. The installation of the stage recorders, and the method for calculating stream discharge are outlined in Church and Kellerhals (1970), Gray (1972) and Corbett et. al. (1943).

Water discharge for smaller streams was measured by a MeBlugel Currentmeter and was used in accordance with the recommendations of Pierce

(1941) and Church and Kellerbals (1970). Discharge from eight tributary streams, plus the main glacial stream were measured on days with no precipitation at 1000,1300 and 1600 hours Yukon Standard Time(YST) in order to determine the amount of water each component was contributing to the total discharge at peak and low flows. On two separate occasions, the effects of precipitation on discharge was assessed at 1500 YST, a time at which average discharge occurs.

To determine subglacial and supraglacial flows, and the rate which meltwater travels from the surface and margin to the terminus, brine or Rhodamine WT dye solutions were used. Rhodamine WT dye was used on two occasions during days with no rain in accordance with the procedures recommended by Wilson Jr. (1968).

Two, one litre dye tracer slugs, twenty percent concentration were used to trace the path of the water from the east tributary glacier. Another two litre dye tracer slug, ten percent concentration was used to trace the water's path from the icefall. Unlike the first two attempts, the third failed. No trace of Rhodamine WT was found in the water samples.

Any number of reasons such as the sampling period chosen, or perhaps a storage mechanism operating within the glacier could be responsible for not finding any trace of the dye. However, it seems likely that the Turner model 110 fluorometer did not detect any trace of dye because of an insufficient concentration of Rhodamine WT dye coupled with high sediment load in each sample bottle which did not allow the light to pass through the samples.

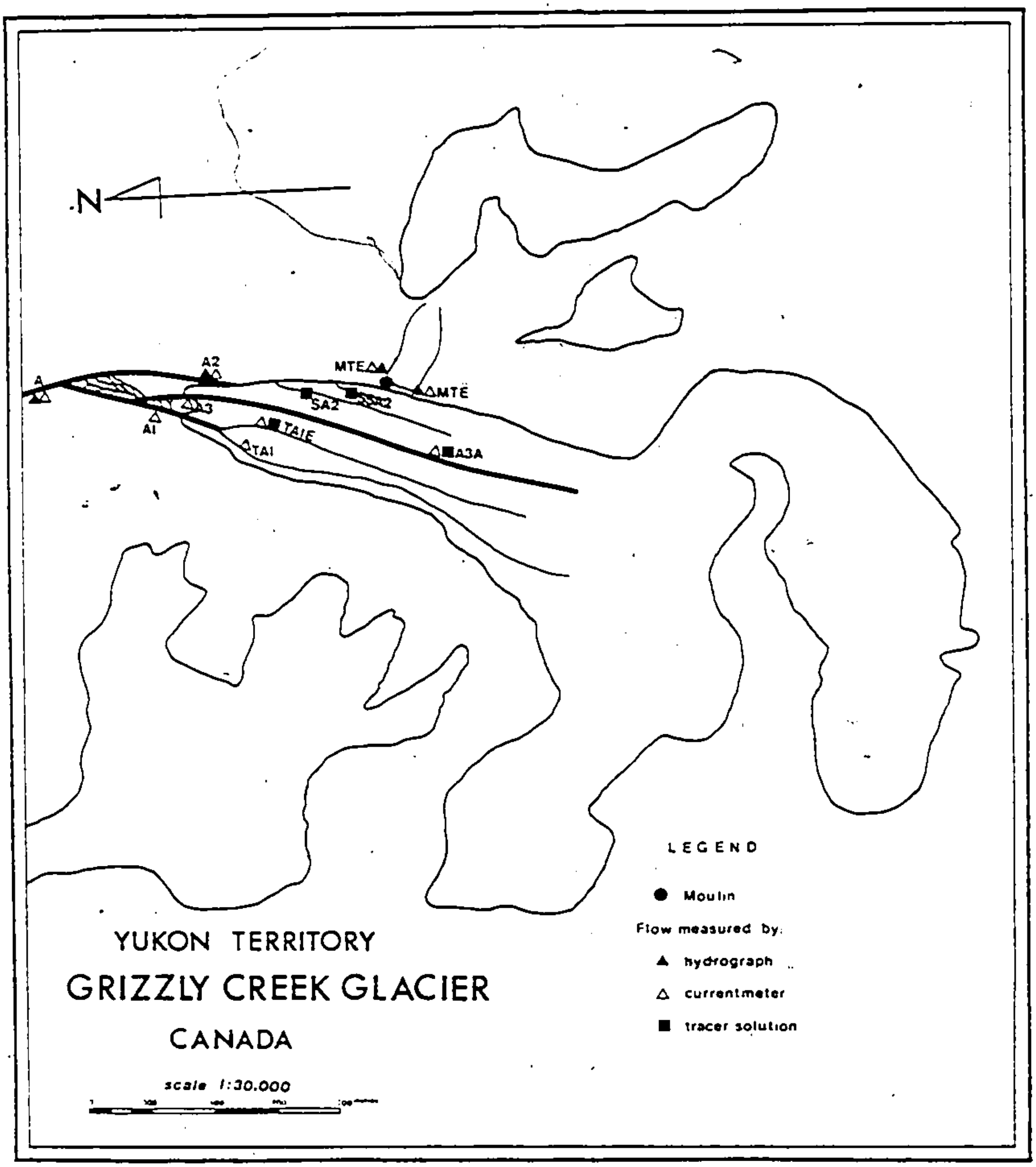
When a brine solution was used the method proposed by Østrem (1964) was implemented. Nine salt tracer experiments were carried out on five supraglacial streams on days with no precipitation at average and low discharge times (1100, 1200, and 1500 YST) The experiment consists in a sudden injection of salt brine into the stream and measuring the changes that occur in electrical conductivity as the salt wave passes the glacier's terminus. Electrical conductivity was measured using a LaMotte model DA-1 conductivity meter and probe.

2.2 Hydrological Measurement of Runoff Components

Employing these three distinct measurement techniques to calculate water discharge from the various runoff components of the glacier, a thorough study of the glacier's drainage network and hydrological regime is gained.

Total discharge from the glacier was continuously measured from June 9th to July 15th, 1979 by a stage recorder approximately 1km from the glacier's terminus. Two other stage recorders were used to monitor the east stream (Figure 3). Subglacial and supraglacial flows were measured using either dye or brine solutions. And a currentmeter was used to measure small supraglacial stream flows. By using three types of measurement techniques, the relative water contribution of the various flow routing components of the runoff system to the total discharge can be calculated with the following equation:

$Q_t = Q_i + Q_b + Q_g + Q_s + Q_a$ modified after Collins and Young, (1978).



DRAINAGE NETWORK AND DISCHARGE MEASUREMENT STATIONS

FIGURE 3

Where: Q_t = Total discharge

Q_i = Small supraglacial streams

Q_b = Meltwaters from basal conduits

Q_g = Meltwaters from tributary glacier

Q_s = Major glacial streams

Q_q = Quickflow resulting from precipitation and snow melt of non-glacierised area of the catchment

And in this particular case, $Q_b = [Q_s(\text{of stream A2}) - Q_g]$.

2.2 a) Relative Flow Contributions by the Various Runoff Components

A partial breakdown of total discharge into the various runoff component contributions to total stream flow is given in Table 1.

On June 13th, at 1000 YST, discharge measurements were made of all streams contributing to the total discharge. Their total recorded discharge was 54.3% of the total flow. Of this 54.3%, the largest amount (41.5%) comes from a well developed internal glacial system located on the east side of the glacier. The remaining 45.7 percent is accounted for by melting winter snowpack, melting of ice cored moraines, perenial snow patches and intermittent rain and snowfall, all in the immediate area of the glacier. Later on in the day, 1600 YST, flow from the glacier streams increased slightly to 56.3 percent while the surrounding area's contribution decreased to 43.7 percent.

Total discharge from the glacial meltwater on the 19th, 1400 YST , was only 7.1 percent. This indicates that the winter snowpack is being saturated by meltwaters and will be "washed off" in the form of slush

TABLE 1

Flow Contributions in m^3/hr.

Date	Time	Qi					Qs			Qb	Qg	Qa	Qt
(1979)	(YST)	A3A	SA2	TA1	TA1E	SSA2	A1	A2	A3	BCA2	MTË/MTE		A
13/06	1000						△ 108	△ 604		568	△ 36	655	△ 1368
13/06	1600						△ 108	△ 630		596	△ 36	630	△ 1368
19/06	1400						△ 36	△ 108		97	△ 11	1980	▲ 864
22/06*	1500			△ 576	△ 3708		△ 3852	△ 7488	△ 828	7452	△ 36		△ 8856
26/06	1300		△ 36	△ 1296				▲ 8100		8085	△ 14		▲ 6804
30/06	1100	△ 360		△ 684	△ 468		△ 324	△ 540	△ 1512	72	▲ 1440		△ 4536
03/07*	1500						△ 4068	△ 11376	△ 9648				▲ 15084
05/07	1200	■ 6	■ 16					▲ 1548					▲ 15084
05/07	1500	■ 5					■ 36	▲ 3276					▲ 16596
09/07	1100		■ 36			■ 6		▲ 1908					▲ 9036
10/07	1200				■ 9			▲ 2268					▲ 10548
10/07	1500				■ 14	■ 6		▲ 2124					▲ 14580

TA1, TA1E, are part of A1 system, Figure 3

BCA2, MTË/MTE, SA2, SSA2, are part of A2 system, Figure 3

A3A is part of A3 system, Figure 3

*Marks days with precipitation

Discharge measurements were made by either stage recorder (▲), currentmeter (△), or tracer solution (■)

NOTE: Stream sites MTË and MTE were measuring the same flow component (Q_g) that of the east side cirque glacier which would switch unpredictablely from stream site (MTË) to the other (MTE) leaving only a trace of water at either MTË or MTE on any given day as a result of the streams meandering in the alluvial plain in front of the east side cirque glacier. In order to minimize possible confusion between the two streams, it was decided to simply present the discharge from the east side cirque glacier as MTË/MTE in the text and Appendices.

flows when it becomes super saturated. The residual, some 92.9 percent of the total flow is accounted for by melting snow and ice in the surrounding area.

A marked increase in stream discharge on June 24th, 1500 YST, and again on June 26th, 1300 YST, is attributed to slush flows and basal conduits being "flushed out" around the glacier's terminus. Consequently, discharge from the east stream exceeds the total flow registered at station A. Water from A2 was diverted by another channel which lead it under the moraine system on the east side, only to emerge further downstream bypassing station A. This channel comes into play early in the season when A2's discharge exceedes 1.84m^3/sec.

As a result of precipitation on June 22nd, small supraglacial streams appeared on the glacier's terminus and contributed 48.3 percent of the total discharge. Basal conduits on the east side doubled their earlier seasonal flow contributions. No precipitation was recorded on the 26th, and as such, the supraglacial streams only contributed 19.5 percent of the total flow. However, the internal network on the east side continued to contribute the major portion of the total discharge. The surrounding area's contribution at this time is considerably less as the winter snowpack had all melted.

Super-saturated snow flows (i.e. slush flows) sliding off the east side tributary glacier and the upper portion of the main glacier's ablation zone on June 30th, swept both hydrographs A2 and MTË/MTE away. Due to reasons covered in the succeeding section, MTË/MTE station was not re-established. Currentmeter measurements revealed that MTË/MTE was contributing 31.7 percent of the total discharge and only twelve percent of this amount was recorded on the hydrograph at A2 because the stream was cutting into the glacier's side, away from the recording station.

The upper ablation zone's drainage is not determined by crevasses, they are filled up by standing water and drained off supraficially by spilling water, consequently, no moulin development on either the upper or lower ablation zones could be found. However, supraglacial streams account for 32.9 percent of the total runoff and will continue to be a major flow factor as long as the snowline keeps receeding. As a consequence of surface drainage, channels within the ice are more open and the time of travel between measuring points is diminished. A substantial rise in discharge on July 3rd as a result of heavy precipitation is reflected in each stream's increased flow. Due to the sudden increase, over 10,000 m^3/hr. of water was diverted via small and large streams past the main stage recorder "A". Later in the season, the majority of the smaller streams merge with the main stream.

As summer progresses, meltwaters from glacier ice and firn increase in importance to the runoff regime. As more and more of the ice surface becomes exposed, the range in diurnal discharge flows decreases, and the addition of precipitation to the daily discharge regime is immediate.

2.2 b) Hydrograph Trend Analysis

The continuity of the hydrological records of streams A, A2 and MTË/MTE over the 1979 field season provide sufficient information for a comparison to be made between the diurnal discharge regimes of these three streams. Figure

4 represents the hydrographs for Grizzly Creek Glacier's streams A, A2 and MTË/MTE. Hourly discharge measurements are available in Appendix B.

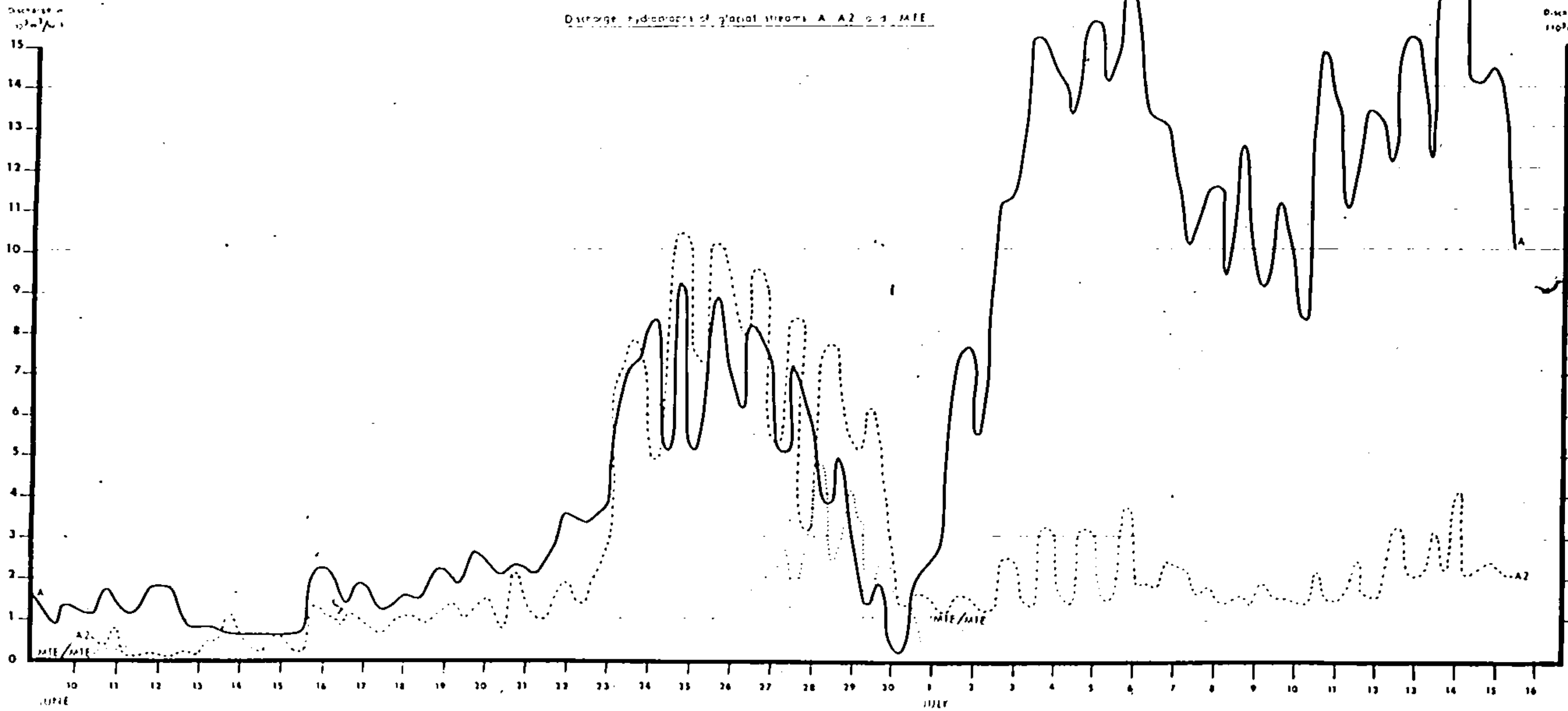
At first glance, the most striking fact about the hydrographs is their great variability throughout the period in question. During the early part of the summer, the range in diurnal flow is small but increases markedly as summer progresses.

Maximum and minimum discharge for all three streams occurs between 1800 and 2200 YST, and 0600 and 1200 YST respectively. This suggests that there is no storage mechanism at work between stations MTE/MTE and A. Dye tracer experiments revealed a twenty-five to seventy minute travel time from station MTË/MTE to station A, and a three to ten minute travel time from station A2 to A, depending on the amount of runoff. Fastest travel times were recorded during peak discharge periods.

An outstanding feature on Figure 4 is A2's discharge curve for the field season. It was obvious that A2 was the major stream contributing meltwater from the glacier to A during the early portion of the summer, and at one point, June 23rd to 30th, it surpassed the total discharge readings at A. The reason why this excess flow did not register further downstream at A is that an old channel re-routed the meltwaters, once they reached a certain level in the main channel, through the lateral moraine system on the east side and do not resurface until well down the valley past hydrograph station A. This situation corrects itself after the pressure dome collapsed and once again all A2's flow was restricted to the main channel.

FIGURE 4

Discharge hydrographs of glacial streams A, A2 and MTE



Because of the extremely variable nature of the two tributary streams (A2 and MTË/MTE) being monitored, several problems were encountered. Continual shifting of the east tributary glacier's stream from one channel (MTË) to another (MTE) approximately 80 meters apart (Figure 3) and sudden outburst floods forced frequent stage recorder re-location, and finally resulted in abandonment of discharge measurements at this site by a stage recorder. Further down the east stream near the glacier's terminus (station A2, Figure 3) the stream constantly cut into the side of the glacier and finally disappeared under it only to re-emerge after a pressure dome had collapsed. As a result, the discharge record for this stream contains inaccuracies towards the end of June and the beginning of July.

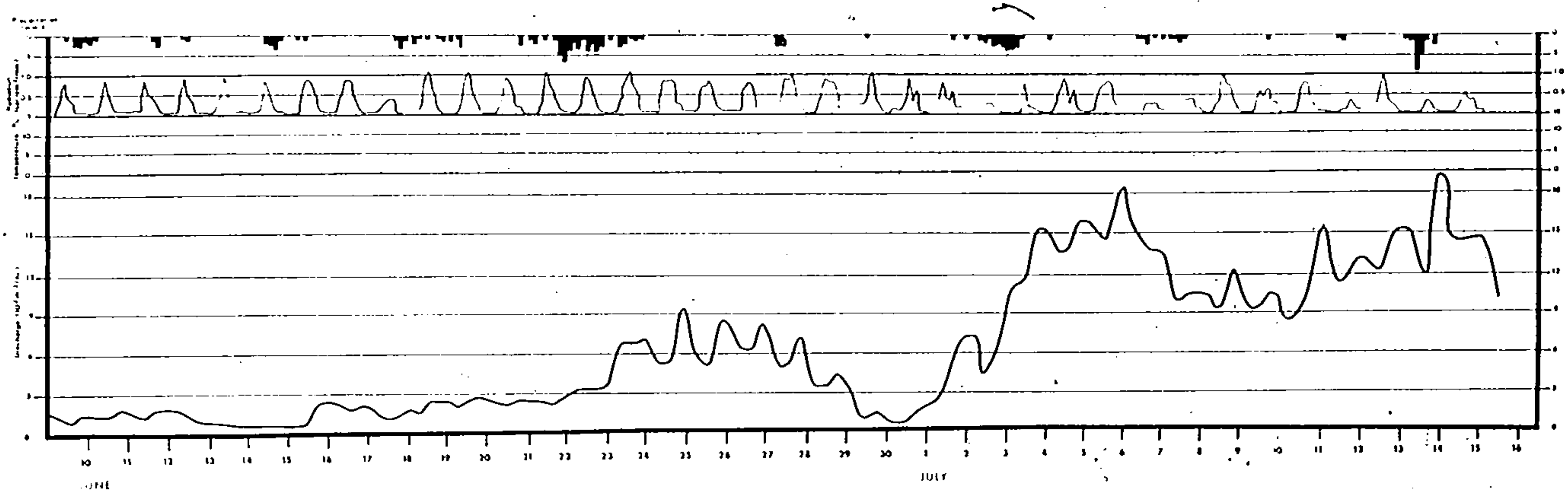
2.3 Meteorological Variables Effects on the Diurnal Discharge Regime

Simple linkages between the discharge curve and meteorological variables are sought to explain hydrological trends. Figure 5, shows a simplified version of the relationship which exists between diurnal discharge and meteorological variables (temperature, solar radiation and precipitation) for Grizzly Creek Glacier during the 1979 field season. Hourly meteorological observations are available in Appendix A.

Temperature influences melt rate immediately and depending on the amount and distribution of snow at the end of winter, a rise and fall in temperature is usually paralleled by a rise and fall in the discharge curve, Figure 5. A drop in temperature such as the one experienced on June 11th, from $10^{\circ}C$ at 1200 YST to $0.0^{\circ}C$ at 1800 YST, reduces the amount of heat being conducted from the air to the ice and snow which in turn decreases melt. If low temperatures persist over an extended period of time, they will affect

FIGURE 5

Summary graph relating discharge, temperature, solar radiation and precipitation



the amount of daily runoff. Average daily temperatures for June 12, 13 and 14 were 0.0°C, 1.3°C and 0.8°C respectively, and as a result, the average daily discharge at station A droped from 0.37m^3/sec on the 12th to 0.20m^3/sec on the 13th and 14th. However, these low temperatures and their effect on the daily discharge were greatly reinforced when approximately 0.9mm (water equivalent) of snow fell on June 12th. Snowfall increases the glacier's albedo, and absorbed short wave solar radiation is reduced. Later on in the season, the glacier's albedo is reduced (0.6 to 0.9 for fresh snow : 0.2 to 0.4 for ice) in the ablation zone, and melting due to solar radiation becomes very significant. (Sugden and John 1976) Above average discharge flows of 1.70m^3/sec and 1.15m^3/sec for the month of June were recorded at Station A on the 27th and 28th. Coincidently, above normal solar radiation values (0.36 cal/cm^2/min on the 27th and 0.40 cal/cm^2/min on the 28th) and moderate temperatures (daily average for the 27th was 5.4°C and 3.3°C for the 28th) were registered over the same period.

Low solar radiation values were recorded on a Weathertronics mechanical pyranograph (transmits 90% of the electromagnetic energy between 0.3 and 3.0 microns) early in the morning over the entire study period (Figure 5), and may be the result of high surface reflectivity from the surrounding snow covered mountain peaks.

Temperature and solar radiation reach their maximum values between 1200 and 1600 YST with their minimums occuring early in the morning between 0100 to 0600 YST whereas maximum discharge flows are recorded between 1800 to 2200 YST with minimums occuring between 0600 to 1200 YST, (i.e. June 24, maximum temperature (13.8°C) and solar radiation (0.81 cal/cm^2/min) at 1600 YST with maximum discharge (2.57m^3/sec) at 2200 YST; minimum temperature (3.3^{o}C) and solar radiation (0.07 cal/cm^2/ min) at 0200 YST with minimum discharge (1.34m^3/sec) at 0800 YST).

This 6 hour lag period between maximums of temperature and solar radiation, and discharge represents the time which is required for the glacial ice and snow to reach their melting point. Once this point has been reached, the latent heat of fusion is used to transform ice into liquid. (Baranowski 1977) Another 6 hour lag period is required before the system can respond to lower temperatures and less incoming solar radiation.

During the early part of summer, precipitation's effect on discharge is not immediate. The winter snowpack, between 38 and 43cm, on the ablation zone acts as a porous medium and absorbs most of the precipitation until it becomes super-saturated and releases it. This causes a delay period between the fall of precipitation and its reaching the gauging stations. For example between June 21 st and 22 nd 39.9mm of rain fell, and it was only on June 23 rd that a substantial rise in daily discharge was recorded at station A (daily discharge for: June 21, 60336m^3 ; June 22, 84708m^3 ; June 23, 184608m^3).

As the season progresses and the snowline retreats, the delay period is substantially reduced. On July 13th, 16.8mm of rain fell between the hours of 0400 and 1400 YST. This event was paralleled by a rise in discharge at station A, from 3.77m^3/sec at 0400 YST to 4.61m^3/sec at 0800 YST and to a daily maximum of 5.60m^3/sec at 1400 YST.

Amomgst the meteorological findings presented here, solar (short wave) radiation emerges as the dominant factor in snow melt even though it depends on the time of year, the time of day, the amount of cloud and snow cover. As the snowline receeds less solar radiation is reflected and scattered, and more of the glacier's surface is exposed. As a result, the glacier is able to absorb more short wave radiation later on in the season even though the average monthly incident radiation may be greater earlier on in the field season. This was the case when a comparison was drawn between the average monthly solar radiation for the months of June and July.

Once the equilibrium line (governed by solar radiation and temperature) between glacial ice and firn is established, fluctuations in the range of daily discharge is greatly reduced and is reflected by a smoother hydrograph trace.

CHAPTER III

HYDROCHEMICAL ANALYSIS

The chemical composition of natural waters is affected by the soluble products of weathering and erosion. Because of the unique characteristics water acquires along its path, water quality analysis, has been used since the end of the 19th century as an accurate and reliable instrument in hydrologic studies. (Hem 1959)

Chemical analysis of water samples is a good indicator of the nature and importance of some of the environmental factors to which water may be exposed in the hydrologic cycle, and has been used extensively in determining the origins of water. (Hem 1959)

Only recently, over the last twenty years, has water quality analysis been applied to glacial meltwaters. Through the use of hydrochemical analysis, this study endeavors to determine the source areas of meltwaters and the effects of mixing, routing, discharge and sediment on the chemical composition of the three main runoff components, snow, ice and meltwaters.

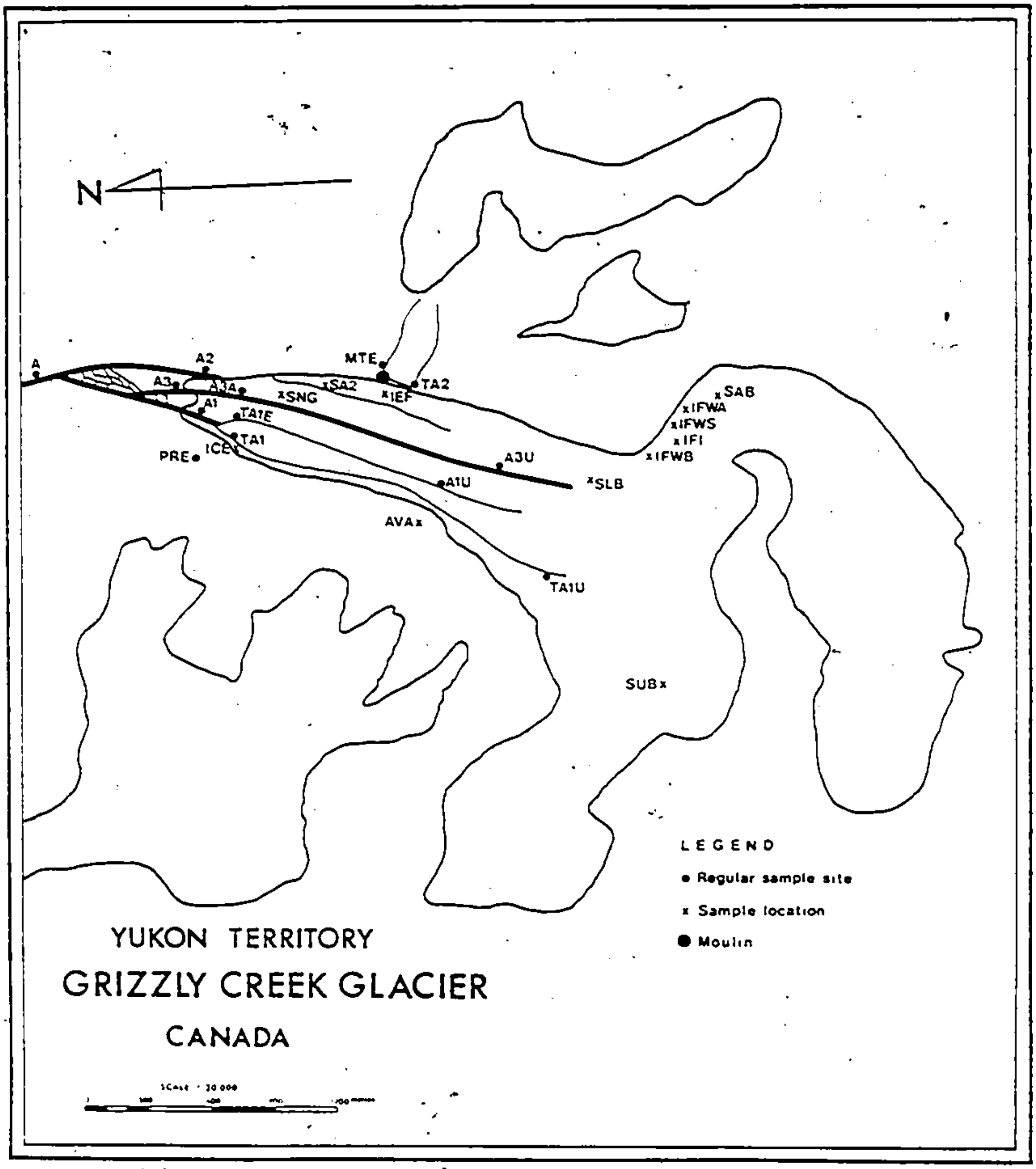
3.1 Equipment and Methodology

The study was designed so that glacial stream water characteristics could be monitored throughout the 1979 field season, to reveal spatial and temporal variations in water quality which occurred over the summer. The sampling procedures used to achieve these objectives, were those recommended by Hem (1959), The United States Army Corps of Engineers (1977), and Collins (1977b).

Almost any substance, whether active or intert can be a critical water quality parameter if introduced in water in sufficient quantity. However, this is not the case for the glacierized basin area of Grizzly Creek where the chemical parameters which will be tested must occur naturally and in significant concentration as to be measurable. Literature on the hydrochemical analysis of glacial meltwaters is in agreement that; pH, electrical conductivity and chemical concentrations of chloride, calcium, magnesium, phosphate and silica are the most common and useful chemial indicators of the processes at work in the hydrological regime of glaciers. (Rainwater and Guy 1958, Slatt 1972, Church 1974, Zeman and Slaymaker 1975, Collins 1977a and 1977b, Collins and Young 1978)

In light of this information, this study adopted the above mentioned water quality parameters for its analysis of Grizzly Creek Glacier's meltwaters. All meltwater samples were collected manually from the various sampling sites located in the Grizzly Creek Glacier study area (Figure 6) at predetermined times by a number of field assistants. These were taken in turbulent water zones oriented at a 90° angle to the stream line at all sites in order to ensure complete mixing.

Meltwater samples were collected in 500ml polyethylene bottles, pre-washed in distilled de-ionised water, and with water from which the sample



DRAINAGE NETWORK AND WATER SAMPLING SITES

FIGURE 6

was about to be collected. In order to minimize the potential effects of adsorption and desorption phenomena (Lorrain and Souchez 1972) on water quality characteristics, all samples were analysed in the field within twenty-four hours of their collection. To avoid gaseous exchange, sample bottles were filled to the top.

Before proceeding with any chemical analysis; each sample bottle was thoroughly agitated, and each piece of equipment used to measure the chemical properties of glacial meltwaters was calibrated just prior to individual sample analysis.

Hydrochemical studies using total ionic concentration of dissolved substances in solution as a measurable water quality parameter have shown that temperature has an effect on specific conductance. Therefore, there was a need to accurately monitor water temperature during analysis. A series of experiments were carried out by Collins (1977d) to determine the relationship between specific conductance and temperature. Results show that the percentage increase should be about ten percent per degree less than 5°C, five percent per degree between 5° and 10°C, and two percent there after for arctic and alpine streams.

Specific conductance measurements of meltwater samples from Grizzly Creek Glacier were made with a LaMotte multirange conductivity meter model DA series between temperatures of 2° and 15°C. This unit was also equiped with a manual temperature compensator which reduces the inherent temperature differences between samples.

Variations in temperature can also affect the pH of meltwater samples by increasing or decreasing the rate of ion dissociation. A LaMotte pH meter model HA series was used to measure the pH of meltwater samples. Temperature variations between meltwater samples were mannually compensated for by an adjustment knob which regulates temperature readings within a 0° to 100°C range.

Using the LaMotte TRL-05 colorimeter outfit, total hardness was determined by employing the titrimetric sodium ethylene-diamine tetraacetate method. Ionic concentrations of chloride were measured using the titrimetric potassium dichromate silver nitrate method, calcium by the titrimetric sodium ethylene diamine tetraacetate method, magnesium concentrations were calculated by subtracting calcium hardness from total hardness, phosphate through the use of colorimetric ascorbic acid reduction and silica by means of colorimetric heteropoly blue method. A detailed methodology can be found in the LaMotte Chemical Operator's Manual (1978).

The equipment used in the field allowed for an accuracy of ±2ppm for Calcium and Magnesium, ±0.5% for conductivity, pH was ±0.05 of a pH unit, ±0.05ppm for Phosphate, ±0.03ppm for Silica and ±5ppm for Chloride.

Sediment samples were seperated from waters in the field by filtration through individual Whatman 42 Ashless filter papers, under pressure from a handpump. Samples were returned to the laboratory in sealded bags, oven dried and analysed for cation concentrations of sodium,potassium, calcium and magnesium by atomic absorbtion spectrophotometer. Samples treatment and method of analysis were described by Lorrain and Souchez (1972). Here too care was taken in calibrating the atomic absorbtion spectrophotometer before testing for each element. The atomic absorbtion spectrophotometer allowed for an accuracy of ±0.05ppm for each of the four elements being tested for.

Reproducibility of the findings presented in this study are dependent upon physical factors not related to instrumentation or handling, and may lower or increase the significance of the differences observed in the water and sediment samples analysed.

In order to obtain a reliable data base, the hydrochemical analysis portion of this study was set up so that every day at fixed sampling sites (Figure 6) two 500ml water samples were collected at hourly intervals between 0800 and 1700 YST during the first week (June 8 to 15). One water sample from each pair taken is filtered in order to make an accurate determination of the chemical composition of water only.

Because of the increased number of streams being monitored after the first week, from three to nine, water samples were collected during optimum chemical concentration times (1000, 1200, 1500 and 1700 YST). During the last three weeks of the field season, water samples from small and supraglacial streams were gathered twice a week on days with no precipitation at 1000, 1200 and 1400 YST. A continuous fourty-eight hour run, with water samples taken at two hour intervals from the three main streams were analysed for diurnal variations in pH and electrical conductivity.

3.2 Spatial, Temporal and Diurnal Variations in the Chemical Composition of Glacial Meltwaters

This section takes into consideration the effects of weather and the source area on the chemical characteristics of glacial meltwaters, but deals mainly with the temporal sequence and its influence on the chemical composition of these waters.

It also inadvertently investigates the effects of mixing on water quality characteristics where two or more glacial streams converge (Figure 6).

The chemical composition of ice, snow and meltwaters of the main glacial streams (A, A1, A2 and A3) at the beginning of the field season (June 8 to 10) are presented in Table 2. Subsequent graphs and tables show spatial, temporal and diurnal variations which occur in water chemistry throughout the summer for each of the water quality parameters. It should also be noted that the main glacial streams' data presented on these graphs and tables are for filtered water samples only. Ice, snow, precipitation and small supraglacial stream samples required no filtration as they contained little or no sediment.

3.2 a) pH

The hydrogen ion concentration or pH depends on the extent of hydrolysis of anions and cations in solution. Figure 7, illustrates the changes which occur in pH levels over the 1979 field season.

During the early part of the summer, all sampling points along

TABLE 2

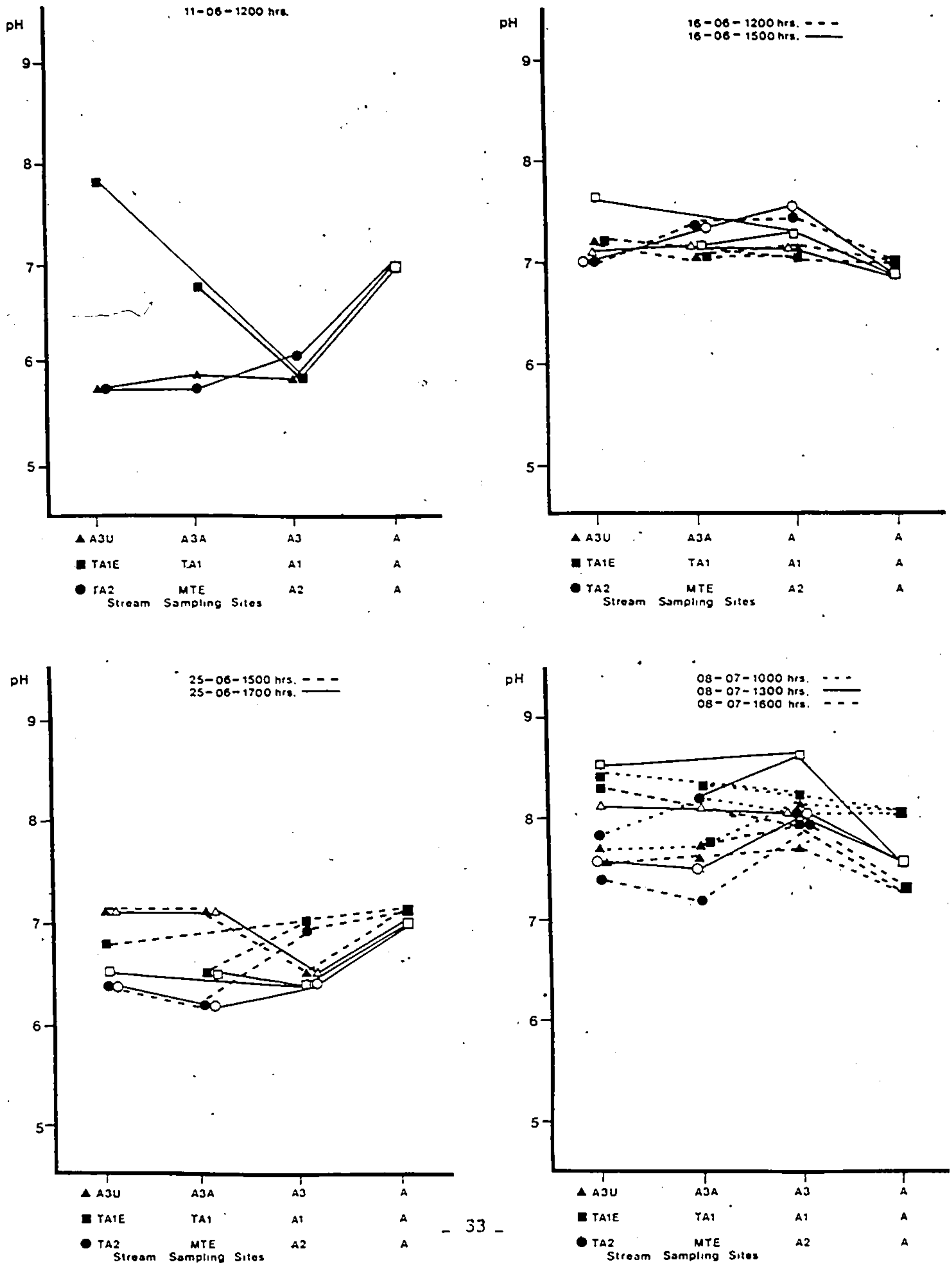
Sample	Date/Time YST	Electrical Conductivity ±0.05%	pH ±0.05	Chemical Concentrations (ppm) Phosphate ±0.05	Ca^{++} ±2	Mg^{++} ±2	SiO_2 ±0.03	Cl^- ±5
SUB	08-06-1400	40	8.4	0.30	NT	NT	0.20	45
SLB	08-06-1400	20	8.0	0.25	NT	NT	0.30	55
AVA	08-06-1200	20	8.4	0.30	NT	NT	0.25	65
SNG	08-06-1100	40	8.4	0.20	NT	NT	0.20	35
ICE	08-06-1300	52	8.3	0.20	NT	NT	0.40	45
IES	08-06-1500	100	7.0	0.53	10	15	1.03	45
IFI	08-06-1500	120	7.0	0.70	15	20	1.20	35
A	09-06-1100	70	7.0	0.20	45	40	0.60	45
A1	09-06-1200	60	6.8	0.35	40	10	0.40	50
A1	09-06-1300	60	6.6	0.45	20	5	0.70	25
A1	09-06-1400	60	7.5	0.20	15	5	0.53	50
A1	09-06-1500	60	7.3	0.20	20	5	0.40	40
A1	09-06-1600	60	6.7	NT	15	5	0.27	35
A1	10-06-1000	80	5.1	0.53	25	20	0.30	40
A2	10-06-1100	180	5.9	0.25	55	40	1.23	35
MTE	10-06-1200	130	5.8	0.35	50	15	1.23	30
A2	10-06-1300	170	6.1	0.20	55	50	1.80	40
A2	10-06-1400	180	5.8	0.20	55	40	1.80	35
PRE	18-06-1600	6	7.1	NT	NT	NT	NT	55
IFWA	20-06-1300	74	7.0	0.30	10	15	1.07	25
IFWB	20-06-1400	74	7.0	0.20	20	5	0.88	25
IFWS	20-06-1500	100	7.0	0.53	15	20	1.20	25
PRE	22-06-1200	6	7.0	NT	NT	NT	NT	60
SA2	25-06-1500	20	8.0	NT	NT	NT	NT	40
PRE	13-07-1000	6	7.0	NT	NT	NT	NT	55

All sample sites are on Figure 6

NT: No trace
PRE: Precipitation
S: Snow
I: Ice

FIGURE 7

Spatial, temporal and diurnal variations in pH



stream systems A1, A2 and A3 are slightly acidic in nature except for sampling site TA1E which is slightly basic.

TA1E is located in an area fed by snow and ice from the glacier's upper ablation and lower accummulation zones, and does not come into contact with the bedrock or moraine systems. Analysis of snow and ice samples from this area (Figure 6) reveal basic pH values (Table 2), and as expected, the pH values for meltwaters from TA1E are similar to those of the source materials. Differences in stream pH values are elaborated further on in sections 3.3 and 3.4.

In constrast, the chemical composition of meltwater samples from stream A cannot be traced to a particular source area, as its water quality characteristics are the end product of the mixing of meltwaters from streams A1, A2 and A3, snowmelt from the surrounding area, and the path taken by the meltwaters over glacial till along its 1km route to the sampling station (Figure 6). Consequently, sampling site A's pH value for June 11th was 7.0.

On June 16th, the range in pH is between 7.0 and 7.6 with TA1E recording the highest pH value. All three streams recorded higher pH levels than on the 11th of June. This indicates the continuing increase in importance of snow and ice as meltwater sources. Sampling site A's pH remained at 7.0 during the early part of the day, but later on (1500 YST) it dropped to 6.8. An increase in suspended sediment load just before peak discharge may account for the decrease with more cations being available at this time for dissolution.

All three stream systems showed a decrease in pH levels on June 25th, coincidentally, discharge for June 25th showed a marked increase from previous days. It is believed that the increase in flow could not be contained within the existing drainage network and spilled over dragging along loose rock debris scattered over the surface of the glacier. The resulting increase in mineral concentration caused a reduction in the meltwaters pH level. In stream system A2's case, the increase in water flow through the basal conduit system caused melting of basal ice which released sediment particles into the water accounting for acidic pH levels.

Figure 7 shows the drop in pH levels at sample sites A1 and A2 just before peak discharge levels. Because stream system A3's main water source is snow and ice from the upper ablation zone, and it runs through the centre of two medial moraines and does not come into contact with either one of them, no change in pH was recorded from 1500 YST to 1700 YST. And no significant change in pH values from June 16th to June 25th for sampling Site A were recorded.

The graph for July 8th exhibits a very interesting temporal sequence which developed over the month of July. All three stream systems pH values are alkaline ranging from 7.4 to 8.2. It is believed that at this time, ice and snow are the main source of meltwaters, and that the major portion of loose debris on the glacier's surface and erodable sediment contained in the conduit system's walls are no longer readily available for transportation as was the case earlier on in June. As such, meltwaters reflect the chemical characteristics of their source materials. Even so, stream system A2 has a slightly lower pH level than the other two stream systems because of the interaction of its meltwaters with the bedrock.

Table 3 contains the diurnal variations in pH over a fourty-eight hour period (July 12 to July 14) for sampling sites A1, A2 and A3. The three main streams reach their maximum basicity level between 1400 to 1800 hrs. YST., just before the peak discharge period, and decreases to a minimum pH value between 0200 to 0800 YST ahead of the low discharge period.

3.2 b) Electrical Conductivity

Conductivity is defined as a solution's capability to conduct an electrical current and is directly related to the total ionic concentration of dissolved substances in the solution. Figure 8 illustrates the variations in electrical conductivity for the 1979 field season.

On the 11th and 16th of June, high conductivity values are recorded for the A2 stream system with peak conductivity occurring late in the afternoon (1500 YST). Stream systems A1 and A3 have fairly constant but much lower conductivity values than the A2 system.

This discrepency in electrical conductivity levels is partly due to the fact that A1 and A3 are supraglacial stream systems fed by snow and ice from the upper ablation zone and have characteristically low conductivity values, (Table 2). However, A1 has a slightly higher conductivity level than A3 because of its contact with the lateral moraine system (Figure 2). Because both systems are supraglacial, their meltwaters have little time for interaction and dissolution of ions from the sediment. But because A2 is a basal conduit system, meltwaters are in constant contact with the bedrock, and interaction time between water and solids is increased and allows for greater dissociation of ions from the sediment which in turn contributes

TABLE 3

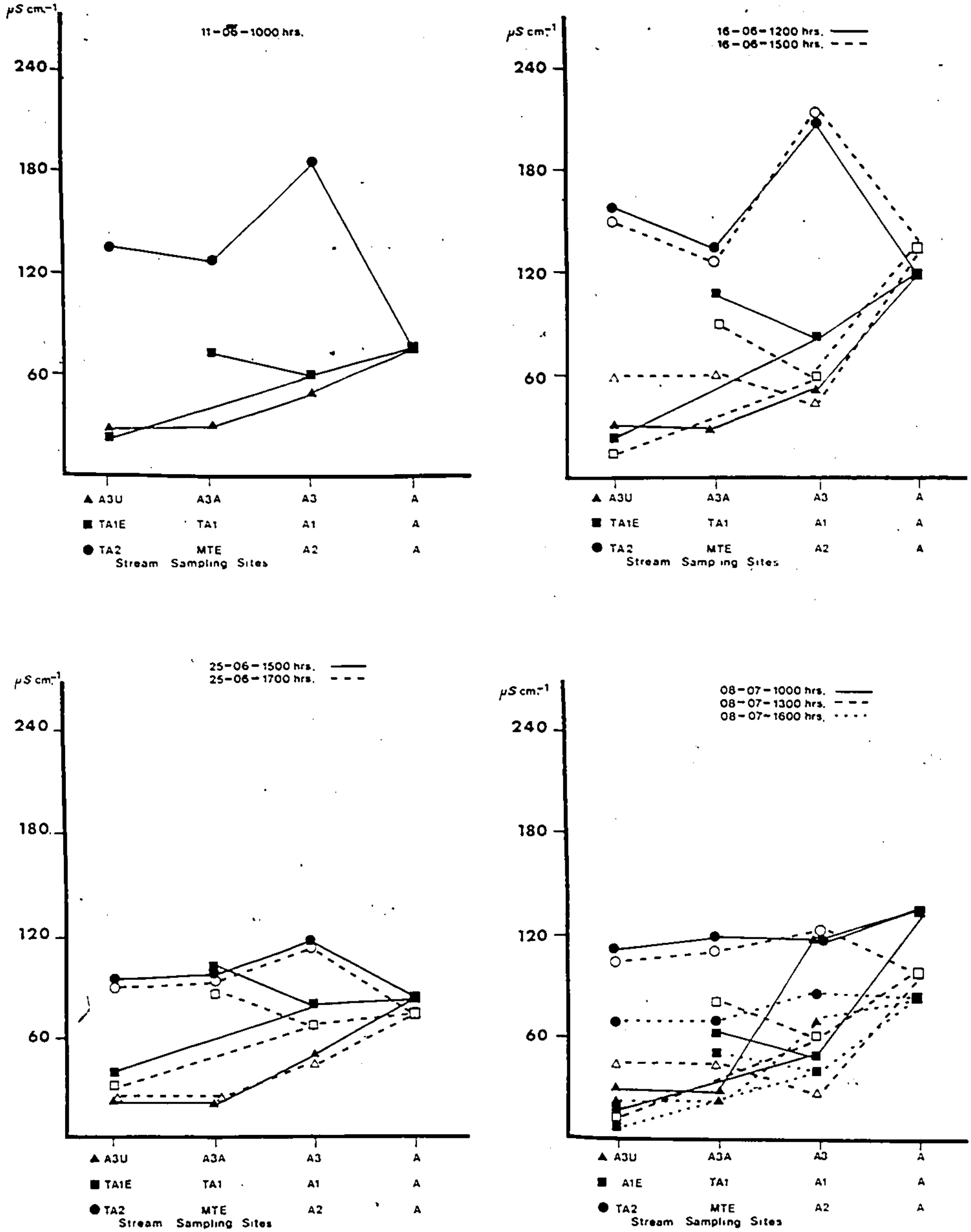
48 Hour pH Run

July 12 to 14, 1979

Time (YST)	Streams		
	A1	A2	A3
2200	7.2	8.0	8.0
2400	7.3	8.2	8.0
0200	7.4	8.1	8.1
0400	7.5	8.2	8.0
0600	7.5	8.0	8.0
0800	8.1	7.9	8.0
1000	8.6	8.0	8.0
1200	8.6	8.0	8.0
1400	8.9	8.0	8.0
1600	8.9	8.2	8.2
1800	8.7	8.2	8.2
2000	8.6	8.1	8.2
2200	8.2	8.1	8.2
2400	7.9	8.1	8.2
0200	7.7	8.0	8.0
0400	7.7	7.9	8.0
0600	7.7	8.0	8.0
0800	8.3	7.9	8.0
1000	8.8	8.0	8.1
1200	8.8	8.0	8.1
1400	8.9	8.3	8.1
1600	8.8	8.5	8.4
1800	8.5	8.5	8.4
2000	8.2	8.4	8.3
2200	8.1	8.3	8.3

FIGURE 8

Spatial, temporal and diurnal variations in electrical conductivity



to the higher conductivity levels.

Sampling site A's conductivity increases from June 11th to 16th as a result of the three stream systems mixing, snowmelt from the surrounding area and the path taken by the meltwaters through glacial till all of which add to the dissolved material content of the meltwaters.

As the season progressed (June 25th to July 8th), lower electrical conductivity levels were recorded for all three stream systems. This decrease in conductivity is associated with increased discharge and flow velocity allowing less contact time between meltwater and sediments.

Sampling sites in the A2 system registered the highest conductivity values for the summer followed by the A1 system and then A3. Sampling site A fluctuated throughout the summer as a result of routing and mixing.

Unlike the diurnal patterns observed for pH, all three streams parallel each other in the timing of maximum and minimum electrical conductivity values, (Table 4). Peak conductivity is registered from 0800 to 1000 YST and shortly there after 1600 to 2000 YST minimum values are recorded. Thus, diurnal variations in electrical conductivity occur inversely and roughly in phase with fluctuations of discharge.

3.2 c) Chloride

Chloride is found in all samples, and may have its source from wind-blown sea salt in rainwater, (see PRE samples, Table 2). The rapid, erratic fluctuations in chloride concentrations combined with a minimal range

TABLE 4.

48 Hour Electrical Conductivity Run

July 12 to 14, 1979

Time (YST)	Streams A1	A2	A3
2200	48	120	120
2400	54	115	120
0200	60	120	120
0400	64	120	120
0600	68	125	140
0800	73	135	140
1000	57	140	135
1200	47	135	120
1400	44	115	100
1600	40	100	87
1800	36	95	86
2000	38	88	87
2200	40	100	91
2400	46	100	98
0200	50	105	110
0400	53	105	120
0600	58	110	120
0800	57	115	130
1000	45	120	110
1200	42	100	86
1400	38	85	78
1600	33	70	68
1800	32	68	70
2000	36	71	72
2200	42	81	81

difference (5 to 15 ppm) from stream system to stream system throughout the field season have rendered chloride less reliable than hoped for as a chemical indicator. Consequently, spatial, temporal and diurnal variations are not marked or consistant. Figure 9 contains chloride fluctuations over the 1979 field season.

Stream systems A1 and A3 have the highest Cl^- concentrations over the entire field season. This is attributed to their source material, snow and ice which also have high chloride concentrations, (Table 2). The A2 stream system shows a falling off of Cl^- towards the end of the field season (July 8th). In this case, decreasing Cl^- concentrations maybe the result of lower surface meltwater contribution to the basal system.

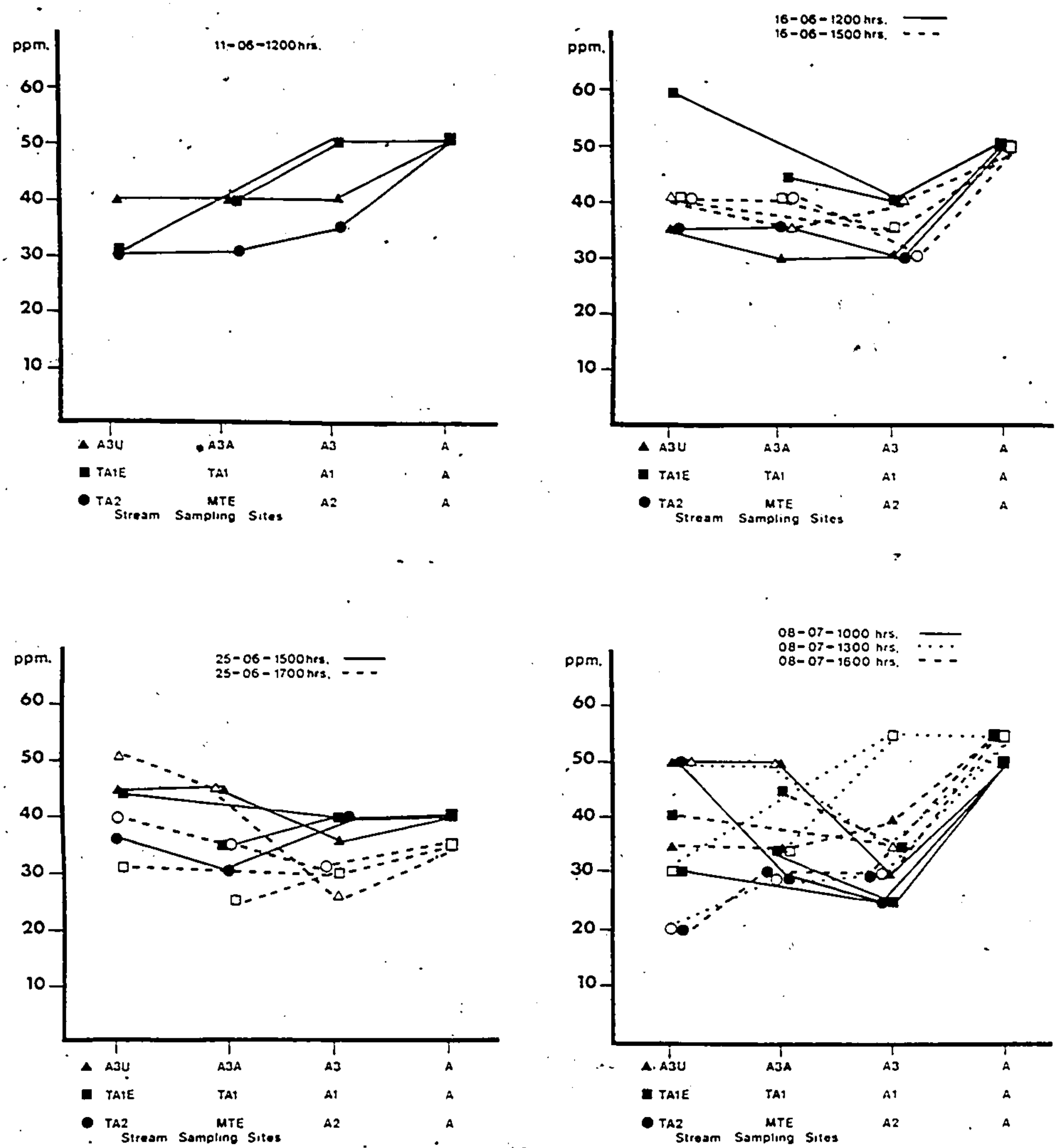
Sampling site A is fairly consistant in its Cl^- concentrations (ranging from 35 ppm to 55 ppm) throughout the field season, as a result of mixing and routing.

A slight increase, from 5 to 10 ppm , in Cl^- content was noted in all samples taken after precipitation occured. This phenomenon lasted for approximately fourty-eight hours after rain had fallen, and is believed to be related to sea salt in rain water.

Diurnal variations show peak chloride concentrations between 1200 and 1300 YST with minimums occuring in phase with peak discharge, between 1800 and 2000 YST.

FIGURE 9

Spatial, temporal and diurnal variations in chloride concentrations



3.2 d) Hardness

Total hardness of meltwaters generally represents the total concentrations of calcium and magnesium ions expressed as calcium carbonate. Calcium and magnesium may be added to the meltwaters as they pass over rock and glacial silts possessing these elements. Figures 10a and 10b illustrate the variations in calcium and magnesium concentrations throughout the 1979 field season.

At the beginning of the season, calcium concentrations were generally higher than magnesium concentrations at all sampling sites with the exception of sites TA1 and A1.

The overall calcium content and somewhat lower magnesium content registered at most sampling sites may be attributed to the entrainment of glacial debris left over from the previous year (1978) in the basal and surface drainage networks. This could account for the above average hardness levels expected for glacial streams fed by snow and ice this early in the season.

On June 16th, a slight drop in Ca^{++} and Mg^{++} concentrations was recorded at most sample sites on the west side. Three sampling sites (A3U, A3A, TA1E) had no trace of either Ca^{++} or Mg^{++}. These stations are influenced by snow and ice melt. Later in the day, (1500 YST) all three stream systems registered higher Mg^{++} concentrations than Ca^{++}.

Calcium and magnesium are components of the silicate minerals which serve as the major constituents in the metamorphic rocks found in the immediate area of Grizzly Creek Glacier. Thus the turn about in increased magnesium

FIGURE 10a

Spatial, temporal and diurnal variations in hardness

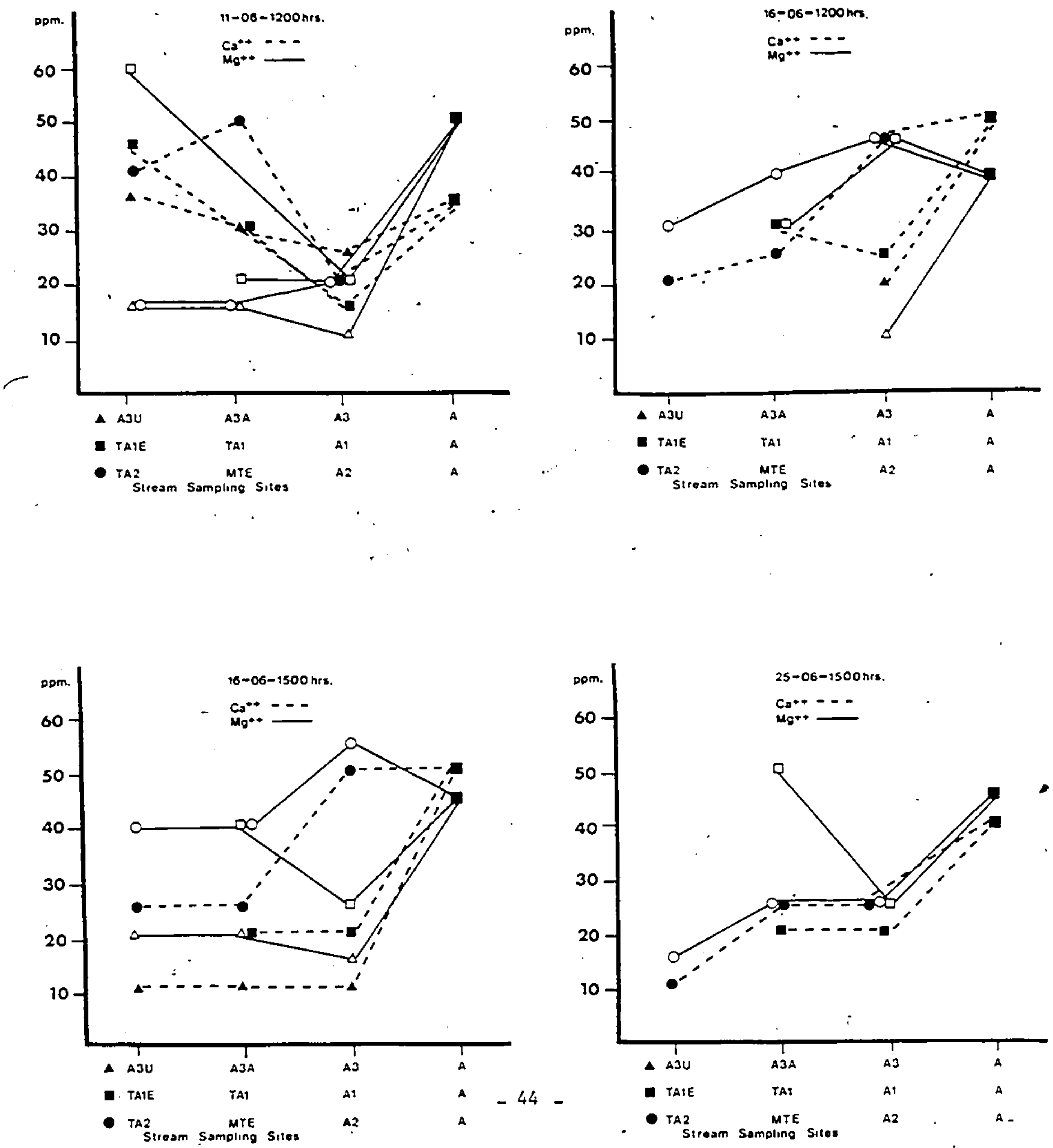
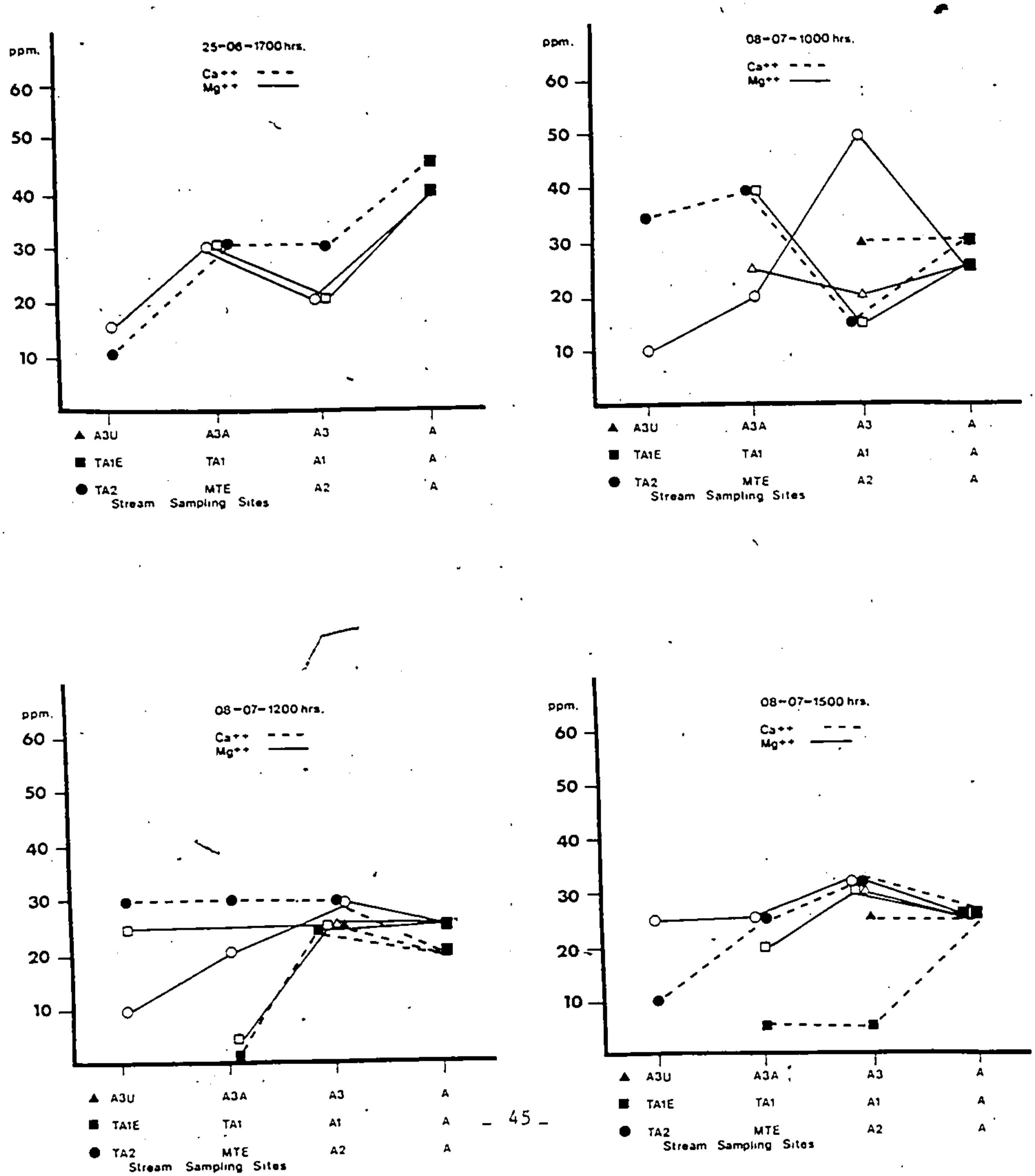


FIGURE 10b

Spatial, temporal and diurnal variations in hardness



concentrations over calcium concentrations can be accounted for by the availability of soluble Mg^{++} from the numerous greenstone fragments strewed throughout the glacierized basin, and in particular on the east side. However, sampling site A does not reflect the aforementioned trend. Its calcium content is usually higher than its magnesium content. These occurences maybe the result of stream A's incisive action on the alluvial plain where there maybe a good chance of meltwaters making contact with calcium rich deposits within the outwashed material before they reach station A.

A further decrease in the hardness levels for all the stream systems was noted on June 25th, with the A3 system having no measurable Ca^{++} or Mg^{++}. As snow and ice become increasingly important as a meltwater source, the probability of "softer" glacial waters increases.

The overall reduction in hardness levels for the stream systems on June 25th is ascribed to a combination of increased discharge resulting from snow and ice melt, dilution, and less interaction time between rock materials and meltwaters.

As the snowline recedes, the head of streams A1 and A3 cut farther up into the accumulation zone. Consequently, sampling stations (A3U, TA1E, A3A) located in the immediate area have no measurable Ca^{++} or Mg^{++} content during the early part of July. Continued reduction in hardness levels at all sampling sites on July 8th was noted.

The temporal sequence in Ca^{++} and Mg^{++} concentrations over the 1979 field season is one of constant decline. Calcium concentrations go from 50 ppm. early in the season to 25 ppm in mid-July. Magnesium concentrations started at 35 ppm and also ended up at 25 ppm in mid-July. As the summer progresses, supraglacial streams low in Ca^{++} and Mg^{++} content play an ever increasing role in glacial runoff, and as such contribute to the decrease in hardness levels. Dilution, interaction time and availability of elements must also be considered as factors contributing to lower hardness levels.

Diurnal fluctuations in hardness levels for glacial streams vary inversely with daily discharge. Peak Ca^{++} and Mg^{++} concentrations occur in between 1000 and 1200 YST and taper off to minimums around 1800 to 2000 YST.

3.2 e) Phosphate

In this glacierized basin, phosphate is largely concentrated in greenstones and schists with apatite as an accessory mineral. Weathering of these rocks tends to release calcium phosphate, which is soluble to some degree in rainwater containing carbon dioxide. Phosphate was tested for during the early part of the season, and the results are contained in Table 5.

Phosphate levels are fairly consistant at the beginning of June (8-13), and vary by only 0.05 ppm to 0.10 ppm at stations A2 and A3. Sampling site A1 however is somewhat more erratic in phosphate content between June 8th and 13th. Meltwaters from this system come into contact with the westside lateral moraine where it picks up available calcium phosphate for solution.

All three sampling sites on June 15th and 16th show a marked decrease

TABLE 5

Phosphate Concentrations

Sample Site A1			A2			A3		
Date	Time (YST)	Phosphate (ppm)	Date	Time (YST)	Phosphate (ppm)	Date	Time (YST)	Phosphate (ppm)
08/06	1500	0.45	10/06	1100	0.25	11/06	1000	0.30
09/06	1200	0.35	10/06	1300	0.20	11/06	1200	0.20
09/06	1300	0.45	11/06	1000	0.25	11/06	1400	0.20
09/06	1400	0.20	11/06	1200	0.25	11/06	1600	0.20
09/06	1500	0.20	11/06	1400	0.15	16/06	1200	0.05
09/06	1600	NT	11/06	1600	0.20	16/06	1600	NT
10/06	1000	0.53	12/06	2000	0.05	18/06*	1000	0.10
11/06	1000	0.15	13/06	1100	0.05	20/06	1500	0.80
11/06	1200	0.35	13/06	1500	0.05	21/06*	1600	0.70
11/06	1400	0.25	16/06	1200	0.05			
13/06	1200	0.10	16/06	1500	NT			
15/06	1500	0.05	18/06*	1000	0.25			
16/06	1200	0.05	20/06	1500	0.45			
16/06	1600	0.05	21/06*	1600	2.20			
18/06*	1100	0.10	22/06	1100	0.15			
20/06	1500	0.35	02/07	1200	0.15			
21/06*	1600	1.42						

*Precipitation

NT: No trace

in phosphate content as a result of last winter's weathered material on the glacier being carried away by spring meltwaters. The possibility that phosphates were redeposited should not be disregarded either.

On June 18th and 21st, phosphate concentrations increased substantially after heavy rainfall. All three stations had higher than usual phosphate concentrations especially on the 21st at sites A1 and A2. Consequently, the mobilizing effect precipitation has on phosphate overshadows those of spatial and temporal variations.

3.3 The Effects of Routing on the Chemical Composition of Meltwaters

This section assess the effects of routing on the various runoff components over the summer by examining pH and electrical conductivity from both filtered and unfiltered samples, and ion concentrations of Cl^-, Ca^{++} and Mg^{++} of filtered samples only. This information is contained in Figures 11 through 14. Also in this section, the silica concentrations in streams A2 and MTE are examined.

In order to assess and compare the effects of routing on the various streams' meltwater characteristics, a control stream was used. The A3 stream system was chosen because it is a supraglacial stream fed entirely by snow and ice, with limited interference from the two medial moraines (Figure 2).

On June 16th (1200 YST) low concentrations of Cl^-, Ca^{++} and Mg^{++}, 30, 20, and 10 ppm respectively, were recorded at sampling site A3. The pH levels for unfiltered samples were higher than filtered samples, and

FIGURE 11

Stream signatures for June 16 - 1200hrs.

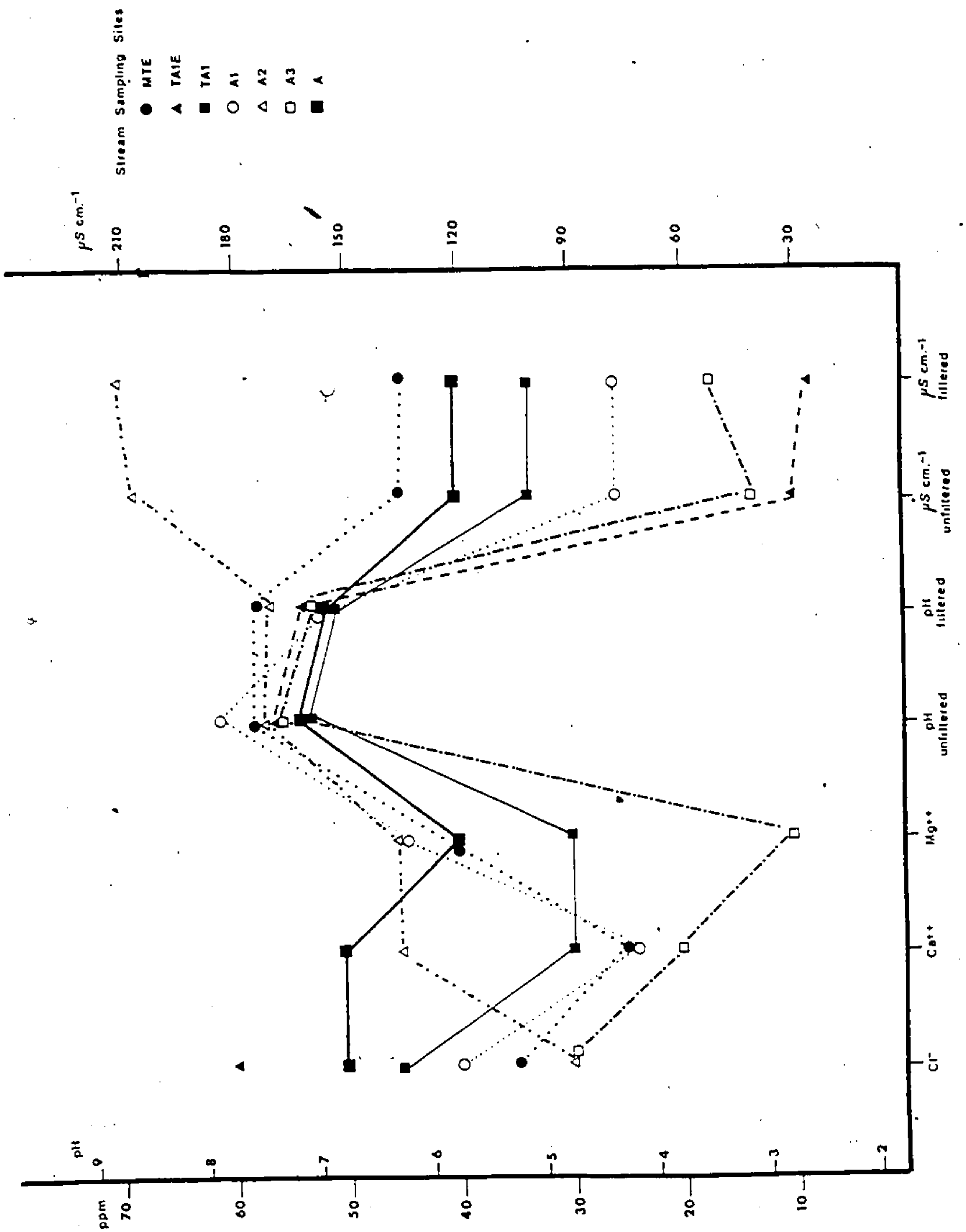


FIGURE 12

Stream signatures for June 20 ~ 1500 hrs.

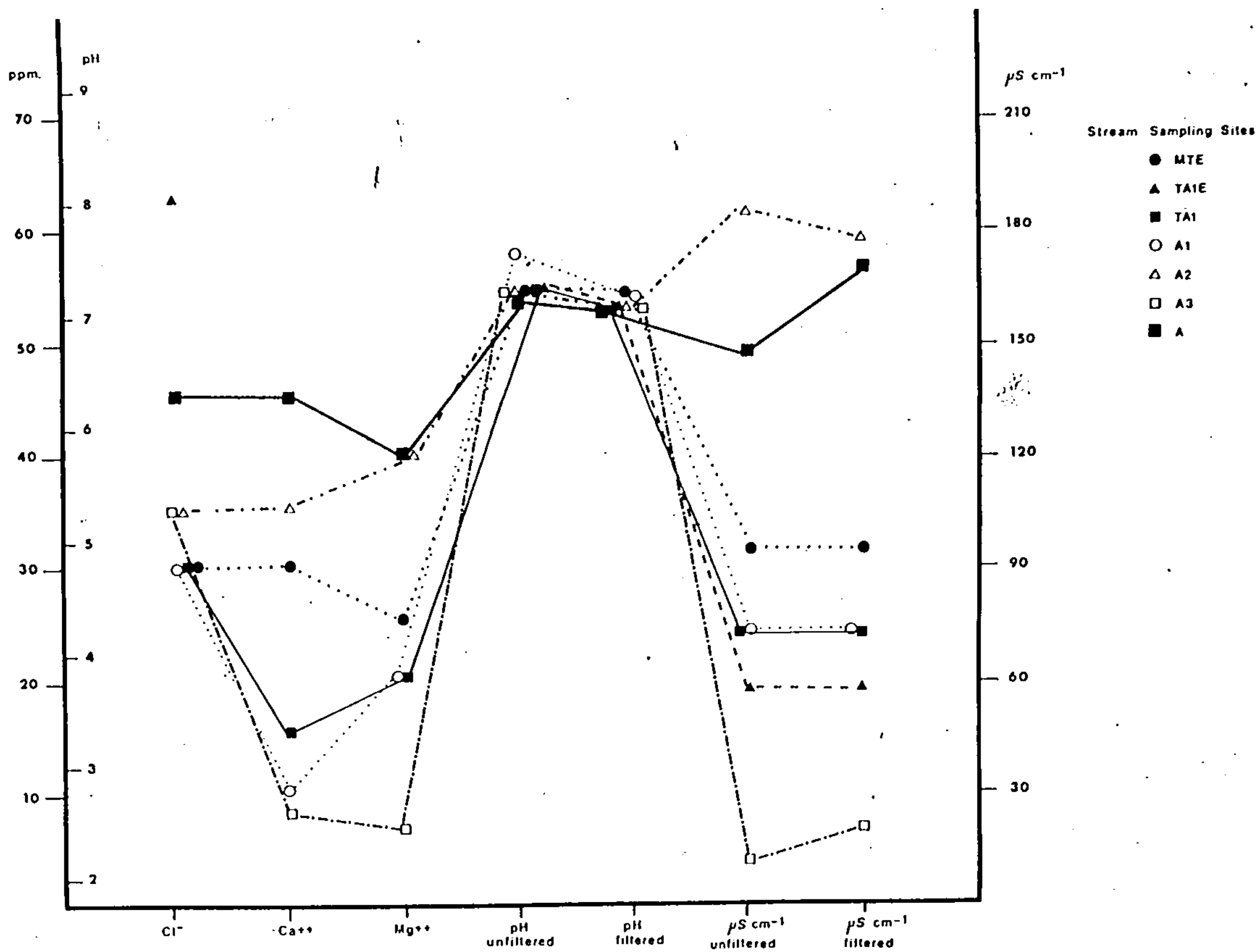


FIGURE 13

Stream signatures for June 25 - 1500 hrs.

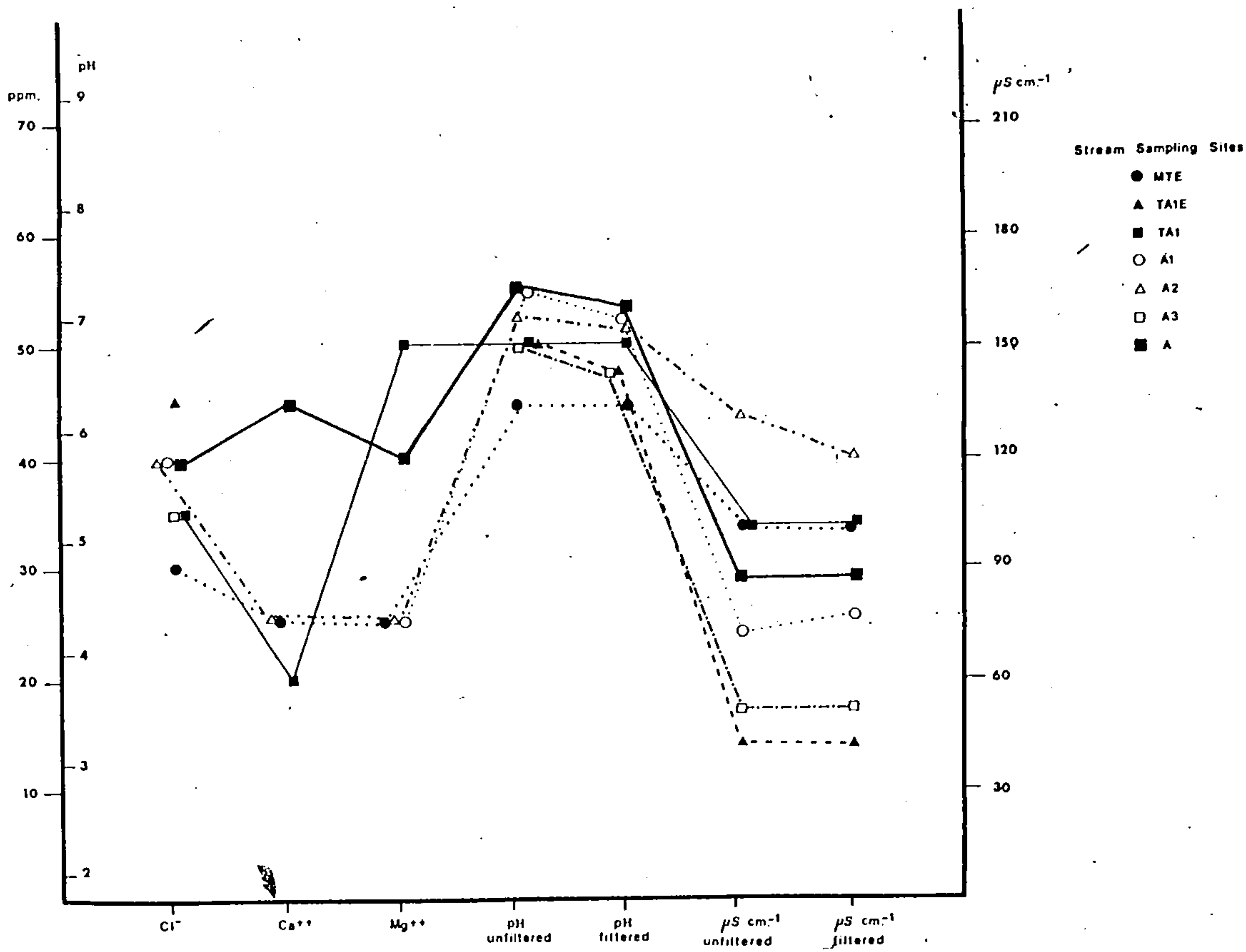
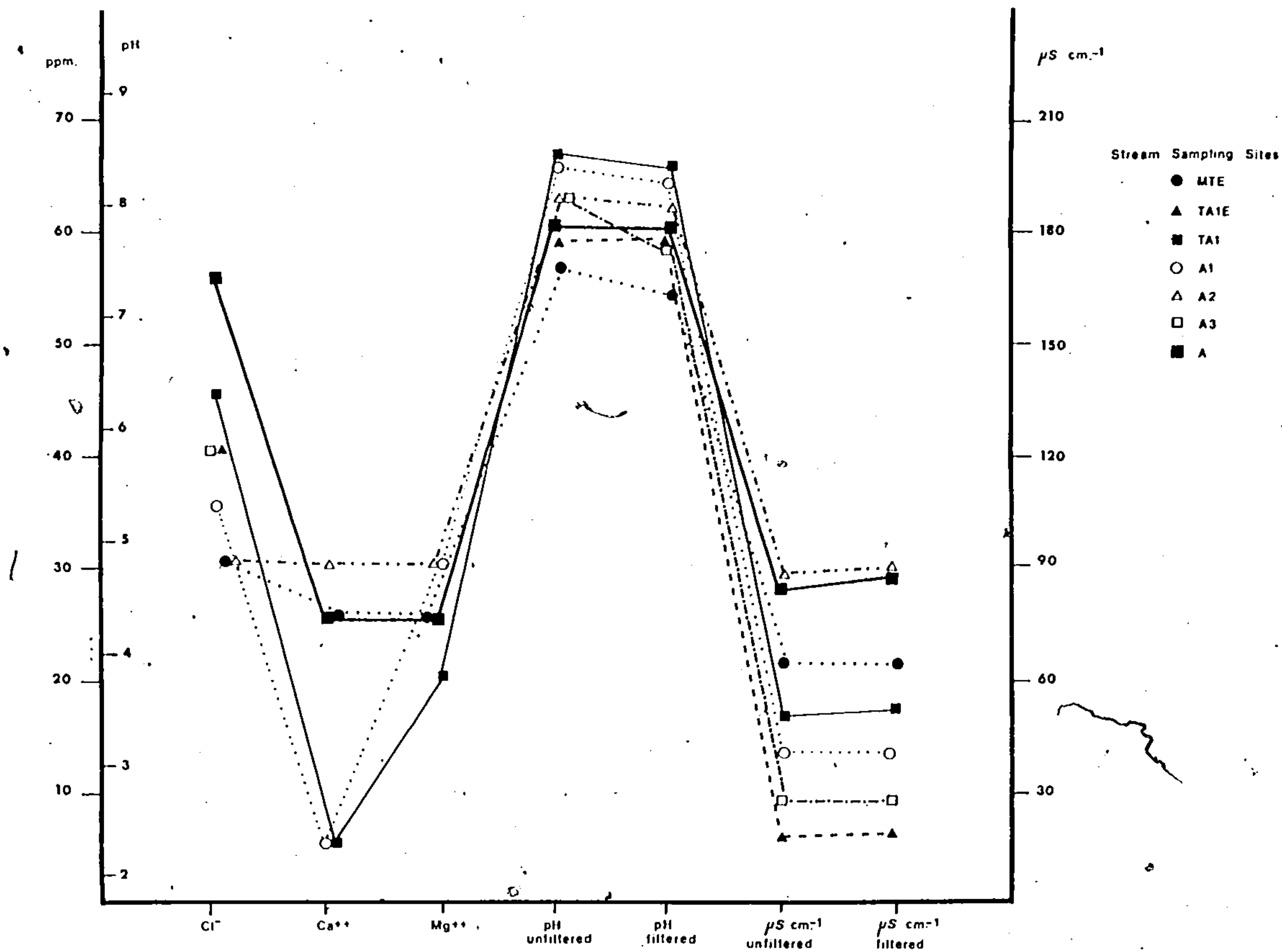


FIGURE 14

Stream signatures for July 8 - 1600 hrs.



the inverse is true for electrical conductivity, (Figure 11). This is a recurring phenomenon and the probable explanation for the increase in conductivity of the filtered sample is that during filtration, ions became desorbed from the surface of sedimentary particles and passed through the membrane during the filtration process. (Lorrain and Souchez 1972).

Four days later on June 20th (1500 YST) chloride content is up from 30 to 35 ppm , Ca^{++} and Mg^{++} are down to 6 and 4 ppm , and pH levels are up to 7.4 and 7.0 with the unfiltered sample highest. Conductivity has decreased slightly, with the filtered sample higher than the unfiltered. (Figure 12).

Towards the end of June beginning of July (Figures 13 and 14), meltwaters at station A3 had no traceable calcium or magnesium. Also, pH levels have become increasingly basic in both filtered and unfiltered samples. Conductivity continues its downward trend, and the gap between filtered and unfiltered samples lessens till they are identical, (Figure 14). Chloride concentrations are fairly stable throughout the season varying between 30 to 40 ppm.

The information presented on Figures 11 through 14 for sample site A3 gives all indications that A3's meltwater characteristics are not the result of routing but rather temporal variations. As the season progresses and the winter's weathered material washed away, the chemical properties of A3's meltwaters fall into line with those of its source material, namely snow and ice.

The A1 stream system is monitored at three main sites, TA1E, TA1 and A1 (Figure 6).

TA1E is a small supraglacial stream with similar water quality characteristics as A3. It behaves as A3 does mainly because its meltwater source area is the same as A3's, and it has minimal interaction with the surrounding environment.

Chloride concentrations at the beginning of the season were quite high, 60 ppm on June 16 (Figure 11) and continued to increase until June 20th (Figure 12). As the winter's snow cover melts away, and ice's contribution to the discharge regime increases, a substantial reduction in Cl^- content was recorded at TA1E (June 25 and July 8: Figures 13 and 14).

No trace of Ca^{++} and Mg^{++} was detected at site TA1E during the period in question (June 16th to July 8th). The pH levels range between 7.0 and 7.6 for filtered samples and between 7.2 and 7.8 for unfiltered. This is the same type of temporal sequence observed at site A3.

Conductivity readings at this site are the lowest registered at any of the main stream stations. The difference between filtered and unfiltered samples is negligable varying at most by 5 micromhos/cm.

Routing has an exiguous effect on the chemical composition of TA1E's meltwaters. In fact, very little variation in water quality characteristics occurs between TA1E's headwaters (A1U, Figure 6) and the lower sampling site as indicated in Table 6.

Another tributary stream in the A1 system is TA1 (Figure 6) fed by snow and ice meltwaters from the upper and lower ablation zones, the accumulation zone, and has the added influence of avalanche activity from the westside ice cap, and farther down the stream passes along side the ice cored lateral moraine (Figure 2).

TABLE 6

Chemical Composition of Meltwaters at A1U

Date	Time (YST)	Cond.	pH	Cl^- (ppm)	Ca^{++} (ppm)	Mg^{++} (ppm)
15/06	1200	20	7.0	45	-	-
16/06	1500	20	6.9	40	-	-
25/06	1500	20	7.1	40		

As a result, TA1's chemical characteristics differ considerably from those of TA1E and A3.

On June 16th, calcium and magnesium concentrations were equal, but as the summer progressed, magnesium dominated calcium content, (Figures 12 to 14). Meltwaters from this stream came into contact with the ultrabasic rocks of the west side moraine system. The basic pH levels recorded at station TA1 are another outcome of this interaction. The pH levels peak in July at this site (see Figure 14). Also, unfiltered samples have higher pH levels than filtered.

Chloride concentrations fluctuate over the entire field season, there is no set pattern. The eratic variations in Cl^- content are due to the snow avalanche contributions from the ice cap which are rich in chloride content (see Table 2, sample AVA for detailed analysis).

Electrical conductivity readings are higher than those at sampling sites A3 and TA1E as a result of the suspended sediment load acquired by TA1 along its route. On June 16th, electrical conductivity for the unfiltered sample was higher than filtered, but as figures 12 to 14 show, conductivity values for both samples, were the same afterward.

Table 7 contains the water quality characteristics for TA1U at the head of stream TA1 (Figure 6). When comparing the chemical characteristics of the meltwaters from sites TA1U (Table 7) and TA1 (Figures 11 and 12) there is a definite difference between the two as a result of meltwaters passing along side the westside lateral moraine system which contributes to the change in water quality characteristics at sampling site TA1.

Streams TA1 and TA1E empty into stream A1 (Figure 6).

TABLE 7

Chemical Composition of Meltwaters at TA1U

Date	Time (YST)	Cond.	pH	Cl^- (ppm)	Ca^{++} (ppm)	Mg^{++} (ppm)
15/06	1500	100	7.8	35	-	-
16/06	1200	100	7.8	35	-	-
20/06	1500	100	8.0	30	-	-

Figures 11 through 14 show A1's water quality characteristics follow essentially the same patterns registered at sites TA1E and TA1. And A1's chemical properties are usually midway between those of TA1E and TA1 — (Figures 11 to 14). Therefore, mixing rather than routing is responsible for A1's chemical properties. Occasionally, small streams from the lateral moraine will empty into A1 between sites TA1E, TA1 and A1, causing brief upserges in chemical concentrations at station A1. However, these interruptions are short lived. Chloride concentrations at station A1 are lower than either TA1's or TA1E's as a result of increased ice melt to water flow at A1.

The other major stream system is the A2 system, with two main sampling sites, A2 and MTE (Figure 6). The A2 system is unique in that its source areas are the icefall and the east side tributary glacier, as well as snow and ice melt from the glacier. To complicate matters even further, meltwaters from the icefall flow through a basal conduit system, and meltwaters from the tributary glacier join this conduit system via a moulin in the glacier's side (Figure 6). Figures 11 through 14 illustrate A2's and MTE's stream signatures for June and July.

At sampling site MTE, chloride concentrations from June 16th to July 8th vary very little. In fact on June 16th (Figure 11) Cl^- content was 35 ppm , and then stayed at 30 ppm on June 20th, 25th and July 8th (Figures 12, 13 and 14). As for hardness it fluctuated at the beginning of the season with magnesium content (40 ppm) superior to calcium (25 ppm) on June 16th. However, on June 20th Ca^{++} was slightly higher than Mg^{++} concentrations. Figures 13 and 14 show calcium and magnesium concentrations are equal at 25 ppm. These variations in calcium and magnesium concentrations are attributed to the availability of these elements for solution throughout the season from the east side basin. Hardness values for this stream do not follow any set pattern as demonstrated in Figures 11 to 14.

The meltwater's pH levels are fairly steady during the early part of June (16th and 20th) at 7.3 and 7.2 respectively for both filtered and unfiltered samples. Correspondingly, electrical conductivity remains the same for filtered and unfiltered samples over the period in question. A temporal sequence was recorded in which conductivity levels decrease as the summer progresses (Figures 11 to 14).

On June 25th, pH is at a low for this time of the season, 6.2. An increase in both discharge and sediment load on this day made more hydrogen ions available for dissolution than usual and accounts for the low pH level at MTE. Both filtered and unfiltered samples had the same pH value. Unfiltered pH levels were above filtered on July 8th and tend to be basic as high discharge flows continue.

Farther down stream at sampling site A2 (Figure 6) the influence of meltwaters from the icefall, basal conduit system, MTE and supraglacial streams (see SA2 Figure 6, and Appendix C for detailed chemical analysis) from the main glacier all mixed together to produce A2's water quality characteristics.

As at MTE, chloride concentrations at A2 are subject to rapid and erratic fluctuations, and as such, no discernable seasonal trend can be identified (Figures 11 to 14).

Calcium and magnesium concentrations at sampling site A2 follow the same temporal sequence as the other stream systems. But unlike the others, A2's hardness levels are consistantly above those of the supra-glacial streams, and its Mg^{++} content is either equal or superior to its Ca^{++} content.

The high hardness levels recorded at station A2 are the direct result of routing. Water which filters through the ice to the basal conduit system has a prolonged contact time with sediments, and meltwaters from the icefall and MTE are in constant contact with the bedrock until they emerge at A2. Further evidence of the meltwater bedrock interaction is reflected in the high conductivity levels recorded at this site. Electrical conductivity follows the same temporal pattern as the other streams, but always manages to remain the highest.

Another prime example of the effects of routing on the chemical composition of meltwaters are the abnormally high silica concentrations recorded at sampling sites A2 and MTE (see Appendix C for detailed chemical analysis and comparison).

Silica is present in quartz as crystalline SiO_2. But because quartz is one of the most resistant of all rock minerals to erosion, for all practical purposes, quartz is usually ignored as a probable source of silica. Because of the freeze-thaw activity in the area, the dissolved silica in the meltwaters is belived to originate from the breakdown of silicates. There are in fact numerous greenstone fragments in the area. However, the likelyhood that the high silica concentrations found in the meltwater samples are entierly attributable to the greenstones in the area is not good and suggests that an additional source of silica exists somewhere in the vicinity.

At the beginning of summer, silica concentrations at A2 were quite high and peaked on June 11th (see Table 8). Silica content varied a great deal over the summer, but had a general downward trend due to element availability and dilution.

Spot checks at MTE, Table 9, also revealed high silica concentrations.

TABLE 8

Silica Concentrations at A2

Date	Time (YST)	Silica (ppm)
10/06	1100	1.23
10/06	1200	1.80
10/06	1300	1.80
11/06	1000	2.10
11/06	1200	2.25
11/06	1400	2.00
11/06	1600	1.95
12/06	2000	1.40
13/06	1100	1.23
13/06	1500	1.83
16/06	1100	1.30
16/06	1500	1.15
*18/06	1100	1.55
*19/06	1100	1.30
20/06	1500	1.70
*21/06	1600	1.03
22/06	1000	0.88
04/07	1400	0.70
08/07	1100	1.10

continued...

*Marks Days with Precipitation

TABLE 8
(continued)

Silica Concentrations at A2

Date	Time (YST)	Silica (ppm)
08/07	1300	1.03
08/07	1600	0.70

TABLE 9

Silica Concentrations at MTE

Date	Time (YST)	Silica (ppm)
10/06	1200	1.23
13/06	1400	0.80
15/06	1400	1.10
16/06	1400	0.70
*19/06	1300	0.80
20/06	1400	0.77
08/07	1100	0.85
08/07	1500	0.57

*Marks Days with Precipitation

At any given time MTE contributed from 45% to 80% of the total silica content recorded at A2.

The combined effects of routing through glacial till, and three glacial streams flowing into stream A, all contribute to the chemical composition of meltwaters from sampling site A. Figures 11 to 14 contain A's stream signature for the 1979 field season.

Chloride concentrations at sampling station A were second only to those measured at TA1E. The high Cl^- concentrations during the early part of June (Figures 11 and 12) are attributed to snowmelt from the surrounding area. Chloride which accummulated in the snowpack over the winter was released in early spring as melting began.

Chloride concentrations imitate the temporal trends observed for most elements, which is one of reduced concentration as the season progresses (Figures 11 to 13). A sudden increase in Cl^- content on July 8th (Figure 14) is believed to be related to the previous day's rainfall.

Calcium content is superior to magnesium content during June (Figures 11 to 13) and equal in July (Figure 14) and is the outcome of routing rather than mixing as most glacial streams at one point or another have superior Mg^{++} concentrations.

The pH levels at station A behave in the same manner as those of the other glacial streams. Its unfiltered sample's pH values are above the filtered, and are equal towards the end of the season, July 8th (Figure 14). Mixing and routing both play an important part in A's acquired pH levels.

Electrical conductivity measured at A, follows the established pattern exhibited by the other streams except on the 20th of June (Figure 12). After two days of rain (June 18th and 19th) its conductivity increased to 170 micromhos/cm for the unfiltered sample, and 190 micromhos/cm for the filtered sample. This particular climatic event underlines the importance of the surrounding area's contribution to A's water quality characteristics.

3.4 The Effects of the Diurnal Discharge Regime on Water Quality Parameters

In order to conduct a thorough investigation of water quality characteristics and what influences them, this section was incorporated, and deals with the effects of the diurnal discharge regime on the chemical composition of meltwaters.

Because of extensive water quality testing at sampling site A2, and a complete hydrological record, this analysis is restricted to the A2 stream system. Figure 15 represents the diurnal variations in flow, electrical conductivity, pH, calcium and magnesium concentrations over the 1979 field season.

Low discharges are associated with high chemical concentrations, whereas high discharges are characterized by low chemical concentrations (Figure 15). This inverse relationship is attributed to dilution and contact time.

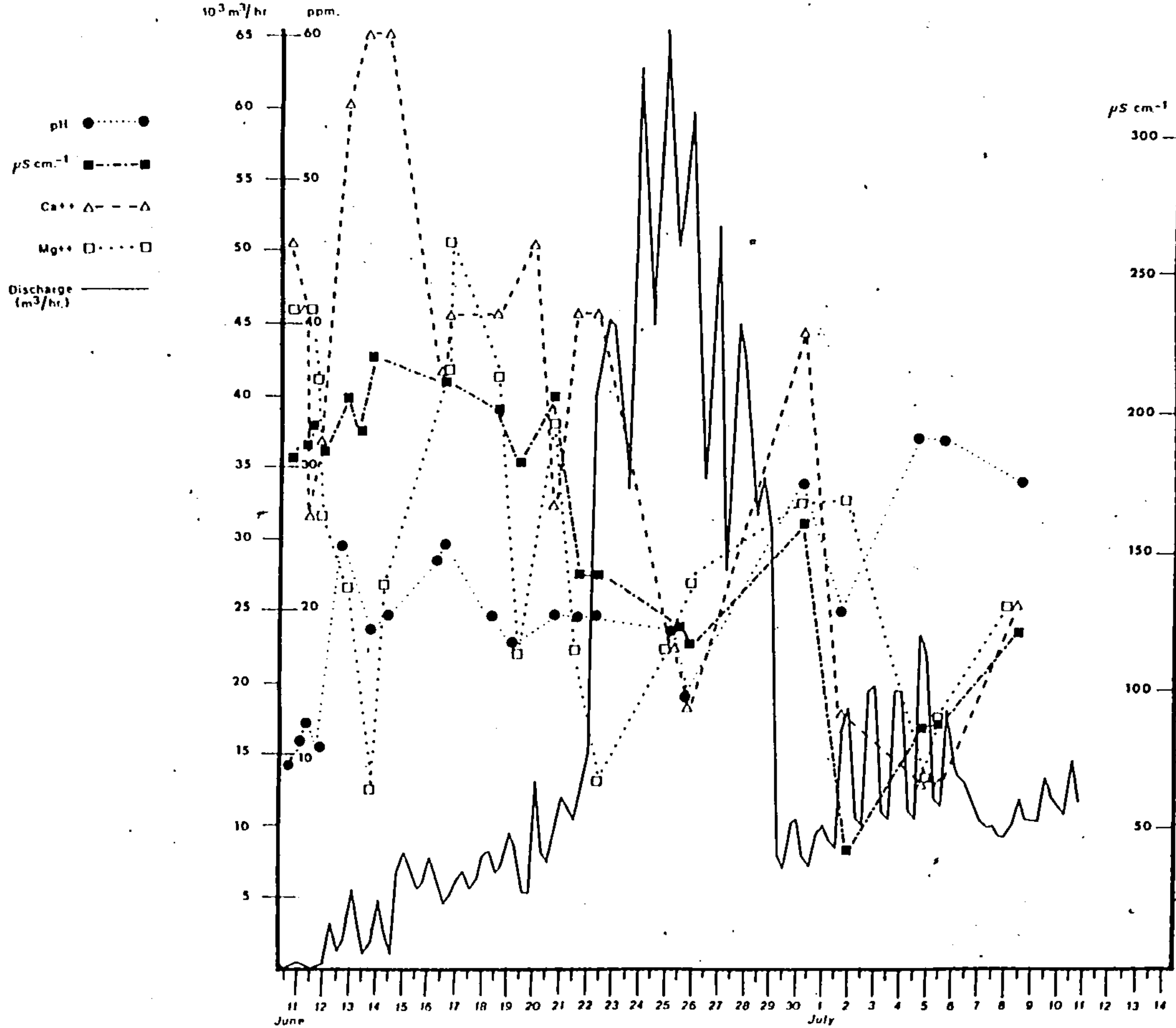
The contact time between the bedrock and meltwaters is relatively short for high discharges, (i.e. June 22nd to 26th). Low discharges have slightly lower velocities and allow for greater contact time between bottom fine sediments and meltwaters, (i.e. June 11th to 21st).

Figure 15 also reveals that fluctuations in electrical conductivity are closely paralleled by magnesium concentrations, and that calcium concentrations are inversely related to magnesium concentrations.

Discharge flows also affect the pH of meltwaters. At the beginning

FIGURE 15

Water quality characteristics and discharge



of the field season (June 11th and 12th) hydrogen ions which accumulated in the snowpack, conduits and crevasses over the winter were carried off with the season's first melt and contributed to the stream's acidic pH. As the summer progresses, increased discharge through increased snow and ice melt allows for less contact time between meltwaters and the bedrock. Consequently, A2's pH retained most of its source material's alkalinity. Occasionally, high discharge flows (June 23rd to 26th) eroded the basal conduit's walls which in turn released sediment particles into the water thereby increasing the hydrogen ion content which contributed to the stream's acidic pH.

3.5 Suspended Sediment Analysis

Another very important factor which should not be neglected when investigating the chemical properties of glacial meltwaters is the effect suspended sediments have on the chemical composition of meltwaters. The sorption of major cations (Ca^{++}, Mg^{++}, K^{+} and Na^{+}) on silt and clay particles affects water composition by decreasing or increasing the number of cations available for ion exchange in meltwaters.

Silt and clay from filtered water samples are subdivided into two groups, those obtained from subglacial streams taken at point of emergence A2, and those from supraglacial streams A3, A1 and TA1.

Results from the atomic absorbtion spectrophotometry analysis of these samples are contained in Table 10 for days with no rain.

TABLE 10

Supraglacial and Subglacial Cation Concentrations

Sample	Date/Time YST	CATIONS (ppm) Na+ ±0.05	K+ ±0.05	Ca++ ±0.05	Mg++ ±0.05
A1	11-06-1000	4.71	2.39	10.28	0.34
A1	11-06-1200	5.53	2.79	15.03	0.86
A1	11-06-1400	2.80	1.11	8.87	0.37
A2	11-06-1000	3.58	1.43	9.43	0.55
A2	11-06-1200	3.81	1.35	7.66	0.64
A2	11-06-1400	4.02	1.74	10.07	0.43
A2	11-06-1600	2.69	1.09	9.24	0.44
A3	11-06-1000	3.05	1.30	4.84	0.15
A3	11-06-1200	4.04	1.36	8.51	0.39
A3	11-06-1400	4.18	1.35	8.80	0.62
A3	11-06-1600	3.02	1.03	7.71	0.36
A1	16-06-1200	5.68	3.59	20.13	2.65
A1	16-06-1600	19.11	12.14	58.03	9.29
TA1	16-06-1200	5.78	3.04	25.57	3.52
TA1	16-06-1600	4.99	4.01	121.44	18.61
A2	16-06-1100	7.07	3.16	33.73	4.01
A2	16-06-1500	5.53	2.55	27.66	3.08
A3	16-06-1200	5.78	2.35	17.68	2.08
A3	16-06-1500	6.52	5.22	60.04	11.82
A1	20-06-1500	4.51	2.03	11.39	0.36
TA1	20-06-1500	5.10	2.34	14.79	0.43
A2	20-06-1500	2.91	1.04	6.25	0.32
A2	20-06-1600	1.51	0.82	6.93	0.06
A3	20-06-1500	3.76	1.44	6.59	0.25
A1	25-06-1500	2.74	1.35	23.97	0.57
A1	25-06-1700	4.18	1.77	14.79	0.20
TA1	25-06-1500	3.29	1.63	26.19	0.79
TA1	25-06-1700	1.99	1.45	13.91	0.53
A2	25-06-1600	6.58	3.67	80.00	3.12
A2	25-06-1700	2.43	1.61	26.68	0.82
A3	25-06-1500	2.58	0.98	7.83	0.15
A3	25-06-1700	2.04	0.88	5.97	0.22
A1	30-06-1300	2.65	3.15	63.22	2.10
TA1	30-06-1300	5.20	1.26	9.67	0.11
A2	30-06-1000	4.33	1.58	13.44	0.44
A2	30-06-1200	5.69	1.84	17.89	0.67
A2	30-06-1300	5.58	1.61	17.41	1.00
A3	30-06-1200	3.45	1.45	13.25	0.28
A3	30-06-1400	4.23	2.31	30.65	1.31
A1	02-07-1100	2.75	1.21	11.40	1.04
TA1	02-07-1100	3.05	1.80	32.49	1.04
A2	02-07-1200	2.90	1.05	9.17	0.02
A3	02-07-1200	4.10	0.99	4.10	1.07
A1	04-07-1400	7.01	1.58	30.18	2.74
A2	04-07-1400	2.75	1.21	11.40	1.04
A2	05-07-1100	1.53	1.29	20.27	1.16
A3	05-07-1100	4.42	1.79	22.99	1.92

Subglacial cation concentrations range from 6.25 to 80.00 ppm for Ca^{++}, 0.02 to 4.01 ppm for Mg^{++}, 1.51 to 7.07 ppm for Na^{+}, and 0.82 to 3.67 ppm for K^{+}. Supraglacial cation concentrations range from 4.10 to 121.44 ppm for Ca^{++}, 0.05 to 18.61 ppm for Mg^{++}, 1.99 to 19.11 ppm for Na^{+}, and 0.83 to 12.14 ppm for K^{+}.

The information presented in Table 10 shows that in general the amount of sorbed cations on suspended sediment particles in supraglacial streams is greater than those held in the subglacial stream. Kennedy (1965) put forth the notion that there is an increase in cation exchange capacity with decrease in grain size. The Gouy layer, composed of hydrogen ions, decreases in thickness as particle size decreases allowing for easier disoluation of sorbed cations. This is indeed applicable to subglacial flows where the material in suspension is a fine powder as a result of the glacier's grinding action against the bedrock. Also, this explanation concurs with the information presented in section 3.3, and offers a further insight as to why subglacial streams have a greater number of chemical elements in solution than supraglacial streams.

Suspended sediment analysis also reveals that calcium is the most abundent of the major cations absorbed to sediment particles. Coincidentaly meltwater analysis displays high Ca^{++} concentrations in all water samples except for those samples taken at TA1 and A1 early in the season. These samples had higher Mg^{++} concentrations than Ca^{++}. Atomic absorption analysis of sediment from these sampling sites show that Ca^{++} concentrations are higher than Mg^{++} concentrations, and in fact, Ca^{++} content at these sites are generally higher than those of the other sites throughout the study period.

As a result, the amount of Ca^{++} in solution is reduced and explains the low Ca^{++} concentrations recorded at TA1 and A1.

Examination of suspended sediment results (See Appendix C for comprehensive suspended sediment analysis) indicates very little correlation with flow. There were no recurrent temporal trends in the chemical composition of suspended sediment samples, and cation concentrations did not increase or decrease proportionately with discharge flows. However, as a general rule, cation concentratios of Ca^{++}, Mg^{++}, Na^{+} and K^{+} increased with increased sediment load.

CHAPTER IV

CONCLUSION

This study sought to examine and explain Grizzly Creek Glacier's hydrological processes during the 1979 field season. By combining hydrochemical and sedimentary analysis with hydrological measurement techniques, further insight into the behavior of supraglacial and subglacial flows, conditions pertaining at the ice-rock interface and the origins of the melt in either snow, ice or precipitation were obtained.

The relative discharge contribution of each of the runoff components to the total flow was monitored from June 8th to July 15th, 1979. During this period, stream flows would rise rapidly and irregularly to a daily maximum. As a result, the dynamic nature of the runoff system posed many monitoring and locational problems which were resolved by the diversity and adaptability of the hydrological measurement techniques employed.

Subglacial flows accounted for the major portion of the total discharge at the beginning of the summer, 41.5 to 84.0 percent of the discharge tapering off to ten percent later on in the season. Towards the end of June beginning of July, supraglacial streams gained in importance as major runoff components contributing fourty-eight percent of the total discharge, a substantial increase over earlier contributions of 7.8 percent. This transition from subglacial to supraglacial streams as the main discharge component is linked to climatological conditions in the glacierized basin.

Climatic impact on the hydrological regime is not felt immediately at the start of the summer due to the high reflectivity of the winter's snowpack and cold temperatures. Meier (1972), Jacobs et. al. (1972) and Lang (1969) all cite surface albedo as the principal factor affecting glacial melt.

Meltwaters originating from the west side of Grizzly Creek Glacier at the beginning of the field season had to percolate through the winter snowpack before reaching the glacier's terminus, whereas east side meltwaters drained more freely through the basal conduit system. As the snowline receeded exposing a greater area of ice in the upper and lower ablation zones and snow depth in the lower accumulation zone decreased, supraglacial streams discharge and velocities increased. By late June the snowline had reached its equilibrium point, and subglacial flows were contributing less to the total discharge. No evidence of a storage mechanism within the glacier was detected. Hence, meltwaters were being diverted away from the complex internal drainage network via the developing surface drainage network. Also, as a result of decreasing snow cover the effects of rainfall on the discharge regime was more pronounced and immediate.

These field observations are in agreement with similar hydrometeorological studies conducted on valley glaciers in the Canadian Rockies, (Krimmel et. al. 1972, Young 1977, Bigras 1978) Northwest Territory (Østrem et. al. 1967) the Swiss Alps (Lang 1969) and northern Sweden (Stenborg 1969, 1970), even though the timing of the events is different for Grizzly Creek glacier, the sequence is similar.

The separation of the three main runoff components through hydrochemical analysis provided a useful and reliable means of determining hydrological process inputs. Zeman and Slaymaker (1975), Church (1974), and Slatt (1972) found major contributing factors in total ion concentrations to be bedrock type, climatic conditions, time of sampling, groundwater contribution to the streams, contaminants in ice and contributions from atmospheric salt for glaciers near coastal areas. In addition, this study found that spatial variations, routing and discharge also affect the chemical composition of glacial meltwaters.

At the beginning of the field season the very diluted character of the glacier ice and snow meltwaters provokes rapid cation exchange and water enrichment as they come into contact with the winter's accumulation of weathered sediments. This accounts for the rapid and often erratic fluctuations in water chemistry during the first two weeks of the season.

Diurnal and seasonal variations in solute concentrations for all three stream systems were shown to depend on the various hydrological environments, routing, climatic and melt conditions. The general trend in water quality characteristics was one of decreasing electrical conductivity and ion concentration, with stream pH's tending to be basic as the field season progressed.

Other hydrochemical studies of glacial meltwaters (Rainwater and Guy 1958, Slatt 1972, Church 1974, Zeman and Slaymaker 1975, Collins 1977a; 1977b, Collins and Young 1978) reveal much the same temporal sequence, with subglacial flows having higher ion concentrations and lower alkaline levels than supraglacial flows. Any further comparison between this study and other hydrochemical studies (i.e. Rainwater and Guy 1958, Ek 1966, Slatt 1972, Ricq-de Bouard 1973, Church 1974, Zeman and Slaymaker 1975, Collins 1977a; 1977b, Collins and Young 1978) is precluded by the distinct nature of each glacierized basin's geological, climatological and physiological characteristics which serve to make up the water quality characteristics of each basin's streams. This point can best be demonstrated by a study performed by Ricq-de Bouard (1973) who measured acidic pH levels in snow samples. These results are in sharp contrast with those of this study and of the literature reviewed, and were due to the glacier's proximity to industrial pollution.

Suspended sediment analysis have shown that sorption of major cations (Na^+, K^+, Ca^{++}, Mg^{++}) on suspended particles is of greater importance for meltwaters running through morainic deposits then for subglacial meltwaters. The presence of high cation concentrations in filtrates from supraglacial streams is attributed to the size of sedimentary particles in suspension. The Gouy layer, composed of hydrogen ions, decreases in thickness as particle size decreases allowing for easier disolution of sorbed cations (Kennedy 1965). This is why subglacial filtrates composed mainly of silt particles had lower cation concentrations than supraglacial filtrates composed of silt and clay size sediments. There was no temporal sequence in the chemical composition of suspended sediment samples, and cation concentrations did not increase or decrease proportionately with discharge. Routing and stream conditions at the time of sampling were the main factors affecting the cation concentrations in suspended sediment samples.

This study brought to light the importance and complex linkages which exist between climatological variable, the discharge regime and the chemical composition of meltwaters, and demonstrates that each link is inextricably interconnected with the other in their effect on the glacier's hydrological regime. It also successfully separates the various runoff components and assesses their relative contribution to the total discharge over the 1979 field season. The evidence substantiates the supposition of a two component system of flow for Grizzly Creek Glacier. The system consist essentially of a rather stable discharge from the basal network with water quality characteristics being diluted to varying degrees with relatively pure precipitation and glacial melt waters. A highly variable supraglacial discharge network makes up the second component in the system with water quality fluctuations the result of routing and climatic variations.

Future investigations in this area should extend over the entier field season (June to August) in order to determine whether or not the dynamic nature of the hydrological regime persist on the system throughout the summer. By way of contributing to this, the use of suspended sediment analysis offers further possibilities in breaking down the chemical composition of the main runoff components and assessing their contributions to the total discharge. In addition, through extensive testing and analysis of snow and ice's chemical properties, there lies the opportunity of determining the temporal sequence of snow and ice as the major runoff source, and helps in predicting peak discharge flows associated with snow and ice melt. In this manner, a better understanding of the influence of the three main runoff components upon discharge flows, and their consequent hydrological response, might be gained.

APPENDIX "A"

DAILY METEOROLOGICAL OBSERVATIONS

GRIZZLY CREEK GLACIER, 1979

DAILY METEOROLOGICAL OBSERVATIONS

GRIZZLY CREEK GLACIER 1979
TIME ZONE: Yukon Standard Time (YST)
LOCATION OF STATION: Westside Lateral Moraine
ELEVATION: 1950m

DATE	HOUR YST	TEMP. °C	Ppt. in. m.m.	WIND m/s	WIND dir'n.	SOLAR RAD. cal./cm²/min.
08/06	1200	8.8			SW	1.09
	1300	8.8			S	0.35
	1400	8.3			NE	0.81
	1500	9.4			S	0.81
	1600	10.0			SE	0.39
	1700	10.0			S	0.39
	1800	10.0			SW	0.67
	1900	5.0			SW	0.32
	2000	4.4			SW	0.21
	2100	4.4			SW	0.14
	2200	4.4			SW	0.04
	2300	4.4			SW	0.04
	2400	3.8			SW	0.04
09/06	0100	1.6			SW	0.04
	0200	1.6			SW	0.04
	0300	2.2			SW	0.04
	0400	2.2			SW	0.04
	0500	1.6			S	0.04
	0600	1.6			SW	0.04
	0700	1.6			SE	0.04
	0800	1.6			SE	0.32
	0900	1.6			S	0.32
	1000	4.4			S	0.53
	1100	4.4			NE	0.84
	1200	1.6	0.6		SW	0.91
	1300	4.4			S	0.63
	1400	5.0			S	0.46
	1500	6.1			S	0.63
	1600	5.5			S	0.32
	1700	2.2	1.5		NE	0.14
	1800	0.0			N	0.09
	1900	0.0			SW	0.09
	2000	0.0	1.5		SW	0.09
	2100	0.0	1.2		SW	0.09
	2200	0.0	0.6		S	0.04
	2300	0.0	0.6		W	0.04
	2400	0.0	0.3		S	0.04
10/06	0100	0.0	0.3		SE	0.04
	0200	0.0	0.6		SE	0.04
	0300	0.0	0.6		SE	0.04
	0400	0.0	0.6		SE	0.04
	0500	0.0	0.6		SE	0.04
	0600	1.6			SE	0.04

DAILY METEOROLOGICAL OBSERVATIONS
(continued)

DATE	HOUR YST	TEMP. °C	Ppt. in m.m.	WIND m/s	WIND dir'n.	SOLAR RAD. $cal./cm^2/min.$
10/06	0700	2.7			SE	0.04
	0800	3.3			NW	0.04
	0900	3.8			S	0.28
	1000	3.8		5	S	0.42
	1100	4.4		7.5	S	0.67
	1200	8.8	0.3		S	0.88
	1300	4.4		7.5	S	0.60
	1400	6.1		5.0	S	0.46
	1500	6.1		5.0	S	0.63
	1600	7.2		5.0	NE	0.35
	1700	7.6		10.0	S	0.14
	1800	7.6		2.5	S	0.11
	1900	7.7		2.5	SW	0.11
	2000	7.2		2.5	SW	0.11
	2100	5.5	0.6	2.5	SW	0.11
	2200	4.4		5.0	SW	0.04
	2300	4.4	0.3	5.0	SW	0.04
	2400	4.4		2.5	NW	0.04
11/06	0100	3.8		2.5	SW	0.04
	0200	2.7		2.5	SW	0.04
	0300	2.7		2.5	SW	0.04
	0400	2.7		2.5	SW	0.04
	0500	2.7		2.5	SW	0.04
	0600	3.3		2.5	SW	0.04
	0700	4.4		5.0	S	0.04
	0800	5.0		5.0	S	0.04
	0900	7.2		5.0	S	0.28
	1000	7.7		5.0	S	0.42
	1100	9.4		5.0	S	0.67
	1200	10		5.0	S	0.88
	1300	9.4		5.0	S	0.53
	1400	9.4		5.0	S	0.53
	1500	9.4		10.0	S	0.53
	1600	4.4	0.6	15.0	NE	0.53
	1700	1.6	2.1	10.0	NE	0.74
	1800	0.0		10.0	NE	0.39
	1900	0.0		10.0	NE	0.25
	2000	0.0		10.0	NE	0.25
	2100	0.0		7.5	NE	0.07
	2200	0.0		7.5	NW	0.07
	2300	0.0		10.0	NW	0.04
	2400	0.0		15.0	NW	0.04
12/06	0100	0.0		15.0	NE	0.04
	0200	0.0		15.0	NE	0.04
	0300	0.0		10.0	NE	0.04

DAILY METEOROLOGICAL OBSERVATIONS
(continued)

DATE	HOUR YST	TEMP. °C	Ppt. in. m.m.	WIND m/s	WIND dir'n.	SOLAR RAD. cal./cm²/min.
12/06	0400	0.0		5.0	NW	0.04
	0500	0.0		5.0	NW	0.04
	0600	0.0		5.0	NW	0.04
	0700	0.0		5.0	NW	0.04
	0800	0.0		5.0	NW	0.04
	0900	0.0		5.0	N	0.32
	1000	0.0	0.3	5.0	NE	0.53
	1100	0.0		5.0	NE	0.84
	1200	0.0		5.0	NE	0.91
	1300	0.0	0.6	5.0	NE	0.63
	1400	0.0		5.0	NE	0.46
	1500	0.0		5.0	NE	0.63
	1600	0.0		5.0	NW	0.32
	1700	0.0		5.0	NW	0.14
	1800	0.0		5.0	NW	0.09
	1900	0.0		5.0	NW	0.09
	2000	0.0		5.0	NE	0.09
	2100	0.0		2.5	NW	0.09
	2200	0.0		2.5	NW	0.04
	2300	0.0		2.5	NW	0.04
	2400	0.0		2.5	SW	0.04
13/06	0100	-1.1		2.5	SW	0.04
	0200	-1.1		2.5	SW	0.04
	0300	-1.1		2.5	SW	0.04
	0400	-1.1		2.5	SW	0.04
	0500	-0.5		2.5	SW	0.04
	0600	-0.5		2.5	NE	0.04
	0700	-0.5		2.5	SE	0.04
	0800	0.5		2.5	S	0.32
	0900	3.3		2.5	S	0.32
	1000	5.0		2.5	S	0.53
	1100	7.2		2.5	SE	0.84
	1200	5.0		2.5	SE	0.91
	1300	5.0		5.0	S	0.63
	1400	5.0		5.0	S	0.46
	1500	2.2		2.5	NE	0.63
	1600	5.5		2.5	SW	0.32
	1700	3.3		10.0	NE	0.14
	1800	0.0		10.0	NE	0.09
	1900	0.0		5.0	NE	0.09
	2000	0.0		5.0	SW	0.09
	2100	0.0		2.5	SW	0.09
	2200	-1.1		2.5	SW	0.09
	2300	-1.1		2.5	SW	0.04
	2400	-1.1		2.5	SW	0.04

DAILY METEOROLOGICAL OBSERVATIONS
(continued)

DATE	HOUR YST	TEMP. °C	Ppt. in m.m.	WIND m/s	WIND dir'n.	SOLAR RAD. cal./cm²/min.
14/06	0100	-1.1		2.5	N	0.04
	0200	-1.1		2.5	N	0.04
	0300	-1.1		7.5	N	0.04
	0400	-1.1		7.5	N	0.04
	0500	-1.1		7.5	N	0.04
	0600	-1.1		7.5	N	0.04
	0700	-1.1		10.0	NW	0.04
	0800	-1.1		7.5	NW	0.04
	0900	-0.5		7.5	NW	0.32
	1000	0.0		10.0	NW	0.53
	1100	0.0		7.5	NW	0.84
	1200	0.0	1.2	5.0	NW	0.91
	1300	1.6	2.7	5.0	NW	0.63
	1400	10.0	3.0	2.5	NE	0.46
	1500	3.8	1.2	5.0	NE	0.63
	1600	14.4	0.3	5.0	NW	0.32
	1700	3.8		5.0	NW	0.14
	1800	0.0		5.0	NW	0.09
	1900	0.5		5.0	NW	0.09
	2000	0.0		5.0	NW	0.09
	2100	-1.1		2.5	NW	0.09
	2200	-1.1		2.5	NW	0.04
	2300	-1.1		2.5	NE	0.04
	2400	-1.1		2.5	NE	0.04
15/06	0100	-1.6		2.5	SW	0.04
	0200	-2.2		2.5	SE	0.04
	0300	-2.2		2.5	SE	0.04
	0400	-2.2		2.5	SW	0.04
	0500	-1.1		2.5	SW	0.04
	0600	-0.5		2.5	S	0.04
	0700	2.7	0.3	2.5	SW	0.04
	0800	3.8		2.5	SW	0.04
	0900	7.2		2.5	SW	0.35
	1000	7.2	0.3	2.5	SW	0.56
	1100	9.4		2.5	NE	0.60
	1200	6.1		2.5	S	0.88
	1300	7.2		2.5	S	0.88
	1400	6.1		2.5	S	0.88
	1500	8.8		2.5	S	0.84
	1600	8.8		2.5	S	0.70
	1700	8.3		2.5	S	0.63
	1800	6.1		5.0	SE	0.63
	1900	4.4		5.0	SW	0.35
	2000	4.4		5.0	SW	0.07
	2100	3.8		5.0	SW	0.07
	2200	2.7		5.0	SW	0.07
	2300	1.6		7.5	SW	0.07
	2400	1.6		5.0	S	0.07

DAILY METEOROLOGICAL OBSERVATIONS
(continued)

DATE	HOUR YST	TEMP. °C	Ppt. in. m.m.	WIND m/s	WIND dir'n.	SOLAR RAD. cal./cm²/min.
16/06	0100	0.0		7.5	S	0.04
	0200	0.0		5.0	SW	0.04
	0300	-1.1		5.0	SE	0.04
	0400	-1.1		5.0	SE	0.04
	0500	0.5		5.0	SE	0.04
	0600	1.6		5.0	NW	0.04
	0700	4.4		5.0	SE	0.42
	0800	3.8		2.5	SE	0.35
	0900	4.4		2.5	NE	0.35
	1000	5.5		2.5	NE	0.53
	1100	5.5		5.0	SW	0.70
	1200	7.7		5.0	SW	0.88
	1300	7.7		5.0	SE	0.88
	1400	8.3		5.0	SW	0.88
	1500	9.4		7.5	SW	0.84
	1600	8.8		7.5	SW	0.84
	1700	8.8		5.0	SW	0.63
	1800	6.1		5.0	SW	0.32
	1900	5.0		5.0	SW	0.21
	2000	4.4		5.0	SW	0.14
	2100	4.4		2.5	SW	0.04
	2200	3.3		2.5	NW	0.04
	2300	3.3		2.5	NW	0.04
	2400	3.3		2.5	NW	0.04
17/06	0100	2.7		2.5	SW	0.04
	0200	0.5		2.5	SW	0.04
	0300	0.0		2.5	SE	0.04
	0400	0.0		2.5	SE	0.04
	0500	0.0		2.5	S	0.04
	0600	0.0		2.5	SW	0.04
	0700	1.1		2.5	NE	0.14
	0800	0.0		2.5	S	0.14
	0900	2.7		2.5	S	0.28
	1000	3.3		2.5	S	0.28
	1100	0.5		7.5	S	0.28
	1200	1.1		10.0	S	0.32
	1300	2.7		5.0	S	0.67
	1400	3.8		5.0	S	0.39
	1500	5.5		5.0	S	0.60
	1600	4.4		5.0	S	0.39
	1700	4.4	0.3	1.25	NE	0.21
	1800	0.5	0.9	1.25	NW	0.07
	1900	0.5	1.2	1.25	SW	0.07
	2000	1.6	1.8	1.25	SW	0.07

DAILY METEOROLOGICAL OBSERVATIONS
(continued)

DATE	HOUR YST	TEMP. °C	Ppt. in. m.m.	WIND m/s	WIND dir'n.	SOLAR RAD. cal./cm²/min.
17/06	2100	2.7	0.9	2.5	SE	0.07
	2200	3.3		2.5	NW	0.07
	2300	3.3		2.5	NE	0.07
	2400	2.2	0.3	2.5	NW	
18/06	0100	1.6	0.3	2.5	NE	
	0200	0.0	0.6	2.5	NE	
	0300	0.0		2.5	NW	
	0400	0.0		2.5	NE	
	0500	0.0	0.9	2.5	NE	
	0600	0.0	0.6	2.5	NE	
	0700	0.0	0.3	5.0	NE	0.07
	0800	0.0	0.3	5.0	NE	0.18
	0900	0.0	0.9	5.0	NE	0.18
	1000	2.7		2.5	NE	0.35
	1100	5.5		2.5	NE	0.91
	1200	2.7	0.3	5.0	NE	1.02
	1300	4.4		5.0	S	0.91
	1400	4.4		5.0	S	1.12
	1500	4.4	0.3	5.0	S	0.84
	1600	4.4	0.6	5.0	NW	0.84
	1700	4.4		5.0	NE	0.63
	1800	3.8	0.6	2.5	NW	0.32
	1900	3.8	0.3	2.5	SE	0.21
	2000	3.3	0.3	1.25	NE	0.14
	2100	3.3		1.25	NE	0.04
	2200	0.5	1.2	1.25	SE	0.04
	2300	0.5		1.25	SW	0.04
	2400	1.1		1.25	S	0.04
19/06	0100	1.1		2.5	SW	0.04
	0200	1.1	0.6	2.5	SW	0.04
	0300	1.1	0.6	2.5	SW	0.04
	0400	0.0		5.0	SW	0.04
	0500	0.0	0.3	5.0	SW	0.04
	0600	0.0	0.3	5.0	S	0.04
	0700	3.3	1.5	5.0	S	0.04
	0800	3.8	1.8	5.0	S	0.14
	0900	4.4		5.0	S	0.18
	1000	5.5		5.0	S	0.35
	1100	6.6		5.0	S	0.91
	1200	6.6		5.0	S	1.02
	1300	7.7		5.0	S	0.91
	1400	8.3		7.5	NE	1.12
	1500	10.0		7.5	S	0.84
	1600	10.0		7.5	NE	0.84

DAILY METEOROLOGICAL OBSERVATIONS
(continued)

DATE	HOUR YST	TEMP. °C	Ppt. in m.m.	WIND m/s	dir'n.	SOLAR RAD. cal./cm²/min.
19/06	1700	9.4		7.5	NE	0.63
	1800	10.0		5.0	SW	0.32
	1900	8.8		5.0	NW	0.21
	2000	7.2		5.0	SW	0.14
	2100	7.2		5.0	NE	0.04
	2200	5.0		2.5	NE	0.04
	2300	4.4		2.5	NE	0.04
	2400	3.3		2.5	NE	0.04
20/06	0100	3.3		2.5	SW	0.04
	0200	2.7		2.5	SW	0.04
	0300	1.6		2.5	SW	0.04
	0400	1.1		2.5	SW	0.04
	0500	0.5		2.5	SW	0.04
	0600	0.5		2.5	SW	0.04
	0700	3.3		2.5	SW	0.18
	0800	5.0		5.0	SE	0.18
	0900	5.5		5.0	S	0.18
	1000	5.0		5.0	S	0.35
	1100	5.0		5.0	S	0.91
	1200	10.0		5.0	S	0.91
	1300	9.4		5.0	NE	1.12
	1400	8.8		5.0	NE	0.84
	1500	8.8		5.0	NE	0.89
	1600	9.4		5.0	NE	0.63
	1700	9.4		7.5	NE	0.32
	1800	6.6		5.0	NE	0.21
	1900	5.0		5.0	NE	0.21
	2000	4.4	1.2	2.5	SW	0.21
	2100	2.8	0.9	2.5	SE	0.09
	2200	3.8		2.5	SW	0.09
	2300	3.8		2.5	SW	0.09
	2400	3.3		1.25	NE	0.04
21/06	0100	3.3		1.25	SW	0.04
	0200	3.3		1.25	SW	0.04
	0300	2.7		1.25	SW	0.04
	0400	2.7	0.3	1.25	SW	0.04
	0500	2.7	0.3	1.25	NE	0.04
	0600	2.7	0.6	1.25	NE	0.04
	0700	2.7	1.2	1.25	SW	0.14
	0800	0.5		1.25	SW	0.14
	0900	2.7		1.25	S	0.18
	1000	4.4		1.25	S	0.32
	1100	4.4	0.3	1.25	S	0.91
	1200	5.5		5.0	S	1.02
	1300	4.4		5.0	S	1.02
	1400	7.2		7.5	S	0.84

DAILY METEOROLOGICAL OBSERVATIONS
(continued)

DATE	HOUR YST	TEMP. °C	Ppt. in. m.m.	WIND m/s	dir'n.	SOLAR RAD. cal./cm²/min.
21/06	1500	5.5		7.5	S	0.84
	1600	5.5	0.6	7.5	SE	0.63
	1700	6.1		7.5	NW	0.35
	1800	5.5		7.5	NW	0.35
	1900	5.0	0.3	5.0	NW	0.21
	2000	4.4	0.9	5.0	NE	0.21
	2100	4.4	1.2	2.5	NW	0.07
	2200	4.4	3.3	2.5	NE	0.07
	2300	0.5	4.8	2.5	SW	0.04
	2400	0.5	1.8	2.5	SW	0.04
22/06	0100	1.1	1.8	2.5	SW	0.04
	0200	1.1	1.5	2.5	SW	0.04
	0300	1.1	2.1	2.5	SE	0.04
	0400	1.6	1.2	2.5	SE	0.04
	0500	2.7	0.3	2.5	SW	0.04
	0600	2.7	1.2	2.5	NW	0.04
	0700	2.7	1.5	2.5	SE	0.18
	0800	3.3	0.9	2.5	SE	0.14
	0900	3.8		2.5	SE	0.18
	1000	3.8	0.9	2.5	NW	0.35
	1100	5.0	0.3	2.5	NE	0.84
	1200	5.5	0.3	2.5	SE	0.91
	1300	4.4	2.4	2.5	NE	1.02
	1400	4.4	0.9	2.5	SW	0.89
	1500	5.5	1.8	5.0	SW	0.84
	1600	5.5	0.3	5.0	S	0.63
	1700	5.0	0.9	7.5	SW	0.35
	1800	3.8	3.3	7.5	NW	0.35
	1900	3.8	2.7	2.5	NW	0.18
	2000	3.8		2.5	S	0.14
	2100	4.4		2.5	SW	0.04
	2200	4.4		2.5	SW	0.04
	2300	3.8		2.5	SW	0.04
	2400	3.8		2.5	SW	0.04
23/06	0100	3.8	0.6	2.5	NW	0.04
	0200	3.3	0.3	2.5	NE	0.04
	0300	3.3	0.3	2.5	NW	0.04
	0400	3.8		2.5	NW	0.04
	0500	3.8		2.5	NE	0.04
	0600	3.8		2.5	NW	0.04
	0700	3.8	1.2	2.5	NW	0.04
	0800	3.3	1.2	2.5	NE	0.04
	0900	3.8	0.6	2.5	NE	0.35

DAILY METEOROLOGICAL OBSERVATIONS
(continued)

DATE	HOUR YST	TEMP. °C	Ppt. in m.m.	WIND m/s	WIND dir'n.	SOLAR RAD. cal./cm²/min.
23/06	1000	3.8	0.9	5.0	SE	0.70
	1100	4.4		5.0	S	0.70
	1200	8.3		7.5	NE	0.84
	1300	7.7		7.5	NE	1.02
	1400	10.0		1.0	NE	1.05
	1500	5.0	0.3	5.0	SW	0.53
	1600	5.5		5.0	S	0.35
	1700	7.7	0.6	5.0	NE	0.25
	1800	7.2		5.0	SW	0.70
	1900	9.4		5.0	SW	0.18
	2000	6.6		2.5	SW	0.07
	2100	5.0	0.6	2.5	SW	0.07
	2200	4.4		2.5	SW	0.07
	2300	5.0		1.25	SW	0.07
	2400	4.4		1.25	SW	0.07
24/06	0100	3.8		1.25	SE	0.07
	0200	3.3		1.25	SE	0.07
	0300	3.8		1.25	SW	0.07
	0400	3.8		1.25	SW	0.07
	0500	3.8		5.0	NW	0.07
	0600	4.4		5.0	S	0.07
	0700	4.4		5.0	S	0.07
	0800	5.5		5.0	SW	0.07
	0900	7.2		5.0	S	0.18
	1000	10.0		7.5	S	0.81
	1100	8.8		7.5	S	0.81
	1200	9.4		7.5	S	0.81
	1300	10.5		7.5	S	0.81
	1400	10.5		7.5	S	0.81
	1500	11.1		7.5	SW	0.81
	1600	13.8		7.5	SW	0.81
	1700	13.8		7.5	SW	0.70
	1800	13.8		7.5	SW	0.28
	1900	10.5		2.5	SW	0.28
	2000	10.0		2.5	SW	0.11
	2100	10.0		2.5	NE	0.11
	2200	7.2		2.5	SW	0.07
	2300	6.1		2.5	SW	0.07
	2400	6.1		2.5	SW	0.07
25/06	0100	5.0		2.5	SW	0.07
	0200	5.0		2.5	SW	0.07
	0300	4.4		2.5	SW	0.07
	0400	4.4		2.5	SW	0.07

DAILY METEOROLOGICAL OBSERVATIONS
(continued)

DATE	HOUR YST	TEMP. °C	Ppt. in m.m.	WIND m/s	dir'n.	SOLAR RAD. cal./cm²/min.
25/06	0500	5.0		5.0	SW	0.07
	0600	4.4		7.5	SW	0.07
	0700	8.3		5.0	S	0.07
	0800	9.4		5.0	SE	0.46
	0900	10.0		5.0	S	0.63
	1000	13.8		7.5	S	0.70
	1100	11.6		7.5	S	0.70
	1200	10.0		7.5	S	0.70
	1300	11.6		7.5	SE	0.81
	1400	15.0		10.0	SW	0.81
	1500	12.7		10.0	SE	0.77
	1600	15.0		10.0	SW	0.63
	1700	11.6		10.0	SW	0.56
	1800	11.1		15.0	SE	0.28
	1900	10.0		15.0	S	0.28
	2000	9.4		15.0	S	0.11
	2100	9.4		15.0	SW	0.11
	2200	8.8		10.0	SE	0.07
	2300	10.0		15.0	NW	0.07
	2400	10.0		7.5	NW	0.07
26/06	0100	8.8		7.5	NE	0.07
	0200	8.8		7.5	NE	0.07
	0300	5.5		7.5	SE	0.07
	0400	6.6		7.5	SW	0.07
	0500	7.2		7.5	NW	0.07
	0600	5.5		7.5	SW	0.07
	0700	5.5		7.5	SE	0.07
	0800	5.0		7.5	NE	0.07
	0900	4.4		5.0	SE	0.07
	1000	5.0		5.0	NE	0.35
	1100	7.2		5.0	NE	0.60
	1200	8.3		5.0	SW	0.70
	1300	10.0		7.5	SW	0.77
	1400	10.5		7.5	SW	0.77
	1500	10.0		7.5	SW	0.77
	1600	10.0		7.5	SE	0.77
	1700	10.0		7.5	SW	0.77
	1800	10.5		7.5	SW	0.67
	1900	8.8		7.5	SW	0.56
	2000	7.2		7.5	SW	0.11
	2100	5.5		5.0	SW	0.11
	2200	5.5		5.0	NE	
	2300	5.0		5.0	NW	
	2400	4.4		5.0	SW	

DAILY METEOROLOGICAL OBSERVATIONS
(continued)

DATE	HOUR YST	TEMP. °C	Ppt. in m.m.	WIND m/s	WIND dir'n.	SOLAR RAD. cal./cm²/min.
27/06	0100	4.4		5.0	NW	
	0200	3.8		2.5	SW	
	0300	3.3		2.5	NW	
	0400	3.8		5.0	NW	
	0500	4.4		5.0	SE	
	0600	3.8		5.0	SE	
	0700	4.4		5.0	SW	
	0800	4.4		10.0	SE	0.25
	0900	4.4		10.0	SW	0.25
	1000	5.5		7.5	SE	0.60
	1100	6.6		7.5	SE	0.77
	1200	7.2		10.0	SE	0.88
	1300	7.2		10.0	SW	0.88
	1400	7.7		10.0	SE	0.88
	1500	8.3		10.0	SE	0.88
	1600	8.8		10.0	SE	0.98
	1700	8.3		10.0	SE	0.67
	1800	7.7		10.0	SE	0.67
	1900	5.5		10.0	SE	0.39
	2000	5.0		10.0	SE	0.14
	2100	4.4		7.5	SE	0.11
	2200	4.4		5.0	SE	0.11
	2300	3.8		7.5	SE	0.07
	2400	3.3		7.5	SE	0.07
28/06	0100	1.6		10.0	SE	0.07
	0200	1.6		10.0	SE	0.07
	0300	1.1		10.0	SE	0.07
	0400	1.6		7.5	SE	0.07
	0500	1.6		7.5	SE	0.07
	0600	0.0		7.5	SE	0.07
	0700	3.8		10.0	SE	0.46
	0800	4.4		7.5	SE	0.35
	0900	4.4		7.5	SE	0.56
	1000	5.5		7.5	SE	0.70
	1100	6.1		7.5	SE	0.77
	1200	6.1		7.5	SE	0.84
	1300	6.1		10.0	SE	0.88
	1400	6.1		7.5	SE	0.88
	1500	6.1		10.0	SE	0.81
	1600	5.0		10.0	SE	0.81
	1700	5.0		7.5	SE	0.81
	1800	5.5		7.5	SE	0.70
	1900	3.3		5.0	NE	0.53
	2000	2.7		5.0	SW	0.11

DAILY METEOROLOGICAL OBSERVATIONS
(continued)

DATE	HOUR YST	TEMP. °C	Ppt. in m.m.	WIND m/s	WIND dir'n.	SOLAR RAD. cal./cm²/min.
28/06	2100	2.2		7.5	SW	0.04
	2200	1.6		5.0	SW	
	2300	0.0		5.0	NW	
	2400	-0.5		5.0	NE	
29/06	0100	-1.1		7.5	NE	
	0200	-1.6		7.5	NE	
	0300	-1.6		2.5	NE	
	0400	-2.2		2.5	NE	
	0500	-2.2		2.5	NE	
	0600	-2.2		2.5	NE	
	0700	-0.5		2.5	NW	
	0800	-0.5		2.5	NE	0.25
	0900	-0.5		7.5	NE	0.25
	1000	-1.1		5.0	NE	0.25
	1100	-1.1		5.0	NE	0.21
	1200	-1.1		2.5	NE	0.28
	1300	-1.1	0.9	2.5	SE	0.53
	1400	-1.1		10.0	SE	0.88
	1500	0.5		10.0	NE	0.95
	1600	0.5		5.0	NE	1.05
	1700	0.5		5.0	NE	0.42
	1800	-0.5		7.5	NE	0.46
	1900	0.5		7.5	NE	0.28
	2000	0.5		7.5	NE	0.25
	2100	-0.5		7.5	NE	0.14
	2200	-0.5		5.0	NE	0.14
	2300	-1.1		5.0	NE	0.04
	2400	-1.1		5.0	NE	0.04
30/06	0100	-1.1		2.5	NE	0.04
	0200	-1.1		2.5	NE	0.04
	0300	-1.1		2.5	SE	0.11
	0400	-1.1		1.25	NE	0.11
	0500	-1.1		1.25	NW	0.11
	0600	-1.1		1.25	NE	0.11
	0700	-0.5		1.25	NW	0.11
	0800	-0.5		5.0	NE	0.11
	0900	1.1		5.0	NE	0.18
	1000	4.4		5.0	NE	0.18
	1100	4.4		7.5	NE	0.18
	1200	4.4		7.5	NE	0.28
	1300	5.0		7.5	NE	0.95
	1400	7.2		10.0	NE	0.84
	1500	7.2		5.0	NE	0.49
	1600	7.2		5.0	NE	0.35

DAILY METEOROLOGICAL OBSERVATIONS
(continued)

DATE	HOUR YST	TEMP. °C	Ppt. in m.m.	WIND m/s	WIND dir'n.	SOLAR RAD. cal./cm²/min.
30/06	1700	7.7		5.0	NE	0.70
	1800	8.3		5.0	NE	0.53
	1900	8.8		2.5	NW	0.18
	2000	8.3		2.5	NW	0.07
	2100	6.6		2.5	NW	0.07
	2200	4.4		2.5	SW	0.07
	2300	3.3		2.5	SW	0.07
	2400	3.3		2.5	SW	0.04
01/07	0100	2.7		5.0	SW	0.04
	0200	2.2		5.0	SW	0.04
	0300	1.6		5.0	SW	0.04
	0400	1.6		7.5	SW	
	0500	1.1		7.5	SW	
	0600	3.3		10.0	SW	
	0700	4.4		5.0	SW	0.32
	0800	5.0		5.0	SW	0.32
	0900	8.3		2.5	NE	0.32
	1000	10.0		2.6	NE	0.74
	1100	10.0		2.5	NE	0.88
	1200	10.0		5.0	NW	0.35
	1300	9.4		7.5	NE	0.70
	1400	7.2		7.5	NE	0.35
	1500	10.0		5.0	NW	0.98
	1600	5.5		10.0	NE	0.53
	1700	6.1	0.6	5.0	NW	0.11
	1800	5.5		5.0	NW	0.11
	1900	6.1		10.0	NW	0.11
	2000	6.1		10.0	NE	0.11
	2100	5.5		10.0	NE	0.11
	2200	6.1		5.0	NW	0.11
	2300	4.4		2.5	NW	
	2400	4.4		2.5	NW	
02/07	0100	4.4		2.5	NW	
	0200	3.8	0.3	2.5	NW	
	0300	3.8		2.5	NW	
	0400	3.8		2.5	SW	
	0500	3.8		2.5	NW	
	0600	3.8		7.5	SE	
	0700	4.4		7.5	NW	
	0800	3.3	0.9	7.5	NW	
	0900	3.3	1.8	5.0	NW	
	1000	3.3	0.9	5.0	NW	
	1100	3.8	1.2	10.0	NW	0.21

DAILY METEOROLOGICAL OBSERVATIONS
(continued)

DATE	HOUR YST	TEMP. °C	Ppt. in. m.m.	WIND m/s	dir'n.	SOLAR RAD. cal./cm²/min.
02/07	1200	3.8	0.6	10.0	NW	0.21
	1300	3.8	0.9	10.0	NW	0.25
	1400	3.8	1.2	10.0	NW	0.25
	1500	3.8	1.8	10.0	NW	0.21
	1600	3.8	2.4	10.0	NW	0.21
	1700	3.8		10.0	NW	0.18
	1800	4.4		10.0	NW	0.14
	1900	4.4	0.6	5.0	NW	0.14
	2000	4.4		5.0	NW	0.04
	2100	4.4	1.2	5.0	NW	0.04
	2200	3.8	0.3	2.5	NW	0.04
	2300	3.8	1.2	2.5	NW	0.04
	2400	3.3	1.5	2.5	SW	0.04
03/07	0100	3.3	1.5	2.5	SW	0.04
	0200	3.8	2.1	1.25	S	0.04
	0300	3.8	2.1	1.25	SW	0.04
	0400	3.8	1.8	1.25	NW	0.04
	0500	4.4	1.5	1.25	NW	0.04
	0600	4.4	1.8	1.25	NW	0.04
	0700	4.4	1.2	2.5	NW	0.04
	0800	4.4	0.9	2.5	NW	0.04
	0900	4.4	0.3	5.0	NW	0.04
	1000	4.4		5.0	NW	0.04
	1100	4.4		5.0	NW	0.11
	1200	5.5		5.0	NE	0.77
	1300	6.1		5.0	NE	0.32
	1400	6.1		5.0	NW	0.18
	1500	6.1		5.0	NW	0.18
	1600	6.1		5.0	NW	0.18
	1700	7.2		5.0	NW	0.07
	1800	7.2		2.5	NW	0.07
	1900	6.6		2.5	NW	0.07
	2000	5.5	0.6	2.5	NW	0.07
	2100	5.5		2.5	SW	0.04
	2200	5.0	0.3	2.5	SW	0.04
	2300	5.0		2.5	SW	0.04
	2400	4.4	1.5	2.5	SW	0.04
04/07	0100	4.4		2.5	SW	0.04
	0200	4.4		5.0	SW	0.04
	0300	4.4	0.9	5.0	SW	0.04
	0400	4.4		2.5	SW	0.04
	0500	5.0		2.5	SW	0.04

DAILY METEOROLOGICAL OBSERVATIONS
(continued)

DATE	HOUR YST	TEMP. °C	Ppt. in m.m.	WIND m/s	WIND dir'n.	SOLAR RAD. cal./cm²/min.
04/07	0600	5.5		2.5	SW	0.04
	0700	5.5		5.0	SW	0.04
	0800	8.8		5.0	SW	0.46
	0900	11.1		5.0	SW	0.60
	1000	9.4		7.5	S	0.60
	1100	10.5		7.5	S	0.67
	1200	11.6		7.5	SW	0.84
	1300	10.0		7.5	S	1.05
	1400	10.0		5.0	S	0.70
	1500	13.8		5.0	SW	0.77
	1600	10.5		5.0	SW	0.28
	1700	10.0		5.0	SE	0.28
	1800	10.5		5.0	SW	0.53
	1900	10.0		5.0	SW	0.21
	2000	10.0		5.0	SE	0.14
	2100	10.0		5.0	SE	0.14
	2200	10.0		5.0	SW	0.04
	2300	9.4		5.0	SW	0.04
	2400	9.4		5.0	SW	0.04
05/07	0100	8.8		2.5	SW	0.04
	0200	8.8		2.5	SW	0.04
	0300	9.4		2.5	SW	0.04
	0400	7.2		2.5	SW	0.04
	0500	7.2		2.5	SW	0.04
	0600	8.8		2.5	SW	0.04
	0700	10.5		2.5	SW	0.04
	0800	10.0		5.0	SE	0.42
	0900	11.1		5.0	S	0.42
	1000	11.6		7.5	S	0.60
	1100	10.5		5.0	S	0.67
	1200	13.8		5.0	NE	0.70
	1300	13.8		7.5	S	0.77
	1400	15.5		7.5	S	0.77
	1500	15.5		7.5	SW	0.77
	1600	12.2		10.0	SW	0.74
	1700	12.2		15.0	SW	0.56
	1800	11.1		10.0	SW	0.49
	1900	10.0		10.0	SE	0.18
	2000	10.0		10.0	SE	0.18
	2100	10.0		10.0	SE	0.11
	2200	10.0		7.5	SW	
	2300	8.8		7.5	SW	
	2400	8.8		10.0	SE	

DAILY METEOROLOGICAL OBSERVATIONS
(continued)

DATE	HOUR YST	TEMP. °C	Ppt. in. m.m.	WIND m/s	WIND dir'n.	SOLAR RAD. cal./cm²/min.
06/07	0100	8.8		5.0	SW	
	0200	8.8		2.5	SW	
	0300	5.5		2.5	SW	
	0400	5.5		2.5	SW	
	0500	5.0		2.5	SW	
	0600	5.5		5.0	SW	
	0700	5.0		5.0	SW	
	0800	4.4	0.3	5.0	NE	
	0900	4.4	0.6	5.0	NE	
	1000	5.0	0.6	5.0	NE	
	1100	5.0	0.6	5.0	NE	0.07
	1200	4.4	1.2	2.5	SE	0.07
	1300	5.0	0.6	2.5	SW	0.18
	1400	6.1		2.5	SE	0.25
	1500	5.5	0.3	2.5	NW	0.25
	1600	5.0	0.3	2.5	NE	0.25
	1700	4.4		2.5	NW	0.25
	1800	5.0	0.6	2.5	NW	0.25
	1900	4.4		2.5	SW	0.25
	2000	3.8		2.5	S	0.25
	2100	3.3	0.3	2.5	SE	0.11
	2200	3.3	0.3	2.5	SE	0.11
	2300	2.7		2.5	S	0.07
	2400	2.2		2.5	SW	0.07
07/07	0100	1.6	0.3	1.25	S	0.04
	0200	1.6		1.25	SW	0.04
	0300	1.6	0.3	1.25	SE	
	0400	1.6	0.3	1.25	SE	
	0500	1.6		1.25	SE	
	0600	2.7	0.3	1.25	SE	
	0700	2.2	0.3	1.25	NE	
	0800	2.7	0.9	1.25	S	
	0900	3.8	0.3	1.25	S	
	1000	3.8	0.9	1.25	NE	
	1100	3.8	0.9	1.25	SW	0.32
	1200	4.4	0.3	5.0	S	0.32
	1300	4.4	0.3	5.0	NE	0.32
	1400	3.8	0.3	7.5	NE	0.32
	1500	4.4		7.5	NE	0.53
	1600	4.4		7.5	NE	0.35
	1700	4.4		5.0	NE	0.35
	1800	4.4		5.0	NE	0.35

DAILY METEOROLOGICAL OBSERVATIONS
(continued)

DATE	HOUR YST	TEMP. °C	Ppt. in. m.m.	WIND m/s	WIND dir'n..	SOLAR RAD. cal./cm²/min.
07/07	1900	4.4		5.0	NE	0.32
	2000	3.8		2.5	NE	0.14
	2100	3.8		2.5	NE	0.14
	2200	3.3		2.5	NE	0.14
	2300	2.2		2.5	SW	0.04
	2400	2.2		2.5	SW	0.04
08/07	0100	2.2		1.25	NE	0.04
	0200	2.2		1.25	SE	0.04
	0300	1.6		1.25	SW	0.04
	0400	1.6		1.25	SW	0.04
	0500	2.2		1.25	SW	0.04
	0600	2.7		1.25	SW	0.04
	0700	3.8		1.25	SE	0.04
	0800	5.0		5.0	SE	0.25
	0900	4.4		5.0	NE	0.35
	1000	4.4		7.5	NE	0.35
	1100	4.4		7.5	NE	0.39
	1200	5.0		7.5	NE	0.95
	1300	5.5		7.5	NE	0.63
	1400	6.6		7.5	NE	0.77
	1500	9.4		5.0	NE	0.88
	1600	9.4		5.0	SE	0.70
	1700	7.2		7.5	SE	0.35
	1800	6.1		5.0	SW	0.35
	1900	6.1		5.0	SW	0.25
	2000	5.0		5.0	SE	0.14
	2100	4.4		5.0	SW	0.07
	2200	4.4		5.0	SW	0.07
	2300	4.4		2.5	SW	0.07
	2400	3.8		2.5	SW	0.07
09/07	0100	2.7		2.5	SW	0.07
	0200	2.7		2.5	SW	0.07
	0300	2.7		2.5	SW	0.07
	0400	2.2		2.5	SW	0.07
	0500	1.6		2.5	SE	0.07
	0600	1.6		2.5	SW	0.07
	0700	5.0		2.5	SE	0.32
	0800	6.1		2.5	SE	0.32
	0900	5.5		2.5	NE	0.32
	1000	8.8		5.0	S	0.53
	1100	9.4		5.0	SE	0.74
	1200	8.3		7.5	SE	0.42

DAILY METEOROLOGICAL OBSERVATIONS (continued)

DATE	HOUR YST	TEMP. °C	Ppt. in. m.m.	WIND m/s	WIND dir'n.	SOLAR RAD. cal./cm²/min.
09/07	1300	9.4		7.5	SE	0.42
	1400	5.5		7.5	SE	0.60
	1500	4.4	0.3	7.5	SE	0.35
	1600	5.5		7.5	S	0.46
	1700	6.1		10.0	S	0.35
	1800	6.1		15.0	S	0.28
	1900	5.0		15.0	S	0.28
	2000	5.0		10.0	S	0.25
	2100	4.4		10.0	S	0.11
	2200	4.4		10.0	S	0.04
	2300	4.4		15.0	S	0.04
	2400	4.4		5.0	S	0.04
10/07	0100	3.8		5.0	SW	0.04
	0200	4.4		2.5	SE	0.04
	0300	3.3		2.5	SW	0.04
	0400	3.3		2.5	SW	0.04
	0500	3.8		2.5	SW	0.04
	0600	4.4		2.5	SW	0.04
	0700	4.4		2.5	SE	0.04
	0800	7.2		2.5	SE	0.14
	0900	7.7		5.0	SE	0.53
	1000	10.0		5.0	S	0.60
	1100	8.8		10.0	S	0.77
	1200	7.2		10.0	S	0.77
	1300	7.7		10.0	S	0.46
	1400	10.0		10.0	S	0.74
	1500	10.5		7.5	S	0.84
	1600	10.5		5.0	S	0.39
	1700	10.5		5.0	SW	0.39
	1800	9.4		5.0	SE	0.21
	1900	10.0		5.0	SW	0.11
	2000	7.7		5.0	SW	0.11
	2100	8.3		2.5	SW	0.11
	2200	7.2		2.5	SW	0.07
	2300	7.2		2.5	SW	0.07
	2400	6.6		2.5	SW	0.07
11/07	0100	6.1		2.5	SW	0.07
	0200	5.5		2.5	SW	0.07
	0300	5.5		2.5	SW	0.07
	0400	5.5		2.5	SW	0.07
	0500	5.5		2.5	SW	0.07
	0600	5.5		2.5	SW	0.07
	0700	5.5		2.5	S	0.07

DAILY METEOROLOGICAL OBSERVATIONS
(continued)

DATE	HOUR YST	TEMP. °C	Ppt. in m.m.	WIND m/s	WIND dir'n.	SOLAR RAD. cal/cm²/min.
11/07	0800	5.5	0.3	2.5	S	0.07
	0900	5.5	0.3	2.5	S	0.07
	1000	5.5		2.5	S	0.07
	1100	5.5	0.9	2.5	S	0.07
	1200	6.1		2.5	S	0.11
	1300	8.8		2.5	SW	0.11
	1400	8.8		2.5	S	0.11
	1500	10.0		2.5	S	0.32
	1600	10.0		2.5	SW	0.32
	1700	9.4		5.0	NE	0.28
	1800	9.4		5.0	SW	0.28
	1900	6.6		5.0	SW	0.21
	2000	6.1		5.0	SW	0.11
	2100	6.1		5.0	S	0.11
	2200	5.0		2.5	S	0.11
	2300	5.0		2.5	S	
	2400	5.0		2.5	SW	
12/07	0100	5.0		2.5	SW	
	0200	5.0		2.5	NW	
	0300	5.0		2.5	SW	
	0400	4.4		2.5	SW	
	0500	4.4		2.5	SE	
	0600	5.0		2.5	SW	
	0700	5.0		2.5	SE	
	0800	6.1		2.5	SE	0.25
	0900	7.7		2.5	SE	0.25
	1000	7.2		2.5	SE	0.67
	1100	8.3		2.5	SE	0.28
	1200	10.5		7.5	NE	1.02
	1300	10.0		7.5	NE	0.91
	1400	10.0		5.0	NE	0.56
	1500	10.0		5.0	NE	0.28
	1600	9.4		5.0	SE	0.28
	1700	8.8		5.0	NE	0.28
	1800	10.0		7.5	NE	0.21
	1900	10.0		7.5	NE	0.14
	2000	9.4		5.0	SW	0.14
	2100	7.7		5.0	NE	0.07
	2200	7.7		5.0	NW	0.07
	2300	6.6		5.0	NE	0.04
	2400	5.0		2.5	NE	0.04

DAILY METEOROLOGICAL OBSERVATIONS
(continued)

DATE	HOUR YST	TEMP. °C	Ppt. in. m.m.	WIND m/s	WIND dir'n.	SOLAR RAD. cal./cm²/min.
13/07	0100	5.0	0.3	2.5	SW	0.04
	0200	5.0		2.5	SW	0.04
	0300	5.5		5.0	NW	0.04
	0400	5.5	0.3	5.0	NE	0.04
	0500	5.0	0.3	5.0	NE	0.04
	0600	5.0	0.3	5.0	NE	0.04
	0700	5.0	0.6	7.5	NE	0.04
	0800	5.0	3.3	7.5	NW	0.04
	0900	5.0	5.4	7.5	NW	0.04
	1000	4.4	2.7	7.5	NW	0.04
	1100	4.4	1.8	5.0	NE	0.04
	1200	4.4	0.9	5.0	SW	0.18
	1300	5.0	0.9	5.0	SW	0.18
	1400	4.4	0.3	5.0	SE	0.32
	1500	4.4		5.0	SE	0.32
	1600	4.4		2.5	SE	0.28
	1700	4.4		2.5	SW	0.14
	1800	4.4	1.2	2.5	SE	0.14
	1900	5.0	0.3	2.5	SW	0.07
	2000	4.4		2.5	SE	0.07
	2100	4.4		2.5	SW	0.07
	2200	4.4		2.5	SW	0.07
	2300	4.4		1.25	SE	0.07
	2400	4.4		1.25	SE	0.07
14/07	0100	4.4		1.25	S	0.07
	0200	4.4		1.25	SE	0.07
	0300	4.4		1.25	SE	0.07
	0400	4.4		1.25	SW	0.07
	0500	3.8		2.5	S	0.07
	0600	4.4		2.5	SW	0.07
	0700	4.4		2.5	SE	0.07
	0800	5.0		2.5	NE	0.11
	0900	5.0		2.5	S	0.11
	1000	5.5		2.5	S	0.28
	1100	5.0		5.0	SE	0.28
	1200	5.5		5.0	S	0.49
	1300	5.0		7.5	S	0.49
	1400	5.5		7.5	S	0.53
	1500	4.4		7.5	S	0.35
	1600	5.0		7.5	S	0.35
	1700	5.0		7.5	SE	0.49
	1800	5.5		10.0	SE	0.39

DAILY METEOROLOGICAL OBSERVATIONS
(continued)

DATE	HOUR YST	TEMP. °C	Ppt. in. m.m.	WIND m/s	WIND dir'n.	SOLAR RAD. cal./cm²/min.
14/07	1900	5.0		10.0	SW	0.11
	2000	5.0		7.5	SW	0.11
	2100	5.0		10.0	SW	0.11
	2200	3.8		7.5	SE	0.04
	2300	3.8		7.5	SE	0.04
	2400	3.3		7.5	SW	0.04
15/07	0100	2.7		10.0	SW	0.04
	0200	2.2		10.0	SW	0.04
	0300	0.0		2.5	SW	0.04
	0400	0.5		2.5	SW	0.04
	0500	0.5		2.5	SW	0.04
	0600	0.0		2.5	NW	0.04
	0700	3.8		5.0	S	0.04
	0800	4.4		5.0	NE	0.32
	0900	7.7		5.0	NE	0.53
	1000			5.0	S	0.63

SUMMARY OF DAILY METEOROLOGICAL OBSERVATIONS

Grizzly Creek Glacier
June 1979
Time Zone: Yukon Standard Time (YST)
Location of Station: Westside Lateral Moraine
Elevation: 1950m.

Date	Temperature			Total Ppt	Ave. Wind		Ave. Solar Rad.
June	Ave. °C	°C Max.	°C Min.	in m.m.	km/sec	dir'n.	cal./cm²/min.
08	7.0	10.0	4.4	-		SW	0.40
09	2.5	6.1	0.0	6.0		S	0.24
10	4.2	8.8	0.0	3.9		S	0.22
11	3.9	9.4	0.0	2.7	10.67	S	0.17
12	0.0	0.0	0.0	0.9	9.00	NW	0.23
13	1.3	7.2	-1.1	-	5.33	SW	0.25
14	0.8	14.4	-1.1	8.4	8.67	NW	0.23
15	3.7	8.8	-2.2	0.6	5.33	SW	0.33
16	4.3	9.4	-1.1	-	7.33	SW	0.35
17	1.9	5.5	0.0	5.4	5.17	S	0.18
18	2.1	5.5	0.0	7.5	5.08	NE	0.33
19	5.2	10.0	0.0	5.1	7.67	S	0.34
20	5.0	9.4	1.1	2.1	6.08	SW	0.31
21	3.7	7.2	0.5	15.6	5.42	SW	0.32
22	3.6	5.5	1.1	24.3	5.00	SW	0.31
23	5.3	10.0	3.3	6.6	6.17	NE/SW	0.31
24	7.9	13.8	3.3	-	7.50	SW	0.33
25	13.8	15.0	4.4	-	13.33	SW	0.34
26	7.3	10.5	4.4	-	10.67	SW	0.32
27	5.4	8.8	3.3	-	12.17	SE	0.36
28	3.3	6.1	-0.5	-	12.00	SE	0.40
29	-0.8	0.5	-2.2	0.9	8.00	NE	0.27
30	3.5	8.8	-1.1	-	6.33	NE	0.25

SUMMARY OF DAILY METEOROLOGICAL OBSERVATIONS

Grizzly Creek Glacier
July 1979
Time Zone: Yukon Standard Time (YST)
Location of Station: Westside Lateral Moraine
Elevation: 1950m.

Date	Temperature			Total Ppt	Ave. Wind		Ave. Solar Rad.
July	Ave. °C	°C Max.	°C Min.	in m.m.	km/sec	dir'n.	cal./cm^2/min.
01	5.6	10.0	1.1	0.6	9.50	NE	0.26
02	3.8	4.4	3.3	16.8	9.83	NW	0.08
03	5.0	7.2	3.3	15.6	5.08	NW	0.11
04	8.6	13.8	4.4	0.9	8.00	SW	0.32
05	10.6	15.5	7.2	-	10.50	SW	0.32
06	4.9	8.8	2.2	5.7	5.17	SW	0.10
07	3.2	4.4	1.6	5.4	4.92	NE	0.16
08	4.6	9.4	1.6	-	6.92	SW	0.29
09	5.0	9.4	1.6	0.3	10.67	S	0.26
10	7.2	10.5	3.3	-	7.67	SW	0.28
11	6.5	10.0	5.0	1.5	4.83	SW	0.12
12	7.3	10.5	4.4	-	6.67	NE	0.23
13	4.7	5.5	4.4	18.6	6.67	SW	0.10
14	4.6	5.5	3.3	-	8.58	S/SE	0.20

APPENDIX "B"

STREAM GAUGE RECORDINGS

GRIZZLY CREEK GLACIER, 1979

GRIZZLY CREEK GLACIER, 1979

GAUGE TYPE: A. OTT. KEMPTEN   YUKON STANDARD TIME

STREAM GAUGE RECORDINGS   LOCATION: SITE A

DAY	DATE	HOUR	DISCHARGE $m^3/sec.$	DAY	DATE	HOUR	DISCHARGE $m^3/sec.$
08	06	1700	0.45	10	06	0800	0.31
		1800	0.51			0900	0.31
		1900	0.51			1000	0.31
		2000	0.53			1100	0.31
		2100	0.53			1200	0.31
		2200	0.53			1300	0.34
		2300	0.51			1400	0.37
		2400	0.45			1500	0.39
09	06	0100	0.37			1600	0.39
		0200	0.37			1700	0.48
		0300	0.34			1800	0.48
		0400	0.31			1900	0.48
		0500	0.31			2000	0.48
		0600	0.31			2100	0.48
		0700	0.28			2200	0.42
		0800	0.28			2300	0.42
		0900	0.27			2400	0.42
		1000	0.27	11	06	0100	0.39
		1100	0.27			0200	0.38
		1200	0.25			0300	0.37
		1300	0.25			0400	0.35
		1400	0.25			0500	0.31
		1500	0.28			0600	0.31
		1600	0.34			0700	0.31
		1700	0.34			0800	0.31
		1800	0.37			0900	0.29
		1900	0.37			1000	0.29
		2000	0.37			1100	0.31
		2100	0.37			1200	0.34
		2200	0.37			1300	0.37
		2300	0.37			1400	0.37
		2400	0.37			1500	0.38
10	06	0100	0.34			1600	0.39
		0200	0.34			1700	0.42
		0300	0.34			1800	0.48
		0400	0.31			1900	0.48
		0500	0.31			2000	0.48
		0600	0.31			2100	0.48
		0700	0.31			2200	0.48

STREAM GAUGE RECORDINGS
(continued)

LOCATION: SITE A

DAY	DATE	HOUR	DISCHARGE $m^3/sec.$	DAY	DATE	HOUR	DISCHARGE $m^3/sec.$
11	06	2300	0.48	13	06	1500	0.20
		2400	0.48			1600	0.20
12	06	0100	0.48			1700	0.20
		0200	0.48			1800	0.20
		0300	0.48			1900	0.20
		0400	0.48			2000	0.20
		0500	0.48			2100	0.20
		0600	0.48			2200	0.20
		0700	0.48			2300	0.20
		0800	0.48			2400	0.20
		0900	0.48	14	06	0100	0.20
		1000	0.48			0200	0.20
		1100	0.48			0300	0.20
		1200	0.37			0400	0.20
		1300	0.27			0500	0.20
		1400	0.27			0600	0.20
		1500	0.27			0700	0.20
		1600	0.27			0800	0.20
		1700	0.27			0900	0.20
		1800	0.27			1000	0.20
		1900	0.27			1100	0.20
		2000	0.27			1200	0.20
		2100	0.27			1300	0.20
		2200	0.27			1400	0.20
		2300	0.27			1500	0.20
		2400	0.27			1600	0.20
13	06	0100	0.27			1700	0.20
		0200	0.27			1800	0.20
		0300	0.27			1900	0.20
		0400	0.27			2000	0.20
		0500	0.27			2100	0.20
		0600	0.27			2200	0.20
		0700	0.27			2300	0.20
		0800	0.27			2400	0.20
		0900	0.27	15	06	0100	0.20
		1000	0.20			0200	0.20
		1100	0.20			0300	0.20
		1200	0.20			0400	0.20
		1300	0.20			0500	0.20
		1400	0.20			0600	0.20

STREAM GAUGE RECORDINGS
(continued)

LOCATION: SITE A

DAY	DATE	HOUR	DISCHARGE m^3/sec.	DAY	DATE	HOUR	DISCHARGE m^3/sec.
		0700	0.20	16	06	2300	0.50
		0800	0.20			2400	0.50
		0900	0.20	17	06	0100	0.48
		1000	0.20			0200	0.45
		1100	0.20			0300	0.45
		1200	0.20			0400	0.42
		1300	0.22			0500	0.42
		1400	0.25			0600	0.39
		1500	0.27			0700	0.39
		1600	0.37			0800	0.37
		1700	0.48			0900	0.37
		1800	0.57			1000	0.37
		1900	0.59			1100	0.37
		2000	0.62			1200	0.37
		2100	0.65			1300	0.37
		2200	0.65			1400	0.37
		2300	0.65			1500	0.37
		2400	0.62			1600	0.37
16	06	0100	0.59			1700	0.37
		0200	0.57			1800	0.39
		0300	0.57			1900	0.42
		0400	0.57			2000	0.42
		0500	0.57			2100	0.45
		0600	0.57			2200	0.45
		0700	0.50			2300	0.45
		0800	0.50			2400	0.45
		0900	0.50	18	06	0100	0.45
		1000	0.45			0200	0.45
		1100	0.42			0300	0.45
		1200	0.42			0400	0.45
		1300	0.42			0500	0.45
		1400	0.42			0600	0.42
		1500	0.42			0700	0.42
		1600	0.45			0800	0.42
		1700	0.48			0900	0.42
		1800	0.50			1000	0.42
		1900	0.50			1100	0.42
		2000	0.57			1200	0.48
		2100	0.54			1300	0.50
		2200	0.54			1400	0.50

STREAM GAUGE RECORDINGS
(continued)

LOCATION: SITE A

DAY	DATE	HOUR	DISCHARGE m^3/sec.
18	06	1500	0.54
		1600	0.57
		1700	0.57
		1800	0.59
		1900	0.59
		2000	0.59
		2100	0.59
		2200	0.59
		2300	0.59
		2400	0.59
19	06	0100	0.59
		0200	0.59
		0300	0.59
		0400	0.57
		0500	0.57
		0600	0.54
		0700	0.54
		0800	0.54
		0900	0.54
		1000	0.54
		1100	0.54
		1200	0.57
		1300	0.57
		1400	0.59
		1500	0.59
		1600	0.65
		1700	0.74
		1800	0.77
		1900	0.77
		2000	0.77
		2100	0.77
		2200	0.77
		2300	0.74
		2400	0.74
20	06	0100	0.71
		0200	0.68
		0300	0.62
		0400	0.62
		0500	0.59
		0600	0.59
20	06	0700	0.57
		0800	0.57
		0900	0.57
		1000	0.57
		1100	0.57
		1200	0.57
		1300	0.57
		1400	0.57
		1500	0.57
		1600	0.62
		1700	0.62
		1800	0.62
		1900	0.62
		2000	0.65
		2100	0.65
		2200	0.65
		2300	0.65
		2400	0.62
21	06	0100	0.59
		0200	0.59
		0300	0.57
		0400	0.57
		0500	0.59
		0600	0.57
		0700	0.57
		0800	0.59
		0900	0.59
		1000	0.59
		1100	0.62
		1200	0.62
		1300	0.62
		1400	0.68
		1500	0.71
		1600	0.74
		1700	0.77
		1800	0.77
		1900	0.82
		2000	0.85
		2100	0.85
		2200	0.91

STREAM GAUGE RECORDINGS
(continued)

LOCATION: SITE A

DAY	DATE	HOUR	DISCHARGE $m^3/sec.$	DAY	DATE	HOUR	DISCHARGE $m^3/sec.$
21	06	2300	0.99	23	06	1500	2.16
		2400	0.99			1600	2.23
22	06	0100	0.99			1700	2.23
		0200	0.99			1800	2.30
		0300	0.99			1900	2.30
		0400	0.99			2000	2.30
		0500	0.96			2100	2.30
		0600	0.96			2200	2.30
		0700	0.96			2300	2.30
		0800	0.96			2400	2.30
		0900	0.96	24	06	0100	2.30
		1000	0.94			0200	2.16
		1100	0.94			0300	2.09
		1200	0.94			0400	2.02
		1300	0.91			0500	1.75
		1400	0.94			0600	1.40
		1500	0.94			0700	1.40
		1600	0.94			0800	1.34
		1700	0.96			1900	1.34
		1800	0.99			1000	1.34
		1900	1.02			1100	1.34
		2000	1.05			1200	1.40
		2100	1.08			1300	1.62
		2200	1.08			1400	1.82
		2300	1.02			1500	2.02
		2400	1.02			1600	2.30
23	06	0100	2.09			1700	2.44
		0200	2.02			1800	2.57
		0300	2.02			1900	2.57
		0400	2.02			2000	2.57
		0500	2.02			2100	2.57
		0600	2.02			2200	2.57
		0700	2.02			2300	2.57
		0800	2.02			2400	2.30
		0900	2.02	25	06	0100	2.16
		1000	2.02			0200	2.02
		1100	2.02			0300	1.89
		1200	2.02			0400	1.75
		1300	2.09			0500	1.62
		1400	2.16			0600	1.40

STREAM GAUGE RECORDINGS
(continued)

LOCATION: SITE A

DAY	DATE	HOUR	DISCHARGE m^3/sec.	DAY	DATE	HOUR	DISCHARGE m^3/sec.
25	06	0700	1.40	26	06	2300	2.16
		0800	1.40			2400	2.09
		0900	1.40	27	06	0100	2.02
		1000	1.40			0200	1.89
		1100	1.40			0300	1.75
		1200	1.62			0400	1.62
		1300	1.89			0500	1.40
		1400	1.89			0600	1.40
		1500	2.16			0700	1.40
		1600	2.30			0800	1.34
		1700	2.44			0900	1.34
		1800	2.44			1000	1.34
		1900	2.44			1100	1.34
		2000	2.44			1200	1.40
		2100	2.44			1300	1.62
		2200	2.44			1400	1.75
		2300	2.44			1500	1.89
		2400	2.30			1600	1.89
26	06	0100	2.30			1700	2.02
		0200	2.30			1800	2.02
		0300	2.44			1900	2.02
		0400	2.02			2000	2.02
		0500	1.89			2100	2.02
		0600	1.89			2200	1.89
		0700	1.89			2300	1.75
		0800	1.75			2400	1.62
		0900	1.75	28	06	0100	1.40
		1000	1.75			0200	1.34
		1100	1.75			0300	1.21
		1200	1.75			0400	1.21
		1300	1.89			0500	1.21
		1400	2.02			0600	1.07
		1500	2.09			0700	1.07
		1600	2.16			0800	0.93
		1700	2.30			0900	0.93
		1800	2.30			1000	1.07
		1900	2.30			1100	1.07
		2000	2.30			1200	1.07
		2100	2.30			1300	1.07
		2200	2.30			1400	1.21

STREAM GAUGE RECORDINGS
(continued)

LOCATION: SITE A

DAY	DATE	HOUR	DISCHARGE m^3/sec.	DAY	DATE	HOUR	DISCHARGE m^3/sec.
28	06	1500	1.34	30	06	0700	0.02
		1600	1.34			0800	0.02
		1700	1.34			0900	0.02
		1800	1.34			1000	0.02
		1900	1.34			1100	0.02
		2000	1.21			1200	0.11
		2100	1.07			1300	0.11
		2200	0.93			1400	0.11
		2300	0.93			1500	0.52
		2400	0.93			1600	0.52
29	06	0100	0.80			1700	0.52
		0200	0.66			1800	0.52
		0300	0.52			1900	0.80
		0400	0.52			2000	0.80
		0500	0.52			2100	0.80
		0600	0.52			2200	0.80
		0700	0.52			2300	0.80
		0800	0.52			2400	0.66
		0900	0.39	01	07	0100	1.52
		1000	0.39			0200	1.38
		1100	0.39			0300	1.24
		1200	0.39			0400	1.10
		1300	0.39			0500	0.96
		1400	0.39			0600	0.75
		1500	0.39			0700	0.75
		1600	0.52			0800	0.75
		1700	0.52			0900	0.75
		1800	0.52			1000	0.75
		1900	0.52			1100	0.96
		2000	0.39			1200	1.52
		2100	0.39			1300	1.52
		2200	0.39			1400	1.66
		2300	0.11			1500	1.66
		2400	0.11			1600	2.09
30	06	0100	0.11			1700	2.09
		0200	0.11			1800	2.09
		0300	0.02			1900	2.23
		0400	0.02			2000	2.23
		0500	0.02			2100	2.23
		0600	0.02			2200	2.23

STREAM GAUGE RECORDINGS
(continued)

LOCATION: SITE A

DAY	DATE	HOUR	DISCHARGE m^3/sec.	DAY	DATE	HOUR	DISCHARGE m^3/sec.
01	07	2300	2.09	03	07	1500	4.19
		2400	2.09			1600	4.19
02	07	0100	1.94			1700	4.05
		0200	1.94			1800	4.05
		0300	1.80			1900	4.05
		0400	1.66			2000	4.05
		0500	1.52			2100	4.05
		0600	1.52			2200	4.05
		0700	1.52			2300	3.91
		0800	1.52			2400	3.91
		0900	1.52	04	07	0100	3.91
		1000	1.66			0200	3.91
		1100	1.80			0300	3.91
		1200	1.94			0400	3.91
		1300	2.09			0500	3.91
		1400	2.51			0600	3.77
		1500	2.79			0700	3.77
		1600	2.79			0800	3.77
		1700	3.07			0900	3.77
		1800	3.07			1000	3.63
		1900	3.07			1100	3.91
		2000	3.07			1200	3.91
		2100	3.07			1300	4.05
		2200	3.07			1400	4.19
		2300	3.07			1500	4.33
		2400	3.07			1600	4.33
03	07	0100	3.20			1700	4.33
		0200	3.49			1800	4.33
		0300	3.77			1900	4.33
		0400	3.91			2000	4.33
		0500	4.05			2100	4.33
		0600	4.19			2200	4.33
		0700	4.19			2300	4.33
		0800	4.19			2400	4.33
		0900	4.19	05	07	0100	4.19
		1000	4.19			0200	4.19
		1100	4.19			0300	4.05
		1200	4.19			0400	3.91
		1300	4.19			0500	3.91
		1400	4.19			0600	3.91

STREAM GAUGE RECORDINGS
(continued)

LOCATION: SITE A

DAY	DATE	HOUR	DISCHARGE $m^3/sec.$	DAY	DATE	HOUR	DISCHARGE $m^3/sec.$
05	07	0700	3.91	06	07	2300	3.49
		0800	3.91			2400	3.20
		0900	3.91	07	07	0100	3.07
		1000	3.91			0200	3.07
		1100	4.05			0300	3.07
		1200	4.19			0400	2.93
		1300	4.33			0500	2.93
		1400	4.47			0600	2.79
		1500	4.61			0700	2.79
		1600	5.03			0800	2.79
		1700	5.31			0900	2.79
		1800	5.31			1000	2.79
		1900	5.31			1100	2.79
		2000	5.31			1200	2.93
		2100	5.17			1300	3.07
		2200	5.03			1400	3.07
		2300	4.89			1500	3.20
		2400	4.61			1600	3.20
06	07	0100	4.61			1700	3.20
		0200	4.33			1800	3.20
		0300	4.05			1900	3.20
		0400	4.05			2000	3.20
		0500	4.05			2100	3.20
		0600	4.05			2200	3.20
		0700	3.91			2300	3.20
		0800	3.63			2400	3.20
		0900	3.63	08	07	0100	3.20
		1000	3.63			0200	3.20
		1100	3.63			0300	3.07
		1200	3.63			0400	2.93
		1300	3.63			0500	2.79
		1400	3.63			0600	2.65
		1500	3.63			0700	2.65
		1600	3.63			0800	2.65
		1700	3.63			0900	2.65
		1800	3.63			1000	2.65
		1900	3.63			1100	2.79
		2000	3.63			1200	2.93
		2100	3.63			1300	3.07
		2200	3.63			1400	3.49

STREAM GAUGE RECORDINGS
(continued)

LOCATION: SITE A

DAY	DATE	HOUR	DISCHARGE $m^3/sec.$	DAY	DATE	HOUR	DISCHARGE $m^3/sec.$
08	07	1500	3.49	10	07	0700	2.37
		1600	3.63			0800	2.37
		1700	3.49			0900	2.51
		1800	3.49			1000	2.65
		1900	3.49			1100	2.93
		2000	3.35			1200	2.93
		2100	3.20			1300	3.07
		2200	3.07			1400	3.49
		2300	2.93			1500	4.05
		2400	2.79			1600	4.05
09	08	0100	2.79			1700	4.19
		0200	2.65			1800	4.19
		0300	2.51			1900	4.19
		0400	2.51			2000	4.19
		0500	2.51			2100	3.91
		0600	2.51			2200	3.91
		0700	2.51			2300	3.91
		0800	2.37			2400	3.77
		0900	2.37	11	07	0100	3.63
		1000	2.37			0200	3.63
		1100	2.51			0300	3.35
		1200	2.65			0400	3.35
		1300	2.79			0500	2.93
		1400	2.93			0600	3.07
		1500	3.07			0700	3.07
		1600	3.07			0800	3.07
		1700	3.07			0900	3.07
		1800	3.07			1000	3.20
		1900	3.07			1100	3.35
		2000	3.07			1200	3.35
		2100	3.07			1300	3.35
		2200	3.07			1400	3.49
		2300	3.07			1500	3.63
		2400	2.79			1600	3.63
10	07	0100	2.65			1700	3.77
		0200	2.65			1800	3.77
		0300	2.51			1900	3.77
		0400	2.51			2000	3.77
		0500	2.51			2100	3.77
		0600	2.37			2200	3.77

STREAM GAUGE RECORDINGS
(continued)

LOCATION: SITE A

DAY	DATE	HOUR	DISCHARGE m^3/sec.	DAY	DATE	HOUR	DISCHARGE m^3/sec.
11	07	2300	3.77	13	07	1500	5.45
		2400	3.63			1600	5.45
12	07	0100	3.63			1700	5.45
		0200	3.49			1800	5.45
		0300	3.49			1900	5.31
		0400	3.35			2000	5.31
		0500	3.35			2100	5.03
		0600	3.35			2200	5.03
		0700	3.35			2300	4.89
		0800	3.35			2400	4.61
		0900	3.35	14	07	0100	4.75
		1000	3.49			0200	4.47
		1100	3.63			0300	4.47
		1200	4.05			0400	4.19
		1300	4.05			0500	4.19
		1400	4.05			0600	3.91
		1500	4.05			0700	3.91
		1600	4.19			0800	3.91
		1700	4.19			0900	3.91
		1800	4.19			1000	3.91
		1900	4.19			1100	3.91
		2000	4.19			1200	3.91
		2100	4.19			1300	3.91
		2200	4.19			1400	3.77
		2300	4.19			1500	3.91
		2400	4.19			1600	4.05
13	07	0100	3.91			1700	4.05
		0200	3.77			1800	4.05
		0300	3.77			1900	4.05
		0400	3.77			2000	4.05
		0500	3.77			2100	4.05
		0600	3.77			2200	3.91
		0700	3.77			2300	3.77
		0800	4.61			2400	3.63
		0900	5.03	15	07	0100	3.63
		1000	5.17			0200	3.49
		1100	5.17			0300	3.49
		1200	5.60			0400	3.07
		1300	5.60			0500	2.93
		1400	5.60			0600	2.79

STREAM GAUGE RECORDINGS
(continued)

LOCATION: SITE A

DAY	DATE	HOUR	DISCHARGE m^3/sec.	DAY	DATE	HOUR	DISCHARGE m^3/sec.
15	07	0700	2.79				
		0800	2.65				
		0900	2.65				
		1000	2.65				
		1100	2.65				

GRIZZLY CREEK GLACIER, 1979

GAUGE TYPE: LEAPOLD AND STEVENS   YUKON STANDARD TIME

STREAM GAUGE RECORDINGS   LOCATION: SITE A2

DAY	DATE	HOUR	DISCHARGE m^3/sec.	DAY	DATE	HOUR	DISCHARGE m^3/sec.
10	06	1000	0.17	12	06	0100	0.02
		1100	0.19			0200	0.02
		1200	0.15			0300	0.02
		1300	0.15			0400	0.02
		1400	0.14			0500	0.003
		1500	0.13			0600	0.003
		1600	0.13			0700	0.003
		1700	0.12			0800	0.003
		1800	0.11			0900	0.003
		1900	0.10			1000	0.003
		2000	0.10			1100	0.003
		2100	0.09			1200	0.003
		2200	0.09			1300	0.003
		2300	0.09			1400	0.03
		2400	0.21			1500	0.03
11	06	0100	0.02			1600	0.04
		0200	0.02			1700	0.02
		0300	0.02			1800	0.02
		0400	0.02			1900	0.02
		0500	0.003			2000	0.02
		0600	0.003			2100	0.02
		0700	0.003			2200	0.02
		0800	0.003			2300	0.02
		0900	0.003			2400	0.02
		1000	0.003	13	06	0100	0.15
		1100	0.003			0200	0.15
		1200	0.003			0300	0.15
		1300	0.003			0400	0.15
		1400	0.003			0500	0.15
		1500	0.003			0600	0.15
		1600	0.004			0700	0.15
		1700	0.02			0800	0.06
		1800	0.02			0900	0.02
		1900	0.02			1000	0.02
		2000	0.02			1100	0.02
		2100	0.02			1200	0.02
		2200	0.02			1300	0.04
		2300	0.02			1400	0.04
		2400	0.02			1500	0.04

STREAM GAUGE RECORDINGS
(continued)

LOCATION: SITE A2

DAY	DATE	HOUR	DISCHARGE $m^3/sec.$	DAY	DATE	HOUR	DISCHARGE $m^3/sec.$
13	06	1600	0.04	15	06	0800	0.04
		1700	0.12			0900	0.04
		1800	0.30			1000	0.04
		1900	0.32			1100	0.04
		2000	0.34			1200	0.04
		2100	0.35			1300	0.17
		2200	0.30			1400	0.17
		2300	0.30			1500	0.17
		2400	0.20			1600	0.29
14	06	0100	0.10			1700	0.32
		0200	0.09			1800	0.39
		0300	0.11			1900	0.39
		0400	0.11			2000	0.39
		0500	0.11			2100	0.39
		0600	0.11			2200	0.37
		0700	0.11			2300	0.36
		0800	0.06			2400	0.34
		0900	0.02	16	06	0100	0.31
		1000	0.02			0200	0.31
		1100	0.02			0300	0.31
		1200	0.02			0400	0.31
		1300	0.04			0500	0.31
		1400	0.04			0600	0.31
		1500	0.09			0700	0.31
		1600	0.09			0800	0.24
		1700	0.15			0900	0.24
		1800	0.15			1000	0.24
		1900	0.15			1100	0.24
		2000	0.20			1200	0.24
		2100	0.30			1300	0.24
		2200	0.28			1400	0.24
		2300	0.25			1500	0.24
		2400	0.16			1600	0.26
15	06	0100	0.14			1700	0.32
		0200	0.09			1800	0.34
		0300	0.09			1900	0.37
		0400	0.09			2000	0.38
		0500	0.09			2100	0.38
		0600	0.07			2200	0.36
		0700	0.07			2300	0.34

STREAM GAUGE RECORDINGS
(continued)

LOCATION: SITE A2

DAY	DATE	HOUR	DISCHARGE m^3/sec.	DAY	DATE	HOUR	DISCHARGE m^3/sec.
16	06	2400	0.32	18	06	1600	0.25
17	06	0100	0.29			1700	0.30
		0200	0.28			1800	0.30
		0300	0.27			1900	0.37
		0400	0.26			2000	0.38
		0500	0.26			2100	0.38
		0600	0.25			2200	0.36
		0700	0.24			2300	0.34
		0800	0.24			2400	0.34
		0900	0.22	19	06	0100	0.34
		1000	0.17			0200	0.39
		1100	0.17			0300	0.39
		1200	0.17			0400	0.39
		1300	0.17			0500	0.37
		1400	0.22			0600	0.36
		1500	0.22			0700	0.30
		1600	0.24			0800	0.30
		1700	0.24			0900	0.30
		1800	0.24			1000	0.30
		1900	0.25			1100	0.30
		2000	0.28			1200	0.30
		2100	0.36			1300	0.30
		2200	0.36			1400	0.30
		2300	0.28			1500	0.33
		2400	0.28			1600	0.34
18	06	0100	0.25			1700	0.36
		0200	0.32			1800	0.36
		0300	0.32			1900	0.41
		0400	0.32			2000	0.43
		0500	0.32			2100	0.48
		0600	0.32			2200	0.43
		0700	0.32			2300	0.43
		0800	0.25			2400	0.40
		0900	0.25	20	06	0100	0.33
		1000	0.25			0200	0.33
		1100	0.25			0300	0.33
		1200	0.25			0400	0.33
		1300	0.25			0500	0.33
		1400	0.28			0600	0.33
		1500	0.28			0700	0.24

STREAM GAUGE RECORDINGS
(continued)

LOCATION: SITE A2

DAY	DATE	HOUR	DISCHARGE m^3/sec.	DAY	DATE	HOUR	DISCHARGE m^3/sec.
20	06	0800	0.24	21	06	2400	0.50
		0900	0.24	22	06	0100	0.53
		1000	0.24			0200	0.53
		1100	0.24			0300	0.53
		1200	0.24			0400	0.53
		1300	0.24			0500	0.53
		1400	0.24			0600	0.46
		1500	0.24			0700	0.48
		1600	0.24			0800	0.48
		1700	0.24			0900	0.48
		1800	0.24			1000	0.49
		1900	0.48			1100	0.44
		2000	0.68			1200	0.44
		2100	0.78			1300	0.46
		2200	0.60			1500	0.52
		2300	0.56			1600	0.52
		2400	0.56			1700	0.54
21	06	0100	0.38			1800	0.54
		0200	0.38			1900	0.60
		0300	0.37			2000	0.95
		0400	0.36			2100	0.95
		0500	0.34			2200	0.79
		0600	0.32			2300	0.68
		0700	0.33			2400	0.68
		0800	0.34	23	06	0100	1.84
		0900	0.36			0200	1.84
		1000	0.36			0300	1.84
		1100	0.30			0400	1.84
		1200	0.30			0500	1.84
		1300	0.38			0600	1.84
		1400	0.38			0700	1.98
		1500	0.42			0800	1.98
		1600	0.42			0900	1.98
		1700	0.42			1000	1.98
		1800	0.49			1100	1.74
		1900	0.49			1200	1.97
		2000	0.58			1300	2.03
		2100	0.70			1400	2.09
		2200	0.55			1500	2.09
		2300	0.50			1600	2.09

STREAM GAUGE RECORDINGS
(continued)

LOCATION: SITE A2

DAY	DATE	HOUR	DISCHARGE m^3/sec.	DAY	DATE	HOUR	DISCHARGE m^3/sec.
23	06	1700	2.11	25	06	0900	2.09
		1800	2.17			1000	2.09
		1900	2.14			1100	2.09
		2000	2.11			1200	2.09
		2100	2.11			1300	2.09
		2200	2.09			1400	3.42
		2300	2.03			1500	3.64
		2400	1.97			1600	2.20
24	06	0100	1.74			1700	2.31
		0200	1.74			1800	2.86
		0300	1.70			1900	3.20
		0400	1.61			2000	3.22
		0500	1.47			2100	3.20
		0600	1.36			2200	2.97
		0700	1.31			2300	2.84
		0800	1.22			2400	2.72
		0900	1.20	26	06	0100	2.64
		1000	1.47			0200	2.59
		1100	1.74			0300	2.59
		1200	2.09			0400	2.50
		1300	2.20			0500	2.50
		1400	2.31			0600	2.47
		1500	2.59			0700	2.39
		1600	2.86			0800	2.39
		1700	2.92			0900	2.39
		1800	2.92			1000	2.36
		1900	2.92			1100	2.22
		2000	2.92			1200	2.22
		2100	2.92			1300	2.25
		2200	2.92			1400	2.31
		2300	2.86			1500	2.45
		2400	2.86			1600	2.50
25	06	0100	2.31			1700	2.59
		0200	2.20			1800	2.67
		0300	2.20			1900	2.78
		0400	2.20			2000	2.84
		0500	2.11			2100	2.84
		0600	2.11			2200	2.78
		0700	2.09			2300	2.75
		0800	2.09			2400	2.59

STREAM GAUGE RECORDINGS
(continued)

LOCATION: SITE A2

DAY	DATE	HOUR	DISCHARGE $m^3/sec.$	DAY	DATE	HOUR	DISCHARGE $m^3/sec.$
27	06	0100	2.40	28	06	1700	2.11
		0200	2.00			1800	2.14
		0300	1.55			1900	2.14
		0400	1.55			2000	2.11
		0500	1.55			2100	1.97
		0600	1.55			2200	1.95
		0700	1.55			2300	1.86
		0800	1.55			2400	1.81
		0900	1.66	29	06	0100	1.74
		1000	1.66			0200	1.70
		1100	1.55			0300	1.64
		1200	1.48			0400	1.58
		1300	2.13			0500	1.56
		1400	2.13			0600	1.56
		1500	2.28			0700	1.50
		1600	2.32			0800	1.50
		1700	2.28			0900	1.47
		1800	2.28			1000	1.45
		1900	2.38			1100	1.42
		2000	2.44			1200	1.42
		2100	2.44			1300	1.42
		2200	2.44			1400	1.44
		2300	2.31			1500	1.44
		2400	2.31			1600	1.44
28	06	0100	1.75			1700	1.74
		0200	1.40			1800	1.74
		0300	1.15			1900	1.74
		0400	1.15			2000	1.74
		0500	1.15			2100	1.68
		0600	1.15			2200	1.35
		0700	1.50			2300	1.04
		0800	1.75			2400	1.04
		0900	1.90	30	06	0100	0.40
		1000	2.03			0200	0.38
		1100	2.03			0300	0.37
		1200	2.03			0400	0.36
		1300	2.03			0500	0.36
		1400	2.03			0600	0.36
		1500	2.09			0700	0.32
		1600	2.09			0800	0.30

STREAM GAUGE RECORDINGS
(continued)

LOCATION: SITE A2

DAY	DATE	HOUR	DISCHARGE m^3/sec.	DAY	DATE	HOUR	DISCHARGE m^3/sec.
30	06	0900	0.30	02	07	0100	0.45
		1000	0.30			0200	0.42
		1100	0.32			0300	0.41
		1200	0.38			0400	0.39
		1300	0.39			0500	0.39
		1400	0.39			0600	0.38
		1500	0.40			0700	0.38
		1600	0.41			0800	0.38
		1700	0.41			0900	0.38
		1800	0.42			1000	0.38
		1900	0.46			1100	0.38
		2000	0.45			1200	0.38
		2100	0.45			1300	0.39
		2200	0.71			1400	1.12
		2300	0.41			1500	0.96
		2400	0.40			1600	0.70
01	07	0100	0.38			1700	0.70
		0200	0.36			1800	0.70
		0300	0.35			1900	0.70
		0400	0.34			2000	1.12
		0500	0.34			2100	1.12
		0600	0.33			2200	0.70
		0700	0.33			2300	0.70
		0800	0.33			2400	0.70
		0900	0.32	03	07	0100	0.59
		1000	0.32			0200	0.45
		1100	0.32			0300	0.45
		1200	0.31			0400	0.45
		1300	0.39			0500	0.45
		1400	0.39			0600	0.45
		1500	0.40			0700	0.45
		1600	0.41			0800	0.45
		1700	0.46			0900	0.49
		1800	0.46			1000	0.49
		1900	0.46			1100	0.45
		2000	0.49			1200	0.41
		2100	0.53			1300	0.91
		2200	0.49			1400	0.90
		2300	0.48			1500	0.88
		2400	0.47			1600	0.86

STREAM GAUGE RECORDINGS
(continued)

LOCATION: SITE A2

DAY	DATE	HOUR	DISCHARGE $m^3/sec.$	DAY	DATE	HOUR	DISCHARGE $m^3/sec.$
03	07	1700	0.91	05	07	0900	0.48
		1800	0.91			1000	0.48
		1900	0.91			1100	0.48
		2000	0.93			1200	0.43
		2100	0.93			1300	0.88
		2200	0.90			1400	1.06
		2300	0.90			1500	1.16
		2400	0.90			1600	1.16
04	07	0100	0.70			1700	1.12
		0200	0.45			1800	1.08
		0300	0.45			1900	1.36
		0400	0.45			2000	0.60
		0500	0.45			2100	0.61
		0600	0.45			2200	0.54
		0700	0.54			2300	0.54
		0800	0.58			2400	0.54
		0900	0.47	06	07	0100	0.54
		1000	0.47			0200	0.54
		1100	0.35			0300	0.54
		1200	0.40			0400	0.54
		1300	0.85			0500	0.54
		1400	0.91			0600	0.54
		1500	0.91			0700	0.54
		1600	0.91			0800	0.54
		1700	0.90			0900	0.54
		1800	0.88			1000	0.49
		1900	0.56			1100	0.49
		2000	1.02			1200	0:52
		2100	1.02			1300	0.88
		2200	0.96			1400	0.87
		2300	0.90			1500	0.85
		2400	0.90			1600	0.83
05	07	0100	0.71			1700	0.90
		0200	0.55			1800	0.69
		0300	0.43			1900	0.69
		0400	0.43			2000	0.69
		0500	0.43			2100	0.69
		0600	0.43			2200	0.67
		0700	0.43			2300	0.67
		0800	0.48			2400	0.65

STREAM GAUGE RECORDINGS
(continued)

LOCATION: SITE A2

DAY	DATE	HOUR	DISCHARGE m^3/sec.	DAY	DATE	HOUR	DISCHARGE m^3/sec.
07	07	0100	0.62	08	07	1700	0.42
		0200	0.61			1800	0.42
		0300	0.61			1900	0.42
		0400	0.61			2000	0.42
		0500	0.61			2100	0.42
		0600	0.61			2200	0.42
		0700	0.61			2300	0.42
		0800	0.61			2400	0.42
		0900	0.61	09	07	0100	0.42
		1000	0.61			0200	0.42
		1100	0.61			0300	0.42
		1200	0.49			0400	0.42
		1300	0.49			0500	0.42
		1400	0.58			0600	0.54
		1500	0.56			0700	0.56
		1600	0.54			0800	0.56
		1700	0.52			0900	0.56
		1800	0.51			1000	0.54
		1900	0.49			1100	0.53
		2000	0.46			1200	0.52
		2100	0.46			1300	0.47
		2200	0.46			1400	0.47
		2300	0.46			1500	0.47
		2400	0.45			1600	0.47
08	07	0100	0.45			1700	0.47
		0200	0.45			1800	0.47
		0300	0.45			1900	0.47
		0400	0.45			2000	0.47
		0500	0.45			2100	0.47
		0600	0.45			2200	0.47
		0700	0.45			2300	0.47
		0800	0.45			2400	0.47
		0900	0.45	10	07	0100	0.47
		1000	0.45			0200	0.47
		1100	0.45			0300	0.47
		1200	0.48			0400	0.47
		1300	0.43			0500	0.47
		1400	0.42			0600	0.46
		1500	0.42			0700	0.51
		1600	0.42			0800	0.52

STREAM GAUGE RECORDINGS
(continued)

LOCATION: SITE A2

DAY	DATE	HOUR	DISCHARGE $m^3/sec.$	DAY	DATE	HOUR	DISCHARGE $m^3/sec.$
10	07	0900	0.54	12	07	0100	0.63
		1000	0.86			0200	0.63
		1100	0.63			0300	0.63
		1200	0.63			0400	0.63
		1300	0.59			0500	0.63
		1400	0.59			0600	0.85
		1500	0.59			0700	0.80
		1600	0.53			0800	0.80
		1700	0.49			0900	0.83
		1800	0.49			1000	0.87
		1900	0.53			1100	0.92
		2000	0.59			1200	0.88
		2100	0.59			1300	0.79
		2200	0.53			1400	0.87
		2300	0.47			1500	0.81
		2400	0.46			1600	0.76
11	07	0100	0.46			1700	0.56
		0200	0.47			1800	0.56
		0300	0.49			1900	0.56
		0400	0.49			2000	0.66
		0500	0.49			2100	0.79
		0600	0.49			2200	0.61
		0700	0.65			2300	0.56
		0800	0.65			2400	0.56
		0900	0.65	13	07	0100	0.56
		1000	0.67			0200	0.56
		1100	0.69			0300	0.63
		1200	0.69			0400	0.82
		1300	0.58			0500	0.84
		1400	0.56			0600	0.86
		1500	0.54			0700	0.63
		1600	0.54			0800	0.62
		1700	0.52			0900	0.59
		1800	0.49			1000	0.59
		1900	0.50			1100	0.59
		2000	0.54			1200	0.62
		2100	0.54			1300	0.76
		2200	0.54			1400	0.76
		2300	0.48			1500	0.78
		2400	0.47			1600	1.06

STREAM GAUGE RECORDINGS
(continued)

LOCATION: SITE A2

DAY	DATE	HOUR	DISCHARGE m^3/sec.	DAY	DATE	HOUR	DISCHARGE m^3/sec.
13	07	1700	1.06	15	07	0900	0.60
		1800	1.12			1000	0.60
		1900	1.12			1100	0.60
		2000	1.12			1200	0.60
		2100	1.08				
		2200	0.60				
		2300	0.61				
		2400	0.60				
14	07	0100	0.60				
		0200	0.61				
		0300	0.61				
		0400	0.61				
		0500	0.61				
		0600	0.61				
		0700	0.62				
		0800	0.62				
		0900	0.62				
		1000	0.65				
		1100	0.68				
		1200	0.63				
		1300	0.62				
		1400	0.62				
		1500	0.67				
		1600	0.68				
		1700	0.68				
		1800	0.68				
		1900	0.68				
		2000	0.67				
		2100	0.67				
		2200	0.66				
		2300	0.65				
		2400	0.63				
15	07	0100	0.63				
		0200	0.62				
		0300	0.61				
		0400	0.61				
		0500	0.61				
		0600	0.61				
		0700	0.61				
		0800	0.61				

GRIZZLY CREEK GLACIER, 1979

GAUGE TYPE: LEAPOLD AND STEVENS   YUKON STANDARD TIME

STREAM GAUGE RECORDINGS   LOCATION: SITE 3TE

DAY	DATE	HOUR	DISCHARGE m^3/sec.	DAY	DATE	HOUR	DISCHARGE m^3/sec.
10	06	1200	0.01	12	06	0400	0.03
		1300	0.01			0500	0.03
		1400	0.01			0600	0.03
		1500	0.02			0700	0.03
		1600	0.03			0800	0.03
		1700	0.03			0900	0.03
		1800	0.03			1000	0.04
		1900	0.03			1100	0.02
		2000	0.03			1200	0.02
		2100	0.03			1300	0.02
		2200	0.03			1400	0.02
		2300	0.03			1500	0.02
		2400	0.03			1600	0.03
11	06	0100	0.03			1700	0.03
		0200	0.03			1800	0.03
		0400	0.03			1900	0.03
		0500	0.03			2000	0.03
		0600	0.03			2100	0.04
		0700	0.03			2200	0.02
		0800	0.03			2300	0.04
		0900	0.03			2400	0.04
		1000	0.04	13	06	0100	0.01
		1100	0.02			0200	0.003
		1200	0.02			0300	0.003
		1300	0.02			0400	0.003
		1400	0.02			0500	0.01
		1500	0.02			0600	0.01
		1600	0.03			0700	0.01
		1700	0.03			0800	0.01
		1800	0.03			0900	0.01
		1900	0.03			1000	0.01
		2000	0.03			1100	0.01
		2100	0.04			1200	0.01
		2200	0.02			1300	0.01
		2300	0.04			1400	0.01
		2400	0.04			1500	0.01
12	06	0100	0.03			1600	0.004
		0200	0.03			1700	0.004
		0300	0.03			1800	0.004

STREAM GAUGE RECORDINGS
(continued)

LOCATION: SITE MTE

DAY	DATE	HOUR	DISCHARGE $m^3/sec.$
13	06	1900	0.01
		2000	0.02
		2100	0.02
		2200	0.02
		2300	0.01
		2400	0.01
14	06	0100	0.003
		0200	0.003
		0300	0.006
		0400	0.006
		0500	0.006
		0600	0.006
		0700	0.007
		0800	0.007
		0900	0.007
		1000	0.007
		1100	0.01
		1200	0.01
		1300	0.007
		1400	0.006
		1500	0.005
		1600	0.005
		1700	0.005
		1800	0.005
		1900	0.005
		2000	0.01
		2100	0.02
		2200	0.01
		2300	0.01
		2400	0.01
15	06	0100	0.01
		0200	0.02
		0300	0.02
		0400	0.02
		0500	0.01
		0600	0.01
		0700	0.01
		0800	0.01
		0900	0.01
		1000	0.03
15	06	1100	0.01
		1200	0.01
		1300	0.01
		1400	0.01
		1500	0.01
		1600	0.01
		1700	0.01
		1800	0.02
		1900	0.02
		2000	0.02
		2100	0.02
		2200	0.02
		2300	0.02
		2400	0.02
16	06	0100	0.02
		0200	0.02
		0300	0.02
		0400	0.02
		0500	0.02
		0600	0.02
		0700	0.02
		0800	0.02
		0900	0.02
		1000	0.02
		1100	0.02
		1200	0.02
		1300	0.02
		1400	0.02
		1500	0.02
		1600	0.02
		1700	0.02
		1800	0.02
		1900	0.02
		2000	0.02
		2100	0.02
		2200	0.02
		2300	0.02
		2400	0.02
17	06	0100	0.01
		0200	0.01

STREAM GAUGE RECORDINGS
(continued)

LOCATION: SITE MTE

DAY	DATE	HOUR	DISCHARGE m^3/sec.	DAY	DATE	HOUR	DISCHARGE m^3/sec.
17	06	0300	0.01	18	06	1900	0.03
		0400	0.01			2000	0.03
		0500	0.01			2100	0.03
		0600	0.01			2200	0.03
		0700	0.01			2300	0.03
		0800	0.01			2400	0.03
		0900	0.08	19	06	0100	0.02
		1000	0.08			0200	0.02
		1100	0.08			0300	0.02
		1200	0.07			0400	0.02
		1300	0.01			0500	0.02
		1400	0.02			0600	0.02
		1500	0.02			0700	0.02
		1600	0.03			0800	0.02
		1700	0.03			0900	0.02
		1800	0.03			1000	0.02
		1900	0.03			1100	0.03
		2000	0.03			1200	0.03
		2100	0.03			1300	0.03
		2200	0.02			1400	0.03
		2300	0.02			1500	0.03
		2400	0.02			1600	0.03
18	06	0100	0.02			1700	0.03
		0200	0.02			1800	0.03
		0300	0.02			1900	0.03
		0400	0.02			2000	0.04
		0500	0.01			2100	0.05
		0600	0.01			2200	0.03
		0700	0.01			2300	0.03
		0800	0.01			2400	0.03
		0900	0.02	20	06	0100	0.03
		1000	0.02			0200	0.03
		1100	0.01			0300	0.03
		1200	0.01			0400	0.04
		1300	0.02			0500	0.05
		1400	0.02			0600	0.06
		1500	0.02			0700	0.03
		1600	0.03			0800	0.03
		1700	0.03			0900	0.03
		1800	0.03			1000	0.03

STREAM GAUGE RECORDINGS
(continued)

LOCATION: SITE MTE

DAY	DATE	HOUR	DISCHARGE $m^3/sec.$	DAY	DATE	HOUR	DISCHARGE $m^3/sec.$
20	06	1100	0.03	22	06	0300	0.06
		1200	0.02			0400	0.06
		1300	0.02			0500	0.06
		1400	0.02			0600	0.08
		1500	0.03			0700	0.08
		1600	0.07			0800	0.07
		1700	0.08			0900	0.04
		1800	0.09			1000	0.04
		1900	0.09			1100	0.04
		2000	0.09			1200	0.04
		2100	0.06			1300	0.07
		2200	0.05			1400	0.07
		2300	0.03			1500	0.07
		2400	0.02			1600	0.09
21	06	0100	0.04			1700	0.09
		0200	0.04			1800	0.09
		0300	0.04			1900	0.09
		0400	0.04			2000	0.09
		0500	0.05			2100	0.10
		0600	0.05			2200	0.09
		0700	0.04			2300	0.09
		0800	0.03			2400	0.08
		0900	0.03	23	06	0100	0.14
		1000	0.03			0200	0.18
		1100	0.03			0300	0.18
		1200	0.02			0400	0.18
		1300	0.02			0500	0.18
		1400	0.02			0600	0.24
		1500	0.03			0700	0.08
		1600	0.07			0800	0.08
		1700	0.08			0900	0.08
		1800	0.09			1000	0.08
		1900	0.09			1100	0.08
		2000	0.09			1200	0.31
		2100	0.09			1300	0.31
		2200	0.08			1400	0.33
		2300	0.04			1500	0.33
		2400	0.02			1600	0.33
22	06	0100	0.06			1700	0.33
		0200	0.06			1800	0.33

STREAM GAUGE RECORDINGS
(continued)

LOCATION: SITE MTE

DAY	DATE	HOUR	DISCHARGE m^3/sec.	DAY	DATE	HOUR	DISCHARGE m^3/sec.
23	06	1900	0.33	25	06	1100	0.12
		2000	0.33			1200	0.12
		2100	0.33			1300	0.24
		2200	0.33			1400	0.31
		2300	0.33			1500	0.35
		2400	0.31			1600	0.35
24	06	0100	0.28			1700	0.04
		0200	0.26			1800	0.12
		0300	0.24			1900	0.24
		0400	0.19			2000	0.24
		0500	0.19			2100	0.31
		0600	0.18			2200	0.28
		0700	0.18			2300	0.28
		0800	0.17			2400	0.28
		0900	0.17	26	06	0100	0.24
		1000	0.17			0200	0.24
		1100	0.17			0300	0.19
		1200	0.12			0400	0.19
		1300	0.19			0500	0.17
		1400	0.24			0600	0.09
		1500	0.33			0700	0.04
		1600	0.38			0800	0.04
		1700	0.38			0900	0.04
		1800	0.42			1000	0.04
		1900	0.42			1100	0.04
		2000	0.42			1200	0.04
		2100	0.38			1300	0.04
		2200	0.33			1400	0.04
		2300	0.28			1500	0.26
		2400	0.26			1600	0.71
25	06	0100	0.24			1700	0.71
		0200	0.21			1800	0.71
		0300	0.21			1900	0.71
		0400	0.21			2000	0.71
		0500	0.19			2100	0.59
		0600	0.19			2200	0.48
		0700	0.19			2300	0.48
		0800	0.14			2400	0.48
		0900	0.12	27	06	0100	0.68
		1000	0.12			0200	0.68

STREAM GAUGE RECORDINGS
(continued)

LOCATION: SITE MTE

DAY	DATE	HOUR	DISCHARGE $m^3/sec.$	DAY	DATE	HOUR	DISCHARGE $m^3/sec.$
27	06	0300	0.56	28	06	1900	1.13
		0400	0.71			2000	1.13
		0500	0.76			2100	1.13
		0600	0.76			2200	1.08
		0700	0.48			2300	1.08
		0800	0.48			2400	1.03
		0900	0.48	29	06	0100	1.00
		1000	0.48			0200	0.93
		1100	0.48			0300	0.93
		1200	0.48			0400	0.93
		1300	0.88			0500	0.93
		1400	0.89			0600	0.93
		1500	0.96			0700	0.93
		1600	1.26			0800	0.93
		1700	1.32			0900	0.93
		1800	1.32			1000	0.59
		1900	1.32			1100	0.21
		2000	1.32			1200	0.21
		2100	1.38			1300	0.26
		2200	1.34			1400	0.30
		2300	1.32			1500	0.40
		2400	1.32			1600	0.55
28	06	0100	0.96			1700	0.59
		0200	0.76			1800	0.64
		0300	0.76			1900	0.74
		0400	0.68			2000	0.77
		0500	0.68			2100	0.77
		0600	0.68			2200	0.74
		0700	0.68			2300	0.74
		0800	0.21			2400	0.69
		0900	0.21	30	06	0100	0.64
		1000	0.21			0200	0.64
		1100	0.21			0300	0.59
		1200	0.88			0400	0.55
		1300	0.93			0500	0.53
		1400	1.03			0600	0.50
		1500	1.08			0700	0.48
		1600	1.08			0800	0.45
		1700	1.13			0900	0.45
		1800	1.13			1000	0.43

STREAM GAUGE RECORDINGS
(continued)

LOCATION: SITE MTE

DAY	DATE	HOUR	DISCHARGE $m^3/sec.$		DAY	DATE	HOUR	DISCHARGE $m^3/sec.$
30	06	1100	0.40					
		1200	0.40					
		1300	0.50					
		1400	0.30					
		1500	0.24					
		1600	0.18					
		1700	0.18					
		1800	0.18					
		1900	0.33					
		2000	0.33					
		2100	0.33					
		2200	0.33					
		2300	0.31					
		2400	0.31					

SUMMARY OF DAILY STREAM GAUGE RECORDINGS

GRIZZLY CREEK GLACIER

JUNE (JULY) 1979

YUKON STANDARD TIME (YST)

LOCATION: SITE A

SITE A2

SITE MTE

GRIZZLY CREEK GLACIER 1979 MONTH: JUNE

STREAM DISCHARGE CALCULATIONS SITE A

Day	Date	Discharge in $m^3 \times 10^3$ 0006-0600	0600-1200	1200-1800	1800-2400	Daily Total in m^3
08	06			1.624	10.944	12564.00
09	06	7.236	5.904	6.588	7.992	27720.00
10	06	7.344	6.696	8.820	9.720	32580.00
11	06	7.596	6.660	8.676	10.368	33300.00
12	06	10.368	9.972	5.832	5.832	32004.00
13	06	5.832	5.076	4.320	4.320	19548.00
14	06	4.320	4.320	4.320	4.320	17280.00
15	06	4.320	4.320	7.776	13.608	30024.00
16	06	12.384	10.044	9.684	11.340	43452.00
17	06	9.396	8.064	8.064	9.504	35028.00
18	06	9.612	9.288	11.772	12.744	43416.00
19	06	12.420	11.772	11.412	16.416	52020.00
20	06	13.716	12.312	12.852	13.824	52704.00
21	06	12.528	12.888	15.444	19.476	60336.00
22	06	21.168	20.520	20.448	22.572	84708.00
23	06	43.884	43.632	47.412	49.680	184608.00
24	06	35.892	29.376	45.972	54.540	165780.00
25	06	39.024	31.032	47.232	52.200	169488.00
26	06	53.028	38.304	45.936	48.420	185688.00
27	06	36.288	29.433	40.284	40.752	146757.60
28	06	26.784	22.104	27.504	23.076	99368.00
29	06	12.744	9.360	9.828	6.876	38808.00
30	06	1.080	0.756	8.280	16.776	26892.00

MONTH: JULY

01	07	24.264	18.972	37.944	48.600	129780.00
02	07	37.368	35.856	58.752	66.312	198288.00
03	07	81.396	90.504	89.496	86.472	347868.00
04	07	83.952	81.936	90.504	93.528	349920.00
05	07	86.976	85.968	104.616	109.152	386712.00
06	07	90.504	79.416	78.408	76.356	323676.00
07	07	64.296	60.768	68.184	69.720	262368.00
08	07	64.224	58.752	74.376	67.778	265140.00
09	07	55.728	53.208	64.800	65.304	239040.00
10	07	54.720	57.744	82.944	84.456	279864.00
11	07	71.856	68.796	77.904	80.928	299484.00
12	07	74.376	76.392	88.992	90.504	330264.00
13	07	81.936	105.660	118.800	109.656	416052.00
14	07	93.528	84.456	85.464	84.456	347902.00
15	07	69.840	48.204			118044.00

GRIZZLY CREEK GLACIER 1979 MONTH: JUNE

STREAM DISCHARGE CALCULATIONS SITE A2

Day	Date	Discharge in $m^3 \times 10^3$ 0006-0600	0600-1200	1200-1800	1800-2400	Daily Total in m^3
10	06		1.296	3.348	2.448	7092.00
11	06	0.309	0.064	0.190	0.432	996.40
12	06	0.309	0.064	0.190	0.432	996.40
13	06	3.166	1.052	2.105	5.395	11728.00
14	06	2.799	1.932	1.866	4.771	10368.00
15	06	2.110	0.900	6.840	8.064	18014.00
16	06	6.696	5.436	5.832	7.740	25704.00
17	06	5.796	4.413	4.833	5.974	21016.00
18	06	6.772	5.470	5.991	7.816	26049.00
19	06	8.115	6.554	7.178	9.365	31212.00
20	06	8.221	5.184	5.184	13.033	31622.00
21	06	7.964	7.240	9.050	11.947	36201.60
22	06	11.181	10.164	12.706	16.773	50824.00
23	06	39.722	41.884	45.288	44.820	171714.00
24	06	36.288	33.336	56.052	62.640	188316.00
25	06	47.268	45.144	59.472	65.340	217224.00
26	06	55.044	50.076	53.172	59.688	217980.00
27	06	38.200	33.966	48.292	51.565	172023.00
28	06	27.900	33.766	44.928	42.624	149218.00
29	06	35.208	31.248	34.396	30.777	131629.00
30	06	7.930	6.820	10.080	10.368	35198.00

MONTH: JULY

01	07	7.560	6.948	9.036	10.044	33588.00
02	07	8.784	8.208	16.452	18.144	51588.00
03	07	10.222	9.868	19.377	19.670	59137.00
04	07	10.640	10.130	19.400	19.316	59486.00
05	07	10.860	10.270	23.269	21.342	65741.00
06	07	11.664	11.232	18.072	14.616	55584.00
07	07	13.212	12.744	11.520	10.008	47484.00
08	07	9.720	9.828	9.108	9.072	37728.00
09	07	9.504	11.772	10.152	10.152	41580.00
10	07	10.116	13.284	11.818	11.418	46636.00
11	07	10.399	14.440	11.600	11.137	47576.00
12	07	13.659	18.343	13.477	13.464	56144.00
13	07	17.400	23.601	16.839	12.888	70728.00
14	07	13.140	13.536	14.220	14.256	55152.00
15	07	13.284	13.032			

GRIZZLY CREEK GLACIER 1979 MONTH: JUNE

STREAM DISCHARGE CALCULATIONS SITE MTE

Day	Date	Discharge in $m^3 \times 10^3$ 0006-0600	0600-1200	1200-1800	1800-2400	Daily Total in m^3
10	06			0.468	0.648	1116.00
11	06	0.648	0.612	0.540	0.720	2520.00
12	06	0.648	0.612	0.540	0.720	2520.00
13	06	0.140	0.210	0.146	0.324	820.00
14	06	0.120	0.180	0.112	0.229	725.00
15	06	0.304	0.272	0.252	0.432	1260.00
16	06	0.432	0.432	0.432	0.432	1728.00
17	06	0.216	0.192	0.483	0.521	1412.00
18	06	0.326	0.282	0.566	0.649	1823.00
19	06	0.430	0.356	0.640	0.758	2184.00
20	06	0.856	0.592	1.112	1.234	3794.00
21	06	0.933	0.649	1.276	1.486	4344.00
22	06	1.343	1.096	1.713	1.946	6098.00
23	06	3.946	2.619	6.984	7.056	20605.00
24	06	4.824	3.528	6.984	7.524	22860.00
25	06	4.500	2.916	5.076	5.868	18360.00
26	06	4.032	0.864	8.976	12.285	26157.00
27	06	14.869	10.393	25.102	28.766	79130.00
28	06	16.304	5.652	22.968	23.688	68612.00
29	06	20.340	13.680	9.864	16.020	59904.00
30	06	12.420	9.396	5.202	7.110	34128.00

APPENDIX "C"

HYDROCHEMICAL ANALYSIS

AND

SUSPENDED SEDIMENT ANALYSIS

GRIZZLY CREEK GALCIER, 1979

HYDROCHEMICAL ANALYSIS

GRIZZLY CREEK GLACIER, 1979 YUKON TERRITORY

Sample	Date/Time YST	Electrical Conductivity Filtered ±0.5%	Electrical Conductivity Unfiltered ±0.5%	pH Fil. ±0.05	pH Unfil. ±0.05	Chemical Concentrations (ppm) Phosphate ±0.05	Ca^{++} ±2.0	Mg^{++} ±2.0	Silica ±0.03	Cl^- ±5.0
SUB	08-06-1400		40		8.4	0.30	NT	NT	0.20	45
SLB	08-06-1400		20		8.0	0.25	NT	NT	0.30	55
AVA	08-06-1200		20		8.4	0.30	NT	NT	0.25	65
SNG	08-06-1100		40		8.4	0.20	NT	NT	0.20	35
ICE	08-06-1300		52		8.3	0.20	NT	NT	0.40	45
IFS	08-06-1500		100		7.0	0.53	10	15	1.03	45
IFI	08-06-1500		120		7.0	0.70	15	20	1.20	35
A	09-06-1100	70	70	7.0	7.1	0.20	45	40	0.60	45
A1	09-06-1200	60	75	6.8	6.9	0.35	40	10	0.40	50
A1	09-06-1300	60	60	6.6	7.5	0.45	20	5	0.70	25
A1	09-06-1400	60	60	7.5	7.5	0.20	15	5	0.53	50
A1	09-06-1500	60	60	7.3	7.7	0.20	20	5	0.40	40
A1	09-06-1600	60	60	6.7	8.2	NT	15	5	0.27	35
A1	10-06-1000	80	80	5.1	5.4	0.53	25	20	0.30	40
A2	10-06-1100	180	180	5.9	6.0	0.25	55	40	1.23	35
MTE	10-06-1200	130	140	5.8	5.9	0.35	50	15	1.23	30
A2	10-06-1300	170	180	6.1	6.5	0.20	55	50	1.80	40
A2	10-06-1400	180	180	5.8	6.0	0.20	55	40	1.80	35
A	11-06-1000	80	80	7.0	7.1		50	35		55
A1	11-06-1000	60	70	5.9	6.0	0.15	15	20	0.70	50
A2	11-06-1000	185	190	6.1	6.2	0.25	50	50	2.10	35
A3	11-06-1000	55	60	5.9	6.1	0.30	25	10	0.33	40
A1	11-06-1200	60	60	6.0	6.3	0.35	20	20	0.30	40
A2	11-06-1200	190	195	6.2	6.3	0.25	35	50	2.25	30
A3	11-06-1200	55	60	6.0	6.2	0.30	20	15	0.40	35
A3A	11-06-1200		30	5.9	6.1		30	15		40
A3U	11-06-1200		30	5.8	6.1		35	15		40

HYDROCHEMICAL ANALYSIS (continued)

GRIZZLY CREEK GLACIER, 1979 YUKON TERRITORY

Sample	Date/Time YST	Electrical Conductivity Filtered ±0.5%	Electrical Conductivity Unfiltered ±0.5%	pH Fil. ±0.05	pH Unfil. ±0.05	Chemical Concentrations (ppm) Phosphate ±0.05	Ca^{++} ±2.0	Mg^{++} ±2.0	Silica ±0.03	Cl^- ±5.0
TA1	11-06-1200	75	80	6.8	7.0		60	45		40
TA1E	11-06-1200	26	30	7.8	8.0		30	20		30
TA2	11-06-1200	135	140	5.8	5.9		40	15		30
MTE	11-06-1200	130	140	5.8	5.9		50	15		30
A1	11-06-1400	160	200	6.0	6.1	0.25	10	5	0.50	30
A2	11-06-1400	190	195	6.0	6.1	0.15	45	45	2.00	35
A3	11-06-1400	55	55	6.0	6.1	0.20	15	10	0.23	40
A2	11-06-1600	180	190	6.5	6.6	0.20	40	35	1.95	35
A3	11-06-1600	50	50	6.0	6.5	0.20	15	NT	0.23	35
A2	12-06-2000	205	205	7.4	7.5	0.05	65	30	1.40	50
A2	13-06-1100	190	220	6.9	6.9	0.05	75	15	1.23	35
A1	13-06-1200	110	110	7.1	7.2	0.10	30	30	0.57	60
MTE	13-06-1400	160	160	7.3	7.3	0.05	45	35	0.80	35
A2	13-06-1500	220	220	7.1	7.2	0.05	75	30	1.80	50
A1U	15-06-1200		20		7.0		NT	NT		45
TA1U	15-06-1200		100		7.8		NT	NT		35
A2	15-06-1330	240	255	7.8	7.8	0.05	75	40	2.00	35
MTE	15-06-1400	160	190	7.4	7.4	0.05	35	35	1.10	30
A1	15-06-1500	160	200	7.9	7.9	0.05	30	50	0.88	40
TA1	15-06-1500	170	180	7.8	8.0	0.10	45	60	0.80	40
A	16-06-1200	120	120	7.0	7.1		50	40		50
A1	16-06-1200	80	80	7.0	7.7	0.05	25	45	0.30	40
A2	16-06-1200	205	210	7.4	7.5	0.05	45	45	1.30	30
A3	16-06-1200	40	50	7.1	7.3	0.05	20	10	0.13	30
A3A	16-06-1200	30	30	7.0	7.2		NT	NT		30
A3U	16-06-1200		30		7.2	NT	NT	NT	0.13	35

HYDROCHEMICAL ANALYSIS
(continued)

GRIZZLY CREEK GLACIER, 1979 YUKON TERRITORY

Sample	Date/Time YST	Electrical Conductivity Filtered ±0.5%	Electrical Conductivity Unfiltered ±0.5%	pH Fil. ±0.05	pH Unfil. ±0.05	Chemical Concentrations (ppm)				
						Phosphate ±0.05	Ca^{++} ±2.0	Mg^{++} ±2.0	Silica ±0.03	Cl^{-} ±5.0
TA1	16-06-1200	100	100	7.0	7.2	NT	30	30	0.33	45
TA1E	16-06-1200	26	30	7.2	7.4		NT	NT		60
TA2	16-06-1200	160	160	7.0	7.2		20	30		35
MTE	16-06-1200	135	135	7.3	7.3	NT	25	40	0.70	35
A	16-06-1500	135	135	6.9	7.0		50	45		50
A1	16-06-1500	60	60	7.3	7.6	0.05	20	25	0.23	35
A2	16-06-1500	210	215	7.5	7.7	NT	50	55	1.15	30
A3	16-06-1500	45	50	7.1	7.2	NT	10	15	0.17	45
A3A	16-06-1500	60	60	7.2	7.4		10	20		35
A3U	16-06-1500	60	60	7.1	7.2	NT	10	20	0.20	40
TA1	16-06-1500	90	105	7.2	7.5	NT	20	40	0.30	40
TA1E	16-06-1500	15	20	7.6	7.8		NT	NT		40
TA2	16-06-1500	150	150	7.0	7.2		20	40		40
MTE	16-06-1500	125	130	7.3	7.3		25	40		40
A1U	16-06-1500		20		6.9	0.05	NT	NT	0.13	40
TA1U	16-06-1500		100		7.8		NT	NT		35
A1	18-06-1100	100	100	7.0	7.2	0.10	15	30	0.37	50
A2	18-06-1100	200	200	7.0	7.1	0.25	50	45	1.55	50
A3	18-06-1100	65	65	6.9	7.0	0.10	10	15	0.27	55
PRE	18-06-1600		6		7.1	NT	NT	NT	NT	55
A2	19-06-1200	180	180	6.8	7.1	NT	55	25	1.30	50
SA2	19-06-1200		20		7.7	NT	NT	NT	NT	50
A3	19-06-1400	45	45	7.0	7.4	NT	5	20	NT	50
MTE	19-06-1400	75	75	7.0	7.5	0.15	20	40	0.80	50
TA1	19-06-1400	120	120	7.0	7.1	NT	45	30	NT	50
A	20-06-1500	200	175	7.0	7.1	0.35	45	40		45

HYDROCHEMICAL ANALYSIS
(continued)

GRIZZLY CREEK GLACIER, 1979 YUKON TERRITORY

Sample	Date/Time YST	Electrical Conductivity Filtered ±0.5%	Electrical Conductivity Unfiltered ±0.5%	pH Fil. ±0.05	pH Unfil. ±0.05	Chemical Concentrations (ppm) Phosphate ±0.05	Ca^{++} ±2.0	Mg^{++} ±2.0	Silica ±0.03	Cl^- ±5.0
A1	20-06-1500	100	100	7.1	7.5	0.35	10	20	NT	30
A2	20-06-1500	205	215	7.0	7.2	0.45	35	40	1.70	35
A3	20-06-1500	20	15	7.0	7.2	0.80	8	7	NT	35
TA1	20-06-1500	75	75	7.0	7.2		15	20		30
TA1U	20-06-1500		100		8.0	0.10	NT	NT	NT	30
TA1E	20-06-1500	80	80	7.0	7.2	NT	NT	NT	0.15	65
TA2	20-06-1500	200	200	7.1	7.1	0.35	45	35	1.55	40
MTE	20-06-1500	125	125	7.2	7.2	0.15	30	25	0.77	30
SA2	20-06-1500		30		7.3	0.10	NT	NT	0.06	40
IFWA	20-06-1300		74		7.0	0.30	10	15	1.07	25
IFWB	20-06-1400		74		7.0	0.20	20	5	0.88	25
IFWS	20-06-1500		100		7.0	0.53	15	20	1.20	25
A1	21-06-1600	60	60	6.8	7.0	1.42	10	20	NT	55
A2	21-06-1600	140	140	7.0	7.0	2.20	50	25	1.03	35
A3	21-06-1600	40	40	6.9	7.1	0.70	NT	20		35
A1	22-06-1000	60	60	6.9	7.0		5	25		50
A2	22-06-1000	140	140	7.0	7.1	0.15	50	15	0.88	35
A3	22-06-1000	30	30	7.0	7.0		NT	25		30
TA1	22-06-1000	65	70	6.9	7.0		20	15		35
TA1E	22-06-1000		20		7.1		NT	NT		35
PRE	22-06-1200		100		7.0	NT	NT	NT	NT	60
A	25-06-1500	88	88	7.1	7.3		45	40		40
A1	25-06-1500	80	70	7.0	7.3		NT	25		40
A2	25-06-1500	120	130	7.0	6.9		25	25		40
A3	25-06-1500	50	50	6.5	6.8		NT	NT		35
A3U	25-06-1500		20		7.1		NT	NT		45

HYDROCHEMICAL ANALYSIS
(continued)

GRIZZLY CREEK GLACIER, 1979 YUKON TERRITORY

Sample	Date/Time YST	Electrical Conductivity Filtered ±0.5%	Electrical Conductivity Unfiltered ±0.5%	pH Fil. ±0.05	pH Unfil. ±0.05	Chemical Concentrations (ppm)				
						Phosphate ±0.05	Ca^{++} ±2.0	Mg^{++} ±2.0	Silica ±0.03	Cl^- ±5.0
A3A	25-06-1500		20		7.1		NT	NT		45
TA1	25-06-1500	100	100	6.8	6.8		20	50		35
TA1E	25-06-1500	40	40	6.5	6.8		NT	NT		45
TA2	25-06-1500	95	80	6.4	6.4		10	15		35
MTE	25-06-1500	100	100	6.2	6.2		25	25		30
SA2	25-06-1500		6		7.0	NT	NT	NT	NT	40
A1U	25-06-1500		20		7.1		NT	NT		40
A	25-06-1700	75	75	7.0	7.1		45	40		35
A1	25-06-1700	70	60	6.4	6.5		NT	20		30
A2	25-06-1700	115	110	6.4	6.5		20	30		30
A3	25-06-1700	45	40	6.5	6.5		NT	NT		25
A3U	25-06-1700		25		7.1		NT	NT		50
A3A	25-06-1700		25		7.1		NT	NT		45
TA1	25-06-1700	85	80	6.5	6.5		NT	30		25
TA1E	25-06-1700	35	30	6.5	6.5		NT	NT		30
TA2	25-06-1700	90	90	6.4	6.4		10	15		40
MTE	25-06-1700	100	100	6.2	6.2		30	30		35
A	30-06-1200	160	160	7.5	7.5		40	25		30
A1	30-06-1300	52	52	8.0	8.0		10	15		35
A2	30-06-1300	160	160	8.0	8.0		50	25		35
A3	30-06-1300	110	120	7.8	7.8		35	25		35
A3A	30-06-1300	39	37	7.5	7.7		NT	20		35
TA1	30-06-1300	77	64	7.8	8.3		20	20		35
TA1E	30-06-1300	36	31	8.4	8.7		NT	NT		35
A	02-07-1100	110	120	7.1	7.2	0.10	25	35		40
A1	02-07-1100	62	45	7.6	7.9		NT	25		55

HYDROCHEMICAL ANALYSIS
(continued)

GRIZZLY CREEK GLACIER, 1979   YUKON TERRITORY

Sample	Date/Time YST	Electrical Conductivity Filtered ±0.5%	Electrical Conductivity Unfiltered ±0.5%	pH Fil. ±0.05	pH Unfil. ±0.05	Chemical Concentrations (ppm) Phosphate ±0.05	Ca^{++} ±2.0	Mg^{++} ±2.0	Silica ±0.03	Cl^{-} ±5.0
A2	02-07-1200	40	25	7.1	7.2	0.14	20	35		40
A3	02-07-1200	110	100	7.2	7.4		35	30		55
TA1	02-07-1200	82	62	7.5	8.0		10	15		60
TA1E	02-07-1200	125	120	7.2	7.2		NT	NT		50
A	04-07-1400	84	82	8.4	8.4		20	20	0.06	50
A1	04-07-1400	44	44	8.9	9.1		5	15		65
A2	04-07-1400	84	80	8.3	8.6		15	15	0.70	40
A3	04-07-1400	78	76	8.4	8.4		20	30		35
A	05-07-1100	100	100	8.1	8.4		20	30		75
A1	05-07-1100	44	36	8.9	9.1		NT	20		85
A2	05-07-1100	88	88	83	8.5		25	30		40
A3	05-07-1100	82	80	8.3	8.6		15	20		50
A	08-07-1000	135	135	8.0	8.0		30	25		50
A1	08-07-1000	47	47	8.2	8.4		NT	15		25
A2	08-07-1000	120	120	8.0	8.0		20	50	1.10	25
A3	08-07-1000	120	120	8.1	8.1		20	30		30
A3U	08-07-1000		25		7.6		NT	NT		35
A3A	08-07-1000	30	29	7.7	7.8		NT	25		50
TA1E	08-07-1000	26	25	8.3	8.6		NT	NT		30
TA1	08-07-1000	64	64	8.4	8.5		5	40		35
TA2	08-07-1000	115	96	7.8	7.9		35	10	0.83	50
MTE	08-07-1000	120	120	7.7	7.8		40	20		30
SA2	08-07-1000	20	30	[illegible]	8.0		NT	NT		25
A	08-07-1300	100	100	7.2	7.7		20	25		55
A1	08-07-1300	60	60	8.6	8.6		NT	25		55
A2	08-07-1300	120	120	8.0	8.0		30	30		30

HYDROCHEMICAL ANALYSIS
(continued)

GRIZZLY CREEK GLACIER, 1979 YUKON TERRITORY

Sample	Date/Time YST	Electrical Conductivity Filtered ±0.5%	Electrical Conductivity Unfiltered ±0.5%	pH Fil. ±0.05	pH Unfil. ±0.05	Chemical Concentrations (ppm)				
						Phosphate ±0.05	Ca^{++} ±2.0	Mg^{++} ±2.0	Silica ±0.03	Cl^- ±5.0
A3	08-07-1300	29	29	8.0	8.0		25	25		35
A3U	08-07-1300		45		8.1		NT	NT		50
A3A	08-07-1300	45	45	8.1	8.2		NT	NT		50
TA1E	08-07-1300	25	24	8.2	8.4		NT	25		30
TA1	08-07-1300	80	84	8.5	8.5		1	4		35
TA2	08-07-1300	105	105	7.6	7.7		30	10		20
MTE	08-07-1300	110	110	7.5	7.6		30	20		30
A	08-07-1600	86	80	7.8	7.8		25	25		55
A1	08-07-1600	40	40	8.2	8.3		5	30		35
A2	08-07-1600	88	88	7.9	8.0		30	30	0.70	30
A3	08-07-1600	72	72	7.6	8.0		25	30		40
A3U	08-07-1600		20		7.5		NT	NT		50
A3A	08-07-1600	28	28	7.6	7.9		NT	NT		35
TA1E	08-07-1600	16	17	7.7	7.7		NT	NT		40
TA1	08-07-1600	49	50	8.3	8.4		5	20		45
TA2	08-07-1600	68	70	7.4	7.4		25	10	0.50	20
MTE	08-07-1600	68	68	7.2	7.4		25	25	0.57	30
PRE	13-07-1000		6		7.0	NT	NT	NT		55

NT: No trace

SUSPENDED SEDIMENT ANALYSIS

GRIZZLY CREEK GLACIER, 1979

YUKON TERRITORY

SUSPENDED SEDIMENT ANALYSIS

Sample	Date/Time YST	CATIONS (ppm.) Na^{+} ±0.05	K^{+} ±0.05	Ca^{++} ±0.05	Mg^{++} ±0.05	Suspended Sediment Concentration (gms./0.51.) ±0.005
A1	11-06-1000	4.71	2.39	10.28	0.34	1.902
A1	11-06-1200	5.53	2.79	15.03	0.86	2.251
A1	11-06-1400	2.80	1.11	8.87	0.37	2.124
A2	11-06-1000	3.58	1.43	9.43	0.55	2.022
A2	11-06-1200	3.81	1.35	7.66	0.64	1.916
A2	11-06-1400	4.02	1.74	10.07	0.43	1.973
A2	11-06-1600	2.69	1.09	9.24	0.44	1.055
A3	11-06-1000	3.05	1.30	4.84	0.15	1.904
A3	11-06-1200	4.04	1.36	8.51	0.39	1.980
A3	11-06-1400	4.18	1.35	8.80	0.62	2.034
A3	11-06-1600	3.02	1.03	7.71	0.36	1.997
A1	16-06-1200	5.68	3.59	20.13	2.65	1.107
A1	16-06-1600	19.11	12.14	58.03	9.29	2.178
TA1	16-06-1200	5.78	3.04	25.57	3.52	1.978
TA1	16-06-1600	4.99	4.01	121.44	18.61	2.181
A2	16-06-1100	7.07	3.16	33.73	4.01	1.076
A2	16-06-1500	5.53	2.55	27.66	3.08	1.912
A3	16-06-1200	5.78	2.35	17.68	2.08	1.009
A3	16-06-1500	6.52	5.22	60.04	11.82	2.350
A	20-06-1600	4.72	1.57	7.34	0.51	2.074
A1	20-06-1500	4.51	2.03	11.39	0.36	2.058
TA1	20-06-1500	5.10	2.34	14.79	0.43	2.103
A2	20-06-1500	2.91	1.04	6.25	0.32	1.956
A2	20-06-1600	1.51	0.82	6.93	0.06	2.053
A3	20-06-1500	3.76	1.44	6.59	0.25	2.006
A1	25-06-1500	2.74	1.35	23.97	0.57	1.883
A1	25-06-1700	4.18	1.77	14.79	0.20	2.215
TA1	25-06-1500	3.29	1.63	26.19	0.79	2.103
TA1	25-06-1700	1.99	1.45	13.91	0.53	1.991
A2	25-06-1600	6.58	3.67	80.00	3.12	2.642
A2	25-06-1700	2.43	1.61	26.68	0.82	2.286
A3	25-06-1500	2.58	0.98	7.83	0.15	1.721
A3	25-06-1700	2.04	0.88	5.97	0.22	1.917
A	30-06-1200	2.55	1.26	13.13	0.56	1.661
A1	30-06-1300	2.65	3.15	63.22	2.10	2.796
TA1	30-06-1300	5.20	1.26	9.67	0.11	1.703
A2	30-06-1000	4.33	1.58	13.44	0.44	1.714
A2	30-06-1200	5.69	1.84	17.89	0.67	1.819
A2	30-06-1300	5.58	1.61	17.41	1.00	1.782
A3	30-06-1200	3.45	1.45	13.25	0.28	1.765
A3	30-06-1400	4.23	2.31	30.65	1.31	2.173

SUSPENDED SEDIMENT ANALYSIS
(continued)

Sample	Date/Time YST	CATIONS (ppm.) Na^{+} ±0.05	K^{+} ±0.05	Ca^{++} ±0.05	Mg^{++} ±0.05	Suspended Sediment Concentration (gms./0.5l.) ±0.005
A	02-07-1200	3.56	1.53	19.62	0.64	1.945
A1	02-07-1100	2.75	1.21	11.40	1.04	2.011
TA1	02-07-1100	3.05	1.80	32.49	1.04	2.095
A2	02-07-1200	2.90	1.05	9.17	0.02	1.803
A3	02-07-1200	4.10	0.99	4.10	1.07	1.684
A	04-07-1400	3.17	2.42	37.76	2.79	2.757
A1	04-07-1400	7.01	1.58	30.18	2.74	2.376
A2	04-07-1400	2.75	1.21	11.40	1.04	2.201
A	05-07-1100	2.16	1.38	16.78	1.53	1.993
A2	05-07-1100	1.53	1.29	20.27	1.16	2.102
A3	05-07-1100	4.42	1.79	22.99	1.92	2.099

BIBLIOGRAPHY

Anonymous (1967). Hydrology of the Lewis Glacier, North-Central Baffin Island, N.W.T., and Discussion of Reliability of the Measurements. Geographical Bulletin, Vol. 9, No. 3, pp. 232-261, 1967.

Baranowski, S. (1977). Meteorology and Physical Climatology. Poland: Institute of Geography, University of Wroclaw, 91p.

Beard, L. (1962). Statistical Methods in Hydrology. Sacramento, California: U.S. Army Corps of Engineers, January, 1962, 61p.

Behrens, H., Bergmann, H., Moser, H., Ambach, W. and Jochum, O. (1975). On the Water Channels of the Internal Drainage system of the Hinterreisferner. Otztal Alps, Austria: Journal of Glaciology, Vol. 14, No. 72, 1975, pp. 375-382.

Behrens, H., Bergmann, H. Moser, H., Rauert, W., Stichler, W., Ambach, W., Eisner, H. and Pessl, K. (1971). Study of the Discharge of Alpine Glaciers by means of Environmental Isotopes and Dye Tracers. Zeitschrift fur Gletscherkunde und Glazialgeologie, Bd. VII, Heft 1-2, 1971, pp. 79-102.

Bigras, S. (1978). Glacier des Poilus. Carleton University Department of Geography, Honours Research Paper, 86p.

Campbell, W.J. and Rasmussen, L.A. (1969). The Production, Flow and Distribution of Melt Water in a Glacier Treated as a Porous Medium. International Association of Hydrological Sciences Publication No. 95, pp. 11-27

Chin, W.Q. and Yevjevich, V. (1974). Almost-Periodic, Stochastic Process of Long-Range Climatic Changes. Inland Water Directorate, Water Resources Branch, Scientific Series No. 39, 71p.

Church, M. (1974). On the Quality of Some Waters on Baffin Island, Northwest Territories. Canadian Journal of Earch Science, Vol. 11, (1974), pp. 1676-1688.

Church, M. and Kellerhals, R. (1970). Stream Gauging Techniques for Remote Areas using Portable Equipment. Energy Mines and Resources, Inland Waters Branch Technical Bulletin No. 25, 90p.

Collier, E.P. (1958). Glacier Variations and Trends in Runoff in the Canadian Cordillera. International Association of Scientific Hydrology, Publication No. 46, pp 344-357.

Collins, D.N. (1977a). Hydrology of an Alpine Glacier as Indicated by the Chemical Composition of Meltwater. Zeitschrift fur Gletscherkunde und Glazialgeologie, Bd. 13, H. 1/2 (1977), pp. 219-238.

Collins, D.N. (1977b). Hydrology of the Gorner Glacier as indicated by the chemical composition of meltwater, University of Manchester, Department of Geography, Gorner Glacier Project, Working Paper Series, 22p.

Collins, D.N. (1977c). Quantitative Determination of the Subglacial Hydrology of Alpine Glaciers. University of Manchester, Department of Geography, 4p. manuscript.

Collins, D.N. (1977d). Expedition to the Gorner Glacier. University of Manchester, Department of Geography, Final report 59p. manuscript.

Collins, D.N. (1978). Sediment and Solute Dynamics in Meltwaters as Indicators of Erosion Processes beneath an Alpine Glacier. University of Manchester, Department of Geography, 32p. manuscript.

Collins, D.N. and Young, G.J. (1978). Separation of Runoff Components in Glacierised Alpine Watersheds by Hydrochemical Analysis. 11p. manuscript.

Corbett, D.M. and Others. (1943). Stream-Gaging Procedure. A manual describing methods and practices of the Geological Survey, U.S. Geological Survey, Water Supply Paper 888, 245p.

Derikx, L. (1968). Glacier Discharge Simulation by Ground-Water Analogue. Inland Waters Branch, Glaciology Subdivision, 10p.

Derikx, A.L. and Loijens, H. (1971). Model of Runoff from Glaciers. Inland Waters Branch, Hydrology Symposium No. 8, Vol. 1 pp 153-199.

EK. C. (1966). Faible agressivité des eaux de fonte des glaciers: l'exemple de la Marmolada (dolomites). Ann . Soc. Géologique de Belgique: T. 89, No. 5-10, pp. 177-188.

Elliston, G.R. (1969). Water movement through the Gornergletscher International Association of Hydrological Sciences Publication No. 95, Cambridge, pp. 79-84

Faber, T. (1968). Some Results of the Hydrological Investigation of the Rusty Glacier Basin. Icefield Range Research Project, Vol. 3, Scientific results, published jointly by the American Geological Society and the Arctic Institute of North America , 12p.

Ferguson, H.L. and Pollock, D.M. (1971). Estimating Snowpack Accumulation for Runoff Prediction. Energy Mines and Resources, Inland Waters Branch, Hydrology Symposium No. 8, Vol. 1, pp. 7-27.

Gray, D.M. (Editeur en chef) 1972. Manuel des principes d'hydrologie. Conseil National de Recherches, Publication du Secrétariat, Comité National de la Décennie Hydrologique International, Ottawa, Canada, 573p.

Goluber, G.N. (1969). Analysis of the Runoff and Flow Routing for a Mountain Glacier Basin. International Association of Hydrological Sciences Publication No. 95, pp. 41-50.

Goodison, B. (1972). An Analysis of Climate and Runoff Events for Peyto Glacier, Alberta. Inland Waters Directorate, Water Resources Branch, Scientific Series No. 21, 29p.

Gudmundsson, G. (1970). Short Term Variations of a Glacier-Fed River. Tellus XXII, 3, pp. 341-353.

Hem, J.D. (1959). Study and Interpretation of the Chemical Characteristics of Natural Water. U.S. Geological Survey, Water Supply Paper 1473, 264p.

Hjelmfelt, Jr. A.T. and Cassidy, J.J. (1975). Hydrology for Engineers and Planners. Iowa State University Press, Ames, Iowa, 210p.

Hoinkes, H., Dreiseitl, E. and Wagner, H.P. (1974). Mass Balance of Hintereisferner and Kesselwandferner 1963/64 to 1972/73 in Relation to the Climatic Environment. Report to International Conference on the Results of the IHD, United Nations Educational, Scientific and Cultural Organization, Paris, pp. 42-51.

Jacobs, J.D., Andrews, J.T., Barry, R.G., Bradley, R.S., Weaver, R., Williams, L.D. (1972). Glaciological and Meteorological Studies on the Boas Glacier, Baffin Island, for two Contrasting Seasons (1969-70 and 1970-71). International Association of Hydrological Sciences Publication No.107, Vol. 1, pp. 371-382.

Johnson, P.G. (1975). Valley Climate: A Basic Presentation of Data 1974 and 1975. University of Ottawa, Department of Geography and Regional Planning. Environmental controls on geomorphic processes, Grizzly Creek, South-West Yukon Territory. Research Notes No. 9, pp. 1-27.

Johnson, P.G. (1975). Grizzly Creek Glacier Ice-Cored Moraine System. Ottawa: University of Ottawa, Department of Geography and Regional Planning, Environmental controls on geomorphic processes, Grizzly Creek, South-West Yukon Territory, Research Notes No.9 , pp. 59-79.

Keeler, C.M. (1964). Relationship between Climate, Ablation and Runoff on the Sverdrup Glacier, 1963, Devon Island, N.W.T. Arctic Institute of North America, Research Paper No. 27 , 37p.

Kendrew, W.G. and Kerr, D. (1955). The Climate of British Columbia and the Yukon Territory. Queen's Printer and Controller of Stationery, Ottawa, 222p.

Kennedy, V.C. (1965). Mineralogy and Cation-Exchange Capacity of Sediments from Selected Streams. U.S. Geological Survey Professional Paper 433-D, 22p.

Kotlyakov, V.M. (1972). Snow Accumulation on Mountain Glaciers. International Association of Hydrological Sciences Publication No. 107, Vol. 1, pp. 394-400.

Krimmel, R.M. and Tangborn, W.V. (1974). South Cascade Glacier: The Moderating Effect of Glaciers on Runoff. Colorado State University, Proceedings of the Western Snow Conference, Anchorage, Alaska, pp. 9-13.

Krimmel, R.M., Tangborn, W.V. and Meier, M.F. (1972). Water Flow Through a Temperate Glacier. International Association of Hydrological Sciences Publication No. 107, Vol. 1, pp. 401-416.

Lang, H. (1969). Variations in the Relation between Glacier Discharge and Meteorological Elements. International Association of Hydrological Sciences Publication No. 95 Cambridge, pp. 85-94.

LaMotte Chemical (1978) TRL 05 Operator's Manual. LaMotte Chemical Products Company, Chestertown, Maryland, 67p.

Lemmens, M. and Roger, M. (1978). Influence of Ion Exchange on Dissolved Load of Alpine Meltwaters. Earth Surface Processes, Vol. 3, pp. 179-187.

Loijens, H.S. (1974). Streamflow Formation in the Mistaya River Basin, Rocky Mountains, Canada. Colorado State University, Proceedings of the Western Snow Conference, Anchorage, Alaska, pp. 86-95.

Lorrain, R.D. and Souchez, R.A. (1972). Sorption as a Factor in the Transportation of Major Cations by Meltwaters from Alpine Glaciers. Quaternary Research, Vol. 2, pp. 253-256.

Male, D.H. and Norum, D.I. (1971). Movement of Water Through Snow and Ice. Energy, Mines and Resources, Inland Waters Branch, Hydrology Symposium No. 8, Vol. 1, pp. 83-107.

Marcus, M.G. (1974). Investigation in Alpine Climatology: The St. Elias Mountains 1963-1971. Montreal: Icefield Ranges Project, Scientific Results Vol. 4, pp. 13-28, Published by the American Geographical Society, New York

Mathews, W.H. (1963). Discharge of a Glacier Stream. International Association of Hydrological Sciences Publication No. 62, pp. 290-300.

Meier, M.F. (1969). Glaciers and Water Supply. Journal of the American Water Works Association, Vol. 61, No. 1, January 1969, pp. 8-12.

Meier, M.F. (1972). Hydrolics and Hydrology of Glaciers. International Association of Hydrological Sciences Publication No. 107, Vol. 1, pp. 353-370.

Morisawa, M. (1968). Streams, Their Dynamics and Morphology. McGraw-Hill Book Company, 175p.

Moser, H. and Ambach, W. (1975). Glacial-Hydrological Investigation in the Oetztal Alps made between 1968 and 1975. 20p. manuscript.

Nakamura, R. (1971). Runoff Analysis by Electrical Conductance of Water. Journal of Hydrology, Vol. 14, (1971), pp. 197-212.

Nye, J.F. (1976). Water Flow in Glaciers: Jokulhlaups, Tunnels and Viens. Journal of Glaciology, Vol. 17, No. 76, pp. 181-207.

Østrem, G. (1964). A Method of Measuring Water Discharge in Terbulent Streams. Geographical Bulletin, Vol. 21, pp. 21-43.

Østrem, G. Bridge, C.W. and Rannie, W.F. (1967). Glacio-Hydrology, Discharge and Sediment Transport in the Decade Glacier Area, Baffin Island, N.W.T. Geografiska Annaler, Vol. 49A (1967), pp. 268-282.

Østrem, G. and Stanley, A. (1966). Glacier Mass Balance Measurements: A Manual for Field Work. Department of Mines and Technical Surveys, Glaciology Section, 81p.

Pierce, C.H. (1941). Investigation of Methods and Equipment used in Stream Gaging. Part 1 Performance of Current Meters in Water of Shallow Depths. U.S. Geological Survey, Water Supply Paper 868-A, 35p.

Rainwater, F.H. and Guy, H.P. (1958). Some Observations on the Hydrochemistry and Sedimentation of the Chamberlin Glacier Area Alaska. U.S. Geological Survey Professional Paper 414-C, 14p.

Rasmussen, L.A. and Tangborn, W.V. (1976). Hydrology of the North Cascades Region, Washington. Runoff, Precipitation, and Storage Characteristics. Water Resources Research, Vol. 12, No. 2, April, 1976.

Ricq-de Bouard, M. (1973). Interpretation de mesures chimiques et physico-chimiques sur des eaux de fusion de neige et de glace. Zeitschrift fur Gletscherkunde und Glazialgeologie, B.D. IX, Heft 1-2, 1973, pp. 169-180.

Rodda, J.C. (1976). Facets of Hydrology, pp. 368, A Wiley-Interscience Publication, John Wiley and Sons, 368p.

Shreve, R.L. (1972). Movement of Water in Glaciers. Journal of Glaciology, Vol. 11, No. 62, pp. 205-214.

Slatt, R.M. (1972). Geochemistry of Meltwater Streams from Nine Alaskan Glaciers. Geological Society of America Bulletin, Vol. 83, April 1972, pp. 1125-1132.

Stenborg, T. (1969). Some Viewpoints on the Internal Drainage of Glaciers. International Association of Hydrological Sciences Publication No. 95, pp. 117-129.

Stenborg, T. (1970). Delay of Runoff from a Glacier Basin. Geografiska Annaler Vol.52A, pp. 1-30.

Stenborg, T. (1965). Problems Concerning Winter Runoff from Glaciers. Geografiska Annaler, Vol. 47A (1965), pp. 141-193.

Sugden, D.E. and John, B.S. (1976). Glaciers and Landscape. A Geomorphological Approach. London: Edward Arnold Publishers Limited, 376p.

Tangborn, W.V. (1967). Mass Balance of some North Cascade Glaciers as Determined by Hydrologic Parameters, 1920-65. International Association of Hydrological Sciences, Publication No.79, pp. 267-274.

Tangborn, W.V. and Rasmussen, L.A. (1976). Hydrology of the North Cascades Region, Washington. A Proposed Hydrometeorological Streamflow Prediction Method. Water Resources Research, Vol. 12, No. 2, April, 1976, pp. 203-216.

Taylor-Barge, B. (1969). The Summer Climate of St. Elias Mountains Region. Montreal: Icefield Ranges Project, Scientific Results Vol. 1, pp. 33-49, Published by the American Geographical Society, New York.

U.S. Army Corps of Engineers (1973). Hydrologic Engineering Methods for Water Resources Development. Volume 4 - Hydrograph Analysis. The Hydrologic Engineering Center, Corps of Engineers U.S. Army, Davis, California, 53p.

U.S. Army Corps of Engineers (1977). Proceedings of a Seminar on Water Quality Data Collection and Management. The Committee on Water Quality, Washington D.C., 155p.

U.S. Army Corps of Engineers (1978). Proceedings of a Seminar on Water Quality Data Interpretation. Committee on Water Quality, Washington D.C. 180p.

Ward, R.C. (1975): Principles of Hydrology. McGraw-Hill Book Company, Second Edition, 403p.

Wilson, Jr. J.F. (1968). Flurometric Procedures for Dye Tracing. Techniques of Water-Resources Investigation of the United States Geological Survey, Book 3, Applications of Hydrolics, 31 p.

Young, G.J. (1977). The Seasonal and Diurnal Regime of a Glacier Fed Stream; Peyto Glacier, Alberta. Fisheries and Environment, Inland Waters Directorate, 18p.

Zeman, L.J. and Slaymaker, H.O. (1975). Hydrochemical Analysis to Discriminate Variable Runoff Source Areas in an Alpine Basin. Arctic and Alpine Research, Vol. 7, No. 4, 1975, pp. 341-351.