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THE QUANTITY OF MELT WATER IN THE MARBLE POINT–GNEISS POINT AREA, McMURDO SOUND, ANTARCTICA*

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ABSTRACT. Among the important factors in the formation of melt water are: (1) The air and soil temperatures. (2) The presence or absence of debris on snow and ice. (3) The surface gradients of the glaciers. These gradients determine the areas of snow and ice in the zone where melting can occur as well as the amount of insolation. (4) The orientation of snow and ice slopes. In general, in the Southern Hemisphere north-facing slopes receive more insolation than south-facing slopes.

The main source of the melt water is Wilson Piedmont Glacier, and the snowdrift-ice slabs are next in importance. The seasonal snowfall is not an important source, nor is the ice in the active zone. As no rain has ever been reported, all run-off is melt water.

The seasonal discharge of the Surko and Scheuren Rivers was roughly measured in 1957–58. It was found to be approximately 13 $m^3 s^{-1}$ d for the Surko River and approximately 19 $m^3 s^{-1}$ d for the Scheuren River, and it seems likely that the total seasonal discharge of all streams in the area was not far from 50 $m^3 s^{-1}$ d.

RÉSUMÉ. *La quantité d'eau de fonte dans la zone Marble Point–Gneiss Point, McMurdo Sound, Antarctica.* Parmi les facteurs importants qui causent l'eau de fonte il y a: (1) les températures de l'air et du sol; (2) la présence ou l'absence de débris sur la neige et la glace; (3) les gradients de surface des glaciers. Ces gradients déterminent les surfaces de neige et de glace dans la zone où la fonte peut avoir lieu aussi bien que la valeur de l'insolation. (4) L'orientation des pentes de neige et de glace. En général, dans l'hémisphère sud, les pentes orientées vers le nord reçoivent plus d'insolation que celles tournées vers le sud.

La principale source d'eau de fonte est le Wilson Piedmont Glacier, et en second les langues de glace parasite de congères. La chute de neige saisonnière n'est pas une source importante, toute décharge est de l'eau de fonte.

La décharge saisonnière des rivières Surka et Scheuren a été grossièrement mesurée en 1957–58. Elle fut d'environ de 13 $m^3 s^{-1}$ d pour la rivière Surko et de 19 $m^3 s^{-1}$ d pour la rivière Scheuren; il semble que la décharge totale saisonnière de toutes les bédières de cette zone n'était pas loin d'atteindre 50 $m^3 s^{-1}$ d.

ZUSAMMENFASSUNG. *Die Schmelzwassermenge im Gebiet von Marble Point–Gneiss Point, McMurdo Sound, Antarctica.* Zu den wichtigen Faktoren der Bildung von Schmelzwasser gehören: (1) Die Luft- und Bodentemperatur; (2) Das Vorhandensein oder Fehlen von Schutt auf Schnee und Eis; (3) Die Oberflächen-Gradienten der Gletscher. Diese Gradienten bestimmen die Gebiete von Schnee und Eis in der Zone, in der die Abschmelzung eintreten kann, sowie das Mass der Sonneneinstrahlung. (4) Die Richtung von schnee- und eisbedeckten Hängen. Generell erhalten in der südlichen Hemisphäre nordorientierte Hänge mehr Sonneneinstrahlung als südorientierte.

Die Hauptquelle des Schmelzwassers ist der Wilson Piedmont-Gletscher; an zweiter Stelle folgen die Schneedrift-Eisplatten. Weder der jährliche Schneefall noch das Eis in der aktiven Zone sind nennenswerte Quellen. Da niemals Regen beobachtet worden ist, besteht der gesamte Abfluss aus Schmelzwasser.

Der jährliche Abfluss wurde 1957–58 am Surko- und am Scheuren-River grob gemessen. Es ergaben sich etwa 13 $m^3 s^{-1}$ d für den Surko River und für den Scheuren River 19 $m^3 s^{-1}$ d; der gesamte Abfluss aller Flüsse dieses Gebietes dürfte nahe bei 50 $m^3 s^{-1}$ d liegen.

INTRODUCTION

The writers were members of a five-man party employed by Metcalf and Eddy, Engineers, Boston, Massachusetts, who were under contract with the U.S. Navy to make a study concerning the feasibility of constructing a land-based airfield in the Marble Point–Gneiss Point area on the western shore of McMurdo Sound, Antarctica.† The field work was carried out between 13 December 1957 and 14 February 1958. The quantity of melt water for two streams was roughly determined because of its importance in drainage and domestic water supply, and because of the possibility that water would be needed for construction if an ice fill proved feasible.

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† U.S. Geological Survey, 1965, 1:250 000, Ross Island.

Description of Area

The area is bounded on the east and north by McMurdo Sound, on the west by Wilson Piedmont Glacier and on the south by the eastern shoulder of Hogback Mountain. Four major melt-water streams are found here. They are, from south to north, the South, Ball, Surko and Scheuren Rivers (Fig. 1). The Surko and Scheuren Rivers originate in the Davis Lakes, shallow moraine-dammed lakes located near the terminus of the glacier (Fig. 2). Only the Surko and Scheuren Rivers were studied.

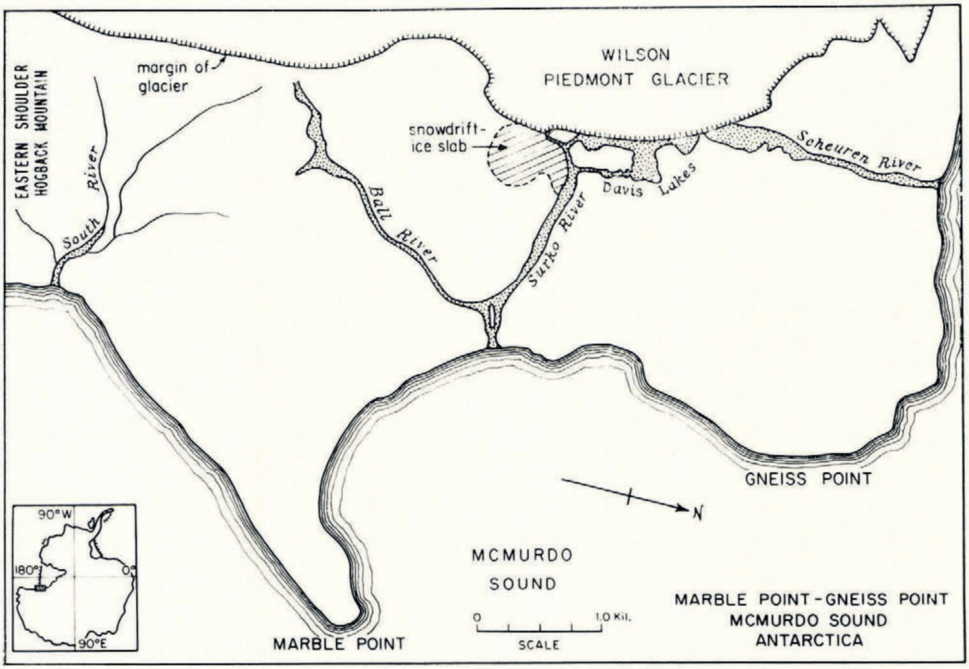

Fig. 1. Map showing the Marble Point–Gneiss Point area, McMurdo Sound, Antarctica

Meteorology

In the interval from 19 December 1957 to 13 February 1958, the highest air temperature at Marble Point was 5.6°C and the daily maximum air temperature was at or above 0°C for 45 days. In the interval from 2 January 1958 to 13 February 1958, the highest average daily soil temperature 2.5 cm below the surface was 11.1°C and the average daily soil temperature 2.5 cm below the surface was at or above 0°C for at least 34 days (Fig. 3).

In the interval from 14 November 1958 to 25 January 1959, the highest air temperature at Marble Point was 5.17°C and the highest soil temperature 2.5 cm below the surface was 20.56°C (Nichols and Ball, 1964[b], p. 358). Extrapolating from the data, it seems likely that between 1 November 1958 and 1 November 1959 the daily maximum air temperature was above 0°C for perhaps 39 days and the daily maximum soil temperature 2.5 cm below the surface was above 0°C for more than 63 days.

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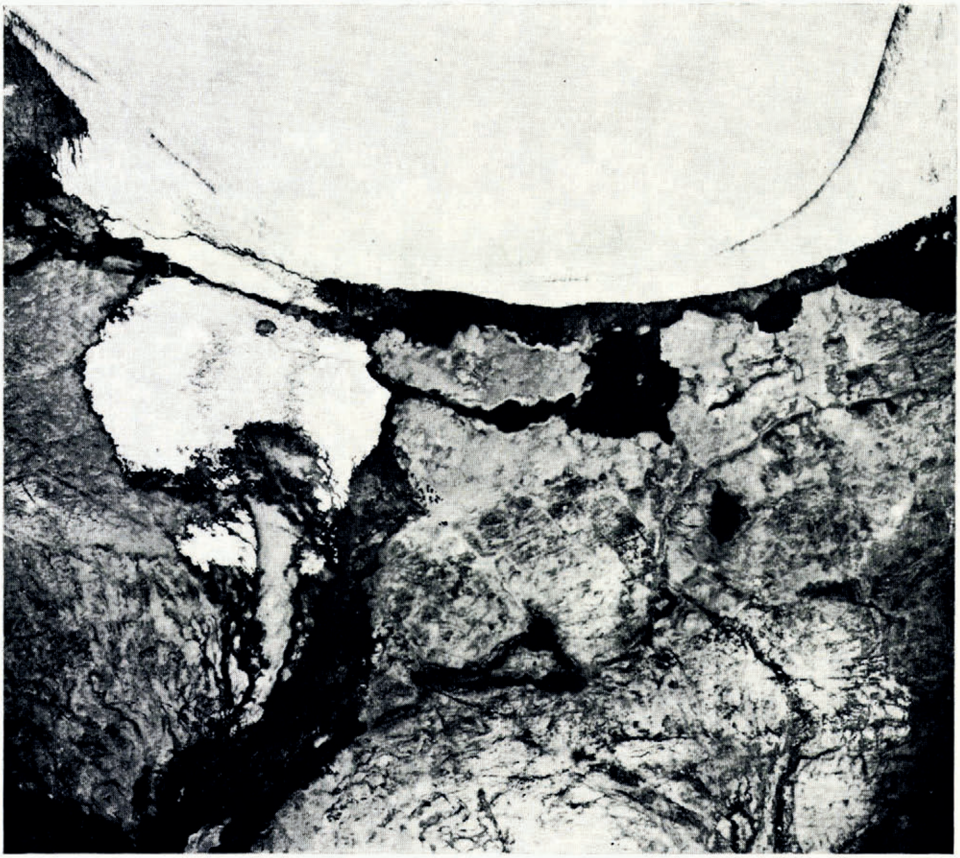

Fig. 2. A vertical aerial photograph showing Wilson Piedmont Glacier, snowdrift-ice slabs, the Davis Lakes and the Surko River (U.S. Navy photograph)

A comparison of the data for air temperature and cloud cover shows that when the cloud cover is absent or scattered the air temperature is high and when it is continuous and dense the air temperature is low (Fig. 3). The air and soil temperatures also correlate reasonably well. With these air and soil temperatures it is not surprising that sizable melt-water streams are found in the summer months in the Marble Point–Gneiss Point area and that alluvial fans, valley trains, marine and lacustrine deltas, kame moraines, hillocks, and ridges, torrential fluvial boulder deposits, thaw channels in ice, marginal channels and ravines cut in surficial deposits are common in this part of Antarctica (Nichols, 1967, p. 33–34).

Melt-water Sources

The main source of the melt water is Wilson Piedmont Glacier and the snowdrift-ice slabs are next in importance (Fig. 4) (Nichols, 1964). Wilson Piedmont Glacier terminates in places in a ramp and in other places in an ice cliff. Small melt-water streams run down the ramp during the warm season and small melt-water waterfalls are found along the ice cliff. No water issues from the bottom of the glacier, however, because the mean annual sea-level air temperature is not far from $-20.0°C$ (Nichols and Ball, 1964[a], p. 355). Small slushers commonly slide down the ramps during the warmest days of summer. They form small snow fans at the edge of the glacier and they remove melt water from it.

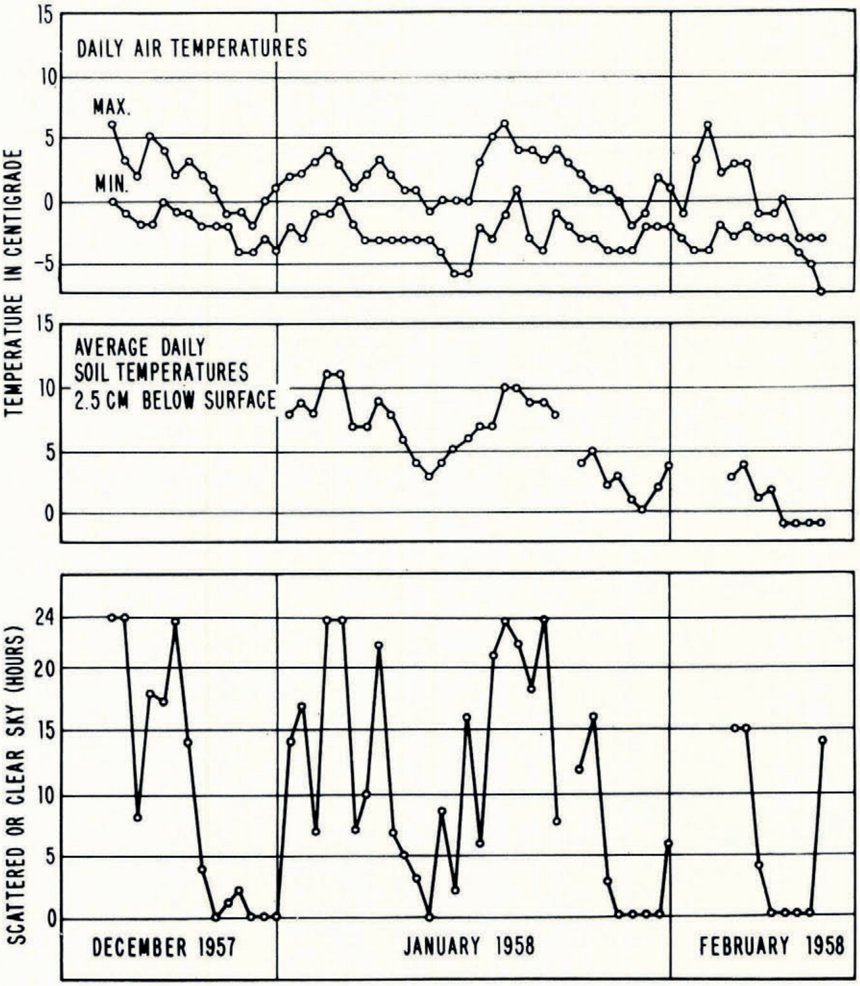

Fig. 3. Daily maximum and minimum air temperatures, daily average soil temperatures and cloud cover during the 1957–58 summer season at Marble Point, McMurdo Sound, Antarctica

The seasonal snowfall is not an important source of melt water. The snowfall is light and the presence of *penitentes*, plough-share snow surfaces and sun cups indicates that much of it is dissipated by evaporation (Nichols, 1953, p. 135–37). The ice in the active zone is of no importance. No rain has ever been reported in the McMurdo Sound area (Simpson, 1919, p. 159); hence all run-off is melt water.

Factors in the Formation of Melt Water

Among the important factors in the formation of melt water are: (1) The air temperature, which depends mainly on the height of the sun, the length of the day and the characteristics of the cloud cover. (2) The soil temperature, which depends mainly on the free-air temperature, the albedo and moisture content of the soil, and insolation. (3) The presence or absence of debris on snow and ice. (4) The surface gradients of the glaciers, as these gradients determine the areas of snow and ice in the zone where melting can occur, as well as the amount of insolation. (5) The orientation of the snow and ice slopes. In general, in the Southern Hemisphere north-facing slopes receive more insolation than south-facing slopes.

Fig. 4. A snowdrift-ice slab adjacent to Wilson Piedmont Glacier approximately 3.5 km west of Marble Point (U.S. Navy photograph)

Hydrology

Data were obtained on the melt-water discharge of both the Surko and Scheuren Rivers (Fig. 1). The construction equipment, instruments and manpower for a comprehensive program were not available. However, sufficient measuring devices were installed to obtain a general picture of the seasonal run-off. No measurements were made before 20 December 1957 or after 12 February 1958. Estimates of the run-off for the periods of melt-water flow not covered by measurements were made by extrapolation from the hydrologic data obtained and from an analysis of the available weather records of the area.

Stream gauging was initially limited to the construction of a small rock-fill dam and weir across one of the two channels of the Surko River, and to a few cross-section and velocity measurements made periodically at other locations along both the Surko and Scheuren Rivers. However, after the arrival of the heavy construction equipment a diversion dam was built and the entire flow of the Surko River was made to pass through the weir. Further details on the measurement procedures can be obtained from an unpublished report submitted to the Department of the Navy, Bureau of Yards and Docks, Washington, D.C. (Metcalf and Eddy, unpublished, p. 180–88).

Temperature, Flow Pattern and Quantity of Melt Water

There is a good correlation between air temperature and melt-water temperature. When the air temperature is high the melt-water temperature is high, and when the air temperature is low the melt-water temperature is low (Fig. 5). The average melt-water temperature is at times several degrees warmer than the average air temperature (Fig. 5). At first this seems surprising, especially in view of the fact that the temperature of the melt water was measured only a few hundred meters from Wilson Piedmont Glacier. However, much of the melt water

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comes from the Davis Lakes, which are shallow. The temperature of one of them in early January was approximately 7°C.

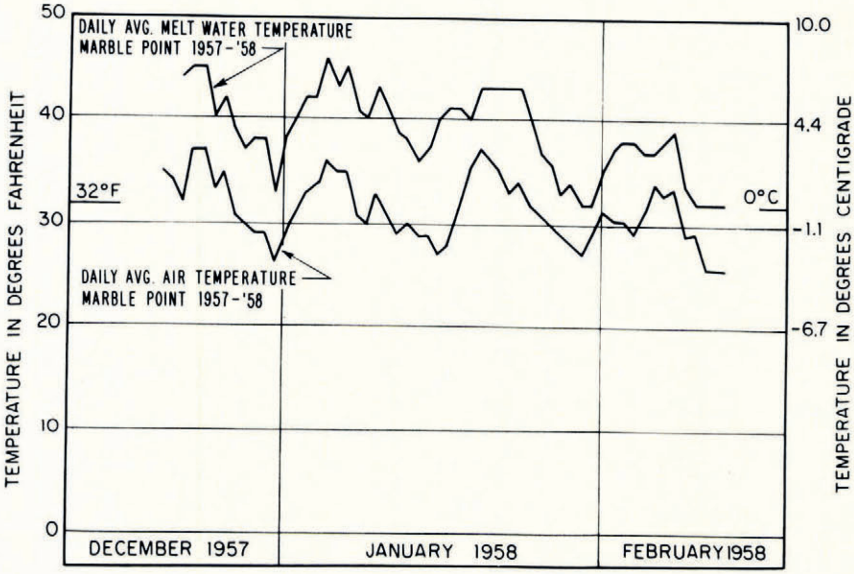

Fig. 5. A comparison of air and melt-water temperatures at Marble Point, McMurdo Sound, Antarctica

The maximum discharge of the north branch of the Surko River for the 1957–58 season occurred on 22 January 1958 (Fig. 6). The melt-water flow in general is at a minimum in the early morning (05.00 h) and rises to a maximum in the mid-afternoon (16.00 h).

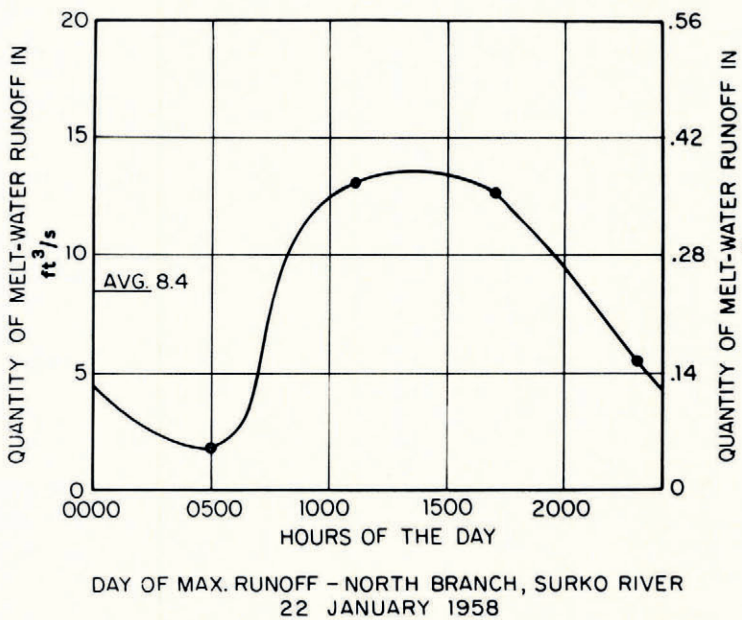

Fig. 6. A typical daily flow pattern of the north branch of the Surko River, Marble Point, McMurdo Sound, Antarctica

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The average daily melt-water discharge for both the Surko and Scheuren Rivers is shown on Figure 7. The maximum average daily melt-water discharge of the Surko River is about 0.39 $m^3 s^{-1}$ (14 $ft^3 s^{-1}$) and the maximum average daily melt-water discharge of the Scheuren River is approximately 0.59 $m^3 s^{-1}$ (22 $ft^3 s^{-1}$) (Fig. 7). There is a good correlation between air temperature and melt-water discharge (Figs. 5 and 7).

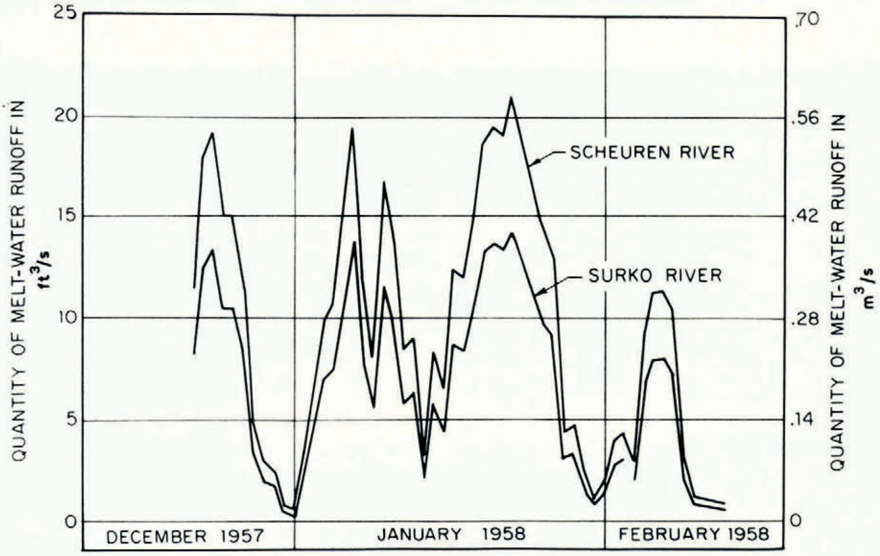

Fig. 7. The average daily melt-water discharge of the Surko and Scheuren Rivers, Marble Point, McMurdo Sound, Antarctica

The seasonal discharge for the Surko River is estimated to be approximately 13 $m^3 s^{-1}$ d (470 $ft^3 s^{-1}$ d), and for the Scheuren River approximately 19 $m^3 s^{-1}$ d (670 $ft^3 s^{-1}$ d) (Fig. 8). The combined seasonal discharge of both rivers is approximately 32 $m^3 s^{-1}$ d (1 140 $ft^3 s^{-1}$ d). It seems likely that the total discharge of all the major melt-water streams

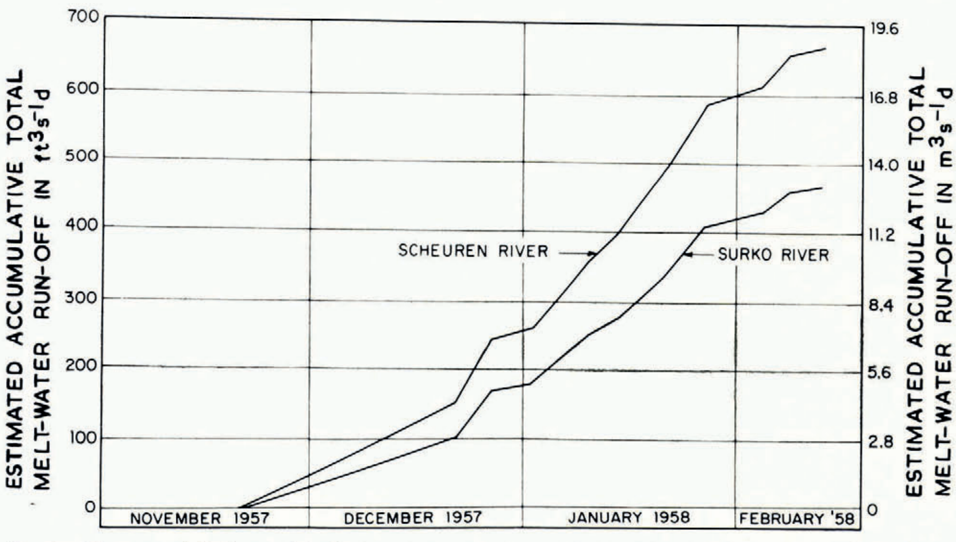

Fig. 8. The seasonal discharge of the Surko and Scheuren Rivers, Marble Point, McMurdo Sound, Antarctica

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of the Marble Point–Gneiss Point area for the 1957–58 melt season was not far from 50 $m^3 s^{-1}$ d (1 800 $ft^3 s^{-1}$ d). The average yearly discharge is unknown, as almost nothing is known of the meteorology of the area.

The glacial front which contributes melt water to the Surko River is approximately 8 300 ft (2 530 m) long. The snowdrift-ice slab found in the drainage basin of the Surko River also contributes significantly to the run-off. The Scheuren River is fed by only 6 300 ft (1 920 m) of the front of the glacier. It seems likely that the Scheuren River receives more melt water from a shorter distance along the front of the glacier because here the glacier slopes more to the north (Fig. 1).

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