

Snow Measurement in the Vicinity of Knob Lake,
Central Labrador-Ungava, Winter 1964-65

by

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INTRODUCTION

During the year 1964-65, the McGill Sub-Arctic Research Laboratory at Schefferville, Québec, made a hydrologic study of the catchment area of Knob Lake (Fig. 1), an area of about 13.5 square miles (see Adams, Shaw and Archer, 1966; Cowan 1966). This is part of the Kaniapiskau-Koksoak drainage system which has an area of about 56,000 square miles. The study area forms, in fact, an enclave of north-flowing drainage within the generally south-flowing Churchill River system. In connection with the work, it was important to obtain as accurate a value as possible for snowfall in the area. The precipitation régime of the interior of the Labrador-Ungava Peninsula, which was very poorly known before the Fifties, is of general interest at the present time in view of the Churchill Falls power scheme. It is also of academic interest as the Peninsula was the source and final location of the Laurentide Ice Sheet (Hare, 1951; Barry, 1960).

Physical setting

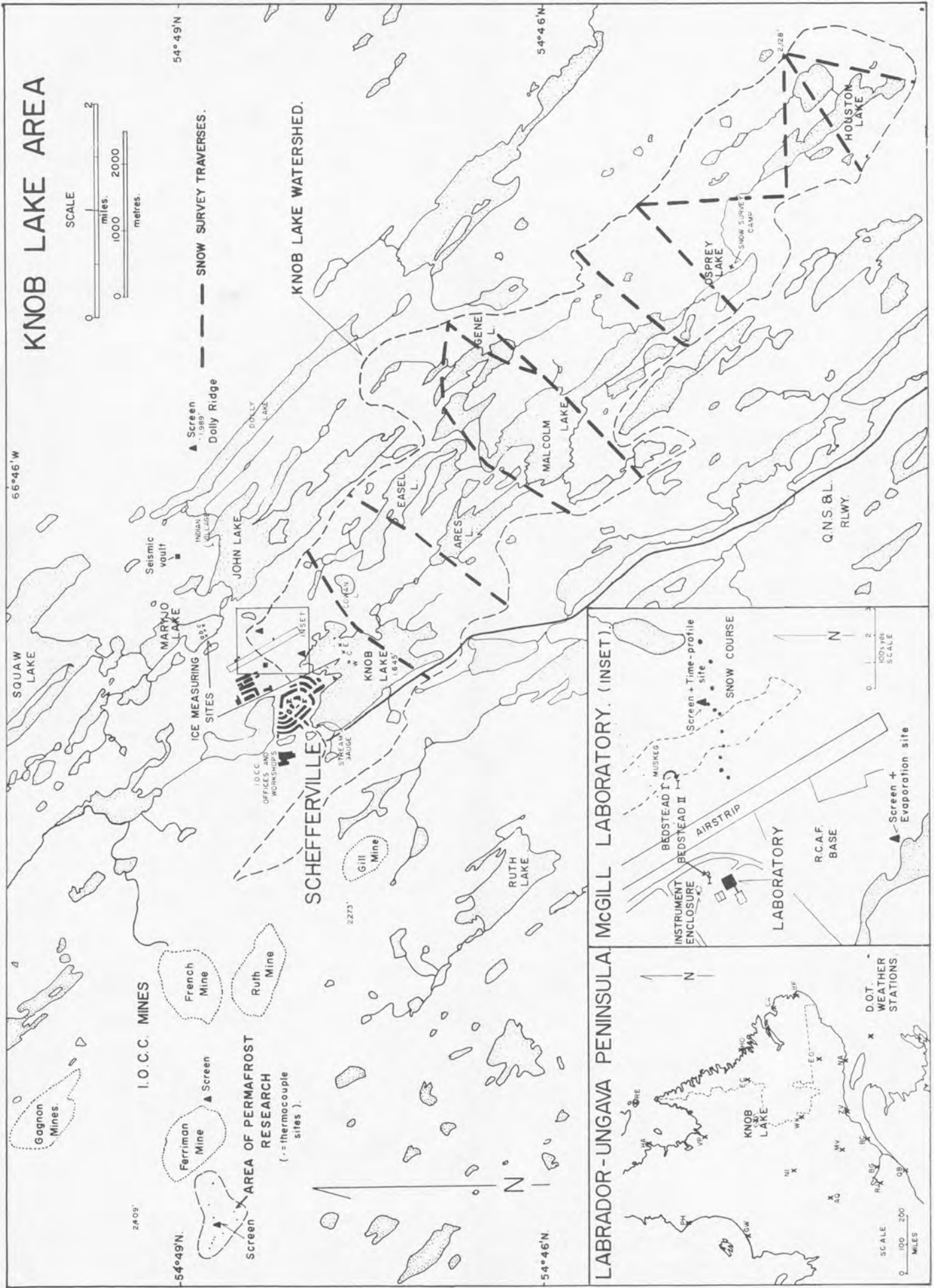
Knob Lake is close to the geographical centre of the Peninsula which is the eastern-most extension of the Canadian Shield. It is located about 54°48'N., 60°49'W., at 1645 feet above sea level. It is the Labrador Trough, a region of Proterozoic metasediments, the folding of which produced NW-SE ridge and valley topography in this particular area. The influence of this structure is apparent in the elongated oval form of the catchment area, which is 10 miles long, and 2 1/2 miles wide at its widest point. The range of altitude within the catchment is approximately 450 feet as compared with a local relief of about 600 feet in the surrounding area.

The vegetation of the whole central part of the Peninsula is transitional between Boreal Forest and Tundra and has been broadly termed Lichen Woodland (Hare, 1950a). This is an open type of vegetation in which the density of trees and shrubs is limited by the lichen cover, notable Cladonia alpestris (see Fraser, 1956, p 8-15). The vegetation within the catchment area is fairly typical for the region, ranging from bare ridges and open muskeg areas to open lichen woodland and to relatively closed stands of Spruce (Picea mariana and P. glauca) which may be over 50 feet in height with a DBH of 20 inches. As elsewhere in Labrador-Ungava, a remarkably high percentage of the vegetation shows signs of recent burning, in this case perhaps 55% of the land area of the drainage basin appears to have been burned over within the last 25 years. Soils are thin or absent in the area except for valley bottom locations where the water table is close to the surface.

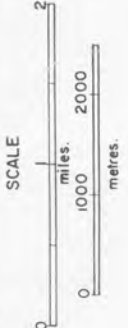
Approximately 18% of the land surface of central Labrador-Ungava is occupied by lakes (Hare, 1950b, p. 10), the proportion is probably higher within the limits of the Trough. Lakes occupy 23% of the drainage basin of Knob Lake.

The Climate

The climate of the area falls into Köppen's Dfc (Subarctic) category which is characterized by a short cool summer, a mean of below 26.6°F. for the coldest month, and precipitation throughout the year. In fact, the ten year mean temperature for



Knob Lake Area



▲ Screen 1985
 --- SNOW SURVEY TRAVERSES.

Knob Lake Watershed

I.O.C.C. MINES

AREA OF PERMAFROST RESEARCH
 (• = thermocouple sites)

McGill Laboratory (Inset)



Labrador-Ungava Peninsula



Knob Lake is below 24°F., three months normally have mean temperatures below 0°F. and only two months have mean temperatures over 50°F. The climate is cloudy so that extremes of temperature are less than in some other parts of the Subarctic, extreme maxima of 80°F. and extreme minima of -50°F. can be expected. Wind speeds average over 10 m.p.h. for every month with a peak in September and the early winter months when the average is close to 12 m.p.h.. There is a very strong prevalence of NW winds which may be to some extent influenced by the orientation of the valleys within the Labrador Trough. The official mean annual precipitation of 28.1 inches is made up of 15.4 inches of rain and 12.7 inches (water equivalent) of snow.

It is this last figure which is of interest to us in this paper.

SNOWFALL AT KNOB LAKE

The accepted mean snowfall for Knob Lake, 12.7 inches of water, is an average of 12 years of measurements at the Department of Transport Station in Schefferville, which is maintained by the McGill Laboratory. The actual method of arriving at the daily snowfall values from which the monthly and annual totals are derived has varied somewhat over the years but a shielded Nipher Gauge has been used for most of the period of measurement. Four times each day, at the regular synoptic hours, the depth of snow and its water equivalent in the gauge are measured. When less than .005 inches of water is measured for the six hour period, a Trace is recorded. Traces do not appear in the daily totals of depth and water equivalent.

It is well known that snow gauges tend to under-measure true snowfall owing to limitations of their catch (e.g. Black, 1954; Inouye and Anzai, 1959). This deficiency is most pronounced in high winds (see Inouye and Anzai, op cit p. 1), wind speeds at the station in Knob Lake are normally over ten miles an hour and they are at a maximum during the fall and early winter months of peak snowfall. In addition, a large proportion of the snow receipts, perhaps two thirds, falls during storms with well above average winds. It would appear likely from this that the Nipher Gauge at Knob Lake, located in an exposed location, would under-estimate the true snowfall. It is possible that this under-measurement also extends to the third or so of the total receipts which does not fall during storms owing to the accumulation of the Traces which are not included in the daily and monthly totals. In an extreme case, 0.012 (4 x 0.004) inches of water can be lost to the daily record. Traces are an important feature of the snowfall at Knob Lake during the extremely cold mid-winter period, retaining the same definition of a Trace but extending the period of measurement from six hours to, for example, 24 hours, many of these would contribute to the annual total snowfall.*

In addition to limitations in the measurement of snow at the site of a meteorological station, it is always difficult for a hydrologist to determine the extent to which the values obtained are representative for his drainage area. There is a strong SE/NW precipitation gradient across the Labrador-Ungava Peninsula and there is a serious shortage of meteorological stations of any sort in the interior. The snowfall of thousands of square miles is being extrapolated from inefficient measurements in a few square inches of gauge. In this study, we were concerned with comparing Nipher Gauge receipts at one location on the watershed of the Knob Lake drainage area (Fig. 1) with the total receipts over its 13.5 square miles.

Station Measurements of Snowfall, 1964-65

For a number of years, the McGill Laboratory has maintained a snowcourse over about $\frac{3}{4}$ miles of the floor of the valley in which Knob Lake is situated. The twelve stakes of this course encompass a reasonable range of vegetation types, including

* See note at end of paper.

SNOW COVER AND VEGETATION*

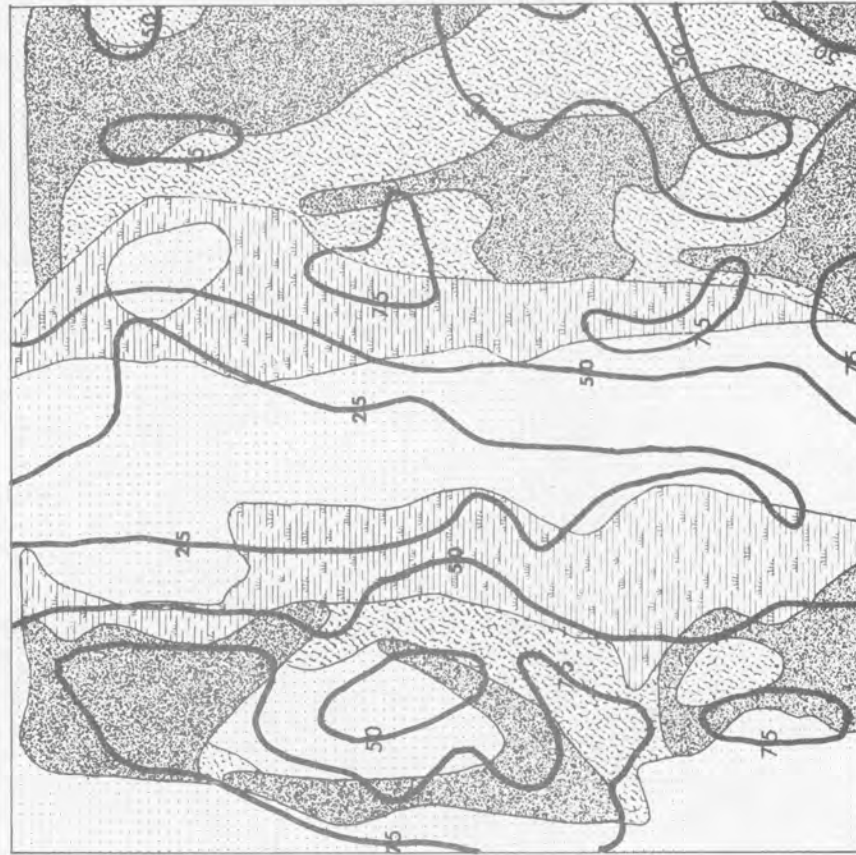


Fig 2
*Vegetation after Gardner

WATER EQUIVALENT OF SNOW COVER

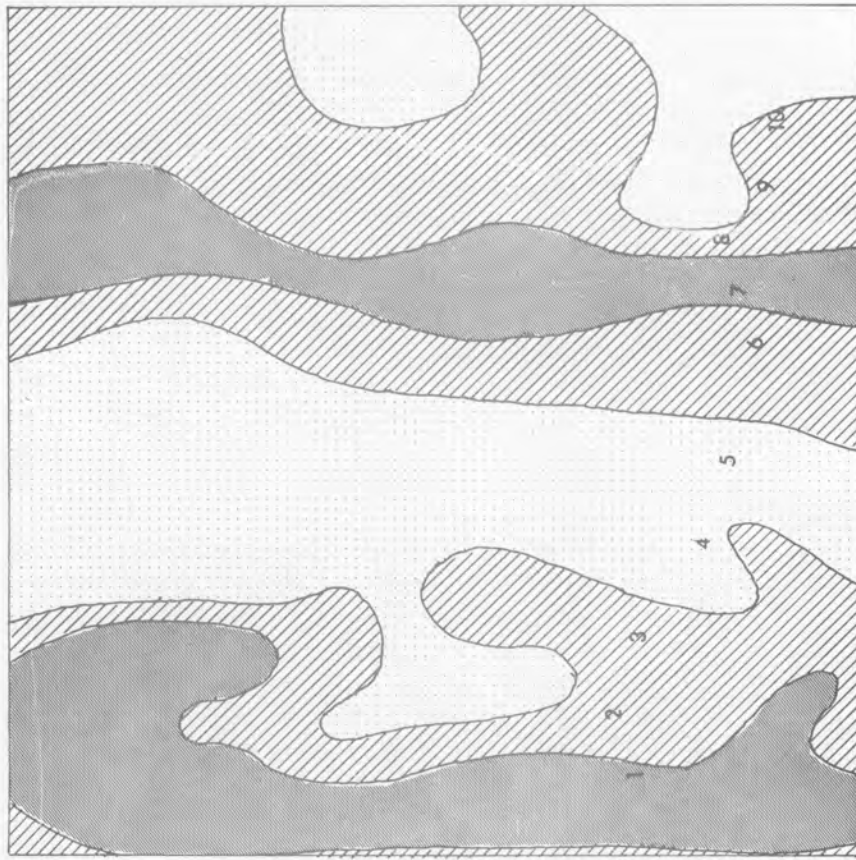


Fig 3

TABLE 1

Snowfall from the survey of the Knob Lake drainage basin

| <u>Cover Type</u> | <u>A</u> Area in Watershed mls ² (%) | <u>B</u> Water Equivalent Arithmetic Mean (inches) | <u>C</u> No. of Samples | <u>D</u> No. of samples per sq. mile | <u>E</u> Total Snow Present (ft ³ water) (AXB) | <u>F</u> Mean Snow Inches Water (Sum of E ÷ A) |
|--|---|--|-------------------------------|--|---|---|
| Burn, open lichen scrub woodland, lichen heath, lichen scrub | 6.35 (47) | 11.9 | 43 | 6.8 | 175.258 x 10 ⁶ | |
| Open lichen woodland | 2.03 (15) | 15.2 | 25 | 12.3 | 71.307 x 10 ⁶ | |
| Open lichen woodland -- closed lichen woodland (transition) | 0.67 (05) | 11.5 | 11 | 16.4 | 17.931 x 10 ⁶ | |
| Closed lichen woodland | 1.35 (10) | 11.4 | 15 | 11.1 | 34.804 x 10 ⁶ | |
| Lake | 3.10 (23) | 6.3 | 11 | 3.6 | 45.372 x 10 ⁶ | |
| | | | | | | 11.0 |

various forms of Lichen Woodland, a patch of muskeg and the bare, exposed, site of the meteorological station itself which is located close to an air strip. Daily depth and weekly water equivalent measurements are made at every stake. The total snow present along the course at the end of April, 1965, was 12.9 inches of water (Cowan, 1966). This was some 20% higher than the 10.29 inches of accumulated receipts of the Nipher Gauge for the period during which snow lay on the ground. A similar discrepancy was found in the previous winter (Gardner, 1964) and the short period measurements during the winter appear to confirm the trend.

As a check on the validity of the snow course stake values for at least the immediate vicinity of the snowcourse, a map of the end-of-winter snowcover of an area 1300 feet square was made (Figs. 2, 3). This map did not extend across the exposed station site but the area traversed by the remainder of the snowcourse was covered in detail -- with 169 depth and 88 water equivalent measurements within the framework of a 100 foot sampling grid. The arithmetic mean of these measurements was 13.4 inches of water as compared with the mean of 13.6 inches for the 11 snow course stakes in the mapped area. The omission of the exposed station site has the effect of exaggerating the difference between the snow course value and the gauge value but it is clear that the snowcourse value is reasonably representative for its area.

However, although the snowcourse appeared to provide a useful indication of snowcover in the immediate vicinity of the meteorological station, its range of cover types and of topographic situations is by no means complete. In particular, lake and ridge top locations are entirely unrepresented. During the later part of March, 1965, we extended the snow survey programme to include the whole drainage area of Knob Lake.

Snow Survey in the Drainage Basin of Knob Lake

As the Laboratory staff numbers only six, of whom at least two are fully occupied with the routine 24 hour per day observational programme, our approach to snowcover mapping in the drainage basin had to be a relatively simple one.

Maps of relief at a scale of 1:50,000, with a contour interval of 50 feet, were available. These were adequate for our purpose as the topography of the drainage basin is relatively simple from the snow survey point of view being essentially a broad, shallow, valley aligned parallel to the prevailing wind. There was also a map series (1:12,000) made by the Iron Ore Company of Canada from specially flown vertical aerial photographs on which lake outlines were shown and on which a number of prominent points in the area were located including several trigonometrical stations. This last map was an excellent basis for the selection of snow traverses and for mapping the vegetation which appeared to be the main variable affecting snow distribution. The vegetation was mapped (Fig. 4) from aerial photographs using six categories from Hare's classification (1950a, 1959); closed lichen woodland, open lichen woodland, open lichen woodland scrub, lichen heath, lichen scrub and muskeg. Burned areas were a complication because of their various stages of regeneration but generally they were allocated to the open lichen scrub or lichen heath categories. From the point of view of the snow surveyor, the important feature of this list of vegetation types is that it is a series of increasing openness. As all forms are relatively open, the pattern of snowcover in this area is a mosaic of exposed open areas, with shallow snow, separated by deep, relatively narrow, drifts. The lakes are additional open areas which have a similar, though larger scale, effect on snow distribution -- thin snowcover out on the lakes with deeper snow on the margins especially in lee and downwind locations. Thus there are relatively few extensive areas with an even snowcover.

Fig. 4.

KNOB LAKE DRAINAGE BASIN

VEGETATION

Schefferville

1 mile



LEGEND






-  closed lichen woodland
-  open lichen woodland
-  open lichen woodland scrub,
lichen scrub, lichen heath,
(largely burned over)
-  marsh
-  lake

TABLE 2

Snow present on the lakes of the Knob Lake watershed,
at end of winter 1964-65.

| | <u>A</u> | <u>B</u> | <u>C</u> | <u>D</u> | <u>E</u> | <u>F</u> | <u>G</u> | <u>H</u> |
|----------------|----------------------------------|--------------------------------|-----------------------------|------------------------|---------------------------|-----------------------|---|----------------------------------|
| | Area | Snow Depth (arith. mean) | No. of Measure- ments | | Density (gm/cc) | Snow Depth (B x E) | Snow Cover (Total) (F x A) | Snow Depth (Lakes' mean) |
| Lake | X10 ⁶ ft ² | ft. | Total | per ml ² | (mean value, see text) | ft ³ water | X10 ⁶ ft ³ water | $\frac{G}{A}$ as inches water |
| Knob | 20.68 | 1.52 | 351 | | 0.277 | 0.421 | 8.706 | |
| Malcolm | 18.88 | 1.50 | 143 | | 0.292 | 0.438 | 8.269 | |
| Easel | 9.68 | 1.54 | 97 | | 0.244 | 0.376 | 3.638 | |
| Houston | 6.40 | 1.31 | 67 | | 0.360 | 0.472 | 3.021 | |
| Ares | 5.76 | 1.61 | 50 | | 0.293 | 0.472 | 2.719 | |
| Gene | 4.25 | 1.50 | 34 | | 0.282 | 0.423 | 1.798 | |
| Osprey | 3.23 | 1.33 | 27 | | 0.328 | 0.436 | 1.409 | |
| Phred | 2.62 | 1.49 | 19 | | 0.284 | 0.423 | 1.109 | |
| Communications | 2.27 | 1.20 | 21 | | 0.250 | 0.300 | 0.682 | |
| South | 1.20 | 1.39 | 7 | | 0.260 | 0.361 | 0.431 | |
| North | 1.08 | 1.22 | 9 | | 0.301 | 0.367 | 0.395 | |
| Middle | 0.57 | 1.08 | 12 | | 0.338 | 0.365 | 0.207 | |
| Cowan | 0.51 | 2.39 | 3 | | 0.167 | 0.399 | 0.204 | |
| Bar | 0.48 | 1.09 | 1 | | 0.295 | 0.322 | 0.155 | |
| Trigger | 0.32 | 1.59 | 5 | | 0.238 | 0.387 | 0.123 | |
| Others | 7.56 | 1.67 | | | 0.250 | 0.418 | 3.159 | |
| Total | 85.00 | | 846 | 274 | | | 36.025 | 5.1 |

We made 12 traverses across the drainage basin (Fig. 1), all approximately perpendicular to the prevailing wind and to the grain of the country. Snow depths were measured at least every 500 feet and water equivalents every 1,000 feet using one Mount Rose Sampler and one Green, Adirondack type, Sampler. The sample points were located by pacing on snow shoes, the observer making careful note of his situation relative to the vegetation and to prominent features shown on his 1:12,000 map. Each traverse began and ended at a prominent landmark, normally a survey beacon, and was no more than 2 1/2 miles in total length. Every traverse crossed lakes on which it was particularly easy to fix a position. We feel that the 19 miles of traverse which were completed were as well controlled as was necessary for our purpose.

We have drawn maps of the snowcover from the traverse data (Fig. 5) but, owing to the extreme local variations which were mentioned, the isopleths give only a very general impression of the true pattern. In all, 114 water equivalent measurements ($8.5/m^2$) and about three times that number of depth measurements were obtained. The arithmetic mean of the water equivalent measurements was 12.2 inches. Allowing for the areas of the different cover types, as indicated in Table 1, this value becomes 11.0 inches. From the beginning of the winter (snow lay on the ground from 22 October) to the time of the survey (mid March), accumulated measurements in the Nipher Gauge amounted to 9.36 inches, water equivalent, 18% lower than the amount present in the basin. Again, the validity of the snowcourse (11.4 inches by this time) appears to be confirmed.

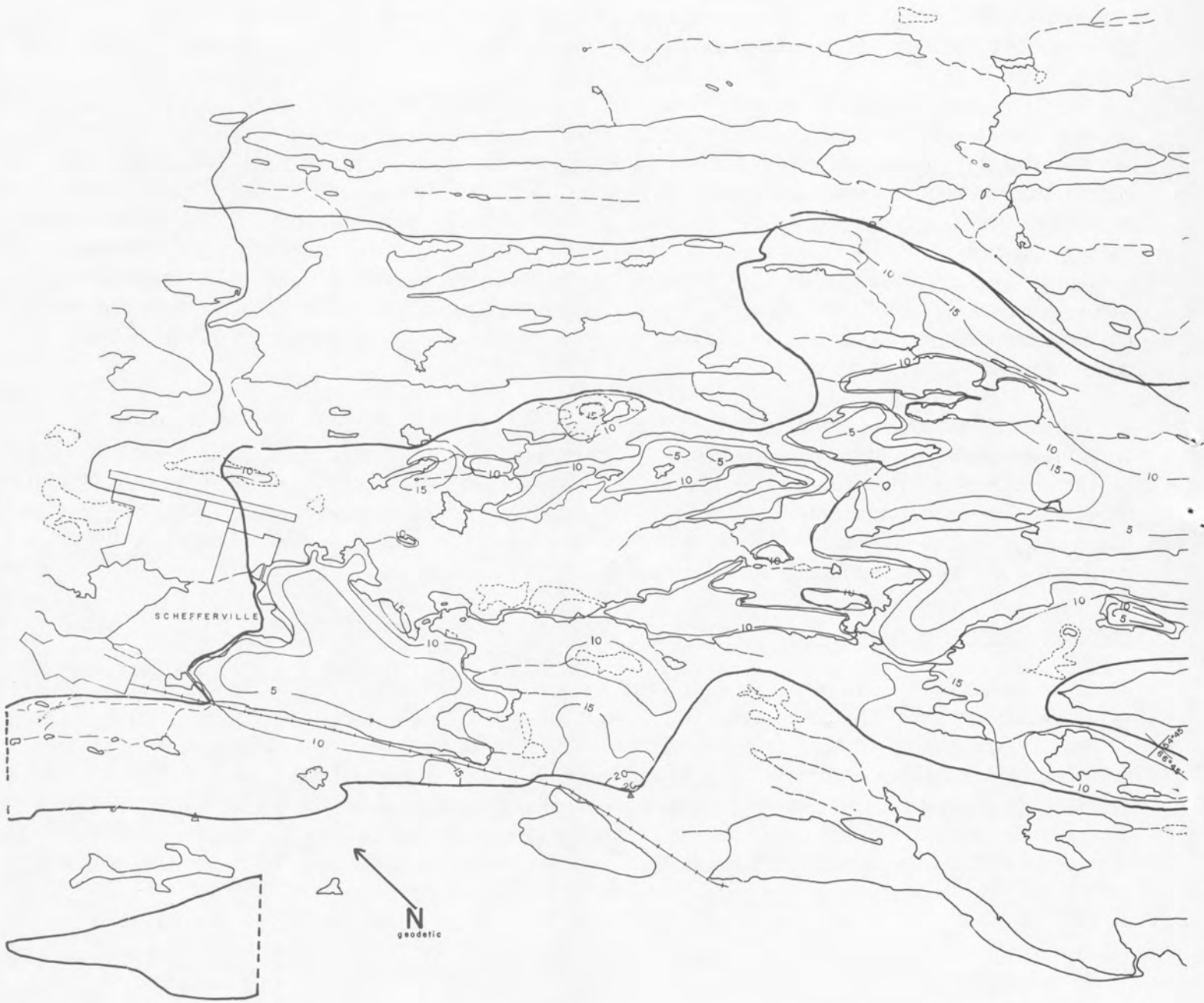
However, as can be seen from Table 1, ridge top locations (in the lichen scrublichen heath vegetation category) and lakes were poorly represented in the survey data. The reason for this is that they have little cross-valley extent but cover a considerable proportion of the catchment because of their extent along the length of the watershed. Our sampling was, of course, across the valley. In the case of the lakes, which were most affected in this way, it was possible to refine the snow measurement considerably.

Snow Survey on the Lakes of the Knob Lake Watershed

Part of the hydrologic study of which the snow measurements under discussion were a part, was detailed study of the ice cover of the lakes which form 23% of the Knob Lake drainage basin. Snow surveying is facilitated on the lakes by the fact that location of sampling points is simple in level open areas as compared with in the bush on slopes of a drainage area. There is some problem in the use of snow samplers, the occasional presence of slush can seriously interfere with progress when the air temperature is twenty below and the pick-up of the samplers is sometimes poor when the snowcover has an ice base. However, we were able to avoid this problem by calculating the total snow present on the lakes by another method.

From the point of view of the distribution of snow present at the time of the survey, the lakes were merely level, exposed, areas which, because of their smooth surface, are particularly susceptible to the re-distribution of snow by wind and deflation. The map of Knob Lake itself (Fig. 6, from Archer, 1966) shows the influence of the strongly prevailing NW wind, with concentrations of snow at the downwind end of the lake and on lee shores. Guest House Point, for example, which is heavily wooded, can be seen to influence snowcover for a considerable distance downwind. This map was drawn from 351 depth measurements made within a grid of 200 stakes. Similar, but less detailed, maps were made of 13 of the major lakes in the watershed -- over 90% of the total ice cover.

The ice cover of a lake is a floating body with a density close to 0.9 gm/cc which is depressed as snow is added to its surface. The density of snow lying on the ice body



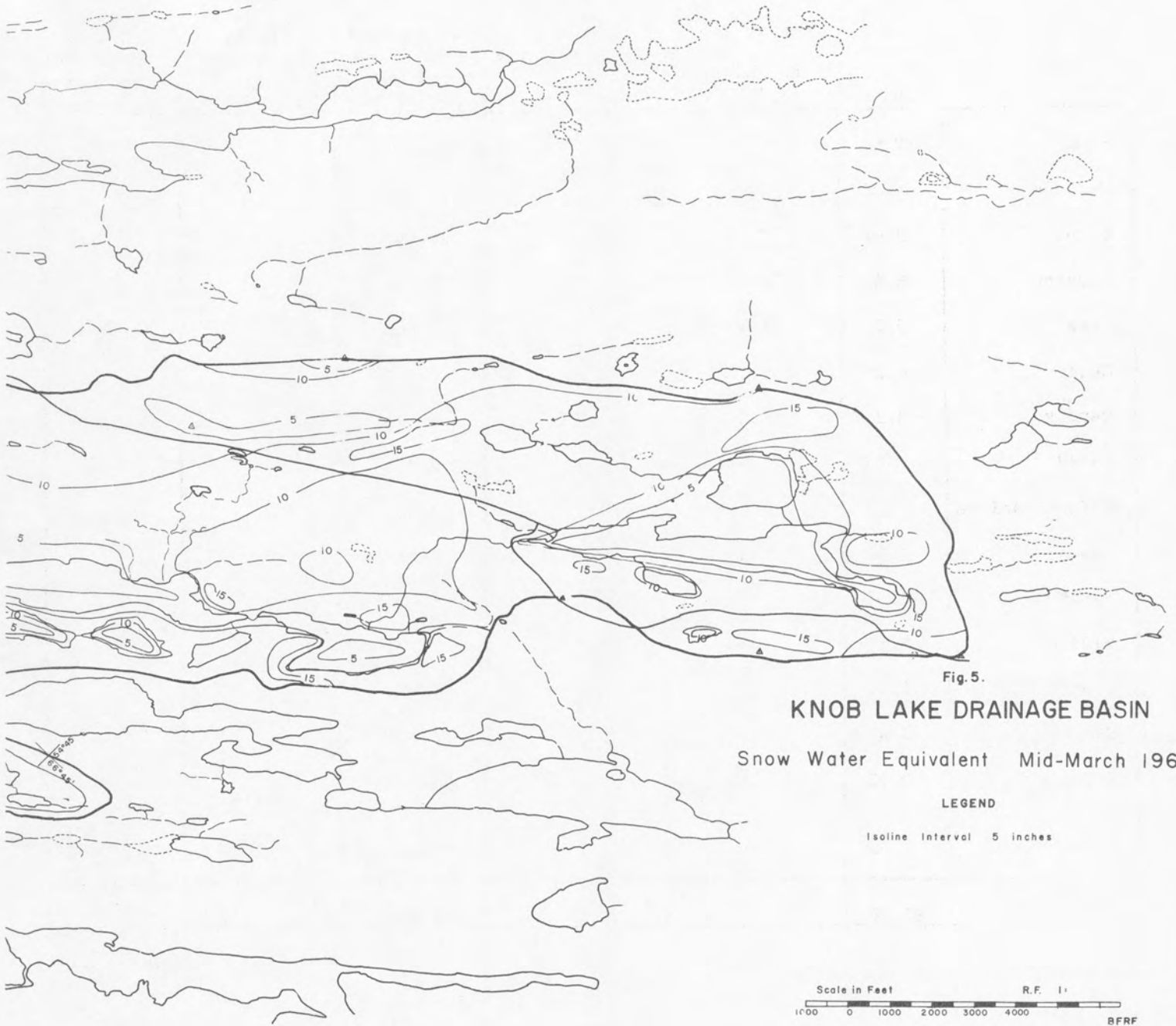


TABLE 3

Snow present on white ice on lakes of the Knob Lake watershed,
end of 1964-65 winter.

| | <u>A</u> | <u>B</u> | <u>C</u> | <u>D</u> | <u>E</u> | <u>F</u> | <u>G</u> |
|----------------|---------------------------|----------------|--------------|-------------------|--|----------------------------------|---------------------------------------|
| | Area | White Ice | No. of | White Ice | Snow as | Snow as | |
| | $\times 10^6 \text{ft}^2$ | Mean thickness | Measurements | Total Volume | White Ice | White Ice | |
| | | ft. | Total | per ml^2 | $\text{A} \times \text{B} \times 10^6 \text{ft}^3$ | $\text{E} \times 0.9 \times 0.3$ | $\frac{\text{F}}{\text{A}}$ as inches |
| | | | | | | $\times 10^6 \text{ft}^3$ water | of water |
| Knob | 20.68 | 1.00 | 310 | | 20.680 | | |
| Malcolm | 18.88 | 1.18 | 130 | | 22.278 | | |
| Easel | 9.68 | 1.11 | 49 | | 10.740 | | |
| Houston | 6.40 | 1.43 | 64 | | 9.152 | | |
| Ares | 5.76 | 1.40 | 45 | | 8.064 | | |
| Gene | 4.25 | 1.38 | 30 | | 5.865 | | |
| Osprey | 3.23 | 1.40 | 19 | | 4.525 | | |
| Phred | 2.62 | 1.09 | 19 | | 2.858 | | |
| Communications | 2.27 | 1.13 | 20 | | 2.566 | | |
| South | 1.20 | 1.31 | 7 | | 1.565 | | |
| North | 1.08 | 1.11 | 8 | | 1.430 | | |
| Middle | 0.57 | 1.09 | 12 | | 0.618 | | |
| Cowan | 0.51 | 1.17 | 3 | | 0.599 | | |
| Bar | 0.48 | 1.04 | 4 | | 0.499 | | |
| Trigger | 0.32 | 1.30 | 5 | | 0.416 | | |
| Other | 7.56 | 1.25 | | | 9.448 | | |
| Total | 85.00 | | 725 | 235 | 101.303 | 27.352 | 3.9 |

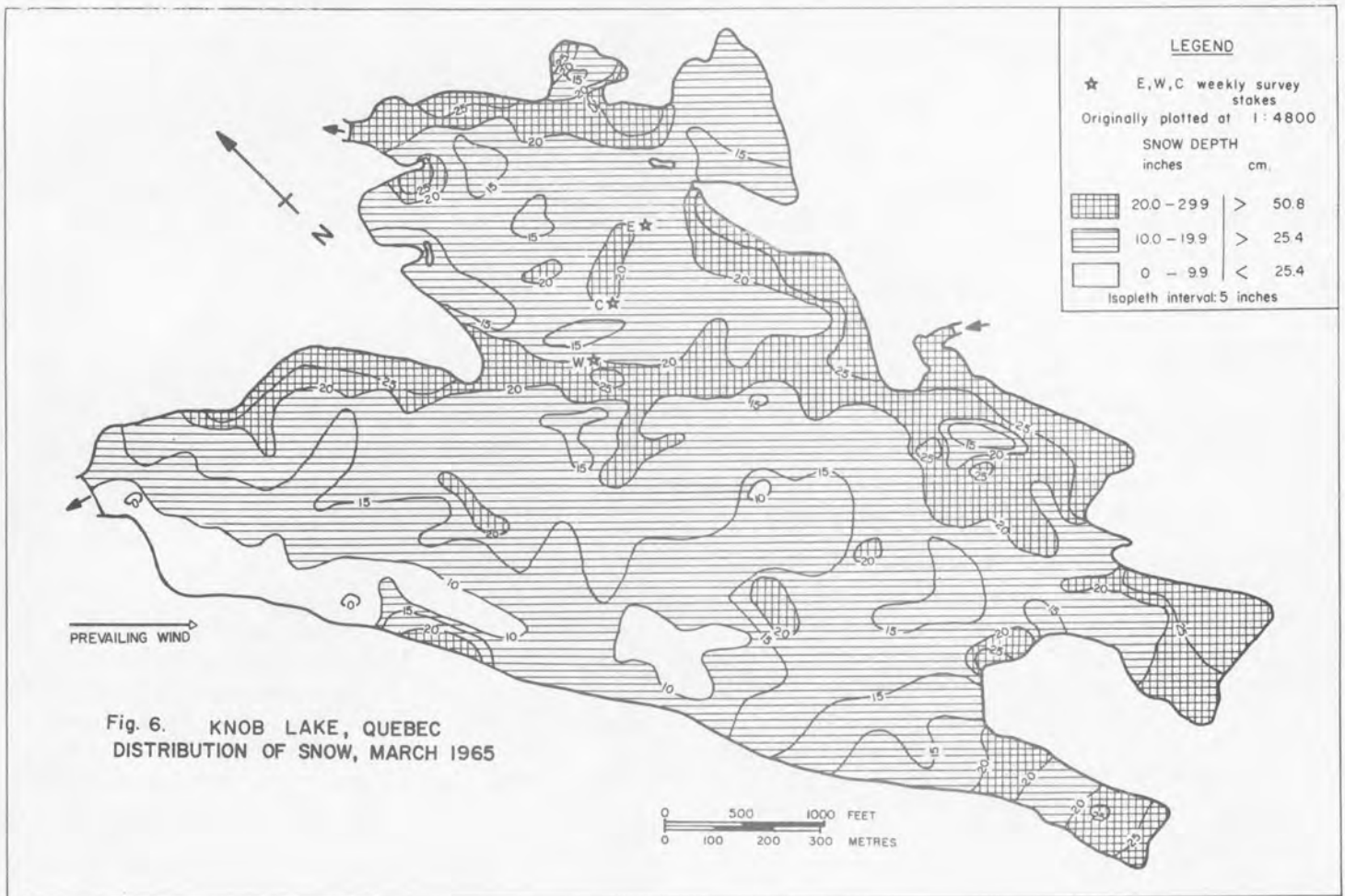


Fig. 6. KNOB LAKE, QUEBEC
DISTRIBUTION OF SNOW, MARCH 1965

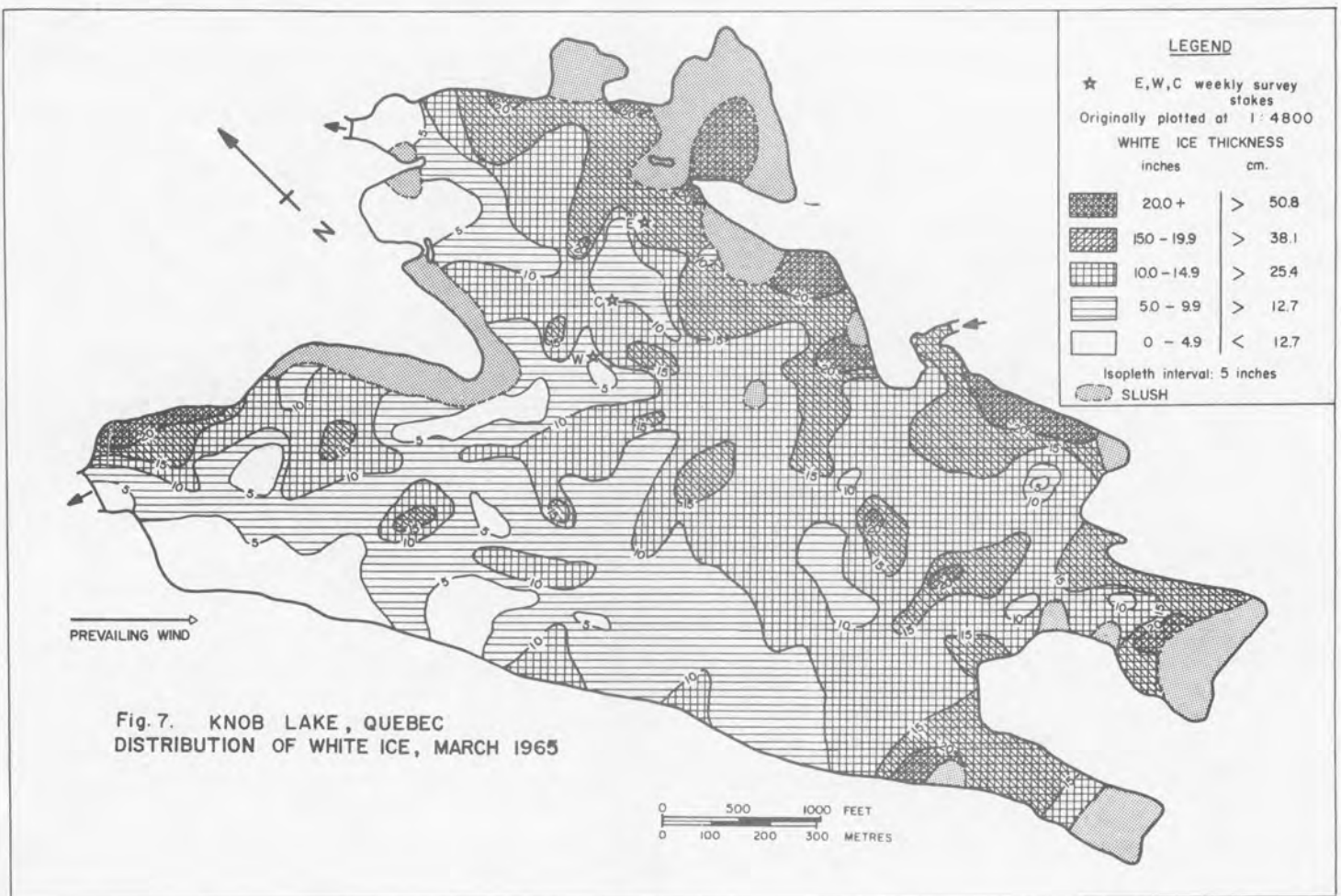


Fig. 7. KNOB LAKE, QUEBEC
DISTRIBUTION OF WHITE ICE, MARCH 1965

can be calculated from measurements of snow depth, ice thickness and of the height of water in holes drilled through the ice. Shaw (1964) gives the following formula:

$$\rho_s = \frac{A_w \rho_w - A_i \rho_i}{A_s}$$

where

- ρ_s is the snow density (gm/cc)
- ρ_w is the water density (1 gm/cc)
- ρ_i is the ice density (c.0.9 gm/cc)
- A_w is the height of water in the drill hole
- A_i is the ice thickness
- A_s is the depth of snow

Assuming that the density of the ice was 0.9 gm/cc, we calculated the mean density of the snow on Knob Lake as 0.28 gm/cm³. This value was based on the arithmetic mean of 188 total ice thickness and water level measurements and on the mean of the 351 snowdepth measurements which were mentioned. The results of similar calculations for the other lakes which were surveyed, with estimates for the 9% of ice cover which was not surveyed, are shown in Table 2. It will be observed that the number of measurements per unit area of ice was very much higher than the density of measurements of snowcover in the watershed as a whole.

Weighting the arithmetic means for the area of the individual lakes concerned (Table 2), we come up with a total snowcover for the lakes of 36.025 x 10⁶ft³, water equivalent, or a mean snow depth of 5.1 inches, water equivalent. This is about an inch lower than the lakes' value from the overall survey (6.3") and is, of course, less than half of the mean snowcover of the entire catchment area. To some extent this deficiency is to be expected from the deflation of snow from the lakes, which has been mentioned. However, it is in fact a considerable underestimation of the total winter receipts of the lakes.

In this area, as in others which have both a cold winter and a relatively high snowfall, the process of ice growth is complicated by the development of white ice on the surface of the normal black ice, as a result of flooding (see Shaw, 1965). The surface of the ice sheet is depressed below the hydrostatic water level by its load of snow and so is liable to flooding should cracking occur. Thus at the end of the winter, the lakes' ice cover consists of a major component, black ice, and a white ice component which on Knob Lake has varied from 13% to 57% of the total at peak ice development during 12 years of measurements. When the ice sheet floods, a considerable amount of snow is incorporated into it. For example, if the ice is flooded to a depth of ten inches, at least ten inches depth of the snowcover becomes ice. Assuming a density of 0.3 gm/cc, three inches of the resultant increment of white ice (2.7 inches of water) is derived from the snowcover. The relation between snowcover and white ice growth (which is the reverse of the normal relationship between ice and snow -- where snowcover retards rather than promotes ice growth) can be seen from Fig. 7. The distribution of white ice is similar to the distribution of snow but more emphatic as the presence of thick white ice reflects the tendency for snow to persistently concentrate in certain areas throughout the winter.

Thus about 30% of the white ice present on Knob Lake at the time of our survey must be included in the total snow receipts of the lake for the winter. This actually amounted to 3 inches of water. Similar maps for the other lakes surveyed (data in Table 3) show that the Knob Lake value for white ice was relatively low for the catchment area as a whole and that 3.9 inches, water equivalent, should be added to the mean depth of snow measured on the lakes. This brings the lakes' contribution to the basin's snowcover up

TABLE 4

Snowfall values for winter Oct. 22 - 18 March, 1964-65, compared

| Method of Measurement | No. of water equivalent measurements | Snowfall (inches, water equivalent) | Snowfall (% of Nipher value) | Notes |
|---|--------------------------------------|-------------------------------------|------------------------------|--|
| Nipher Gauge at McGill Laboratory | Accumulated six hourly measurements | 9.36 | 100 | Exposed, valley, location. Affected by deficiencies of catch and procedure. |
| Snowcourse close to Laboratory | 12 | 11.4 | 122 | Includes open Laboratory-airstrip site which appears to compensate for lack of lake and ridge locations. |
| Snowcourse without open Lab. site | 10 | 12.5 | 134 | Includes open muskeg area but exposed sites under-represented. |
| Map of snowcourse area (1300 ft. x 1300 ft.) | 88 | 12.3* | 132* | Ditto |
| KL watershed survey - arith. mean | 114 | 12.2 | 131 | Too high for snow actually present due to under-representation of ridge and lake sites in mean. |
| KL watershed survey - weighted for cover types | 114 | 11.0 | 118 | Lower as result of greater weight of open cover types. Good value for snow actually present? |
| KL watershed survey - adjusted for white ice and lake snow survey | | 11.52 | 123 | Improved lakes' value for snow, addition of snow-from-white-ice. BEST VALUE FOR WINTER'S SNOWFALL. |

* Adjustments have been made for snow receipts between the main survey and the date of this survey.

to 9 inches of water, still below the mean value for the entire catchment but very similar to the accumulated Nipher Snow gauge receipts. Allocating 9" to the lakes' area, mean snowfall in the drainage basin becomes 11.52 inches, water equivalent.

COMPARISON OF SNOWFALL VALUES

The various snowfall values for the period during which snow lay on the ground in 1964-65, before the major snow survey (22 October to 18th March) are listed in Table 4. The Nipher Gauge value appears to be low, assuming that the adjusted catchment map value is the best available, the underestimation amounted to 23%. There is no reason to believe that the under-measurement does not extend to the full snow year so that the official, July - July, snowfall value of 12.43 inches, water equivalent, probably represents an actual fall of about 15.3 inches.

Under-measurement by the gauge was also suggested by measurements of discharge from the drainage basin during summer, 1965 (Findlay, 1966). As evaporation, which may have accounted for a loss of something less than one inch of water from the basin snowcover during the winter, has not been considered, the suggested under-measurement can be considered as a minimum: the snow gauge value would be little affected by this loss.

CONCLUDING REMARKS

Although the work discussed was carried out during only a single winter and in a very small drainage basin, some general points deserve mention;

1. The snowfall of 1964-65 at Knob Lake was average in amount and was in no way abnormal in character so that under-measurement by the Nipher Gauge does not appear to be a special feature of this particular year. There is no reason to believe that the values provided by the other gauges in Labrador-Ungava, which are very few indeed, are any better than those for Knob Lake. Hare (1964, pers. comm.) points out that run-off from the Lake Plateau (central Labrador-Ungava) is remarkably high. The Churchill, at Churchill Falls, and the Manicouagan and other rivers from the interior plateau, average 1.9 to 2.0 cfs per square mile of catchment. This represents some 25 to 27 inches of precipitation. Measured precipitation for the whole plateau area, which includes a large area south of Knob Lake is 30 to 33 inches water equivalent per year, but of this 10 to 15 inches must evaporate. In other words, there is a general lack of precipitation. The deficiencies in gauge snowfall measurement which we have demonstrated for Knob Lake explain this lack in part.
2. The snowcourse at Knob Lake appears to provide a useful regional value despite its limited coverage of cover types and topographic situations. Ultimately, in an area like Labrador-Ungava, extended snow surveys are essential if good overall snowfall values are to be obtained. This could be initiated quite simply as extensive vegetation mapping of the Peninsula has already been completed (Hare, 1959) and as the relief of some areas is already quite well known. Short snow courses in selected areas (perhaps sub-basins) could produce useful results with relatively small effort. With an aircraft, two or three weeks of work per winter would achieve a good deal.
3. In areas of the Subarctic which have a high density of lakes, snowmapping without a consideration of white ice can cause a significant under-estimation of snow receipts.
4. Recent changes in Department of Transport procedures for reporting snowfall -- involving measurements over periods shorter than six hours during periods of heavy snowfall -- while an improvement for some meteorological purposes, may possibly be a retrograde step from the hydrological point of view. It would be very simple, and cheap, to

install one of the storage snow gauges which are now available at meteorological stations as a standard of comparison for the Nipher Gauges. This would require no more than one additional measurement per month by the stations' personnel. Alternatively, it might be possible to locate some Nipher Gauges in very sheltered sites (which are in other respects poor meteorological locations) to obtain daily snowfall values.

Acknowledgments

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- Footnote (see p. 2) The problem of Traces, which are of great importance in the High Arctic, is considered in; Jackson, C. I., 1960. Snowfall measurements in northern Canada. Q.J.R.M.S., 86, No. 368 p. 273-5. D.O.T. procedures for snow measurement are also discussed in this paper and in a number of the references cited by Jackson.