Fisheries and Environment Canada
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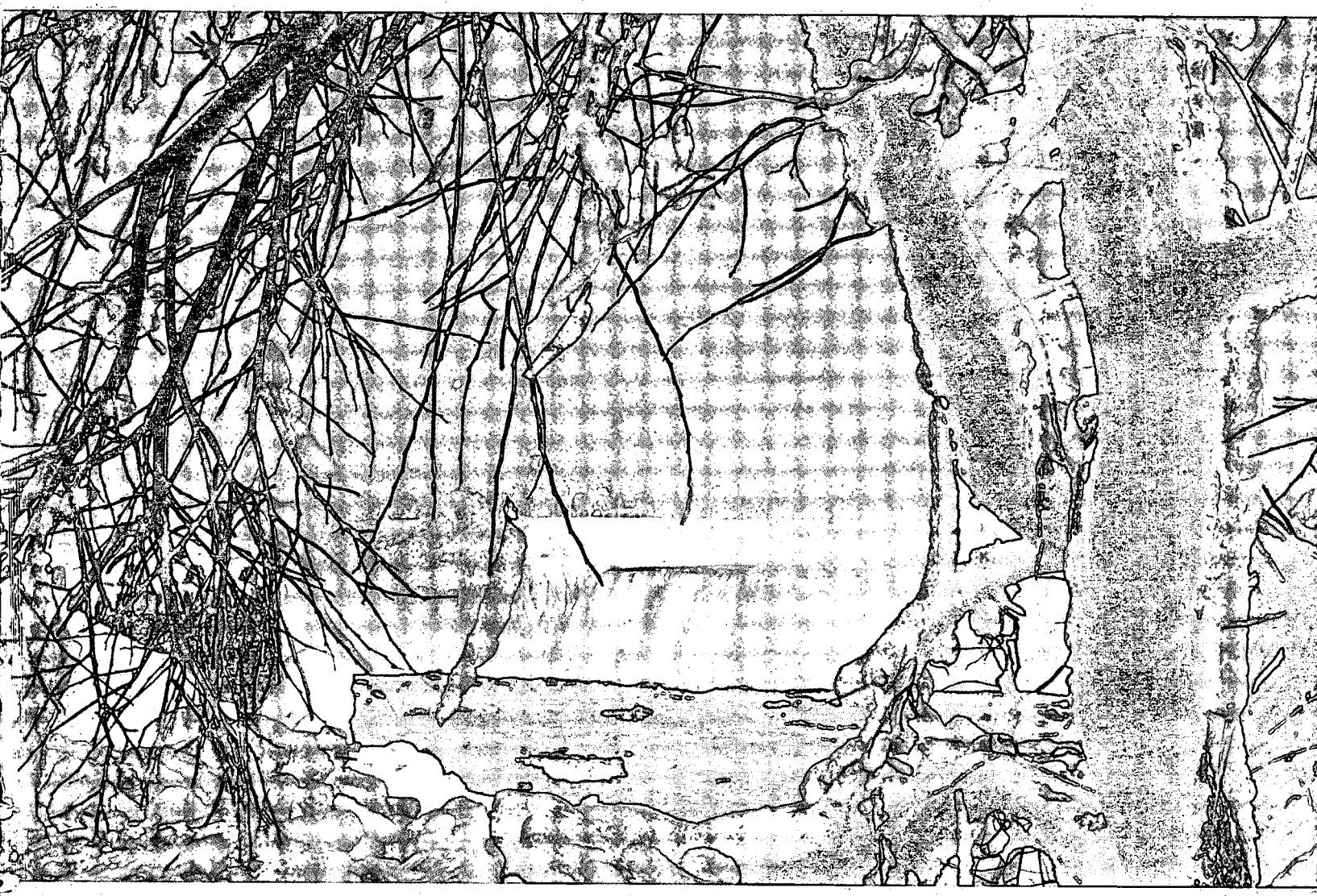
Canadian Glaciers in the International Hydrological Decade Program, 1965-1974

No. 2. Place Glacier, British Columbia — Summary of measurements

O. Mokievsky-Zubok and A. D. Stanley



SCIENTIFIC SERIES NO. 69
(Résumé en français)

INLAND WATERS DIRECTORATE,
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Contents

Illustrations

Abstract

Place Glacier, located in the Coast Mountain Range of British Columbia, is one of five glaciers studied in Western Canada as part of the Canadian contribution to the International Hydrological Decade (IHD). Studies began in 1965.

The report describes the main parameters of the glacier, geology of the basin and gives summaries of glaciological, meteorological and hydrological data collected until the end of the 1974 field season, together with reference to special studies on the glacier.

Résumé

Le glacier Place, situé dans la chaîne Côtière de la Colombie-Britannique, est au nombre des cinq glaciers qui ont fait l'objet d'études menées dans l'ouest du Canada en 1965, dans le cadre de la participation canadienne à la Décennie hydrologique internationale.

Le présent rapport montre les principaux paramètres du glacier, la géologie du bassin et, de façon concise, les données glaciologiques, météorologiques et hydrologiques recueillies sur place jusqu'à la fin de 1974. Il comprend aussi certaines références à des études particulières sur le glacier Place.

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INTRODUCTION

The need for glaciological research on a global scale was emphasized by the General Assembly of the International Association of Scientific Hydrology (IASH) held in Helsinki in 1960 (IUGG/IASH, 1961). At that meeting more comprehensive work on glaciers was recommended to the Commission of Snow and Ice. The program subsequently prepared by the Subcommittee on Variation of Existing Glaciers was a major step forward in international glaciological research and was accepted by the Commission of Snow and Ice at the Symposium of Obergurgl in 1962 (IUGG/IASH, 1962). This program led the 1964 General Conference of the United Nations Educational, Scientific and Cultural Organization (UNESCO) to implement the world-wide International Hydrological Decade program on glaciers (Resolution I-13 UNESCO/NS/198).

Canada took active interest in this program of glaciological research and part of its commitment to IHD was the survey of a chain of five glacier basins for study of mass and water balance. This chain represents a transect across the southern part of the Canadian Cordillera and forms part of the IHD network of glacier basins which extends to Europe and Asia in a west-east direction and runs from Alaska to South America in a north-south direction (Mokievsky-Zubok, 1973a).

The five glacier basins in southwestern Canada selected for a long-term detailed study of mass and water balance were Sentinel, Place, Woolsey, Peyto and Ram River (Fig. 1). Responsibility for carrying out these studies was given to the Glaciology Section of the Geographical Branch, Department of Mines and Technical Surveys, which is now the Glaciology Division, Water Resources Branch, Inland Waters Directorate, Department of the Environment, Ottawa.

This report deals with data collected at Place Glacier from 1965 to the end of IHD on December 31, 1974.

GENERAL DESCRIPTION

Place Glacier (lat. 50° 26 ′ N, long. 122° 36 ′ W) is located in the Coast Mountain Range of Western Canada, 135 km north of Vancouver (Fig. 1). The glacier is influenced by a maritime climate; however, it is outside the belt of high winter precipitation, and seasonal snow cover rarely exceeds 5 m anywhere on the glacier.

The glacier's main parameters are:

Glacier area	3.980 km² in 1965 3.893 km² in 1974
Maximum elevation	2602 m a.s.l.
Minimum elevation	1820 m a.s.l.
Mean elevation	2211 m a.s.l.
Average gradient	9°
Azimuth	329°
Mean specific winter balance, 1965-1974	1.99 m (standard deviation, 0.38)
Mean specific summer balance, 1965-1974	2.39 m (standard deviation, 0.42)
Mean specific net balance, 1965-1974	-0.40 m (standard deviation, 0.60)
Accumulation area ratio	0.46
Mean equilibrium line, 1965-1974	2138 m (standard deviation, 140)

The glacier is nearly 4 km² and covers about 60% of the total area draining into the meltwater channel above a well-constructed stream gauge. This station has a concrete weir for measuring the water level and discharge on a year-round basis. The dam is located approximately 250 m downstream from the glacier tongue. There is a small terminal lake, bordered partly on its eastern side by an ice-cored moraine.

The firn line is normally at the foot of the upper basin at an elevation of 2140 m.

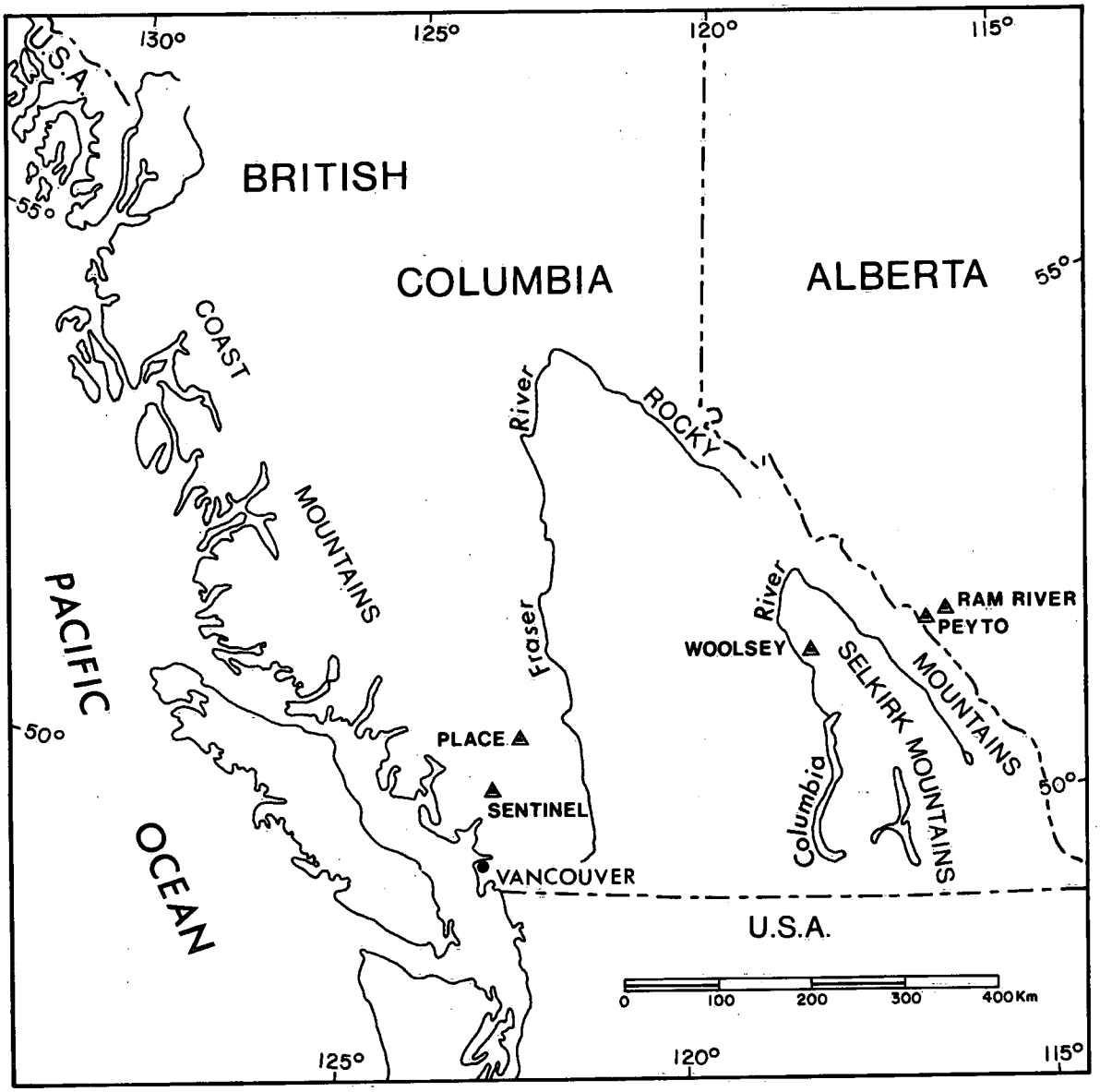

Figure 1. Location of glacier basins in the Canadian Cordillera selected for combined balance studies.

Place Glacier has two distinct basins with steep valley walls: the smaller, upper basin facing west and the larger, lower basin facing north. The glacier surface between the basins is steep and contains numerous crevasses. The catchment basin is relatively flat with several large crevasses, but becomes progressively steep towards the head. The lower basin rises gradually from the terminus, extending in a southern direction for about 2.5 km to the divide with Joffre Glacier. The lower basin is characterized by a large number of smaller crevasses and by numerous moulins.

GEOLOGY

The bedrock about Place Glacier is metamorphosed sedimentary rock of Mesozoic age. It consists of an undifferentiated series of volcanic and argillaceous rocks that show low-grade metamorphic assemblage introduced by sills, dykes and small bodies of granodiorite.

DATA COLLECTION

Personnel were stationed at Place Glacier from May to September for the years 1965-1969. From 1970, when

meteorological long-term recorders were installed, the glacier was visited 3-4 times per season. Data collected may be divided into three major groups: glaciological, hydrological and meteorological.

Glaciological Data

Summaries of net mass balance for 1965-1974 are presented in Appendix I. The values given were obtained by standard mass balance measurements (Østrem and Stanley, 1966), as recommended by the Subcommittee on Variation of Existing Glaciers to the Commission on Snow and Ice of IASH and accepted in a resolution at the Symposium of Obergurgl in 1962 (IUGG/IASH, 1962, pp. 306-309).

Maps showing stake nets, sounding profile, survey points, winter and summer balance and net balance are shown in Appendix II. Stake nets were established at the beginning of the program. Aluminum stakes were drilled into the ice and drilled again whenever they were close to melting out. In the spring of each year, when the stakes were covered by snow, temporary stakes were inserted in the snow as close as possible to the original stakes. The measured snowmelt at a temporary stake was assumed to be that of the nearest permanent stake when it appeared on the surface in the course of the summer.

Concurrently with the snow measurement and at regular intervals throughout the field season, density measurements were obtained for calculation of water equivalents for snow depth values. During the melt periods 1965-1969 measurements of snowmelt were taken at intervals of 8-10 days. From 1970 on they were taken 3-4 times per season. At the end of the season the remaining snow cover was probed again.

From these measurements of snow cover and snow and ice melt, maps have been compiled and the winter and summer balances calculated. For each sounding point on the sounding profiles, snow depth values in water equivalents were entered on a 1:10,000 scale map and lines of equal snow depths drawn at increments of 50 cm of water equivalent.

The area between successive isopleths and each elevation interval was planimetered and multiplied by the average water equivalent value to provide the water equivalent volume. Results for all elevation intervals were added. The sum represented the total of either winter or summer balance (Mokievsky-Zubok, 1973b). The net mass balance is either positive or negative according to the equation (UNESCO/IASH, 1970):

$$b_n = b_w + b_s$$

where

b_n is the net mass balance
b_w is the winter balance
b_s is the summer balance

Maps representing net mass balance in Appendix II were obtained by using values from an alternative method that is based on subtracting the volume of remaining snow cover from ice and firn ablation. The thickness of the remaining snow cover was sounded at the end of the ablation season and its volume obtained by following procedures similar to those used for determining winter balance. Accuracy analysis of mass balance values was discussed previously (Mokievsky-Zubok, 1974).

The collected glaciological data are summarized in a series of graphs and tables (Appendix III).

GRAPHS

1. Variation of net balance with elevation, 1965-1974.
2-11. Variation of winter, summer and net balances with elevation for each year.
12. Net mass balance fluctuations, 1965-1974.
13. Analysis of surface measurement methods.

TABLES

1-10. Summaries of net mass balance data by contour intervals, 1965-1974.
11. Equilibrium lines, 1965-1974.
12. Glacier's gain or loss in volume of water, 1965-1974.
13. Comparison of mass balance results obtained by two surface methods to show their internal consistency.

Hydrological Data

At present meltwater from Place Glacier enters immediately into a small lake which extends for approximately 250 m in front of the terminus. From the lake, water flows out by a single bedrock-controlled channel. In 1969, the channel was dammed near the lake outflow by a concrete weir built by the Water Survey of Canada. The total structure comprised a covered rectangular weir and a 20-ft tower containing equipment to measure summer discharge and to monitor winter flow. A Stevens A-35 stage recorder was used for recording the water level on a year-round basis.

Discharge measurements were made each year at regular intervals of approximately 6 weeks. Summer measurements were very accurate, but the accuracy diminished in winter when icing occurred at the weir despite the heating installations.

Detailed discharge measurements are available from the Glaciology Division and a rating curve is given in Appendix IV. Daily river discharges are presented in graphical form in Appendix V.

Meteorological Data

At Place Glacier, as at other glaciers in the Canadian IHD program, considerable attention was given to meteorological data. From 1966 to 1969 during the summer months the data were collected daily; observations were taken 4 times a day for temperature, relative humidity, wind direction, wind velocity and precipitation. Visual records of visibility, fog, cloud cover in tenths, height and type of clouds and general weather were also obtained.

Instrumentation on the glacier was placed at the base camp, located at 1840 m a.s.l., 250 m from the terminus. From 1965 to 1970 it consisted of a thermohygrograph, simple precipitation gauges (Pluvius type - see Østrem, 1966) and, in 1966, an anemometer. In 1967, the Fischer-Porter automatic rain gauge was added.

In 1970, when short-term recorders were replaced by long-term ones, visits to Place Glacier were made about once a month. Records were obtained for temperature, relative humidity, precipitation, wind speed and wind direction. Some information is available for limited periods during the winter months.

The collected data have been reduced, summarized and tabulated. Stored at Glaciology Division, Inland Waters Directorate, they are available on request. The data are presented in graphical form in Appendix V.

SPECIAL STUDIES

Mass Balance by Various Methods

Two surface balance methods were used to establish the accuracy of the measurements by determining the degree of internal consistency (Mokievsky-Zubok, 1973a).

Surveying of Stakes for Ice Movement

Survey data are available for each year for all permament stakes that reappear from winter snow by the middle of August.

Winter Flow

An attempt to obtain accurate measurements of the glacier's winter flow was unsuccessful. Formation of ice within the weir and outside the dam caused water in the well to fluctuate abnormally, giving erroneous readings. Heating installations were insufficient to combat these difficulties and testing of new methods is now in progress.

SUMMARY

Place Glacier presented little difficulty in obtaining mass balance values. Snow depths were normally consistent with rise in elevation; and special accumulation patterns, the extent of which depended on the overall snowfall, were predictable from year to year. Measurements of snow depth were reliable, as most of the winter snow cover was deposited over the glacier ice and easy to measure. The use of two surface methods reduced any possible error in measurement. All areas were accessible for measurement, so that no subjective extrapolation in drawing snow depth or water-equivalent isolines was exercised.

Collection of meteorological data suffered during non-resident years when instruments failed. Hydrological data are reliable, however, and considered to be the most accurate of all Canadian IHD glacier basins since the construction of the controlled bed and measuring installation in 1969.

ACKNOWLEDGMENTS

The cooperation and assistance of Water Survey of Canada, Vancouver Office, in building stream-measuring installations under extreme logistic difficulties and in obtaining flow measurements at regular intervals is greatly appreciated. Special thanks are due to C. Watson and A. Waraway for their dedication in solving icing problems.

Each summer the project was aided by student assistants. We value their efforts and concern.

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Appendix I

Summary of mass balance data

Table I-1. Place Glacier – Summary of Mass Balance Data, 1965 – 1974

Year	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
					Specific water equivalents, m*					
Winter balance	1.58	2.02	2.10	2.32	2.05	1.43	2.04	1.76	1.79	2.77
Summer balance	2.23	1.91	3.31	2.45	2.26	2.94	2.39	2.10	2.09	2.21
Net balance	-0.65	+0.11	-1.21	-0.13	-0.21	-1.51	-0.35	-0.34	-0.30	+0.56
					$10^6 m^3$ water equivalents					
Winter balance	6.293	8.018	8.315	9.162	8.106	5.689	8.087	6.853	6.980	10.781
Summer balance	8.890	7.567	3.957	9.681	8.956	11.648	9.446	8.192	8.139	8.592
Net balance	-2.597	+0.451	-4.798	-0.519	-0.850	-5.959	-1.359	-1.339	-1.159	+2.189

*The specific values are obtained by dividing total mass of water equivalents by area.

Appendix II

Maps of summer, winter and net balance

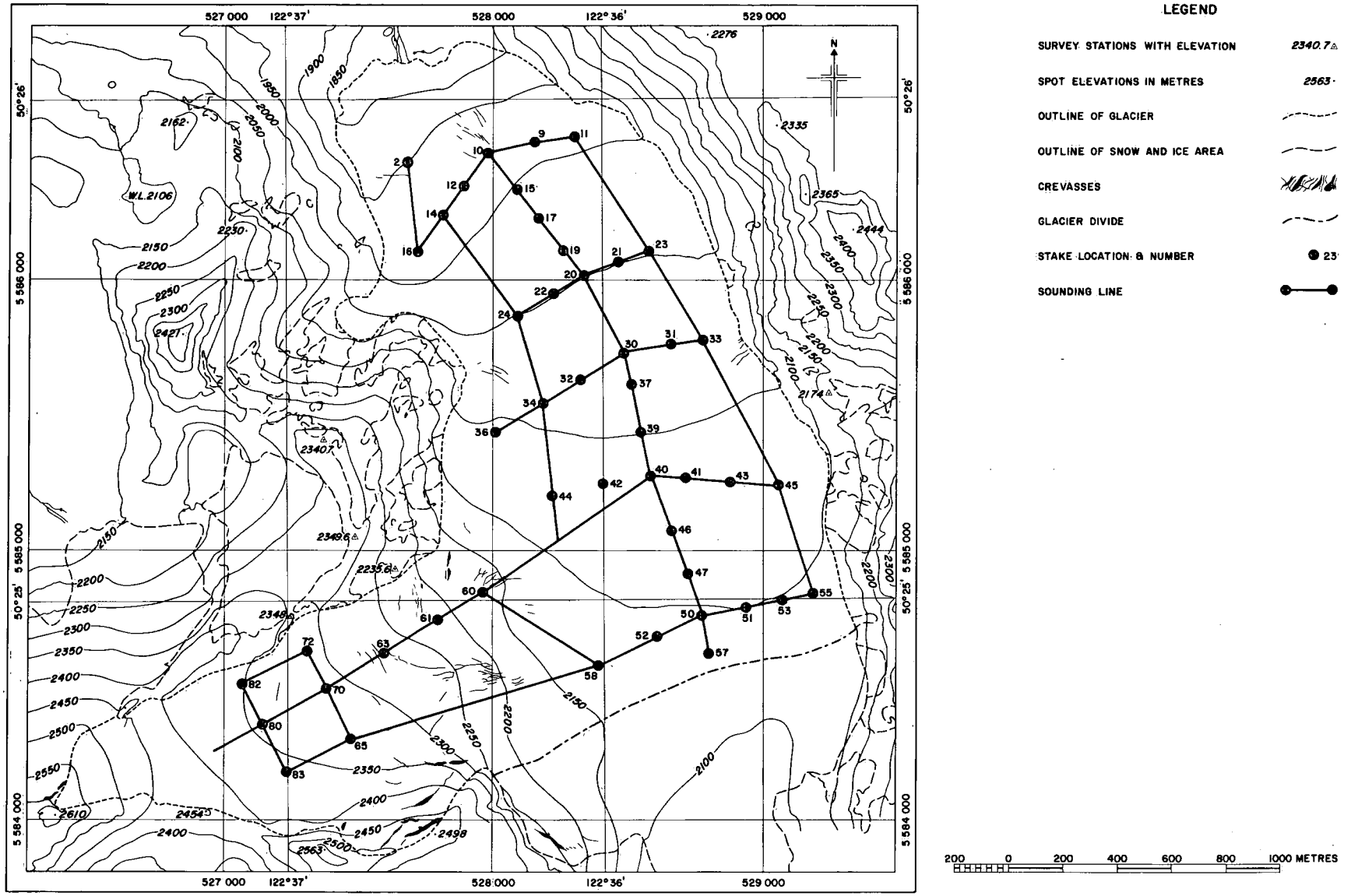


Figure II-1. Map of stake net, sounding profiles and survey points.

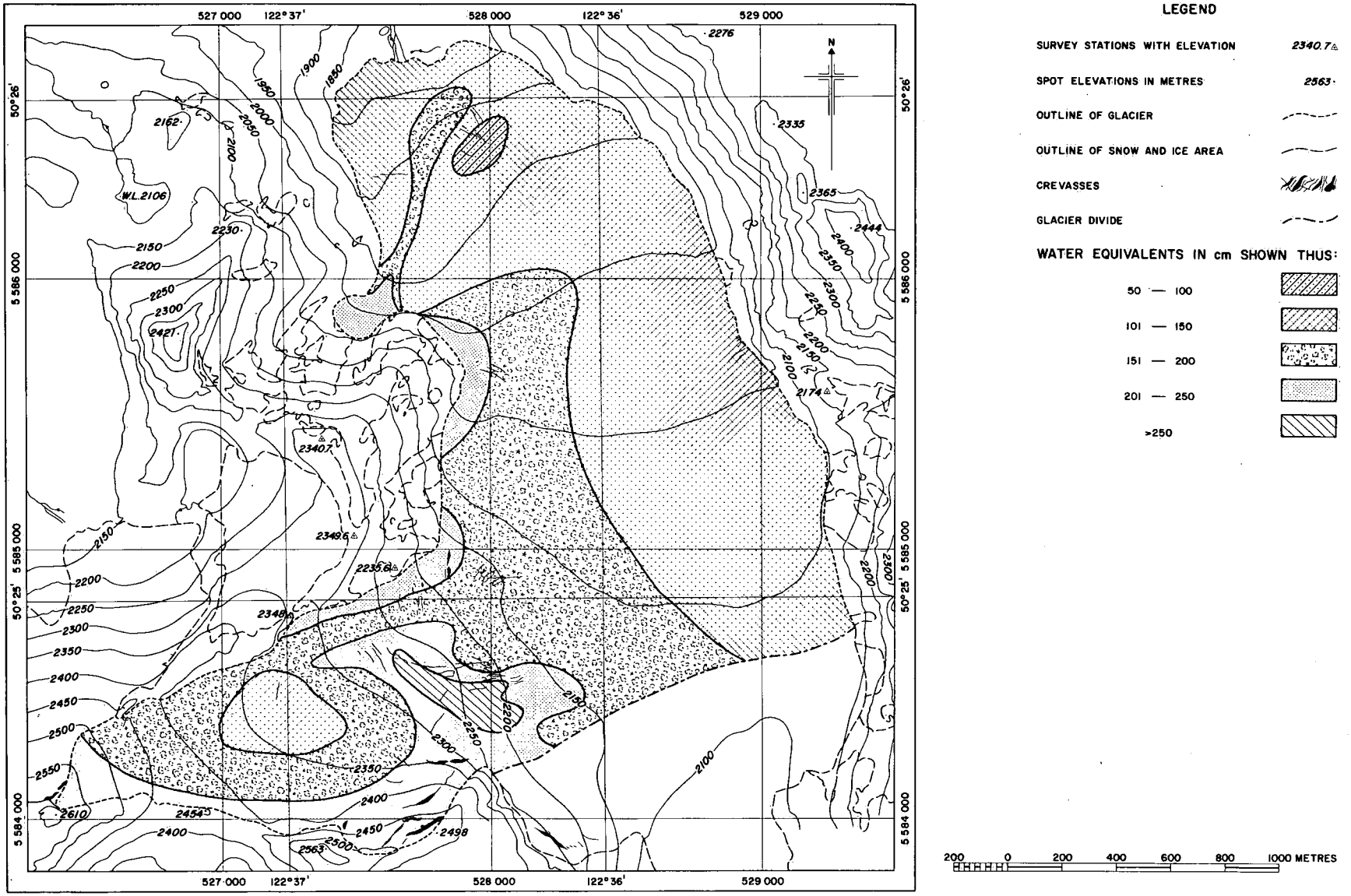


Figure II-2. Map of winter balance to April 18, 1965.

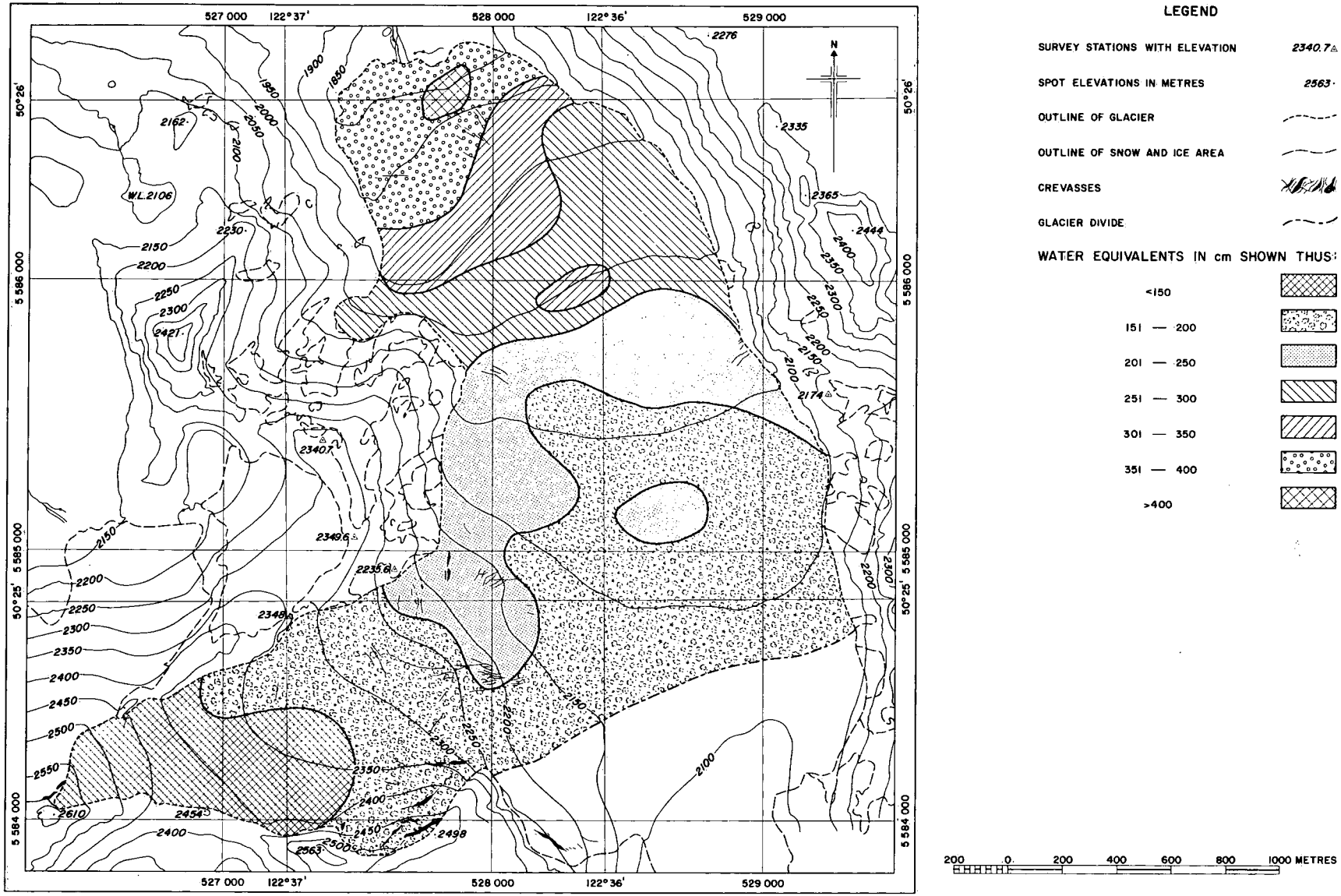


Figure II-3. Map of summer balance to September 10, 1965.

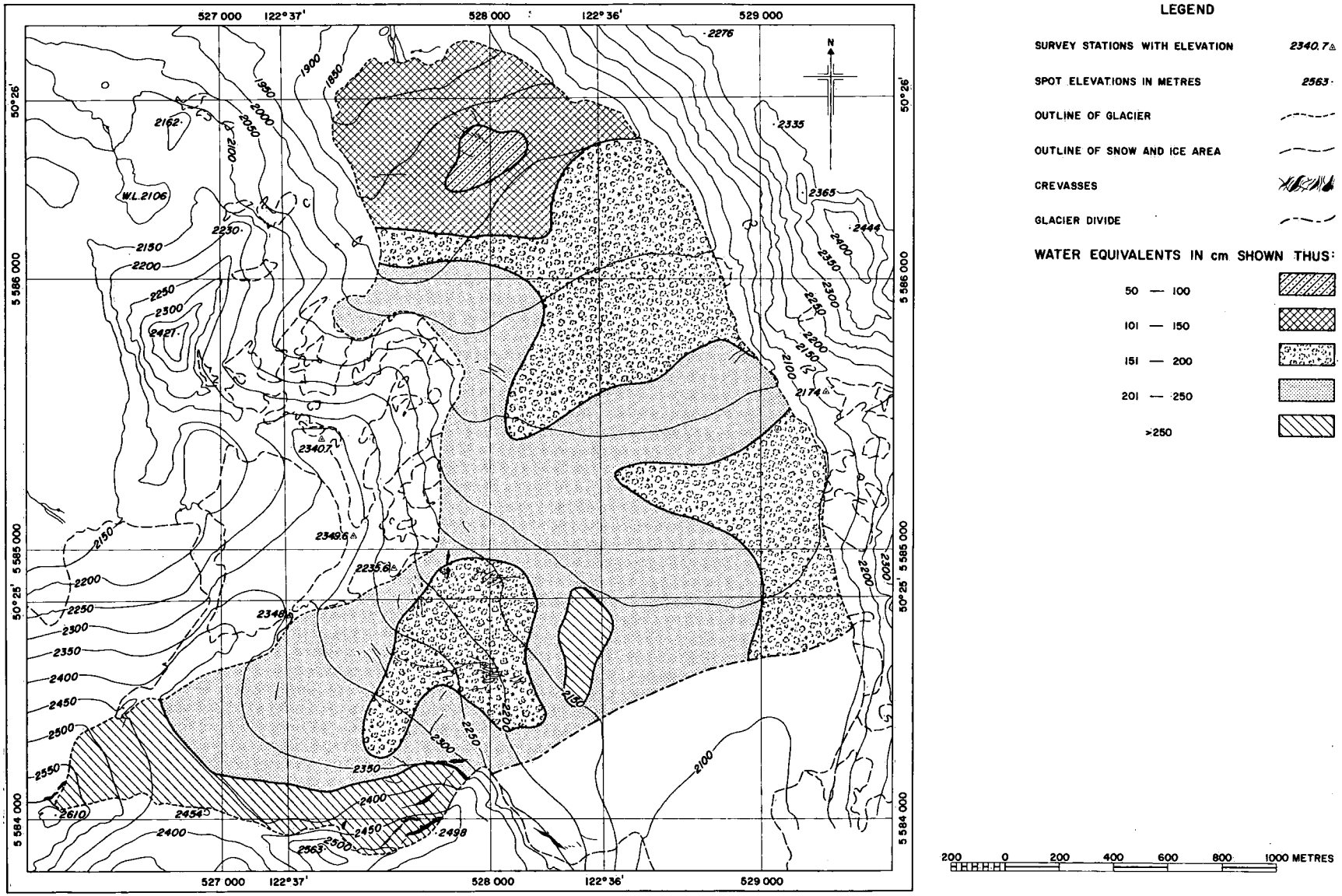


Figure II-4. Map of winter balance to June 15, 1966.

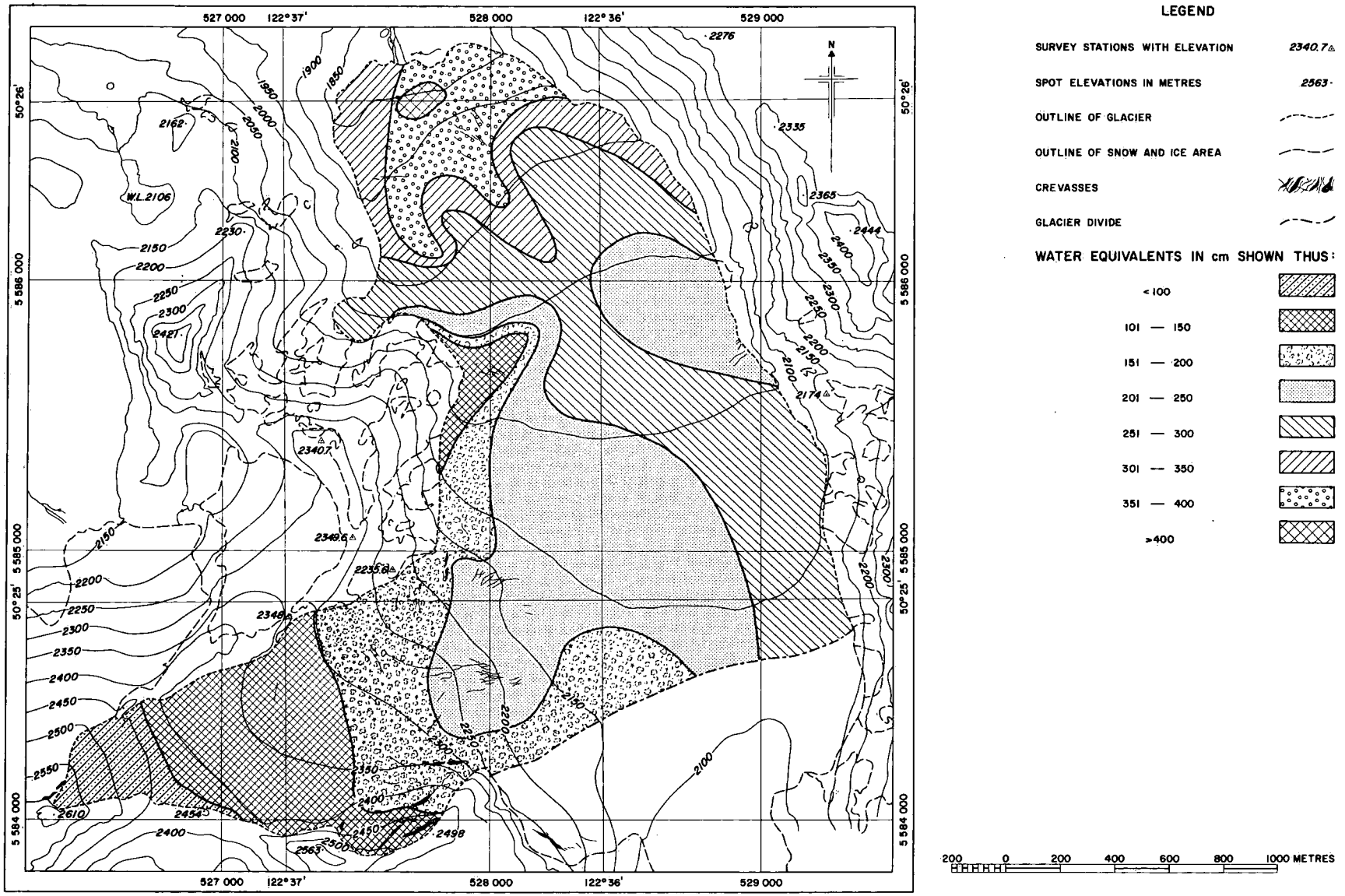


Figure II-5. Map of summer balance to September 3, 1966.

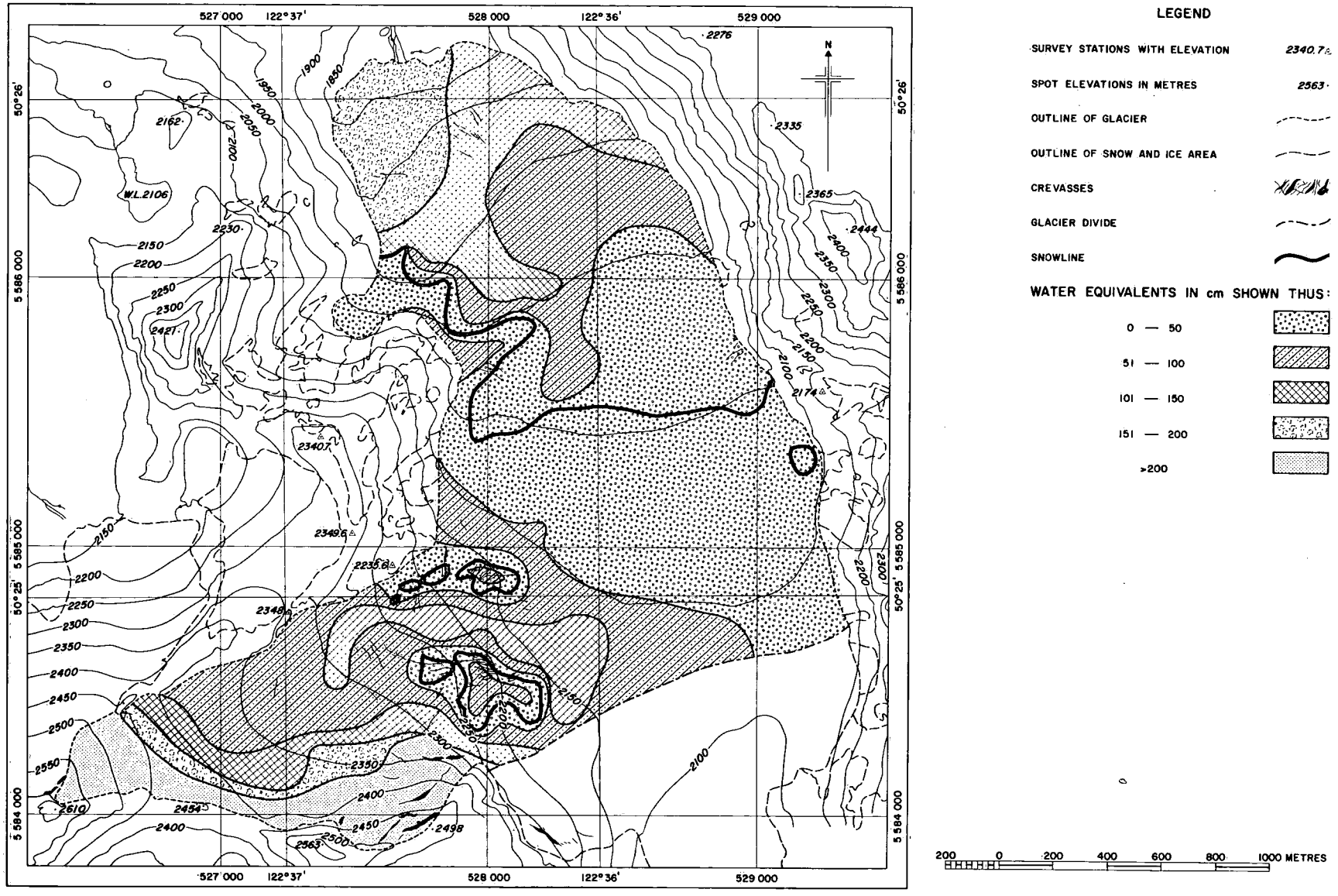


Figure II-6. Map of net balance, June 15 to September 3, 1966.

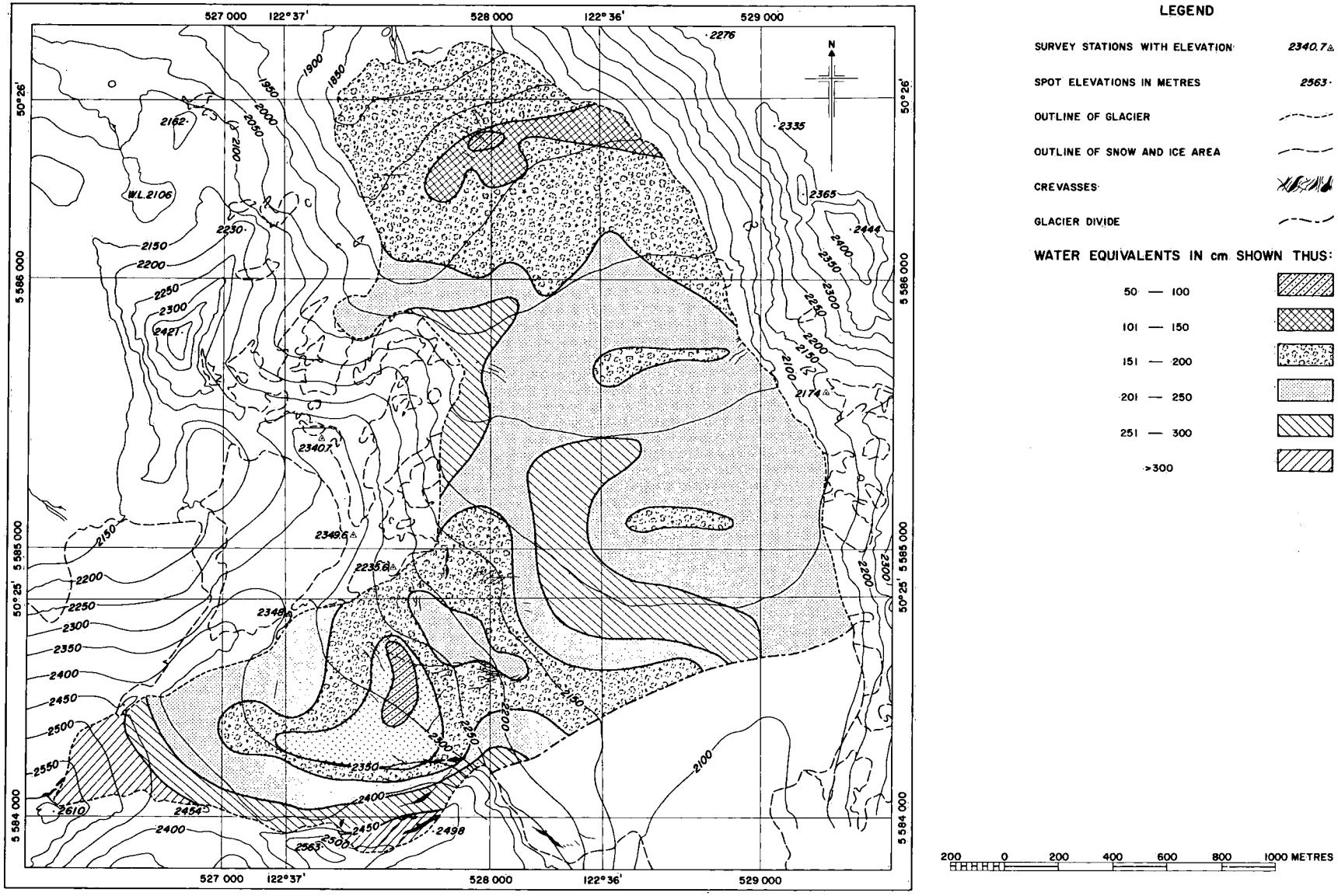


Figure II-7. Map of winter balance to May 31, 1967.

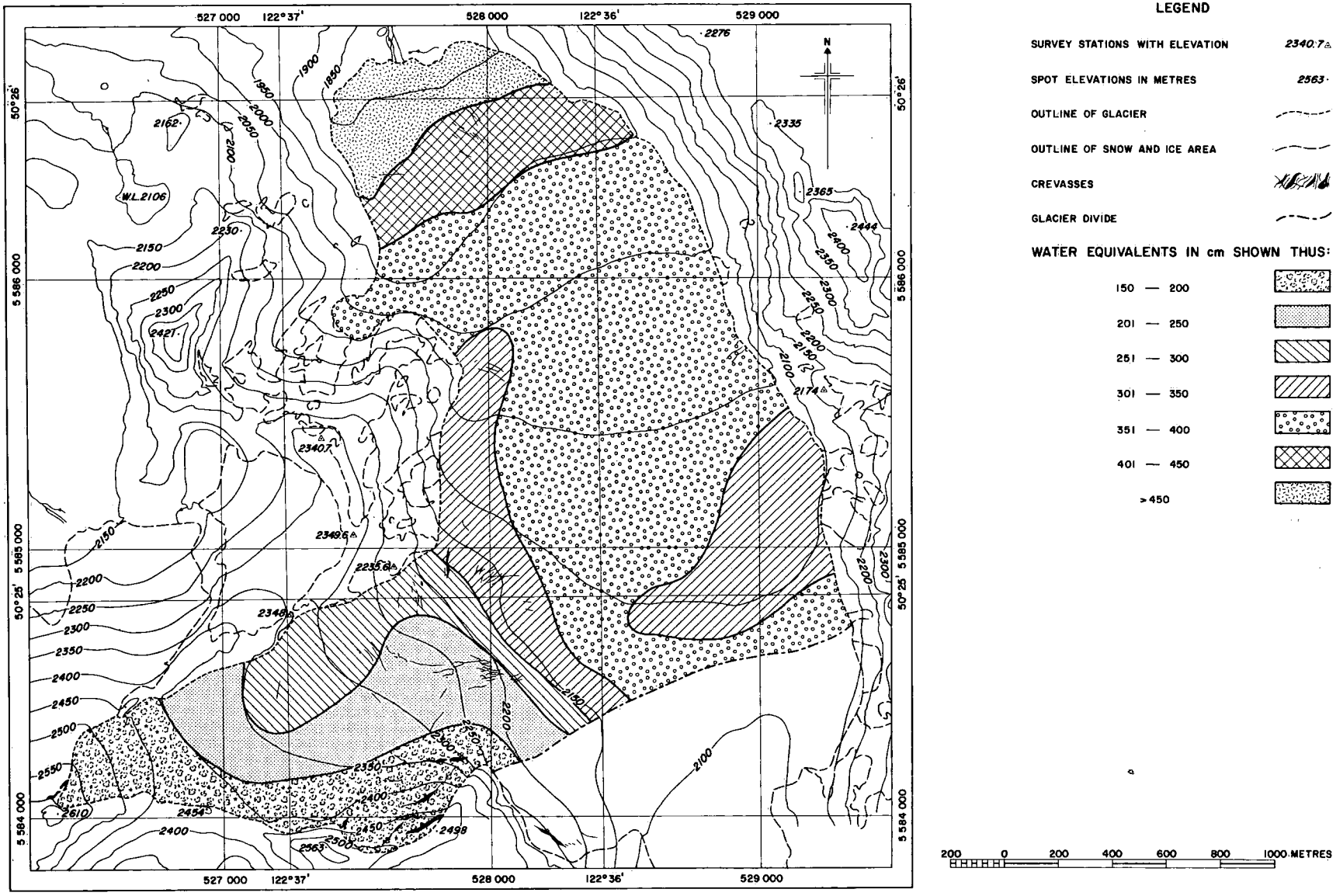


Figure II-8. Map of summer balance to October 16, 1967.

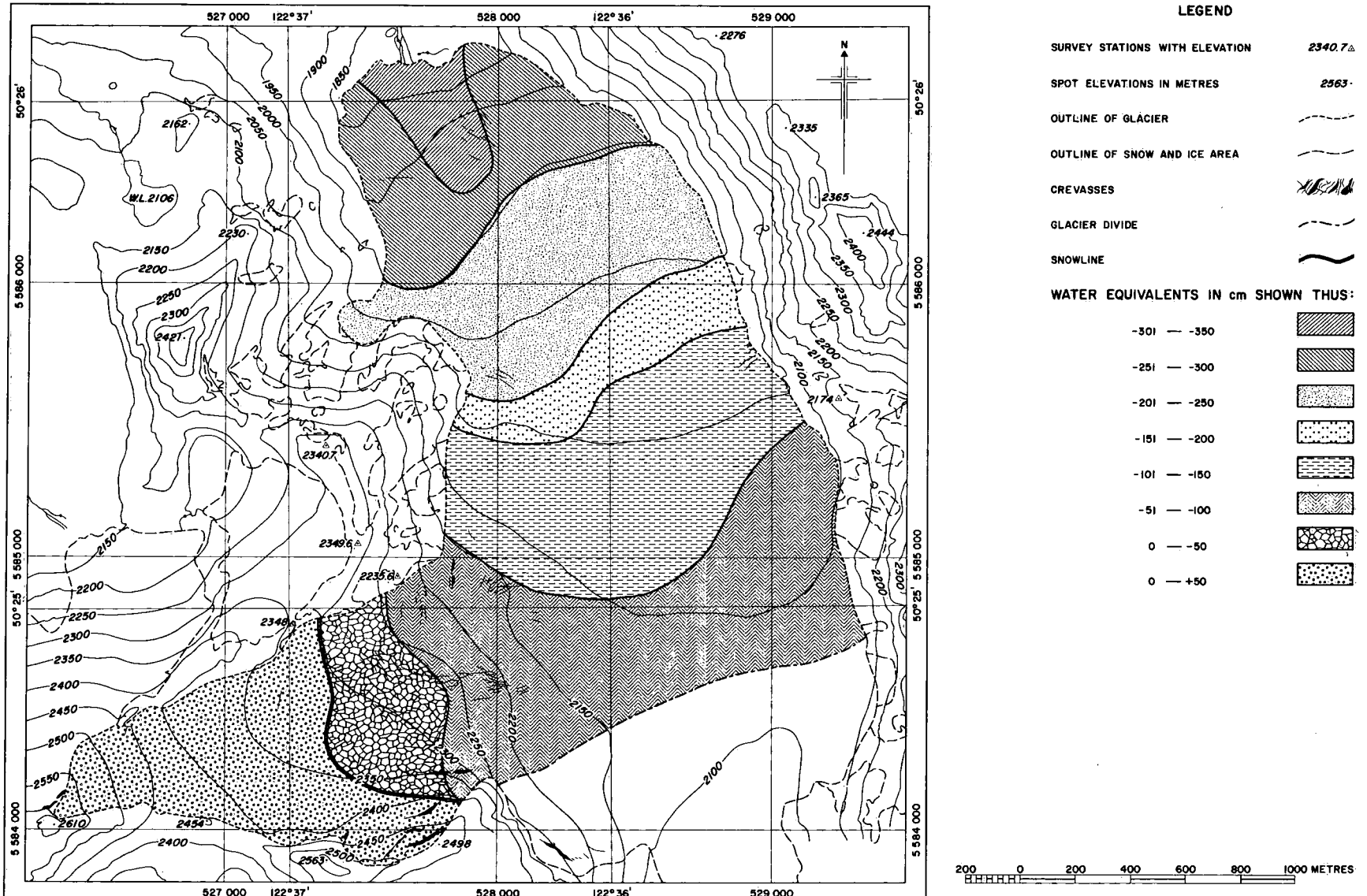


Figure II-9. Map of net balance, May 31 to October 16, 1967.

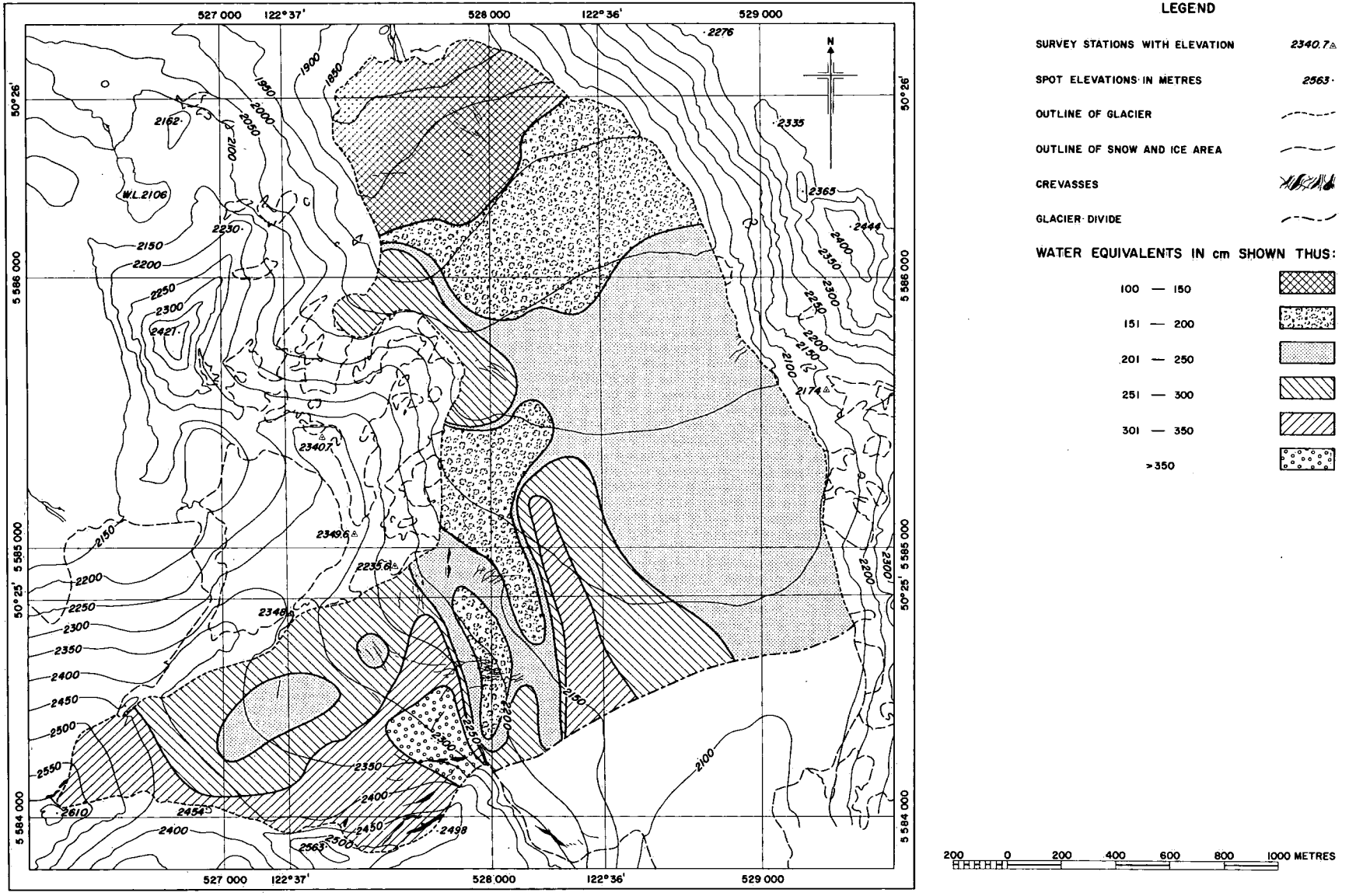


Figure II-10. Map of winter balance to June 5, 1968.

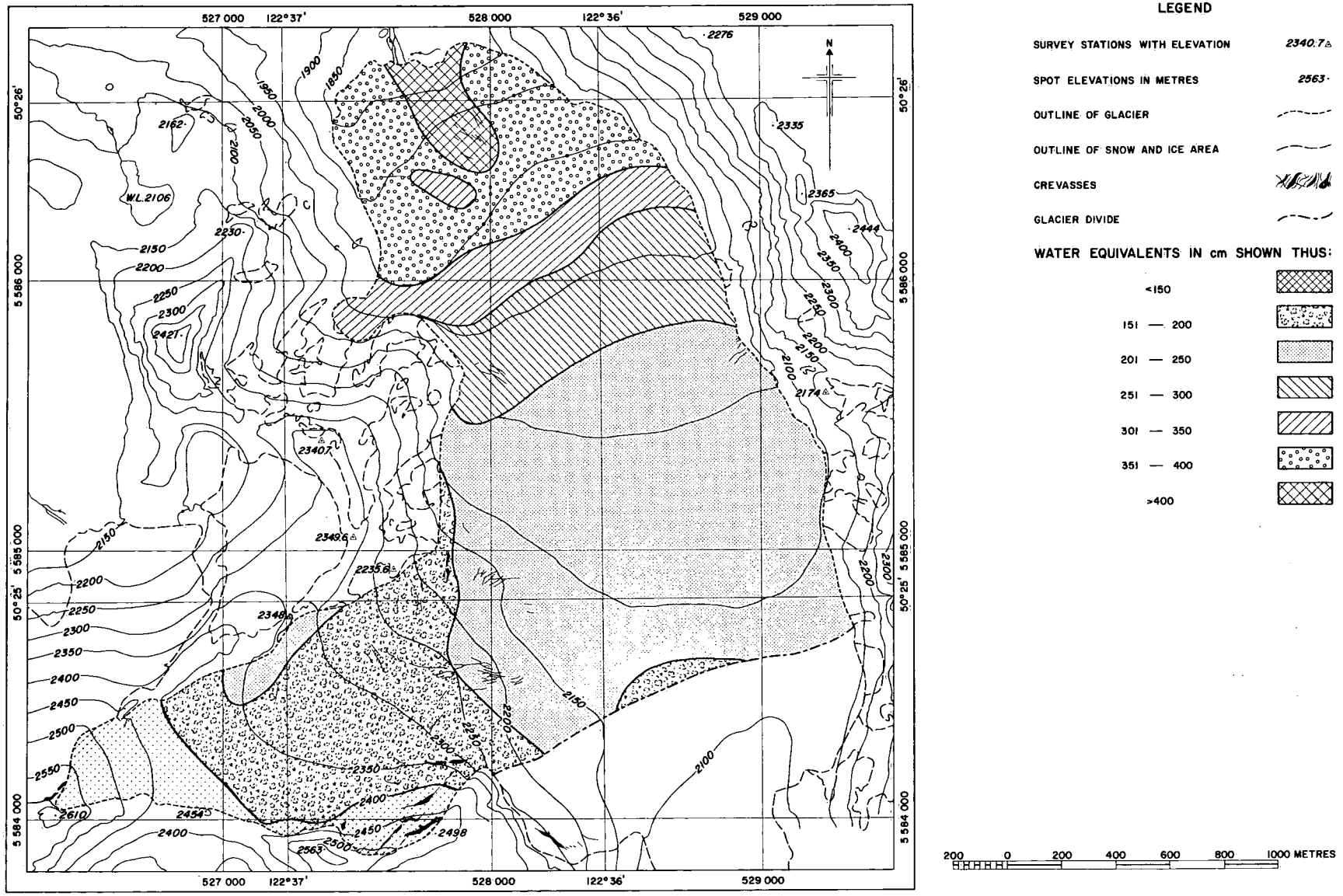


Figure II-11. Map of summer balance to October 1, 1968.

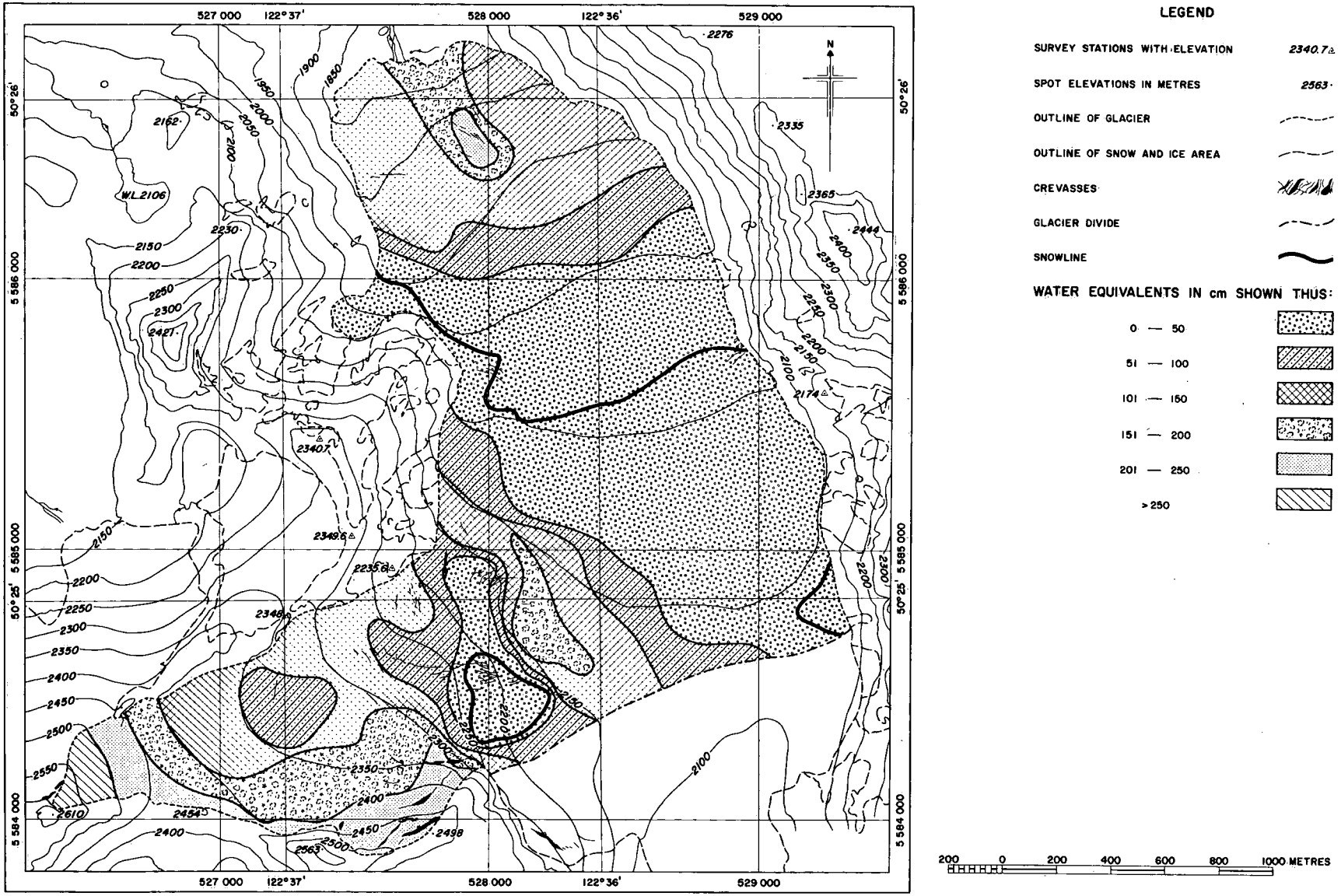


Figure II-12. Map of net balance, May 28 to October 1, 1968.

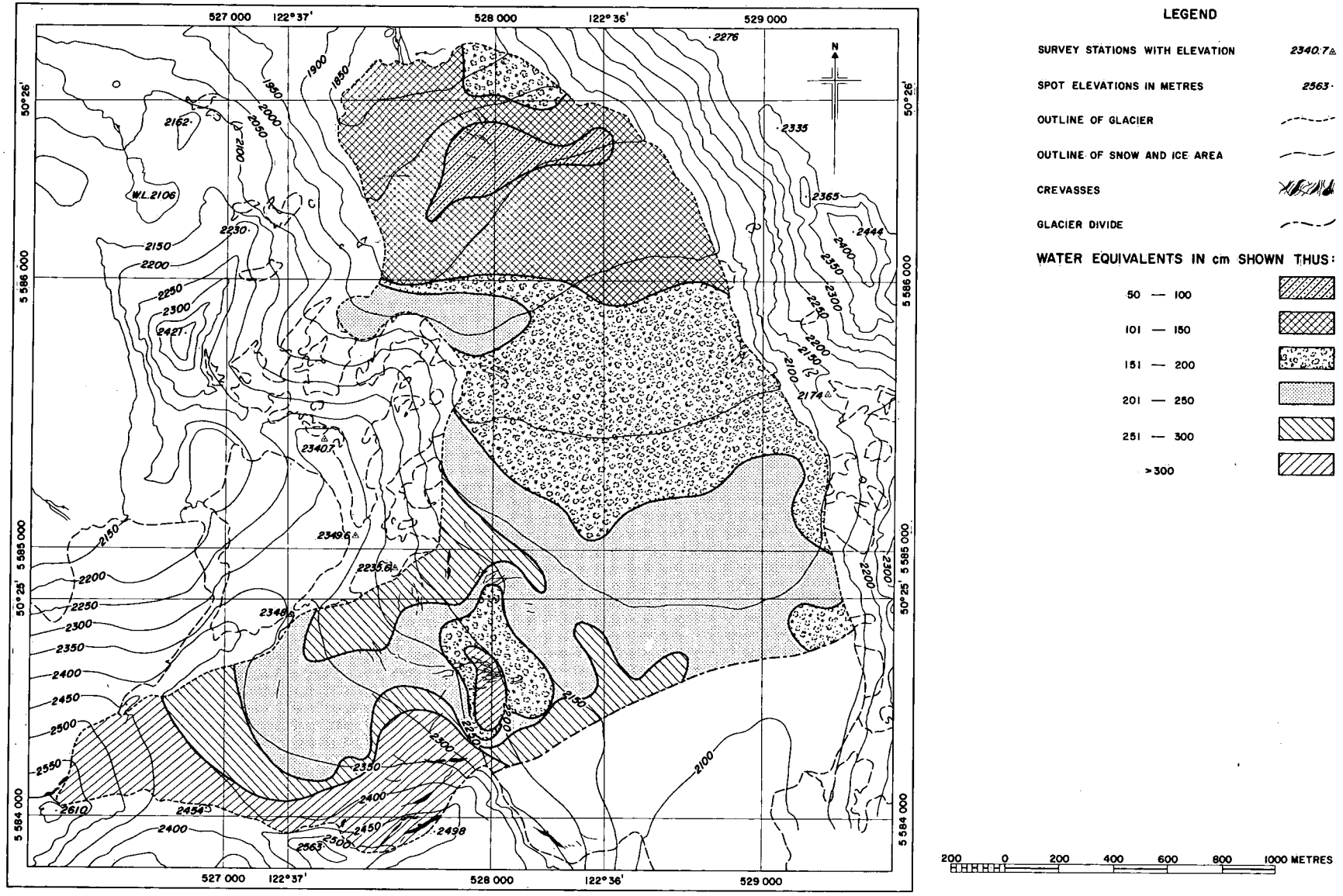


Figure II-13. Map of winter balance to June 6, 1969.

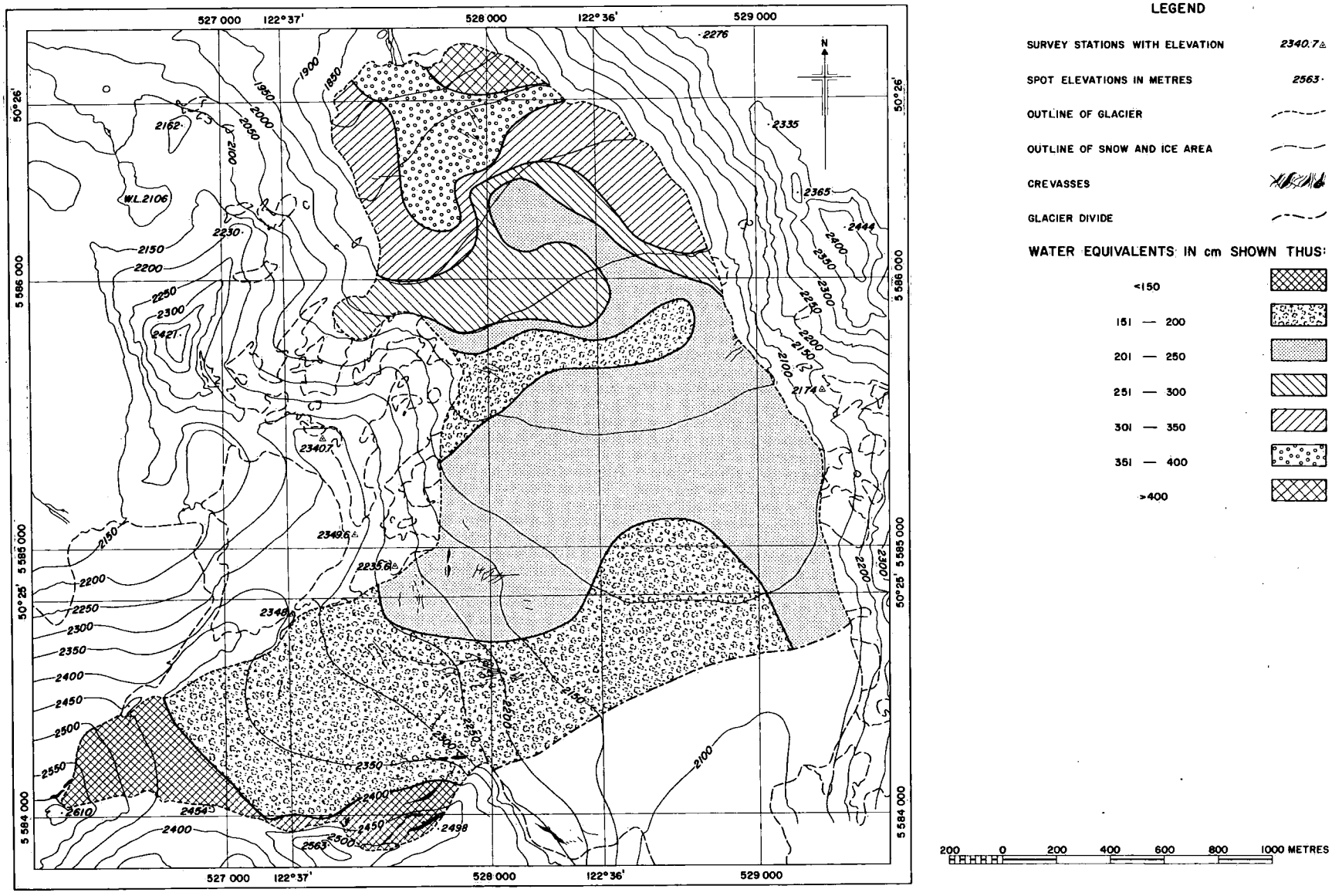


Figure II-14. Map of summer balance to September 29, 1969.

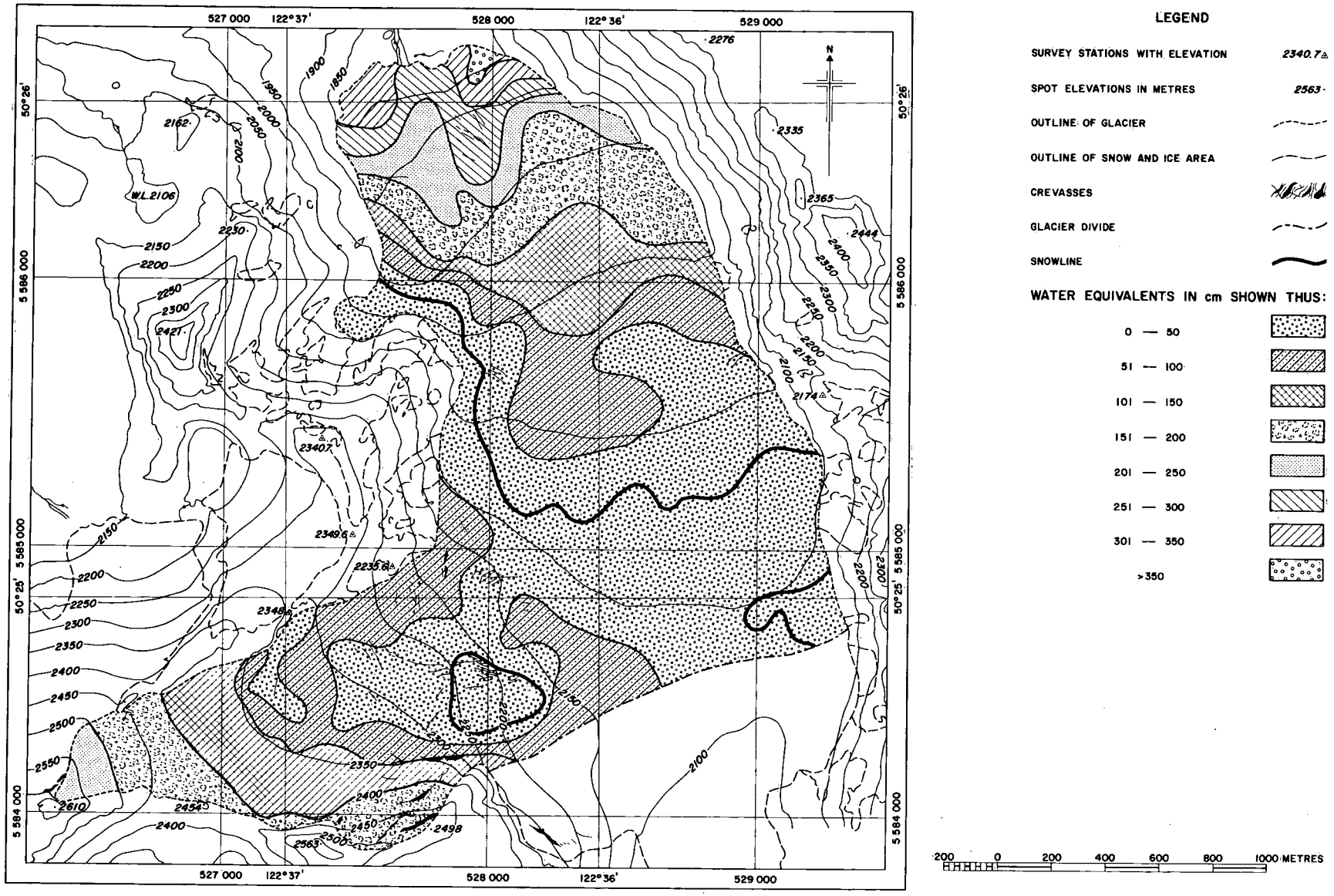
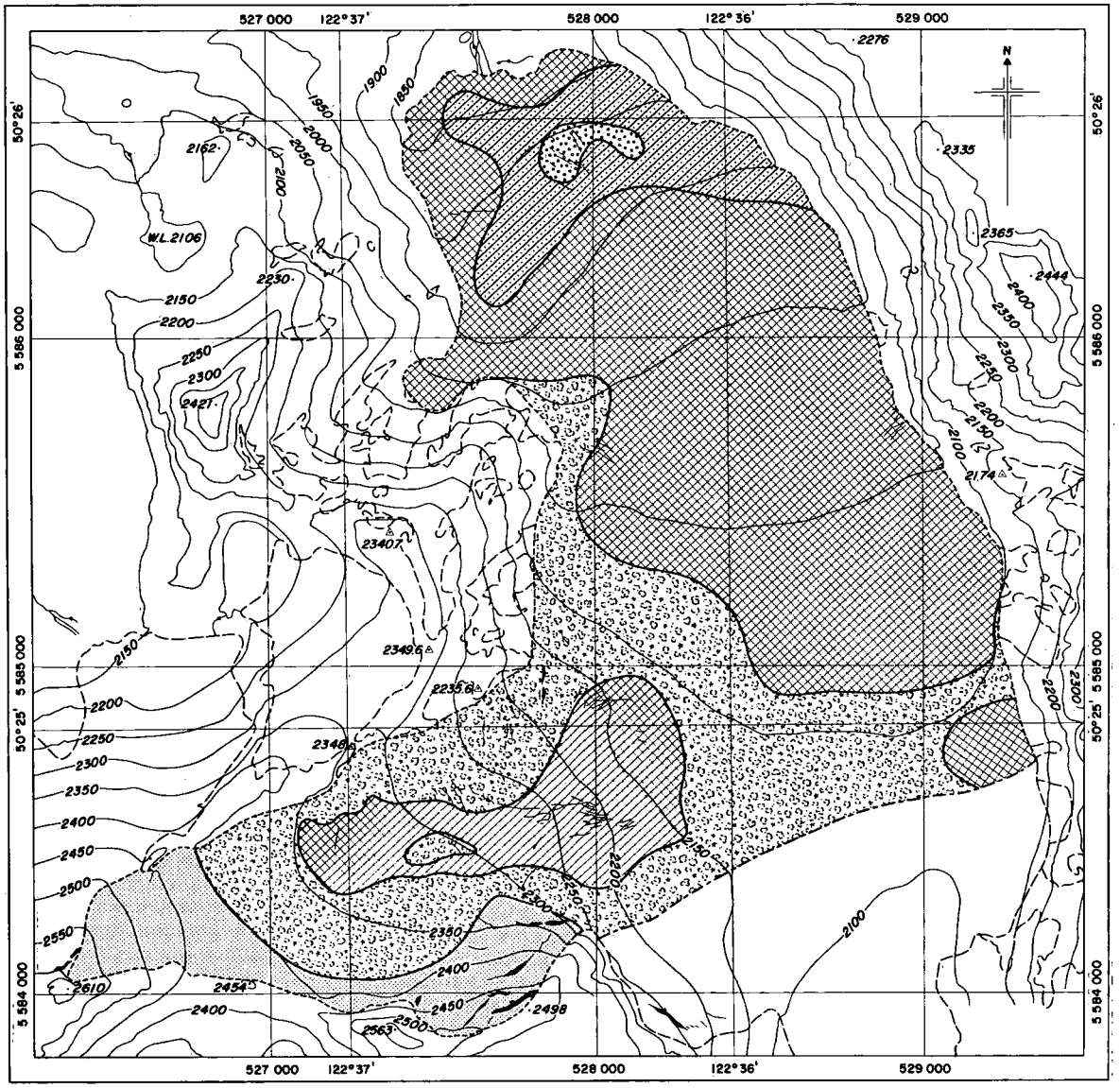


Figure II-15. Map of net balance, June 8 to October 1, 1969.



LEGEND

SURVEY STATIONS WITH ELEVATION 2340.7△

SPOT ELEVATIONS IN METRES 2563

OUTLINE OF GLACIER

OUTLINE OF SNOW AND ICE AREA

CREVASSES

GLACIER DIVIDE

WATER EQUIVALENTS IN cm SHOWN THUS:

0 — 50

51 — 100

101 — 150

151 — 200

>200

200 0 200 400 600 800 1000 METRES

Figure II-16. Map of winter balance to May 23, 1970.

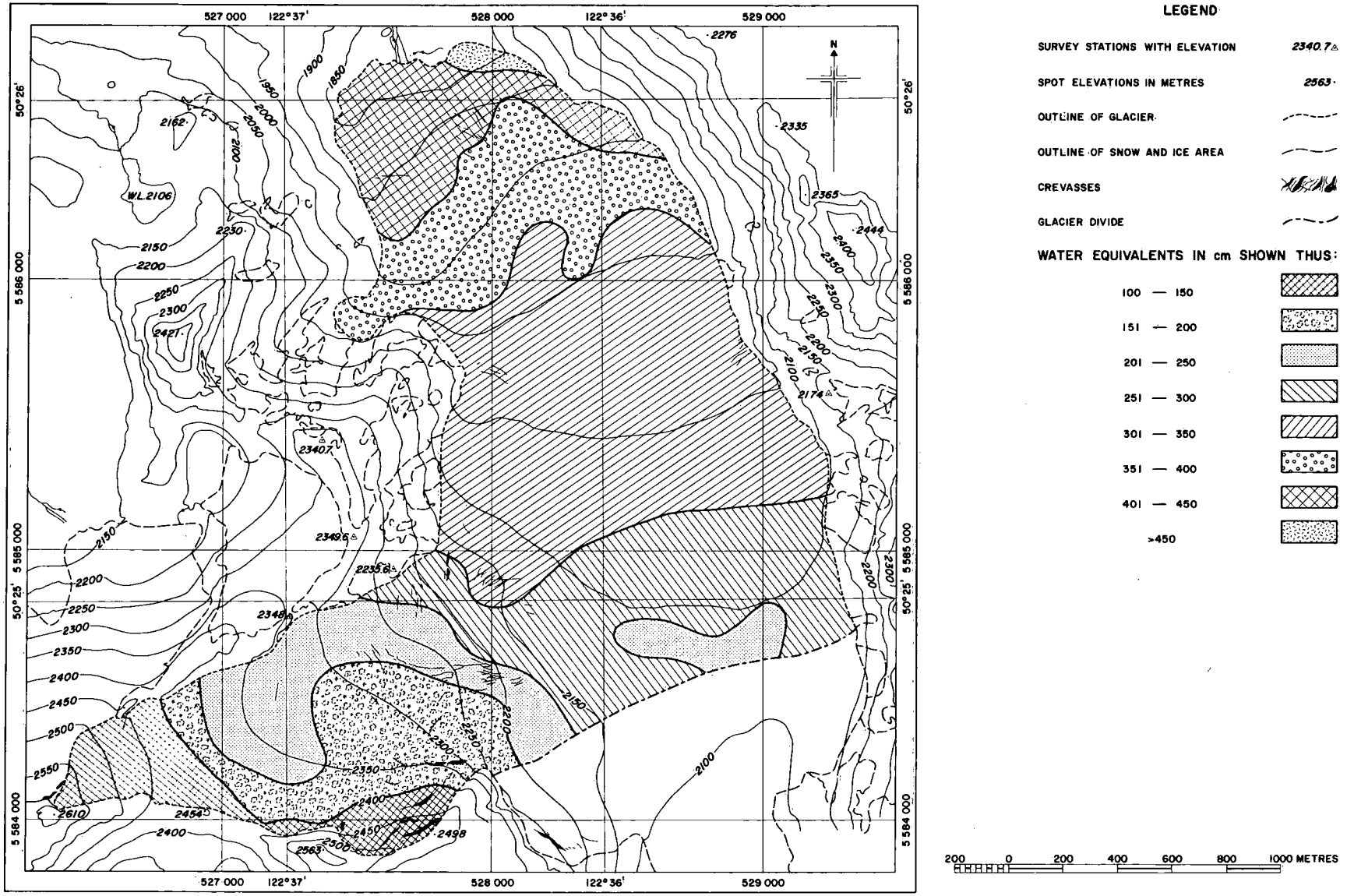


Figure II-17. Map of summer balance to September 19, 1970.

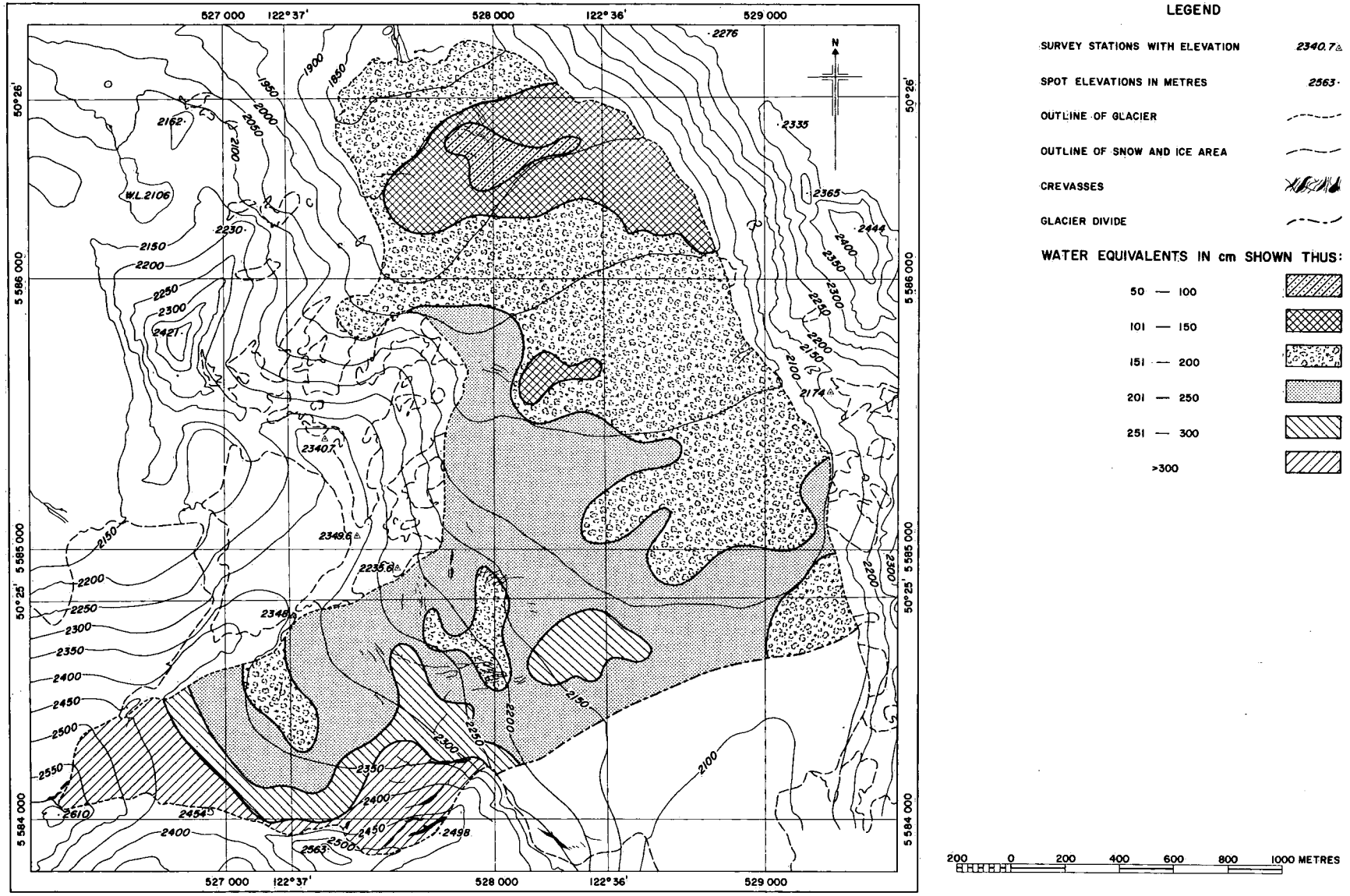


Figure II-18. Map of winter balance to May 27, 1971.

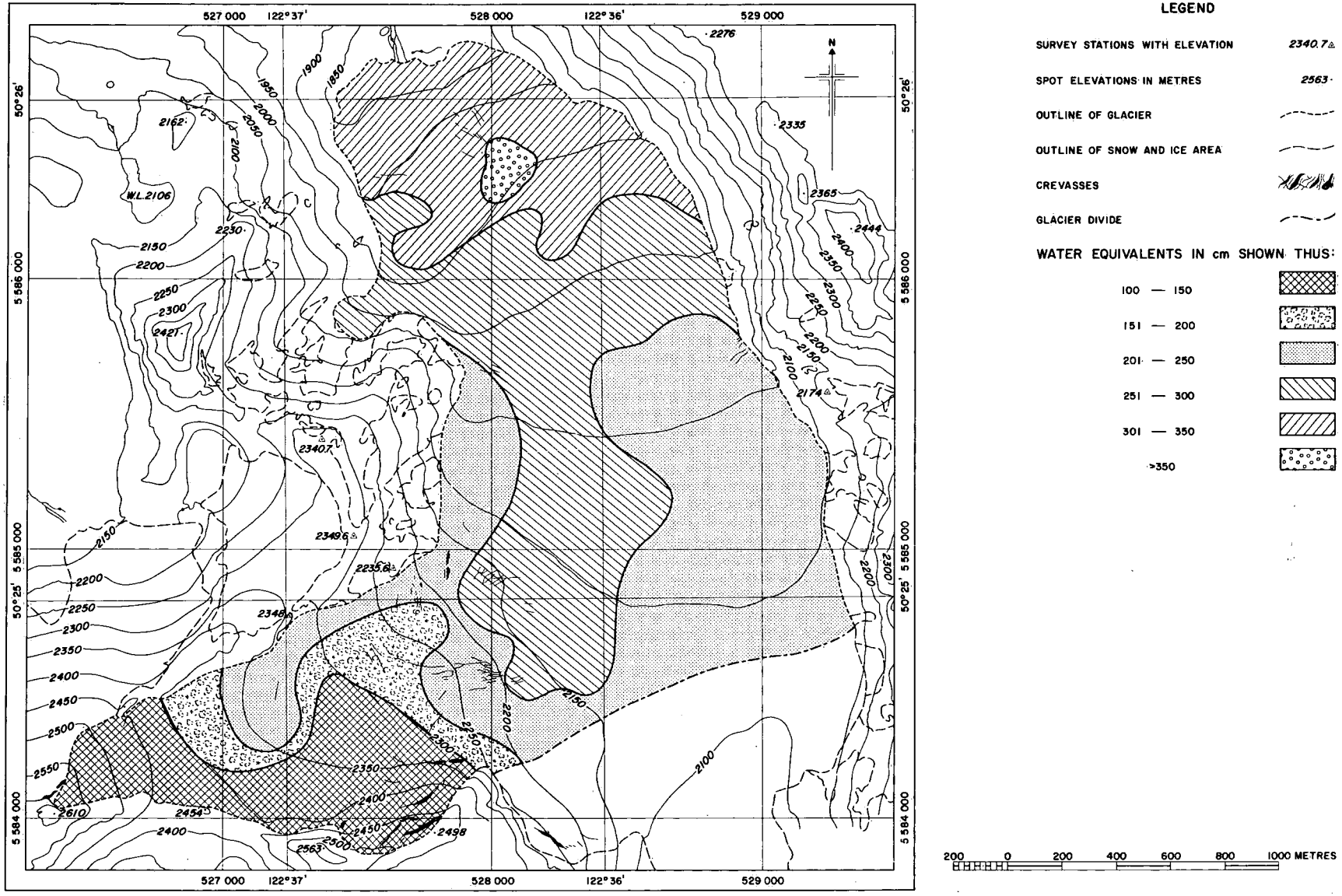


Figure II-19. Map of summer balance to October 7, 1971.

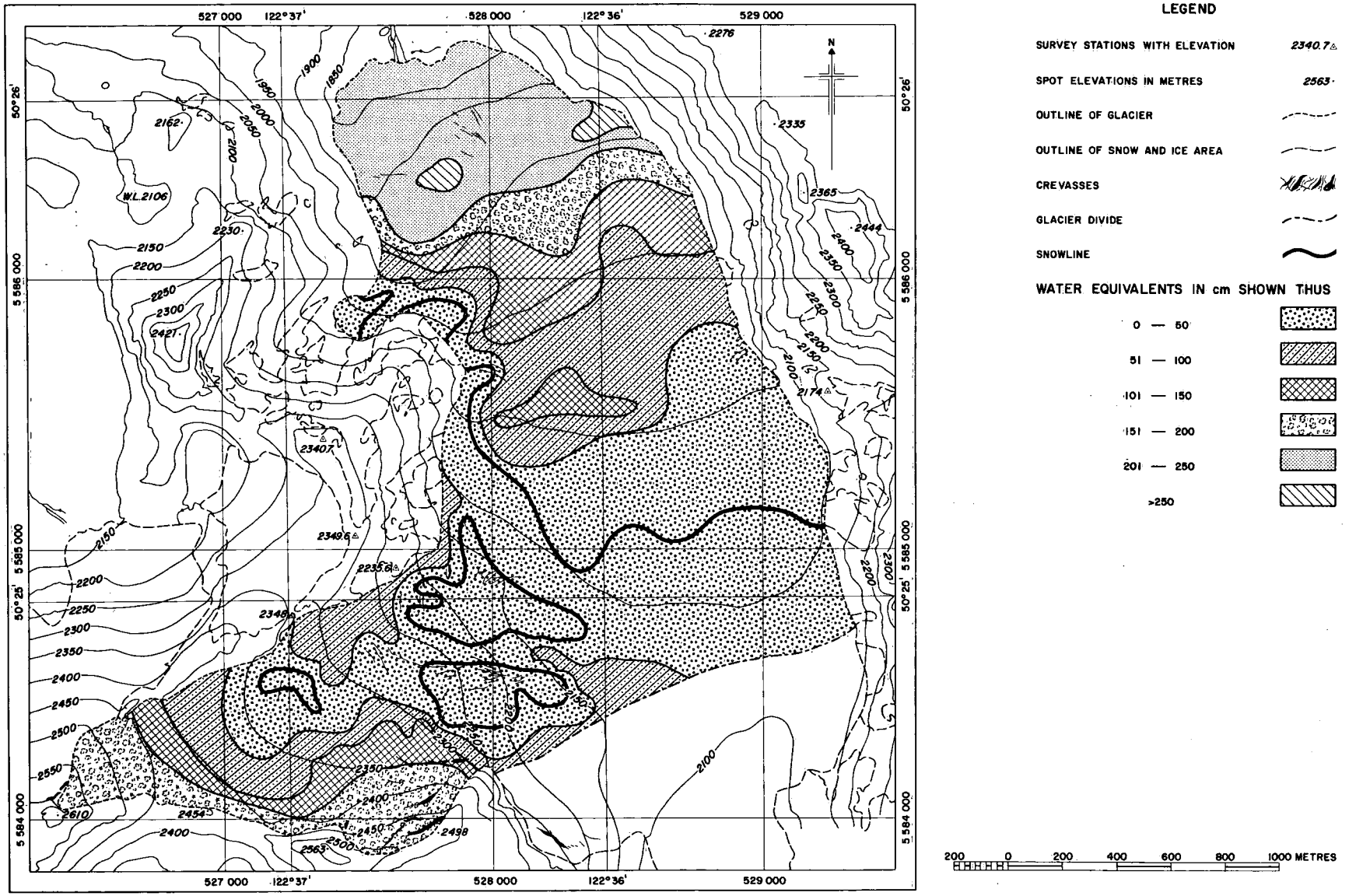


Figure II-20. Map of net balance, May 27 to October 7, 1971.

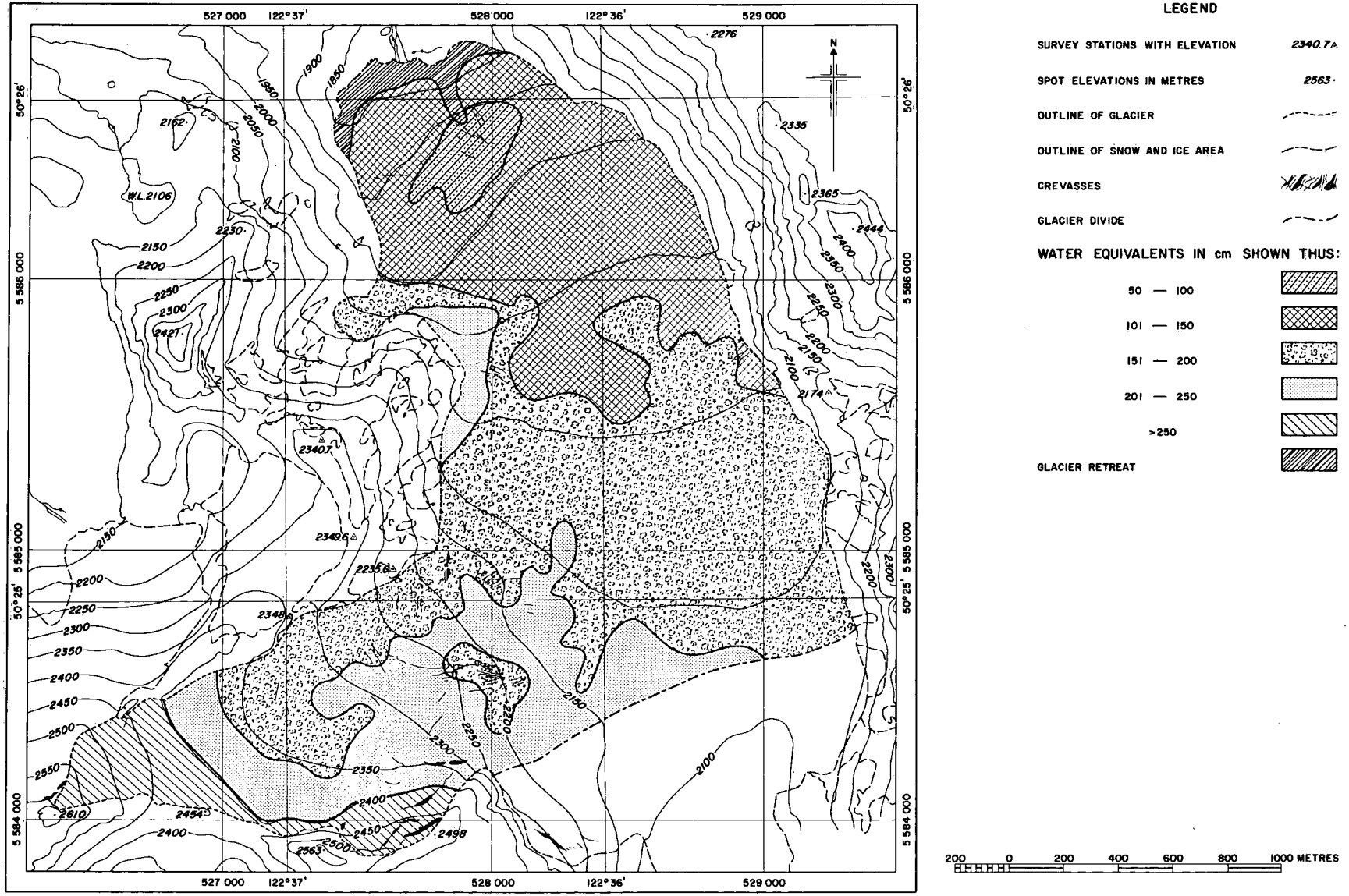


Figure II-21. Map of winter balance, June 14, 1972.

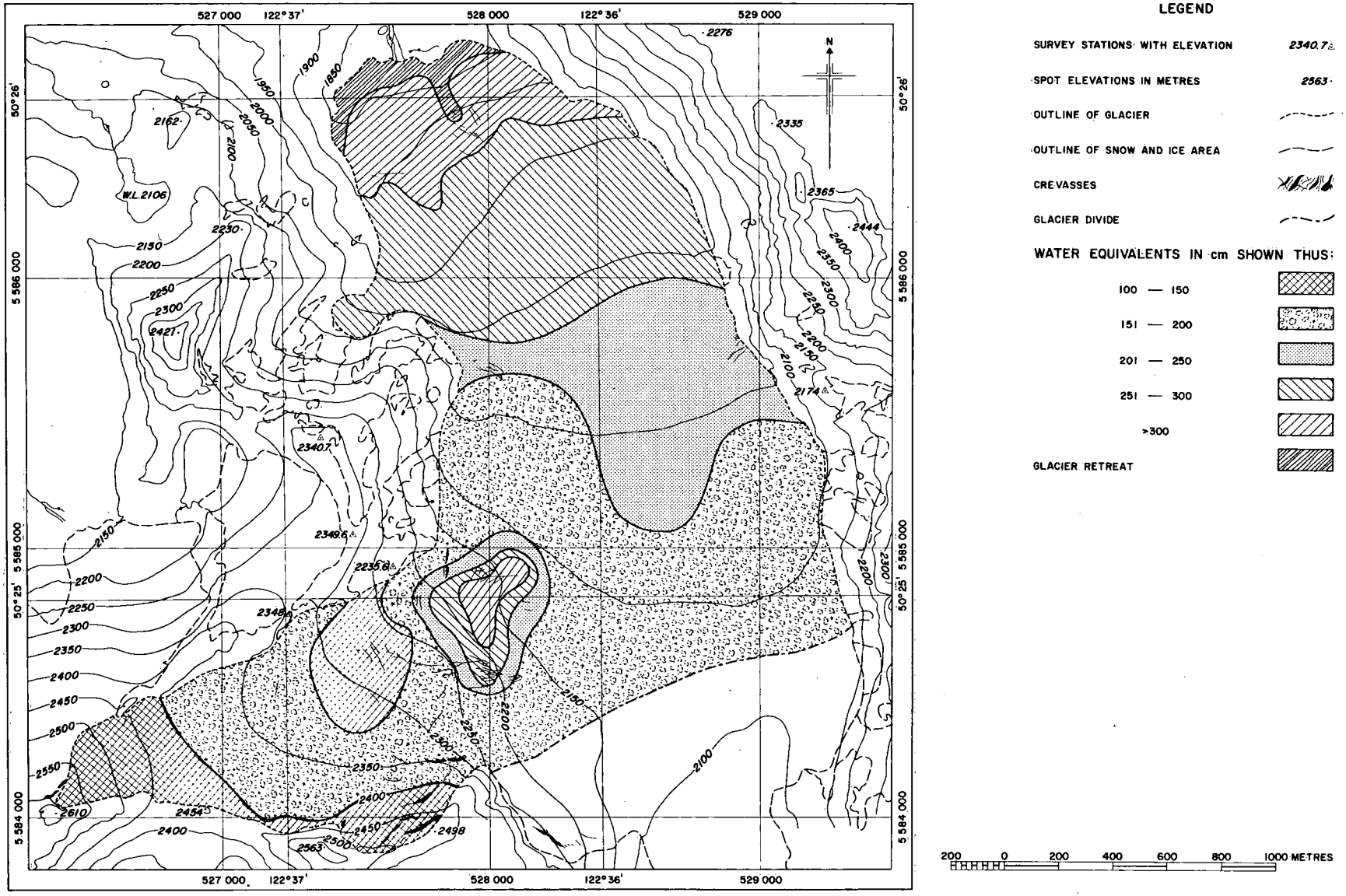


Figure II-22. Map of summer balance to October 1, 1972.

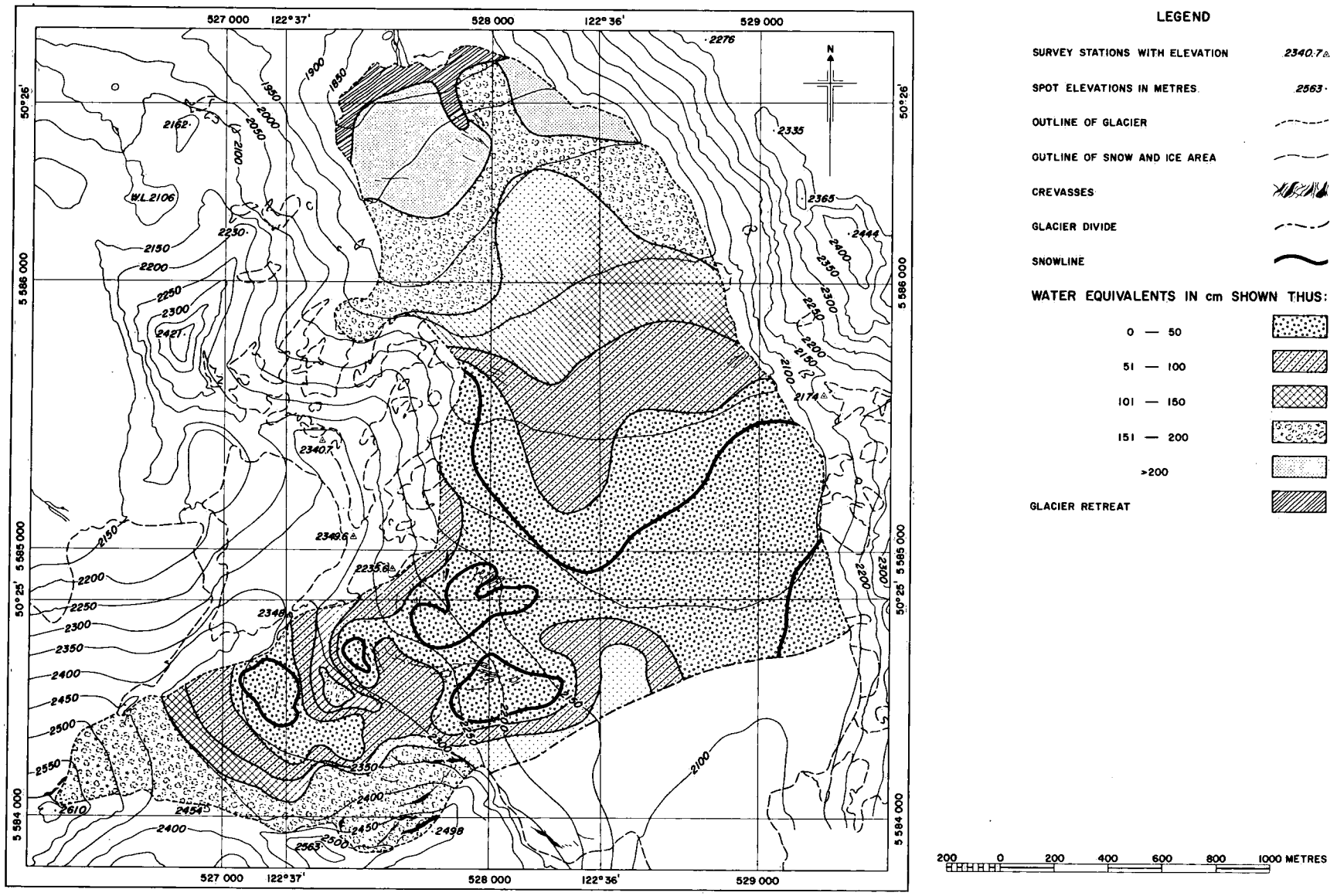
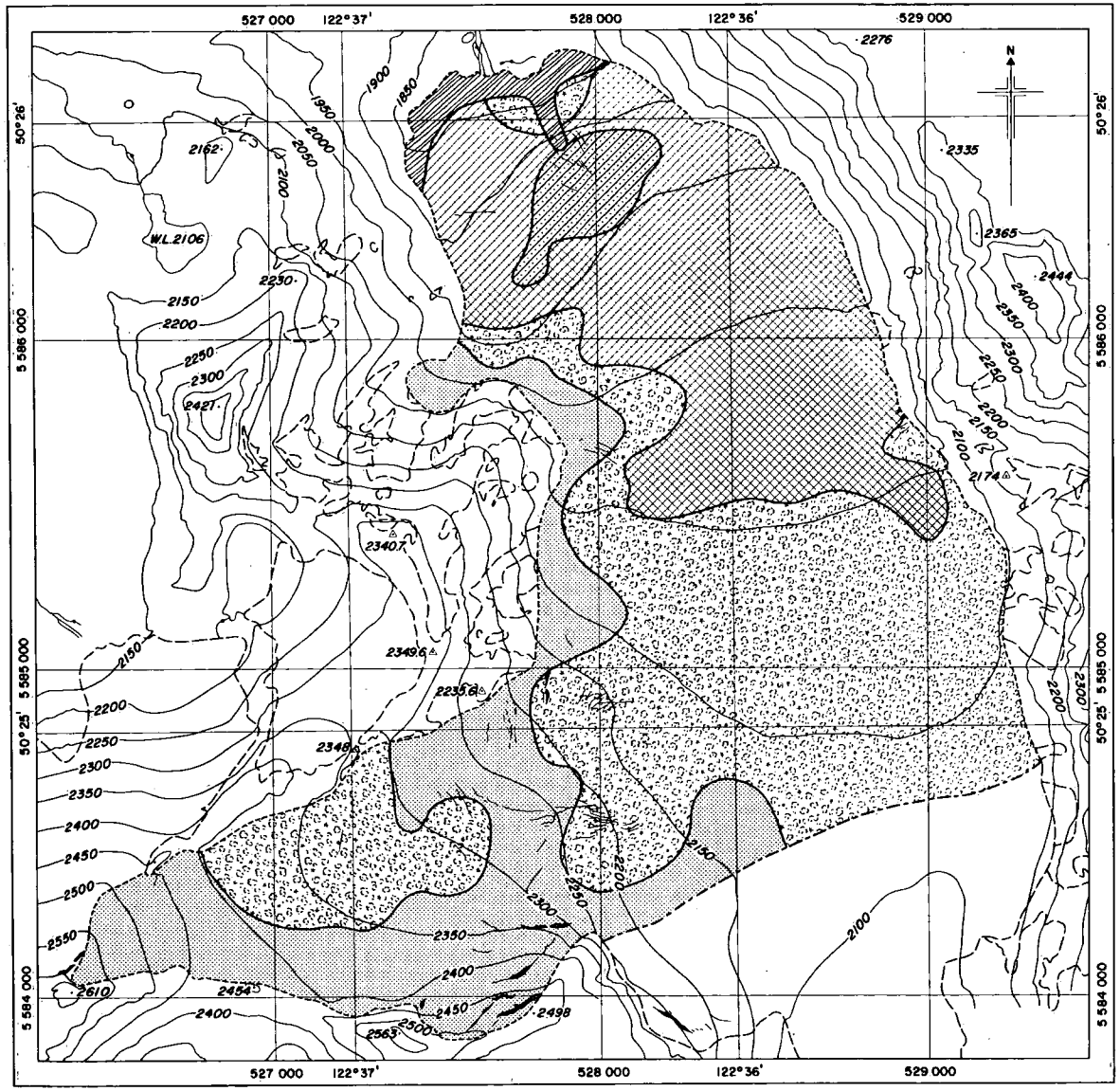


Figure II-23. Map of net balance, June 14 to October 1, 1972.



LEGEND

SURVEY STATIONS WITH ELEVATION 2340.7△

SPOT ELEVATIONS IN METRES 2563

OUTLINE OF GLACIER

OUTLINE OF SNOW AND ICE AREA

CREVASSES

GLACIER DIVIDE

WATER EQUIVALENTS IN cm SHOWN THUS:

50 — 100

101 — 150

151 — 200

>200

GLACIER RETREAT

200 0 200 400 600 800 1000 METRES

Figure II-24. Map of winter balance to May 25, 1973.

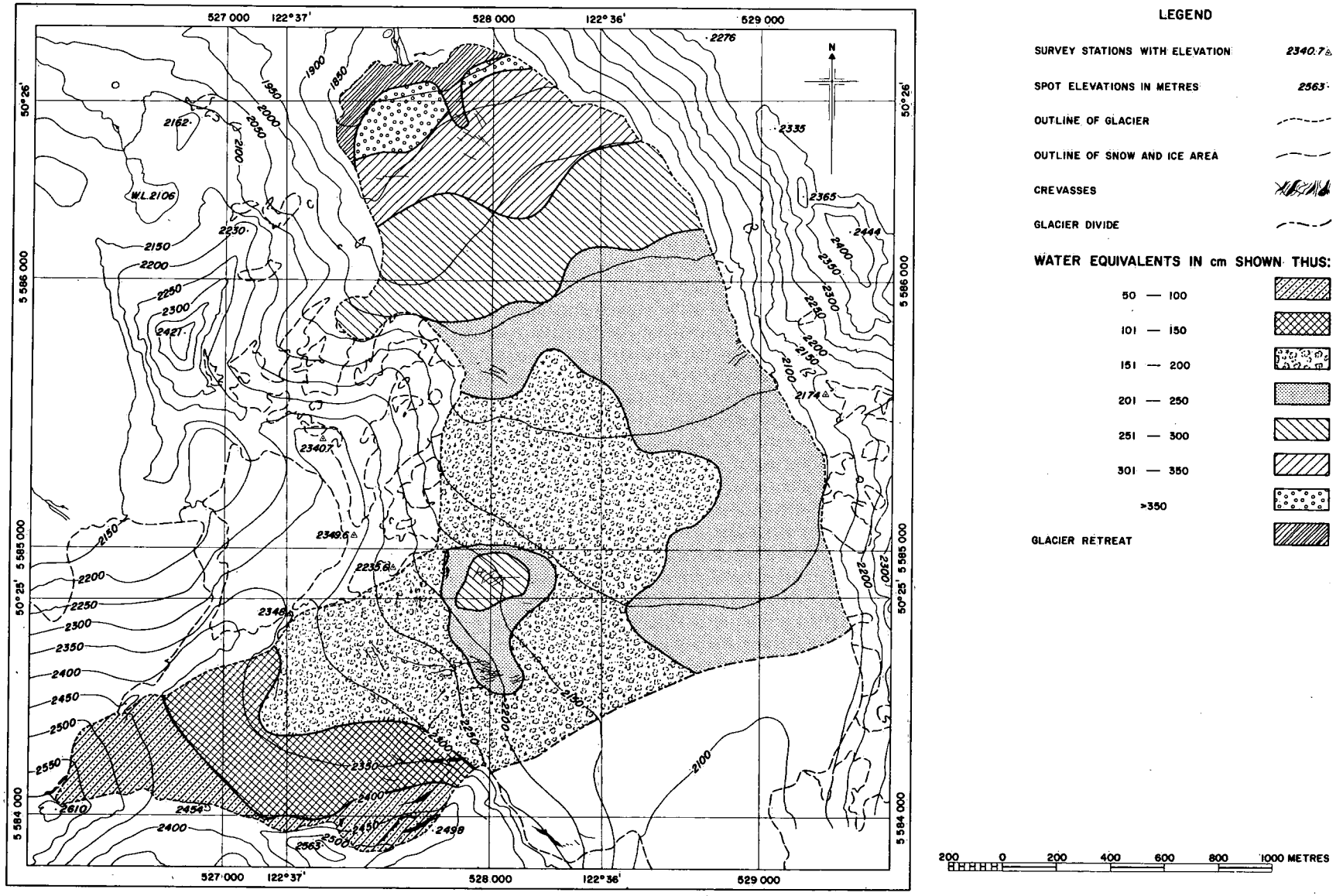
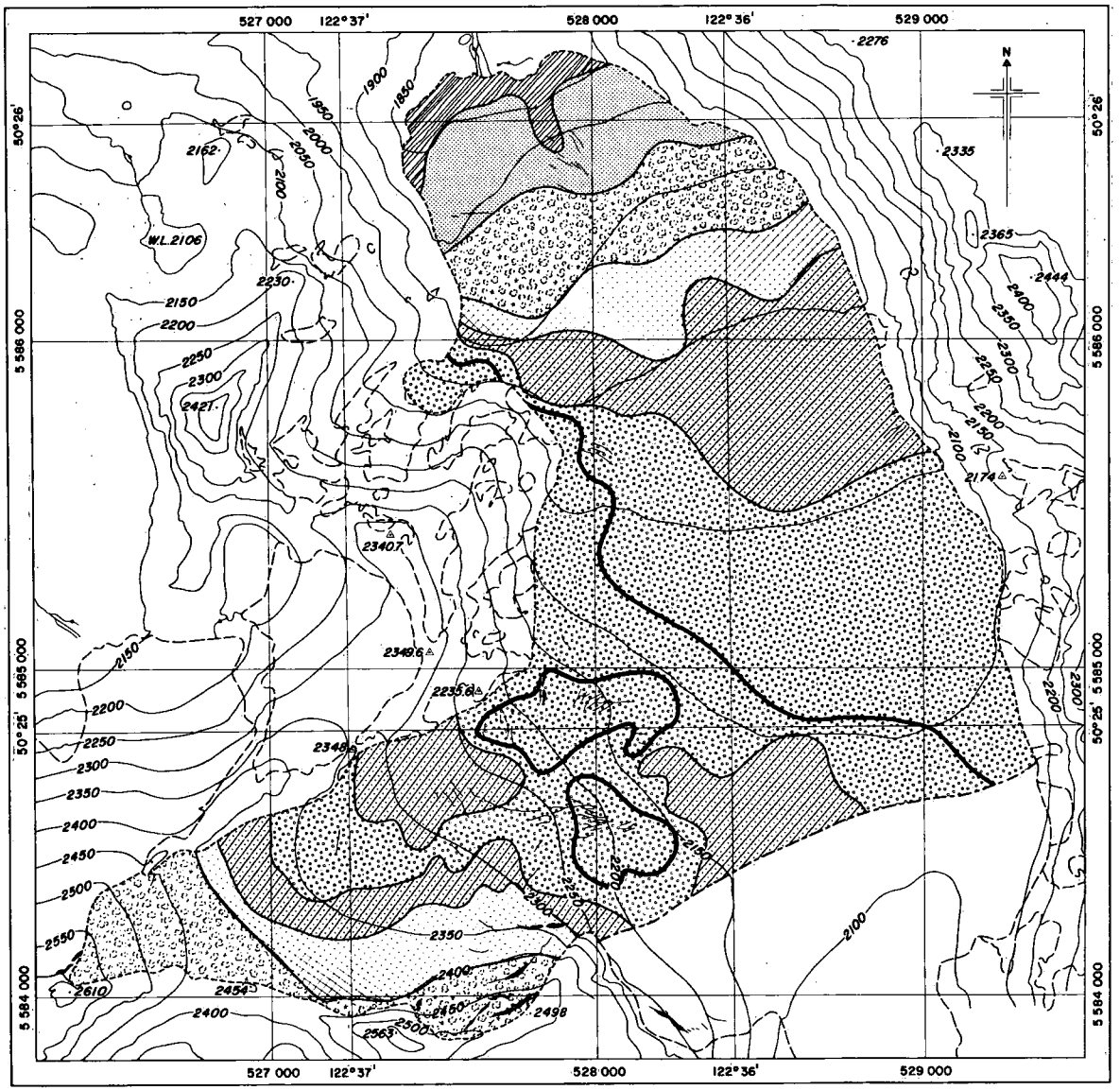


Figure II-25. Map of summer balance to October 1, 1973.



LEGEND

SURVEY STATIONS WITH ELEVATION 2340.7△

SPOT ELEVATIONS IN METRES 2563

OUTLINE OF GLACIER

OUTLINE OF SNOW AND ICE AREA

CREVASSES

GLACIER DIVIDE

SNOWLINE

WATER EQUIVALENTS IN cm SHOWN THUS:

0 — 50

51 — 100

101 — 150

151 — 200

>200

GLACIER RETREAT

200 0 200 400 600 800 1000 METRES

Figure II-26. Map of net balance, May 25 to October 1, 1973.

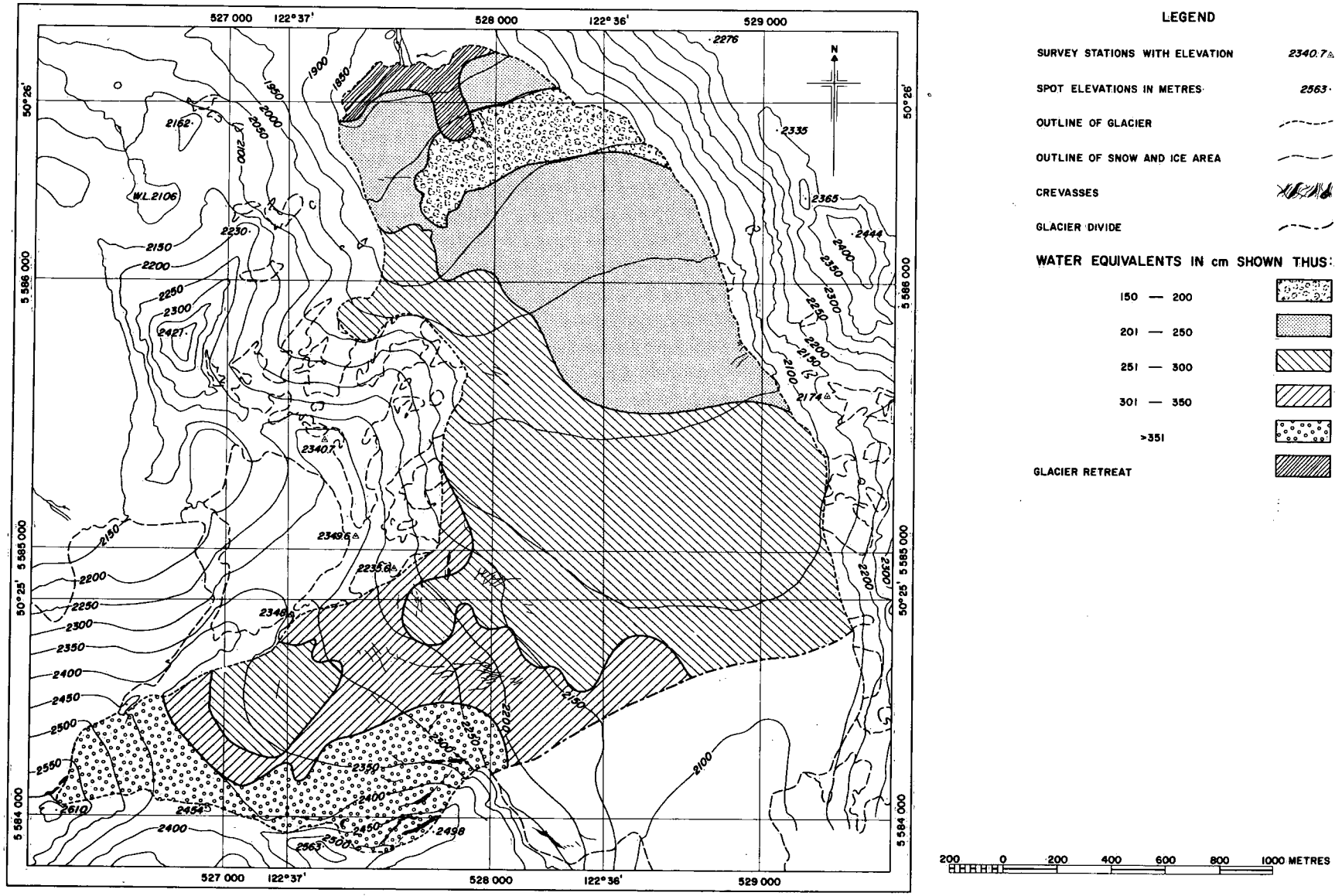


Figure II-27. Map of winter balance to June 7, 1974.

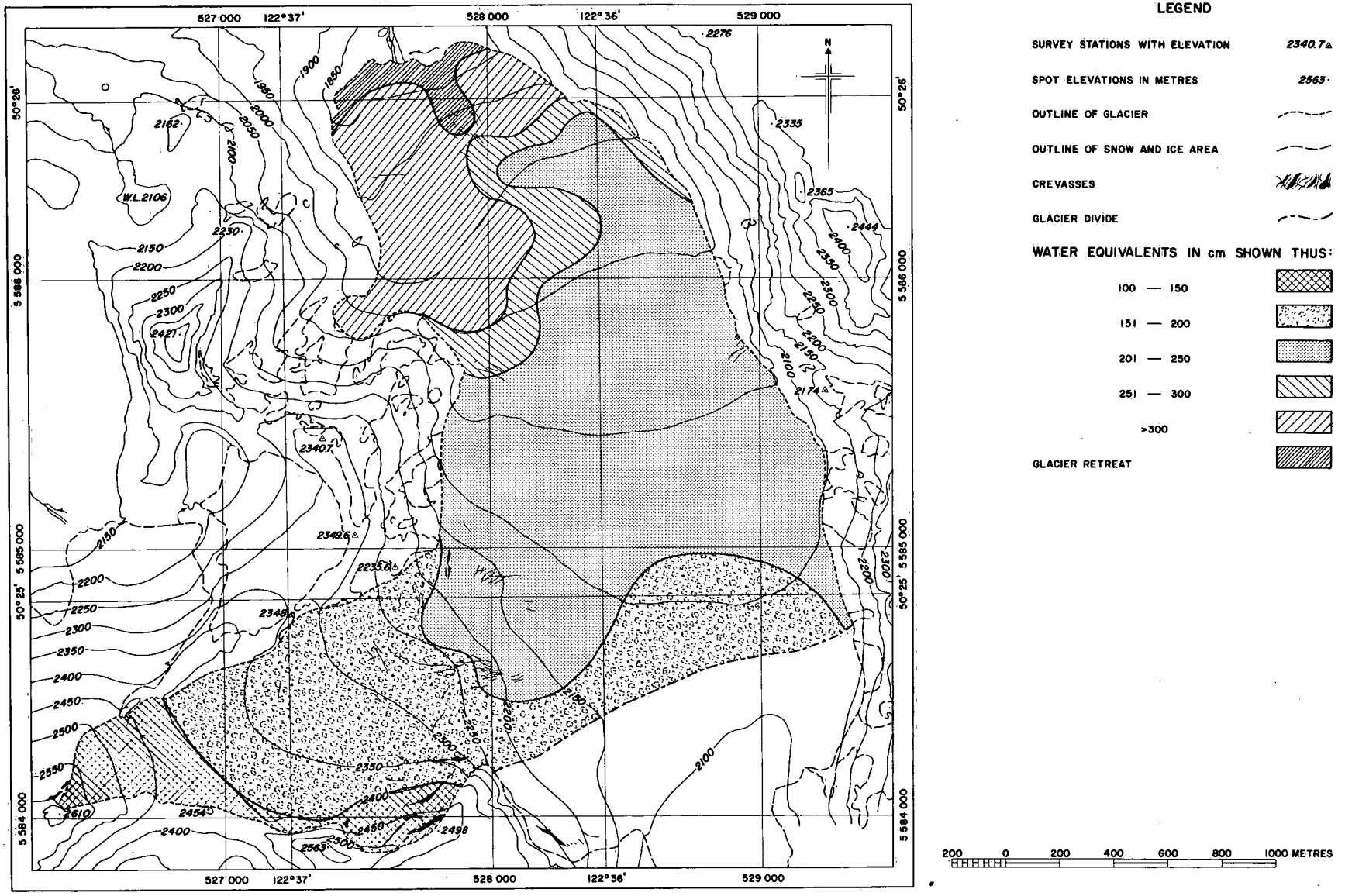


Figure II-28. Map of summer balance to October 11, 1974.

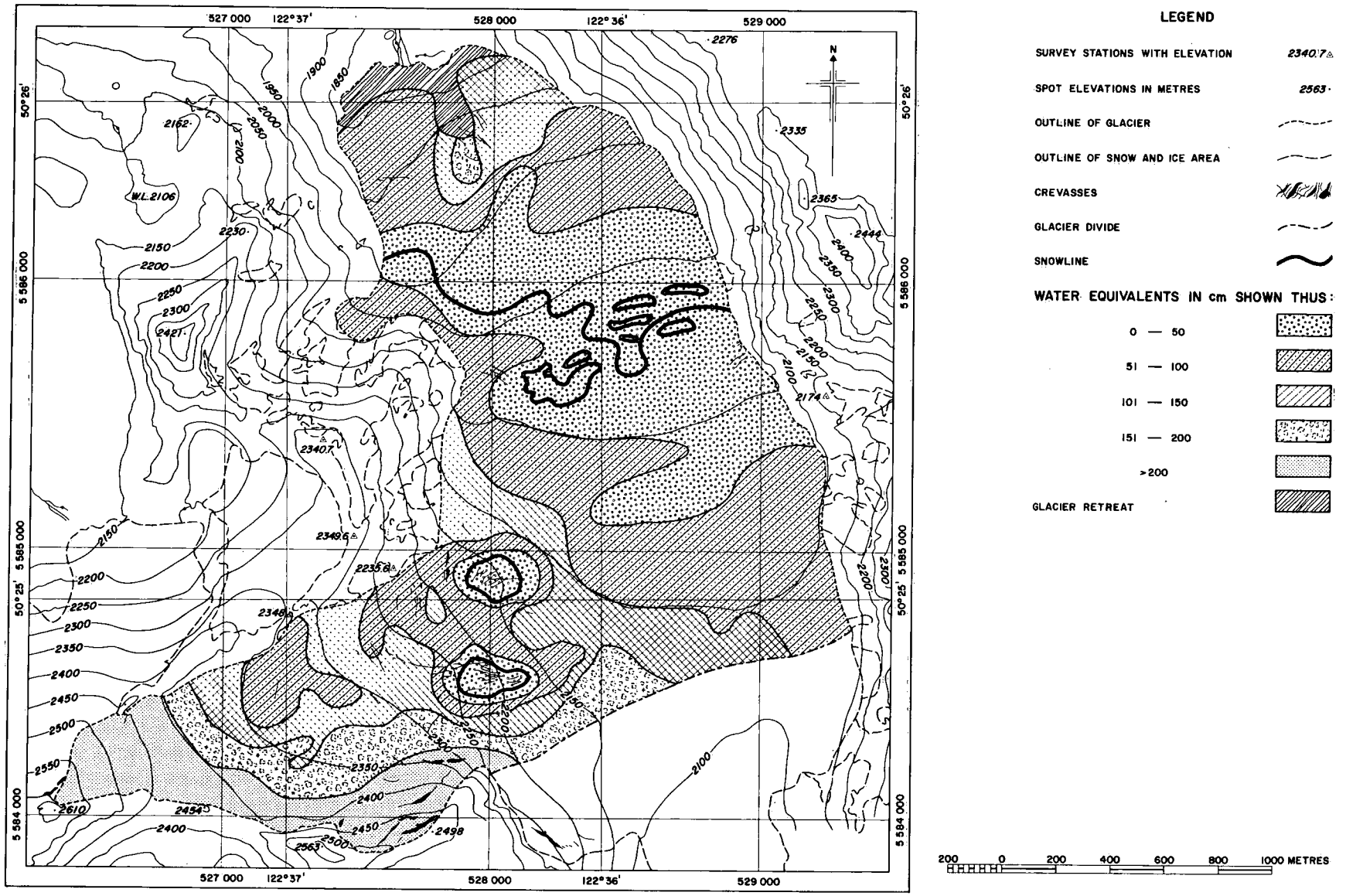


Figure II-29. Map of net balance, June 7 to October 11, 1974.

Appendix III

Glaciological graphs and tables

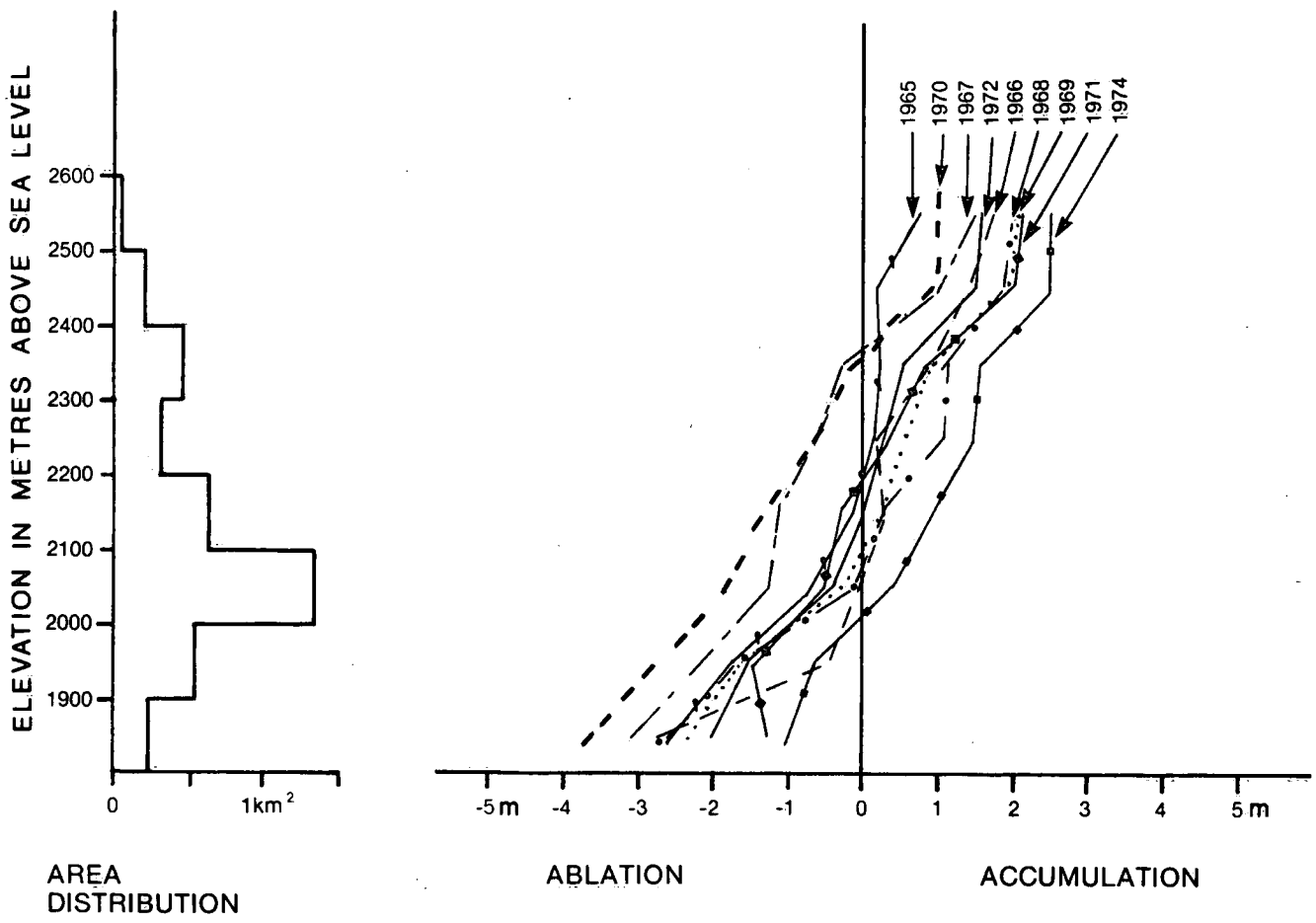


Figure III-1. Variation of net balance with elevation, 1965-74.

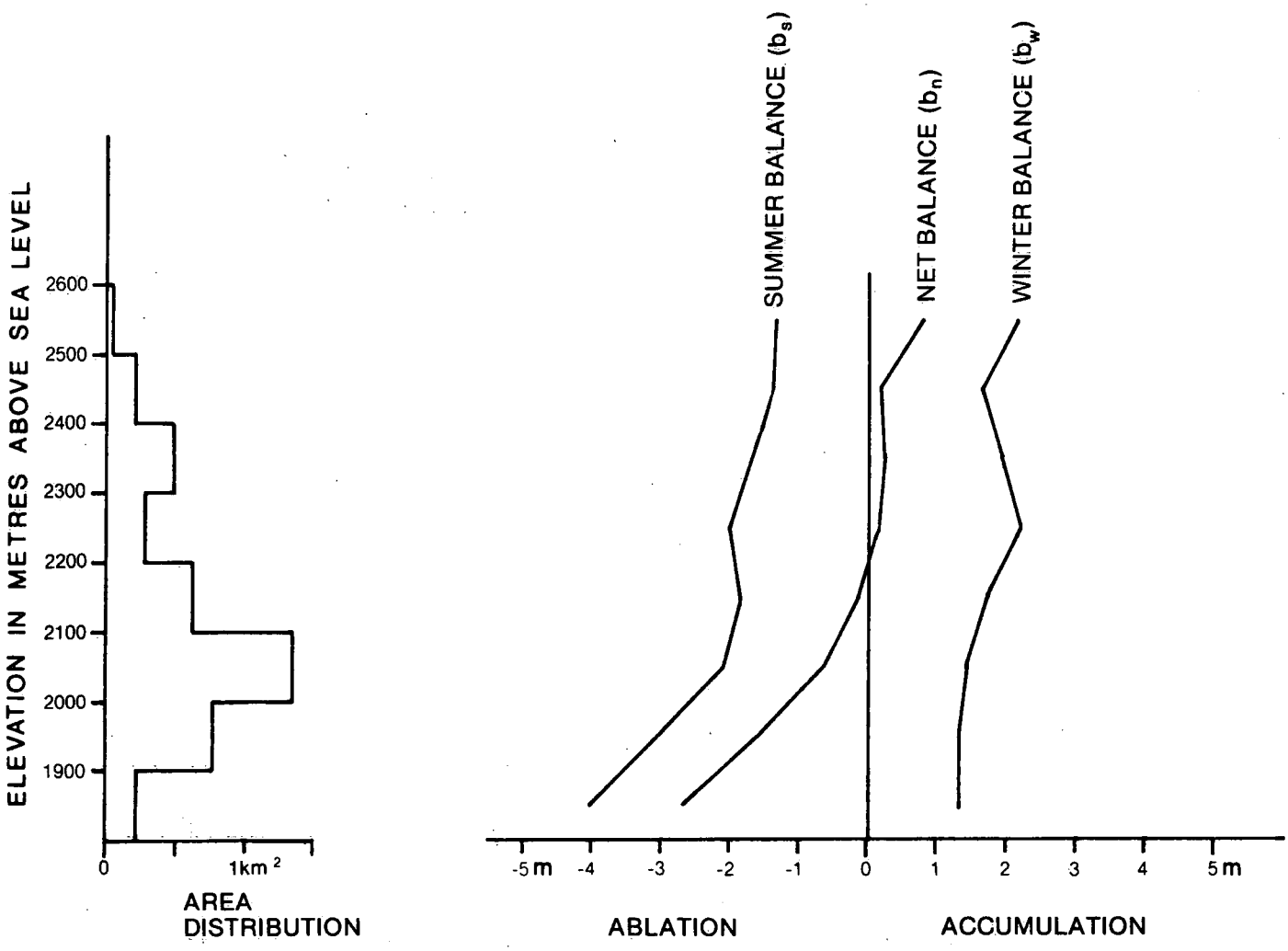


Figure III-2. Variation of winter, summer and net balances with elevation, 1964-65.

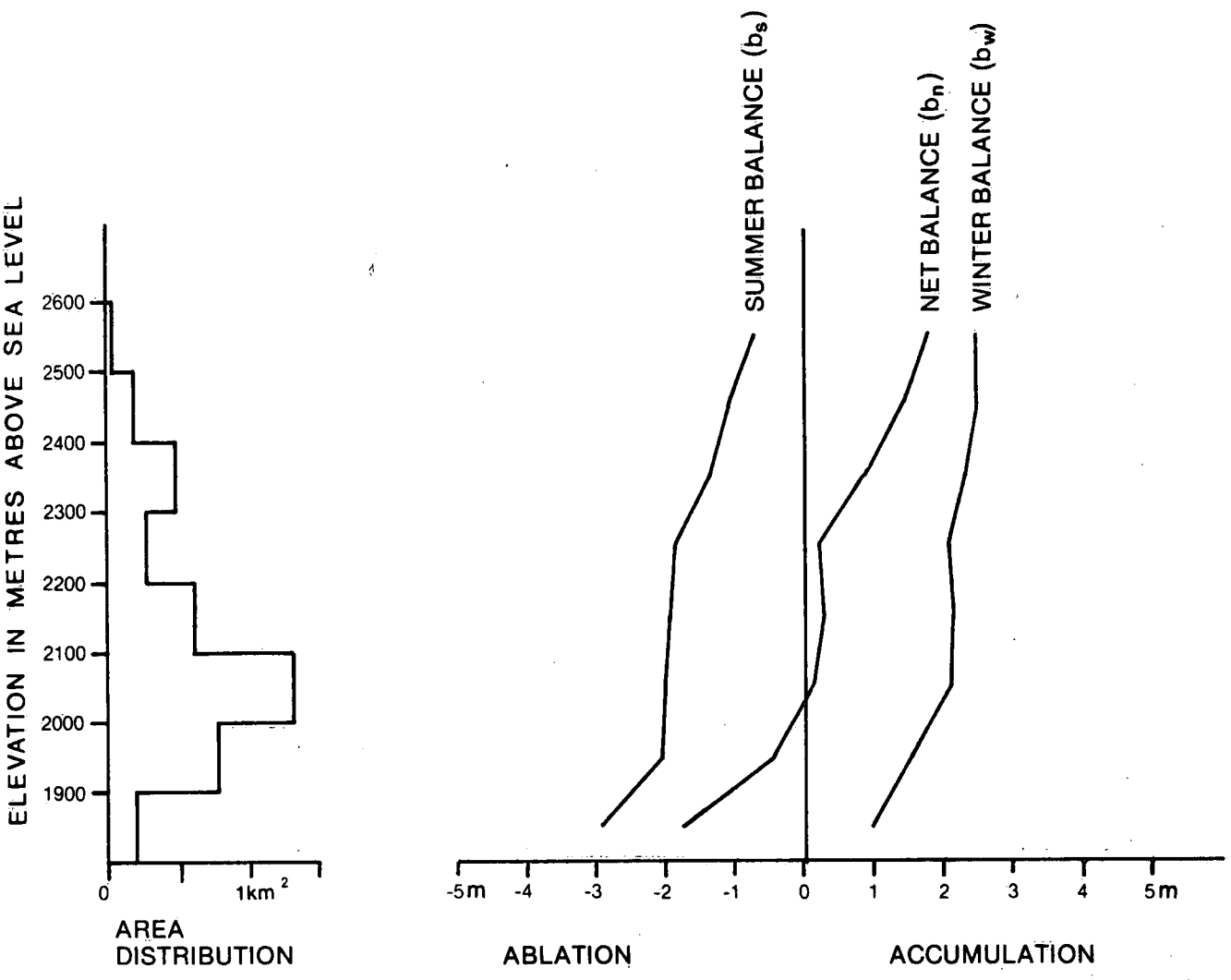


Figure III-3. Variation of winter, summer and net balances with elevation, 1965-66.

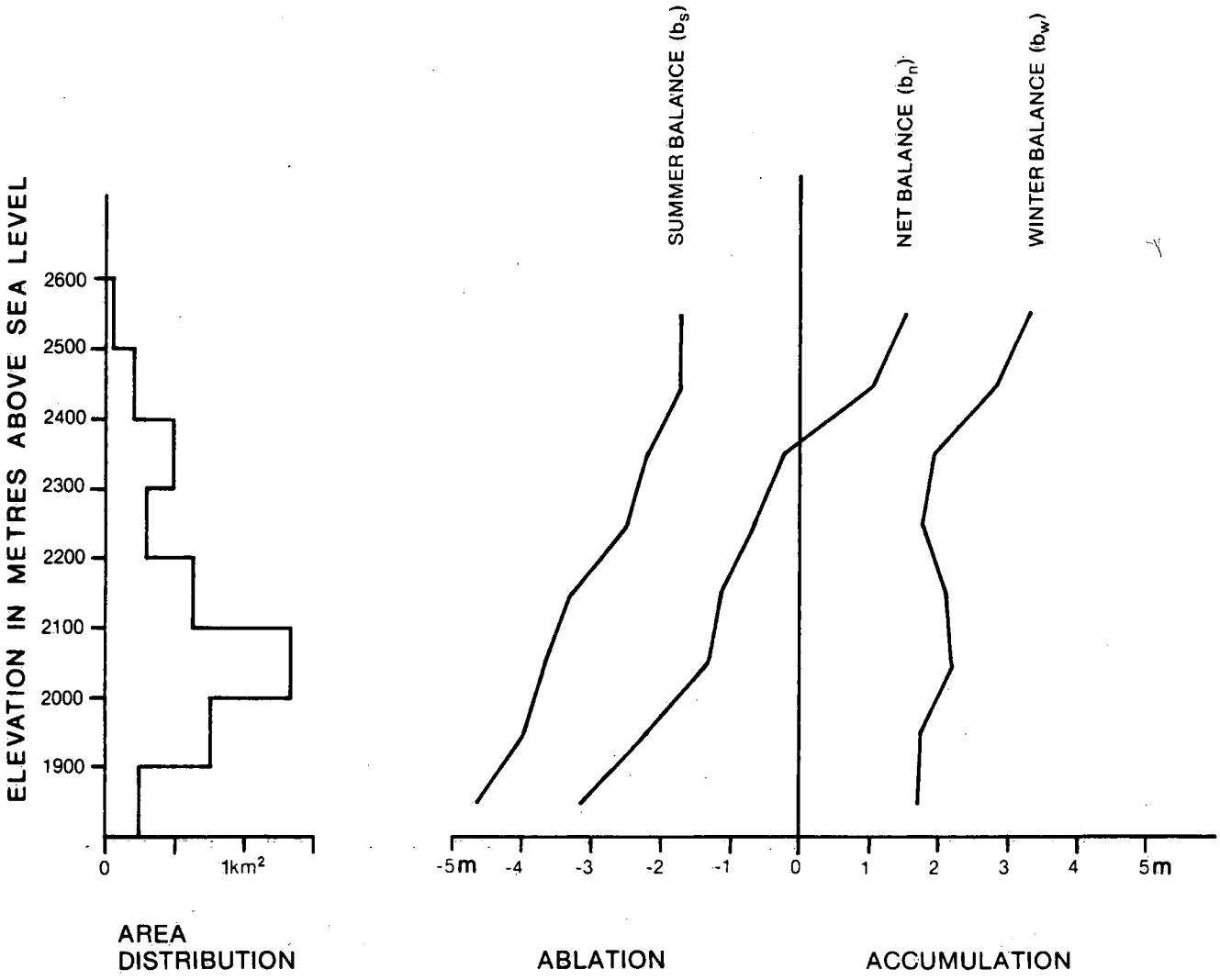


Figure III-4. Variation of winter, summer and net balances with elevation, 1966-67.

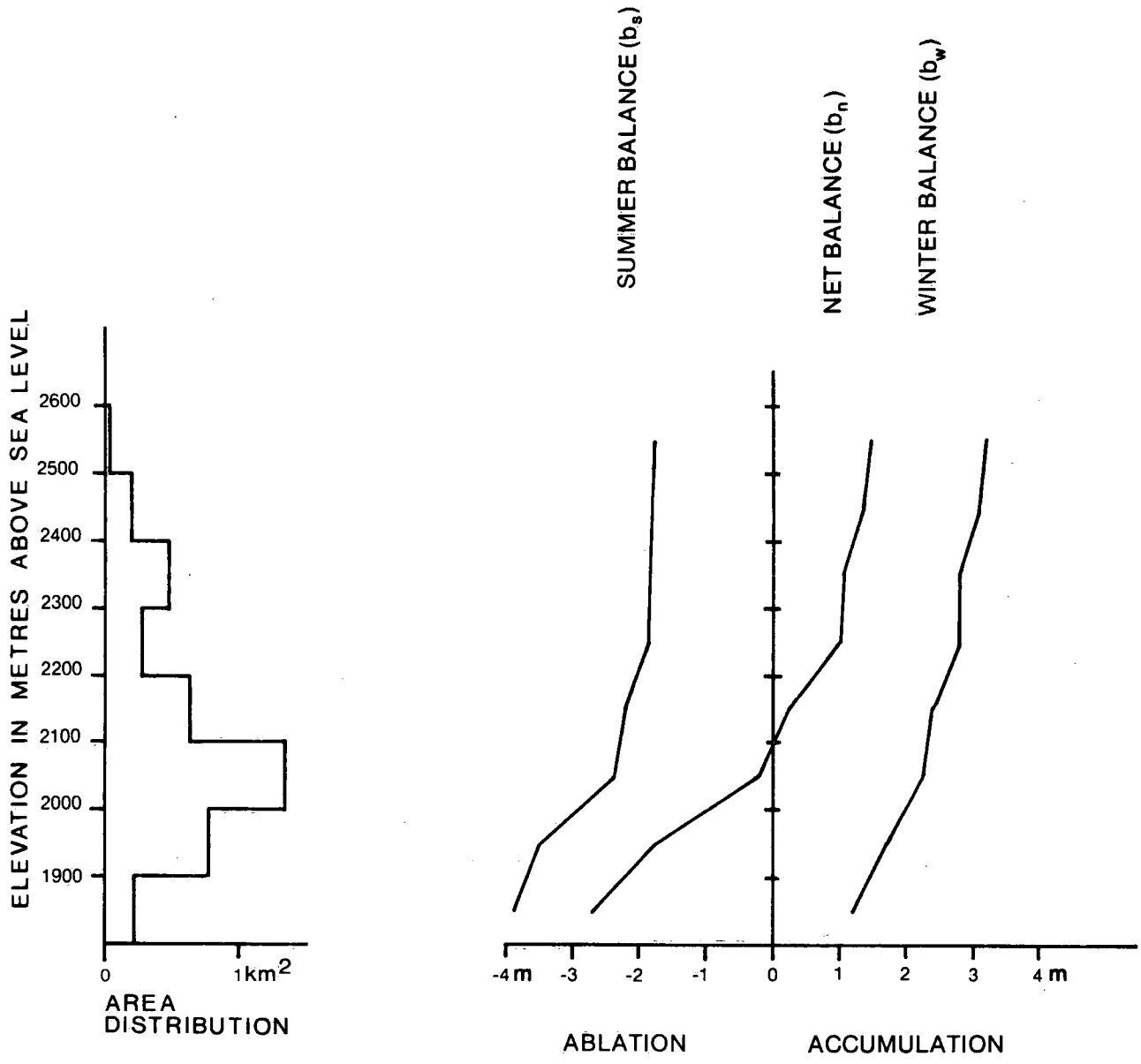


Figure III-5. Variation of winter, summer and net balances with elevation, 1967-68.

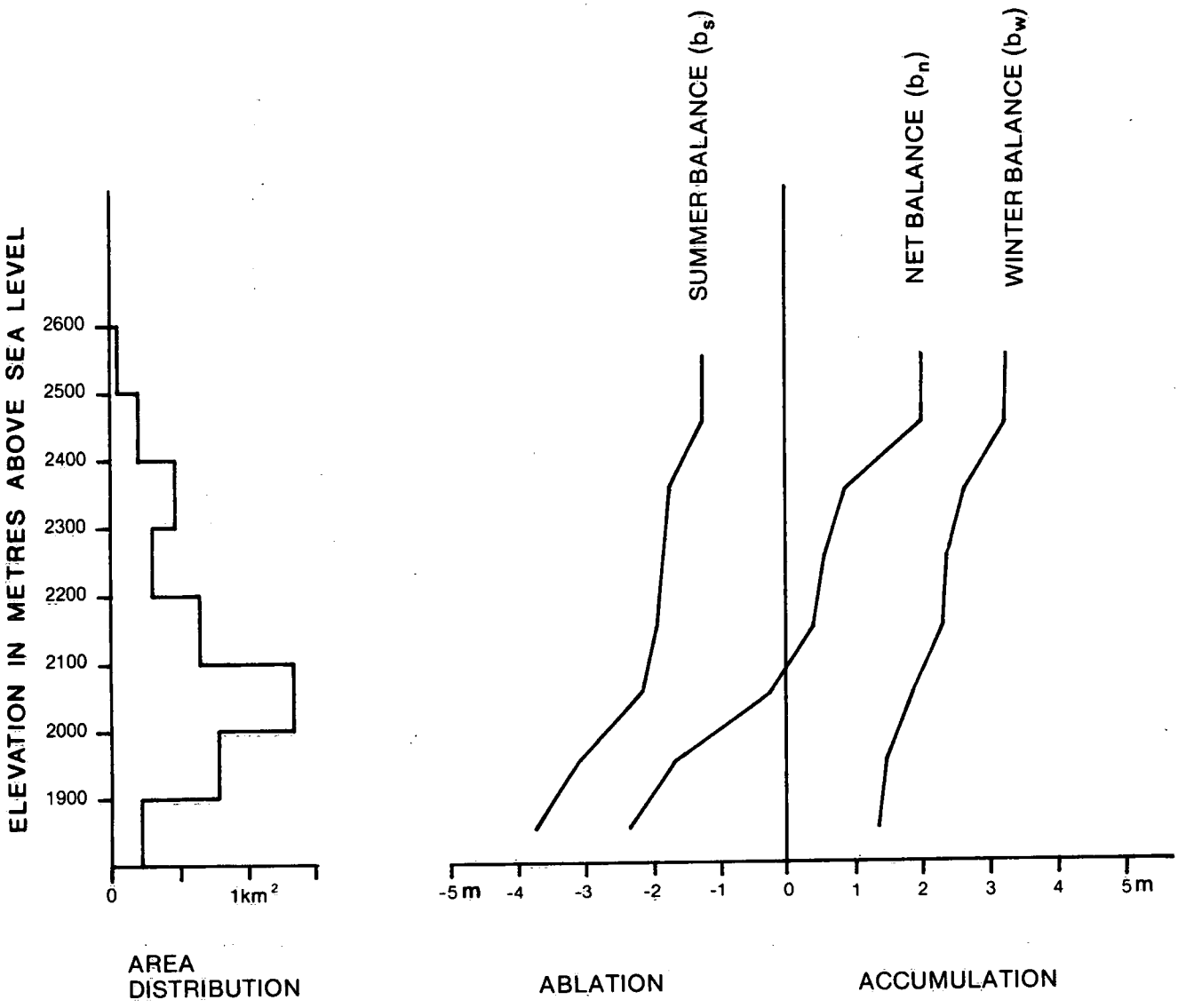


Figure III-6. Variation of winter, summer and net balances with elevation, 1968-69.

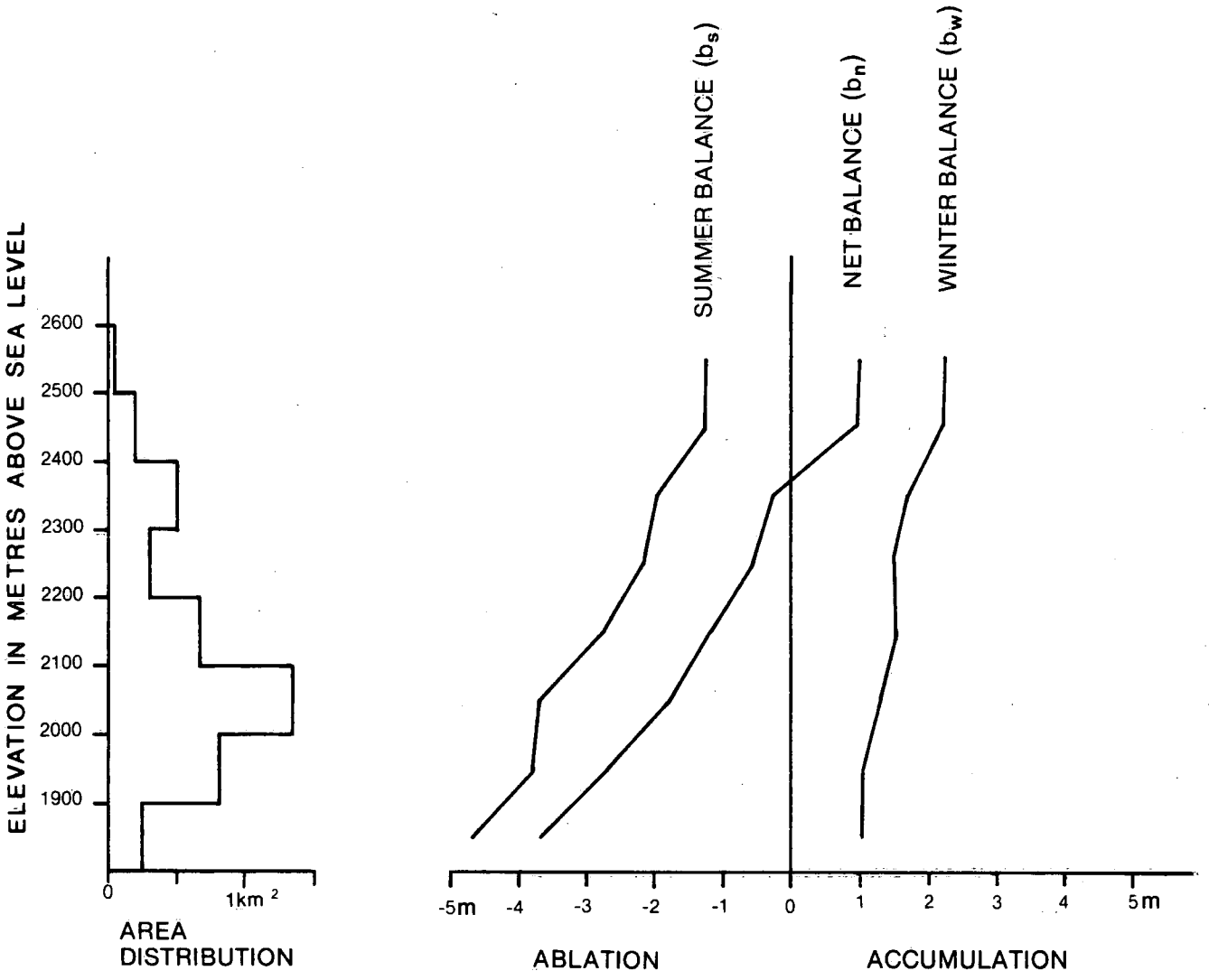


Figure III-7. Variation of winter, summer and net balances with elevation, 1969-70.

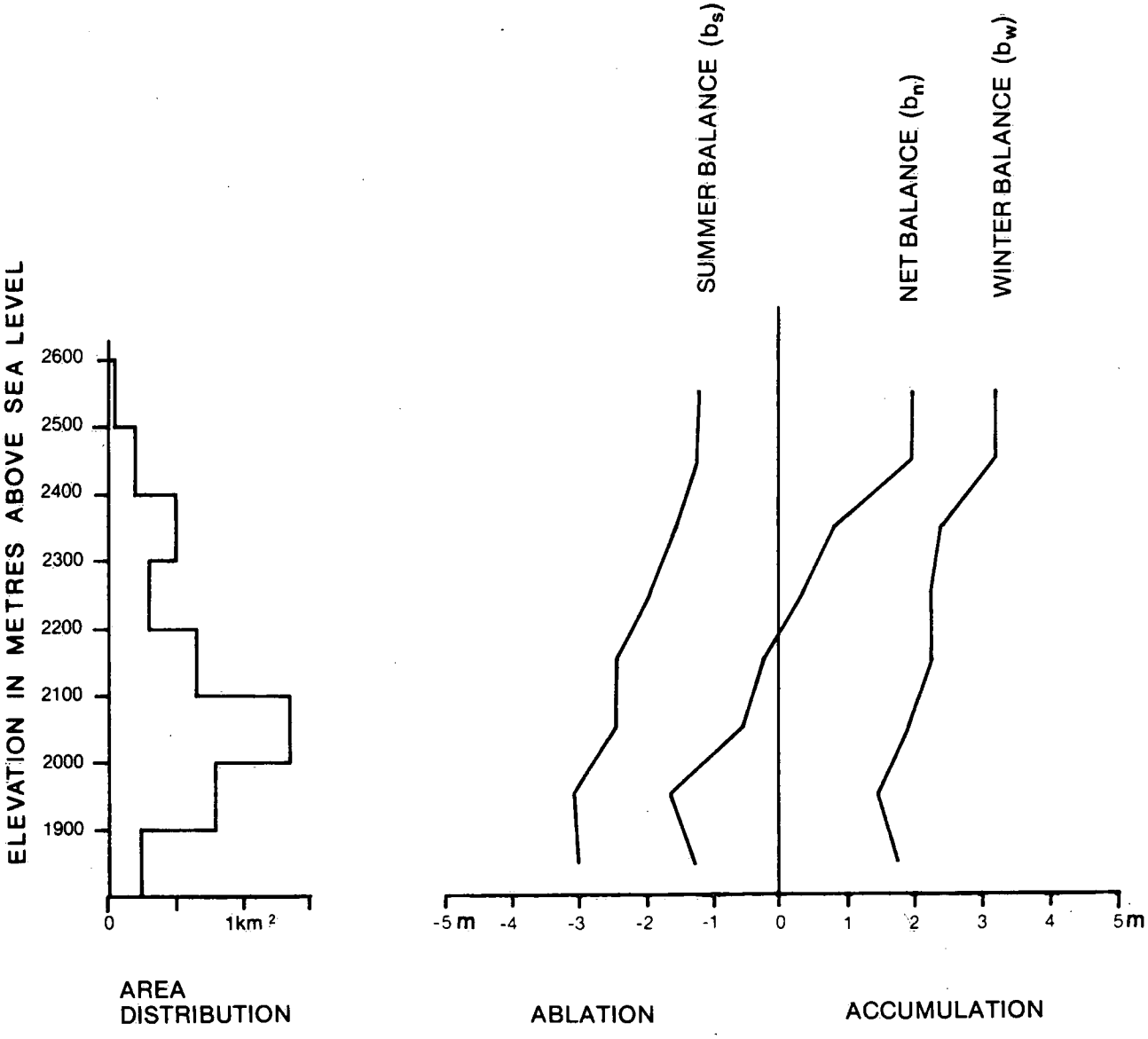


Figure III-8. Variation of winter, summer and net balances with elevation, 1970-71.

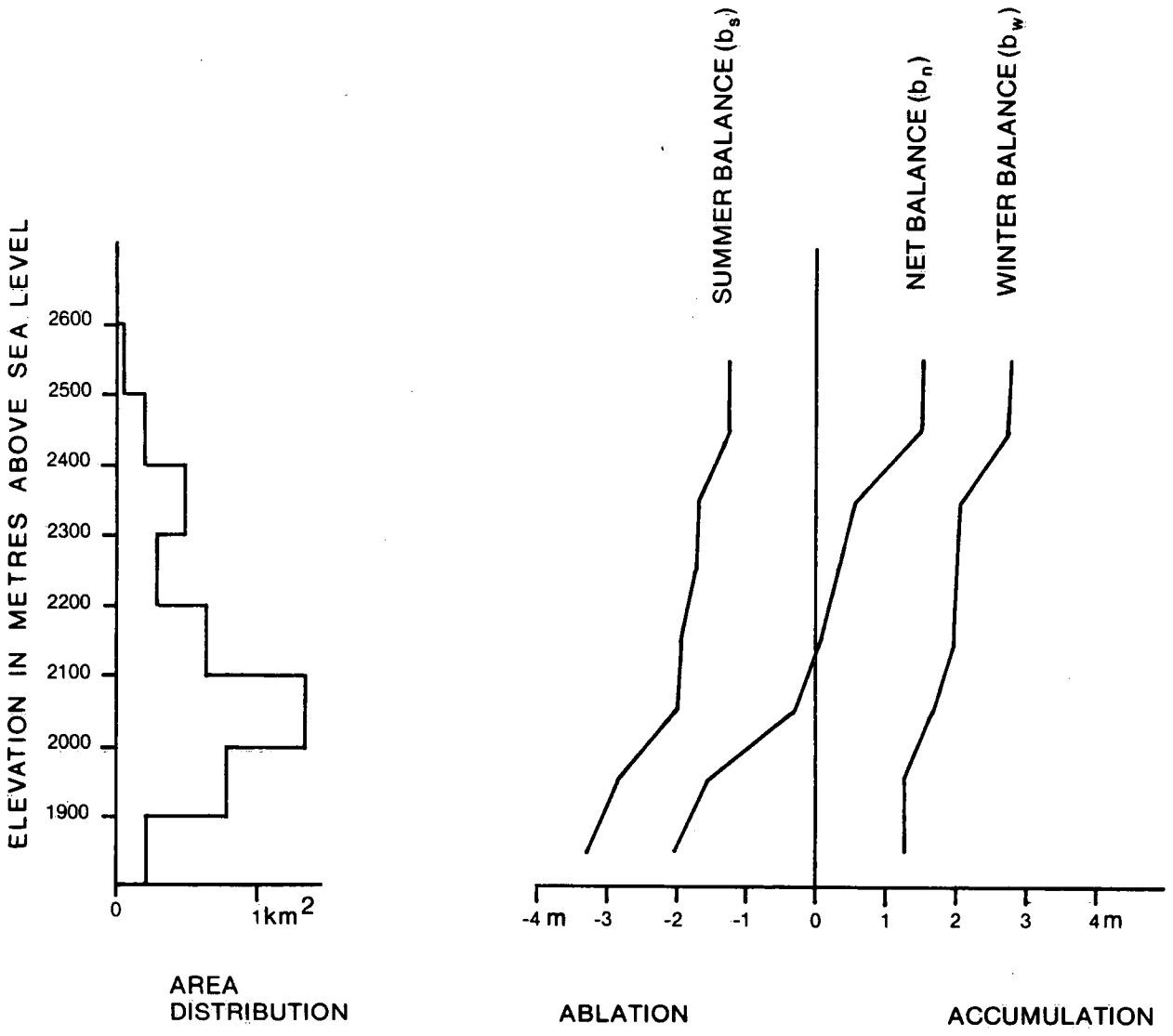


Figure III-9. Variation of winter, summer and net balances with elevation, 1971-72.

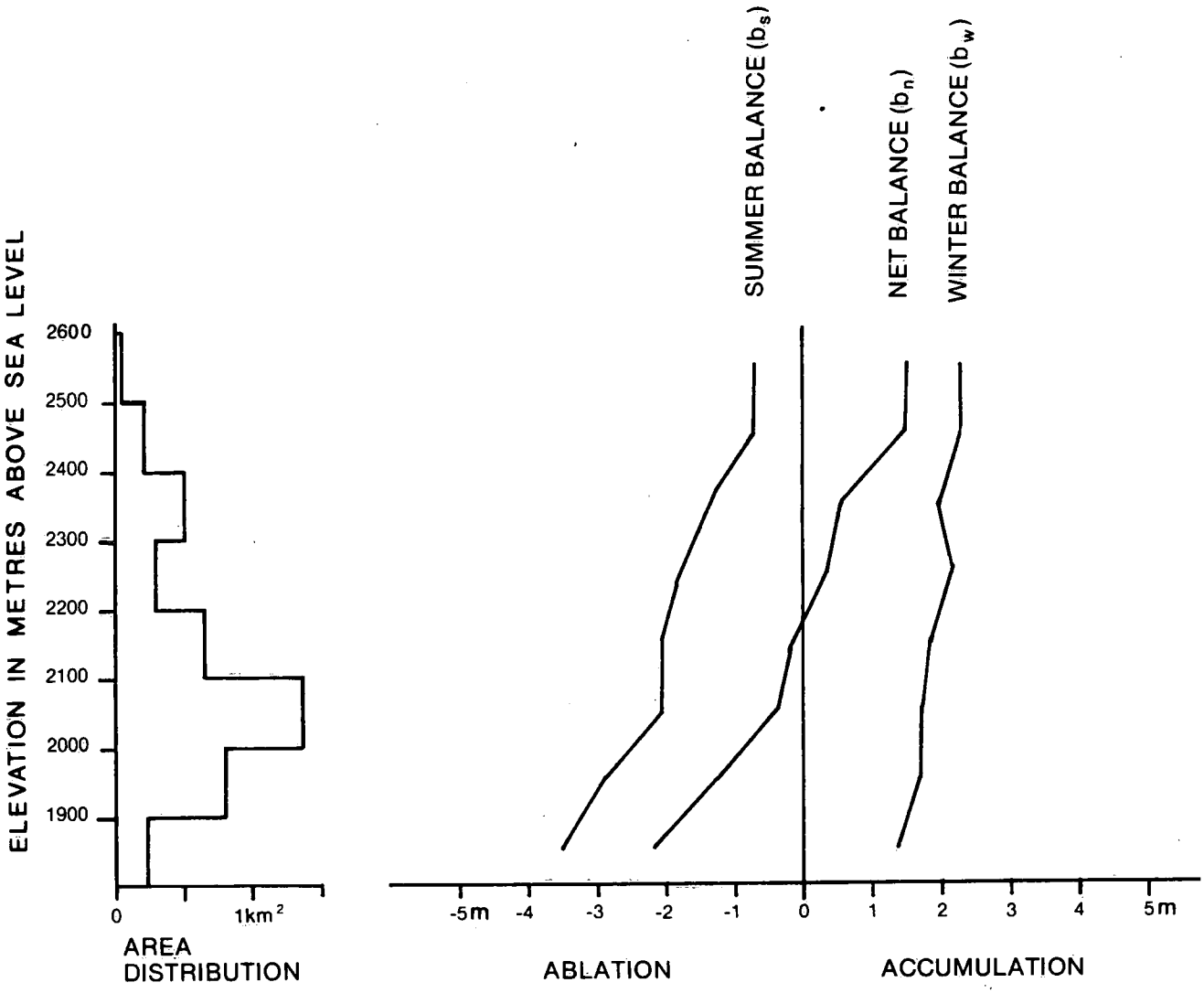


Figure III-10. Variation of winter, summer and net balances with elevation, 1972-73.

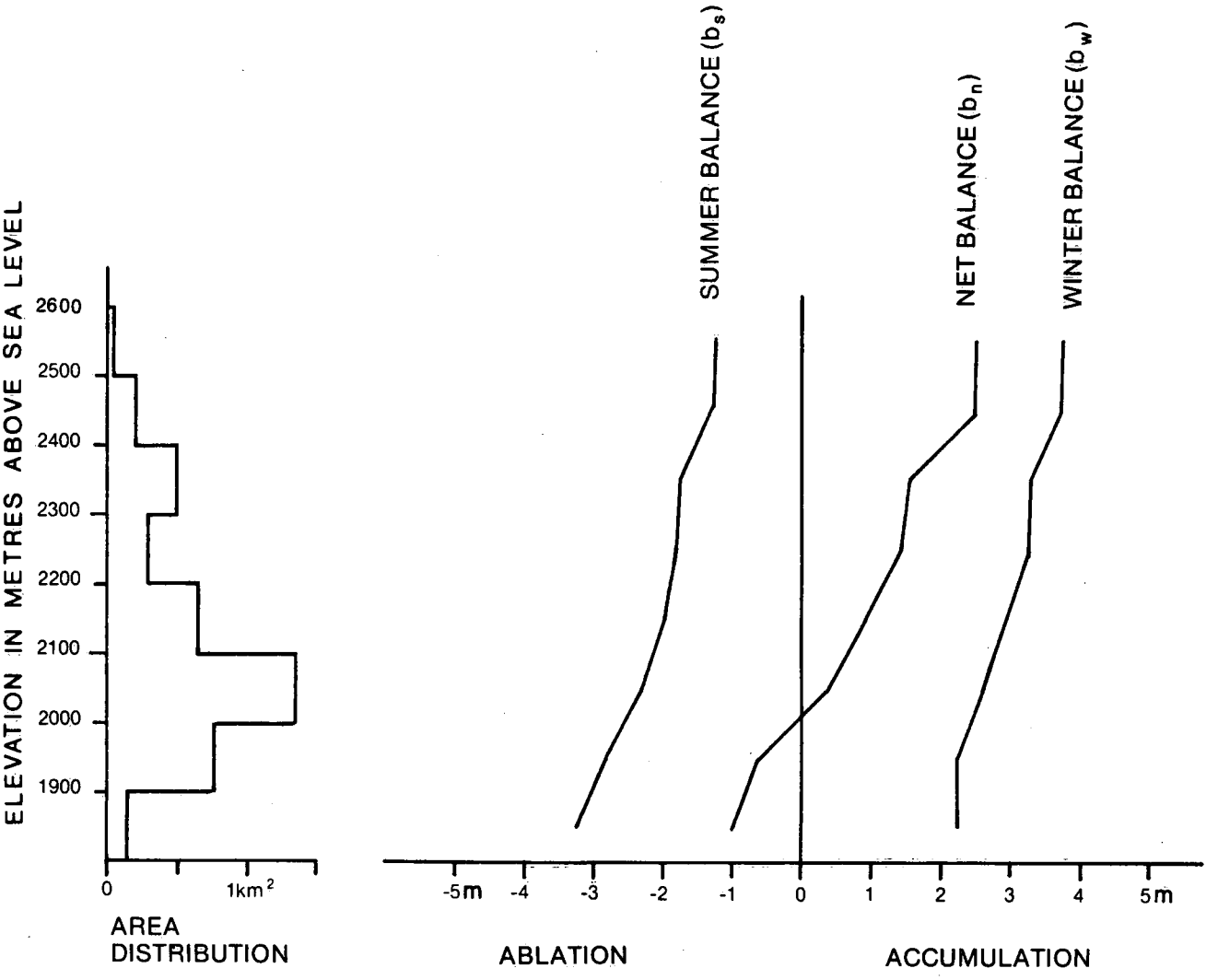


Figure III-11. Variation of winter, summer and net balances with elevation, 1973-74.

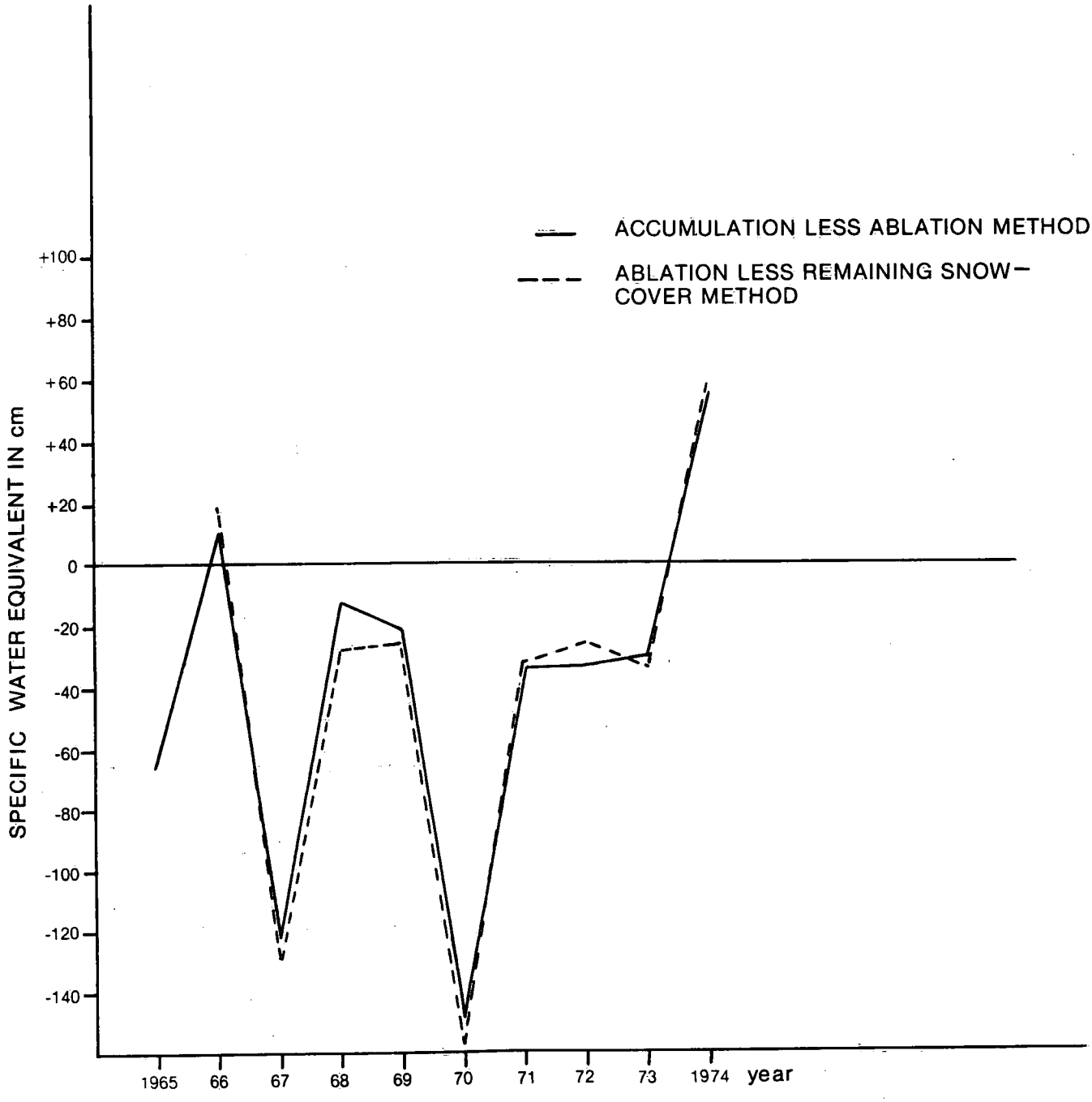


Figure III-12. Place Glacier—Net mass balance fluctuations, 1965-74.

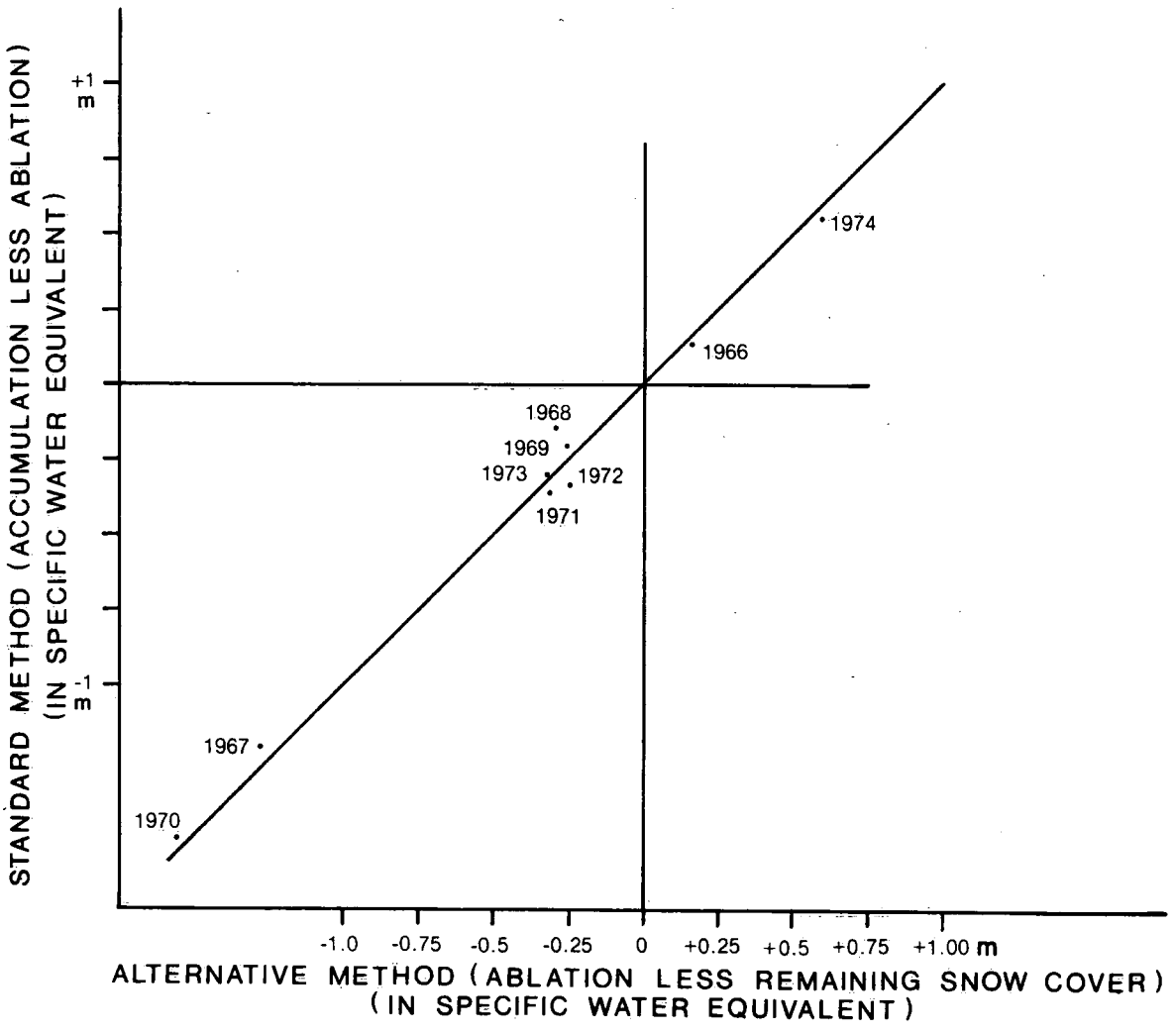


Figure III-13. Analysis of surface measurement methods, 1966-74.

Table III-1. Mass balance
Place Glacier
Year: 1964-1965

Start: September 1964 Winter: to April 18, 1965 Summer: to September 10, 1965

Contour interval, m	Area, km^2	Winter balance, m, water equiv.	Summer balance, m, water equiv.	Net balance m, water equiv.
2500+	0.23	2.17	1.38	+0.79
2400–2500	0.29	1.60	1.42	+0.18
2300–2400	0.26	1.93	1.71	+0.22
2200–2300	0.18	2.17	2.06	+0.11
2100–2200	0.79	1.69	1.86	−0.17
2000–2100	1.24	1.45	2.13	−0.68
1900–2000	0.75	1.32	3.08	−1.76
<1900	0.24	1.32	3.84	−2.52
Totals	3.98	1.58	2.23	−0.65

Equilibrium line: 2200 m

Table III-2. Mass balance
Place Glacier
Year: 1965-1966

Start: September 10, 1965 Winter: to June 15, 1966 Summer: to September 3, 1966

Contour interval, m	Area, km^2	Winter balance, m, water equiv.	Summer balance, m, water equiv.	Net balance, m, water equiv.
2500–2600	0.05	2.50	0.74	+1.76
2400–2500	0.20	2.50	1.07	+1.43
2300–2400	0.47	2.31	1.37	+0.94
2200–2300	0.29	2.02	1.87	+0.15
2100–2200	0.64	2.19	1.91	+0.28
2000–2100	1.34	2.12	2.03	+0.09
1900–2000	0.76	1.59	2.04	−0.45
1800–1900	0.21	1.25	2.98	−1.73
Totals	3.96	2.02	1.91	+0.11

Equilibrium line: 2070 m

Table III-3. Mass balance
Place Glacier
Year: 1966-1967

Start: September 3, 1966 Winter: to May 31, 1967 Summer: to October 16, 1967

Contour interval, m	Area, km^2	Winter balance, m, water equiv.	Summer balance, m, water equiv.	Net balance, m, water equiv.
2500–2600	0.040	3.25	1.75	+1.50
2400–2500	0.200	2.83	1.75	+1.08
2300–2400	0.467	1.93	2.21	−0.28
2200–2300	0.296	1.76	2.40	−0.64
2100–2200	0.637	2.16	3.30	−1.14
2000–2100	1.345	2.30	3.61	−1.31
1900–2000	0.762	1.78	3.92	−2.14
1800–1900	0.210	1.75	4.76	−3.00
Totals	3.967	2.10	3.31	−1.21

Equilibrium line: 2370 m

Table III-4. Mass balance
Place Glacier
Year: 1967-1968

Start: October 16, 1967 Winter: to May 28, 1968 Summer: to October 1, 1968

Contour interval, m	Area, km^2	Winter balance, m, water equiv.	Summer balance, m, water equiv.	Net balance, m, water equiv.
2500–2600	0.040	3.25	1.25	+2.00
2400–2500	0.200	3.15	1.25	+1.90
2300–2400	0.467	2.88	1.80	+1.08
2200–2300	0.296	2.88	1.82	+1.06
2100–2200	0.637	2.43	2.20	+0.23
2000–2100	1.345	2.29	2.36	−0.07
1900–2000	0.762	1.73	3.43	−1.70
<1900	0.210	1.25	3.88	−2.63
Totals	3.957	2.32	2.45	−0.13

Equilibrium line: 2030 m

Table III-5. Mass balance
Place Glacier
Year: 1968-1969

Start: October 1, 1968 Winter: to June 8, 1969 Summer: to October 1, 1969

Contour interval, m	Area, km^2	Winter balance, m, water equiv.	Summer balance, m, water equiv.	Net balance, m, water equiv.
2500–2600	0.040	3.25	1.25	+2.00
2400–2500	0.200	3.25	1.25	+2.00
2300–2400	0.467	2.64	1.75	+0.89
2200–2300	0.296	2.38	1.85	+0.53
2100–2200	0.637	2.32	1.98	+0.34
2000–2100	1.345	1.89	2.16	−9.27
1900–2000	0.762	1.41	3.07	−1.66
<1900	0.210	1.36	3.72	−2.36
Totals	3.957	2.05	2.26	−0.21

Equilibrium line: 2090 m

Table III-6. Mass balance
Place Glacier
Year: 1969-1970

Start: October 1, 1969 Winter: to May 23, 1970 Summer: to September 19, 1970

Contour interval, m	Area, km^2	Winter balance, m, water equiv.	Summer balance, m, water equiv.	Net balance, m, water equiv.
2500–2600	0.040	2.25	1.25	+1.00
2400–2500	0.200	2.25	1.25	+1.00
2300–2400	0.467	1.73	1.96	−0.23
2200–2300	0.296	1.54	2.11	−0.57
2100–2200	0.637	1.59	2.72	−1.13
2000–2100	1.345	1.36	3.15	−1.79
1900–2000	0.762	1.08	3.76	−2.68
1800–1900	0.210	1.02	4.68	−3.66
Totals	3.957	1.43	2.94	−1.51

Equilibrium line: 2380 m

Table III-7. Mass balance
Place Glacier
Year: 1970-1971

Start: September 19, 1970 Winter: to May 28, 1971 Summer: to October 7, 1971

Contour interval, m	Area, km^2	Winter balance, m, water equiv.	Summer balance, m, water equiv.	Net balance, m, water equiv.
2500–2600	0.040	3.25	1.25	+2.00
2400–2500	0.200	3.25	1.25	+2.00
2300–2400	0.467	2.43	1.58	+0.85
2200–2300	0.296	2.33	1.98	+0.35
2100–2200	0.637	2.23	2.44	-0.21
2000–2100	1.345	1.93	2.46	-0.53
1900–2000	0.762	1.44	3.05	-1.61
1800–1900	0.210	1.75	2.99	-1.24
Totals	3.957	2.04	2.38	-0.34

Equilibrium line: 2195 m

Table III-8. Mass balance
Place Glacier
Year: 1971-1972

Start: October 7, 1971 Winter: to June 15, 1972 Summer: to October 15, 1972

Contour interval, m	Area, km^2	Winter balance, m, water equiv.	Summer balance, m, water equiv.	Net balance, m, water equiv.
2500–2600	0.040	2.75	1.25	+1.50
2400–2500	0.200	2.75	1.25	+1.50
2300–2400	0.467	2.05	1.70	+0.35
2200–2300	0.296	1.99	1.72	+0.21
2100–2200	0.637	1.97	1.95	+0.02
2000–2100	1.345	1.67	2.03	-0.36
1900–2000	0.760	1.26	2.81	-1.55
1800–1900	0.148	1.25	3.25	-2.00
Totals	3.893	1.76	2.10	-0.34

Equilibrium line: 2130 m

Table III-9. Mass balance
Place Glacier
Year: 1972-1973

Start: October 1, 1972 Winter: to May 25, 1973 Summer: to October 1, 1973

Contour interval, m	Area, km^2	Winter balance, m, water equiv.	Summer balance, m, water equiv.	Net balance, m, water equiv.
2500–2600	0.040	2.25	0.75	+1.50
2400–2500	0.200	2.25	0.75	+1.50
2300–2400	0.467	1.95	1.40	+0.55
2200–2300	0.296	2.14	1.78	+0.36
2100–2200	0.637	1.87	2.03	-0.16
2000–2100	1.345	1.67	2.05	-0.38
1900–2000	0.760	1.64	2.90	-1.26
1800–1900	0.148	1.36	3.53	-2.17
Totals	3.893	1.79	2.09	-0.30

Eqiilibrium line: 2185 m

Table III-10. Mass balance
Place Glacier
Year: 1973-1974

Start: October 1, 1973 Winter: to June 7, 1974 Summer: to October 11, 1974

Contour interval, m	Area, km^2	Winter balance, m, water equiv.	Summer balance, m, water equiv.	Net balance, m, water equiv.
2500–2600	0.040	3.75	1.25	+2.50
2400–2500	0.200	3.75	1.25	+2.50
2300–2400	0.467	3.29	1.75	+1.54
2200–2300	0.296	3.27	1.84	+1.43
2100–2200	0.637	2.92	1.99	+0.93
2000–2100	1.345	2.61	2.24	+0.37
1900–2000	0.760	2.20	2.85	−0.65
1800–1900	0.148	2.25	3.25	−1.00
Totals	3.893	2.77	2.21	+0.56

Equilibrium line: 2010 m

Table III-11. Place Glacier – Equilibrium Lines.

Year	Equilibrium lines, m, a.s.l.
1965	2200
1966	2070
1967	2370
1968	2030
1969	2090
1970	2380
1971	2195
1972	2130
1973	2185
1974	2010
Mean	2138
Standard deviation	140.71

Table III-12. Place Glacier – Water Loss or Gain, 1965 – 1974.

Year	Amount of water loss or gain in $10^6 m^3$
1965	− 2.597
1966	+ 0.451
1967	− 4.798
1968	− 0.519
1969	− 0.850
1970	− 5.959
1971	− 1.359
1972	− 1.339
1973	− 1.159
1974	+ 2.189
Total net loss	−15.940

Table III-13. Comparison of mass balance results obtained by two surface methods to show their internal consistency.

Year	Specific water equivalents, m Method 1	Method 2	Difference m	Difference* %
1965	−0.65			
1966	+0.11	+0.17	0.06	2.9
1967	−1.21	−1.28	0.07	3.3
1968	−0.13	−0.28	0.15	6.4
1969	−0.21	−0.25	0.04	1.9
1970	−1.51	−1.56	0.05	3.5
1971	−0.35	−0.31	0.04	1.9
1972	−0.34	−0.25	0.09	5.1
1973	−0.30	−0.32	0.02	1.2
1974	+0.56	+0.59	0.03	1.1
				Av. 3.03

*The difference in per cent is the relation of the difference between the results obtained from the two methods to the thickness of the winter snowpack expressed in water equivalents.

Appendix IV

Rating curve

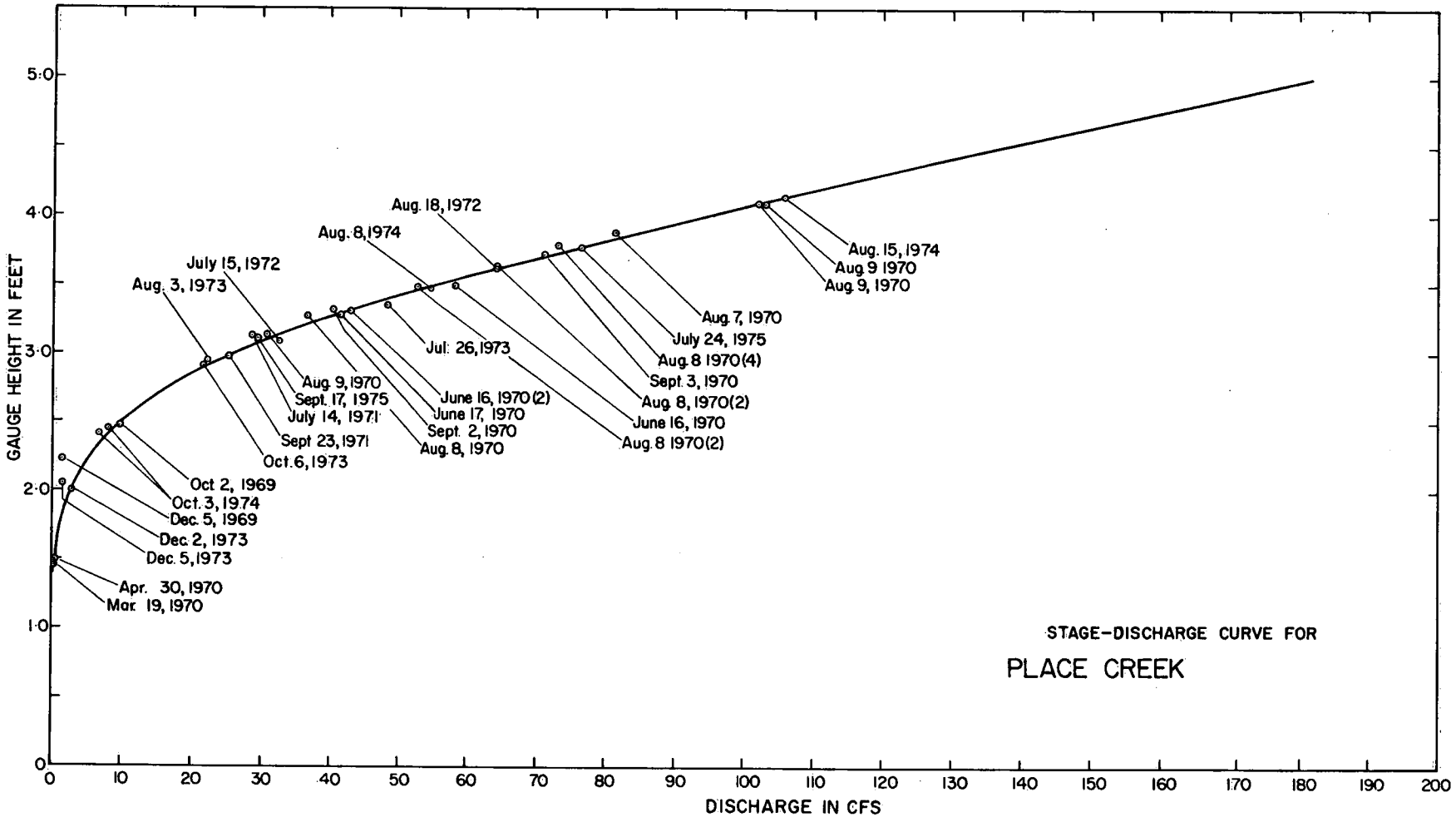


Figure IV-1. Rating curve.

Appendix V

Summarized meteorological parameters and river discharge

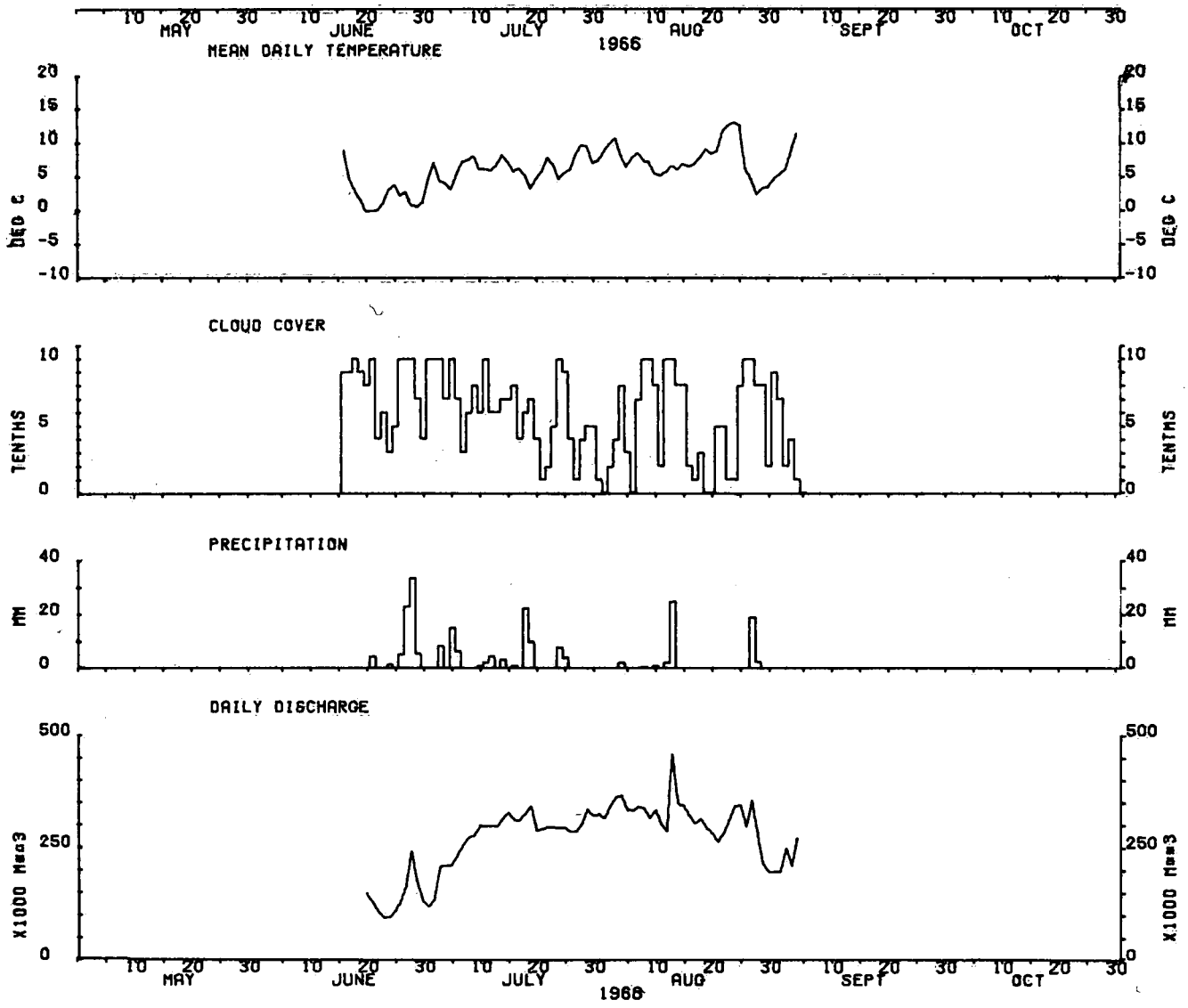


Figure V-1. Place Glacier, 1966.

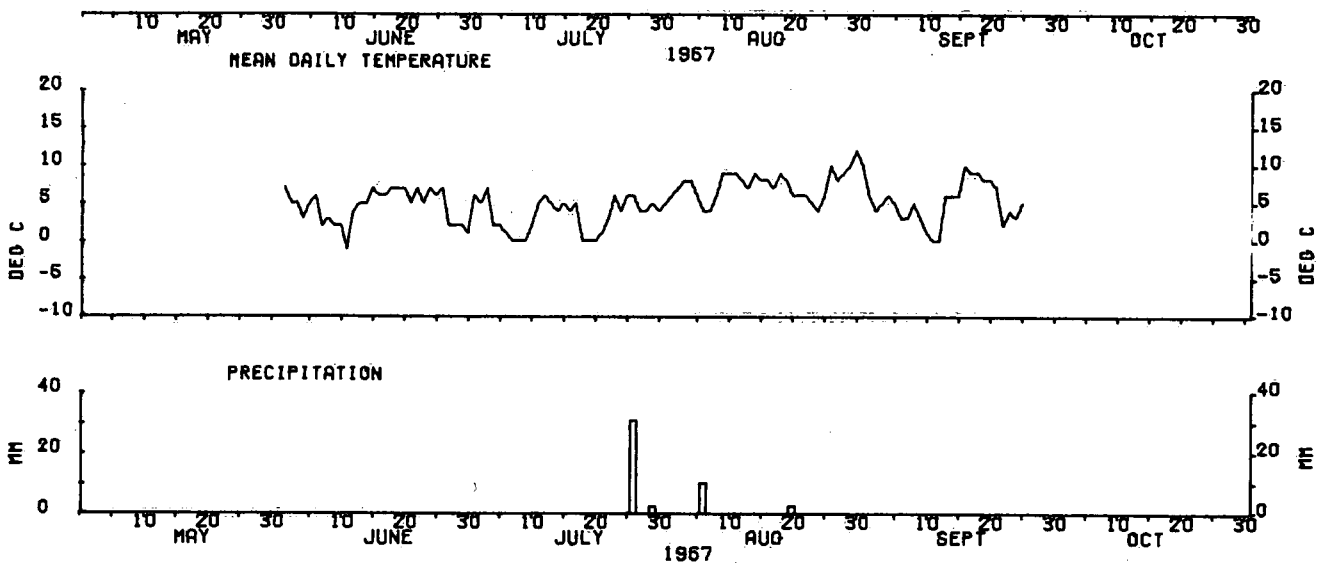


Figure V-2. Place Glacier, 1967.

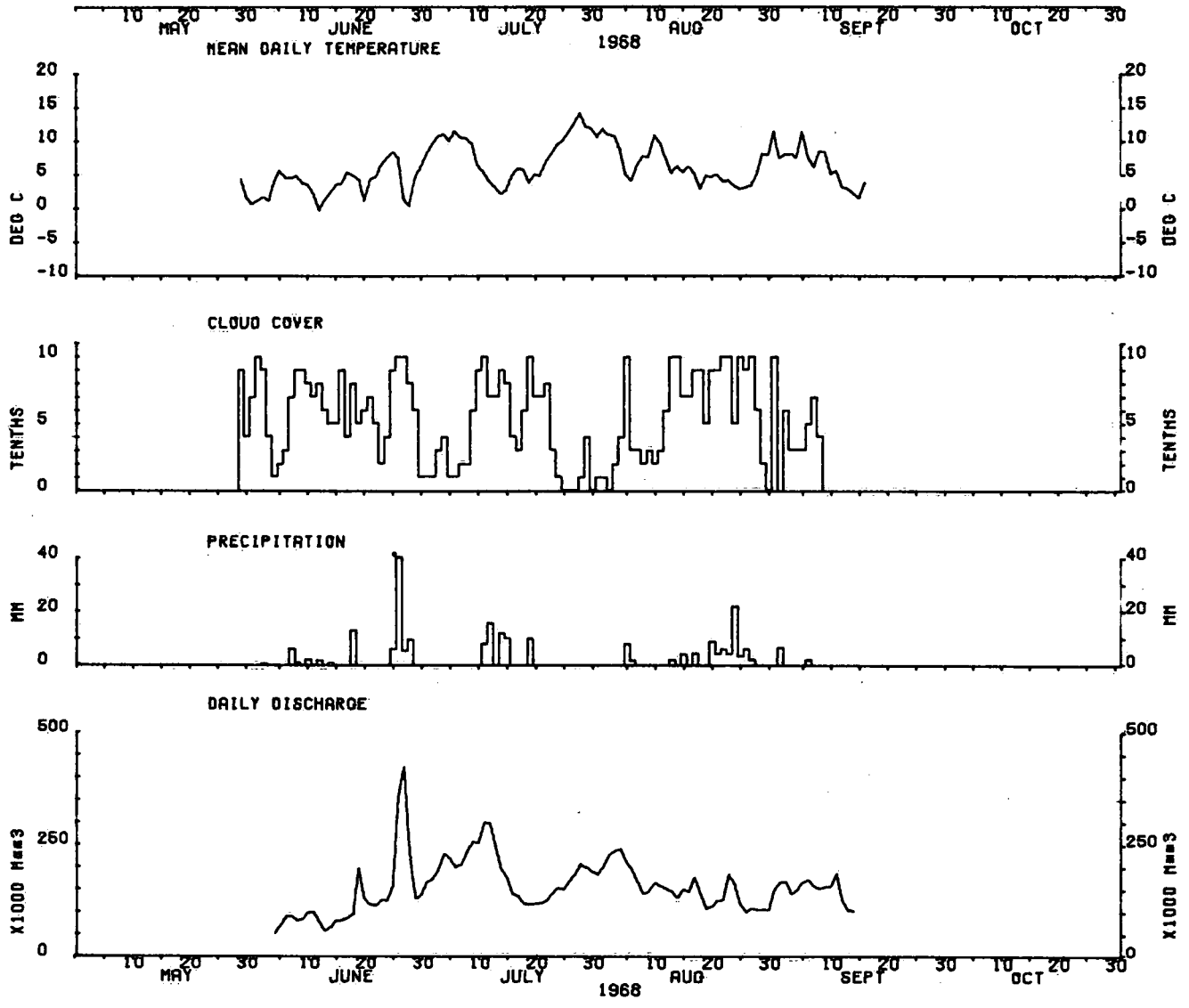


Figure V-3. Place Glacier, 1968.

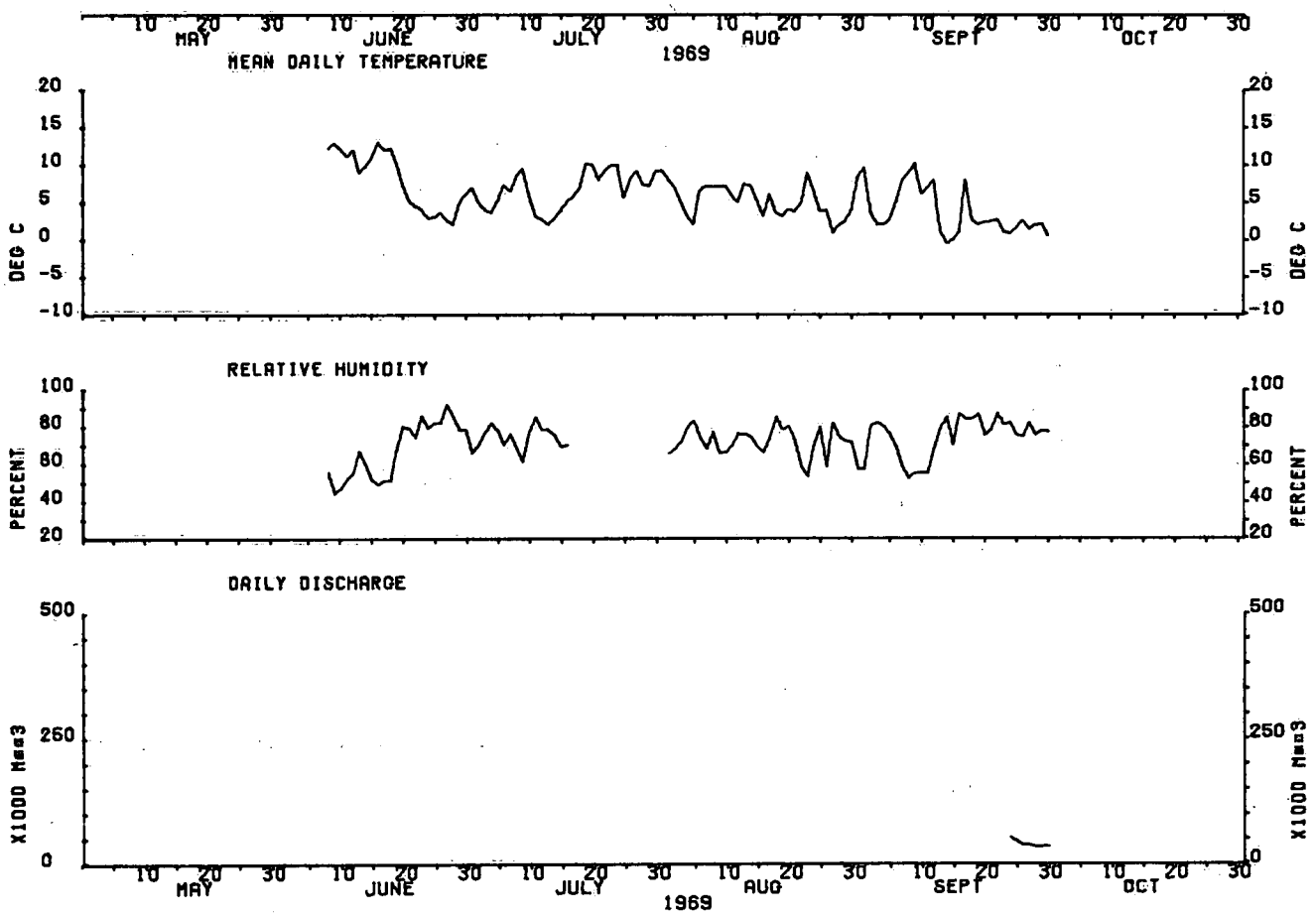


Figure V-4. Place Glacier, 1969.

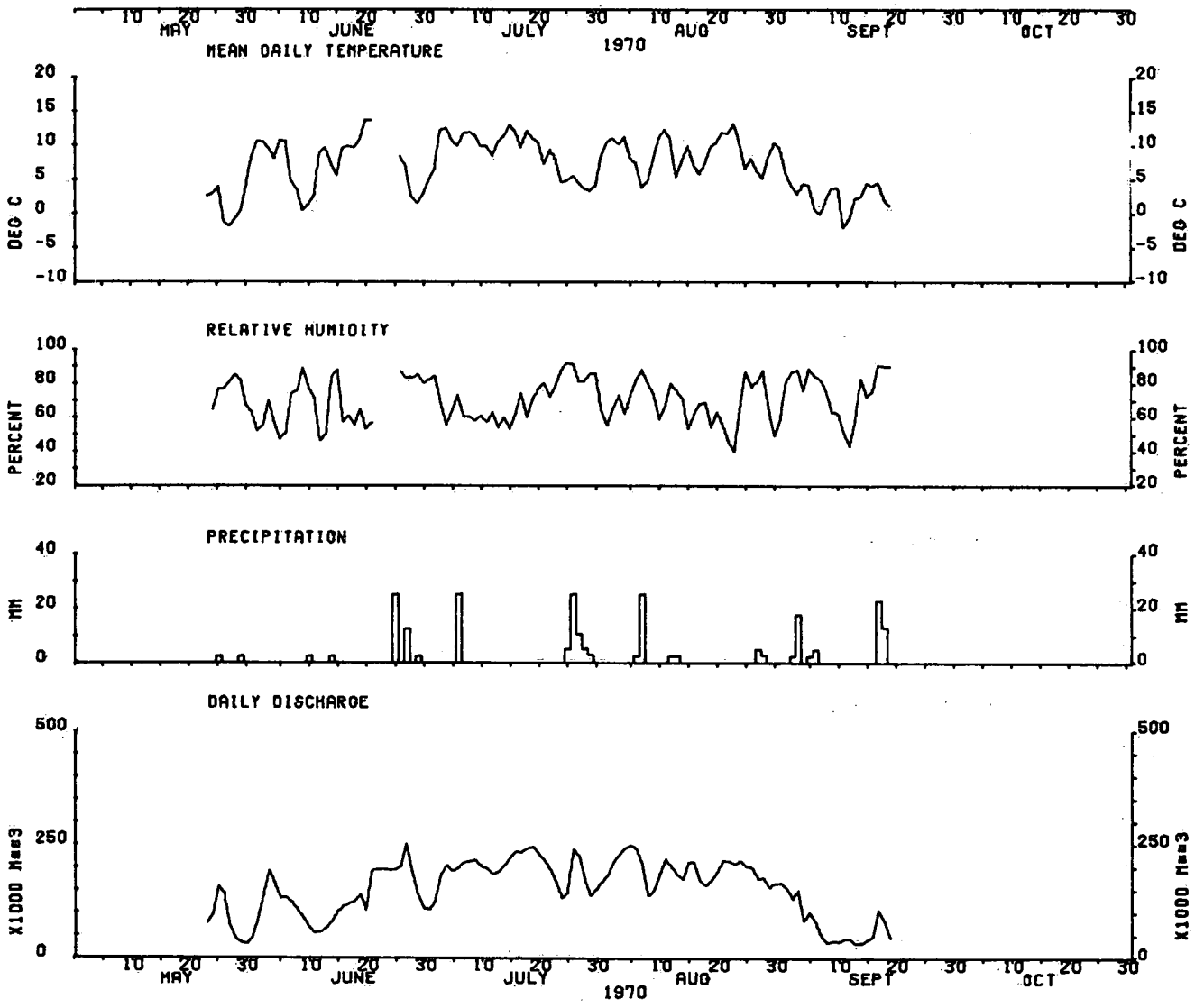


Figure V-5. Place Glacier, 1970.

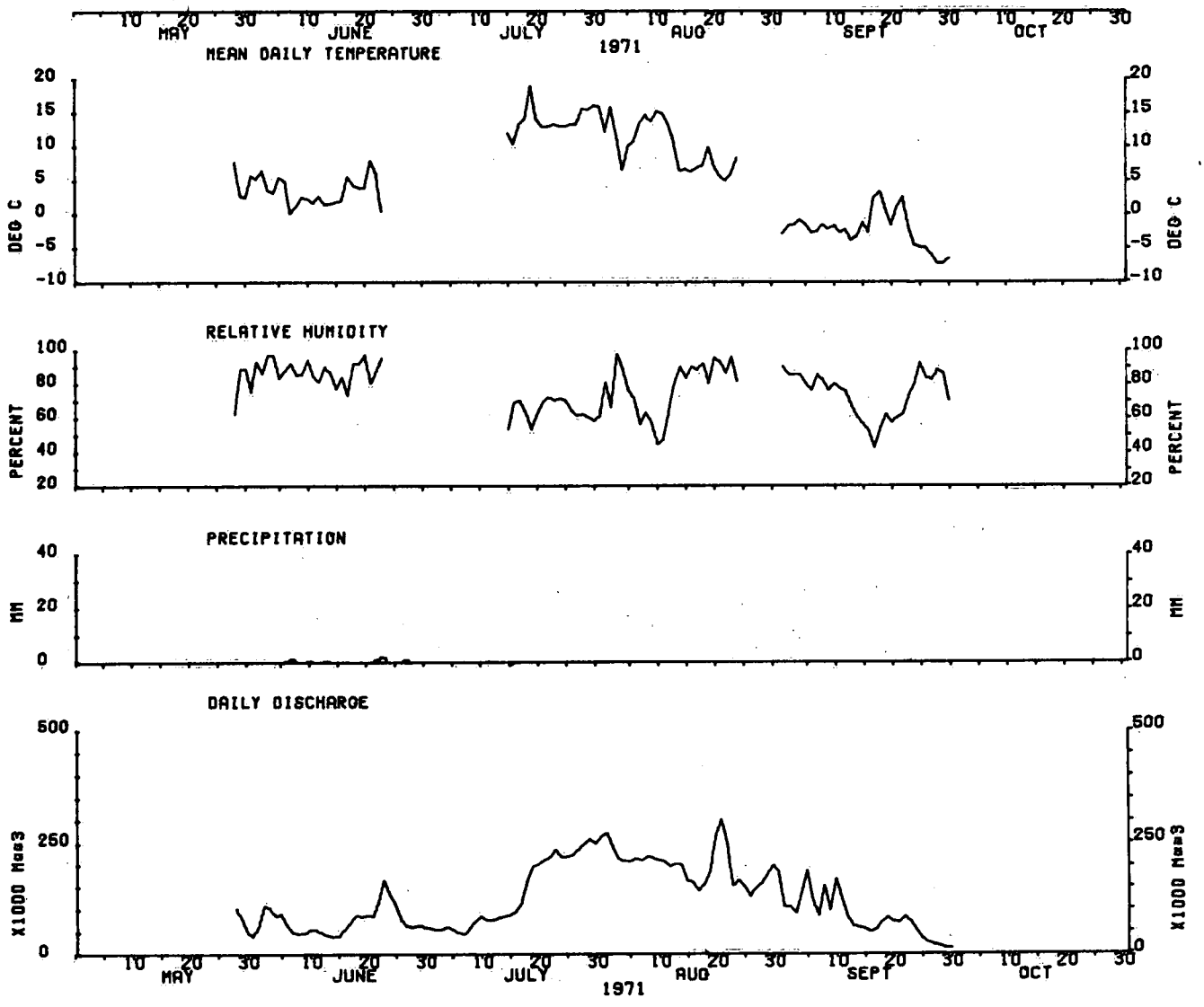


Figure V-6. Place Glacier, 1971.

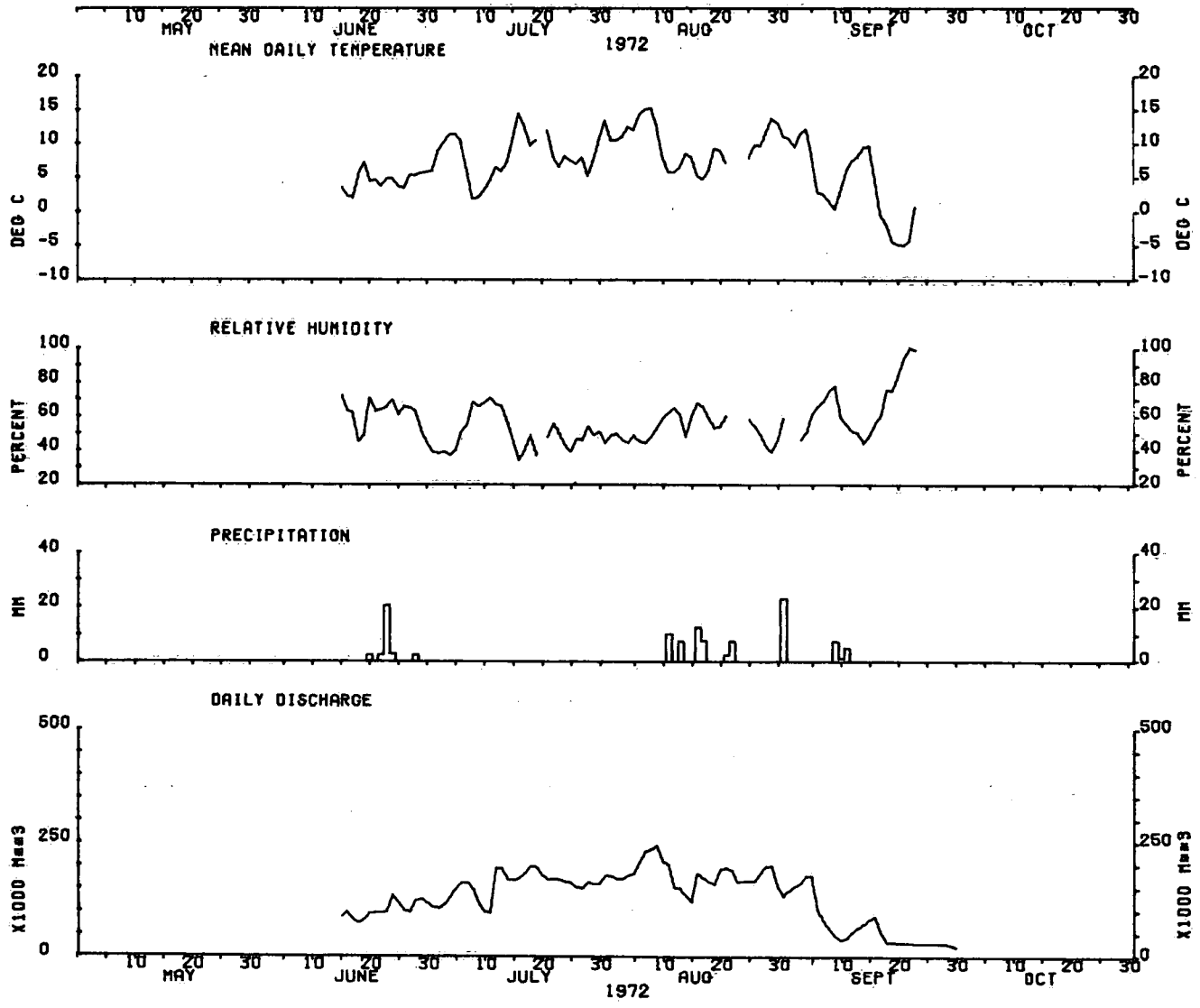


Figure V-7. Place Glacier, 1972.

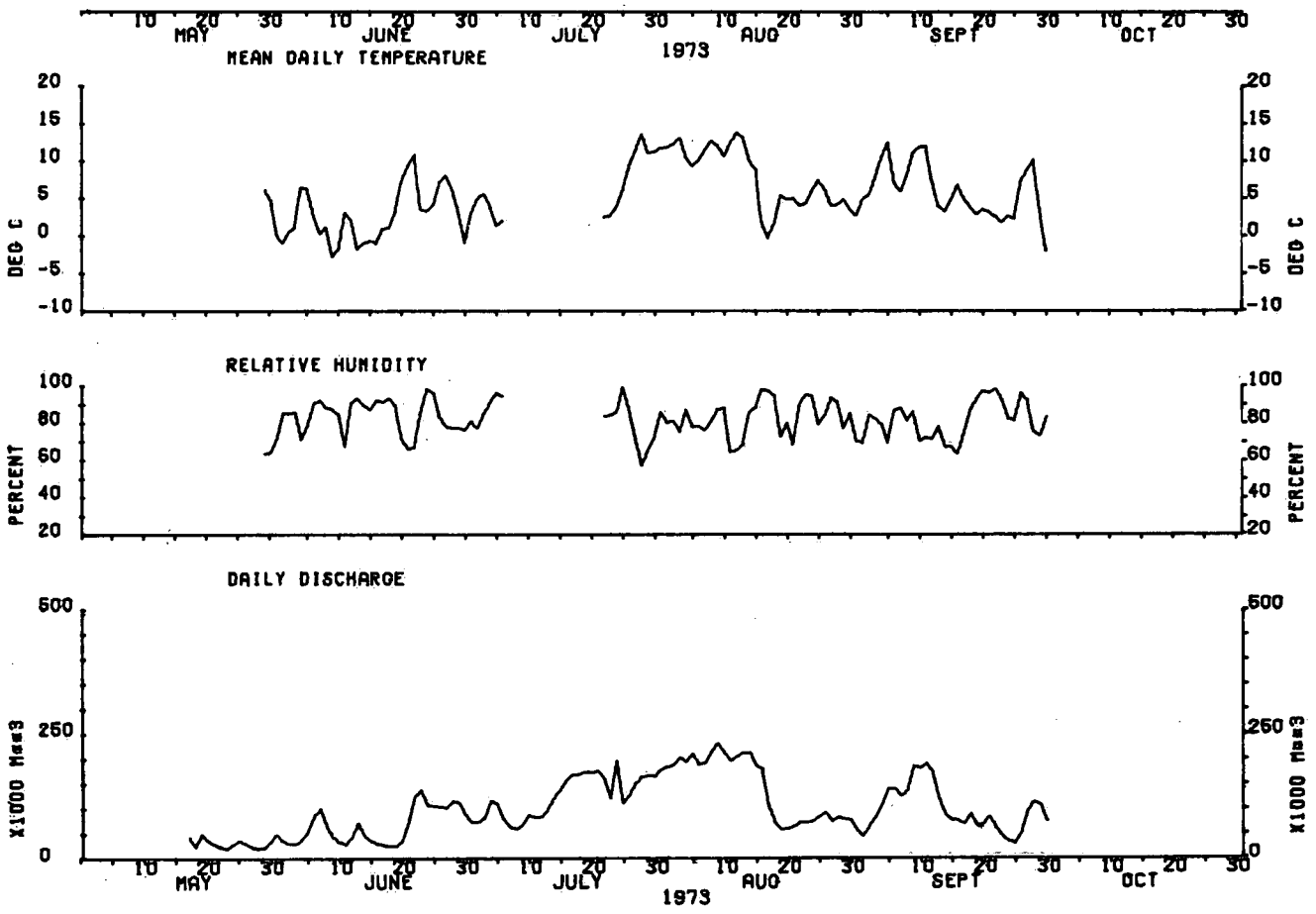


Figure V-8. Place Glacier, 1973.

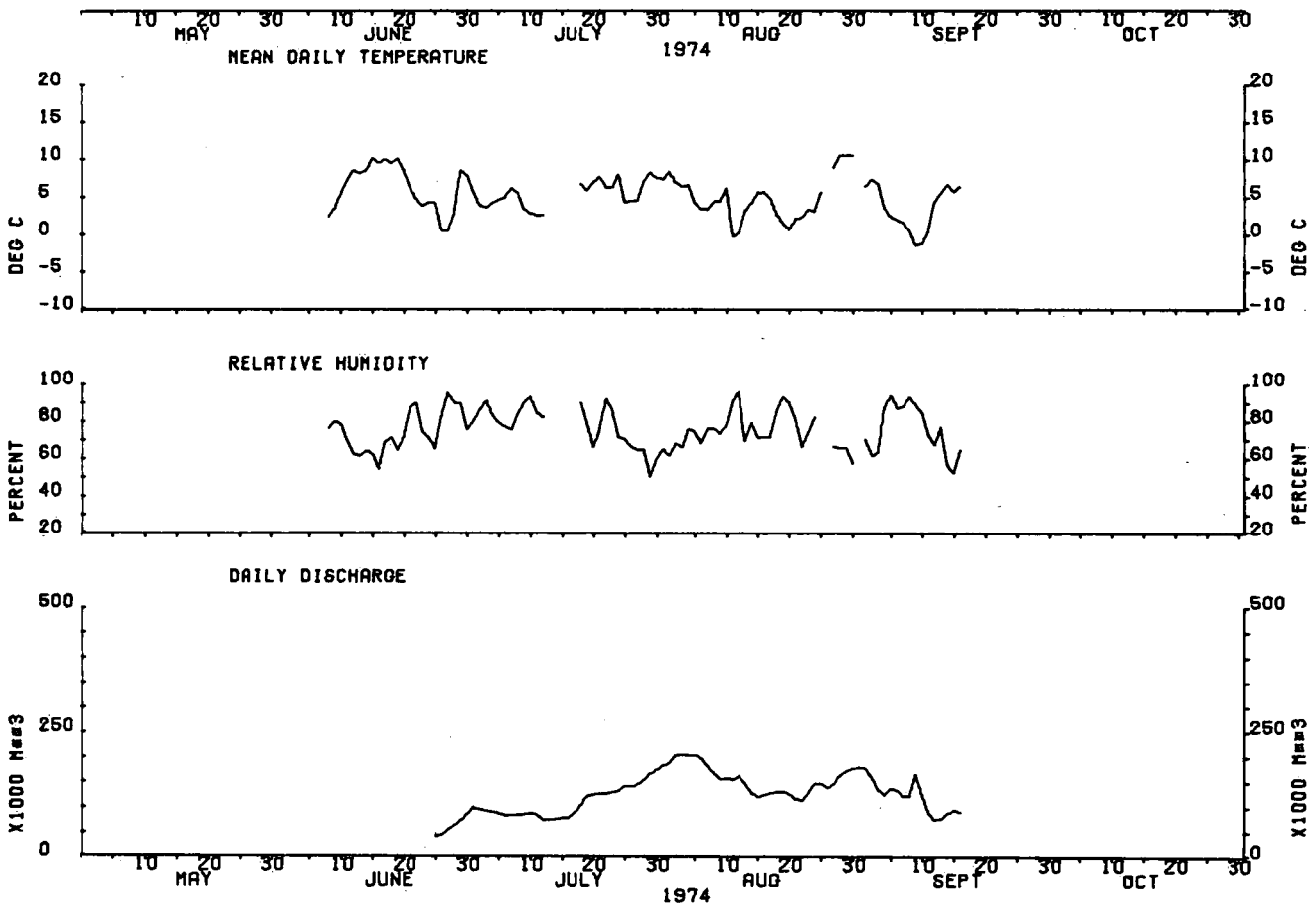


Figure V-9. Place Glacier, 1974.