SNOW COVER SUITABILITY PERCENTILES FOR SKIING AND SNOWMOBILING

R.B. Crowe

Atmospheric Environment Service
Department of Fisheries and Environment
Downsview, Ontario.

ABSTRACT

In a recent recreation climate study of Ontario, a percentile of snow cover suitability for skiing and snowmobiling was developed. Snow cover suitability for winter recreation implies not only snow depth, but also snow state or condition. The criteria proposed involve the snow depth, absence of liquid precipitation and the daily maximum temperature. Data from a small number of synoptic weather stations were correlated with mean maximum temperature, total precipitation, and time of year for a large number of climatological stations.

The data are presented at 10-day intervals through the winter and in a probability range from zero to 100. Snow cover was considered unreliable for winter sports if the percentile values were in the range zero to 49, marginally reliable for the range 50 to 74 and reliable for the range 75 to 100.

INTRODUCTION

In a recent recreation-tourism climatic study of Ontario (Crowe, McKay and Baker, 1977), three climatic factors were identified as important to winter recreation:

1. comfort satisfaction, related to air temperature and wind chill,
2. weather satisfaction, related to the occurrence, non-occurrence and types of cloud and precipitation,
3. snow cover suitability, related to the depth and quality of the snow pack.

A suitable snow cover is obviously a necessary prerequisite for the pursuit of skiing or snowmobiling, regardless of the levels of comfort and weather satisfaction. This paper deals specifically with snow cover suitability, and the material is taken directly from Volume Three of the above-mentioned publication.

WINTER SNOW COVER IN ONTARIO

A suitable snow cover for winter sports implies a snow cover of good quality as well as one of sufficient depth, as the existence of a crust or of wet snow conditions places limitations on the quality of skiing and snowmobiling.

Figure 1 shows the median depth of snow cover at the end of January. The greatest depths, 1 foot (30cm) or more, occur to the lee of Lake Superior, Georgian Bay and Lake Huron, and over most of northern Ontario generally, while the least depths occur over southwestern Ontario. These isopleths are based mostly on data from airport sites, where values may be lower than regional averages, due to wind-swept exposures. Certainly, snow depths in nearby wooded areas, which are of interest to snowmobilers and cross-country skiiers, would be considerably greater. The variability in the depth of snow cover is often great from day to day and also from one season to the next. Snow cover is very unreliable over all of southwestern Ontario and most of southern Ontario, due to frequent

thaws, and not infrequently in these areas the ground becomes bare of snow for a number of days at mid-winter.

Snow quality is usually high at those areas where the snow pack is commonly deep, particularly over northern Ontario. Over those parts of southern and southwestern Ontario where snow cover is unreliable and the snow pack usually marginal in depth, the snow quality is often poor as well, due to frequent thaws and rain.

DEVELOPMENT OF A SNOW COVER-SUITABILITY PERCENTILE

Snow cover suitability implies not only snow depth, but also snow state or condition. A suitable snow cover for skiing and snowmobiling must have at least a certain minimum snow depth, good tractionability and a snow surface that is not crusty or wet. Since the exact parameters and limits for satisfactory activity participation are unknown, some judgement decisions were necessary as to quality and depth. For simplicity, the following criteria were proposed for a day suitable for several activities, including cross-country skiing, downhill skiing and snowmobiling:

1. snow cover of two inches (5 cm) or more at 7 a.m.,
2. no measurable liquid precipitation (rain, drizzle, freezing rain or freezing drizzle) during the 24-hour period,
3. maximum temperature for the day less than 40°F (4.4°C).

The choice of the above limits was determined in part by the nature of the available data; for example, snow depth data are available on a daily basis only for 7 a.m., EST. Most of the stations used in the analysis are located at airport sites. Since these are highly exposed, greater depths would usually be found in surrounding areas. It was decided that the occurrence of a two-inch (5 cm) depth of snow cover at the airport sites was a good index of adequate snow depths for regional winter sports, especially in mid-winter and spring.

The percentage of days with suitable snow cover, based on the above definition, was immediately available for only ten stations, each having a relatively short period of record (7 to 19 years). It was desirable, therefore, to correlate this data with long-term mean values for other climatological elements recorded at a large number of stations. In this respect, the mean percentage of days correlated well with three parameters:

1. mean maximum temperature,
2. total precipitation,
3. time of year.

In Figure 2, the correlations with the three parameters are schematically shown, using (10-day) data from all ten stations. Values shown are for mean ten-day (one-third-month) precipitation totals of 0.8 inches (20 mm) (dashed line) and 1.2 inches (30 mm) (solid line). As an illustration, suppose the mean maximum temperature at the end of December (21st to 31st) at locality "A" is 20°F (-6.7°C). If the total precipitation in this ten-day period is normally 1.2 inches (30 mm) (solid line), the mean percentage of days having a suitable snow cover is greater than 90, say 92. On the other hand, if the total precipitation in this same period is only normally 0.8 inches (20 mm) (dashed line), the mean percentage is less than 90, say 89.

Mean temperature is a major control. The lower the temperature, the higher the chance of having a suitable snow cover. However, it can be seen that this relationship is not linear. At mean maximum temperatures between about 30 to 35°F (-1.1 to 1.7°C), there is about a 50 per cent chance of having a suitable snow cover. With increasing temperature, this falls off rapidly to about 10 per cent at 40 to 45°F (4.4 to 7.2°C) and then less rapidly at higher temperatures. Similarly, with decreasing maximum temperatures below 30 to 35°F (-1.1 to 1.7°C) the percentages for suitable snow-cover days increase rapdily to about 90 at 20 to 25°F (-6.7 to -3.9°C), and then less rapidly at lower temperatures. It is stressed that this relationship holds only for long-term mean temperature values, day-to-day variations normally being large.

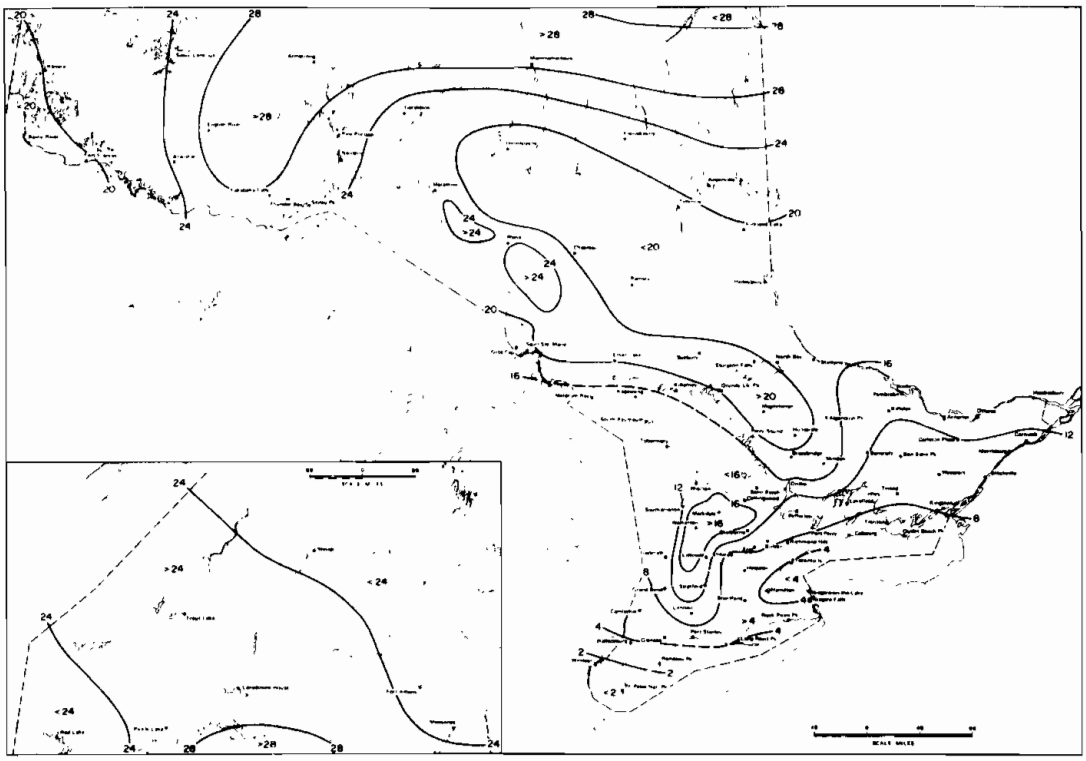
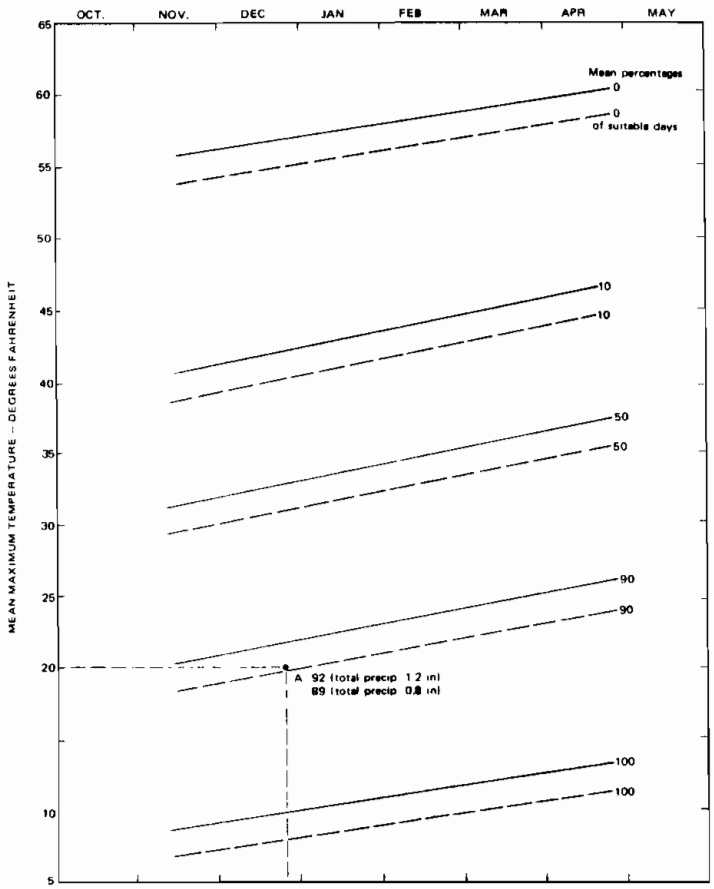


Figure 1. Median depth of snow cover at the end of January (inches)



Total ten-day precipitation 0.8 in

Total ten-day precipitation 1.2 in

Figure 2. Mean percentage of days through the winter with suitable snow cover for skiing and snowmobiling as a function of mean maximum temperature and total precipitation

The time of year also has a significant effect upon the percentage values of days with suitable snow cover. From the slopes of the various lines in Figure 2, it can be seen that as winter progresses, higher and higher mean maximum temperatures result in the same mean percentage values. In other words, the percentage values increase through the winter for a given mean temperature. For example, the 50% chance of suitable days is found with a mean maximum temperature of about 30°F (-1.1°C) in mid-November, but at the end of April, this percentage value is correlated with a mean maximum temperature of about 35°F (1.7°C).

At reasonably low temperatures, the greater the precipitation, the greater the snowfall, and thence the higher the chance of a suitable snow cover. Logically, at higher temperatures, a higher precipitation would result in more rain, with a decreasing chance of suitable snow cover. However, through the process of selecting the winter season, and considering that mean values are used this negative correlation is not encountered.

Figure 3 shows how the mean percentage of days with suitable snow cover for skiing and snowmobiling varies with mean maximum temperature at mid-February, assuming a ten-day total precipitation of one inch (25 cm). These percentage values were defined as snow cover suitability percentiles. At this time of winter and for one-inch (25 cm) precipitation amounts, the percentile value of 25 occurs with a mean maximum temperature of 37°F (2.8°C), the value of 50 at 32°F (0°C), and 75 at 27.5°F (-2.5°C). The data in Table 1, showing the estimated snow cover suitability percentiles based on mean maximum temperature data, were taken directly from Figure 3.

The data in Table 1 are valid only for mid-February, and only for a mean ten-day precipitation amount of one inch. To calculate snow cover suitability percentiles for other time periods and other mean precipitation amounts a correction table (Table 2) was prepared. A snow cover suitability percentile at a particular locality for any time of the winter was then calculated as follows. Using the mean precipitation amount and time of year, a correction value was first obtained from Table 2. This correction value then was applied to the mean maximum temperature values given in Table 1 so as to obtain a percentile estimate. As an example, suppose it was necessary to calculate the snow cover percentile for a station at mid-December where the mean ten-day precipitation at that time of year is 0.8 inches (20 mm) and the mean temperature 27°F (-2.8°C). From Table 2, the correction factor is 3°F (1.7°C). From Table 1, for a corrected mean temperature of 30°F (-1.1°C), the percentile value is 62.

MAPS OF SNOW COVER SUITABILITY PERCENTILES

Using ten-day means of temperature and total precipitation, snow cover suitability percentiles were calculated for a number of Ontario stations for the 5th, 15th and 25th of each month. These values were plotted, analysed and smoothed areally. Figures 4,5,6 and 7 show the isopleths of percentile values and interpolated values at a number of sites for December 15, January 15, February 15 and March 15, respectively. The higher values occur to the lee of the Great Lakes in particular and in northern Ontario in general.

The lowest percentiles are found in southwestern Ontario. At the height of winter a suitable snow cover for skiing and snowmobiling ranges from four days out of ten near Windsor to five or six a little farther to the northeast.

Across southern Ontario, the percentile values are much higher than over the southwestern part of the Province. The highest values at mid-winter, 70 to 80, occur to the lee of Lake Huron and Georgian Bay, indicating that the chance of a suitable snow cover is about three days out of four. Considerably lower values, only slightly better than one day in two, occur along the Lake Ontario shore at mid-winter.

The northern sections of eastern Ontario display percentiles about 80 for about two months at mid-winter. Only slightly lower values are found farther south.

Over central Ontario, the chance of a suitable snow cover ranges from eight to nine days out of ten for almost two months at the height of winter.

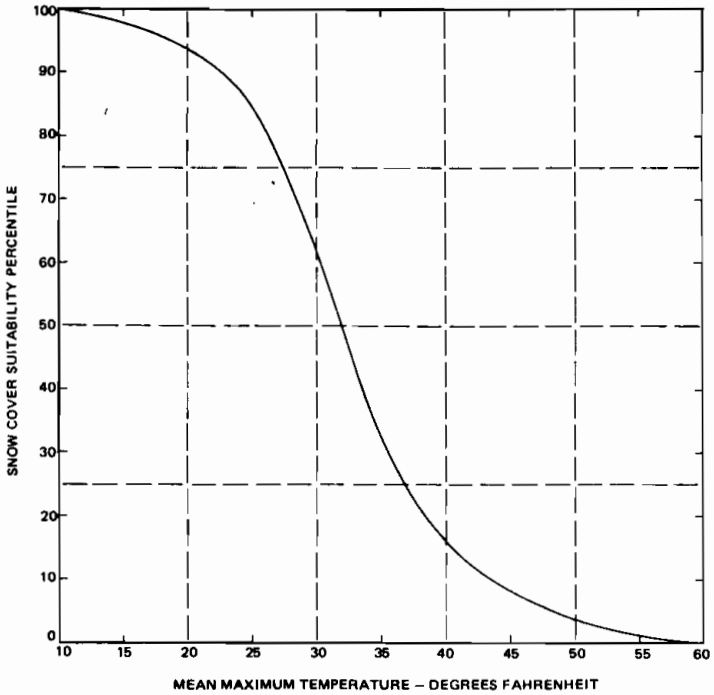


Figure 3. Mean percentage of days with suitable snow cover for skiing and snowmobiling (snow cover suitability percentile) as a function of mean maximum temperature at mid-February, assuming a ten-day total precipitation of one inch

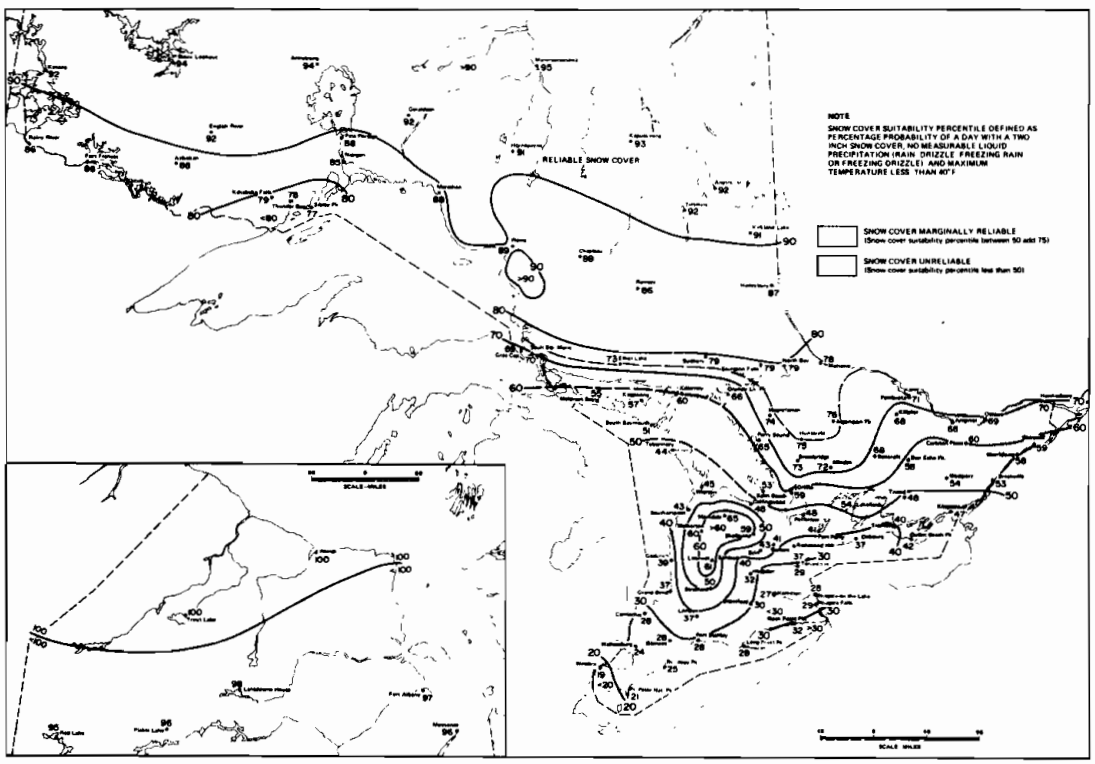


Figure 4. Snow cover suitability percentile – December 15

Table 1. Calculation of snow cover suitability percentile from mean daily maximum temperature at mid-February, assuming a ten-day total precipitation of one inch

Mean temp. °F	Percentile value	Mean temp. °F	Percentile value	Mean temp. °F	Percentile value
57½ and higher	0	41½	13	25½	83
57	1	41	14	25	85
56½	1	40½	15	24½	86
56	1	40	16	24	87
55½	1	39½	18	23½	88
55	1	39	19	23	89
54½	2	38½	20	22½	90
54	2	38	21	22	91
53½	2	37½	23	21½	91
53	2	37	25	21	92
52½	3	36½	27	20½	92
52	3	36	29	20	93
51½	3	35½	31	19½	93
51	3	35	33	19	94
50½	4	34½	35	18½	94
50	4	34	37	18	95
49½	4	33½	40	17½	95
49	5	33	43	17	95
48½	5	32½	46	16½	96
48	5	32	50	16	96
47½	6	31½	53	15½	96
47	6	31	56	15	97
46½	7	30½	59	14½	97
46	7	30	62	14	97
45½	8	29½	65	13½	98
45	8	29	68	13	98
44½	9	28½	71	12½	98
44	9	28	73	12	99
43½	10	27½	75	11½	99
43	10	27	77	11	99
42½	11	26½	79	10½	99
42	12	26	81	10 and lower	100

Table 2. Correction to mean daily maximum temperature for the purposes of calculating snow cover suitability percentiles, allowing for variations in time through the winter and a ten-day total precipitation amounts.

Ten-day total precipitation (in.)	Oct.			Nov.			Dec.			Jan.			Feb.			Mar.			Apr.			May		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
0.2	+8	+7½	+7½	+7	+6	+6	+6	+6	+5½	+5	+5	+4½	+4½	+4	+3½	+3½	+3	+3	+2½	+2	+2	+1½	+1½	+1
0.3	+7½	+7	+7	+6½	+5½	+5½	+5½	+5½	+5	+4½	+4½	+4	+4	+3½	+3	+3	+2½	+2½	+2	+1½	+1½	+1	+1	+ ½
0.4	+7	+6½	+6½	+6	+5	+5	+5	+5	+4½	+4	+4	+3½	+3½	+3	+2½	+2½	+2	+2	+1½	+1	+1	+ ½	+ ½	0
0.5	+6½	+6	+6	+5½	+4½	+4½	+4½	+4½	+4	+3½	+3½	+3	+3	+2½	+2	+2	+1½	+1½	+1	+ ½	+ ½	0	0	- ½
0.6	+6	+5½	+5½	+5	+4	+4	+4	+4	+3½	+3	+3	+2½	+2½	+2	+1½	+1½	+1	+1	+ ½	0	0	- ½	- ½	- 1
0.7	+5½	+5	+5	+4½	+3½	+3½	+3½	+3½	+3	+2½	+2½	+2	+2	+1½	+1	+1	+ ½	+ ½	0	- ½	- ½	- 1	- 1	- 1½
0.8	+5	+4½	+4½	+4	+3	+3	+3	+3	+2½	+2	+2	+1½	+1½	+1	+ ½	+ ½	0	0	- ½	- 1	- 1	- 1½	- 1½	- 2
0.9	+4½	+4	+4	+3½	+2½	+2½	+2½	+2½	+2	+1½	+1½	+1	+1	+ ½	0	0	- ½	- ½	- 1	- 1½	- 1½	- 2	- 2	- 2½
1.0	+4	+3½	+3½	+3	+2	+2	+2	+2	+1½	+1	+1	+ ½	+ ½	0	- ½	- ½	- 1	- 1	- 1½	- 2	- 2	- 2½	- 2½	- 3
1.1	+3½	+3	+3	+2½	+1½	+1½	+1½	+1½	+1	+ ½	+ ½	0	0	- ½	- 1	- 1	- 1½	- 1½	- 2	- 2½	- 2½	- 3	- 3	- 3½
1.2	+3	+2½	+2½	+2	+1	+1	+1	+1	+ ½	0	0	- ½	- ½	- 1	- 1½	- 1½	- 2	- 2	- 2½	- 3	- 3	- 3½	- 3½	- 4
1.3	+2½	+2	+2	+1½	+ ½	+ ½	+ ½	+ ½	0	- ½	- ½	- 1	- 1	- 1½	- 2	- 2	- 2½	- 2½	- 3	- 3½	- 3½	- 4	- 4	- 4½
1.4	+2	+1½	+1½	+1	0	0	0	0	- ½	- 1	- 1	- 1½	- 1½	- 2	- 2½	- 2½	- 3	- 3	- 3½	- 4	- 4	- 4½	- 4½	- 5
1.5	+1½	+1	+1	+ ½	- ½	- ½	- ½	- ½	- 1	- 1½	- 1½	- 2	- 2	- 2½	- 3	- 3	- 3½	- 3½	- 4	- 4½	- 4½	- 5	- 5	- 5½

I = 1st to 10th
II = 11th to 20th
III = 21st to end

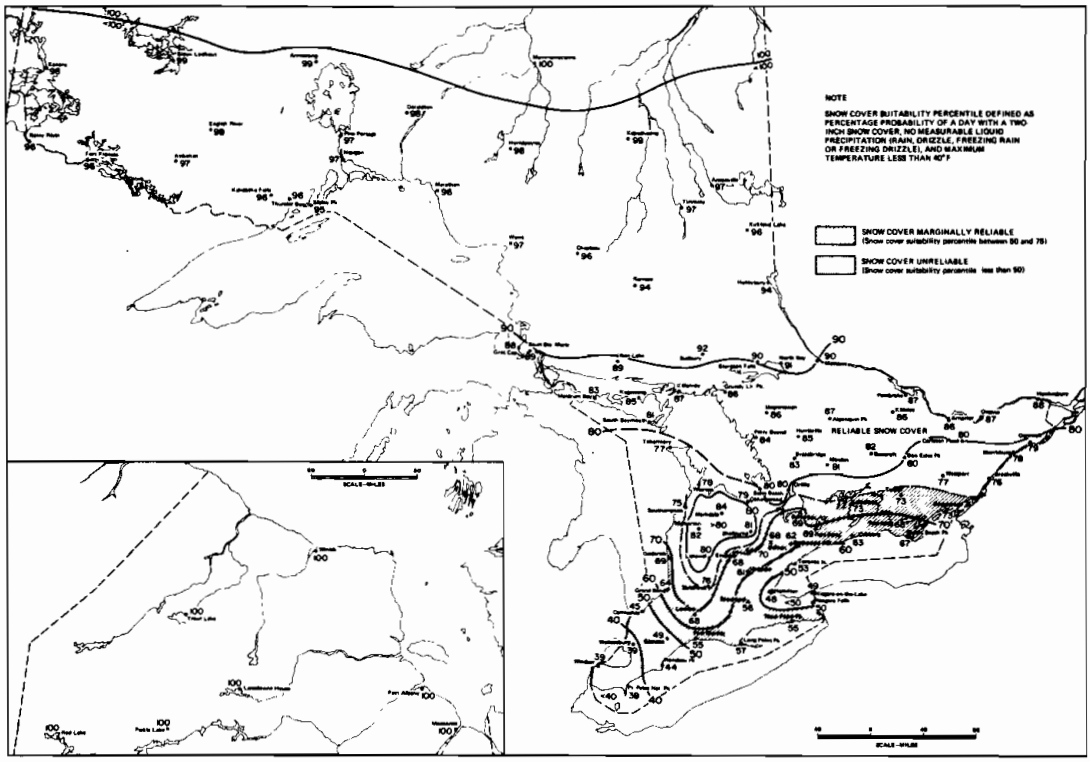


Figure 5. Snow cover suitability percentile – January 15

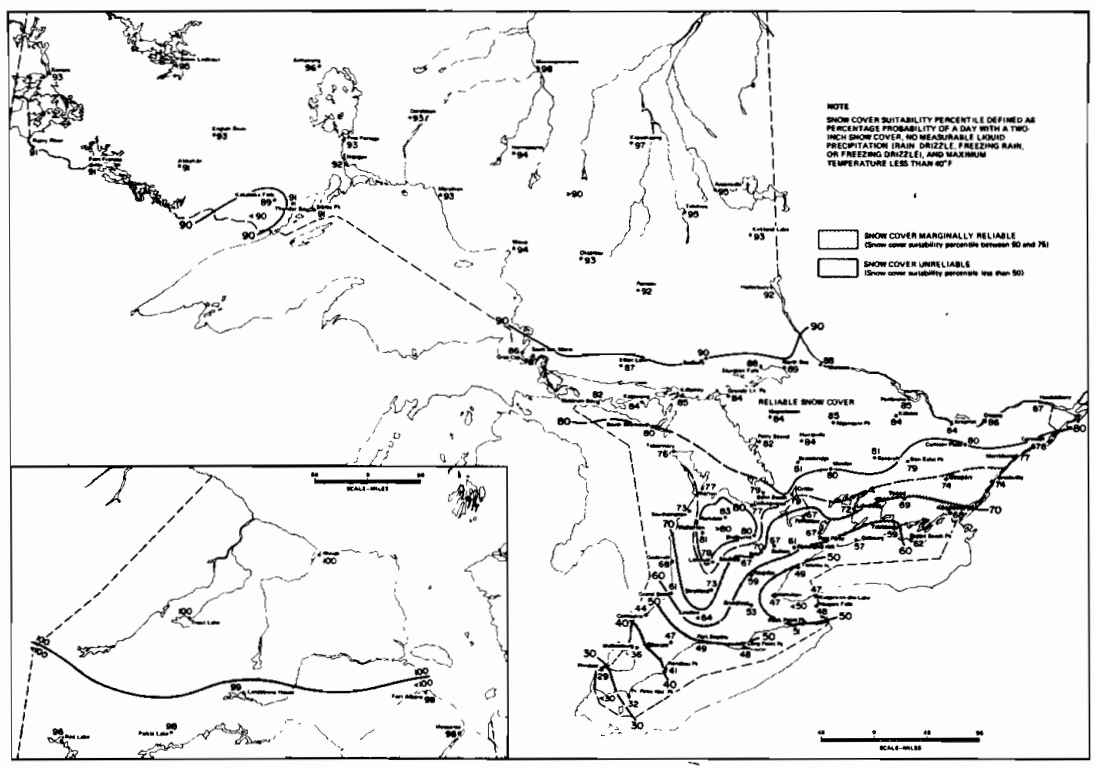


Figure 6. Snow cover suitability percentile – February 15.

In northeastern and northwestern Ontario, percentile values are 90 and over from December to February. Moreover, there is very little variation from place to place in this three-month period.

Throughout far northern Ontario, percentile values are 100 for a month at the height of winter and 90 or over form early November to mid-March. There is little variation across the region except over the extreme north, where Winisk's values in late winter are similar to those farther south about a month earlier.

SKIING AND SNOWMOBILING SEASON LENGTH

Snow cover suitability can be considered the determinant of season length for skiing and snowmobiling, because if there is no suitable snow cover, participation in these activities is completely thwarted.

If there is less than a 50 per cent chance of a suitable cover at a given date, it is reasonable to describe the situation as unreliable for winter sports. In the same vein, if on over three days out of four the mean cover was suitable, then conditions were reasonably reliable. Between these two limits, the snow cover was considered only marginally reliable. The suitability percentile values for snow cover reliability were, therefore, described as follows:

Snow cover suitability percentile	Reliability
0 - 49	Unreliable
50 - 74	Marginally reliable
75 - 100	Reliable

The first date of occurrence of snow cover suitable for skiing and snowmobiling at the 50-percentile level is given in Figure 8, while the last data is given in Figure 9. These show that in those parts of southwestern Ontario to the west of Comlachie and Glencoe and around the western end of Lake Ontario, the snow cover is unreliable through the entire winter.

The length of days of snow cover suitable for skiing and snowmobiling at the 50-percentile level is shown in Figure 10. These data define the period during which the snow cover is marginally reliable or better. As noted, there is no such period in the extreme southwestern part of Ontario. The period is less than two months over much of southern Ontario; however, to the lee of Lake Huron, it is at least three months. Most of central and eastern Ontario has between three and four months of reliable or marginally reliable snow cover. Over the North, this period is as long as five months.

The first date of occurrence of snow cover suitable for skiing and snowmobiling at the 75-percentile level is given in Figures 11, while the last date is given in Figure 12. These dates indicate the beginning and ending of reliable snow cover. Note that all of southwestern Ontario and much of southern Ontario never experience reliable snow cover conditions (on the average) at any time during the entire winter.

The length of the season in which the snow cover suitable for skiing and snowmobiling at the 75-percentile (reliable) level is given in Figure 13. A large portion of southern Ontario adjacent to major population concentrations lies outside these limits.

REFERENCE

Crowe, R.B., McKay, G.A. and Baker, W.M., 1977. The tourist and outdoor recreation climate of Ontario. Fisheries and Environment Canada, Atmospheric Environment Service, Publications in Applied Meteorology REC-1-73; 3 volumes, 742 pages.

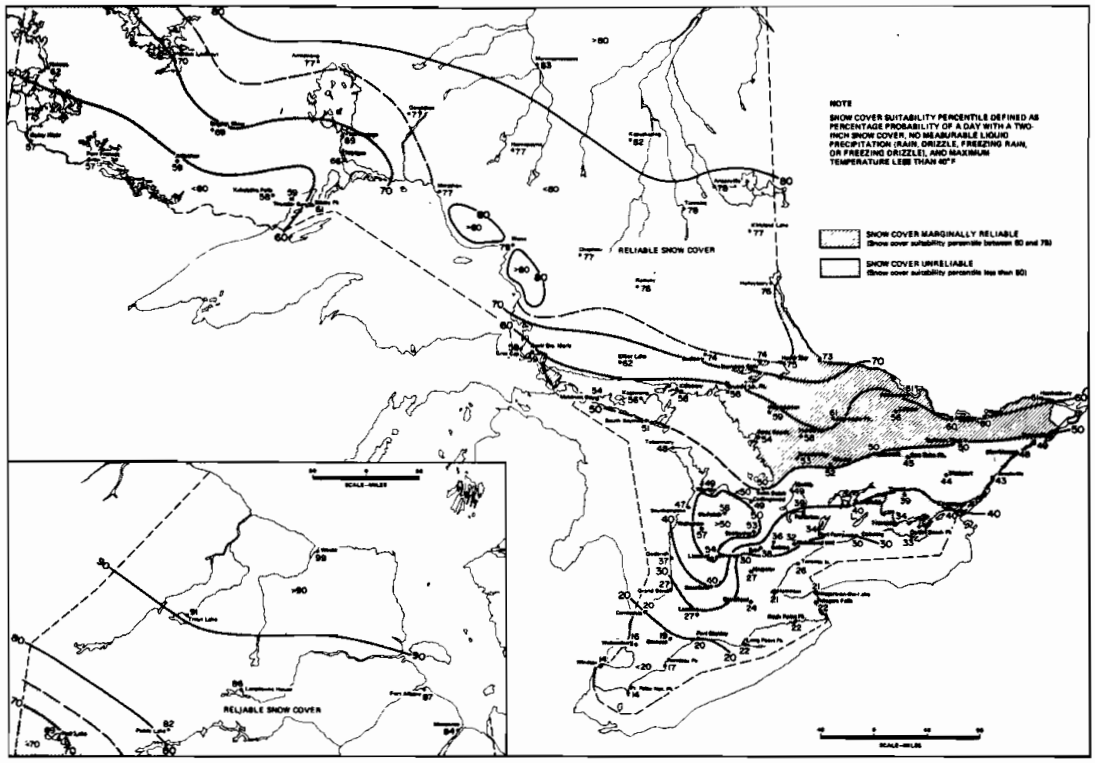


Figure 7. Snow cover suitability percentile – March 15

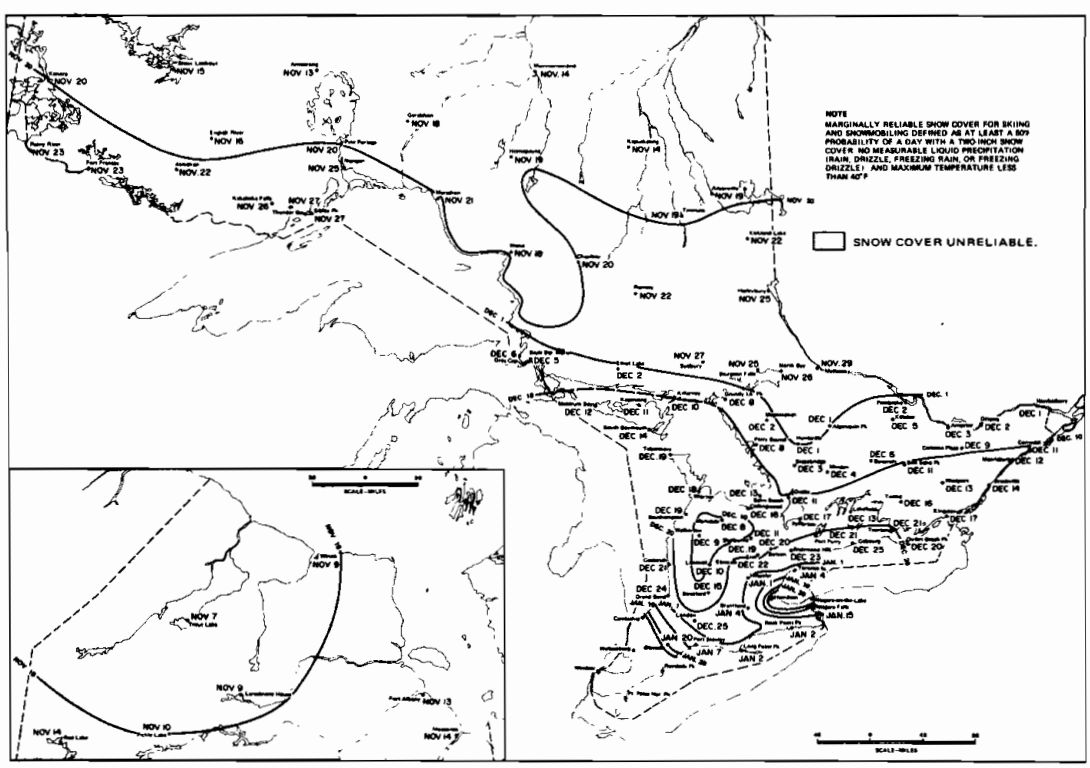


Figure 8. First date of occurrence of snow cover suitable for skiing and snowmobiling at the 50 percentile level (marginally reliable snow cover)

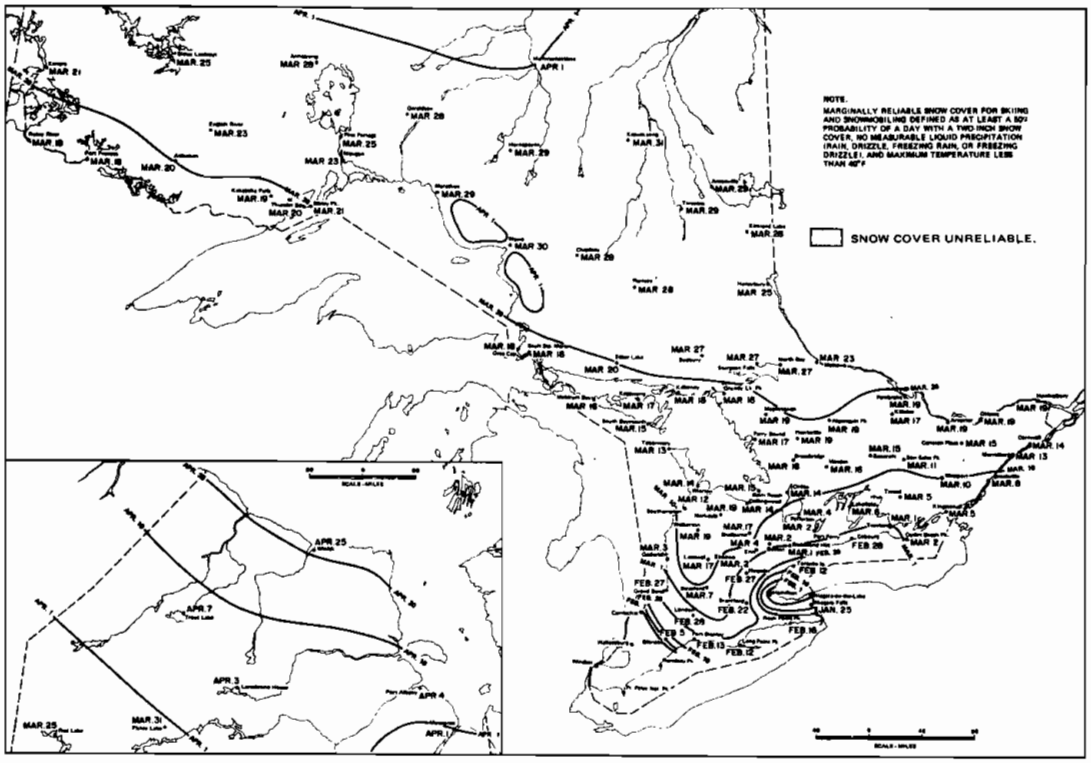


Figure 9. Last date of occurrence of snow cover suitable for skiing and snowmobiling at the 50 percentile level (marginally reliable snow cover)

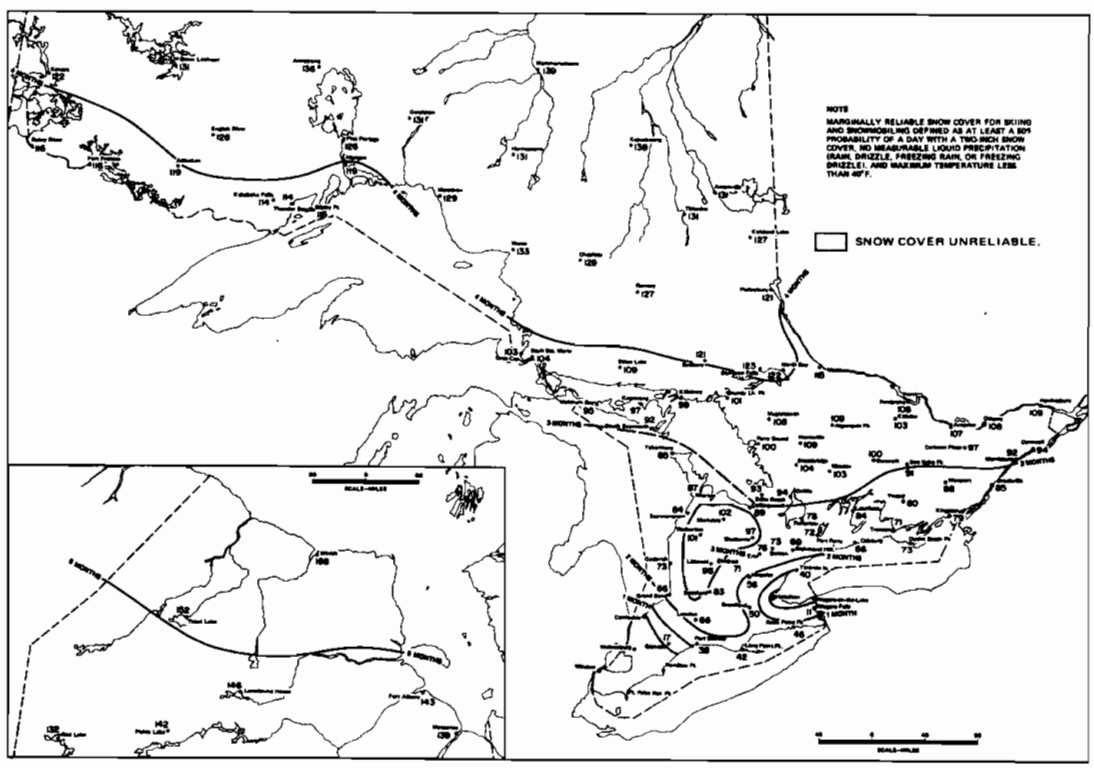


Figure 10. Length in days of snow cover suitable for skiing and snowmobiling at the 50 percentile level (snow cover marginally reliable or better)

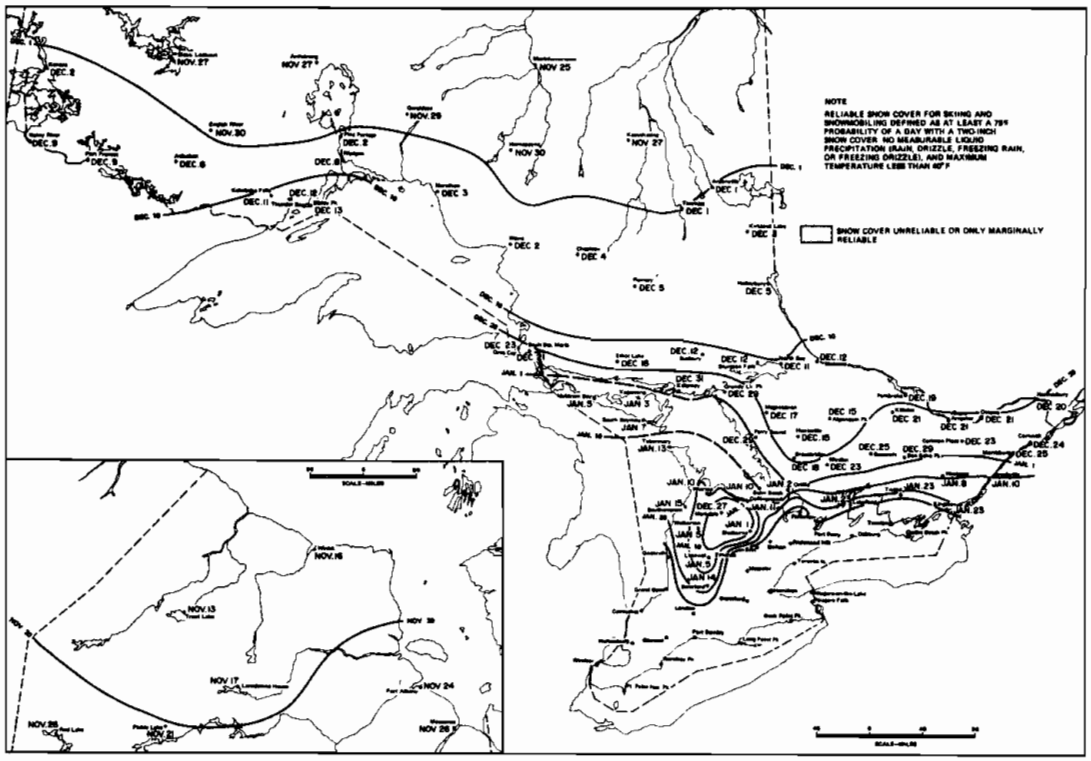


Figure 11. First date of occurrence of snow cover suitable for skiing and snowmobiling at the 75 percentile level (reliable snow cover)

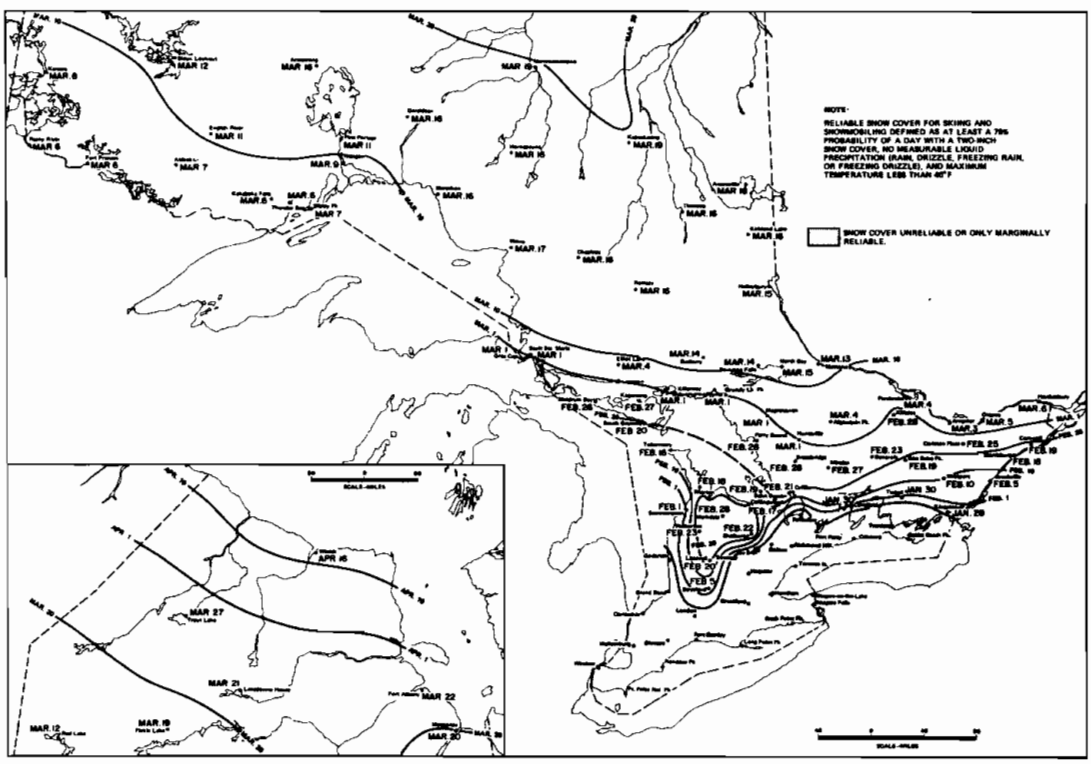


Figure 12. Last date of occurrence of snow cover suitable for skiing and snowmobiling at the 75 percentile level (reliable snow cover)

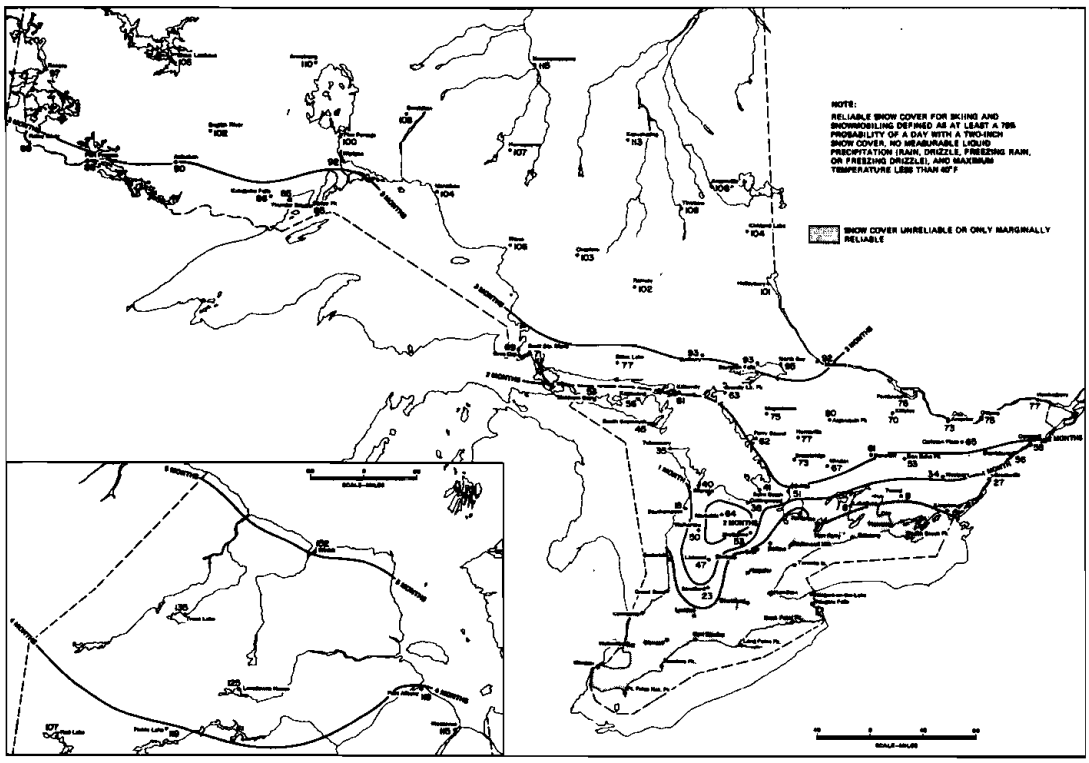


Figure 13. Length in days of snow cover suitable for skiing and snowmobiling at the 75 percentile level (reliable snow cover)