Kiggavik Uranium Project

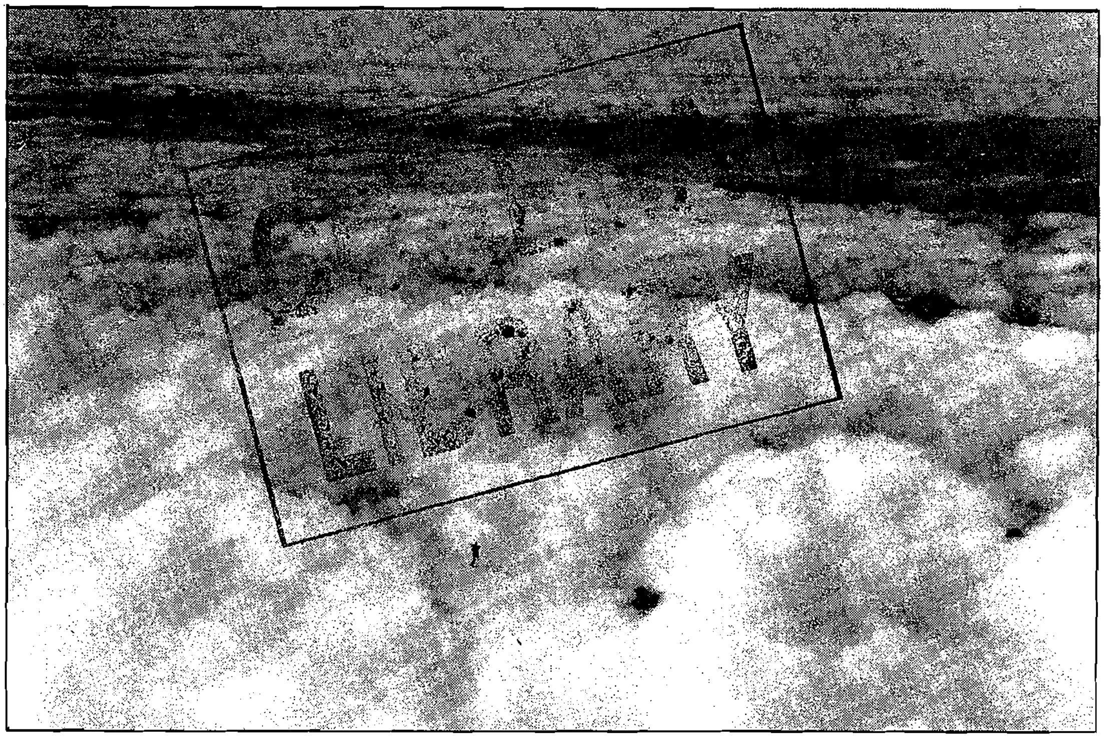
Baker Lake Northwest Territories Canada

Environmental Assessment

Prepared by Beak Consultants Limited

Supporting Document No. 1

The Climatological and Atmospheric Environment



Urangesellschaft Canada Limited

Toronto, Ontario Canada
January 1990

SUPPORTING DOCUMENT NO. 1

THE CLIMATOLOGICAL AND ATMOSPHERIC ENVIRONMENT

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December 1989
BEAK Ref. 2305.3

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1.0 REGIONAL CLIMATOLOGY

The climate of the District of Keewatin, in which the Kiggavik project site is located, is classified as Arctic continental. The area is characterized by long, cold winters, brief transitional seasons, and short, warm summers. The primary factors which determine local climates in this region are the latitude, topography and nature of the ground surface, and, most importantly, proximity to large bodies of water.

Latitude partly determines the type and frequency of weather systems to which the region is exposed. Moreover, at latitude 64°N, the small amount of solar radiation received at the surface during most of the year limits the amount of energy available to drive atmospheric motion. Table 1.1 shows the minimum number of possible daylight hours for the month and the possible number of daylight hours on the fifteenth of each month for selected latitudes.

The low, rolling terrain of the tundra barrens west of Hudson Bay has an important effect on winds. The essentially smooth, treeless surface of the barrens promotes strong surface winds, making this region one of the windiest in Canada. Strong winds can arise suddenly, and persist for days.

The nature of the underlying surface also controls local climates. The reflection of solar radiation from tundra barrens varies from 25% in early summer to about 80% for fresh snowcover. Because of the high reflectivity, ice- and snow-covered surfaces require considerable thermal energy for melting, which delays the arrival of spring in the Arctic. The nature of the surface can also exert a modifying influence during summer and fall since open waters and marshes over the permafrost provide a ready supply of moisture for cloud and fog formation and the generation of snow squall activity (in the fall). In the early winter, the large ice-free lakes can choke low-lying areas with fog for prolonged periods of time. In the spring, appreciable cooling of the air can occur in areas up to 4 km away from large lakes.

The following discussion of average seasonal atmospheric concentrations is largely abstracted from Crowe (1976), who provides the most comprehensive discussion of the climate of the inland regions of the Keewatin district. Information provided by Maxwell (1980) is largely confined to the coastal areas of Arctic waters.

TABLE 1.1: MINIMUM NUMBER OF POSSIBLE HOURS OF DAYLIGHT FOR EACH MONTH AND ON THE 15th OF THE MONTH (h + min)

Latitude		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
70 N	Min	0	04:59	09:33	14:04	18:58	24	21:30	15:36	11:15	6:34	0	0
	Mid	0	07:23	11:36	16:12	22:52	24	24	18:12	13:23	9:04	3:48	0
65 N	Min	3:55	6:54	10:07	13:37	17:06	20:42	18:22	14:47	11:25	7:55	4:42	3:35
	Mid	5:04	8:30	11:42	15:13	18:45	21:54	20:13	16:37	13:05	9:44	6:14	3:41
60 N	Min	6:03	8:01	10:29	13:19	16:00	18:18	16:54	14:14	11:32	8:47	6:31	5:52
	Mid	6:44	9:13	11:46	14:35	17:10	18:49	18:03	15:29	12:53	10:12	7:32	5:56

The Kiggavik project site is located at latitude 64^{o}25'N.

1.1 December to February

This period is the "dead of winter" in the Northwest Territories because much of the higher latitudes are under the influence of the polar night, when the sun is totally beneath the horizon for days or weeks. Due to a lack of insolation and continual heat loss from snow- and ice-covered surfaces, the air is bitterly cold during these months, averaging from -20°C to -30°C in the southern regions, and as low as -35°C to -40°C in the northern part of the Arctic Archipelago. Occasionally, warmer air masses penetrate the perimeter of this frigid core of air and bring above-freezing temperatures to the southern part of the District of Mackenzie and to the islands of Hudson Bay. Such mild temperatures are practically unknown over the central part of the Keewatin District in which the project site is located. In fact, extreme temperatures in mid-winter can fall to -55°C at interior continental locations (such as where the Kiggavik site is located).

Winds are often strong in winter months, particularly over the open tundra areas north of the tree-line. The combination of high winds and low temperatures produces a very high "windchill" effect, limiting outdoor human activity. A discussion of wind chill factors and working conditions is given in Section 3.3. Although snowfall is extremely light during these months, high winds cause blowing and drifting snow conditions, reducing visibility to a kilometre or less.

1.2 March and April

March and April are months of generally fine weather over the Arctic, although some of the lowest air temperatures of the year occur in early March. It is not until April that the incident solar radiation is sufficient to significantly raise daytime temperatures. Temperatures rarely rise above the freezing point, and extreme nighttime readings of -40°C or -50°C can still occur.

Winds drop off somewhat during this period over the high arctic, but may remain strong farther south, over the District of Keewatin. The windchill at the Kiggavik site may thus remain severe during these months. March and April snowfalls are light and infrequent, and late April temperatures are high enough that at least some rainfall may occur in the Kiggavik area.

1.3 May and June

These are transition months, when air temperatures can vary tremendously over the continental sections of the Districts of Mackenzie and Keewatin.

Mean daily air temperatures are consistently above freezing and, under the most favourable conditions, extreme maximum temperatures of 15°C to 25°C are possible. On the other hand, below freezing temperatures are not uncommon.

The weather is frequently poor in May and June, with overcast skies and frequent precipitation. The mild air and melting snow and ice cover may combine to produce extensive fog, particularly at coastal locations and in the vicinity of large inland water bodies.

1.4 July and August

The short summer season in the Arctic comprises July and August. In the Keewatin District, this period is relatively warm, with mean daily air temperatures in the 15°C range. Maximum air temperatures occasionally reach 25°C to 30°C, while minima may fall below 4°C during July, and below 0°C in August.

July and August are the wettest months of the year. Most of the precipitation falls as rain, but wet snow can occur during August. Fog is widespread over coastal regions, but inland areas are rarely affected.

1.5 September to November

This is another transition period. Summer-like conditions prevail in early September, but, by the end of September, mean daily air temperatures are below-freezing over most inland areas. Temperatures continue to fall rapidly through the next two months and by the end of November, daily means are below -20°C in the northern regions of the Keewatin District. Generally, more snow falls during this period than any other time. In general, these months are the snowiest of the whole winter. Cold winds blowing across open stretches of water pick up moisture, which subsequently falls as snow squalls along the shores and slopes downwind of the water body.

2.0 ASSESSING THE REPRESENTATIVENESS OF BAKER LAKE DATA FOR USE AT THE KIGGAVIK STUDY SITE

The closest weather-reporting station to the Kiggavik site is at Baker Lake, some 80 km to the east-southeast. The station was originally established in 1946 as a synoptic reporting site (four observations daily) but, from June 1955 to October 1962, observations were recorded eight times per day. Since November 1962, the station has made hourly observations.

The station is located at the airport (64°18'N), situated at the western end of Baker Lake. Baker Lake itself is 72 km long, 35 km wide and empties into Chesterfield Inlet, which flows into Hudson Bay 285 km southeast of the airport. The Kiggavik site lies at an elevation of 180 m, compared with a 12 m elevation of the Baker Lake station. The intervening terrain consists of undulating hills with an extensive network of lakes and river valleys oriented in a northwesterly direction. The highest ground between the Kiggavik site and Baker Lake rises to 230 m, approximately 30 km east of the project site.

In general terms, considering the amount of data and length of record available at Baker Lake and its relative close proximity to the Kiggavik site, the climatological normals for Baker Lake provide a good approximation of climatic conditions at the project site.

Differences in the meteorological conditions between the Kiggavik site and Baker Lake are likely to be caused by: the higher elevation of the site, the effect of Baker Lake during the ice-free season, and the siting of the Baker Lake Station at the head of the lake.

Considering only the difference in elevation, mean and minimum temperatures may be expected to be 1-2°C lower at Kiggavik during the warmer months. In winter, however, frequent inversion conditions (resulting in the pooling of colder air in low-lying areas) may cause minimum temperatures to be lower at Baker Lake than at the Kiggavik site. The higher elevation would also lead to somewhat higher wind speeds at the Kiggavik site and, during frontal passage of summer storms, a greater incidence of low cloud/fog and a slight increase in precipitation.

The presence of a large, cool body of water during the ice-free season (late July-late October) will have a modifying influence at Baker Lake. The small, shallow lakes near the project site would not be expected to have as marked an effect. Spring and summer temperatures would be kept lower at Baker Lake, while fall temperatures would be higher. The diurnal temperature range at Baker Lake would not be as marked as at the Kiggavik site during these seasons. The incidence of fog at Baker Lake in spring and summer would be more than at the Kiggavik site. Snow squall activity would lead to increased precipitation at Baker Lake during the fall until complete freeze over. The occurrence of the first fall frost is likely to occur earlier than at Baker Lake while the frost-free period may be shorter at the Kiggavik site.

The single most significant difference in meteorological conditions between the two sites is in the directional frequency and intensity of winds. As described in Section 3.2, there appears to be a distinct directional bias in the Baker Lake wind rose. While it is to be expected that at this latitude the prevailing winds will be northerly, the minimal proportion of winds from the south-through-west sectors is exceptional. Moreover, the tendency for frequent east and southeast winds at Baker Lake reflects the channeling effect of Chesterfield Inlet and the formation of onshore lake breeze airflow, neither of which are present at the Kiggavik project site. Consequently, it is concluded that the wind data from Baker Lake are not truly representative of the Kiggavik project site. Although the differences are expected to be significant, there are no alternatives to the Baker Lake Station. The nearest other weather reporting station, at Ennadai Lake, is over 300 km south and west of Baker Lake, and cannot be considered to be any more representative than Baker Lake.

Reliance on biased wind data is likely to result in an overestimation of wind frequencies for northwest through north winds and an underestimation of winds from other directions. Therefore, predicted ambient concentrations of contaminants emitted at the project site may be higher to the south through southeast of the Kiggavik site than may actually occur. Similarly, predicted ambient concentrations in other direction sectors may be lower than will actually occur.

3.0 LOCAL CLIMATOLOGY OF THE KIGGAVIK AREA

3.1 Air Temperature

Table 3.1 lists the annual and monthly mean, mean maximum, mean minimum and extreme temperatures for Baker Lake as listed in the most recent summary of climate normals. The mean monthly air temperatures rise above 0°C only between June and September. The average frost-free period is 67 days, with the average date of last spring frost occurring around 23 June, and the average date of first fall frost on 30 August. The earliest date of last spring frost is 7 June and the latest date 15 July. The earliest date of first fall frost is 27 July and the latest date of first fall frost is 18 September. The longest frost-free period on record is 92 days and the shortest period is 13 days.

For the period 1951-1980, extreme maximum and minimum temperatures range from 30.6°C in July to -50.6°C in January, respectively[1]. Extreme minimum temperatures below -30°C can occur in any month from October to March inclusive. The longest periods of consecutive days with maximum temperatures at or below a specific value are: 14 days at -35°C, five days at -40°C, and one day at -45°C.

3.2 Surface Winds

Surface wind data for Baker Lake are presented in Tables 3.2 and 3.3, while the seasonal wind roses are depicted in Figure 3.1. The data show a strong preponderance of north-through-northwest winds, with a secondary preference for east and east-southeast winds. There is an almost complete absence of winds from the south-through-west and only occasional winds (i.e., 3% frequency of occurrence) from the northeast. The prevailing winds are thus aligned with the dominant topographic features. The north, north-northwest and northwest winds are oriented in roughly the same direction as the river valleys at the western end of Baker Lake, while the east and east-southeast winds flow parallel to the long axis of the lake itself. Moreover, there is little seasonal variation in wind direction frequencies, contrary to what would be expected. It is therefore highly likely that the wind direction data for Baker Lake are biased and may

[1] A maximum temperature of 34°C was recorded in 1989.

TABLE 3.1: TEMPERATURE NORMALS AT BAKER LAKE (1951-1980)
(Source: Canadian Climate Normals - Volume 2: Temperature (1982))

Temperature (°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean	-33.0	-32.6	-27.9	-17.3	-6.4	4.1	11.0	9.7	2.3	-7.7	-20.3	-28.2	-12.2
Maximum	-29.5	-29.2	-23.7	-12.5	-2.6	7.9	16.0	13.8	5.3	-4.4	-16.4	-24.7	-8.3
Minimum	-36.4	-36.0	-32.0	-22.1	-10.2	0.2	6.0	5.5	-0.7	-11.0	-24.0	-31.6	-16.0
Extreme Maximum	-8.2	-7.8	-1.1	5.0	11.7	23.3	30.6	27.8	21.1	9.4	2.2	-1.7	30.6
Extreme Minimum	-50.6	-50.0	-50.0	-41.1	-27.8	-13.9	-1.7	-3.4	-14.4	-30.6	-40.6	-45.6	-50.6

TABLE 3.2: MONTHLY AND ANNUAL SURFACE WIND SPEEDS AT BAKER LAKE
(Source: Canadian Climate Normals - Volume 5: Wind (1982))

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Wind Speed, All Directions (km/hr)	25.0	24.0	23.3	21.8	20.9	19.1	18.8	18.6	20.5	22.4	22.8	22.1	21.6
Prevailing Direction 16-Point Compass	N	N	N	N	N	N	N	N	NNW	N	N	N	N
% Frequency	20.9	20.5	18.9	17.1	16.8	14.6	18.3	16.7	15.3	13.1	17.4	19.2	17.3
Mean Speed (Prevailing Direction) (km/hr)	35.3	31.6	30.9	28.7	26.3	24.2	23.5	22.0	25.3	25.7	32.3	30.8	27.9
% in Sector (NW-NNW-N)	55.0	56.3	52.5	39.1	40.5	36.9	45.2	41.0	43.8	38.0	45.8	48.1	45.2
% Frequency of Calms	7.5	10.0	9.5	10.2	7.0	8.4	10.4	6.8	4.6	4.4	9.1	7.9	8.0
Maximum Hourly Speed (km/hr)	105	106	93	74	72	121	66	69	64	89	87	85	121
Direction	N	NNW	WNW	NNW	SVL	WNW	NNW	SVL	NNW	NW	N	NNW	WNW
Maximum Gust Speed (km/hr)	140	127	121	97	101	177	90	105	103	105	121	109	177

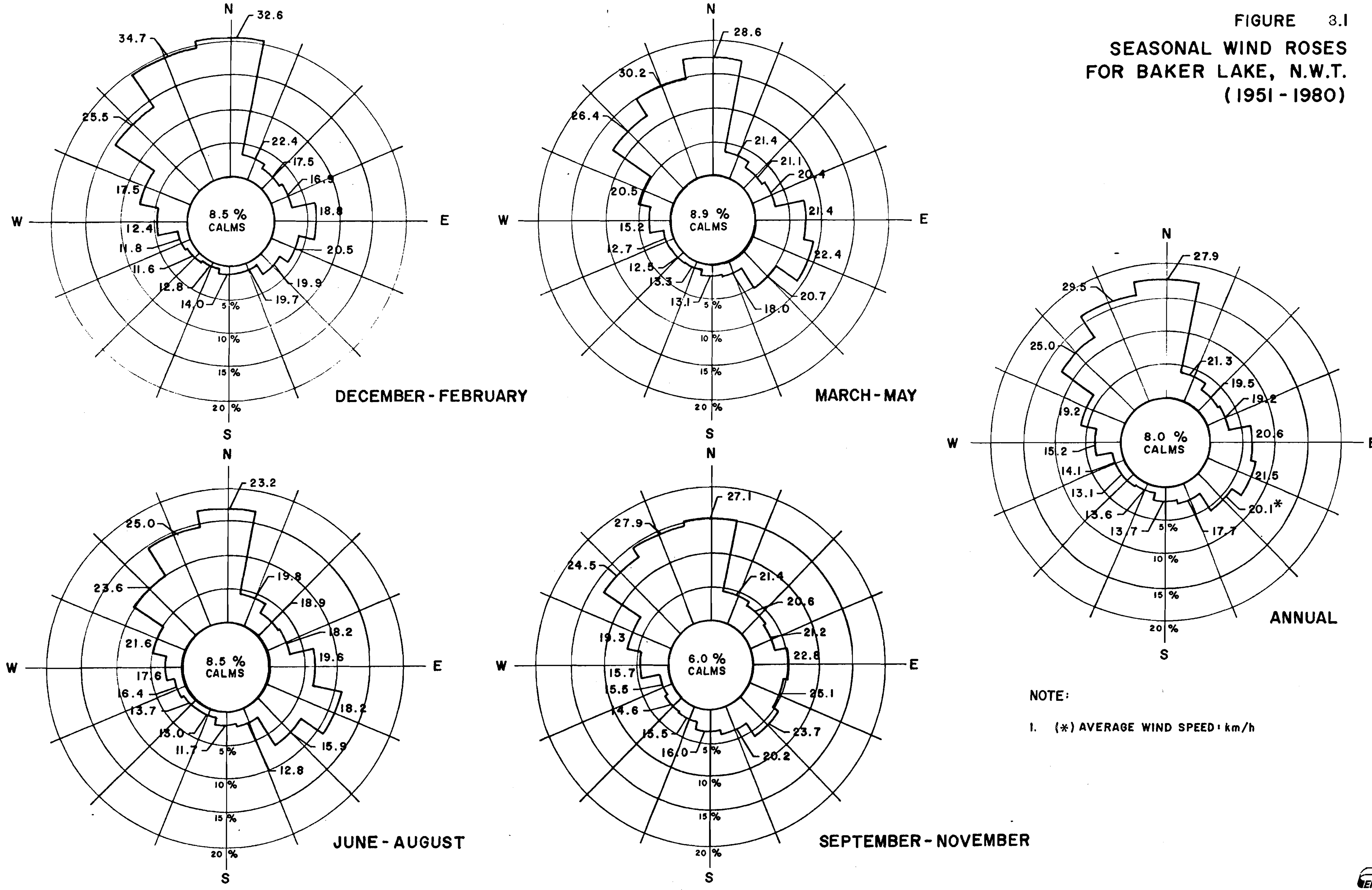
SVL = Several observations from different directions.

TABLE 3.3: ANNUAL DIRECTIONAL FREQUENCIES AND SPEEDS AT BAKER LAKE
(Source: Canadian Climate Normals - Volume 5: Wind (1982))

Direction	Annual Percent Frequency	Annual Mean Speed (km/hr)
N	17.3	27.9
NNE	3.9	21.3
NE	3.0	19.5
ENE	3.2	19.2
E	6.6	20.6
ESE	7.5	21.5
SE	5.3	2.1
SSE	2.4	17.7
S	2.1	13.7
SSW	1.1	13.6
SW	1.2	13.1
WSW	1.3	14.1
W	3.5	15.2
WNW	5.7	19.7
NW	12.1	25.0
NNW	15.8	29.5
Calm	8.0	-

FIGURE 3.1

SEASONAL WIND ROSES FOR BAKER LAKE, N.W.T. (1951 - 1980)



NOTE:

1. (*) AVERAGE WIND SPEED: km/h

not be representative of wind direction frequencies at the Kiggavik site. As discussed in the preceding section, this bias is likely to introduce a degree of error into the modelling of air emissions at the Kiggavik project site. Site-specific measurements would be required to estimate the magnitude of the bias.

Mean monthly wind speeds at Baker Lake are lowest in summer, at 18.6 km/hr in August, and highest in winter, at 25.0 km/hr during January. For the dominant wind directions of north, north-northwest and northwest (occurring 45.2% of the time) the average wind speeds for the months of December through February are 32.6, 34.7 and 25.5 km/hr respectively. The probability of occurrence of wind speeds at Baker Lake listed in Table 3.4 has been calculated using the two parameter Weibull frequency distribution. Monthly and annual scale and shape parameter values for computing the distributions were provided by the Atmospheric Environment Service based on one-minute average wind speeds from the period 1967 to 1976. For comparison, the cumulative frequency distributions for Uranium City in northern Saskatchewan have also been provided in Table 3.5. The annual distributions are shown graphically for Baker Lake and Uranium City in Figure 3.2.

These data show that higher wind speeds are far more common at Baker Lake than at Uranium City. Whereas, for any given month, 96 to 99% of all winds at Uranium City are less than or equal to 30 km/h, only between 69 and 87% of winds at Baker Lake are less than or equal to 30 km/h, depending on the most of the year. For dispersion of fugitive dust from stockpiles, the critical wind speed for calculating resuspension of dust is 20 km/h (U.S. EPA, 1985). While winds greater than 20 km/h occur on average between 8% of the time in February and 18% of the time in June at Uranium City, resuspension of exposed surface dust at Baker Lake may be expected to occur from 35% of the time in July to 52% of the time in February. Snow cover is not expected to be a factor in reducing wind erosion of stockpiles in winter at Baker Lake, since the high winds will tend to remove the fine snow from stockpiles. However, the frozen nature of the surface will prevent excessive loss of material from stockpiles in winter. Moreover, with frequent strong winds, the fraction of erodable particles available for resuspension are likely to be quickly diminished.

The maximum hourly wind speed on record is 121 km/hr for west-northwest winds. The probability of occurrence of various annual maximum wind speeds is estimated at:

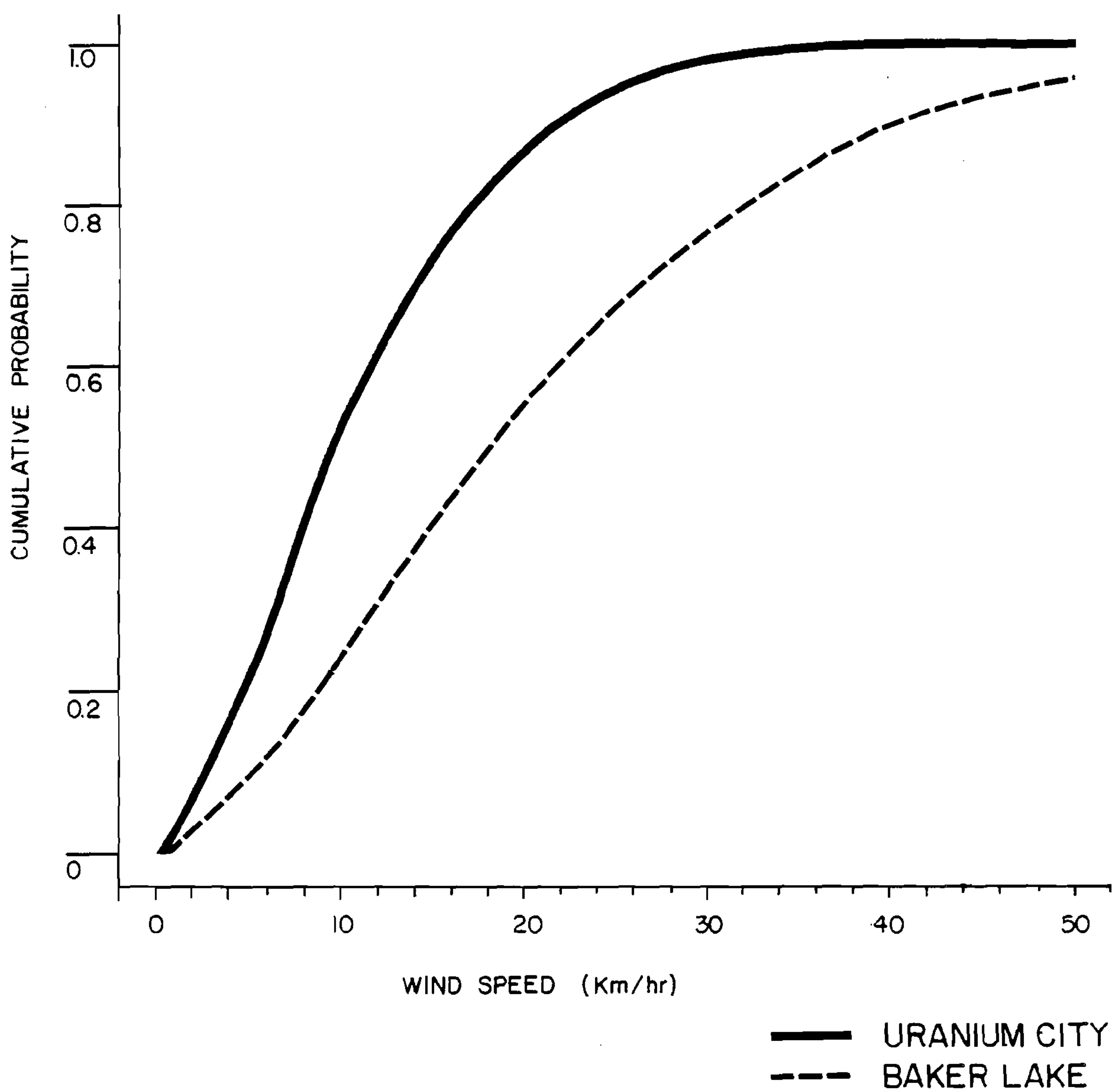
TABLE 3.4: CUMULATIVE PROBABILITY OF OCCURRENCE OF WIND SPEED AT BAKER LAKE, NORTHWEST TERRITORIES

	Wind Speeds (km/h)									
	≤ 5	≤ 10	≤ 15	≤ 20	≤ 25	≤ 30	≤ 35	≤ 40	≤ 45	≤ 50
January	10	24	39	53	65	74	81	87	91	94
February	8	21	35	48	60	69	77	83	88	92
March	9	23	38	52	64	74	81	87	91	94
April	11	28	44	59	70	79	86	91	94	96
May	7	21	38	55	70	81	89	94	97	98
June	12	29	46	61	72	81	87	92	95	97
July	10	28	48	65	78	87	93	96	98	99
August	9	26	45	62	75	85	92	95	98	99
September	5	18	35	52	67	79	88	93	97	98
October	6	19	35	51	65	76	85	91	95	97
November	10	26	41	55	66	76	83	88	92	95
December	11	28	44	58	70	79	86	91	94	96
ANNUAL	9	25	41	55	67	77	85	90	93	96

TABLE 3.5: CUMULATIVE PROBABILITY OF OCCURRENCE OF WIND SPEED AT URANIUM CITY, SASKATCHEWAN

	Wind Speeds (km/h)									
	=5	≤ 10	≤ 15	≤ 20	≤ 25	≤ 30	≤ 35	≤ 40	≤ 45	≤ 50
January	35	67	85	94	98	99	100	-	-	-
February	33	63	82	92	97	99	100	-	-	-
March	23	53	75	89	95	98	99	100	-	-
April	18	45	68	83	92	97	99	100	-	-
May	17	43	66	83	92	97	99	100	-	-
June	19	45	67	82	91	96	98	99	100	-
July	21	50	73	87	95	98	99	100	-	-
August	22	50	73	86	94	97	99	100	-	-
September	17	43	66	82	92	96	99	100	-	-
October	15	41	66	83	93	97	99	100	-	-
November	19	48	72	87	95	98	99	100	-	-
December	31	61	80	91	96	98	99	100	-	-
ANNUAL	22	51	73	87	94	98	99	100	-	-

FIGURE-3.2
Cumulative Annual (1967-1976) Frequency Distribution of Wind Speeds at Baker Lake and Uranium City.



1/10	105 km/hr
1/30	119 km/hr
1/50	126 km/hr
1/100	134 km/hr

The design criteria for hourly wind pressures at Baker Lake are listed at:

1/10	0.42 kPa
1/30	0.50 kPa
1/100	0.59 kPa

It is significant that wind speeds are generally higher over tundra areas in the District of Keewatin than at coastal locations and in sheltered valleys. Therefore, it may be assumed that wind speeds at the Kiggavik site could be slightly higher than those reported for Baker Lake.

3.3 Wind Chill and Working Conditions

From the standpoint of human comfort, it is necessary to consider the combined effect of temperature and wind, referred to as windchill factor. Table 3.6 lists the threshold values of different comfort classes for various temperature-windchill indices. Uncomfortable conditions prevail with classes IV and greater, including dangerous conditions with classes VI and VII.

In the Northwest Territories, the highest mean windchill occurs over the eastern part of the Keewatin District, in the vicinity of Baker Lake and Chesterfield Inlet. This area has the most extreme combination of low temperatures and strong winds. The mean monthly windchill factor at Baker Lake (Table 3.7) shows that conditions in January make outdoor work and travel difficult, while those in December and February are only marginally better. Even in March and April, when normal outdoor activity is resuming after the polar night, the windchill factors at Baker Lake are extremely high.

Windchill factors have been computed for two temperature threshold levels which can be related to human activities, as determined by the American Conference of Governmental Industrial Hygienists (ACGIH). They have classified two levels of windchill factors:

TABLE 3.6: TEMPERATURE-WIND CHILL INDEX

Wind Chill Units	Comfort Class	
< 800	I	Comfortable with normal precaution.
800-1,200	II	Work and travel become uncomfortable unless properly clothed.
1,200-1,400	III	Work and travel become more hazardous unless properly clothed. Heavy outer clothing necessary.
1,400-1,600	IV	Uprotected skin will freeze with direct exposure over prolonged period. Heavy outer clothing becomes mandatory.
1,600-1,900	V	Unprotected skin can freeze in one minute with direct exposure. Multiple layers of clothing mandatory. Adequate face protection becomes important. Work and travel alone not advisable.
1,900-2,200	VI	Adequate face protection becomes mandatory. Work and travel alone prohibited. Exposure times must be carefully controlled.
> 2,200	VII	Personnel become easily fatigued. Buddy system and observation mandatory.

TABLE 3.7: MEAN MONTHLY WIND CHILL FACTORS FOR SELECTED STATIONS IN THE NORTHWEST TERRITORIES (in wind chill units)
(Source: Crowe (1976))

	Chesterfield Inlet	Baker Lake
January	1,950	1,980
February	1,920	1,870
March	1,720	1,660
April	1,480	1,450
May	1,160	1,080
June	860	840
July	670	640
August	730	650
September	910	890
October	1,190	1,210
November	1,520	1,520
December	1,780	1,790

- increasing danger (windchill equivalent temperature of -30°C or less), and
- great danger (windchill equivalent temperature of -60°C or less).

The ACGIH recommends that non-emergency work should cease when windchill factors enter the "great danger" area. Monthly wind speed graphs were used to compute the percentage of time each month that the wind speed would cause "increasing danger" and "great danger". These were done for Baker Lake and northern Saskatchewan (i.e., Uranium City and Brochet, Manitoba) for comparative purposes. The percentage of time that the windchill is expected to reach each threshold value is shown in Figure 3.3 for Baker Lake, and Figure 3.4 for northern Saskatchewan. Results are tabulated in Table 3.8.

The period of "increasing danger" implies periods of significantly lower productivity for outside activities, while "great danger" is when conditions are so severe that unprotected outside work should actually be stopped. As can be seen, the difference between Baker Lake and northern Saskatchewan is "dramatic". Periods of "great danger" are almost non-existent in northern Saskatchewan, whereas it represents a significant proportion of the time in Baker Lake during at least three months of the year. When looking at the numbers presented in Table 3.8, the percentage of time that is expected to be in the "great danger" area is higher in Baker Lake by a factor of almost 60 as compared to northern Saskatchewan.

The data presented in Table 3.8 and Figures 3.3 and 3.4 were computed using monthly wind speed frequencies and reference temperatures of -30°C and -60°C. As such, they do not consider the joint probability of occurrence of wind speeds and specific temperatures. Although such data are not readily available for Baker Lake, the frequency of occurrence of wind chill comfort classes has been computed for other locations in the eastern Arctic (Maxwell, 1980). The closest station to Baker Lake is Coral Harbour in Hudson Bay. Table 3.9 lists the frequency of occurrence of comfort classes as defined in Table 3.6. Since wind speeds are slightly higher at Baker Lake, the mean January wind chill at Coral Harbour is approximately 100 wind-chill units lower at Coral Harbour (Crowe, 1976). Therefore, the frequencies listed in Table 3.9 may underestimate the actual occurrence of comfort classes IV through VII at Baker Lake.

FIGURE - 3.3
The Percentage of Time that Windchill is Expected to Reach 'Little Danger' and 'Increasing Danger' Levels in Baker Lake.

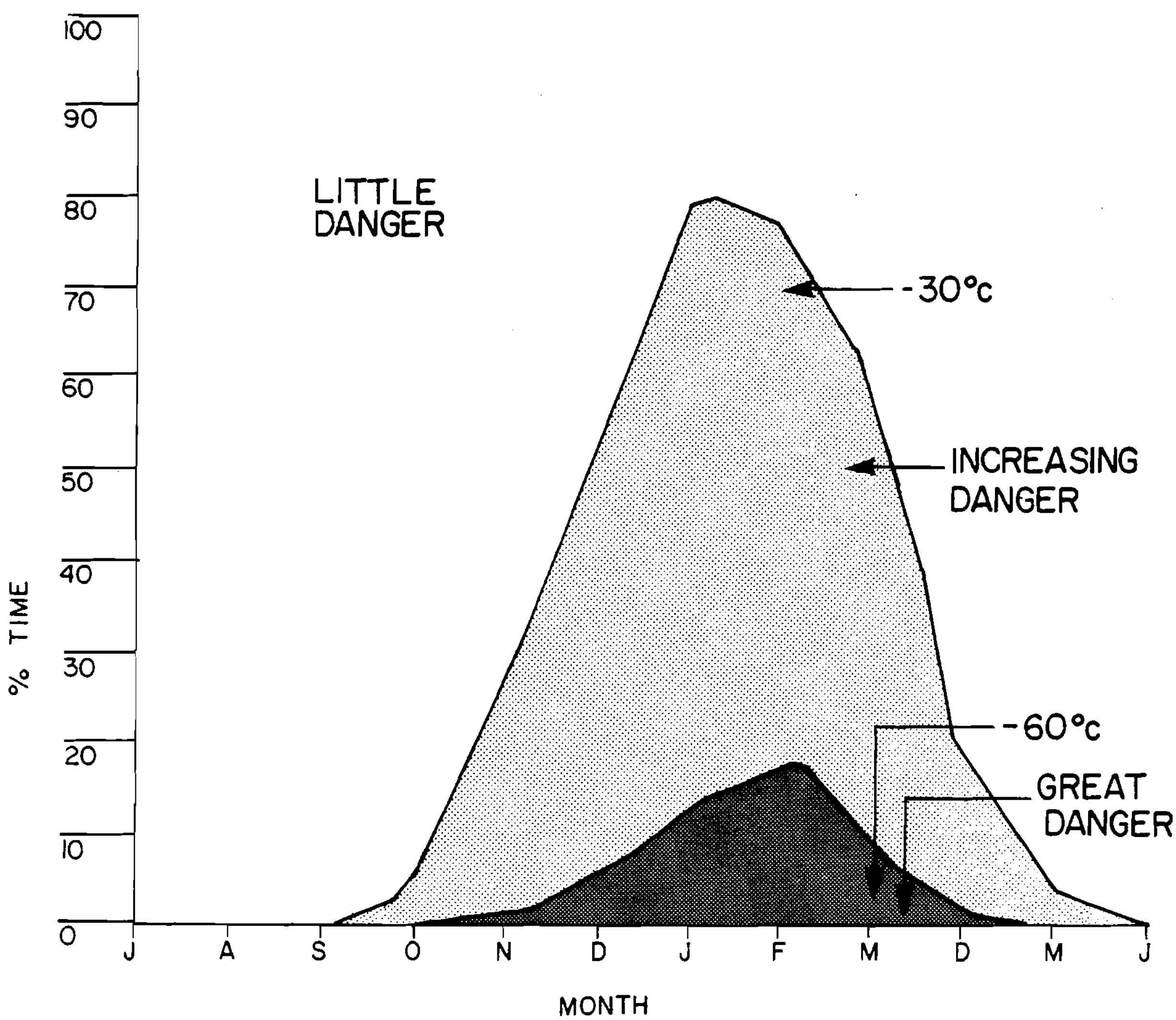


FIGURE - 3.4
The Percentage of Time that Windchill is Expected to Reach 'Little Danger' and 'Increasing Danger' Levels in Northern Saskatchewan

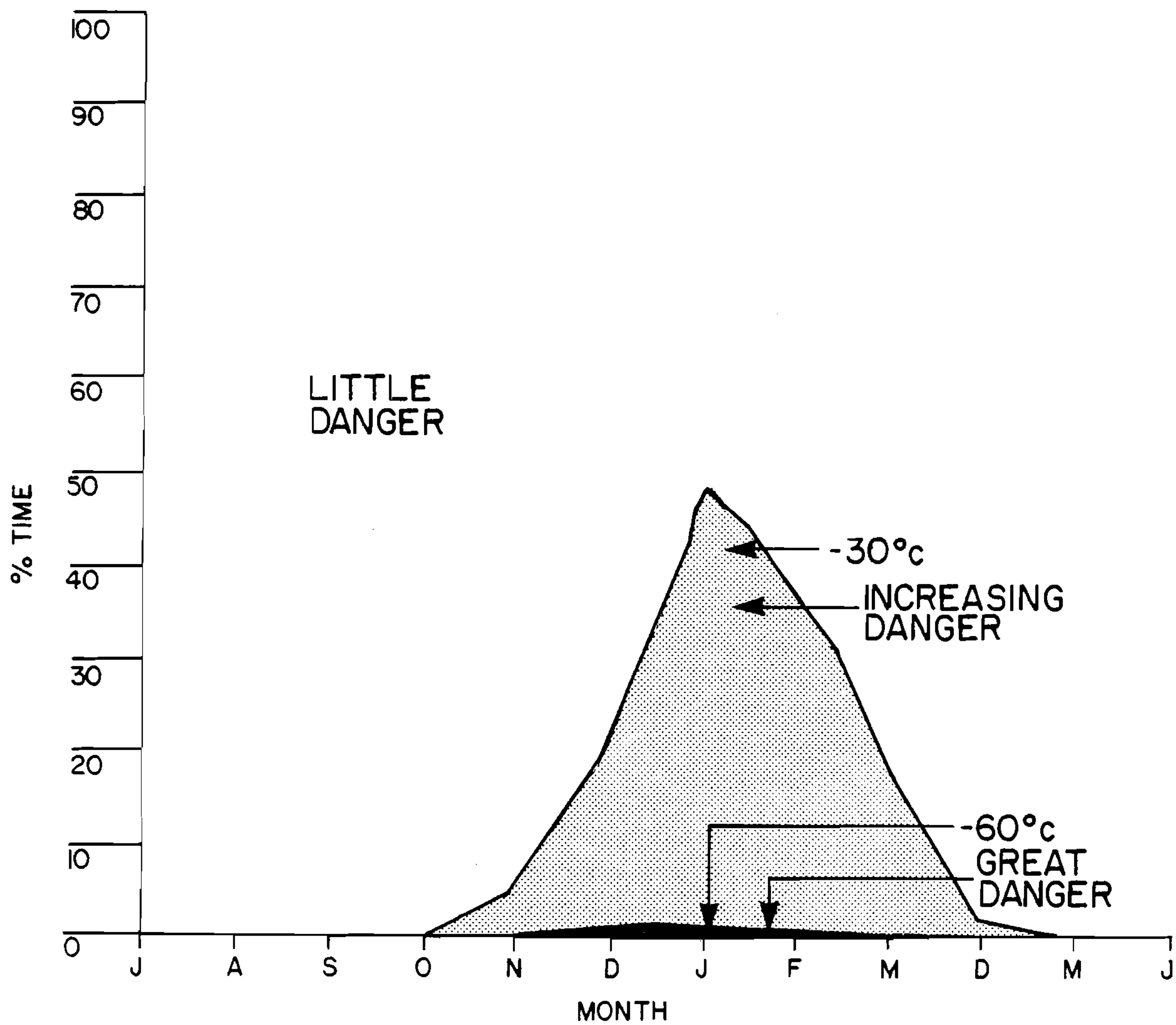


TABLE 3.8: WIND CHILL EFFECT

	% "Increasing Danger"		% "Great Danger"	
	Baker Lake	Northern Saskatchewan	Baker Lake	Northern Saskatchewan
October	4	0	0	0
November	27	5	1	0
December	52	22	6	0.4
January	79	47	14	0.5
February	77	37	17	0.3
March	59	17	8	0.3
April	20	2	0.5	0
May	4	0	0	0

TABLE 3.9: FREQUENCY OF OCCURRENCE (%) OF COMFORT CLASSES AT CORAL HARBOUR, NORTHWEST TERRITORIES (1962-1973)

Month	I-III	IV*	V*	VI-VII**
January	20	17	32	31
March	33	23	24	20
May	93	4	3	-
July	100			
September	100			
November	46	20	21	13

Associated Work/Warmup Schedule for Four-Hour Shift:

Comfort Classes	Maximum Work Period	No. of Breaks
I-III	Normal breaks	1
IV	55-75 minutes	2-3
V	30-40 minutes	4-5
VI-VII	Non-emergency work should cease	

(Source: Maxwell, 1980)

* Roughly corresponds to "increasing danger" class as determined by the American Conference of Governmental Industrial Hygienists (ACGIH).

** Roughly corresponds to "great danger" class as determined by ACGIH.

These severe climatic conditions must be taken into consideration in all design and operating philosophies. Both construction and operational periods will be affected. In fact, it is very unlikely that outdoor work such as open pit mining can continue year-round. A mid-winter shutdown of the open pit may be appropriate.

3.4 Precipitation

Moisture in Arctic regions is in short supply, particularly in winter, when extremely low temperatures prevail. Of the total (30-year normal) annual precipitation of 234.6 mm (total water equivalent of snowfall plus rainfall), approximately 60% falls as rain, and practically all of this falls in the short period from July to September (see Table 3.10). Of the total snowfall of 100 cm, 54% falls during the three months of April, October and November. October is the month with greatest snowfall due in part to the availability of moisture from the still unfrozen surface of Baker Lake. Snowfall during the mid-winter months is generally light.

Extreme snowfall statistics indicate that October and November are the months with greatest 24 hr snowfall accumulations, with 30.3 cm being the maximum recorded snowfall on record. Extreme rainfall data show the maximum 24 hr rainfall on record to be 52.1 mm. This is equivalent to a one-in-fifty year event. Table 3.11 lists calculated extreme rainfall statistics for various durations at Baker Lake.

Thunderstorms and hail are rare in this area, although freezing rain can be expected during the spring and fall. Freezing rain and drizzle can result in significant ice accretion on structures, and must be considered in design specifications. Data on ice accretion at Baker Lake are not available at this time. Calculated ice accretion estimates for the one-in-ten and one-in-twenty year events at the nearest other weather station, Ennadai Lake (61°08'N, 100°54'W), may be used as a guide in estimating possible ice accretion events at Baker Lake and the Kiggavik site, although the validity of such extrapolations is not resolved. The ice accretion estimates for Ennadai Lake area listed in Table 3.12.

3.5 Visibility

Poor visibility may place severe restrictions on outdoor activity by limiting aircraft operations and movement on the ground. Visibility can be reduced by particles suspended

TABLE 3.10: PRECIPITATION NORMALS AT BAKER LAKE (1951-1980)
(Source: Canadian Climate Normals - Volume 3: Precipitation (1982))

Precipitation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Rainfall (mm)	0.0	0.0	0.0	0.4	5.9	18.1	38.1	36.9	31.4	7.5	T	T	138.3
Snowfall (cm)	8.0	5.4	8.3	13.6	6.3	2.8	0.0	0.4	5.9	23.2	17.4	8.7	100.0
Total Precipitation (mm)	7.7	4.9	7.6	13.8	12.0	20.9	38.1	37.3	37.0	30.6	16.9	8.2	234.6
Extreme Rainfall in 24 Hours (mm)	0.0	T	0.0	8.0	22.4	17.5	52.1	45.5	35.3	27.9	0.3	0.3	52.1
Extreme Snowfall in 24 Hours (cm)	10.2	9.9	8.1	16.1	8.6	12.6	T	5.0	8.9	20.8	30.3	7.4	30.3
Days with Rain	0	0	0	*	1	6	9	10	8	3	*	*	37
Days with Snow	7	6	8	9	6	2	0	*	5	12	10	8	73
Days with Precipitation	7	6	7	9	7	7	9	10	12	14	10	8	106
Days with Hail	0	0	0	0	*	0	*	*	*	0	0	0	3
Days with Thunderstorms	0	0	0	0	0	0.2	1	0.3	0.1	0	0	0	1.6
Days with Freezing Precipitation	0	*	0	1	2	1	0	*	1	3	1	*	9

* Day with less than 0.2 mm rain or less than 0.2 cm snow.

T = Trace, less than 0.1 mm of rain or less than 0.1 cm of snow.

TABLE 3.11: EXTREME RAINFALL STATISTICS (in mm) - BAKER LAKE, NORTHWEST TERRITORIES
(Source: Hogg and Carr (1985))

Duration	Return Period (years)					
	2	5	10	20	50	100
24 hours	24.4	33.2	39.1	44.7	51.9	57.4
12 hours	16.1	20.6	23.5	26.3	30.0	32.7
6 hours	11.9	15.0	17.1	19.0	21.6	23.5
1 hour	5.2	6.8	7.8	8.9	10.2	11.1
15 minutes	2.2	3.3	4.0	4.6	5.5	6.2

TABLE 3.12: ICE ACCRETION ESTIMATES FOR ENNADAI LAKE, NORTHWEST TERRITORIES
(Source: Chaine _et al._ (1974))

	Probability of Occurrence	
	1/10	1/20
Accretion on horizontal surface (in)	0.13	0.22
Accretion on vertical surfaces (in)	0.29	0.22
Equivalent radial accretion on one-inch conductor (in)	0.20	0.32
Maximum accretion on horizontal surfaces associated with peak wind gusts (in)	-	0.19
Maximum accretion on vertical surfaces associated with peak wind gusts (in)	-	0.44
Maximum equivalent radial accretion associated with peak wind gusts (in)	-	0.28

in the air (i.e., water droplets or ice crystals forming fog), solid particulate matter (smoke or haze), by falling precipitation, or by blowing snow.

Table 3.13 lists the mean number of days per month with reduced visibility due to fog (less than 1 km), smoke or haze (visibility less than 10 km) and of blowing snow (horizontal visibility less than or equal to 10 km). The percentage number of hourly observations per month (based on the main synoptic hours) with visibility reduced to 1 km, however caused, is also given, together with the extreme durations of fog, blowing snow and visibility reduced to 1 km. At a windy station like Baker Lake, blowing snow occurs one quarter of the time or more between December and February. Even in March and April, when much outdoor activity is resuming in the Territories, the frequencies of blowing snow at Baker Lake are 18% and 19% respectively.

At most Arctic locations during the long November-April period, blowing snow is the most frequent cause of low visibility. Winter snowfall at these latitudes is powder-fine and, depending upon whether the snow is wind-packed or new, even relatively light winds may cause drifting or blowing snow. The extent to which blowing snow reduces the visibility is directly related to the speed of the surface winds. Surface wind speeds and winter visibility in blowing snow are related approximately as follows:

Windspeed (km/h)	Visibility (km)
< 25	> 10
25	5-10
30	2-3
40	1-2
> 50	< 1
> 65	near zero

While this relationship applies to most arctic stations, it is not universally applicable, and stations such as Baker Lake tend to have low visibilities in blowing snow with relatively light winds. The cooling effects of low temperatures and strong winds (windchill), combined with limited visibility in blowing snow, make unprotected outdoor activity in the months of December through February extremely hazardous.

TABLE 3.13: VISIBILITY AT BAKER LAKE (1953-1980) (Source: Environment Canada (1987))

Visibility	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
No. of Days with Fog	4	4	3	2	3	2	2	1	1	3	2	3	30
No. of Days with Smoke or Haze	*	*	0	*	0	0	*	*	0	0	0	*	*
No. of Days with Blowing Snow	17	14	13	10	5	*	0	0	1	6	12	13	91
% Frequency Blowing Snow	27	30	18	17	9	0	0	0	0	8	19	25	
% of Hourly Observations of Visibility 1 km	15.5	15.5	10.3	6.6	3.0	0.7	1.0	0.7	0.6	4.6	8.5	10.4	6.45
Longest Duration (hrs) of:													
Fog	72	61	62	49	23	38	31	21	24	38	69	66	72
Blowing Snow	89	99	116	58	30	4	0	18	22	54	87	97	116
Visibility 1 km	74	89	67	45	19	8	28	12	10	25	82	87	89

* At least one observation during the period of record.

Snowfall in itself usually limits visibility to less than 10 km, but in the absence of wind, visibilities are seldom reduced to less than 3 to 5 km in mid-winter because of the extreme dryness of the air at such low temperatures. In early and late winter, however, when temperatures are much higher, falling snow often reduces the visibility to less than 1 km.

The frequency of occurrence of blizzard conditions (defined as snow or blowing snow, winds of 40 km/hr or greater, visibility 0.8 km or less, and air temperatures below -12.2°C) has been estimated to be less than two percent at sheltered locations, between two and five at most locations, and as high as ten percent at the windiest stations. Generally, the eastern Arctic stations such as Baker Lake tend to have slightly higher frequencies than in the western Arctic. For the most part, the duration of blizzard conditions is under seven hours. The maximum duration in any given month is generally 50 hours, but two or three-day blows are not uncommon during the winter in the eastern Arctic.

While fog can occur throughout the year, the frequency of occurrence is greatest in the months of June, July and August at coastal locations, while inland areas are relatively free of fog. At Baker Lake during these months, fog occurs on only 1-3 days per month.

Ice fog is another cause of reduced visibility which has proved to be a hazard to operations in northern locations. Caused by emissions of moisture to the air through fuel combustion, ice fog usually bears a close relationship to the size of the area of human activity. This type of fog occurs at temperatures below about -30°C, and can be exceptionally dense due to the large numbers of small particles. As a result, outdoor human activities can be severely restricted.

Ground-based ice fog layers generally range in thickness from 10 to 30 metres, with a sharply defined upper boundary. Its depth increases as the temperature remains below -40°C and it may, on occasion, reach 100 metres deep. Ice fog incidents may last for days, but the majority of cases are of less than six hours duration. In the absence of specific data on ice fog formation, the frequency of occurrence and duration may be assumed to be similar to the concurrence of calm conditions (i.e., inversions) with the frequency of occurrence of air temperatures less than -30°C.

3.6 Cloudiness

Cloud cover has a direct impact on air travel in the Northwest Territories. Air travel is limited mainly by the occurrence of very low cloud and/or visibilities. The height of cloud base above ground is commonly referred to as the cloud ceiling. Table 3.14 lists the percentage frequency of occurrence of various combinations of cloud ceilings and visibility ranges for Baker Lake. A ceiling of 1000 ft and 3-mile visibility may be considered to be the lower limit of visual-flight-rules flying. Ceilings below 500 ft and 200 ft and/or visibilities below one mile and one-half mile, respectively, are considered to be the lower limits of operation of aircraft, the choice between the limits depending upon the type of aircraft and airfield in question. The data indicate that, in general, good flying weather exists over the open tundra areas of the Districts of Mackenzie and Keewatin in the summer months, but is relatively poor in the winter months. Data for coastal locations on Hudson Bay indicate that poor flying weather is common for most of the year over coastal areas of the Bay, but especially during the summer months.

3.7 Arctic White-Out

Arctic white-out is an optical phenomenon which occurs when the sky is overcast with stratiform clouds, the ground is snow covered, and the sun lies low in the sky. During the spring and fall (February/March and October/November), when the sun is near the horizon and the snow surface and clouds are of a uniform whiteness, it is often difficult to distinguish either the horizon or objects close at hand. With these conditions, the greyish-white landscape blends with the grey clouds, so that the horizon disappears, ground features lack shadows, and there is no sense of perspective. Since there is no horizon or shadow for reference, the judgement of distance is limited, although the actual horizontal visibility of dark objects is not materially impaired.

Under these conditions, navigation by sight becomes difficult. Drifts, footprints and tracks produced by vehicles may not be readily apparent, and a person may stumble and fall over minor surface features.

Arctic white-out condition is extremely hazardous for all forms of travel, both surface and air. Because of its subjective nature, no statistics are available to indicate the frequency of occurrence at various stations, and it can only be discussed qualitatively.

TABLE 3.14: COMPARISON OF PERCENTAGE FREQUENCY OF POOR FLYING WEATHER AT BAKER LAKE

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ceilings less than 1,000 feet and/or visibilities less than 3 miles	27	28	17	17	16	9	6	6	10	20	21	22
Ceilings less than 500 feet and/or visibilities less than 1 mile	18	19	8	7	6	3	1	2	2	7	11	13
Ceilings less than 200 feet and/or visibilities less than 0.5 mile	12	12	5	4	3	1	*	*	1	3	6	7

* Less than 1% but not 0% (less than 0.5%).

A zero visibility and ceiling condition caused by blowing snow should not be confused with the "white-out" condition discussed above.

3.8 Dust and Atmospheric Chemistry

Dust samples were collected from the Kiggavik site (atop a ridge to the north of Sauna Lake) and from Baker Lake (outside the Urangesellschaft office) in August 1989. Filters from the Hi-vol samplers were analyzed for total particulates and for heavy metal and radionuclide chemistry. These results are presented in Table 3.15. Radon concentrations were also measured at the Kiggavik site (in 1988) and at Baker Lake (in 1989). Terradex TRACK-ETCH Type 'F' detectors were deployed in protective canisters 1 m above the ground. The locations of these collectors and results are listed in Table 3.16. Gamma measurements were taken throughout the Kiggavik project development area in 1989. The locations and readings are shown in Figures 3.5 and 3.6. Background air quality can be taken from published reports. A summary of reported Arctic air quality is given in Table 3.17, along with corresponding measurements of Baker Lake air quality.

The elemental chemistry of air samples collected at Baker Lake is representative of a road dust source. High levels of Ca, Mg and Al are present in Baker Lake soils, and in the filters collected in town. Air quality at the Kiggavik site is much more representative of plant debris, with generally higher concentrations of SO_4 and K than Baker Lake samples.

Mean radon concentrations for Baker Lake are 16 Bq/m^3, which is higher than the general background level of 10 Bq/m^3 for continental air masses (UNSCEAR, 1982). The mean radon concentration for the Kiggavik site is 6.3 Bq/m^3 (Table 3.16). It is not uncommon for radon levels to be variable because of the varying radium concentrations in the rocks. Natural radon levels will vary from one point to another, even over a relatively small area.

Gamma levels vary over the Kiggavik project area and range from about 5 uR/h to over 1,800 uR/h (over an exposed section of the Main Zone ore body). Levels are generally about 10 to 15 uR/h, which are similar to the 5 to 10 uR/h range measured in Baker Lake.

TABLE 3.15: CHEMISTRY OF AIR SAMPLES COLLECTED AT THE KIGGAVIK SITE AND AT BAKER LAKE IN AUGUST 1989

Filter No.	Location	Cl	SO_4	Ca	Mg	Na	K	Al	Mn	Pb	V	U	Th	Si	Pb-210	Ra-226
					Elements (ug/g)											
017	Baker Lake	0.02	0.2	L 0.01	L 0.01	0.01	0.01	0.04	L 1.4E-4	L 5.7E-4	L 4E-5	L 1E-5	2E-5	0.3	BDL	BDL
018	Baker Lake	0.02	0.01	0.03	0.02	0.04	0.01	0.03	8E-5	3.3E-4	3E-5	L 2E-6	1E-5	0.3	BDL	BDL
019	Baker Lake	0.03	0.03	0.09	0.04	0.03	0.04	0.07	L 3E-4	L 0.001	L 7E-5	L 2E-5	4E-5	0.6	BDL	BDL
020	Kiggavik Site (ug/filter)*	0.35	0.40	0.05	-	1.8	0.1	0.09	-	-	-	-	-	0.1	BDL	BDL
Baker Lake Soil Sample		500	15	8,950	7,550	9,950	16,700	55,000	198	8	30	1.1	7.1	226	BDL	BDL

L = less than.

* = damaged filter.

BDL = below detection limit.

TABLE 3.16: RADON LEVELS MEASURED IN THE KIGGAVIK PROJECT AREA AND IN BAKER LAKE (1988 and 1989)

Collection Date	Location	Radon Concentration[1] (Bq/m^3)
17 August 1988	West of Lone Gull Camp	7.4
	Ridge Lake	4.4
	Drumlin Airstrip	4.4
	Main Zone	4.4
	Pointer Peninsula	11.1
06 July 1989	Mullens (Baker Lake)	14.8
	RCMP Office (Baker Lake)	18.5
	UG Office (Baker Lake)	14.8

[1] Average radon concentration over continents is 1 to 10 Bq/m^3, with higher concentrations inland than along marine coasts (UNSCEAR, 1982).

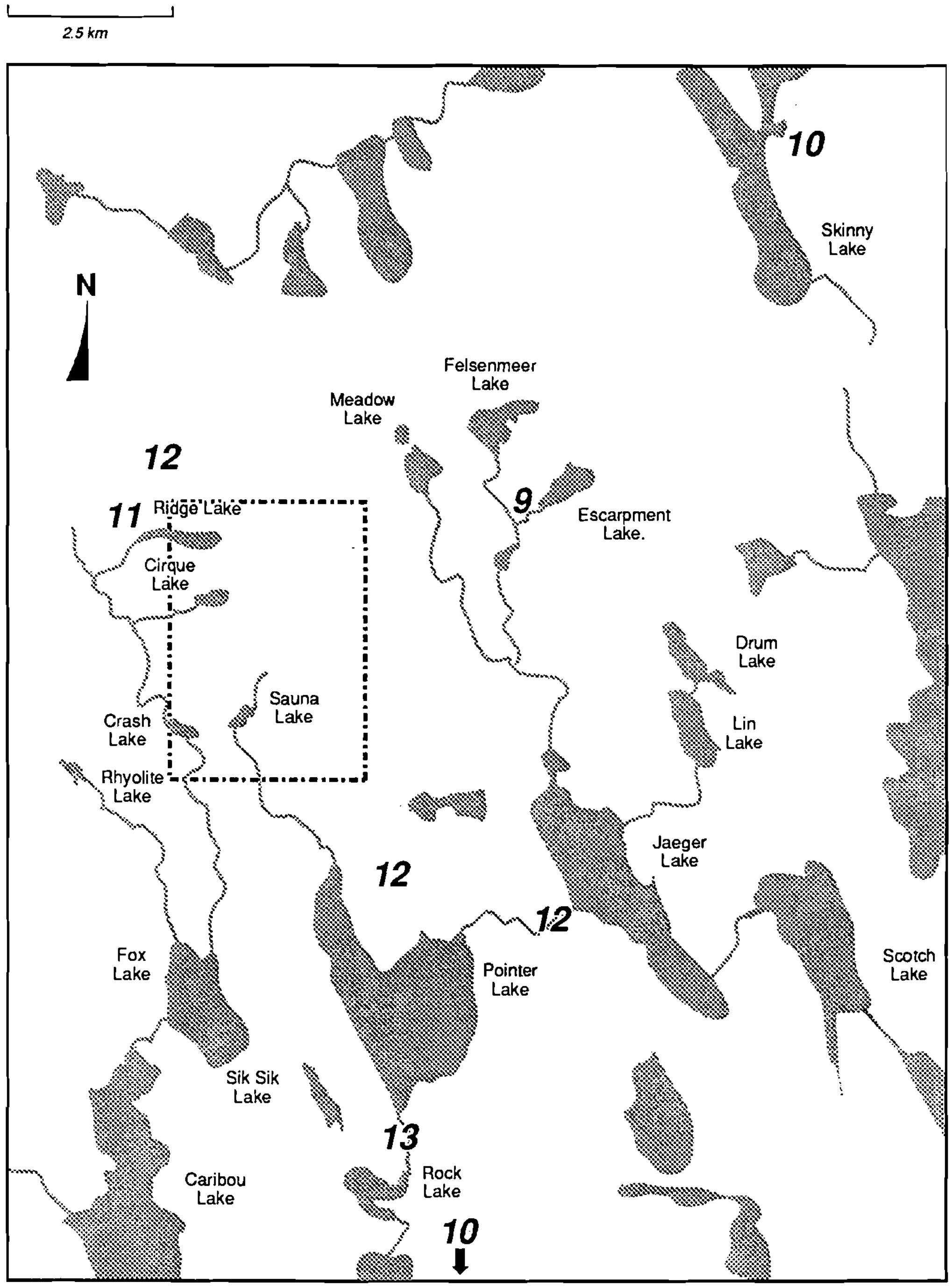


figure ***3.5***

Gamma distribution over the general Kiggavik development area.

13 *Gamma survey reading (uR/hr.)*

Kiggavik work site (see enlargement)

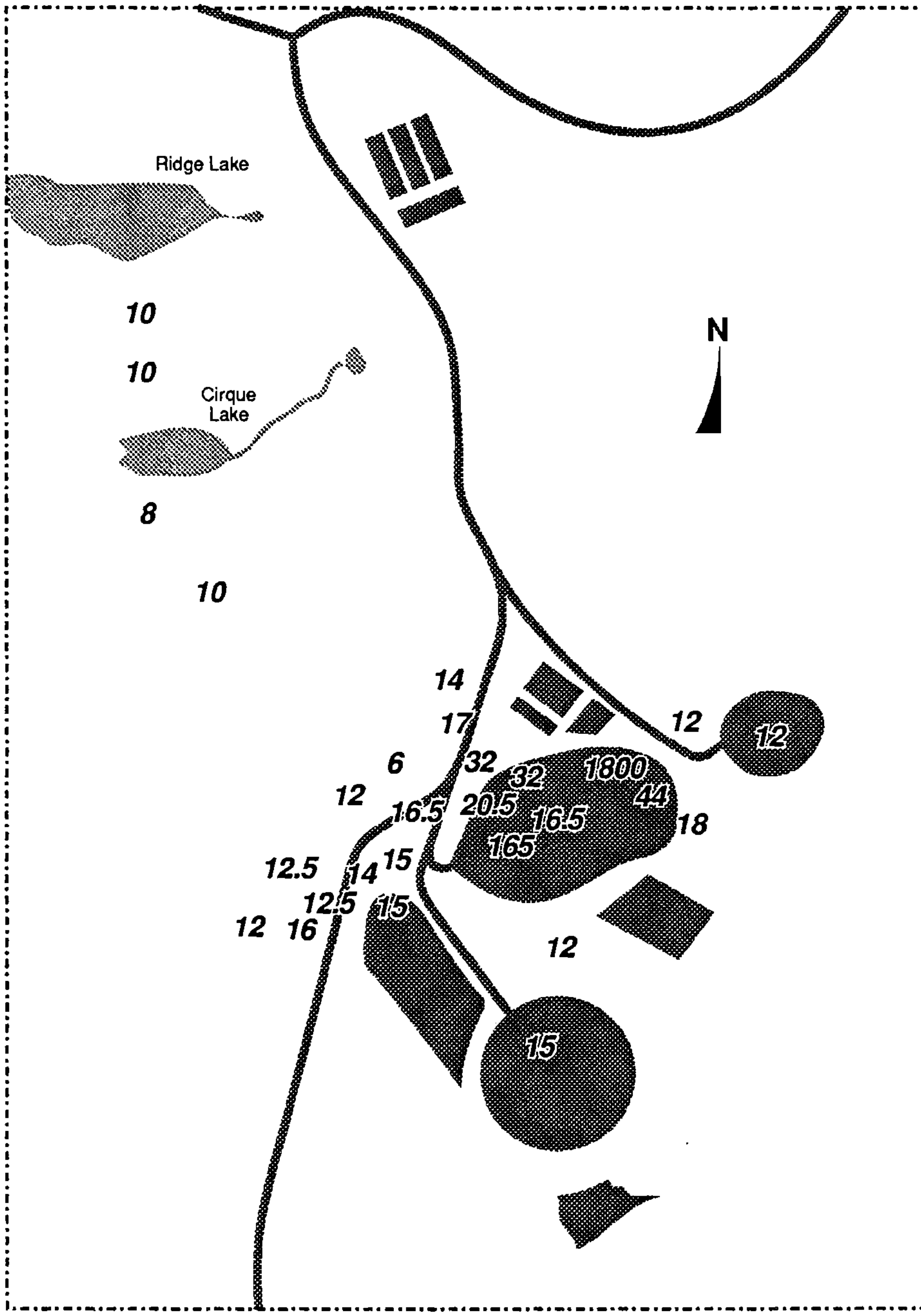


figure **3.6**

Gamma distribution over the Kiggavik site

13 *Gamma survey reading (uR/hr.)*

TABLE 3.17: BACKGROUND AIR QUALITY DATA FROM PUBLISHED REPORTS OF ARCTIC AIR CHEMISTRY

Substance[1]	Alert[2]	Igloolik[2]	Mould Bay[2]	Birch Mountain[3]	Fort Smith[3]	Baker Lake Filter No. 17	Baker Lake Filter No. 18	Baker Lake Filter No. 19
Cr	0.16-0.30	0.06-0.15	0.31-0.32	-	-	-	-	-
Cu	0.78-1.33	0.69-1.13	1.02-1.61	L 0.78-L 1.2	0.70	-	-	-
Mn	1.5-1.6	0.45-0.71	0.79-0.87	0.51-0.78	1.2	-	1.1	-
Ni	0.32-0.38	0.14-0.27	0.40-0.45	-	-	-	-	-
Pb	1.70-1.72	3.61-3.84	2.0-3.2	-	-	-	4.5	-
Sr	0.30-0.57	0.35-0.67	0.35-0.41	-	-	-	-	-
V	0.36-0.62	0.21-0.47	0.28-0.56	0.40-3.6	0.17	-	0.5	-
Zn	2.80-3.48	3.45-3.80	2.82-3.79	3.2-6.0	3.1	-	-	-
H	6.3-7.4	4.0-5.9	6.5-9.2	-	-	-	-	-
NH_4	82-102	77-95	72-125	-	-	-	-	-
SO_4	890-1,052	667-966	738-1,036	-	-	425	135	70
NO_3	55-74	62-71	59-67	-	-	-	-	-
Br	3.8-8.9	5.7-14	6.7-16	1.4-3.6	0.44	-	-	-
I	0.43-0.49	0.96-1.03	0.45-0.46	0.36-0.42	0.16	-	-	-
F	2.0-7.0	5.8-7.2	5.4-6.7	-	-	-	-	-
Na	121-158	229-313	179-243	52-101	15	270	600	85
Cl	114-182	368-505	251-354	42-142	7	390	340	80
K	11-16	17-31	11-15	19-27	44	215	180	110
Mg	84-92	99-129	63-69	18-24	-	-	100	55

[1] Substances recorded in ng/m^3.

[2] From: Barrie, L.A. and R.M. Hoff. 1985. (1980-1982).

[3] From: Barrie, L.A. 1986. (1971).

L = less than.

Air quality at Baker Lake is generally similar to that reported for other Arctic sites (Table 3.17). Values for SO_4 are slightly lower than reported for other areas, while those for Na, Cl, K and Mg are slightly higher.

4.0 ASSESSING THE POTENTIAL FOR AIR POLLUTION

Air pollution potential is defined as the meteorological condition which, given the existence of emissions, would be conducive to poor air quality. Conditions which allow for the accumulation of pollutants denote high air pollution potential.

Parameters from which air pollution potential may be evaluated include the duration of light surface winds, atmospheric stability, mixing heights and mixed layer wind speeds and ventilation coefficients. Data concerning these parameters are presented below for Baker Lake.

4.1 Duration of Light Surface Winds

The horizontal transport and dispersion of pollutants is limited under light wind conditions. If light winds persist for prolonged periods, severe air pollution episodes may result.

Tables 4.1 and 4.2 show the average number of occurrences for specific durations of calms and winds of less than 8 km/hr (not including calms), respectively. For example, from Table 4.1, a calm persisting for five to six hours can be expected to occur once in January. The longest duration of each event is also given.

4.2 Atmospheric Stability

In its simplest terms, the stability of the atmosphere is its tendency to resist or enhance vertical motion. Stability is related to both wind speed and vertical temperature profile. Three states of atmospheric stability are distinguished: unstable, neutral and stable.

Unstable conditions occur with a decreasing temperature gradient with height greater than $0.98^{o}C/100$ m in conjunction with low wind speeds. Under unstable conditions, strong vertical motion is present, usually caused by radiational heating of the earth's surface. Dispersion is generally good under unstable conditions and air pollution potential low.

TABLE 4.1: AVERAGE NUMBER OF OCCURRENCES OF CALMS FOR SPECIFIC DURATIONS AT BAKER LAKE (1953 to 1983)

	Duration in Hours								
	1	2	3	4	5-6	7-9	10-12	12	Longest Duration
January	19.2	5.1	2.2	1.3	1.0	0.6	0.2	0.1	22
February	22.5	4.6	2.0	0.8	1.3	0.6	0.4	0.4	34
March	21.1	4.3	1.9	1.2	1.5	1.0	0.5	0.6	24
April	16.6	3.8	1.9	0.9	1.5	1.0	0.6	0.5	51
May	12.8	3.6	1.5	1.3	1.2	0.9	0.3		63
June	15.3	3.9	2.3	1.3	1.3	1.0	0.3	0.3	18
July	18.8	5.8	3.0	2.1	2.5	1.0	0.4	0.2	23
August	16.3	4.0	1.9	1.0	1.5	0.6	0.2		13
September	9.9	3.3	1.7	0.8	0.5	0.3			19
October	9.8	2.6	0.8	0.7	0.5	0.5	0.1		21
November	17.5	4.0	2.4	1.0	1.1	0.8	0.4	0.7	29
December	19.9	5.4	2.1	1.4	1.0	0.7	0.1	0.1	22

TABLE 4.2: AVERAGE NUMBER OF OCCURRENCES OF WINDS LESS THAN 8 km/hr FOR SPECIFIC DURATIONS AT BAKER LAKE (1953 to 1983)

	Duration in Hours								
	1	2	3	4	5-6	7-9	10-12	12	Longest Duration
January	36.6	6.5	2.7	0.9	0.6	0.6			31
February	35.9	5.9	2.4	0.9	0.6	0.2			7
March	35.4	6.0	2.4	1.0	0.4	0.3			13
April	28.4	7.3	2.3	1.1	0.9	0.4			9
May	27.2	5.2	3.2	1.4	0.9	0.4	0.1	0.1	16
June	30.4	6.9	3.4	1.4	0.6	0.3		0.1	14
July	35.4	6.3	2.6	0.9	0.7	0.2			8
August	31.4	6.8	3.3	1.3	0.9	0.4	0.1	0.2	26
September	23.3	6.6	2.4	1.4	0.8	0.5	0.1		10
October	22.9	5.7	2.2	1.3	1.0	0.4	0.1		10
November	32.2	7.9	2.4	1.3	0.8	0.5	0.2		20
December	36.0	8.2	3.4	1.4	1.0	0.2			13

Neutral conditions exist when the temperature gradient is equal to -0.98°C/100 m. Neutral conditions normally occur on cloudy and windy days. Horizontal dispersion will dominate over vertical dispersion under neutral conditions.

Stable conditions occur with light winds when the temperature decrease with height is less than 0.98°C/100 m. Air pollution potential is generally highest under stable conditions. If a temperature inversion exists (increase in temperature with height), the top of the inversion forms an effective lid trapping pollutants below it. Dispersion under stable conditions is confined to the horizontal; however, stable conditions are frequently associated with low wind speeds. Inversions are common in Arctic regions during the winter months. Munn et al. (1970) calculated that inversions occur between 60 and 75% of the time, both during morning and afternoon temperature soundings at Arctic stations.

A stability analysis has been performed for Baker Lake using the STAR software program available through the Canadian Climate Centre (AES). Six stability classes are defined according to the scheme developed by Pasquill (1961) and modified by Gifford (1961). The definitions of these stability classes are shown in Table 4.3. The D-category is separated into two classes, D-day and D-night, representing daytime and nighttime neutral conditions, respectively. The E and F categories are combined into one stable classification.

Table 4.4 shows the monthly frequency distribution of stability classes for Baker Lake for the ten-year period 1975 to 1984. The predominant class is D-neutral which can be expected to occur 70.4% of the time. The critical (from an air pollution potential standpoint) E and F stable occurs 19% of the time, but more than 25% of the time during the winter months of November through March. Unstable conditions occur little more than 10% of the time.

4.3 Mixing Heights and Mixed Layer Wind Speeds

The mixing height is a parameter used to define the effective depth of the atmosphere (measured from the surface) through which the dispersion of pollutants can take place. Heat transferred to the atmosphere at the earth's surface results in convection and vertical mixing. The parameter most used when considering air pollution potential is the maximum afternoon mixing height. Mean values of this parameter for Canadian upper

TABLE 4.3: METEOROLOGICAL STABILITY CATEGORIES

Surface Wind Speed (m s^{-1})	Daytime Insolation			Nighttime Conditions	
	Strong	Moderate	Slight	Thin Overcast or 4/8 Cloudiness	3/8 Cloudiness
2	A	A-B	B		
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
6	C	D	D	D	D

A = Extremely unstable conditions.
B = Moderately unstable conditions.
C = Slightly unstable conditions.
D = Neutral conditions*.
E = Slightly stable conditions.
F = Moderately stable conditions.

* The neutral condition D should be assumed for overcast conditions during day or night.

TABLE 4.4: PASQUILL STABILITY CLASS PERCENT FREQUENCY DISTRIBUTION (1975 to 1984)

Month	A	B	C	D-Day	D-Night	E and F	Total
January	0.0	0.0	1.8	11.0	58.6	28.6	100
February	0.0	0.2	4.1	22.4	44.9	28.4	100
March	0.0	3.3	7.2	29.2	35.7	24.6	100
April	0.3	5.2	10.2	38.1	30.1	16.1	100
May	1.1	7.3	10.6	48.3	23.2	9.5	100
June	1.0	8.3	14.2	51.5	15.3	9.7	100
July	0.8	7.5	14.4	49.4	15.8	12.1	100
August	0.2	4.9	10.9	43.8	23.6	16.6	100
September	0.0	1.2	5.0	39.7	37.9	16.2	100
October	0.0	0.2	2.6	29.8	57.4	10.0	100
November	0.0	0.0	2.2	15.8	56.6	25.4	100
December	0.0	0.0	1.3	7.6	59.9	31.2	100
Annual	0.3	3.2	7.1	32.3	38.1	19.0	100

air stations, including Baker Lake, have been prepared by Portelli (1977) for the four-year period July 1965 to June 1969.

The observed wind speeds within the maximum afternoon mixed layer have been averaged to provide a mean mixing layer wind speed. This is considered a more representative value than surface wind speed for use in dispersion studies.

Table 4.5 gives the mean monthly maximum afternoon mixing heights and the mean mixed layer wind speeds for Baker Lake. As would be expected, mixing heights are highest during the summer months of July and August. For the winter months of November through March, the mixing heights are low. It should be emphasized that these values are the maximum daytime mixing heights. Nighttime values in this area will likely be close to zero most of the time.

Joint frequencies of maximum afternoon mixing heights versus mixed layer wind speeds and mixed layer wind directions are presented in Tables 4.6 and 4.7, respectively.

4.4 Mixed Layer Ventilation Coefficients

The product of the mixing height and the mean wind speed in the mixed layer is referred to as the "Ventilation Coefficient".

This parameter attempts to combine the vertical and horizontal dispersive power of the lower atmosphere. The higher the ventilation coefficient, the more able the atmosphere to disperse pollutants. Table 4.8 gives the mean monthly maximum afternoon ventilation coefficients for Baker Lake. Again, it should be emphasized that these are the maximum daily values.

Although it has been suggested by the U.S. Air Pollution forecast program that ventilation coefficients which do not exceed 6,000 m^2/sec are indicative of high pollution potential, the applicability of this standard to northern Canada has not yet been investigated.

A joint frequency of ventilation coefficients and mixed layer wind speeds is presented in Table 4.9. A ventilation coefficient of less than 6,000 m^2/sec and a mixed layer wind of

TABLE 4.5: MEAN MAXIMUM AFTERNOON MIXING HEIGHTS AND MEAN MIXED LAYER WIND SPEEDS FOR BAKER LAKE (1965 to 1969) (from Portelli, 1977)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Maximum Afternoon Mixing Height (m)	107	150	220	278	384	637	1,016	982	664	347	172	136	458
Mean Mixed Layer Wind Speeds (m/s)	6.6	6.4	7.1	6.4	7.0	6.9	7.5	8.0	8.0	7.1	6.8	7.3	7.1

TABLE 4.6: MAXIMUM MIXING HEIGHT, MIXED LAYER WIND SPEED AND JOINT FREQUENCY, BAKER LAKE, JULY 1965 TO JUNE 1969

Mixed Layer Wind Speed (m/s)	Mixed Layer Height (m) 0	1 to 199	200 to 399	400 to 599	600 to 799	800 to 999	1,000 to 1,199	1,200 to 1,399	1,400 to 1,599	1,600 to 1,799	1,800 to 1,999	GT 2,000	Total
0.0-2.0	0.2	4.9	2.3	1.0	0.3	0.2	0.1	0.0	0.1	0.0	0.0	0.0	9.1
2.1-4.0	0.4	5.9	3.6	1.6	1.1	0.5	0.4	0.4	0.1	0.1	0.1	0.0	14.2
4.1-6.0	0.1	5.1	4.9	2.5	1.2	1.2	1.0	0.6	0.6	0.3	0.1	0.4	18.0
6.1-8.0	0.3	4.0	4.2	2.5	1.6	0.8	0.8	0.4	0.5	0.3	0.1	0.2	15.7
8.1-10.0	0.1	3.8	3.8	1.6	1.3	0.8	0.3	0.3	0.2	0.2	0.3	0.1	12.8
10.1-12.0	0.1	1.9	2.2	1.3	1.2	0.4	0.8	0.3	0.1	0.2	0.1	0.1	8.7
12.1-14.0	0.1	1.0	1.3	0.8	0.3	0.1	0.1	0.2	0.0	0.1	0.1	0.0	4.1
14.1-16.0	0.1	0.8	0.5	0.4	0.4	0.1	0.1	0.1	0.1	0.0	0.0	0.1	2.7
16.1-18.0	0.0	0.5	0.1	0.3	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	1.1
18.1-20.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.4
20.1-30.0	0.0	0.2	0.0	0.2	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.7
GT 30.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	1.4	28.2	23.0	12.3	7.5	4.2	3.8	2.3	1.8	1.2	0.9	0.9	87.5
Missing Data													12.5

GT = greater than.

TABLE 4.7: VENTILATION COEFFICIENT, MIXED LAYER WIND DIRECTION AND PERCENT JOINT FREQUENCY, BAKER LAKE, JULY 1965 TO JUNE 1969

Mixed Layer Wind Direction (degrees)	Mixed Layer Height (m) 0	1 to 199	200 to 399	400 to 599	600 to 799	800 to 999	1,000 to 1,199	1,200 to 1,399	1,400 to 1,599	1,600 to 1,799	1,800 to 1,999	GT 2,000	Total
Calm	0.1	1.6	0.9	0.5	0.1	0.3	0.1	0.0	0.1	0.0	0.1	0.0	3.8
010-040	0.1	3.4	1.9	1.0	0.5	0.5	0.3	0.2	0.3	0.3	0.0	0.1	8.6
050-080	0.4	2.0	1.5	0.4	0.3	0.1	0.1	0.1	0.0	0.0	0.1	0.0	5.0
090-120	0.0	2.8	1.6	0.6	0.5	0.2	0.1	0.1	0.0	0.0	0.0	0.0	5.9
130-160	0.1	2.7	3.8	2.0	0.7	0.2	0.1	0.0	0.0	0.0	0.0	0.0	9.6
170-200	0.0	0.5	2.0	1.0	0.6	0.3	0.1	0.1	0.1	0.0	0.0	0.0	4.7
210-240	0.0	0.8	0.5	0.5	0.5	0.1	0.3	0.1	0.0	0.0	0.1	0.1	3.0
250-280	0.0	0.9	1.2	0.6	0.7	0.1	0.2	0.2	0.1	0.0	0.0	0.3	4.3
290-320	0.1	3.3	3.1	2.5	0.9	1.0	1.0	0.5	0.5	0.4	0.2	0.3	13.8
330-360	0.6	10.0	6.1	3.1	2.2	1.1	1.2	1.0	0.6	0.3	0.3	0.2	26.7
TOTAL	1.4	28.0	22.6	12.2	7.0	3.9	3.5	2.3	1.7	1.0	0.8	1.0	85.4
MISSING DATA													14.6

GT - greater than

TABLE 4.8: MEAN MAXIMUM AFTERNOON VENTILATION COEFFICIENTS FOR BAKER LAKE (1965 to 1969) (from Portelli, 1977)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Ventilation Coefficient (m^2/sec)	720	1,020	1,620	1,800	2,810	4,490	8,256	7,660	5,330	2,710	1,260	1,160	3,450

TABLE 4.9: MAXIMUM MIXING HEIGHT, MIXED LAYER WIND SPEED AND AND PERCENT JOINT FREQUENCY, BAKER LAKE, JULY 1965 TO JUNE 1969

Mixed Layer Wind Speed (m/s)	Mixed Layer Height (m) 0 to 10	11 to 20	21 to 30	31 to 40	41 to 50	51 to 60	61 to 70	71 to 80	81 to 90	91 to 100	101 to 110	GT 110	Total
0.2-2.0	8.6	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.1
2.1-4.0	9.1	2.3	1.7	0.5	0.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0	14.1
4.1-6.0	5.1	4.6	2.8	1.2	1.2	1.2	0.6	0.2	0.5	0.1	0.1	0.3	17.9
6.1-8.0	2.9	3.4	2.4	2.3	1.0	0.9	0.5	0.5	0.5	0.2	0.4	0.7	15.7
8.1-10.0	1.8	2.7	2.2	1.6	0.6	0.9	0.8	0.4	0.3	0.3	0.2	1.0	12.8
10.1-12.0	0.8	1.0	1.3	0.8	0.7	0.5	0.6	0.5	0.3	0.2	0.3	1.8	8.8
12.1-14.0	0.5	0.5	0.3	0.5	0.3	0.2	0.3	0.3	0.1	0.1	0.1	0.6	3.8
14.1-16.0	0.5	0.3	0.1	0.1	0.2	0.1	0.3	0.1	0.1	0.2	0.1	0.5	2.6
16.1-18.0	0.1	0.2	0.1	0.1	0.1	0.0	0.1	0.2	0.1	0.0	0.0	0.3	1.3
18.1-20.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.5
20.1-30.0	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.3	0.7
30.1+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	29.6	15.5	10.9	7.1	4.5	4.1	3.3	2.2	2.1	1.2	1.2	5.6	87.3
MISSING DATA													12.7

GT = greater than

less than 4 m/sec can be expected to occur about 23% of the time. This would represent severely limited dispersion conditions.

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