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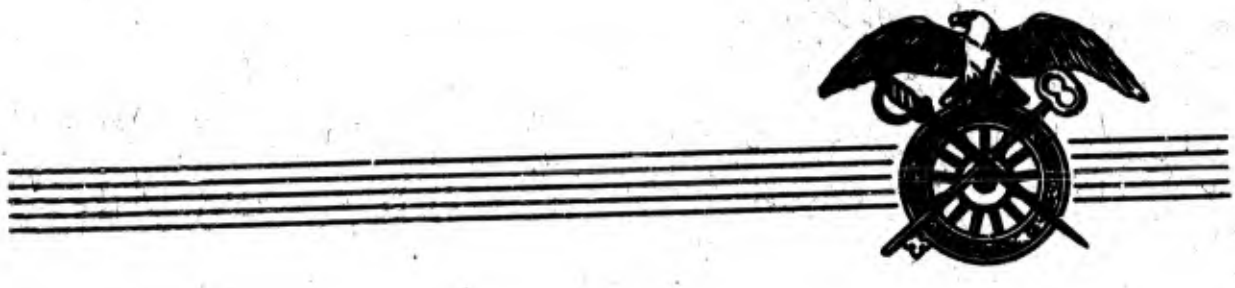
HEADQUARTERS
QUARTERMASTER RESEARCH & DEVELOPMENT COMMAND

TECHNICAL REPORT
EP-4

HANDBOOK OF FORT CHURCHILL ENVIRONMENT



QUARTERMASTER RESEARCH & DEVELOPMENT CENTER
ENVIRONMENTAL PROTECTION DIVISION

AUGUST 1954

NATICK, MASSACHUSETTS

HEADQUARTERS QUARTERMASTER RESEARCH & DEVELOPMENT COMMAND
Quartermaster Research & Development Center, US Army
Natick, Massachusetts

ENVIRONMENTAL PROTECTION DIVISION

Technical Report
EP-4

HANDBOOK OF FORT CHURCHILL, MANITOBA, CANADA, ENVIRONMENT

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ENVIRONMENTAL RESEARCH BRANCH

Project Reference:
7-83-03-008

August 1954

Foreword

This report is one of a series of studies designed to provide pertinent information concerning environmental conditions at Army testing sites. Inaugurated in August, 1952, at the request of the Test Coordinator, Research and Development Division, Office of The Quartermaster General, the program of test site studies was undertaken to enable test planners to select optimal conditions for scheduling performance tests of Quartermaster equipment at selected testing installations. By request of the Assistant Chief of Staff, G-4, environmental studies for Dugway Proving Ground, Utah (Environmental Protection Division Report No. 227), and Devils Lake, North Dakota, were included in the site study program to complete the coverage of installations presently used by agencies of the Department of the Army.

This test site study will serve as a convenient reference for those who require information concerning the climate, terrain, and vegetation at Fort Churchill, Manitoba, Canada.

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Acting Chief
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Approved:

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Contents

Abstract

Fort Churchill, Manitoba, Canada, is located approximately 500 miles south of the Arctic Circle on the west shore of Hudson Bay in the transition region between the Arctic and Subarctic.

Extreme low temperatures, often in combination with high wind speeds, and long periods of daylight in winter provide ideal conditions for cold weather testing. The absolute minimum temperature recorded was only -57°F (because of the proximity of Hudson Bay), but temperatures at or below -25°F occur on one-half the days of January and February. Long periods of daylight (6 hours in December, 18 hours in June), when compared with arctic stations, is a decided advantage for arctic testing in high latitudes.

The Fort Churchill area is a flat, waterlogged plain averaging less than 25 feet in elevation. Exceptions to this are ridges of hard, crystalline rock and a few scattered gravel ridges which rise to 100 feet and upon which the main part of the installation is located. The ground is frozen and snow-covered from late September or early October until April or May. During the remaining months the swampy terrain is dotted by many shallow lakes and creeks which make movement by men and vehicles difficult.

The area is located in the transition zone between the subarctic forest and the arctic tundra and the vegetation shows pronounced evidence of the severe environment. Trees are few or entirely absent from the more exposed positions, those exposed to the wind are one-sided in appearance, and because of the swampy conditions generally associated with a high permafrost table, plants well-adapted to moist or wet ground conditions tend to dominate. Two major vegetation types may be distinguished: (1) the northern coniferous forest and (2) the tundra which is composed of the lichen-covered high tundra, found on the ridges, and the muskeg, or low tundra.

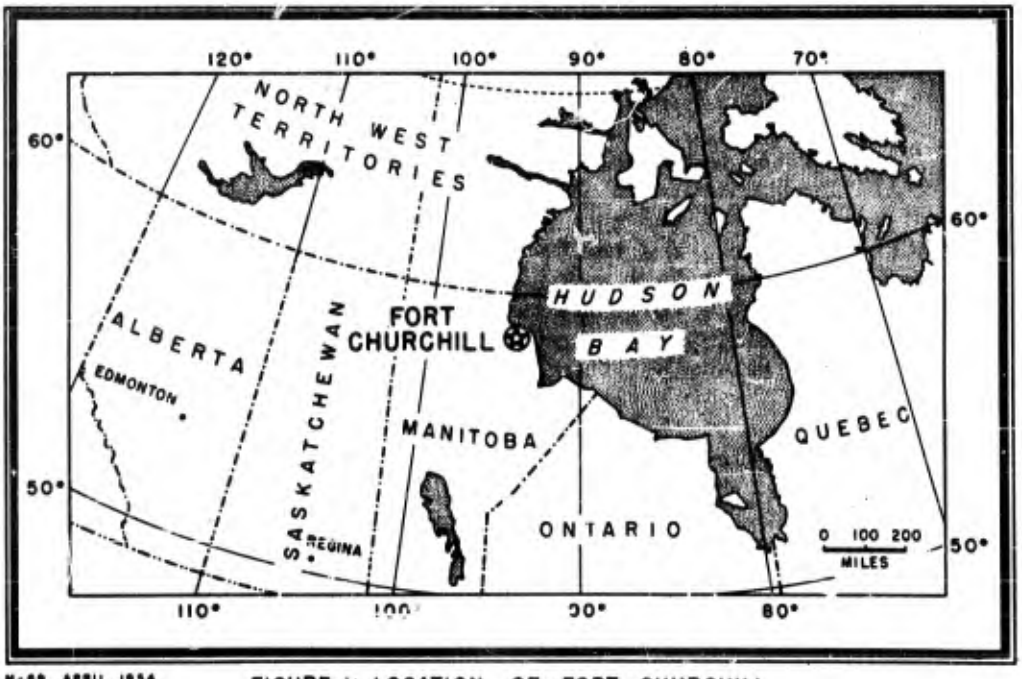
HANDBOOK OF FORT CHURCHILL, MANITOBA, CANADA, ENVIRONMENT

1. Introduction

Fort Churchill (latitude 58°47'N., longitude 94°17'W.) is located about 500 miles south of the Arctic Circle on the west shore of Hudson Bay near the mouth of the Churchill River (Fig. 1). The military camp is situated just southeast of the town of Churchill (Fig. 2). Churchill has the dual distinction of being the most northern rail-served port in Canada and the only deepwater port on Hudson Bay with railroad facilities. Its population, consisting of a permanent core of white people supplemented by nomadic Indians and Eskimos, is employed chiefly as trappers, fur traders, and by the Canadian National Railroad and the Churchill Harbor Board.

The original Army post, established by the United States in 1942, was planned as an air evacuation center for casualties from Europe. Never used as such, it became a service station for aircraft engaged in the transfer of lend-lease goods to England. In 1944 control of the station passed into the hands of the Canadian Government which administered the affairs of the base through its Department of Transport.

LOCATION MAP



M-69 APRIL, 1954

FIGURE 1: LOCATION OF FORT CHURCHILL

The post has served as a base for various Exercises including "Exercise Lemming" in 1945 and "Exercise Muskox" in February 1946, but in recent years has been used mainly for winter testing. Between July and September 1946 the summer trials of the Directorate of Vehicle Development were staged in the vicinity of Churchill.

The Canadian Army assumed administrative control of the post in 1946, giving it the name "Fort Churchill" to distinguish it from the town and to identify it as a military installation.

Few, if any, military installations in northerly latitudes are better situated to execute the mission for which they were established. A terminal point for both air and rail traffic, Fort Churchill is adequately served year-round. Twice weekly, commercial planes (Canadian Pacific Airlines) make the trip from Winnipeg, arriving and departing the same day. The Royal Canadian Air Force provides air service, on a trip-a-week schedule, from Montreal via Winnipeg. United States Military Air Transport Service flights are made from Washington, via Westover Air Force Base, Massachusetts. Biweekly train service from Winnipeg is maintained throughout the year. The modern harbor of Churchill is accessible to ocean-going transport for at least three months of the year and the navigation season for overseas vessels is from 5 August to 15 October. Housing facilities, limited at first to the United States Evacuation Hospital and a number of semi-permanent buildings, have been greatly expanded and improved by the Canadian Army. The installation offers easy access to extensive areas of arctic tundra, and field testing programs can be readily supported and administered. Fort Churchill experiences arctic conditions in winter; however, there is always at least 6 hours of daylight, a distinct advantage for field testing.

Although the Canadian Army serves as the maintenance unit, Fort Churchill is operated on a joint service and interservice basis. Canadian elements at the base include representatives of the Navy, the Army, the Air Force, and the Defense Research Board; the United Kingdom Winter Warfare Study Team represents the military services of the UK; and the First Arctic Test Detachment represents the U.S. Army. In addition to its military functions, the station is used as a base of operations for scientists from all fields. The services of the airport are also available to both military and civilian aircraft, but the operation and control of the field are the function of a unit of the Royal Canadian Air Force.

The mission of the United States Army Detachment includes the testing of Army materiel and equipment under arctic conditions. The 7099th Area Service Unit (FATD, USA), organized under the Commanding General, Military District of Washington, provides logistic and administrative support for the various technical service teams sent to Fort Churchill. Only such equipment as may be required for testing is brought to Fort

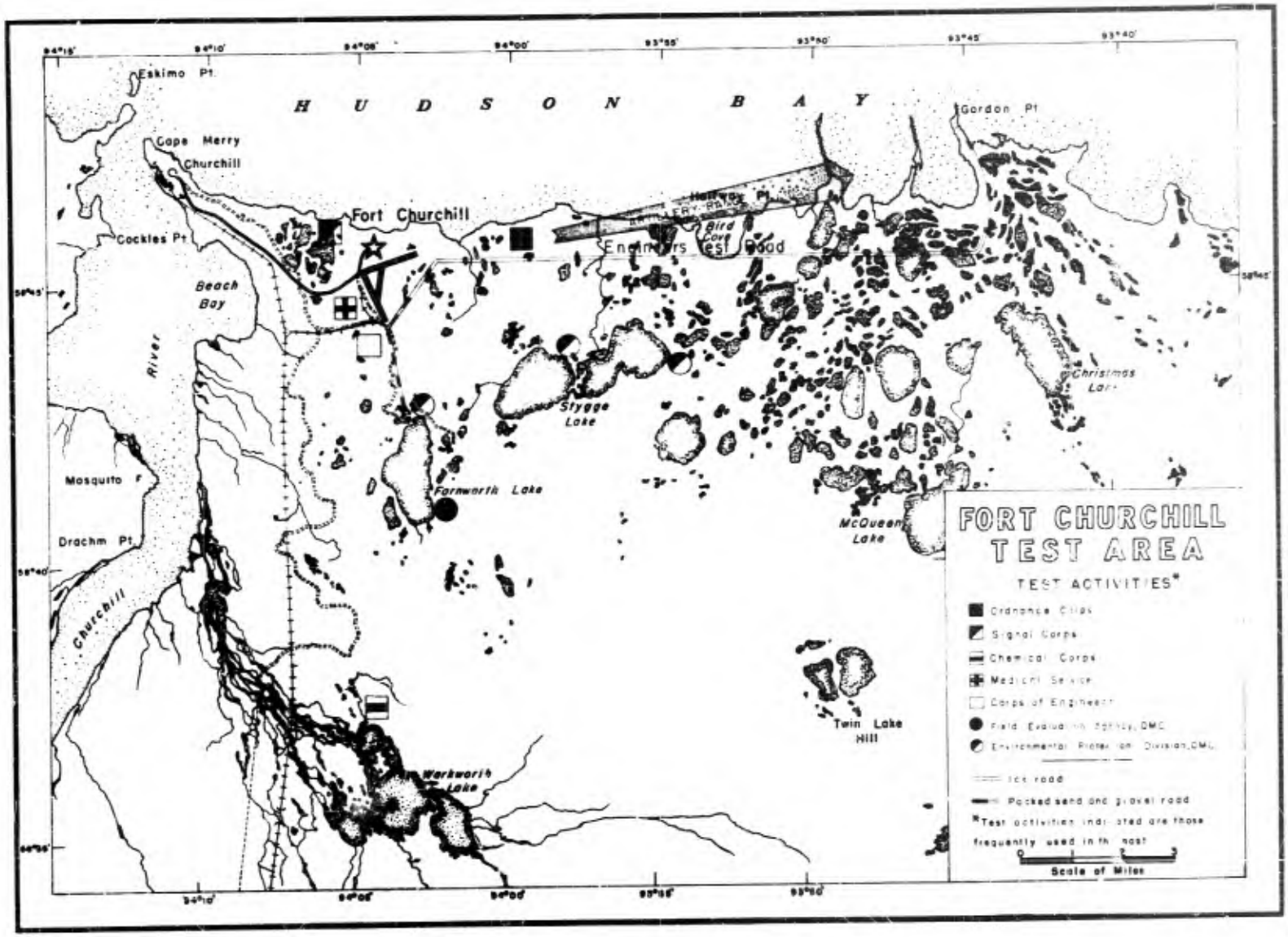


FIGURE 2. FT. CHURCHILL: LOCATION OF TEST ACTIVITIES

Churchill by the test teams. These teams are afforded maximum freedom to devote entire effort to their respective test programs.

Winter testing, which usually begins early in November and ends the last of March, has been undertaken by the following technical services of the United States Army: Quartermaster Corps (Field Evaluation Agency and Environmental Protection Division), Chemical Corps, Army Medical Service, Corps of Engineers, Signal Corps, Ordnance Corps and Transportation Corps. Transportation Corps headquarters is located at the main base and is not shown on the map (Fig. 2).

2. Climate

a. General. Climatically, the Fort Churchill test area may be considered transitional between the Arctic and Subarctic. By the definition that uses a mean temperature of 50°F in the warmest month to establish the line of division,* Churchill's average July temperature of 54°F places it on the subarctic side of the boundary. Winters are long and severely cold and summers are short and cool. Climatic severity is best illustrated by the low winter temperatures, which in combination with strong winds create the extremes necessary for arctic testing. Precipitation, though adequate for forest growth, is light, and winter snow cover is not deep except where accentuated by drifting. The Fort Churchill test area offers three essentials for cold-weather experimentation: (1) extreme cold; (2) severe windchill; (3) blowing and drifting snow.

b. Temperature. Mean monthly temperature at Fort Churchill ranges from -19°F in January to 54°F in July. Extremely low temperatures are characteristic of the long winter season. Temperatures below -25°F may be expected on about 16 days in January and 15 days in February and less frequently in the other months from November through April. Temperatures below -25°F have been recorded on an average of 46 days each year. An absolute low of -57°F occurred in January, and temperatures below -50°F have been recorded in November, January, February and March. Normally, low temperatures are most likely to occur from December to the end of February.

Summers are cool to moderately warm. Temperatures above 80°F may be expected no more than four days each year, and occur most frequently in July, the warmest month. While high temperatures are rare (a high of 96°F has been recorded in July), relatively warm weather is characteristic of midsummer, with temperatures above 60°F expected on about half of the days in July and in August.

*Köeppen W. and Geiger R. Handbüch der Klimatologie. Vol. 1, C, Verlagsbuchhandlung, Gebrüder Borntraeger, Berlin, 1936.

c. Precipitation. Precipitation averages 14.4 inches per year with more than 10 inches falling from June to October. July, the rainiest month, averages 2.8 inches, closely followed by August with 2.5 inches. The maximum monthly rainfall, 7.3 inches, was recorded in July 1934. Although as much as 3.7 inches has fallen in a 24-hour period, most summer precipitation falls as light rain or drizzle, seldom exceeding a total of 0.5 inch in a 24-hour period. Even though the greatest amounts of rainfall occur in July and August, rain is most frequent in September and October, when more than a trace is likely on about 16 days per month. A very small part of summer precipitation may be expected in the form of snow, since snowfall has been recorded in all months except July.

Winter is the dry season; January and February precipitation averages but 0.4 inch per month and no month from November through May averages more than 0.8 inch. Practically all winter precipitation falls in the form of snow, and snow cover may be expected from October to April or May. Although the season of snowfall is long, total snowfall is relatively small. It averages 43.8 inches per year. October, November, March and April are the months of heaviest snowfall, each averaging more than 6 inches.

Snow depths are difficult to measure because of drifting caused by strong winds. In forested areas accumulations may be deep, while in open country snow is blown from exposed positions and accumulates in depressions.

d. Wind. Prevailing winds are from the northwest and are generally strong throughout the year. Wind speed averages 16 to 17 mph from September through November, when maximum speeds greater than 32 mph may be expected seven or more days each month. Wind speed averages more than 12 mph in every month except July. The absolute maximum recorded wind speed occurred in December, averaging 78 mph over a one-hour period. Comparable hourly averages greater than 40 mph have been recorded in all months except July.

e. Windchill. Strong winds and low temperatures combine to make Fort Churchill an area of extreme windchill. Windchill, or dry atmospheric cooling, is a measure of the heat which the atmosphere is capable of removing from exposed skin surface, computed in units of kilogram-calories per square meter per hour. A windchill factor over 1,400 is considered freezingly cold and one over 1,900 dangerously cold.* Windchills over 1,400 are reported 76 to 89 percent of the time from December through February. From November through April, windchill exceeds 1,400 approximately 62 percent of the time, and values greater than 1,900 have occurred in all months during this period, with the most in January (39 percent of the time).

*Windchill terms are taken from Fort Churchill Meteorological Office, Daily Weather Observations.

f. Humidity. Relative humidity is high throughout the year. Readings at 0730 hours and 1930 hours are highest during November and December, when they average over 94 percent. Lowest relative humidity occurs in June and July, when it averages 88 and 89 percent, respectively, at the morning reading, and 78 and 71 percent at the evening reading. Despite the high relative humidity, the absolute moisture content of the air is extremely low, especially during winter. During this period there is rapid loss of body water through evaporation from the lungs and skin.

g. Obstructions to Vision. Visibilities of less than one mile are reported 5 percent or more of the time in all months except May, September and October. Visibility is poorest in November when approximately 16 percent of all observations are less than one mile. In summer, the chief restriction is fog; in winter, blowing snow. Fog is most common during July and August, restricting visibility to less than one mile in 7 percent of all observations; blowing snow reaches its greatest intensity during November, when it restricts visibility in 14 percent of all observations.

h. Cloudiness. Cloud cover is relatively extensive in all seasons. September and October, the cloudiest months, report more than 8/10 of the sky covered on 73 to 77 percent of all observations. Even from January through March, the least cloudy period, 8/10 or more cloud cover is reported on 39 to 42 percent of all observations. Ceiling heights of 950 feet or more are reported at 28 percent of all observations during November, when low overcast cloudiness is most frequent. Heights of 9,750 feet or more are reported on 70 percent of all observations during March.

i. Solar Radiation. Located approximately 7 to 8 degrees south of the Arctic Circle, Fort Churchill experiences tremendous variation in insolation from summer to winter. In June, the period from sunrise to sunset averages more than 18 hours; in December, about 6 hours. Despite relatively cloudy skies, the longer periods of sunlight and the greater altitude of the sun allow greater amounts of solar radiation to be received in summer. By contrast, in winter, insolation is very restricted; however, no day is without some sunlight, a decided advantage for arctic testing in high latitudes.

Solar radiation on a hor[illegible]ital surface has been computed for Fort Churchill from observation[illegible] Winnipeg, with proper adjustment for the difference in latitude. Radiation ranges from a low of 25 langleys* in December to a high of 550 langleys in June. Because of long summer daylight the June value equals or exceeds that at many low-latitude stations.

*Langley may be defined as one gm-cal/cm^2.

j. Climatic Summary. A summary of most of the climatic features mentioned above is given in Table I. Detailed data on climate are given in Appendix A (Figs. 5-41).

3. Terrain and Surface Conditions

a. General. In general, the Fort Churchill test area is a flat waterlogged plain averaging less than 25 feet in elevation. Exceptions to this are areas to the east of the town and along the shore of Hudson Bay, where ridges of hard, massive, crystalline rock may rise to over 100 feet, and a few gravel ridges scattered throughout the test area. The main part of the Fort Churchill installation is located on the largest of the bedrock ridges, and the airport runways occupy a low gravel ridge just south of the post. The remaining swampy terrain is dotted by many shallow lakes and creeks so closely spaced that in summer it is impossible to walk for any distance without continually altering direction.

Ground conditions vary radically from summer to winter. The surface is frozen and snow-covered from September or early October until April or May. Lowland flats or depressions that are impassable in summer are frozen and easily passable in winter.

Permafrost is ever present, and the depth to which the soil thaws in summer depends on the thickness and insulating quality of the overlying peat and the density of vegetation. Generally, the permafrost layer is within 2 to 4 feet of the surface but dips considerably under rivers and other bodies of water and under areas where the vegetation cover has been removed.

b. Foreshore Flats. Bordering Churchill Bay and Hudson Bay there is a broad belt of gently sloping land, inundated at high tide, which is termed the "foreshore flats". Though mapped as a hydrographic feature the flats are a continuation of the arctic plains and are treated in this report as a terrain unit. The foreshore flats are widest just south of the port of Churchill and just east of Halfway Point. Except for occasional patches of sand and gravel, boulder-strewn clays constitute the surface materials of the flats. The gentle slope of the land, combined with the great range of tide (an average of 14 feet) accounts for the great width of the zone. At its widest point, the width of beach uncovered at low tide amounts to more than a mile.

In summer, tides run at a speed of approximately 10 knots and constitute a hazard for small boats which operate in Churchill Bay and off the shore of the test area. In winter, the flats are covered with ice, some of which may be large, rough lumps of old pack ice; in the fall season this is pressed and piled on the shore by wind and tide and left there. This is known as pressure ice and together with the new ice cracked and heaved by the tides, and the rough-surfaced pack ice, is a type of surface common along arctic coasts.

TABLE I: CLIMATIC SUMMARY FOR FORT CHURCHILL, MANITOBA, CANADA*
(Elevation 115 feet)

TEMPERATURE (°F)

Month	Monthly	Mean Max.	Daily Min.	Record Highest	Record Lowest	Number of Days: Maximum ≥50°	Maximum ≥32°	Maximum ≤32°	Minimum ≤0°	Minimum ≤-25°
Jan	-18	-11	-27	39	-57	0	<1	31	29	16
Feb	-17	- 8	-25	31	-52	0	0	31	27	15
Mar	- 6	4	-16	41	-52	0	1	31	25	6
Apr	14	24	4	62	-26	1	6	30	13	0
May	30	38	22	87	-14	3	23	27	<1	0
Jun	43	52	34	88	13	13	29	11	0	0
Jul	54	64	43	96	22	28	31	<1	0	0
Aug	52	62	43	87	25	27	31	<1	0	0
Sep	42	49	34	84	15	12	29	6	0	0
Oct	27	34	20	62	-17	2	20	24	<1	0
Nov	6	13	- 2	45	-53	0	2	30	15	1
Dec	-11	- 3	-19	34	-47	0	<1	31	27	8

PRECIPITATION (INCHES) / RELATIVE HUMIDITY (%)

	Mean in Month	Max. in Day	Mean Snowfall	Number of Days ≥ .01	(0730 Hrs.)	(1930 Hrs.)
Jan	0.41	0.80	4.1	7	91	88
Feb	0.36	0.50	3.4	6	92	90
Mar	0.63	2.20	6.3	7	91	93
Apr	0.69	1.10	6.0	7	90	92
May	0.65	1.00	2.1	8	93	89
Jun	1.51	1.27	0.8	9	88	78
Jul	2.81	3.71	0	10	89	71
Aug	2.54	1.60	T	12	93	74
Sep	1.97	1.87	0.3	12	94	85
Oct	1.50	1.10	7.6	12	94	90
Nov	0.78	0.80	7.6	11	96	94
Dec	0.56	0.71	5.6	9	95	95

WIND / SKY COVER / POSSIBLE SUNSHINE

	Speed (mph) Mean	Speed (mph) Max. in Hr.	Prev. Dir.	No. of Days ≥32 mph	SKY COVER (No. of Days) Clear	Partly Cloudy	Cloudy	POSSIBLE SUNSHINE (No. of Hours)
Jan	14.9	52	W	3	15	3	13	7
Feb	14.6	45	NW-N	3	13	4	11	9
Mar	14.2	41	N	3	14	4	13	12
Apr	14.3	54	NW	3	10	5	15	15
May	13.4	51	N	1	4	5	22	17
Jun	12.2	41	N	1	5	6	19	18
Jul	11.5	37	N	1	7	8	16	18
Aug	13.0	42	N	2	6	7	18	16
Sep	16.3	55	N	7	3	5	22	13
Oct	17.1	54	NW	7	4	4	23	10
Nov	16.9	58	N	7	6	3	21	8
Dec	14.9	78	N	3	12	4	15	6

*Data largely from original records. Period of record approximately 19 years or more for all items except Relative Humidity which is for 4 to 6 years.

c. Rock Outcrops. Along the shore of Hudson Bay between Churchill and Halfway Point, outcrops of bedrock alternate with gravel beaches. The outcrops provide an excellent foundation for all types of structures in an area where permafrost limits serviceable base conditions over wide areas. These rocks also provide solid footing for infantry overland movement but they are, for the most part, in their natural state, too frost shattered and irregularly surfaced to be suitable for vehicular traffic.

d. Gravel Ridges. Gravel ridges found throughout the test area are glacial deposits or raised beaches resulting from marine terracing. In addition to gravel, they contain other sorted materials, ranging from fine clays and sands to pebbles and stones two to three inches in diameter. These ridges serve as a source of good gravel for roads and building construction. Although some are covered with a thin layer of peat, parts of the ridges known as eskers are so well drained as to prevent the gravel from cementing with ice; they thus form a readily accessible, friable source of gravel for road surfacing and other purposes in both winter and summer. Some of the gravel ridges offer areas of easy movement, although their small extent and lack of continuity limit their usefulness.

e. Swamp and Marsh. Most of the test area can best be described as swamp and marsh. Treeless grassy marsh, often called "muskeg", is found near the Churchill River, in lowlands bordering Hudson Bay, and in poorly drained depressions throughout the test area. The swamp is characteristically dominated by moisture-tolerant trees such as black spruce and tamarack. A soft spongy matting of peat, varying in thickness from two inches to several feet, and composed of partially decayed plants and plant roots, overlies the swamp and marsh soils. This peat, however, is separate from the underlying soil. Free water is usually encountered at the surface and in the upper part of the peat. The moisture content of the peat is very high, ranging from about 350 to 600 percent of the dry weight. Under the peat, soils consist of varying percentages of sand and gravel mixed with silt and clay. In winter, when the swamp and marsh are completely frozen, the major restrictions to overland movement are those caused by irregularities in the hard frozen surface. During summer, however, the ground thaws to a depth of 20 to 40 inches, and muskeg soils will not support vehicular traffic. Even men on foot are likely to find walking difficult. Scattered rocks and boulders constitute another danger for vehicular traffic.

Many shallow lakes and creeks are associated with the marsh and swamp terrain. They rarely exceed 8 feet in depth and many of the smaller ones are less than a foot deep. Lake floors are frequently covered with a uniform layer of rocks and boulders and may be crossed by vehicular traffic. The steep banks inclosing them, however, are difficult to negotiate. In winter, frozen lakes and streams provide a

suitable surface for travel. However, danger of soft or thin ice is always present in crossing water bodies with heavy equipment, especially if deep snow has accumulated before a thick ice cover has formed. In fact, a deep snow cover will usually prevent the formation of thick ice. In the frozen muskeg the numerous hummocks may cause some trouble for travelers.

f. Summary of Terrain Condition. A summary of terrain conditions is given in Table II. The terrain map is given in Figure 3.

4. Vegetation

a. General. Since the area is located within the transition zone between the arctic tundra and the subarctic forest, the vegetation shows pronounced evidence of the severe environment. Trees are few or entirely absent from the more exposed positions and even the lichen-moss cover is thin and composed of relatively few species. All plants exposed to the wind are markedly one-sided in their appearance. The gnarled spruce occasionally found on higher positions, though perhaps more than 100 years old, are short and bent toward the leeward, and their windward sides are completely bare of branches.

Because of the swampy conditions generally associated with a high permafrost table, plants well-adapted to moist or wet conditions tend to dominate. Exceptions to this are the plant communities occupying the low ridges near the coast and the occasional low gravel ridges farther inland.

There are two distinct types of vegetation recognized within the test area: (1) Northern coniferous forest and (2) Tundra or treeless marsh. This division is probably adequate during winter. In summer, the tundra may be subdivided as follows: (a) High tundra - occupying the drier, more exposed ridges and low hills, and for the most part, blanketed by a continuous lichen-moss cover, and (b) Muskeg or low tundra - characteristically a marshland too moist for most trees and dominated by swamp grass, sedge, and water-tolerant shrubs and bushes.

b. Northern Coniferous Forest. The principal species of the coniferous forest are white spruce, black spruce, and tamarack (American larch). White spruce occupies the higher, better drained land and is indicative of the most trafficable ground conditions within the forested area; black spruce, the most prevalent species, usually occurs in poorly drained terrain bordering muskeg or low tundra; tamarack, the least numerous, is most common on moist low ground adjacent to streams. There are considerable differences in density and tree size within the forest. Scattered stands of scrub trees tend to prevail, although thick stands of taller trees are common, especially in areas well-sheltered from the wind. Trees rarely exceed 30 feet in height. Undergrowth consists of dwarf willow and dwarf birch, together with numerous berry bushes,

TABLE II: SUMMARY OF TERRAIN AND SURFACE CONDITIONS IN FORT CHURCHILL TEST AREA

Terrain Types	Elevation	Surface Materials	Vegetation	Remarks
FORESHORE FLATS	Area of tidal inundation (sea level).	Clay and sand with many stones and boulders.	Grasses, sea weed, and low beach plants such as sandwort.	Exposed at low tide, covered with pressure ice in winter.
ROCK OUTCROPS*	25 to 150 feet above sea level.	Hard rock outcrops. Numerous loose surface rocks.	Heath, lichens, and small shrubs.	Moderate slopes but many abrupt surface irregularities. Excellent foundations for construction. Fair trafficability, hampered by rough surface.
GRAVEL RIDGES	25 to 100 feet above sea level.	Gravels prevail. Well-sorted soil materials range from clays to pebbles. Some ridges covered with peat.	Frequently bare, but more often mantled with heath and lichens on top with shrubs and small trees on sides.	Glacial moraines and old marine terraces. Gently undulating relief. Good trafficability.
SWAMP AND MARSH	Sea level to 75 feet above sea level.	Relatively soft mat of partially decayed plant material overlying silty or clayey sands and gravels. Often numerous surface rocks, especially in forested areas.	White spruce, black spruce, tamarack, dwarf birch, alder, willow, Labrador tea, reindeer moss, heath, sedges, mosses, cotton grass, meadow gale, water hemlock, and water parsnip.	Flat, poorly drained. Dotted with numerous lakes. Generally poor trafficability in summer but good in winter. High permafrost table.

*See Figures 42 and 43 in Appendix B.

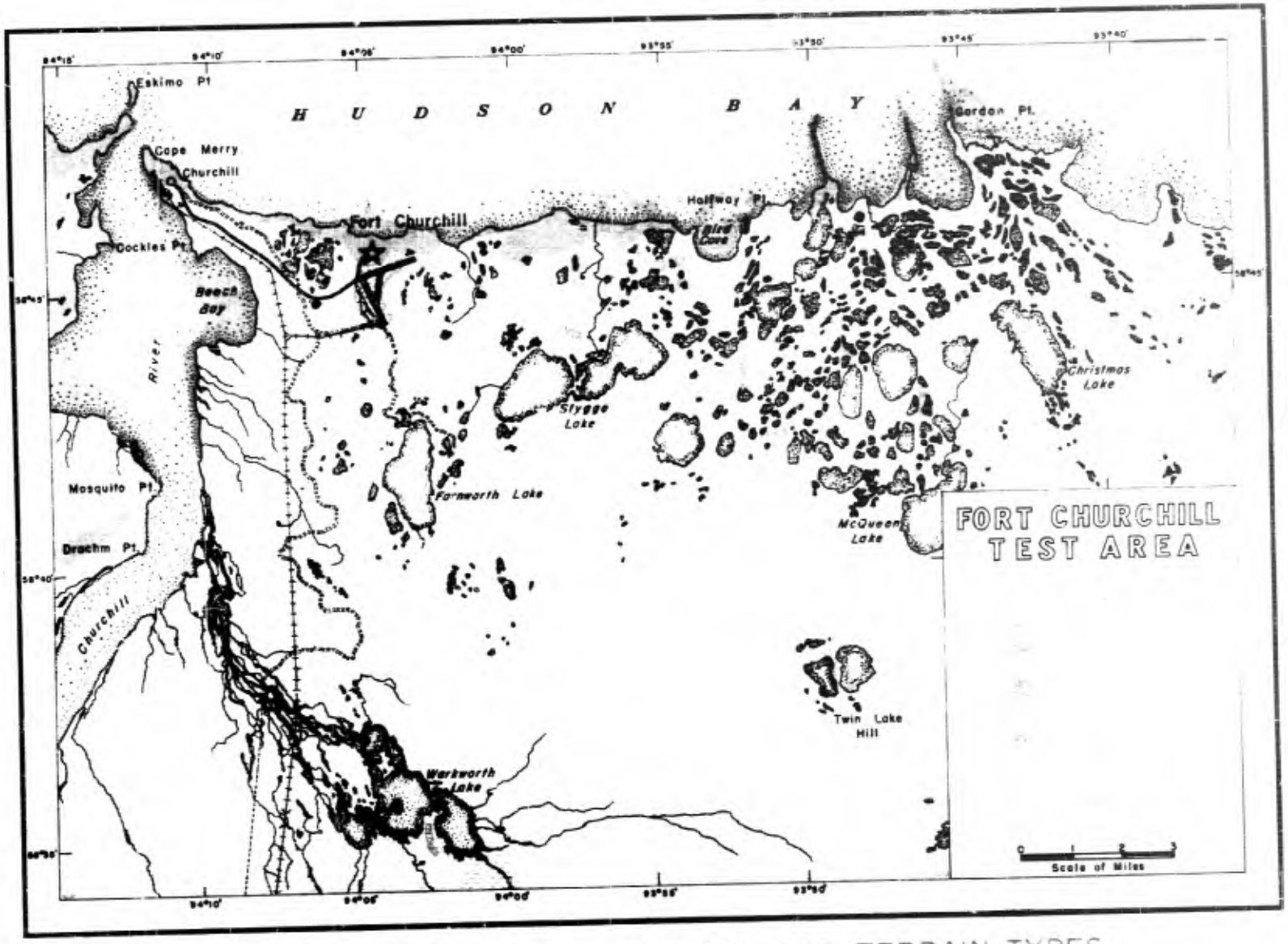


FIGURE 3 FT. CHURCHILL SURFACE AND TERRAIN TYPES

grasses, lichens, and mosses. Mosses are a prominent element in the undergrowth in moist situations, and lichens are more widespread on the drier, better drained soils.

One of the outstanding characteristics of this marginal northern forest is its lack of uniformity. Not only are there considerable differences in tree size and form but also numerous breaks in the continuity of the forest. Lines of high tundra appear atop the exposed low ridges, and patches of grassy muskeg frequently interrupt the forest stand in poorly-drained depressions.

Trafficability is fairly good in all forested areas in dry weather but low areas may be badly waterlogged in rainy periods. Willow and alder thickets bordering water bodies are difficult to penetrate at all times.

c. Tundra or Treeless Marsh

(1) High tundra. The high tundra occupies better drained exposures on the hard rock ridges along the coast and the gravel ridges scattered throughout the area. Reindeer moss (a lichen) dominates the plant cover which includes a number of grasses, herbs, low shrubs, and flowering plants (saxifrage, vetches, and heather). Rock outcrops are usually covered with rock lichens and are surrounded by small shrubs, principally cranberry. On the more exposed ridges the lichen cover is thin and there are fewer flowering plants. A very scanty and widely scattered bush and tree growth is present, composed principally of dwarf birch, and, in moist situations, clusters of willow.

(2) Low tundra or muskeg. Muskeg occupies most of the surface of the test area. Its composition differs greatly from the high tundra and the physical conditions which govern plant growth are also quite different.

Muskeg, occupying poorly-drained surfaces, is very common throughout the forested area. Generally, such areas are hummocky and waterlogged much of the time. The dominant vegetation is swamp grass with a considerable admixture of dwarf willow and dwarf birch. Other common plants are alder, Labrador tea, bog bilberry, black crowberry, cotton grass, mosses, and marsh marigold. In many areas black spruce and tamarack grow, very stunted in form and seldom exceeding eight to ten feet in height.

Trafficability is generally poor in the muskeg. Thickets of willow bordering streams, lakes, and ponds constitute one of the obstacles to traffic in all seasons.

d. Strand. Strand vegetation occupies large parts of the zone of tidal inundation, which is most extensive in Churchill Bay and along the beach to the east of Gordon Point. Sandwort and blooming yarrow

cover the narrow belt of sand and gravel beach above the reach of the tides.

e. Classification of Vegetation. Table II gives a classification of vegetation in the test area. Figure 4 gives a vegetation map of the area.

5. Insects

Insects constitute a serious problem during summer. At least 17 species of mosquitoes have been reported within the test area. Mosquito larvae begin hatching at the end of May, pupate in mid-June, and usually emerge as full grown mosquitoes in late June. They are a serious pest from early June to mid-July, then gradually decrease in number, disappearing almost completely with the first killing frost. Arctic mosquitoes are not known to be transmitters of malaria, yellow fever, or other diseases commonly transmitted by mosquitoes in warmer climates. They are found in all parts of the test area but are more numerous in damp, poorly drained forest situations. Camps located on slopes freely exposed to coastal winds tend to be less affected since mosquito activity decreases with wind speeds exceeding 3 mph. Activity also decreases when temperatures fall below 45°F. In addition to mosquitoes, black flies and deer flies are widespread pests. Black flies, which appear about the first of July, breed in great numbers in swift flowing streams, and are far less common in open tundra than in forest regions. Deer flies bite less frequently than mosquitoes and black flies, but their bite is especially severe, causing the affected area of the skin to swell and itch. They appear to be more common in or near the forest.

6. Summary

Climatic conditions suitable for cold-weather testing occur throughout the long winter season at Fort Churchill, Manitoba, Canada. Low temperature, the governing climatic control for arctic testing, strong winds, drifting and blowing snow prevail in winter. Mean monthly temperatures range from -19°F in January to 54°F in July. Daily extremes below -25°F may be expected on at least half of all days in January and February, and below-freezing temperatures may be expected on all days from November through April. Precipitation is light, averaging less than 15 inches per year, and is concentrated chiefly in the period from June to October. Winter precipitation is almost entirely in the form of snow, which though small in amount, remains on the ground from October until May. Exposed surfaces are swept bare of snow by strong winds, deep drifts accumulate in sheltered places, and deep soft snow gathers beneath the stunted trees and about the shrubs and bushes. Winds, predominantly from the northwest, are strong throughout the year.

Except for small coastal rock outcrops and a few small gravel ridges, the test area is a flat, marshy plain. The thin acid soils are generally covered with a thick, partially decayed layer of peat. In summer the area is essentially a lake-dotted bog, which may be crossed with difficulty. In winter, when the ground and the surface water bodies are

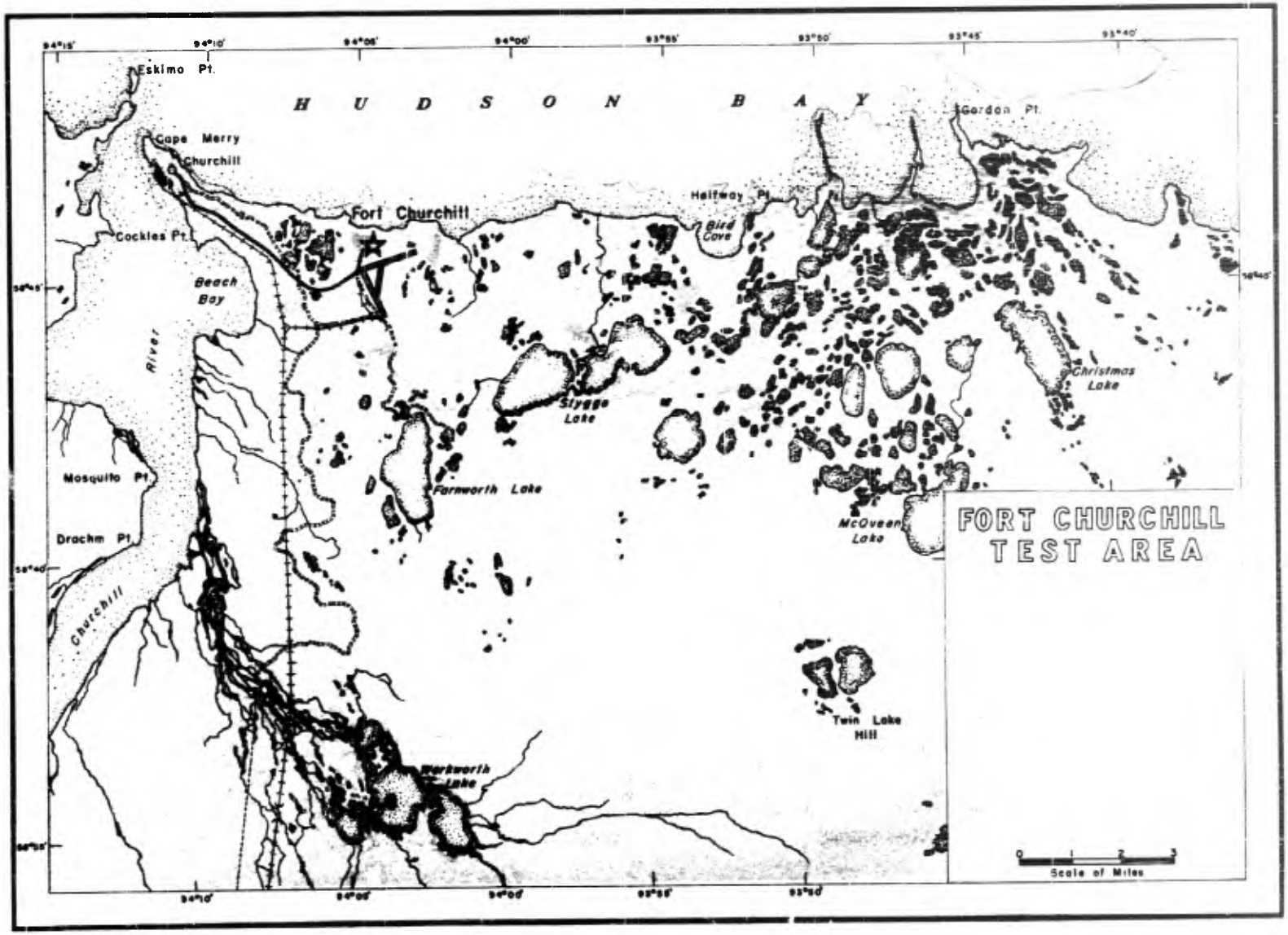


FIGURE 4 FT CHURCHILL VEGETATION

TABLE III: CLASSIFICATION OF VEGETATION WITHIN THE PORT CHURCHILL TEST AREA

General Type	Habitat	Principal Species	Vegetation	Seasonal Color Change	Remarks
NORTHERN CONIFEROUS FOREST*	Terrain flat to gently undulating. Poorly decayed peaty layer overlies soils varying from well-drained sands and gravels to heavy clays or silts in early stages of waterlogging.	White spruce, reindeer moss, rock and other lichens, heath plants, dwarf birch, Labrador tea and grass on drier soils. Black spruce, tamarack, dwarf birch, willow, sedge, cotton grass, meadow gale, mosses, water hemlock and water parsnip on wetter soils.	Scattered scrub growth, 8 to 10 feet high. Occasional thick stands of taller trees up to 30 feet high. Undergrowth forms a thick cover in most places. Tree trunks seldom greater than 5 inches in diameter. Forest continuity often broken by high tundra and treeless marsh.	Summer forest is mottled green dominated by dark green of spruce. In open and better drained parts lichens ranging from light gray-green to brown brighten the tone of the forest; in moist situations dark green mosses cover the forest floor and blend with tree colors. Forest is usually open type with better visibility than is true of forests farther south. In winter, the forest centers are dark green on white with frequent patches of brown stemmed shrubs projecting above snow surface. But from ground level and at fairly close quarters the gray-green of shrub trunks studded with lichens predominates at the edge of forest areas. Tamarack adds another shade of brown to the winter landscape.	White spruce common in uplands; black spruce dominates in lowlands. Tamarack, scattered throughout, is most common near streams and lakes. Trafficability best within white spruce forest. Willow thickets adjacent to streams and lakes constitute one problem for transportation.
TUNDRA AND TREELESS MARSH (1) HIGH TUNDRA**	Well drained soils. Thin peat layer occupies rock ridges along coast, gravel ridges in the forest zone, and better drained terrain north of the forest area.	Low growing plants are prevalent and include dominant reindeer moss, rock lichens, saxifrage, vetches, numerous heaths, grasses and other herbs. Dwarf birch, willow, and alder are scattered throughout and stunted white spruce occur in well protected places.	Reindeer moss and other lichens form a fairly continuous carpet. Heather appears in dense clumps. Dwarf birch and other shrubs are widely scattered. Occasional alder and willow thickets at lake and stream margins. Most woody growth is less than 3 feet tall. Willows near water may reach 5 feet.	In summer, reindeer mosses are several shades of gray, green, and brown lighter in tone than other vegetation types. Interspersed with green flowering plants and green shrubs these present a mottled appearance. Flowers are in abundance during short summer. Brown tone dominates in fall. Winter is dominated by snow with clumps of brown stemmed bushes and shrubs projecting above.	Reindeer moss and rock lichens dominate more exposed ridges. Dwarf birches and shrubs occur on less exposed positions; willow and alder common near water. Generally good trafficability but willow and alder thickets at stream margins are often difficult to penetrate.
(2) LOW TUNDRA***	Occupies depressions and flats north of the forest zone and appears as islands in the forest. Soils generally waterlogged and overlain by thick layer of peat.	Low plants prevail: grasses, mosses, cotton grass, sedge, water hemlock, water parsnip, marsh marigold and other herbs. Bush growth of dwarf birch alder, and willow. Shrubs include meadow gale, bog bilberry, crowberry, and Labrador tea. Infrequent black spruce and tamarack.	Dwarf tree and shrub growth less than 5 feet tall. Often in thickets. Tallest and densest are willows at water margins. A thick dense moss, grass, and herbaceous layer covers all areas.	Mottled green appearance in summer with darker shades prevailing. Grasses and sedges and most mosses are dark. Shrubs have many shades of green. Cotton grass blooms in July giving landscape appearance of a cotton patch. Many flowering plants add color to the countryside in summer. In winter, land is largely snow-covered with higher bushes projecting above. Scattered spruce stand out as dots of green.	Most areas are hummocky and waterlogged much of the time. Dominant vegetation is swamp grass. Thick peat layer rests over a high permafrost table. Summer trafficability generally poor.
STRAND	Tidal flats and sand gravel beaches.	Strand grass, seaweed, sandwort and yarrow.	Scattered tufts of lush grass. Sandwort in patches along with common yarrow.	Snow and ice-covered in winter. Mottled green in summer.	Grass and seaweed in tidal flat. Sandwort and yarrow above tidal flow.

*See Figure 44, Appendix B
**See Figures 46 and 47, Appendix B
***See Figure 45, Appendix B

frozen, movement is restricted by surface rocks and trees and bushes.

Located within the transition zone between forest and tundra, the Fort Churchill test area exhibits many features of each. Low tundra prevails on well-drained situations north of the forest zone and on exposed ridges within the forest. A grass marsh, often referred to as muskeg, occupies poorly drained sites throughout the test area. Such bogs are most difficult to cross in summer. Trees are stunted in form and rather widely dispersed. The fringe forest begins some distance south of the base station and covers the southern two-thirds of the test area. It is frequently interrupted by grass marsh at low elevations and by high tundra along the exposed ridge tops.

Insects abound during the short summer period, reaching their greatest activity early in July. The worst pests are mosquitoes and black flies.

7. Acknowledgments

Appreciation is expressed to Sir Hubert Wilkins and Mr. Sigmund J. Falkowski for their aid in preparing this report; to Miss Gertrude Barry, Mrs. Anna Richmond and Mr. Donald Cox for their advice and aid in preparing graphs and maps; to Mr. Thomas Dee for providing supplementary information regarding test activities, for aid during field investigations, and for checking and confirming the identification of certain rock outcrops along the coast of Hudson Bay; and to Mr. Louis Moore, who took all photographs used.

Winter field studies in the Fort Churchill area were made possible through the cooperation of the First Arctic Test Detachment, United States Army.

8. Bibliography and Aerial Photography Coverage

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b. Aerial Photography Coverage

RCAF, 1946; Approx. 1:100,000; Code #All022. (Mosaic of northern portion of test area).

USAAF, May 1943; Approx. 1:200,000; Code #1-2050. (Trimetrogon east-west coastal strip and northeast-southwest cross section).

APPENDIX A

CLIMATIC DATA

SOURCE OF DATA

Climatic data used were obtained from Air Weather Service, US Army Air Force; Air Services Meteorological Division, Department of Transport, Toronto; the files of the Environmental Protection Division, Quartermaster Research and Development Command, Natick; and certain basic articles included in the bibliography. Many of the findings presented are derived from data accumulated over a relatively short period of time. Length of record is shown on all graphs and tables and should be considered by personnel using the handbook as a guide to the reliability of the data presented. It is believed that this information, when used in conjunction with the tables and maps of vegetation and terrain and ground conditions will provide valuable information to personnel concerned with planning test programs.

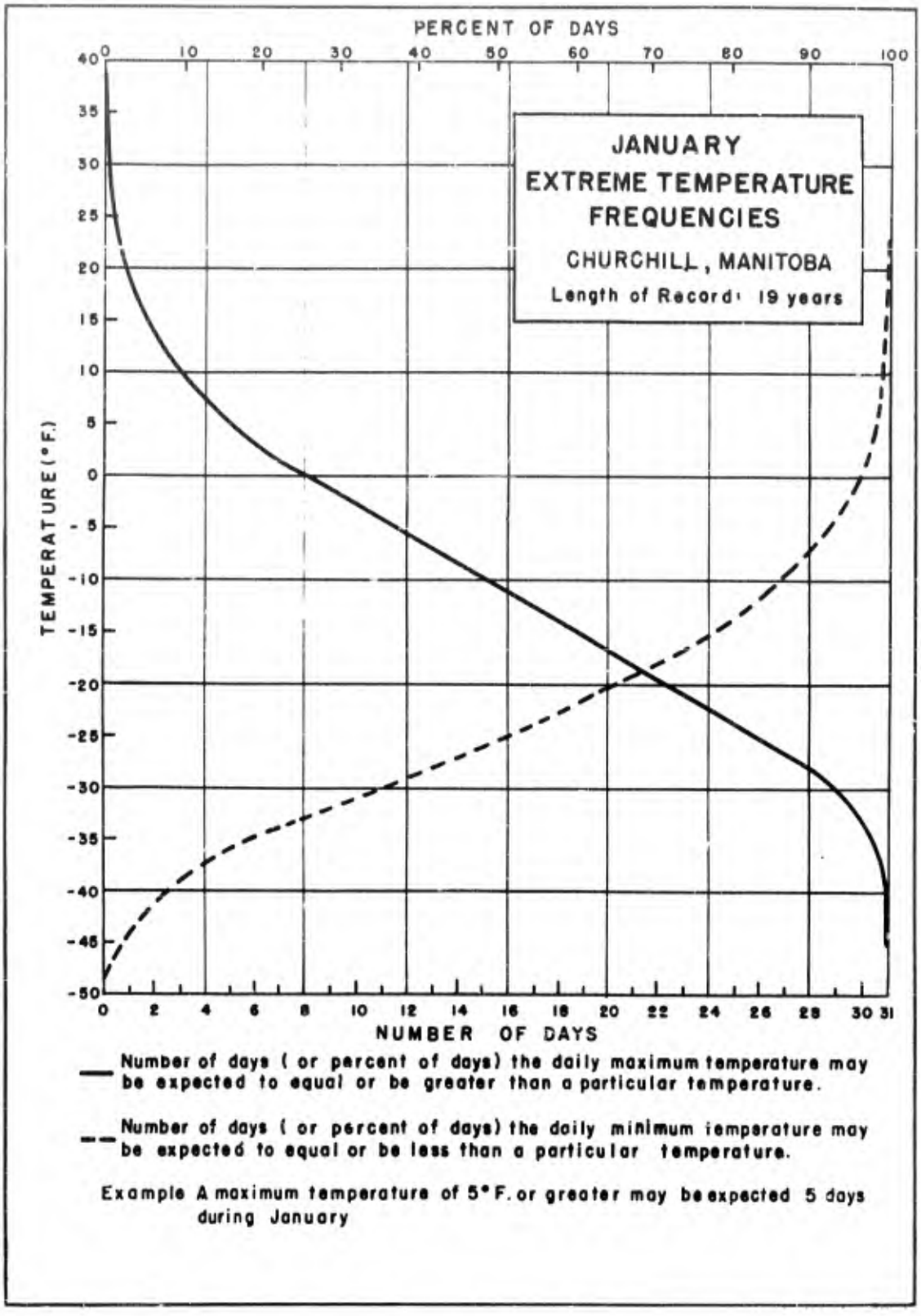
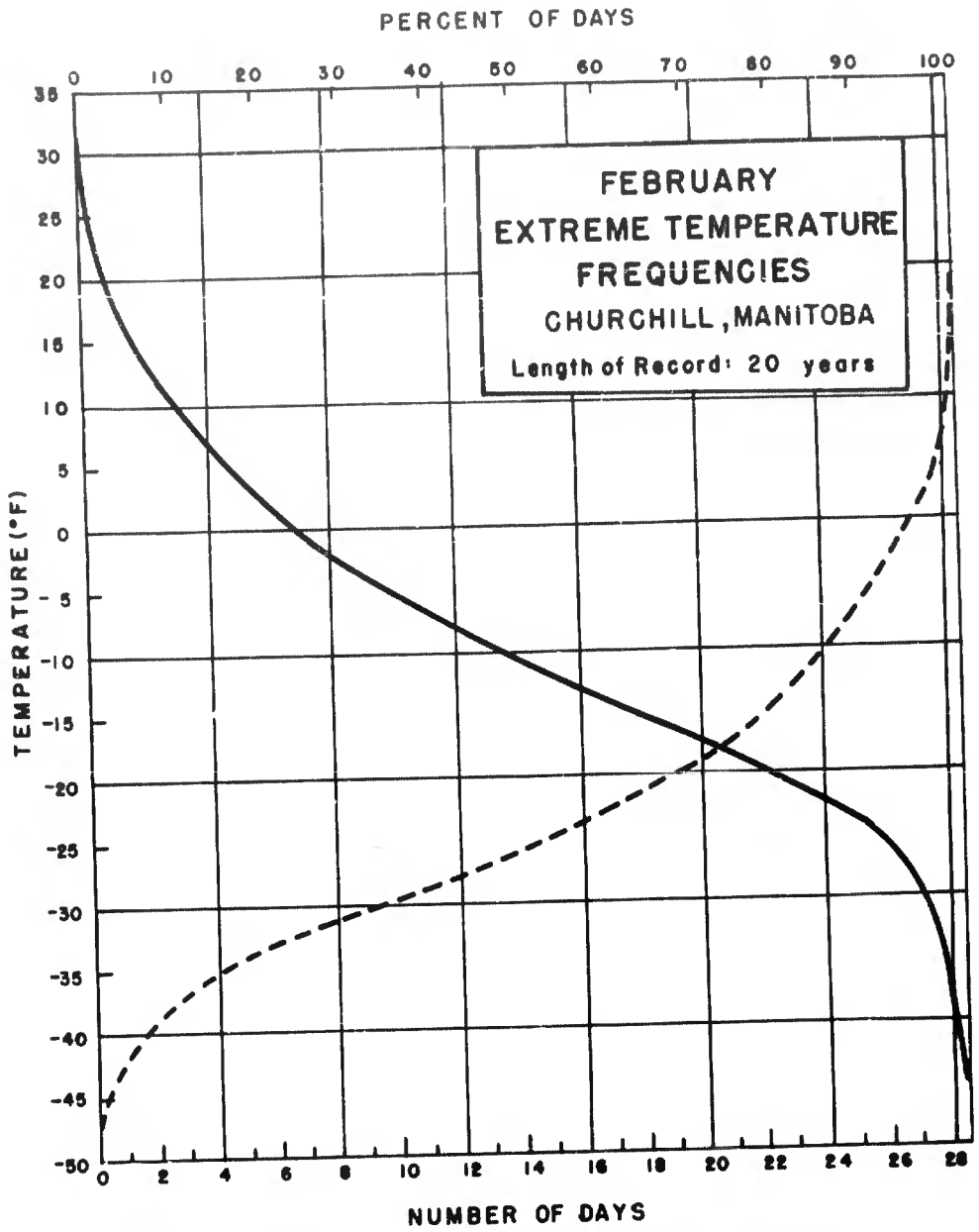

PERCENT OF DAYS
0 10 20 30 40 50 60 70 80 90 100
40 35 30 25 20 15 10 5 0 -5 -10 -15 -20 -25 -30 -35 -40 -45 -50
TEMPERATURE (°F.)
JANUARY
EXTREME TEMPERATURE
FREQUENCIES
CHURCHILL, MANITOBA
Length of Record: 19 years
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 31
NUMBER OF DAYS
Number of days (or percent of days) the daily maximum temperature may be expected to equal or be greater than a particular temperature.
Number of days (or percent of days) the daily minimum temperature may be expected to equal or be less than a particular temperature.
Example A maximum temperature of 5° F. or greater may be expected 5 days during January

Figure 5



—— Number of days (or percent of days) the daily maximum temperature may be expected to equal or be greater than a particular temperature.

– – Number of days (or percent of days) the daily minimum temperature may be expected to equal or be less than a particular temperature.

Example: A maximum temperature of -5°F. or greater may be expected 10 days during February.

Figure 6

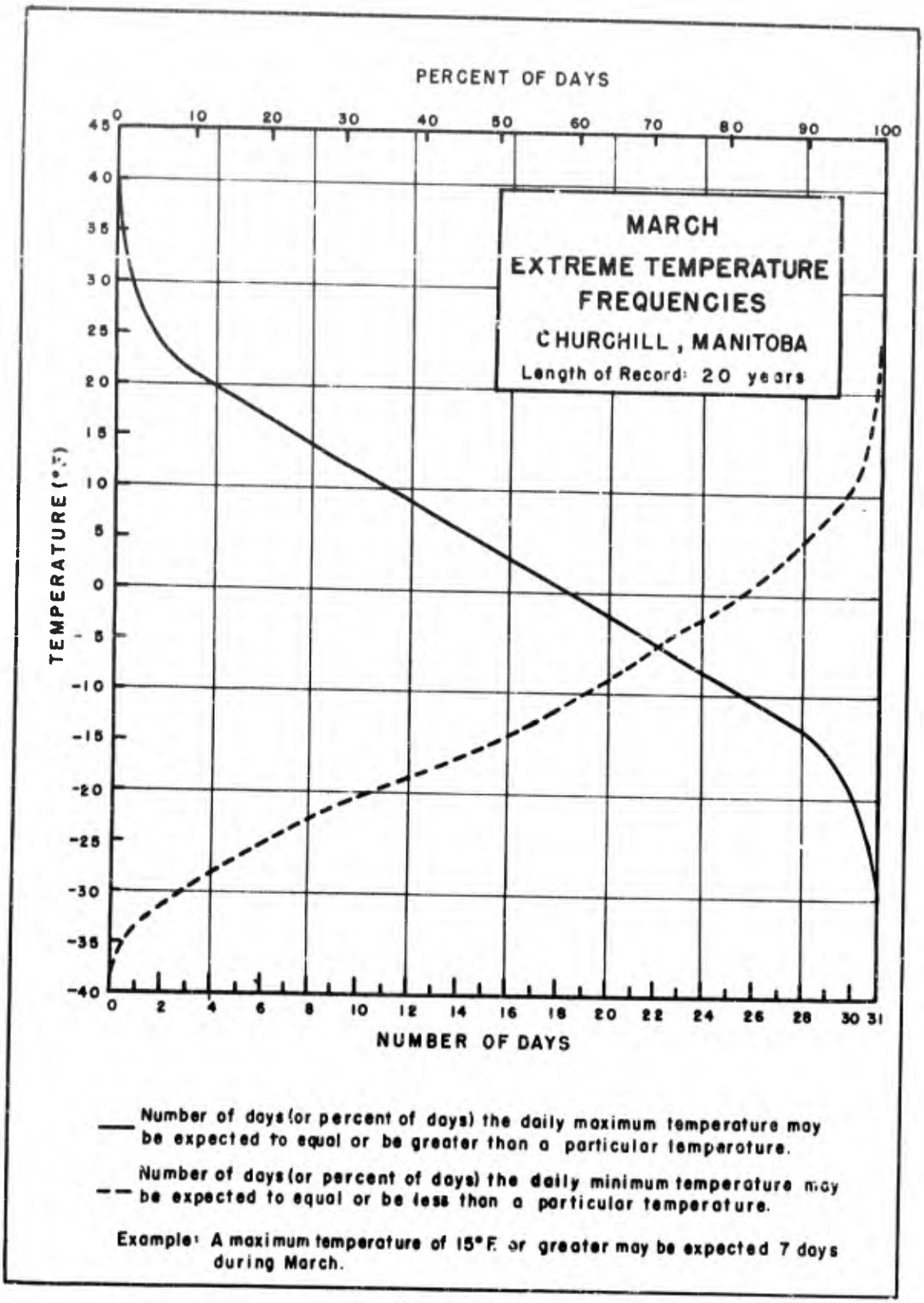
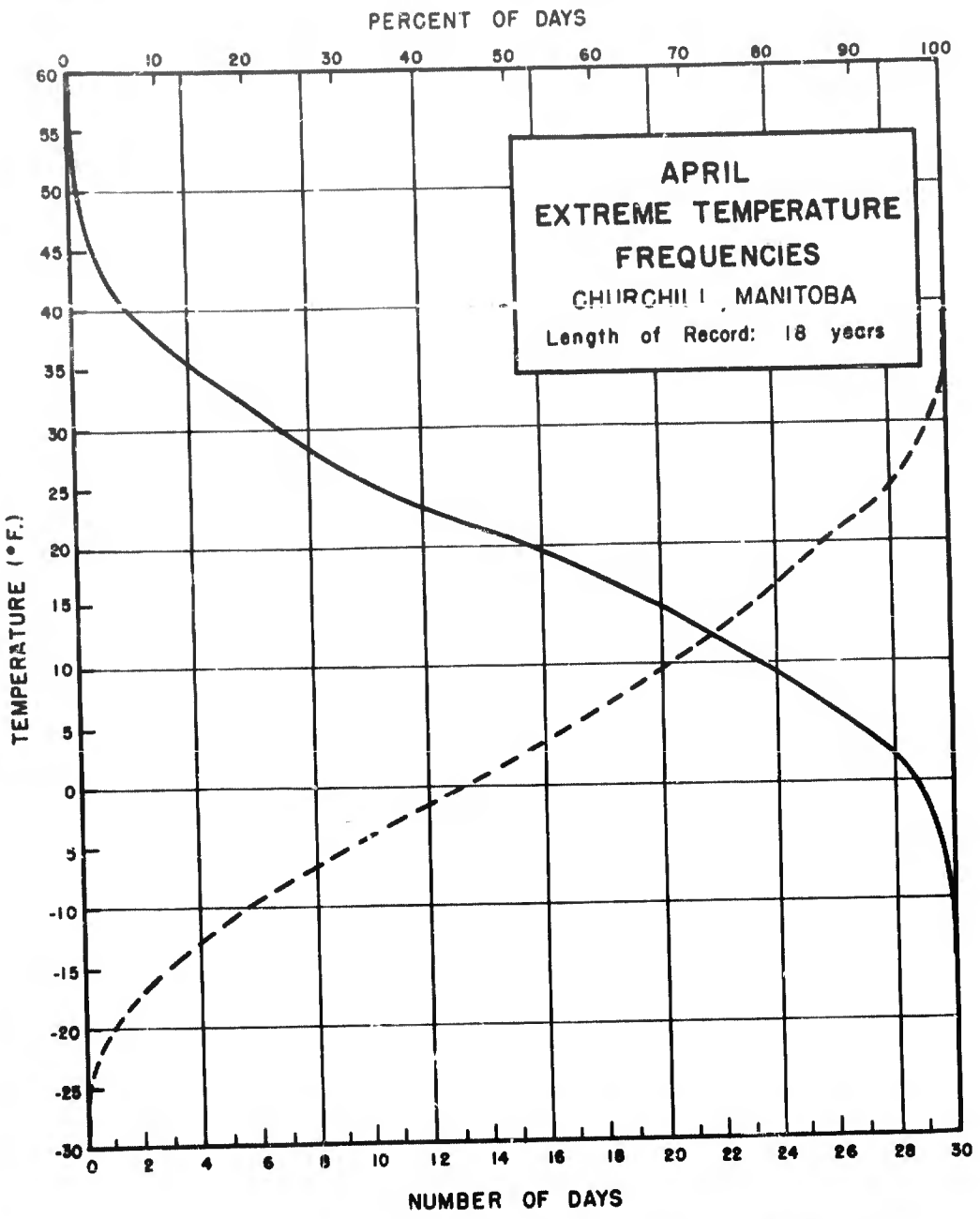

PERCENT OF DAYS
0 10 20 30 40 50 60 70 80 90 100
MARCH
EXTREME TEMPERATURE
FREQUENCIES
CHURCHILL, MANITOBA
Length of Record: 20 years
TEMPERATURE (°F)
45 40 35 30 25 20 15 10 5 0 -5 -10 -15 -20 -25 -30 -35 -40
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 31
NUMBER OF DAYS
Number of days (or percent of days) the daily maximum temperature may be expected to equal or be greater than a particular temperature.
Number of days (or percent of days) the daily minimum temperature may be expected to equal or be less than a particular temperature.
Example: A maximum temperature of 15°F or greater may be expected 7 days during March.

Figure 7

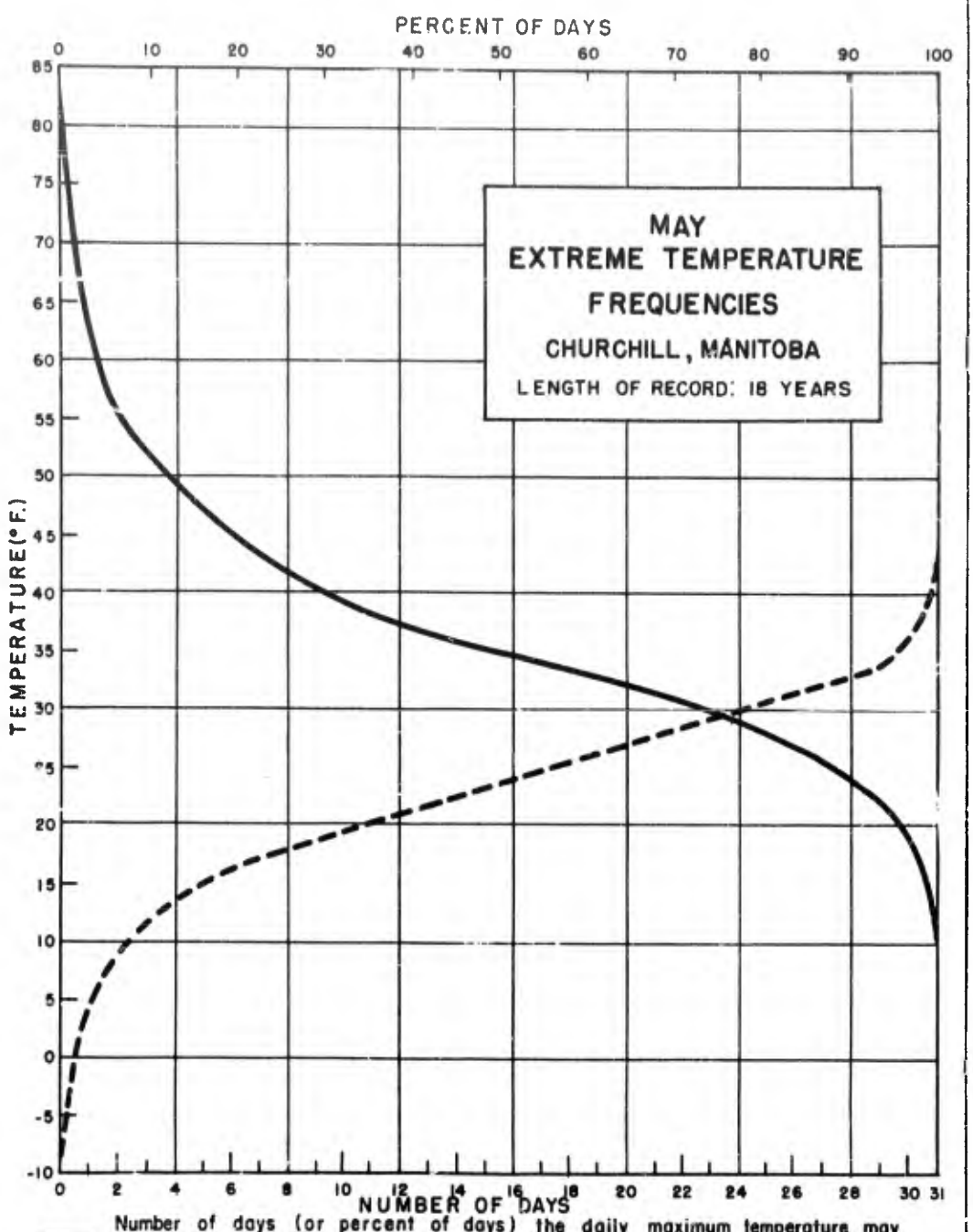


—— Number of days (or percent of days) the daily maximum temperature may be expected to equal or be greater than a particular temperature.

– – Number of days (or percent of days) the daily minimum temperature may be expected to equal or be less than a particular temperature.

Example: A maximum temperature of 30° F. or greater may expected 7 days during April.

Figure 8

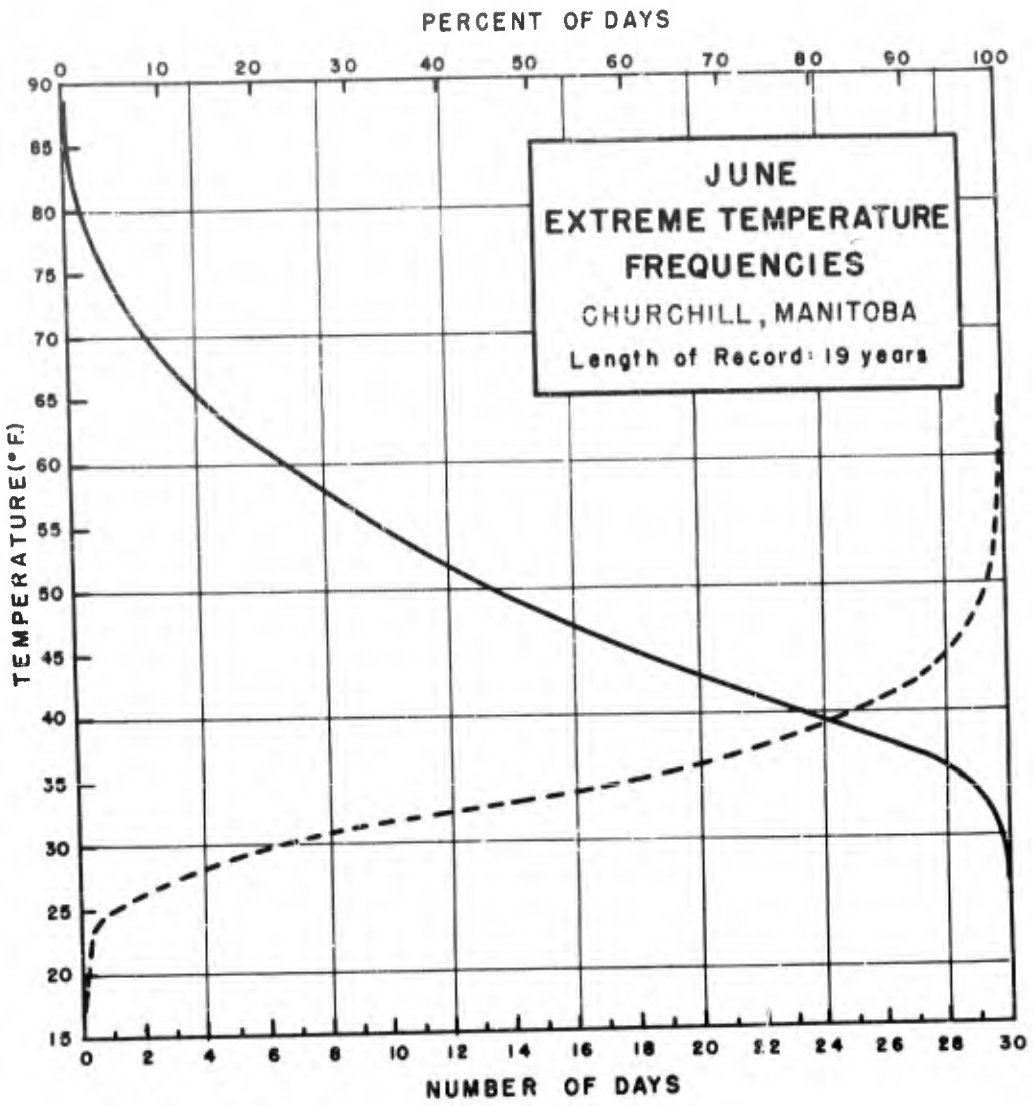


—— Number of days (or percent of days) the daily maximum temperature may be expected to equal or be greater then a particular temperature.

— — Number of days (or percent of days) the daily minimum temperature may be expected to equal or be less ther a particular temperature.

Example: A maximum temperature of 35°F. or greater may be expected 15 days during May.

Figure 9

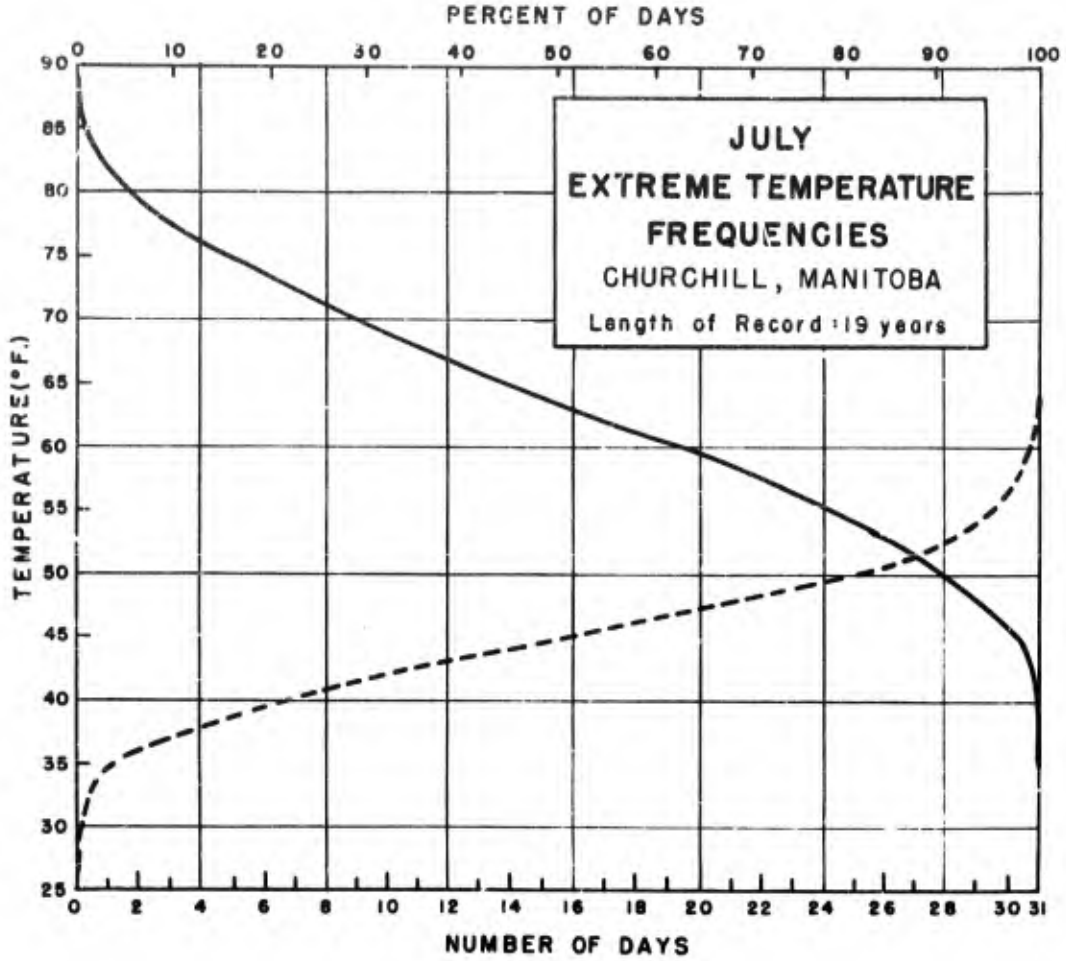


—— Number of days (or percent of days) the daily maximum temperature may be expected to equal or be greater than a particular temperature.

– – Number of days (or percent of days) the daily minimum temperature may be expected to equal or be less than a particular temperature.

Example: A maximum temperature of 45°F or greater may be expected 17.5 days during June.

Figure 10

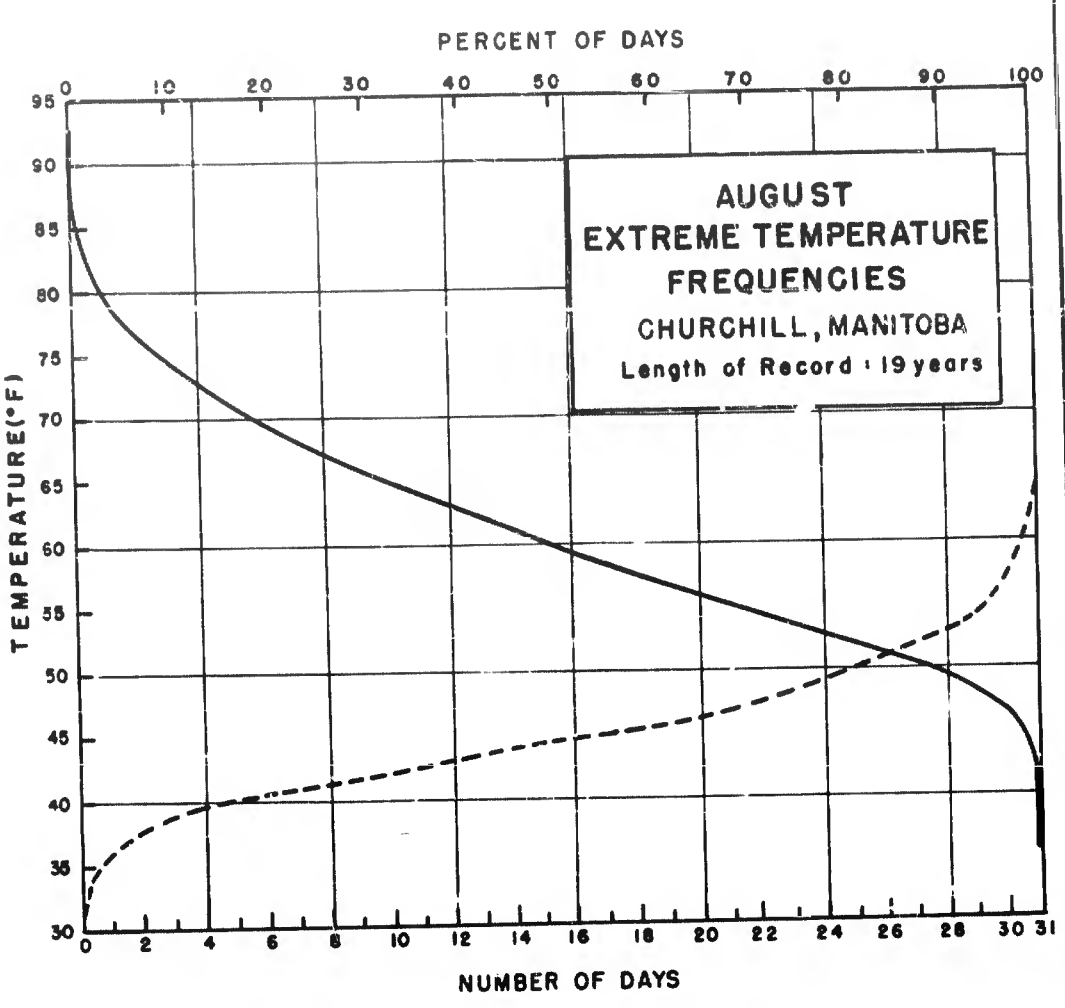


—— Number of days (or percent of days) the daily maximum temperature may be expected to equal or be greater than a particular temperature.

– – Number of days (or percent of days) the daily minimum temperature may be expected to equal or be less than a particular temperature.

Example: A maximum temperature of 70°F. or greater may be expected 9 days during July.

Figure 11

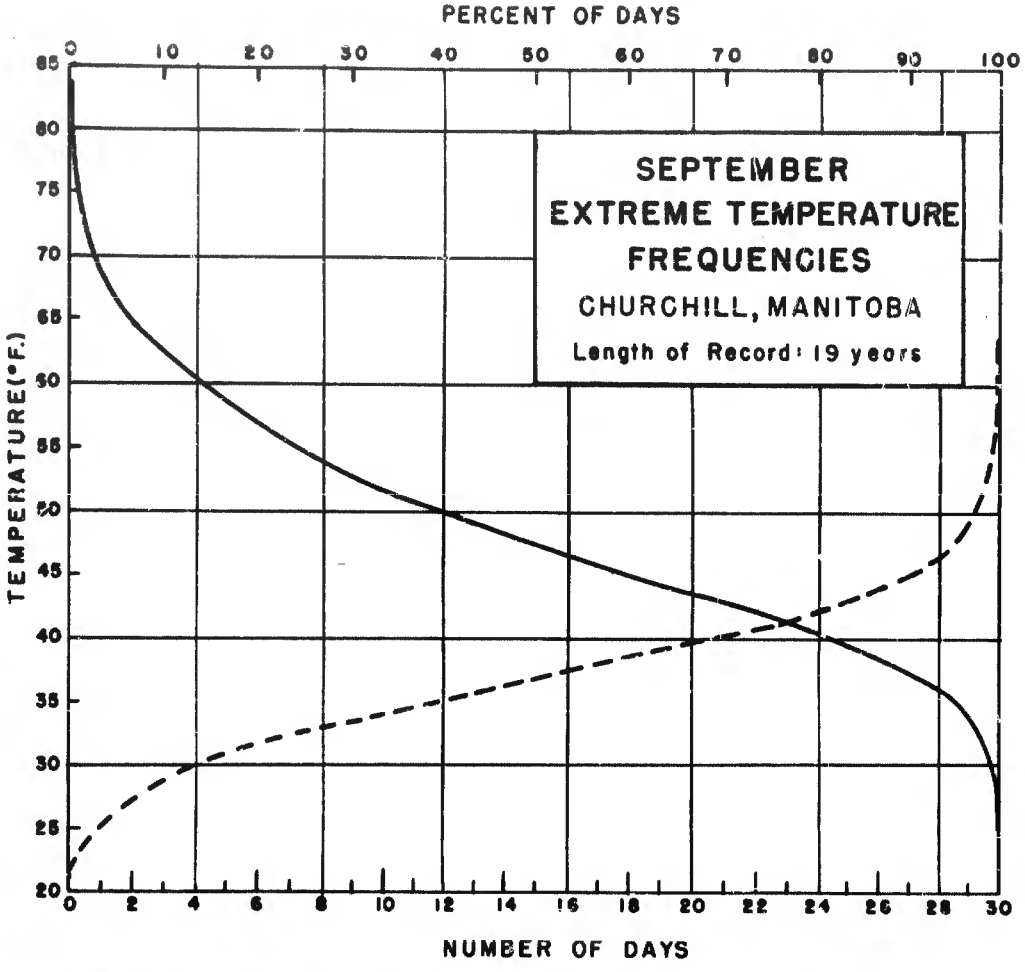


—— Number of days (or percent of days) the daily maximum temperature may be expected to equal or be greater than a particular temperature.

– – Number of days(or percent of days) the daily minimum temperature may be expected to equal or be less than a particular temperature.

Example: A maximum temperature of 65° F or greater may be expected 10 days during August.

Figure 12

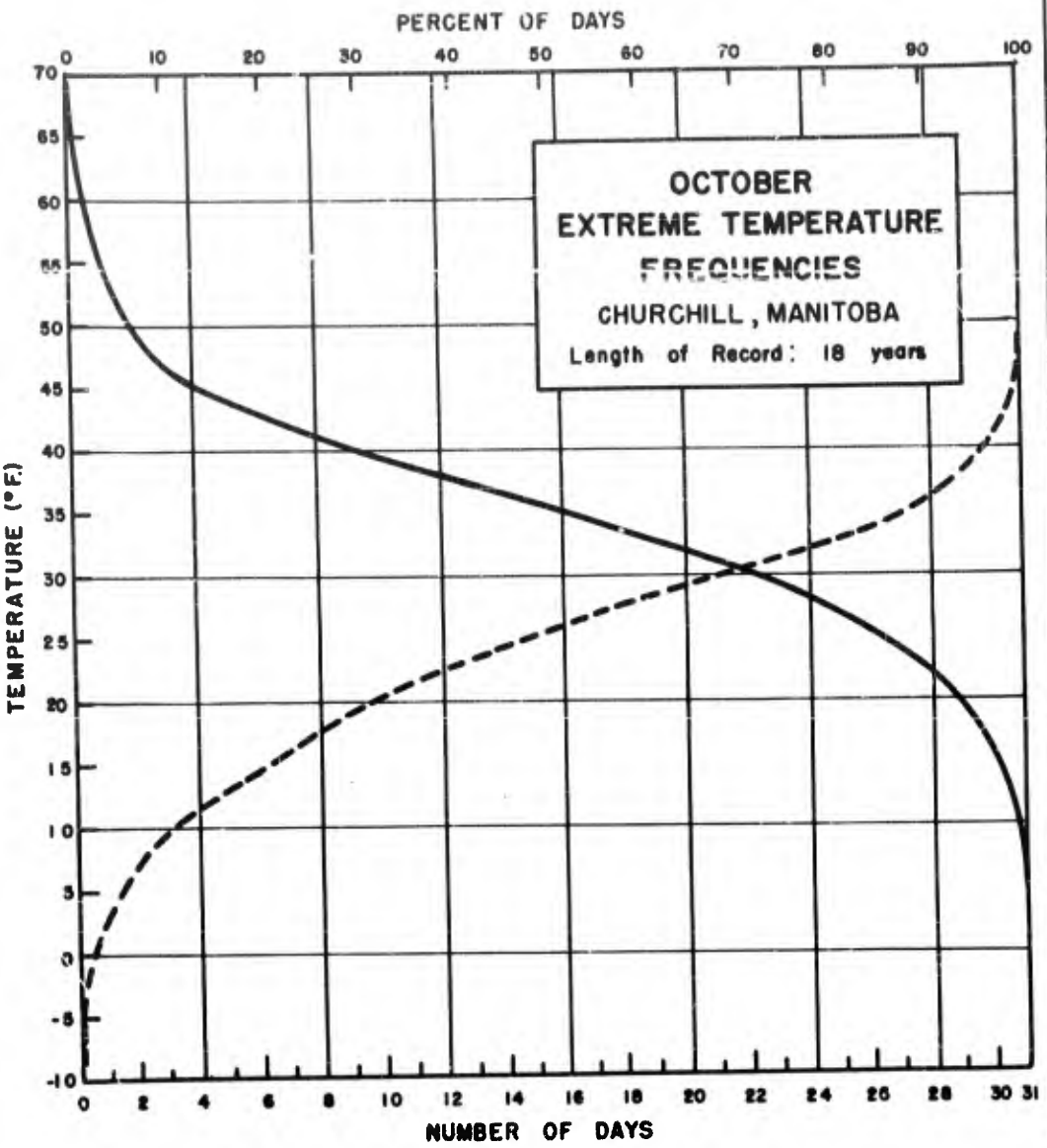


—— Number of days (or percent of days) the daily maximum temperature may be expected to equal or be greater than a particular temperature.

– – Number of days (or percent of days) the daily minimum temperature may be expected to equal or be less than a particular temperature.

Example: A maximum temperature of 60°F. or greater may be expected 4 days during September.

Figure 13

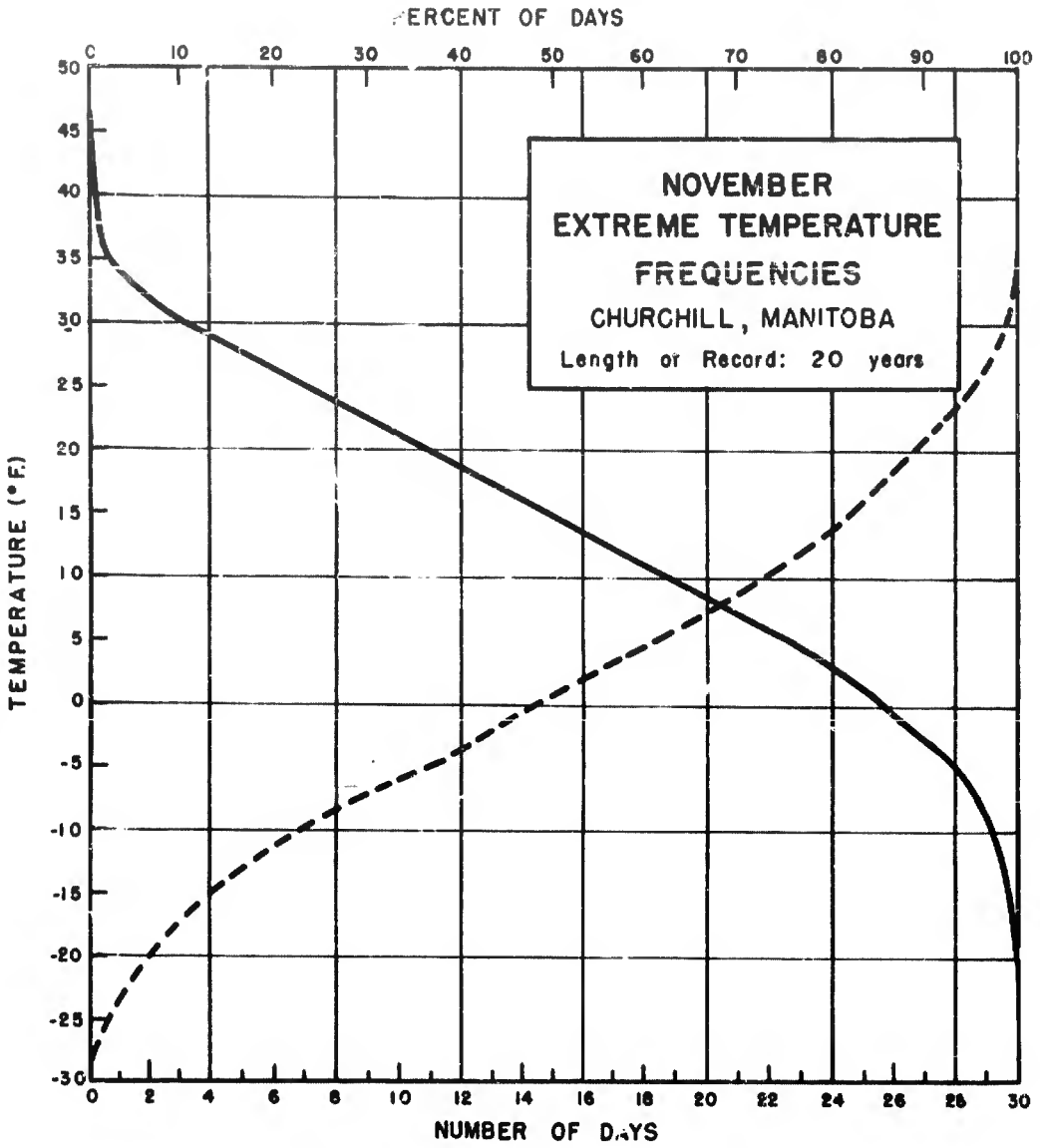


—— Number of days (or percent of days) the daily maximum temperature may be expected to equal or be greater then a particular temperature.

– – Number of days (or percent of days) the daily minimum temperature may be expected to equal or be less then a particular temperature.

Example: A maximum temperature of 30° F. or greater may be expected 22 days during October.

Figure 14

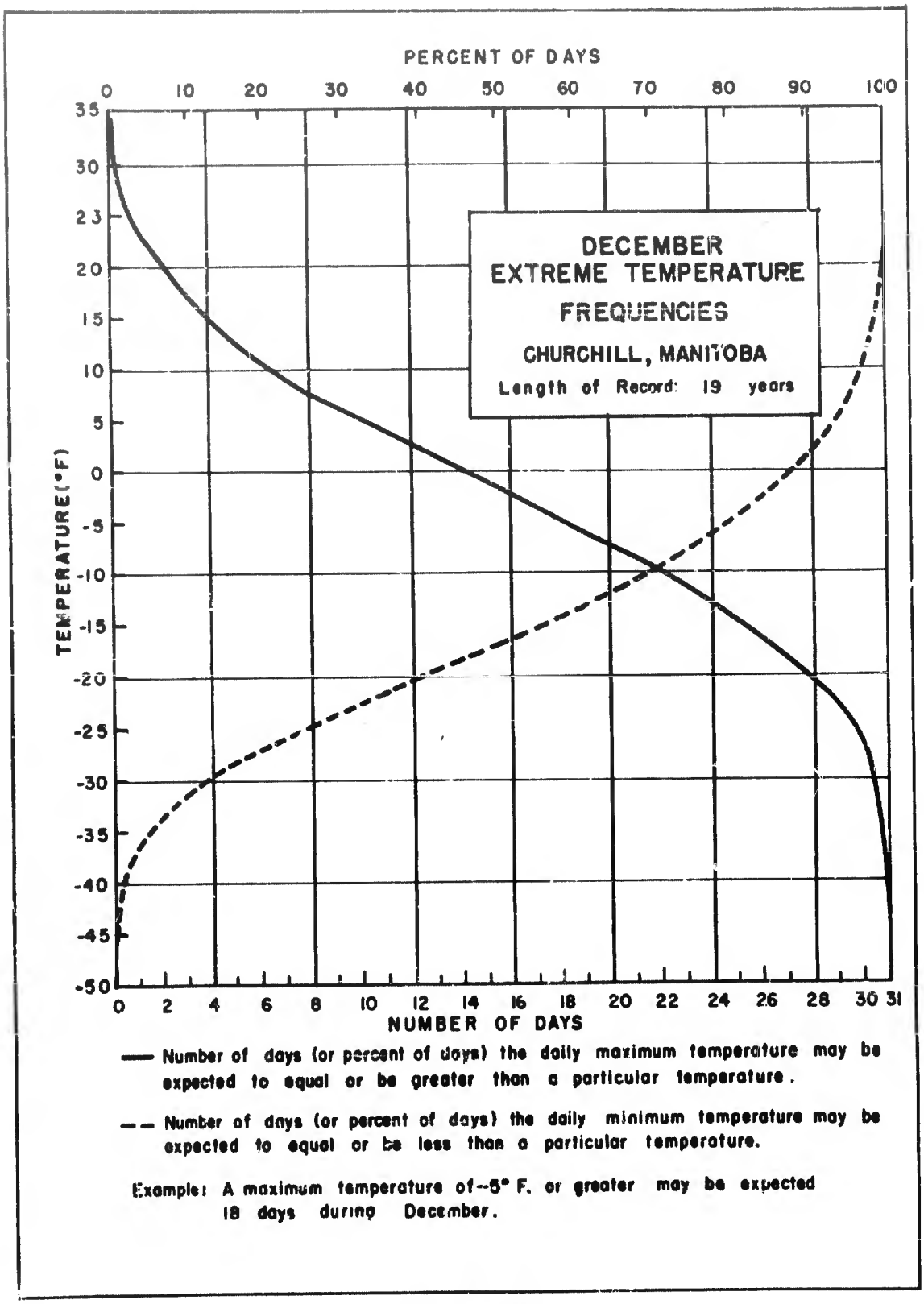


—— Number of days (or percent of days) the daily maximum temperature may be expected to equal or be greater than a particular temperature.

– – Number of days (or percent of days) the daily minimum temperature may be expected to equal or be less than a particular temperature.

Example: A maximum temperature of 25° F. or greater may be expected 7 days during November.

Figure 15



—— Number of days (or percent of days) the daily maximum temperature may be expected to equal or be greater than a particular temperature.

– – Number of days (or percent of days) the daily minimum temperature may be expected to equal or be less than a particular temperature.

Example: A maximum temperature of -5° F. or greater may be expected 18 days during December.

Figure 16

TEMPERATURE REGIME

CHURCHILL, MANITOBA

Length of Record: 30 years

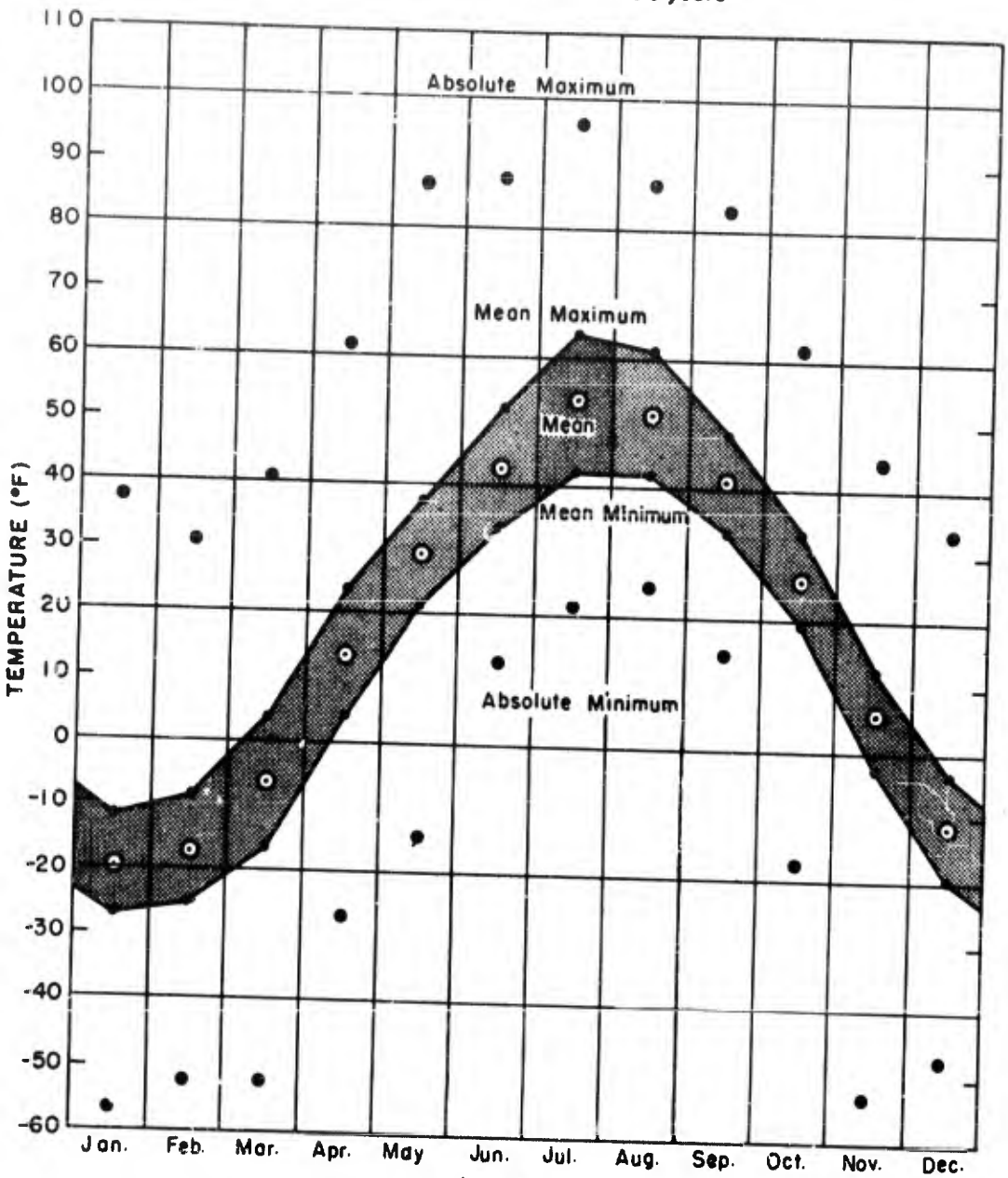
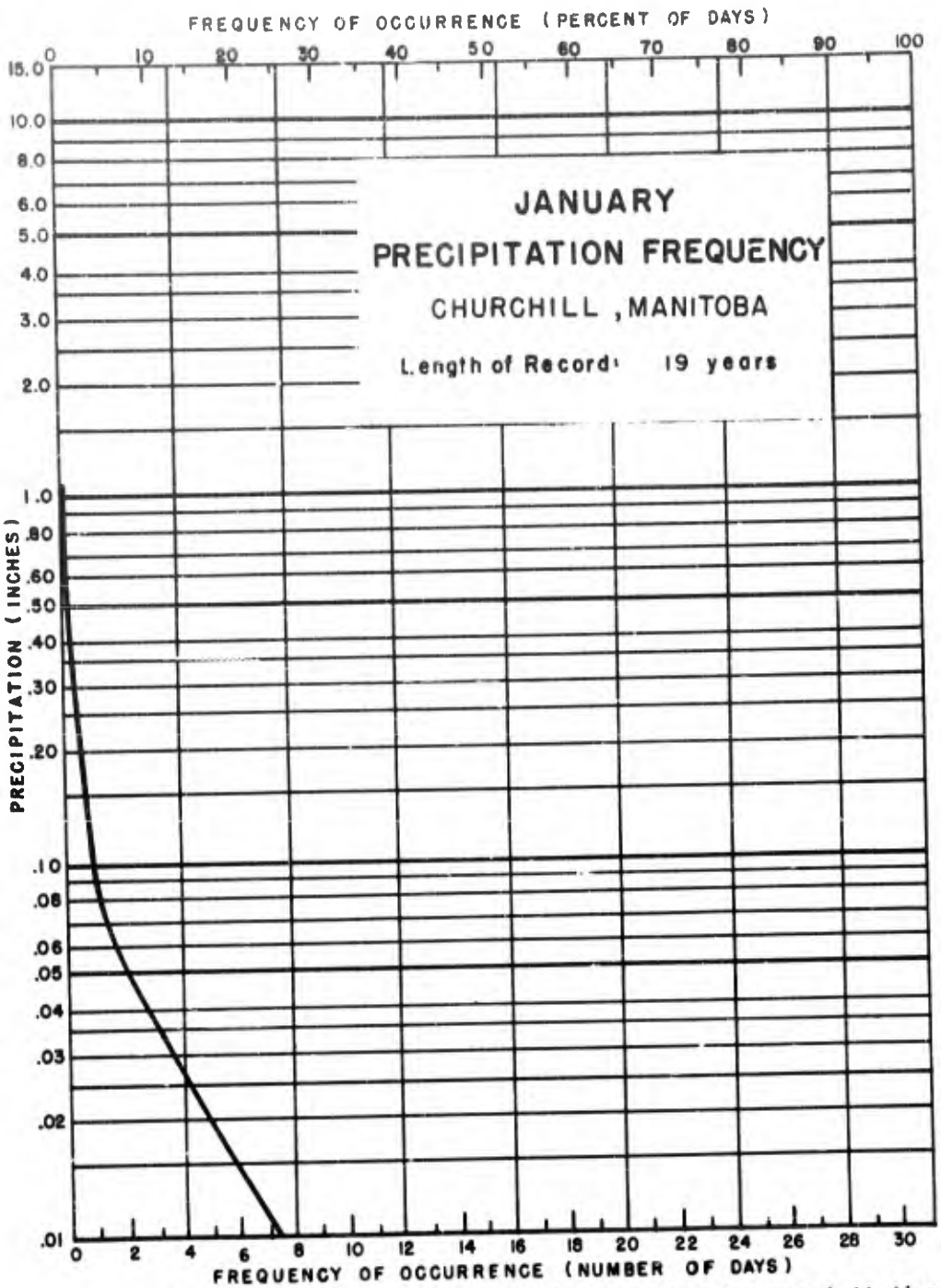


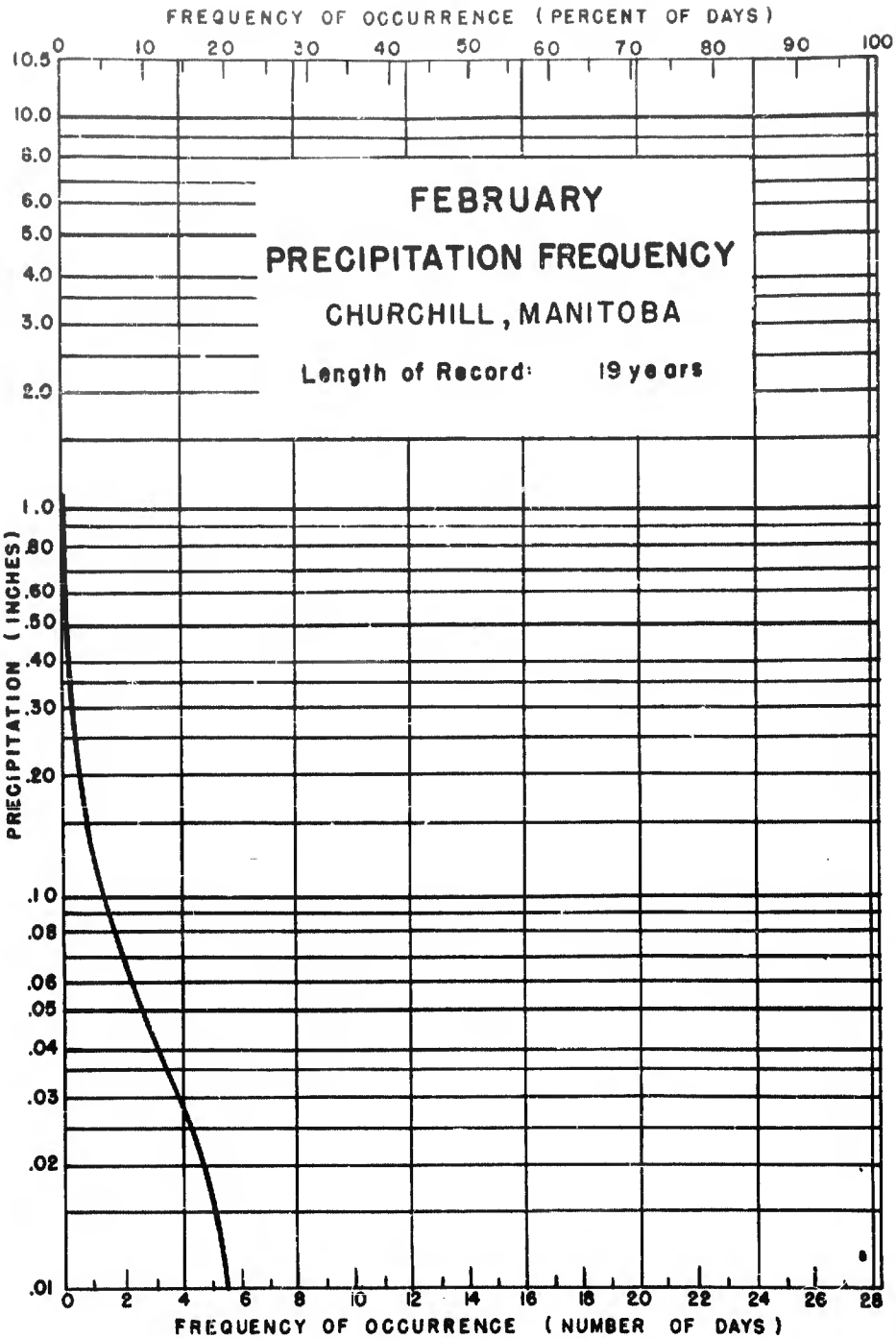
Figure 17



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.02 inches or more precipitation may be expected to occur 5 days during January (or approximately 16 percent of the days).

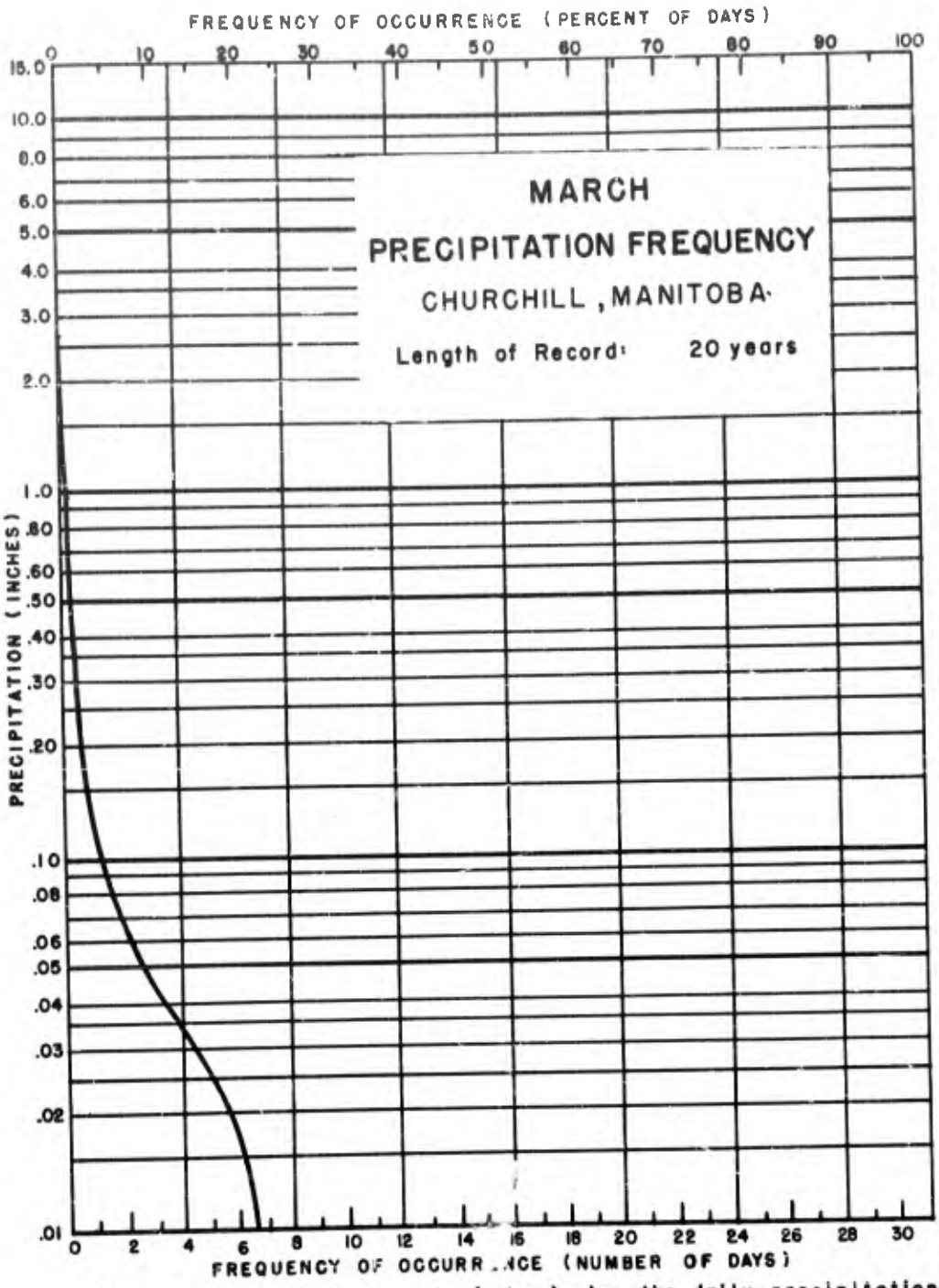
Figure 18



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.02 inches or more precipitation may be expected to occur 4.7 days during February (or approximately 17 percent of the days).

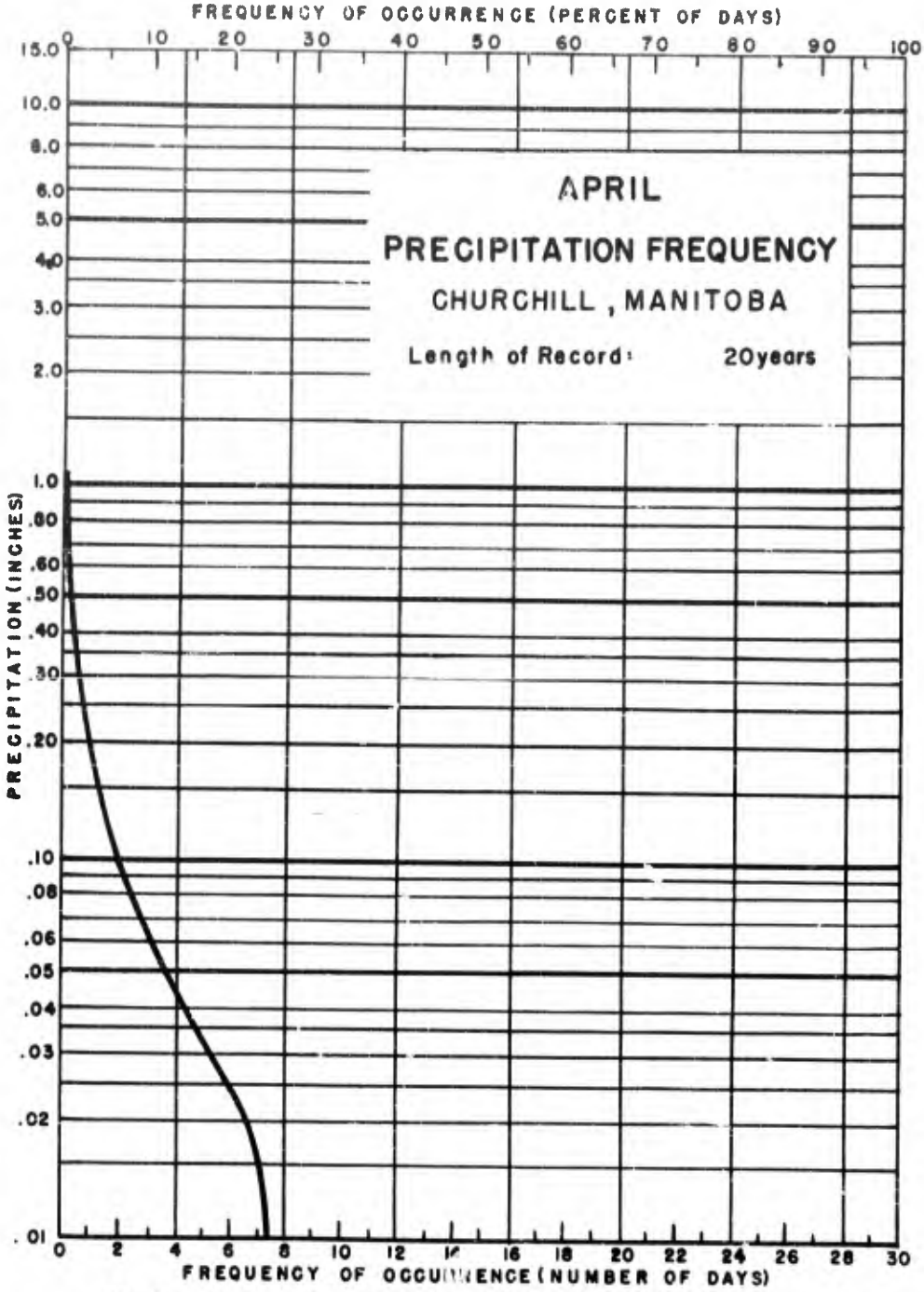
Figure 19



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.03 inches or more precipitation may be expected to occur 4.2 days during March (or approximately 14 percent of the days).

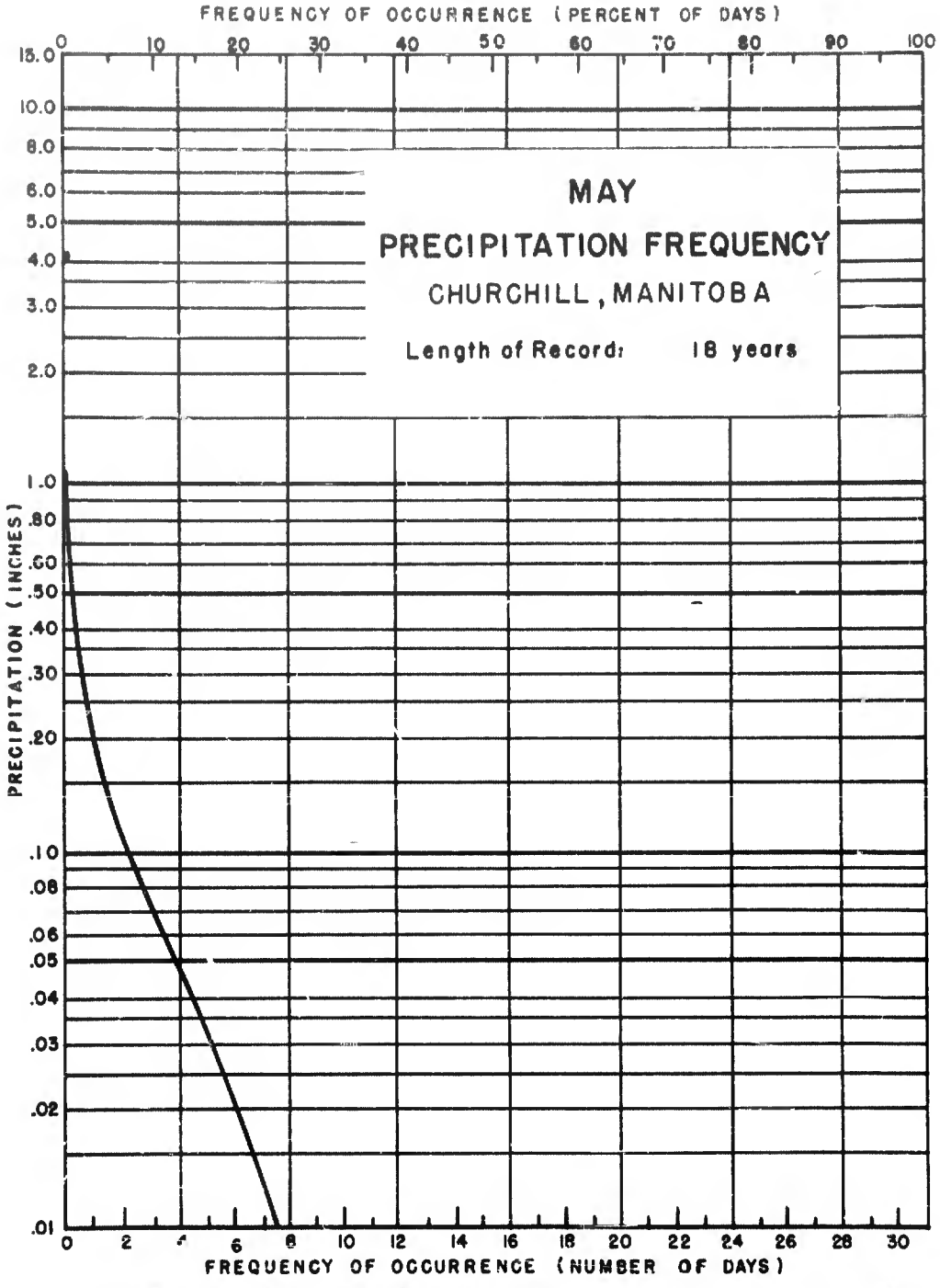
Figure 20



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.02 inches or more precipitation may be expected to occur 6.5 days during April (or approximately 22 percent of the days).

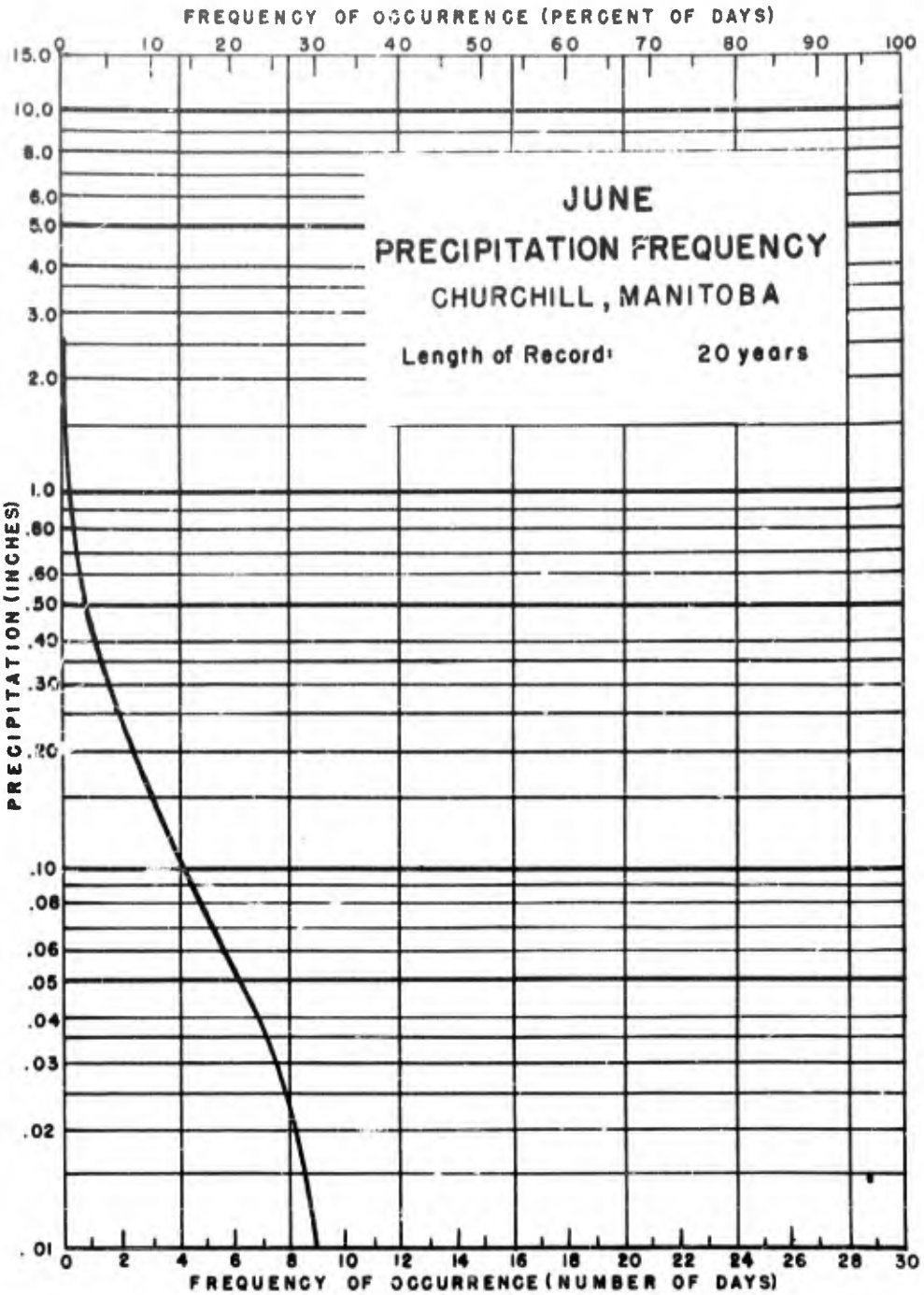
Figure 21



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.05 inches or more precipitation may be expected to occur 4 days during May (or approximately 13 percent of the days).

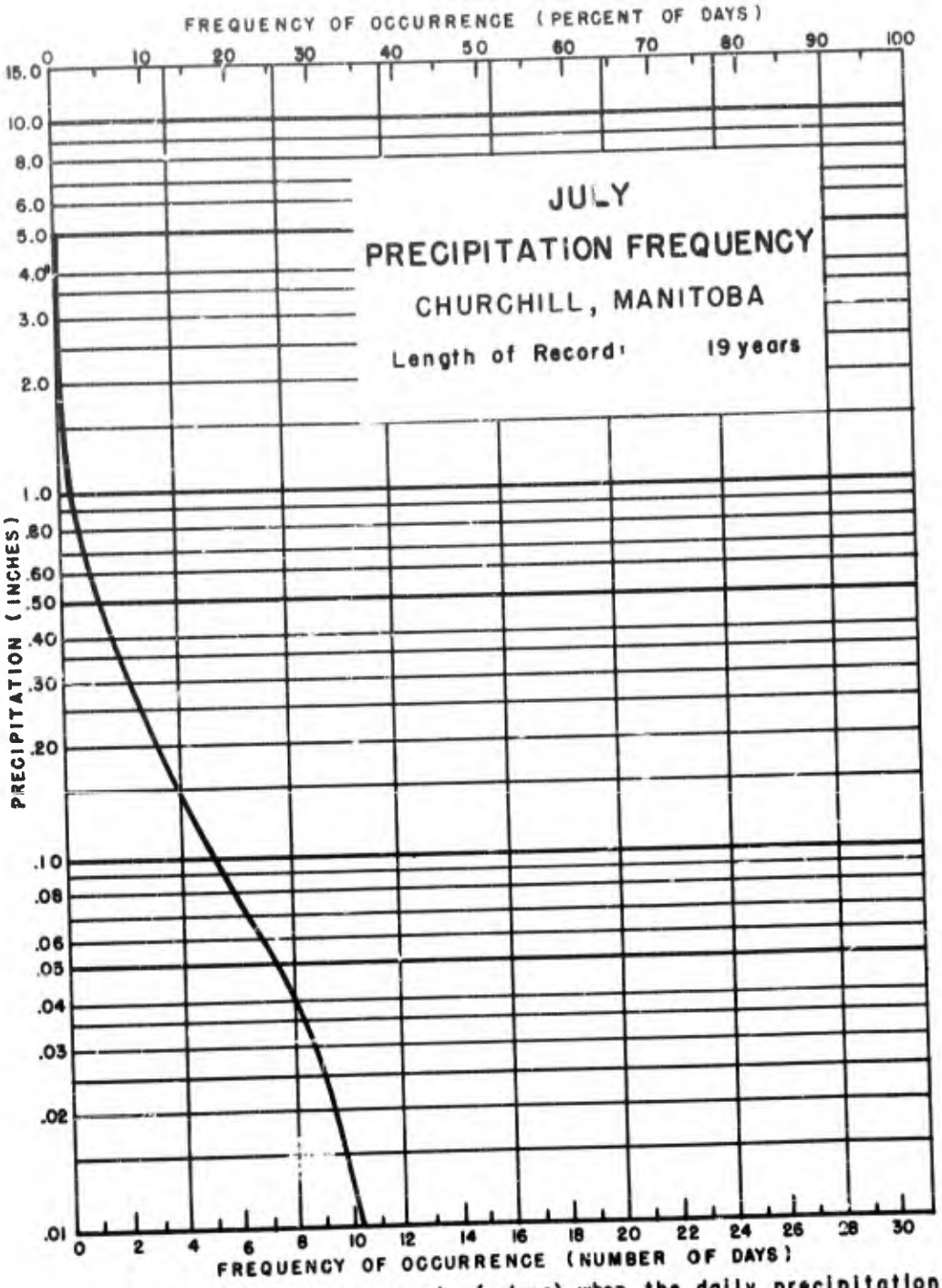
Figure 22



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.11 inches or more precipitation may be expected to occur 4 days during June (or approximately 13 percent of the days).

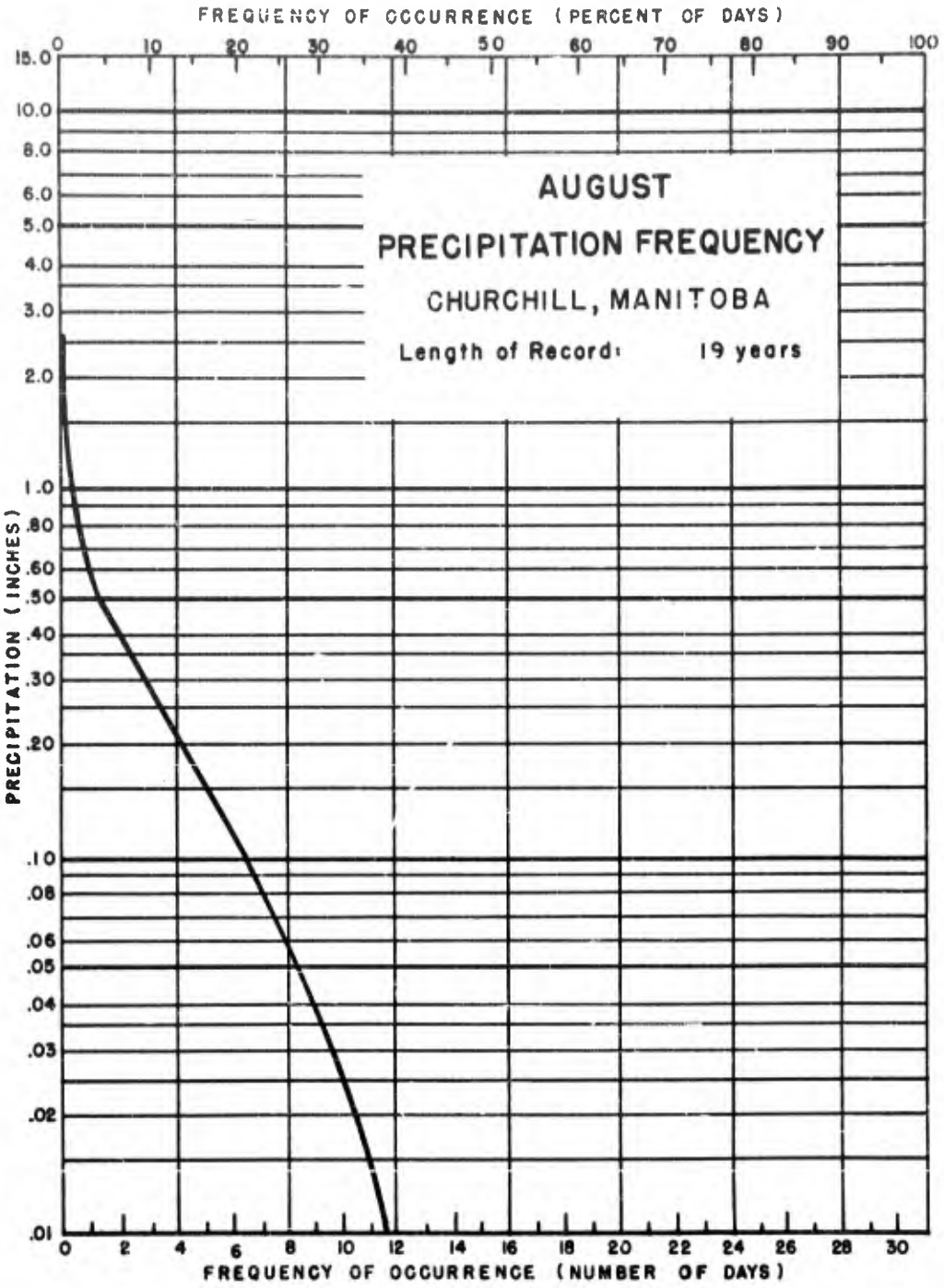
Figure 23



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.04 inches or more precipitation may be expected to occur 8 days during July (or approximately 26 percent of the days).

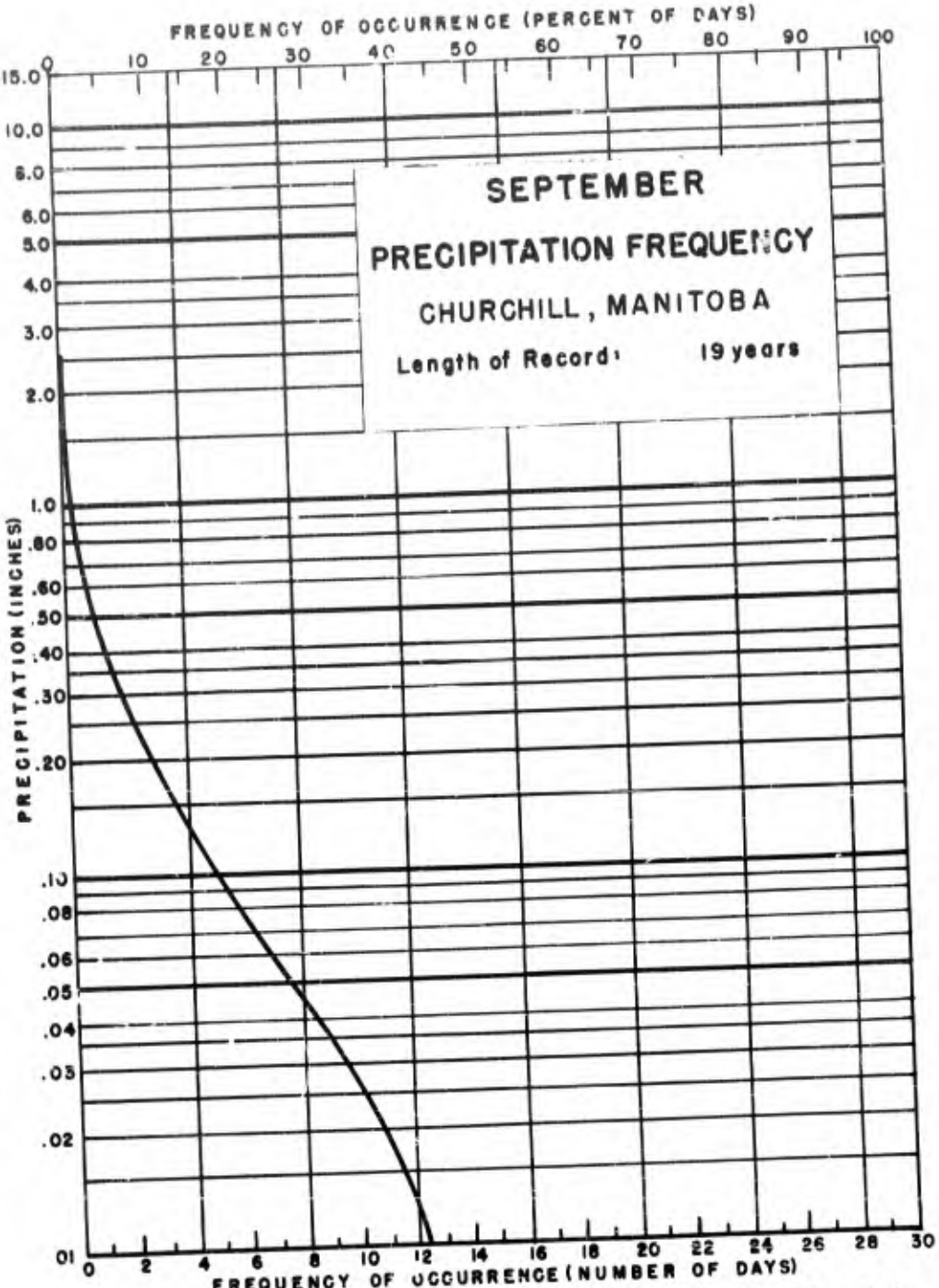
Figure 24



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.05 inches or more precipitation may be expected to occur 8 days during August (or approximately 26 percent of the days).

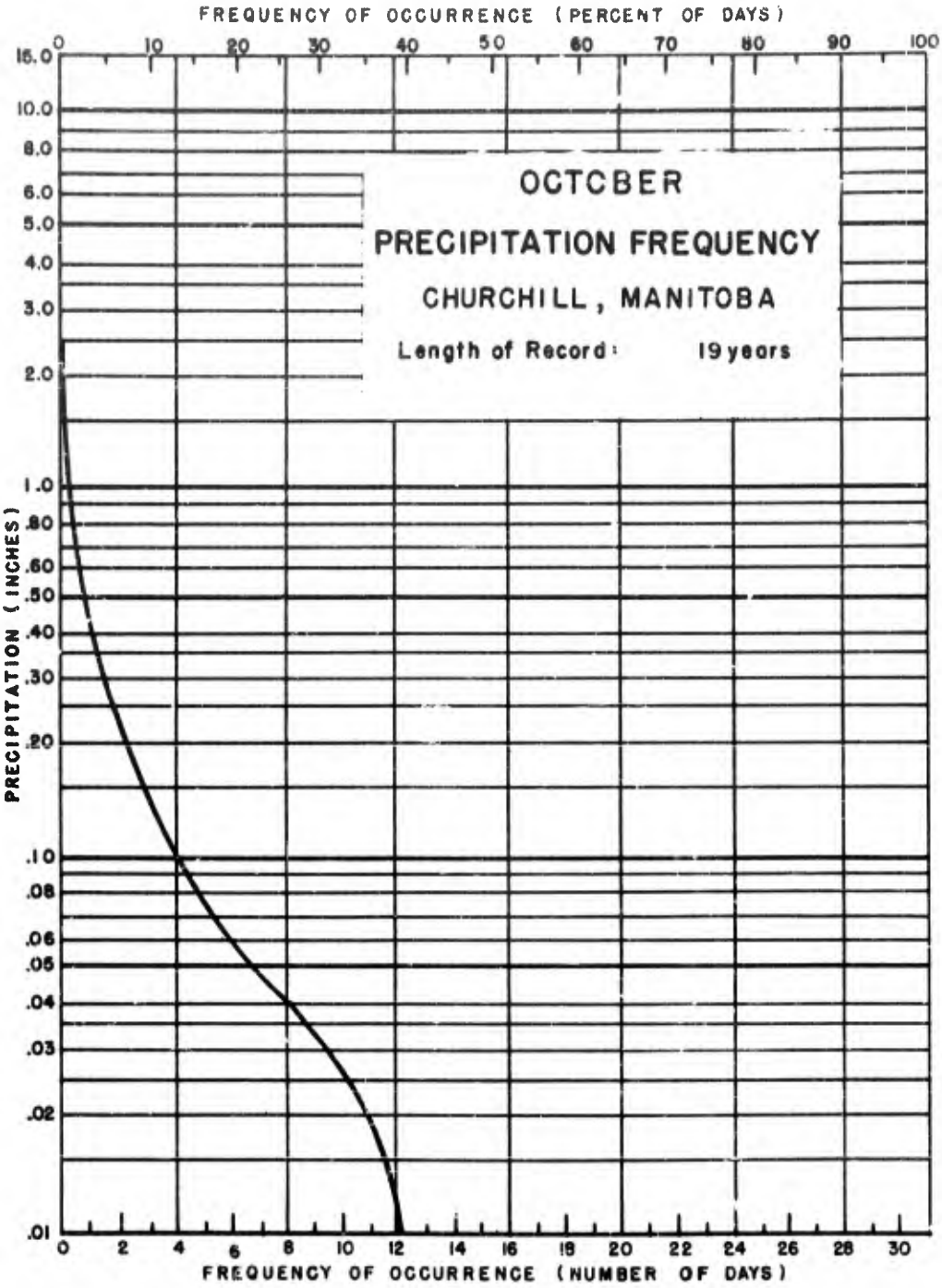
Figure 25



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.02 inches or more precipitation may be expected to occur 11 days during September (or approximately 37 percent of the days).

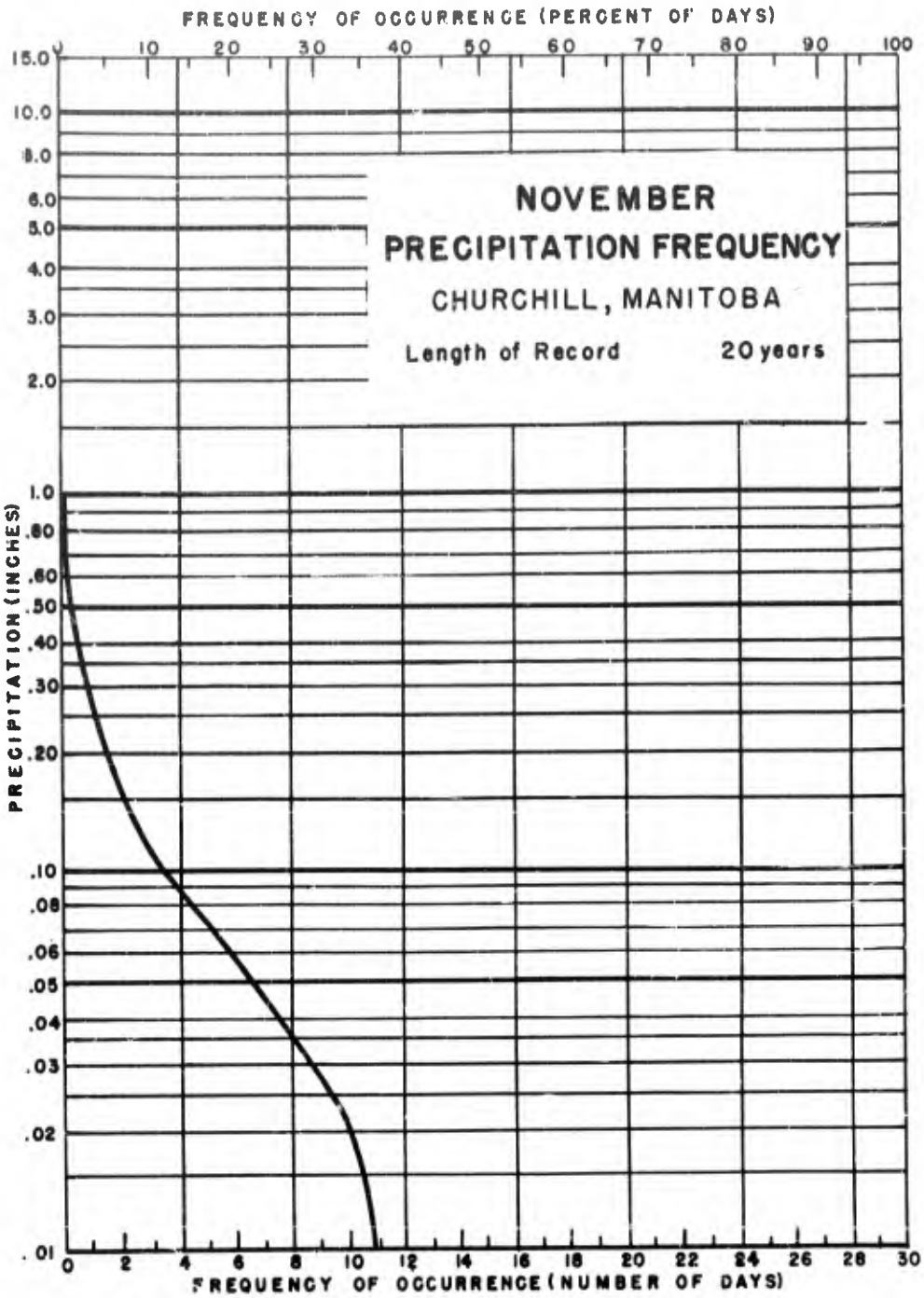
Figure 26



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.04 inches or more precipitation may be expected to occur 8 days during October (or approximately 27 percent of the days).

Figure 27

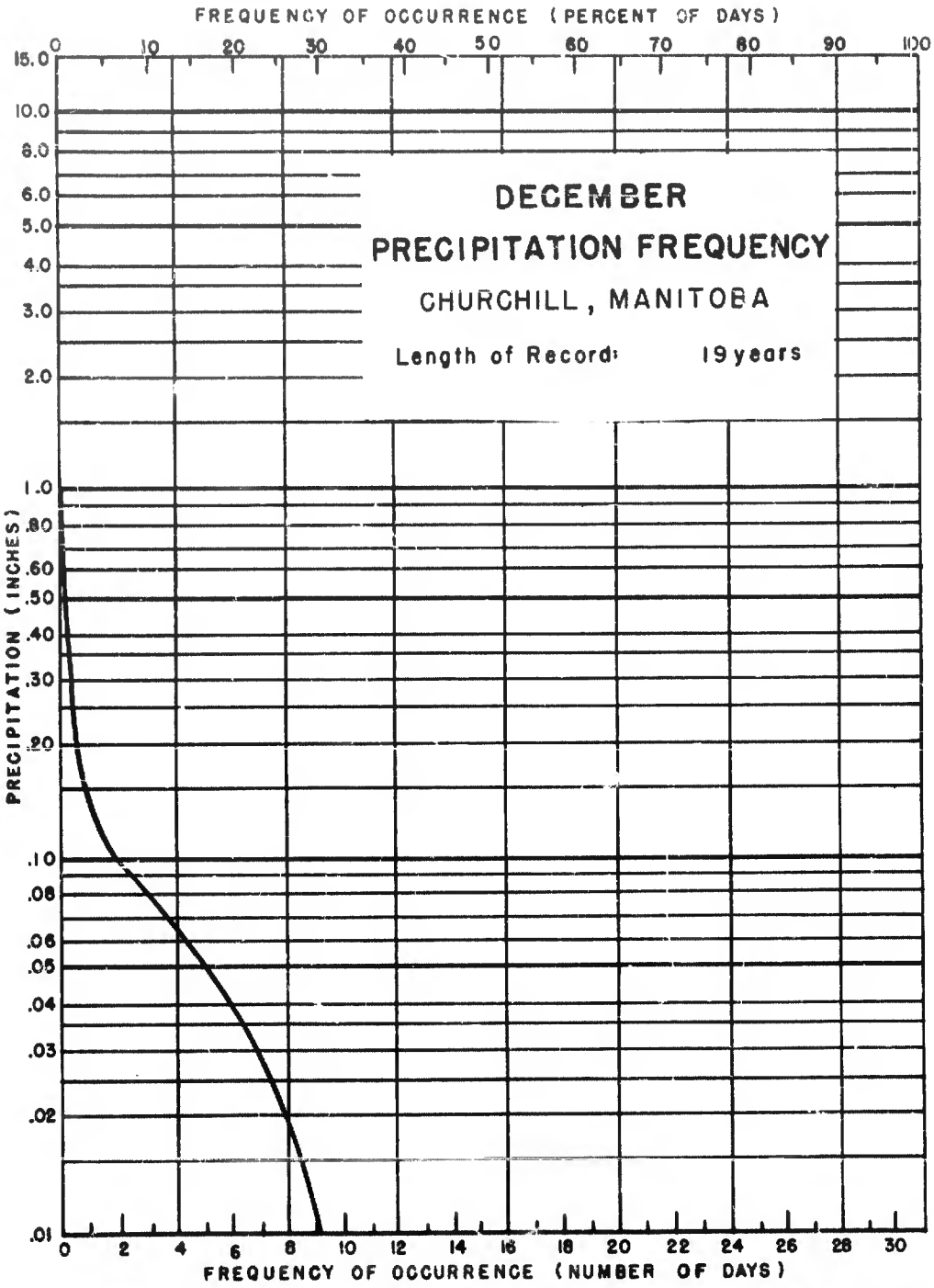


Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.09 inches or more precipitation may be expected to occur 4 days during November (or approximately 13 percent of the days).

D26881

Figure 28



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.04 inches or more precipitation may be expected to occur 6 days during December (or approximately 19 percent of the days).

Figure 29

PRECIPITATION REGIME

CHURCHILL, MANITOBA

Length of Record: 16 to 19 years

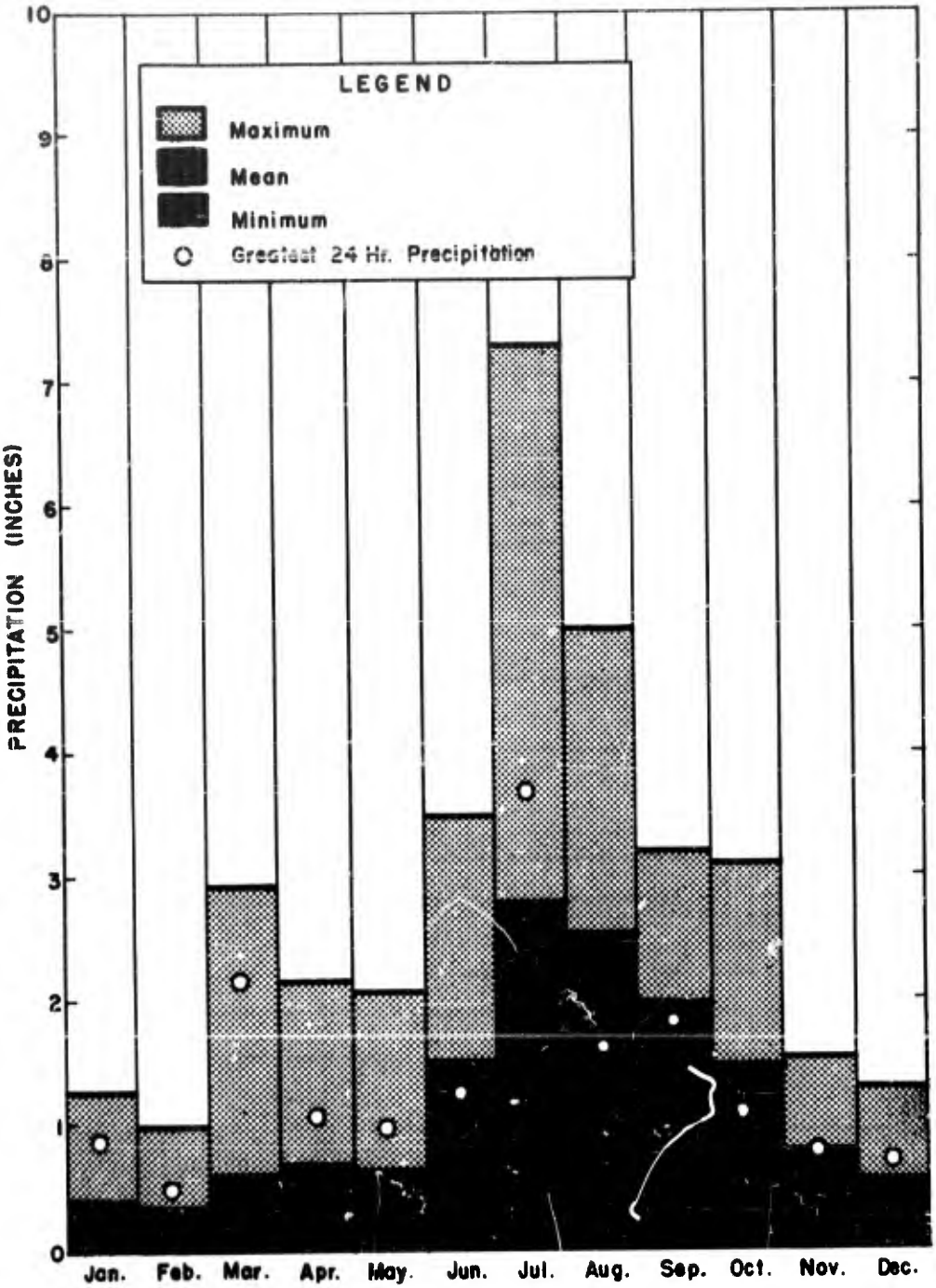


Figure 30

MEAN MONTHLY SNOWFALL

CHURCHILL, MANITOBA

Length of Record: 30 years

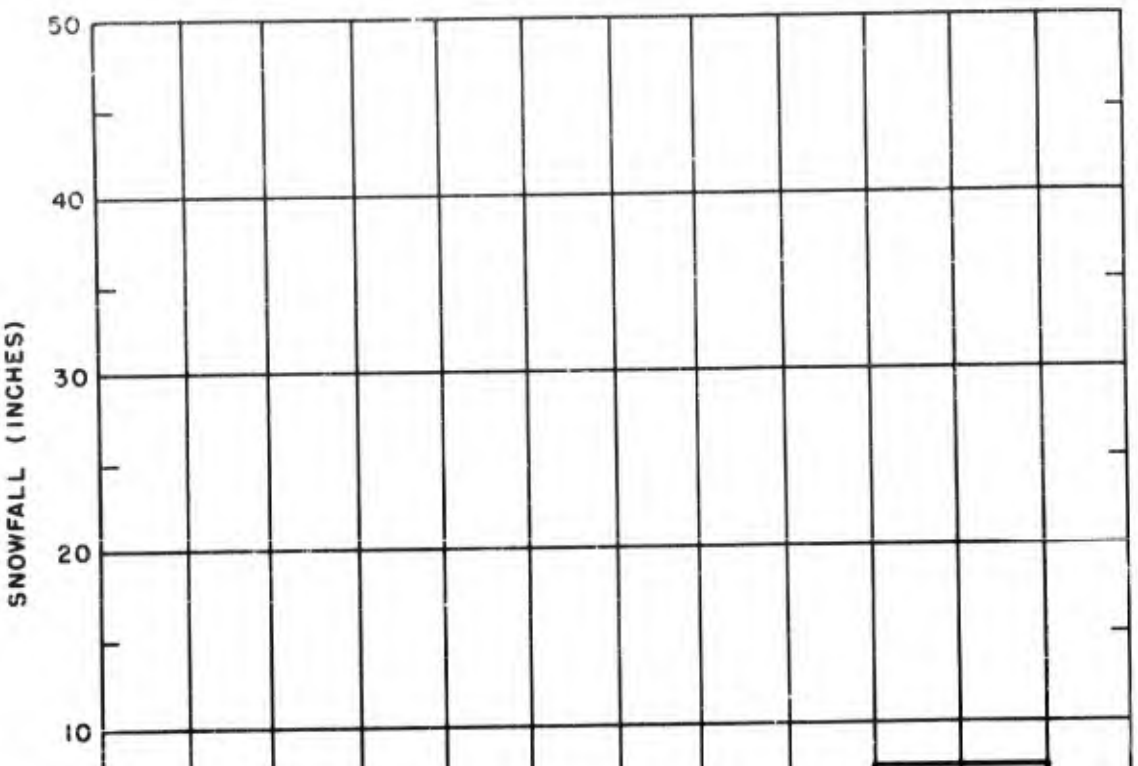


Figure 31

PERCENTAGE OCCURRENCE OF WIND SPEED BY GROUPS

CHURCHILL, MANITOBA

Length of Record: 10 to 14 years

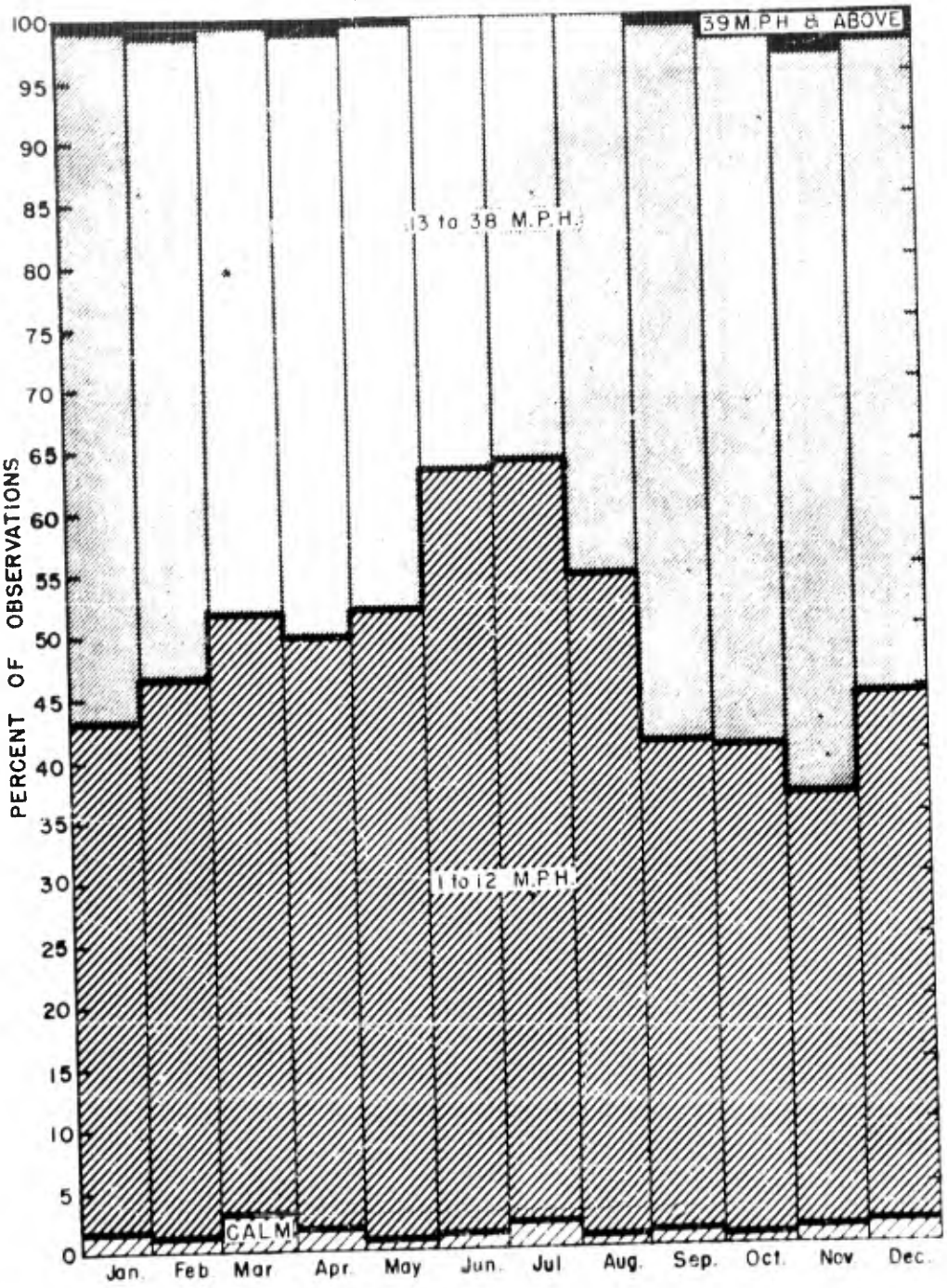


Figure 32

MEAN RELATIVE HUMIDITY AT SPECIFIED HOURS

CHURCHILL, MANITOBA

Length of Record: 4 to 6 years

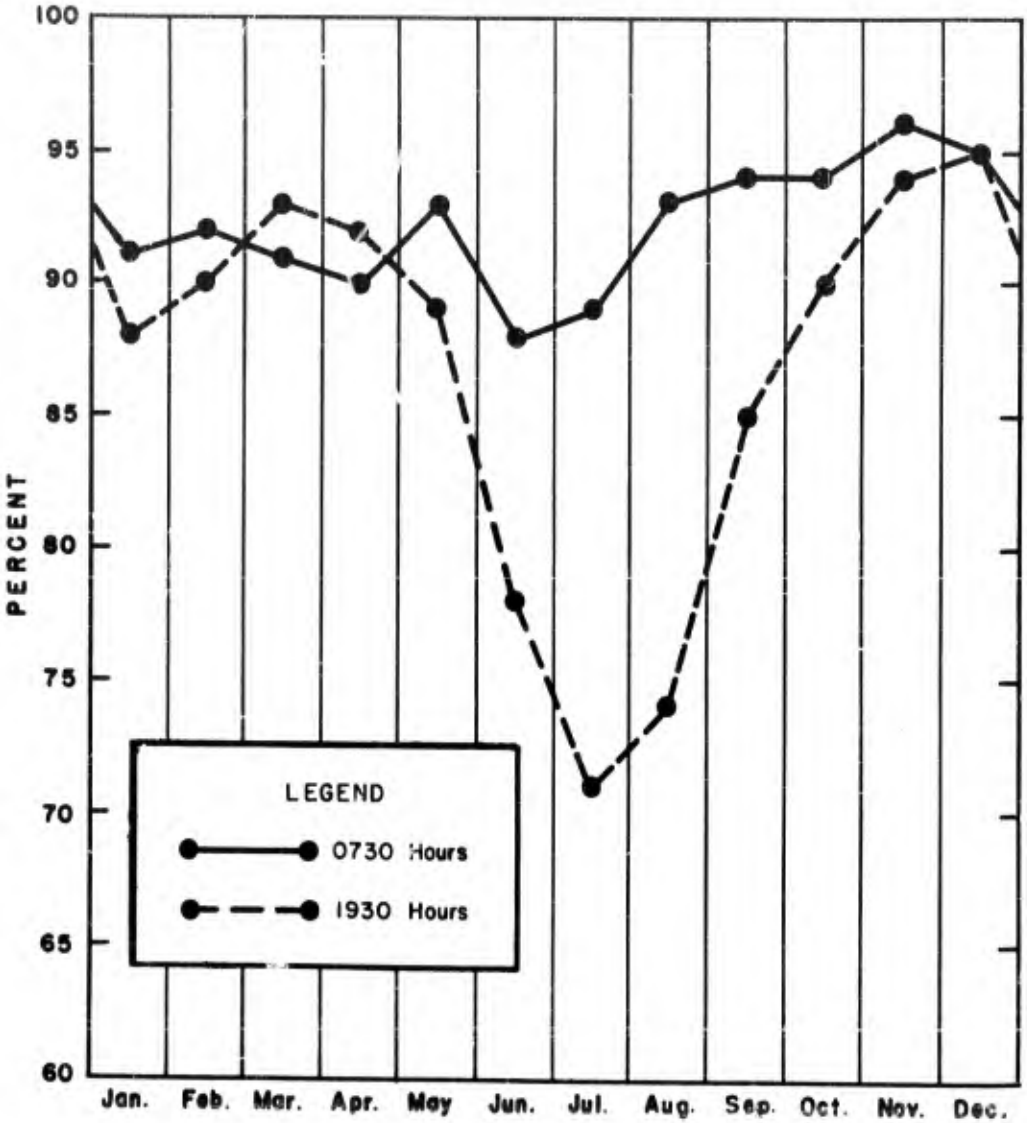
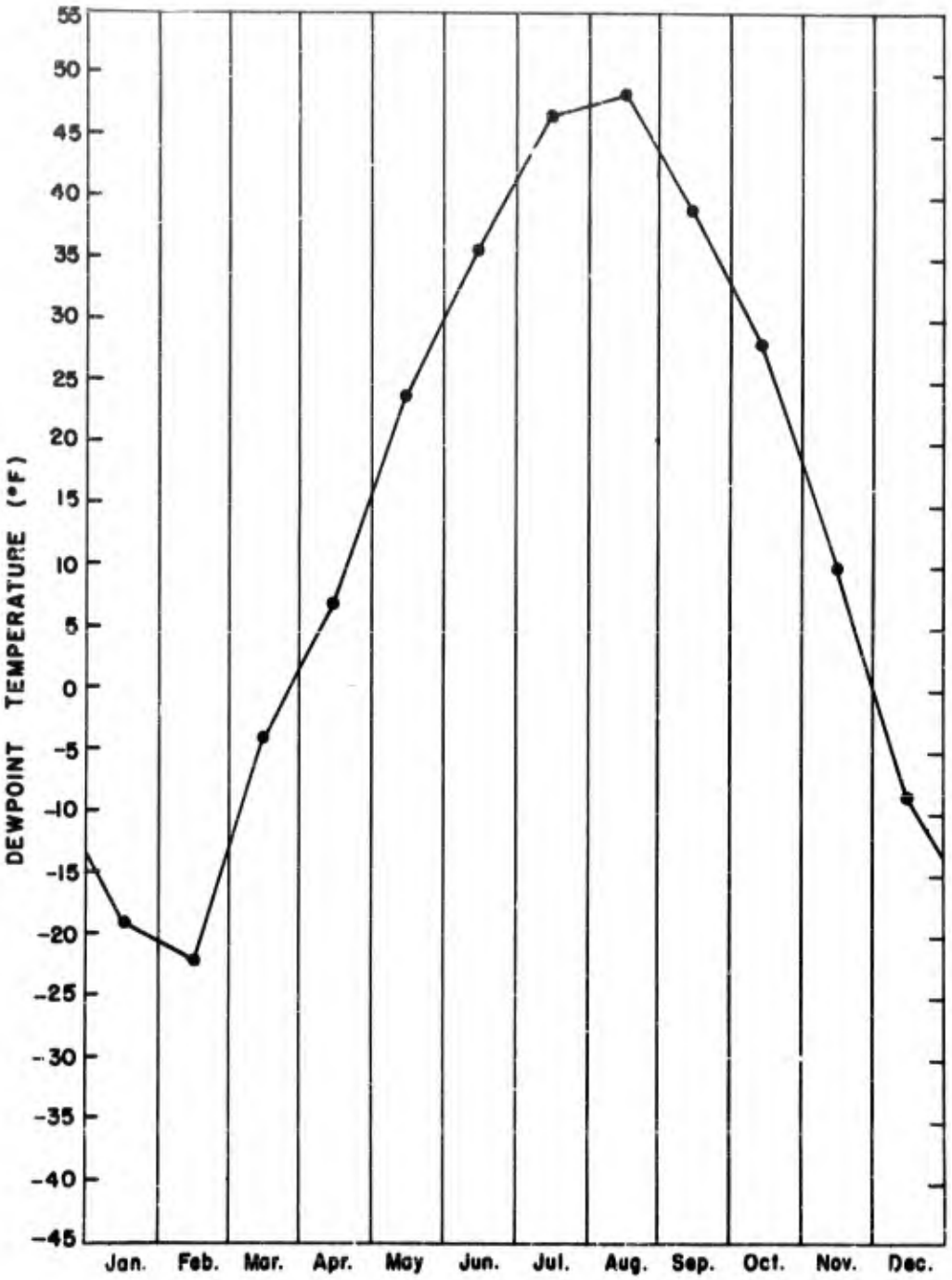


Figure 33

Mean Dewpoint Temperature

FORT CHURCHILL, MANITOBA

Length of Record: 4 to 6 years



Dewpoint data obtained by averaging 0130, 0730, 1330 and 1930 values.

Figure 34

TYPES OF SKY COVER

CHURCHILL, MANITOBA

Length of Record: 8 to 10 years

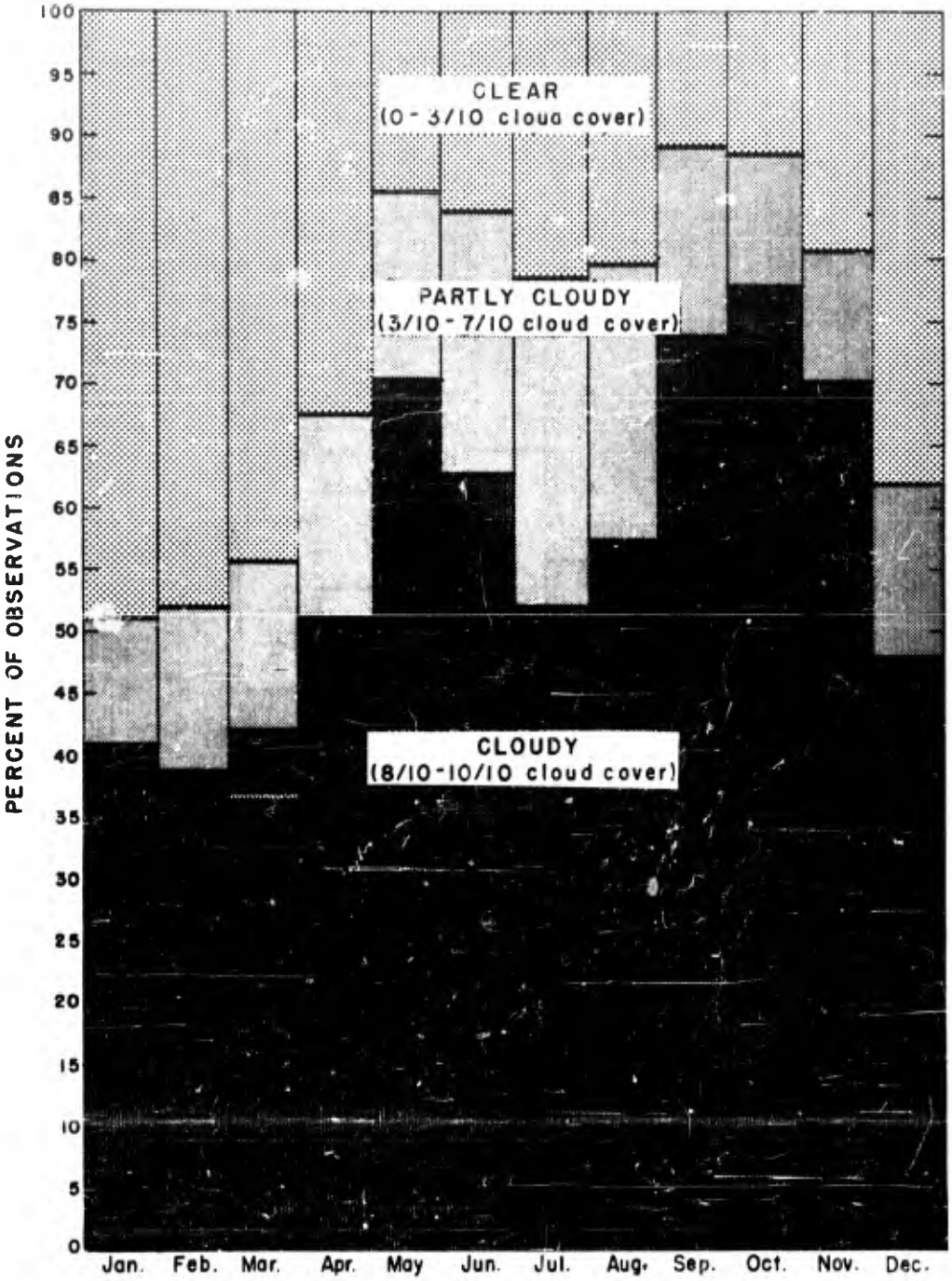


Figure 35

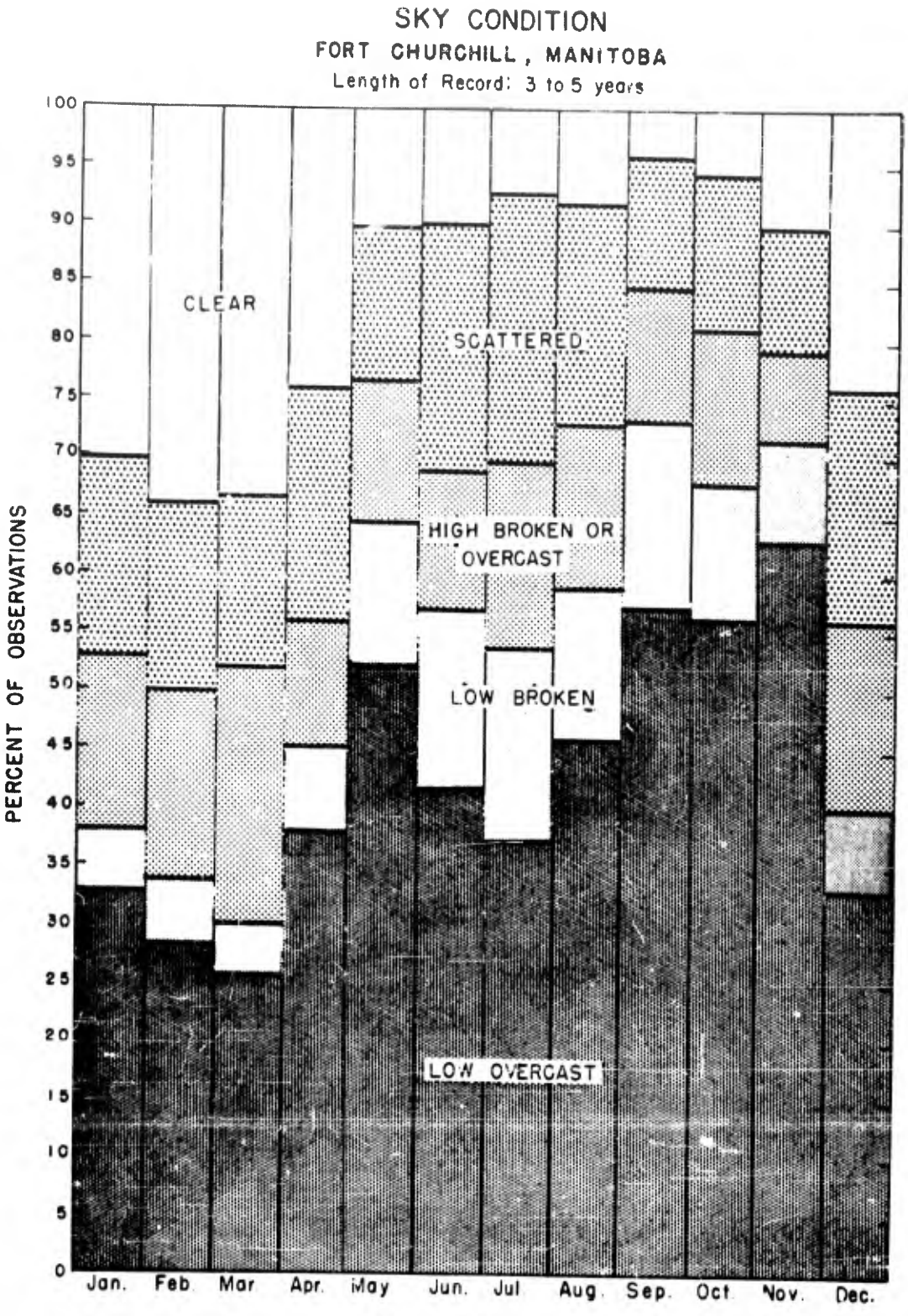

SKY CONDITION
FORT CHURCHILL, MANITOBA
Length of Record: 3 to 5 years
PERCENT OF OBSERVATIONS
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
CLEAR
SCATTERED
HIGH BROKEN OR OVERCAST
LOW BROKEN
LOW OVERCAST
Jan.
Feb.
Mar.
Apr.
May
Jun.
Jul
Aug.
Sep.
Oct.
Nov.
Dec.

Figure 36

HOURS OF POSSIBLE SUNSHINE

CHURCHILL, MANITOBA

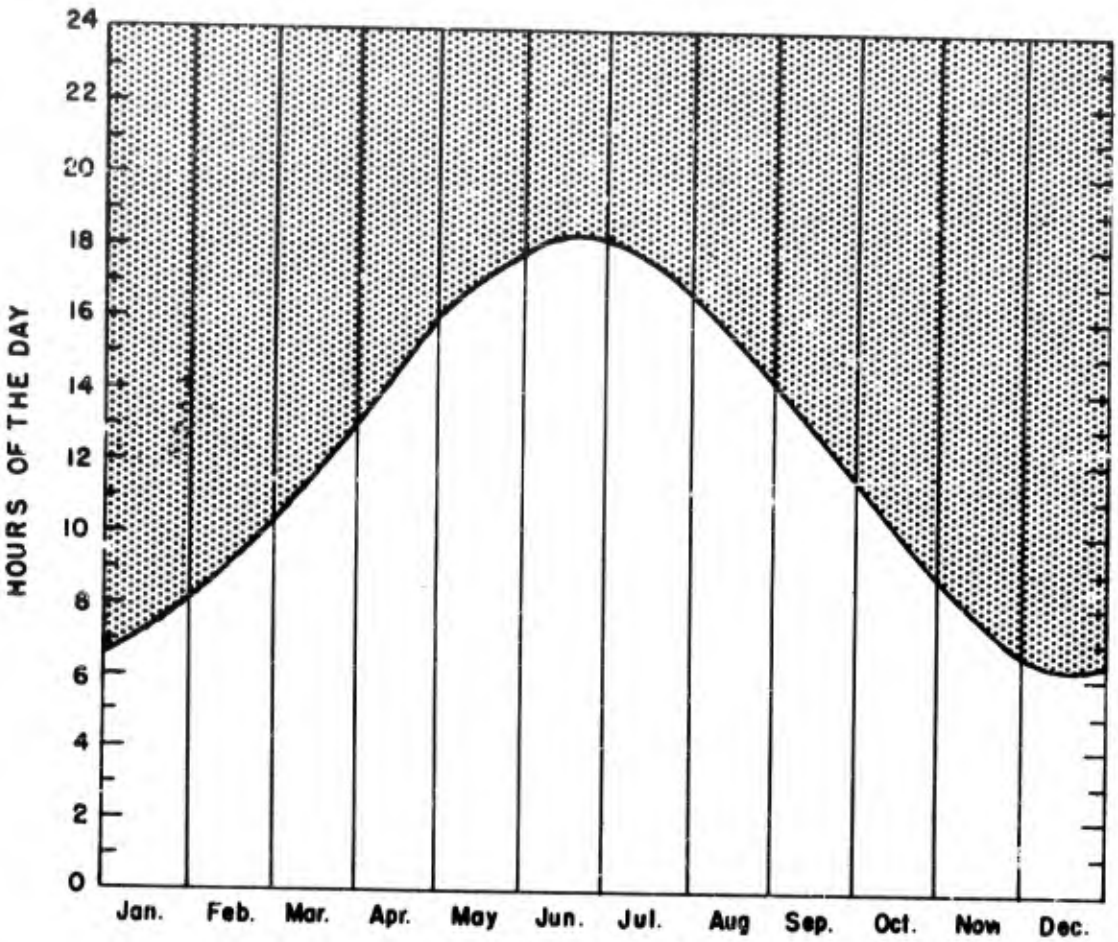


Figure 37

SOLAR RADIATION
FORT CHURCHILL, MANITOBA

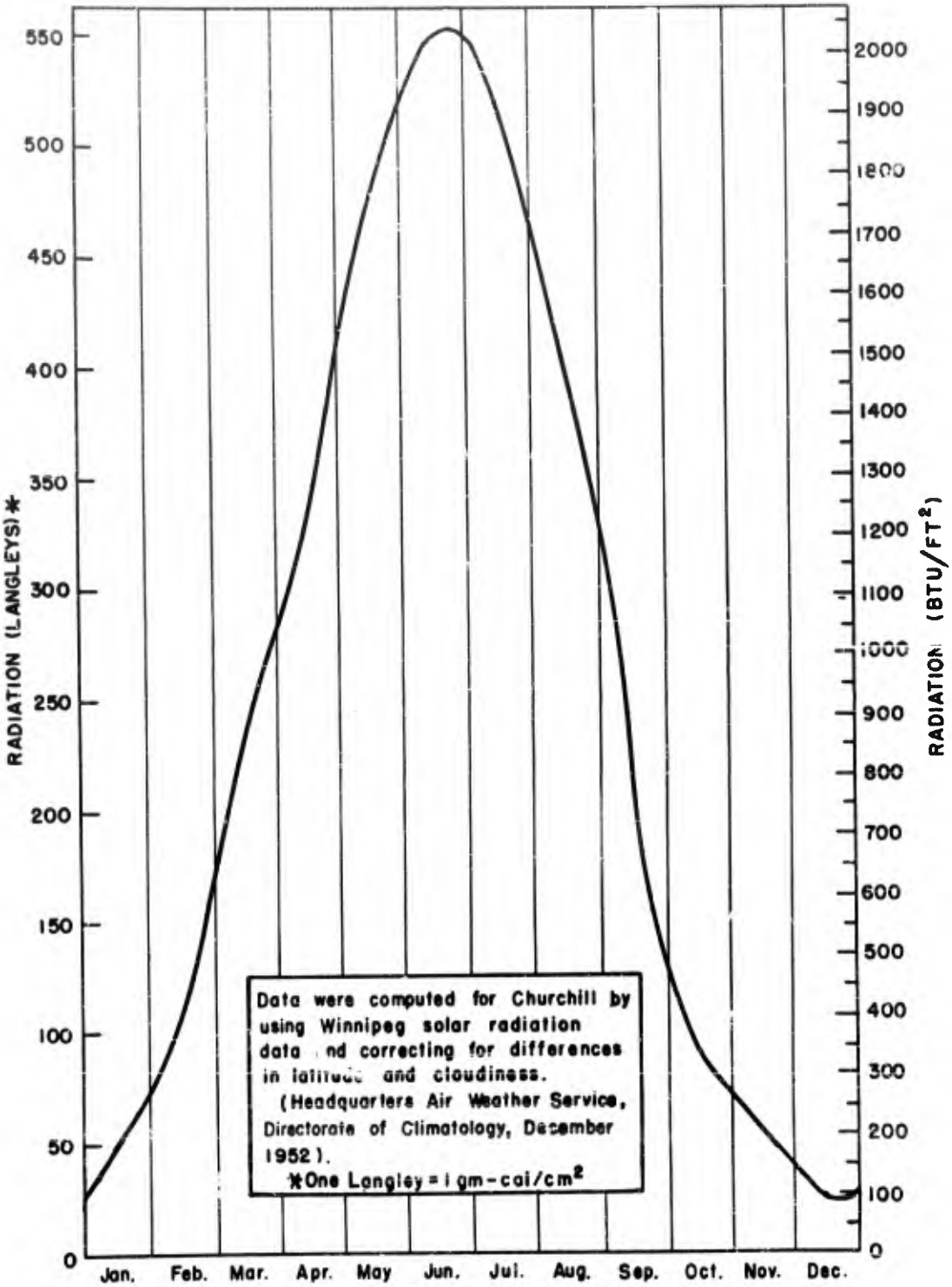


Figure 38

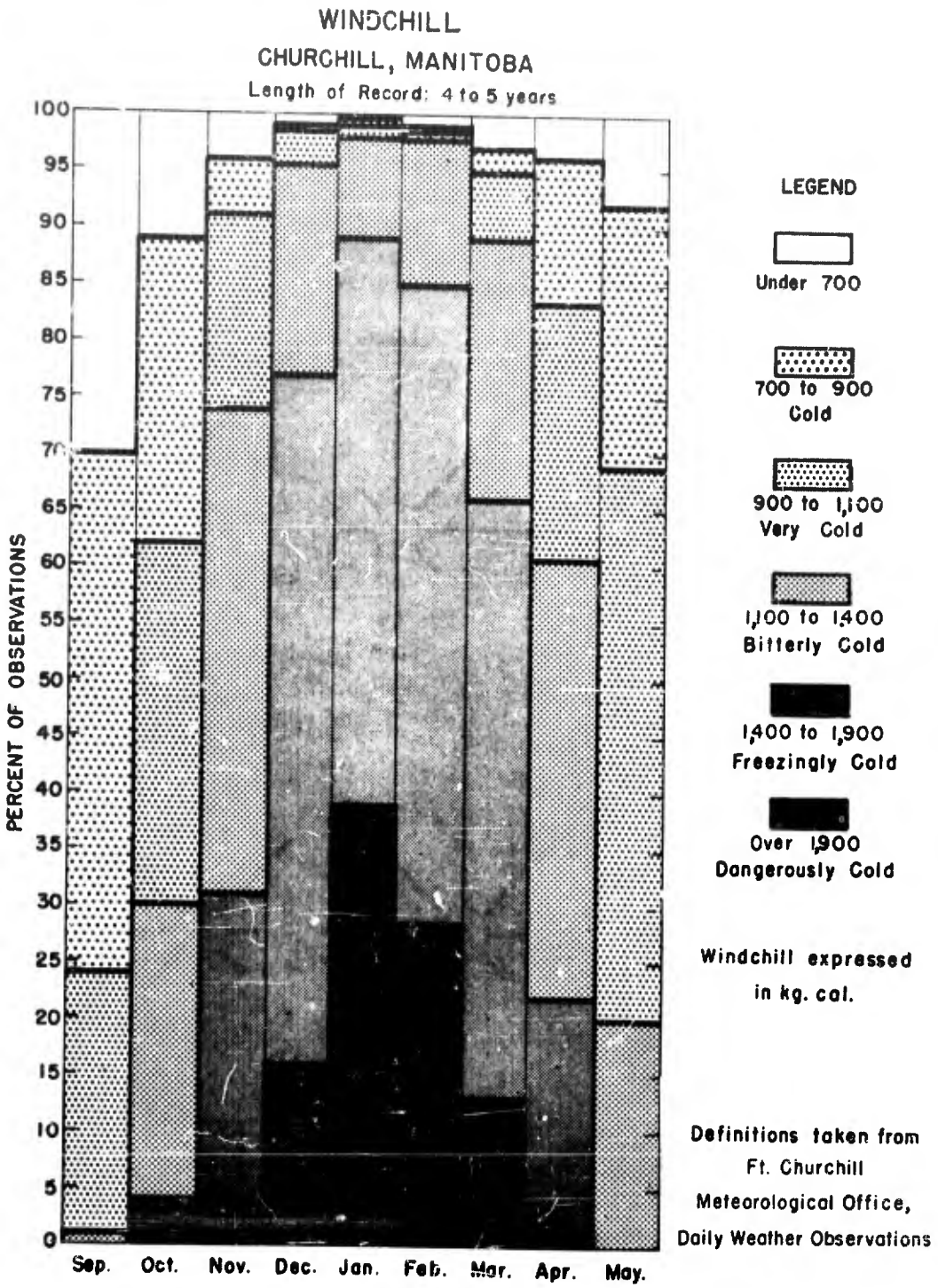

WINDCHILL
CHURCHILL, MANITOBA
Length of Record: 4 to 5 years
PERCENT OF OBSERVATIONS
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Sep.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May.
LEGEND
Under 700
700 to 900
Cold
900 to 1,100
Very Cold
1,100 to 1,400
Bitterly Cold
1,400 to 1,900
Freezingly Cold
Over 1,900
Dangerously Cold
Windchill expressed
in kg. cal.
Definitions taken from
Ft. Churchill
Meteorological Office,
Daily Weather Observations

Figure 39

SURFACE WINDS
PERCENTAGE FREQUENCY OF
OCCURRENCE BY DIRECTION
CHURCHILL, MANITOBA
LENGTH OF RECORD - 9 TO 12 YEARS

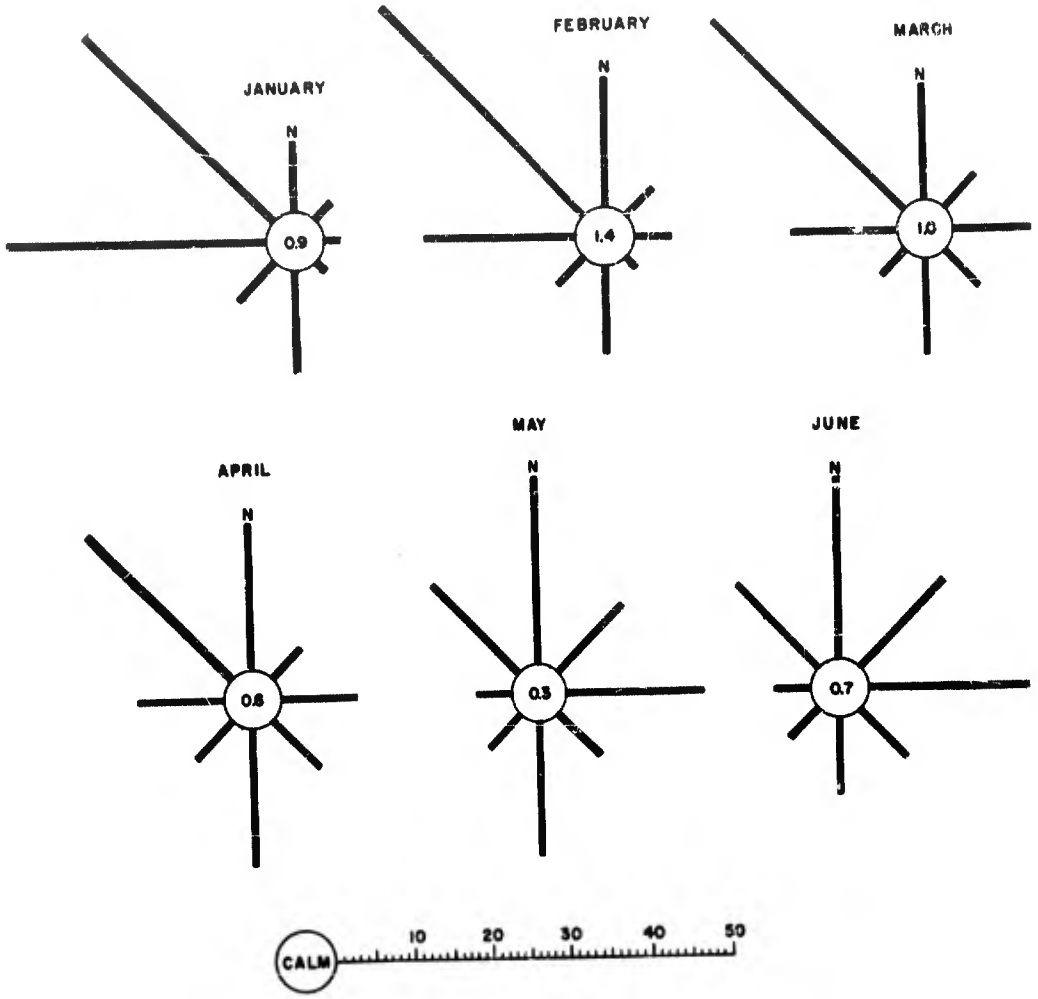


Figure 40

SURFACE WINDS
PERCENTAGE FREQUENCY OF
OCCURRENCE BY DIRECTION
CHURCHILL, MANITOBA
LENGTH OF RECORD - 9 TO 12 YEARS

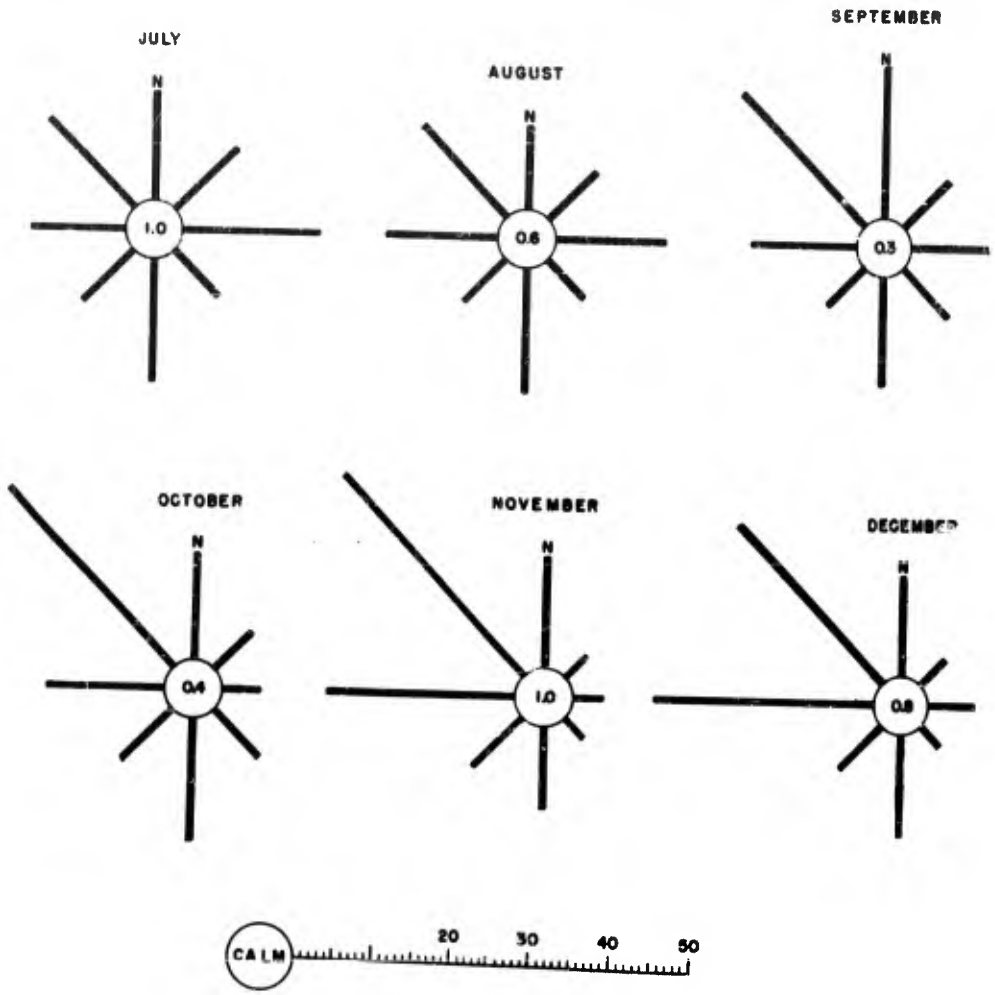


Figure 41

APPENDIX B

PHOTOGRAPHS

Fig. 42: Rock outcrops along Hudson Bay coast

Fig. 43: Crystalline rock outcrop at Halfway Point

Fig. 44: Subarctic forest south of Fort Churchill

Fig. 45: Low tundra in forest zone south of Fort Churchill

Fig. 46: Tundra south of Fort Churchill

Fig. 47: Arctic tundra along Hudson Bay east of Fort Churchill

Fig. 42. Fractured rock outcrops along the Hudson Bay coast at Fort Churchill. Dwarf spruce trees in background. Vehicular movement in such areas is difficult during all seasons.

Fig. 43. Crystalline rock outcrop at Halfway Point, east of Fort Churchill.

Fig. 44. Subarctic forest south of Fort Churchill. Snow accumulation is much greater in forested areas in tundra. Note open character of forest.

Fig. 45. A small patch of low tundra in forest area south of Fort Churchill. Low marsh vegetation projects above winter snow. Spruce trees that appear in the background are among largest found in Fort Churchill area.

Fig. 46. Tundra south of Fort Churchill showing scattered dwarf spruce trees that are characteristic of much of the area.

Fig. 47. Arctic tundra along Hudson Bay, a few miles east of Fort Churchill.

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