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THE CLIMATIC CHARACTER OF THE AUCKLAND RURAL AREA

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Abstract

The characteristics of the climate of the rural area surrounding the Auckland urban area are discussed. Data used, is predominantly from published reports of the New Zealand Meteorological Service giving annual summaries of observations made at the various climatological, synoptic and rainfall recording stations. The mean characteristics of the area's climatic elements are considered together with their extremes. It is concluded that warm temperatures throughout the year, high humidity, variations in amount and intensity of rainfall, prevailing westerly and infrequent easterly winds and high sunshine hours characterise the climate of this part of northern New Zealand.

The climate of the Auckland area is influenced to a high degree by its northerly position in New Zealand, by the close proximity of oceans to the east and west and to a lesser extent by the topography. The Auckland area is here considered arbitrarily as the "mainland" stretching from a line drawn east-west through the southern end of the Kaipara Harbour to a line drawn between the mouth of the Waikato River and the Gulf of Thames (Figure 1.) Within this area lies the Auckland urban area containing by far the largest concentration of urban development in New Zealand. The urban area covers approximately 180 square miles, of which 100 square miles are built up, and which had an estimated population of 565,000 in April, 1967 (Department of Statistics, October, 1967). The climate of the built-up area within the urban area is distinctly modified by the urban structures, road systems, artificial space heating and industrial activities. The characteristics of the urban area's climate will not, for the most part, be discussed as these are being considered elsewhere and have already been briefly described by de Lisle (1965).

The Auckland rural area — that is the area defined but excluding the built-up area of the urban area — lies in the northern New Zealand climatic type according to Garnier (1958). The weather systems influencing New Zealand, and more specifically the Waikato Valley, have been discussed recently by de Lisle (1967). Those affecting rural Auckland are essentially similar to the weather systems influencing the Waikato although the area lies closer to the belt of sub-tropical high pressure and tends to be affected more by tropical cyclones.

The climate of the Auckland rural area is characterised by warm mean summer temperatures in the upper 60°'s F. in February. Winter temperatures are mild, being in the low 50°'s or high 40°'s F. in July. The greatest range of temperatures is recorded at inland stations relatively isolated from the moderating influence of the oceans. Humidity — measured at 0900 hours N.Z. Standard Time — is high throughout the year, being normally above 70 per cent in all months. The high humidity combined with the relatively high temperatures recorded in late summer, accounts for the "stickiness" which is so characteristic of Auckland's climate at that time of the year. Rainfall varies from about 45 inches per annum on the South Auckland lowlands to over 80 inches per annum in the Waitakere and Hunua Ranges. The rainfall is usually distributed throughout the year although more than

30 per cent of the annual total falls in the three winter months of June, July and August (Garnier, 1958, pp. 74-75). Late autumn also tends to be wetter than the rest of the year. In summer precipitation is normally at its lowest and is often exceeded by evapotranspiration. Periods of high-intensity rainfall occur in rural Auckland most frequently in summer and early autumn as a result of tropical cyclones. Other intense rainfalls are associated with severe depressions of extra-tropical origin or stationary fronts such as that which brought more than nine inches of rain to the rural Auckland area in three days in August 1965, causing loss of life and serious economic losses (Wright, 1966).

The general climate of this part of New Zealand can be studied from data collected essentially by the New Zealand Meteorological Service. Additional data relating to precipitation is obtained by the Auckland Regional Authority for parts of the Hunua and Waitakere Ranges. The rain gauges in these two areas were originally established and operated by the water supply division of the Auckland City Council in conjunction with their water catchment areas used to provide the city's water supply. Details of the local climates caused mainly by relief features and contrasts in vegetative cover cannot be studied from the available data.

The data thus comes from:

(1) The climatological stations located within the Auckland area which record some, or all, of the elements of climate at 0900 hours New Zealand Standard Time. There are eleven such stations located at Woodhill, Riverhead Forest, Whenuapai, Albert Park, Auckland City (NAC centre), Oratia Henderson, Owairaka, Mangere, Otara, Auckland International Airport and Maioro. Of these, the stations at Albert Park, Auckland City, and Owairaka are within the closely built-up urban area and are thus not regarded as being representative of the rural Auckland area. The station at Otara is located in rural surroundings although urban encroachment has become more pronounced in recent years. In previous years (1944-59) a climatological station operated at Paerata and three other stations, all in the urban area, produced a limited amount of data. Rainfall data for Paerata is available for a much longer period of time.

(2) The synoptic reporting stations which provide the basic information for weather forecasting services to the public and aviation. In the Auckland rural area there are three synoptic stations — at Tiritiri lighthouse, Manukau Heads and Auckland International Airport. Within the urban area the only synoptic station is on top of the NAC building in Victoria Street West. It is from here that all forecasts are prepared based on information from the other synoptic stations in the area, from satellite data and from information sent from the head office of the Meteorological Service in Wellington.

(3) The rainfall recording stations. Some of these stations have gauges which are read daily at 0900 hours New Zealand Standard Time while others are read weekly or monthly. More than 50 (see Figure 1) such stations are located in the area and, when taken in conjunction with the climatological and synoptic recording stations, give an adequate, if uneven cover, of the area. There have been numerous changes in rainfall recording stations both in terms of actual numbers and specific sites.

The distribution of the various recording stations inevitably leaves many gaps from which it would be desirable to have data. Some of the more extreme conditions which are experienced in rural Auckland are in areas in which detailed records of the climatic elements are not available. The answers to many requests for more detailed local forecasts — for example from farmers — than are normally provided have, for the most part, to be based on the general data available from the synoptic

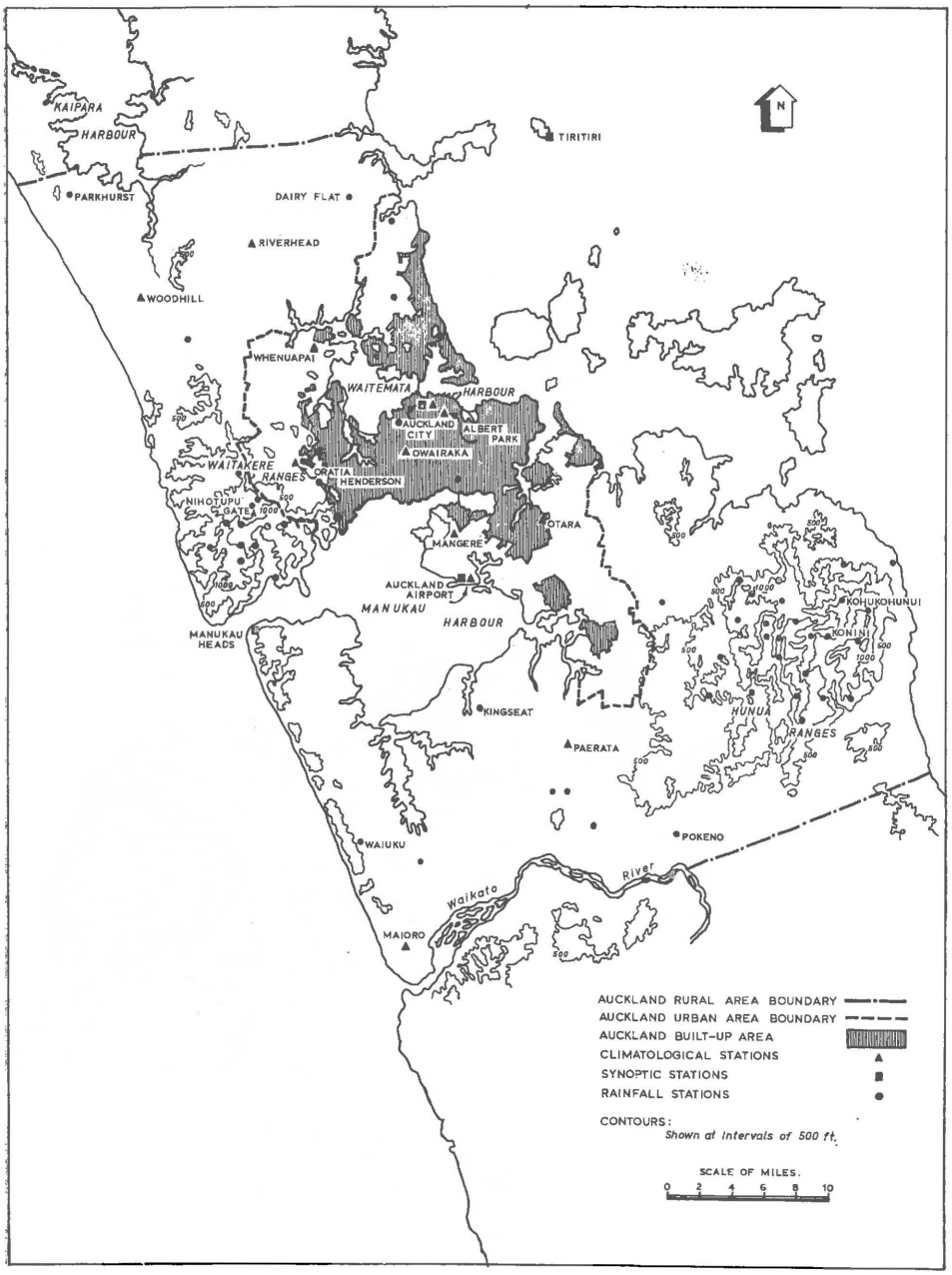

Figure 1. The Auckland area and location of climatological, synoptic and rainfall recording stations.

and climatological stations and on the forecaster's own knowledge of local conditions.

The climate of an area can be discussed by examining the mean characteristics of the elements of climate and their extremes based on long-term data. The main elements of climate able to be considered from the available data are rainfall, evaporation, sunshine, temperature, frost and wind.

RAINFALL

Average values for annual rainfall totals are based mainly on the existing 30-year normals (1921-50) although these are due for revision for the period 1931-60. In some cases mean annual and monthly values have been used based on a much shorter time period in order that data from other stations located in the area can be used. Where the normal annual average is available this has also been included for comparison. Marked variations between the data from Waiuku where the 1921-50 normal of 49.7 inches compares with the 1941-65 value of 57.2 inches, and Manukau Heads — 44.9 inches compared with 40.3 are noted.

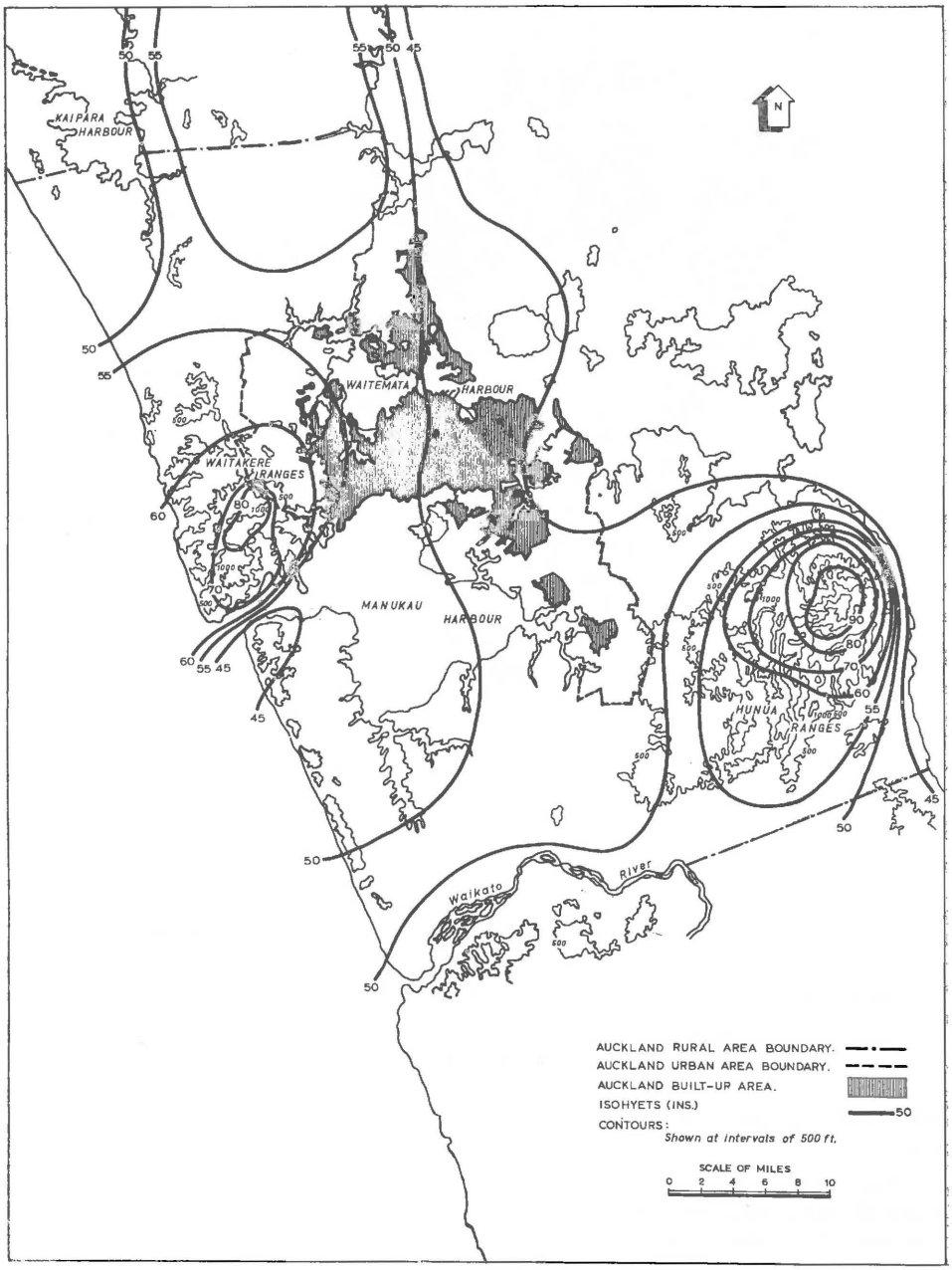

Figure 2. Distribution of average annual rainfall in the Auckland area in inches.

Average annual rainfalls vary from less than 45 inches in the South Auckland lowlands and some extreme eastern parts of the area to over 80 inches on the highest parts of the Waitakere and Hunua Ranges (Figure 2 and Table 1). The majority of the area receives 45 - 55 inches although variations occur as a result of local topographical features such as the west coast sand dunes of the Awhitu Peninsula and the dunes stretching from Muriwai to the south Kaipara Head. For example, in 1951 the rainfall recorded at Muriwai beach was 4.2 inches less than that recorded at Woodhill, six and a-half miles away on the inland side of the dunes. Muriwai had rain on 195 days compared with 202 at Woodhill. For the four years for which records were taken at Muriwai there was an average of 4.2 inches of rain less than at Woodhill. Lowest average rainfalls are recorded at Otara in South Auckland, at Manukau Heads on the West Coast, and at the Tiritiri Matangi lighthouse, off the eastern end of the Whangaparaoa peninsula. The highest average figures are those for Kohukohunui — the highest point in the Hunua Ranges at an altitude of 2256 feet above sea level — which, over the period 1961-1964, had an average of almost 98 inches compared with an average of 94 inches over the period 1955-1960 while the long-term 1949-1964 average is 91.4 inches. The next highest figures come from the rain gauge at Nihotupu Gate in the Waitakere Ranges with an average in excess of 86 inches per annum.

Average rainfall in general shows a winter maximum and a summer minimum. Late autumn is also characterised by high rainfalls by comparison with other seasons. The Auckland area is not one normally associated with periods of drought, although occasionally in summer evapotranspiration exceeds precipitation. At Albert Park in Auckland of a total annual calculated evapotranspiration of 29.5 inches, more than 11 inches or 38 per cent is lost in the summer months which have an average rainfall of 15.3 inches, thus indicating that there is normally a surplus of precipitation over evapotranspiration (Garnier, 1958).

Evaporation has been measured by the raised pan method (Finkelstein, 1961) at Mangere at the Sewage Treatment Works and at the Fertiliser Research Station at Otara since 1962. Errors in measurement can be caused by wind and rain and the values recorded are higher than would be recorded from an open water surface such as a lake. Finkelstein suggests that a reduction factor of 0.69 should be applied to the measurements made in New Zealand by the raised pan method. This would reduce the annual value recorded at Mangere to the equivalent of 31.3 inches evaporated from an open water surface. Figures obtained in this manner are not representative of evapotranspiration losses from pastures and crops and reduction factors need to be applied to values for evaporation from tanks to obtain a reasonably reliable figure for evapotranspiration. Finkelstein suggests that a reduction factor of 0.54 should be applied to raised pan measurements to give evapotranspiration. This would give a value of 24.5 inches for evapotranspiration at Mangere. The data for Otara is not complete but that for Mangere shows that an average evaporation loss of 45.4 inches was recorded over the period 1962-1965 compared with an average rainfall of 48.2 inches. In 1963 evaporation exceeded precipitation by nine inches while in other years a surplus of precipitation was recorded overall although evaporation exceeded precipitation for six months at Mangere. The greatest average excess of evaporation over precipitation was recorded in January when it was 4.7 and 3.3 inches at Mangere and Otara respectively (Table 2).

Average annual rainfalls show considerable variation from year to year as can be seen from data for a small selection of recording stations illustrated in Table 3. These figures show variations of up to 38 per cent below and 64 per cent above the mean value (Table 4). As the means for Waiuku, Manukau Heads, Riverhead, Woodhill and Tiritiri are based on at least 18 years' records they are more reliable than those from some of the stations used with only short-term records.

Table 1. Mean monthly and annual rainfall (ins.) at selected stations.

Selected Stations	Period	J	F	M	A	M	J	JY	A	S	O	N	D	Year
Maioro	1921–50	3.4	3.7	3.3	4.5	4.7	5.2	5.6	4.7	4.1	4.5	3.4	3.1	50.2
Paerata	1921–50	3.2	3.7	3.0	4.3	4.5	5.1	5.3	4.3	3.8	4.0	3.3	3.0	47.5
Pokeno	1953–65	2.7	3.7	4.2	4.3	5.9	6.2	6.3	5.5	3.8	4.6	3.1	4.0	54.3
Waiuku	(1921–50) 1941–65	3.2	4.0	3.6	4.8	5.6	6.5	6.4	5.8	4.0	5.3	4.0	4.0	(49.7) 57.2
Manukau Heads	(1921–50) 1941–43, 1947–59, 1961–65.	2.2	2.4	2.8	3.5	4.2	5.1	4.4	4.6	2.6	3.3	2.6	2.6	(44.9) 40.3
Kingseat	1960–64	2.5	3.1	3.4	3.9	5.1	6.5	5.9	4.2	5.0	4.3	2.8	3.5	50.2
Kohukohunui	1961–64	5.9	6.2	8.0	8.1	7.5	10.9	11.5	9.9	8.1	8.9	5.3	7.6	97.9
Otara	1921–50	2.9	3.5	2.8	3.7	4.4	4.8	4.7	3.7	3.4	3.7	2.9	2.9	43.4
Oratia Henderson	1921–50	4.1	5.0	4.0	5.0	6.4	6.9	6.8	5.4	4.8	5.3	4.1	4.3	62.1
Nihotupu Gate	(1921–50) 1958, 1961–64.	4.2	5.9	6.5	6.5	8.4	10.0	10.0	7.5	7.5	7.8	5.1	6.8	(87.1) 86.2
Whenuapai	1921–50	3.7	4.4	3.1	4.5	5.4	6.0	6.2	4.7	4.2	4.5	3.6	3.5	53.8
Riverhead	1921–50	3.8	4.6	3.4	4.7	5.7	6.2	6.7	5.1	4.4	4.6	3.8	3.5	56.5
Woodhill	1921–50	3.5	4.1	3.0	4.2	5.2	5.5	5.6	4.7	3.9	4.2	3.4	3.3	50.6
Parkhurst	1958–61	2.9	4.5	2.9	3.1	5.1	5.3	5.2	4.0	3.7	3.0	2.0	4.8	46.5
Dairy Flat	1953–65	2.7	3.8	4.1	4.6	6.5	6.6	6.7	6.3	4.2	5.0	3.0	3.8	57.3
Tiritiri	1947–65	2.0	3.1	2.7	3.6	4.2	4.5	4.6	4.9	2.9	3.5	3.1	2.8	41.9

Table 2. Average evaporation and rainfall (ins.) at Mangere and Otara 1962–65.

Station		J	F	M	A	M	J	JY	A	S	O	N	D	Year
Mangere	Evaporation	7.4	5.7	4.4	2.5	1.7	1.4	1.4	1.7	3.1	4.3	5.7	6.1	45.4
	Rainfall	2.7	2.7	4.6	3.2	5.4	4.8	5.6	5.8	2.9	3.9	3.1	3.5	48.2
Otara	Evaporation	7.1	5.7	4.6	2.9	1.7	NA	NA	1.7	3.0	3.9	5.5	6.5	NA
	Rainfall	3.8	2.6	4.0	3.2	4.5	5.0	6.2	5.9	3.3	4.2	2.9	3.4	49.0

NA = Not Available.

Table 3. Variation of annual rainfall totals (ins.) and number of raindays at selected stations.

Selected Stations	Period	Mean Annual Rainfall	Minimum Annual Rainfall	Maximum Annual Rainfall	Average Number of Raindays	Minimum Number of Raindays	Maximum Number of Raindays
Pokeno	1953–65	54.3	43.5	71.3	178	151	204
Waiuku	1941–65	57.2	41.5	83.9	199	155	239
Manukau Heads	1941–43, 1947–59, 1961–65. (1921–50)	40.3 (44.9)	27.5	61.6	164	128	205
Kohukohunui	1949–64	91.4	66.5	116.0	NA	NA	NA
Oratia Henderson	1948–65 (1921–50)	63.5 (62.1)	44.9	91.9	185 (185)	150	201
Riverhead	1941–65 (1921–50)	57.8 (56.8)	42.9	77.1	188 (188)	153	221
Woodhill	1948–65 (1921–50)	52.1 (50.6)	39.6	64.8	178 (180)	145	213
Parkhurst	1958–61	46.5	41.4	51.3	150	127	175
Dairy Flat	1953–65	57.3	40.2	75.6	192	168	215
Tiritiri	1947–65	41.9	31.2	60.8	154	126	185

Table 4. Percentage variation of annual totals of rainfall compared with mean at selected stations.

Selected Stations	Period	Mean Annual Rainfall (ins.)	% Variation of Minimum Annual Rainfall	% Variation of Maximum Annual Rainfall
Waiuku	1941–65	57.2	37.8	64.3
Manukau Heads	1941–43, 1947–59, 1961–65.	40.3	31.8	52.9
Oratia Henderson	1948–65	63.5	29.2	44.7
Riverhead	1941–65	57.8	25.7	33.4
Woodhill	1948–65	52.1	24.3	24.3
Tiritiri	1947–65	41.9	25.5	44.9

Rainfall variability is a feature of New Zealand, as shown by Seelye (1940) and by Coulter (1966) with specific reference to northern New Zealand. Variability of annual rainfall is defined as the average departure of the annual totals from the long-term mean expressed as a percentage of the mean. The map drawn by Seelye shows that variability ranges from 12 per cent in the South Auckland lowlands to 16 per cent on parts of the east coast of the area. The increase in variability in areas affected by winds from an easterly quarter can be explained by "the effect of cyclones of tropical origin, and the erratic occurrences of these and the heavy rains associated with them" (Seelye, 1940: p. 18B).

Rain falls on between 160 and 180 days on the average in rural Auckland although values as low as 126, 127 and 128 days have been recorded at Tiritiri, Parkhurst and Manukau Heads respectively and as high as 239 and 221 days at Waiuku and Riverhead (Table 3). Daily data is unfortunately not available for comparative purposes from many of the recording stations with the greatest annual totals — those in the Hunua and Waitakere Ranges.

Periods of high intensity rainfall occur although they are not as common as in, for example, the East Coast region around Gisborne or parts of the Coromandel Peninsula. Maximum recorded rainfalls for a series of different durations have been prepared by the New Zealand Meteorological Service (1964). Data for stations in the Auckland rural area is given in Table 5 which shows that within the area high intensity rainfalls are recorded although these are not as extreme as those recorded, for example, at Waihi or Tauranga. Maximum daily rainfalls recorded exceed four inches at most of the stations in the rural Auckland area. Table 6 shows the maximum daily rainfalls by months for selected stations in the area. It can be seen that the month in which the maximum daily fall has been recorded varies from station to station but that the two highest 24-hour period rainfalls occurred last summer — in February — at Waiuku and Riverhead.

Table 5. Maximum recorded rainfalls of given durations at selected stations (ins).

Station	Years of Record	Minutes				Hours					
		10	20	30	60	2	6	12	24	48	72
Dairy Flat ...	11	0.62	0.75	0.94	1.37	2.01	3.07	4.39	4.96	5.77	8.08
Whenuapai ...	17	0.88	1.18	1.34	1.94	2.31	3.84	5.51	5.51	6.12	8.97
Otara	11	0.64	0.85	1.04	1.53	1.96	2.99	4.63	5.72	6.69	6.69
Pokeno ...	11	0.74	1.41	1.54	1.55	1.64	2.77	3.77	5.00	6.01	8.76
Waihi*	14–38	0.85	1.12	1.80	2.50	3.60	6.00	11.30	13.30	18.60	23.80
Tauranga* ...	19	1.33	2.00	2.67	3.75	5.75	8.35	8.69	9.04	10.31	10.79

* Included for comparison.

Table 6. Maximum daily rainfalls at selected stations.

Station	Period	Maximum daily fall (ins.)											
		J	F	M	A	M	J	JY	A	S	O	N	D
Waiuku	1941–65	2.1	6.2	3.9	2.7	2.5	3.5	2.9	—	3.4	2.4	—	3.2
Manukau Heads ...	1941–43, 1947–59, 1961–65.	3.6	3.1	3.6	4.3	3.7	3.1	2.2	3.1	—	—	2.5	—
Oratia Henderson	1921–50	3.4	4.0	4.0	4.3	3.8	2.9	3.0	2.2	2.0	1.9	3.9	3.5
Whenuapai ...	1943–60	3.1	3.2	3.2	4.8	3.4	2.6	2.4	2.4	2.5	2.5	3.5	2.5
Riverhead ...	1921–50	4.2	7.5	4.9	4.1	4.3	2.9	3.6	3.8	2.5	2.5	4.5	2.5
Woodhill ...	1921–50	2.1	3.1	2.4	2.5	3.2	2.3	2.6	2.3	1.9	1.9	3.0	3.0
Tiritiri	1947–65	2.5	4.3	2.7	3.2	2.3	3.4	4.8	3.8	—	—	2.7	—

Such intense falls of rain have serious effects on the area both in terms of economical losses caused by flooding, damaged roads and crops and in loss of life on occasions and loss of land. This results from accelerated mass movement as has occurred in the Ness and Orere Valleys in the Hunuas after periods of high-intensity rainfall in August 1965 and February 1966 and 1967. In some areas of the Hunua foothills up to 20 per cent of the land under pasture was lost as a result of major mass movement features resulting from the high-intensity rainfall of February 1966 when more than seven inches were recorded at Cossey's Dam in nine hours. Heavy rains in February 1967 also caused further erosion. At Konini, between 7 a.m. on February 3rd and 1 a.m. on February 4th more than 10.5 inches of rain fell with a maximum intensity of 1.1 inches in 18 minutes (Figure 3).

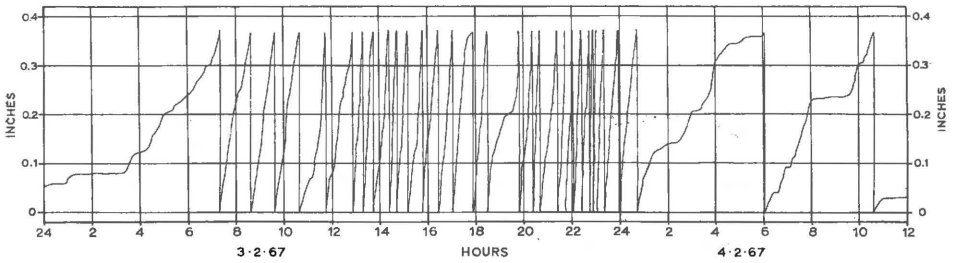

Figure 3. Example of high-intensity rainfall recorded at Konini in the Hunua Ranges, February 3rd - 4th, 1967.

Robertson (1963) has studied the frequency of high-intensity rainfalls in New Zealand by a statistical analysis of recording raingauge data. He has shown that the amounts of rainfall in periods of 10 and 30 minutes and 1, 12, 24 and 72 hours likely to be exceeded once in 2, 5, 10, 20 and 50 years at Whenuapai are as follows (Table 7).

Table 7. Estimated frequency of high-intensity rainfalls at Whenuapai.

	Amount of rain (ins.) once in:				
Duration of Fall	2 years	5 years	10 years	20 years	50 years
10 minutes	0.39	0.59	0.71	0.83	0.99
20 minutes	0.60	0.87	1.05	1.23	1.45
1 hour	1.09	1.46	1.70	1.93	2.22
12 hours	2.60	3.49	4.07	4.63	5.36
24 hours	3.12	4.48	5.37	6.22	7.33
72 hours	4.47	6.55	7.91	9.22	10.91

OTHER FORMS OF PRECIPITATION

Forms of precipitation other than rain are not commonly recorded in the Auckland rural area. Hail occurs on the average a maximum of less than four days a year in the area. Hail is normally associated with violent turbulence associated with thunderstorms occurring at the passage of a cold front or as a result of strong surface heating. Figures for the occurence of hail are shown in Table 8. Paerata records an average of 3.7 days of hail a year, while Oratia Henderson has an average of less than one day per year. As would be expected, snow is not a normal occurrence at this latitude and the long-term averages show a complete absence of records of snow. However, snow has occurred on rare occasions in the Hunua Ranges and also in the Waitakere Ranges — for example on 8 and 9 July, 1939, 14 August, 1939, 26 July, 1945, and 28 September, 1949 (Gluckman, 1963: p. 38).

Table 8. Days of hail at selected stations.

Station	Period	J	F	M	A	M	J	JY	A	S	O	N	D
Maioro	1940–60	0.1	0.1	—	0.1	0.3	0.6	0.4	0.6	0.1	0.2	0.4	0.1
Paerata	1944–59	—	—	—	0.1	0.1	0.7	0.6	0.7	0.3	0.5	0.4	0.2
Otara	1952–60	—	—	—	0.1	0.4	0.6	0.6	0.7	0.2	0.3	—	0.2
Oratia Henderson	1948–60	—	—	—	—	—	0.1	—	0.2	0.1	—	—	—
Whenuapai ...	1945–60	—	—	—	0.1	0.2	0.4	0.4	0.8	0.4	0.6	0.4	0.1
Riverhead ...	1928–60	—	—	0.1	—	0.4	0.4	0.8	0.4	0.5	0.4	0.3	0.1
Woodhill	1928–60	—	—	0.1	0.1	0.4	0.7	0.4	—	—	0.6	0.3	—

Table 9. Number of days with fog at selected stations

		Number of days with fog												
Station	Period	J	F	M	A	M	J	JY	A	S	O	N	D	Year
Maioro	1940–60	0.8	1.1	1.6	1.8	3.0	3.1	3.4	2.1	1.4	0.8	0.4	0.6	20.1
Paerata	1944–59	1.4	1.2	1.9	1.4	2.3	1.4	1.9	1.1	1.5	1.1	0.9	0.3	16.4
Otara	1952–60	0.2	0.2	0.8	2.6	2.2	2.2	2.7	2.2	1.3	0.1	0.3	0.1	14.9
Oratia Henderson	1948–60	—	—	—	0.5	1.0	0.2	1.1	0.9	0.4	—	—	—	—
Whenuapai ...	1945–60	2.6	4.1	4.7	6.5	7.1	6.3	7.0	6.1	5.4	2.9	3.6	2.9	59.2
Riverhead ...	1928–60	0.6	0.9	2.5	1.6	2.5	2.4	1.6	2.0	1.1	0.2	0.2	0.4	16.0
Woodhill ...	1952–60	—	1.1	1.4	1.9	2.4	1.7	2.4	1.8	1.0	0.7	0.4	0.2	15.0

FOG

Fogs in the Auckland rural area are most frequently recorded at Whenuapai and least often at Oratia Henderson (Table 9). The fogs are mainly of the radiation type although some frontal fog also occurs. Localised fog conditions may be intensified by cold air drainage thus accentuating radiation cooling and may be aggravated by the addition of contaminants. Pollution is, however, mainly a problem within the urban area although the effects of the iron and steel industry at Waiuku have yet to be seen. It is anticipated, however, that by making use of the most modern air pollution control equipment available, this major industry will not pollute the environment around Glenbrook. Fogs occur most frequently during late autumn and winter months with July being generally the foggiest month and summer being relatively fog-free throughout the area.

Fog at Whenuapai has been studied by Moir (1944) and Kerr (1950). Moir showed that katabatic winds flowing from the ranges to the west at a speed of one - three miles per hour aid in fog formation. Fogs are usually densest to the north and east of Whenuapai, close to the Waitemata Harbour. As cooling continues fog forms over the low hills to the south-east — if conditions for fog formation continue then the entire Whenuapai area becomes blanketed in thick fog. Minimum temperatures were found to coincide within half an hour of sunrise. Moir went on to show that most fogs clear within two hours of sunrise and are normally between 100 and 150 feet deep, although occasionally may reach 500 feet. Kerr suggested that fogs lasted for 2.2 hours on average after sunrise and in some extreme cases up to seven hours. Practical results of this work were achieved by producing some rules for forecasting the time of clearance of fogs at Whenuapai aerodrome.

SUNSHINE

The Auckland rural area receives approximately 2000 hours of bright sunshine a year on the average. This represents 48 per cent of the possible sunshine and compares with the 57 per cent recorded at Nelson aerodrome. Data from Whenuapai and Mangere is given in Table 10. Maximum duration of bright sunshine is recorded in January which has an average of 7.8 hours of sunshine at Mangere while July has the lowest hourly average of 3.1. January has the highest percentage of possible sunshine and May the lowest at Whenuapai. Sunshine hours vary both locally during any one year and at the same station over a number of years. Over the period 1964-65 the differences between Whenuapai and Mangere were less than those shown in Table 10. A maximum monthly difference of 10 hours was recorded in September when Whenuapai recorded 166 hours of bright sunshine compared with Mangere's 156.

TEMPERATURE

Extreme maximum temperatures in the area have all been above 85° F. while extreme minima have varied from 21.7° F. at Riverhead to 29.8° F. at Paerata. The extreme range of temperature is over 60° F. at all stations in the rural area except at Paerata where the extreme range is 57° F. (Table 11). Woodhill has recorded an extreme maximum of 88° F. which is 2.4° F. less than the Albert Park maximum in the urban area. Undoubtedly higher and lower extremes occur in areas away from recording stations such as in the sand dune country on the West Coast. The absolute range of temperature in the area is 66° F. compared with 58° F. at Albert Park and 71° F. at Dunedin, 78° F. at Christchurch and 59° F. at Wellington. Figures 4 and 5 are a series of graphs which show the extreme maximum and minimum, the mean daily maximum and minimum and mean monthly maximum and minimum temperature in degrees Fahrenheit for seven of the climatological recording stations in the Auckland rural area. It can be seen from these graphs that the average daily summer maximum temperatures are over 70° F. except in coastal areas where they are just below 70° F. Otara, in February, has the highest average daily maximum of almost 76° F. Daily maxima in winter are in the high 50°'s F. with Woodhill, Otara, Paerata, Oratia Henderson and Maioro all recording 57° F. in July — Riverhead and Whenuapai are approximately 1° F. warmer. Average daily maximum temperatures show a range from 16° F. at Riverhead and Maioro to 19° F. at Otara.

The extreme minimum in the area has been at Riverhead in June when a temperature of 21.7° F. was recorded. Extreme minimum temperatures have also been recorded in June at Whenuapai and Riverhead while July has been the month in which Maioro, Oratia Henderson and Otara have recorded extreme minima and August at Paerata has been fractionally colder than June. Not all stations' extreme minima are below freezing point and no station in the area has an average daily minimum in winter below 39° F. During the summer months daily minimum temperatures range from 51° F. in December at Riverhead to 60° F. at Woodhill in February. The range of average daily minimum temperatures varies from 14° F. at Paerata, Woodhill and Riverhead to 19° F. at Otara. This range of daily minimum temperatures is thus of the same order of magnitude as the range of daily maxima indicating that there is not as great a contrast between average daily maxima and minima as in more inland parts of the central North Island or in inland South Island.

The mean daily range and the extreme range of temperatures are shown in Table 11. The mean daily range is generally highest in late summer and early autumn, 20.0° F. in March at Riverhead being the highest range recorded. Lowest ranges occur, as would be expected, in winter and spring — for example, 11.9° F. at Woodhill in June. The extreme daily range varies from 51° F. at Riverhead in March to 34.7° F. at Woodhill in November. Extreme ranges of over 40° F. occur

Table 10. Mean hours of bright sunshine and sunshine as percentage of possible at Whenuapai 1954–60.
Mean hours of bright sunshine at Mangere 1964–65.

		J	F	M	A	M	J	JY	A	S	O	N	D	Year
Mean hours bright sunshine	Mangere	241	191	156	155	134	109	108	123	156	184	194	249	2000
	Whenuapai	225	185	175	162	126	118	129	155	170	187	215	214	2061
Percentage of Possible	Whenuapai	52	50	48	50	42	43	44	49	50	48	53	49	48

Table 11. Mean daily range (a) and extreme range (b) of temperature at selected stations (°F.)

Selected Stations	Period		J	F	M	A	M	J	JY	A	S	O	N	D	Year
Maioro	1940–60	(a)	14.3	15.4	15.6	14.4	14.0	13.7	14.5	14.3	14.6	13.7	13.7	13.6	14.3
		(b)	40.3	39.0	49.7	46.5	46.3	39.2	40.9	42.0	38.8	39.9	44.6	42.6	60.9
Paerata	1944–59	(a)	18.8	18.9	18.1	16.2	14.8	14.9	14.7	15.0	16.1	15.9	17.6	17.6	16.6
		(b)	44.9	43.4	48.0	42.8	43.0	36.2	48.0	39.5	40.9	43.5	42.4	42.8	57.1
Otara	1952–60	(a)	16.7	16.7	16.5	16.7	15.0	14.8	16.5	15.7	16.4	14.6	15.7	15.3	15.9
		(b)	43.6	42.7	50.2	43.8	40.2	42.6	41.0	40.4	38.7	39.1	39.4	42.4	60.4
Oratia Henderson	1948–60	(a)	18.6	18.4	17.8	17.3	15.7	15.3	16.4	17.0	17.5	16.3	17.5	17.5	17.1
		(b)	44.5	43.1	47.4	45.0	44.5	41.8	40.4	42.6	40.3	41.7	41.9	45.2	60.6
Whenuapai	1945–60	(a)	18.1	18.6	18.1	16.5	15.4	15.3	15.8	15.9	16.5	15.1	16.5	16.8	16.5
		(b)	44.5	47.3	50.1	47.9	46.9	45.6	41.0	42.6	39.8	41.8	44.7	47.8	62.7
Riverhead	1928–60	(a)	19.5	19.6	20.0	18.4	17.9	17.1	17.7	18.1	18.9	17.6	18.3	18.9	18.5
		(b)	50.3	50.4	51.0	50.3	50.1	47.3	43.7	43.5	46.0	48.5	50.2	50.1	64.7
Woodhill	1952–60	(a)	14.4	14.7	14.0	13.1	12.0	11.9	13.2	13.1	13.1	12.0	12.6	13.0	13.1
		(b)	42.2	38.9	47.5	39.7	39.2	39.8	38.1	35.6	35.7	39.2	34.7	40.0	60.8

during one or more months at all stations in the area and at Otara, Riverhead and Whenuapai extreme ranges of over 50° F. have been reported.

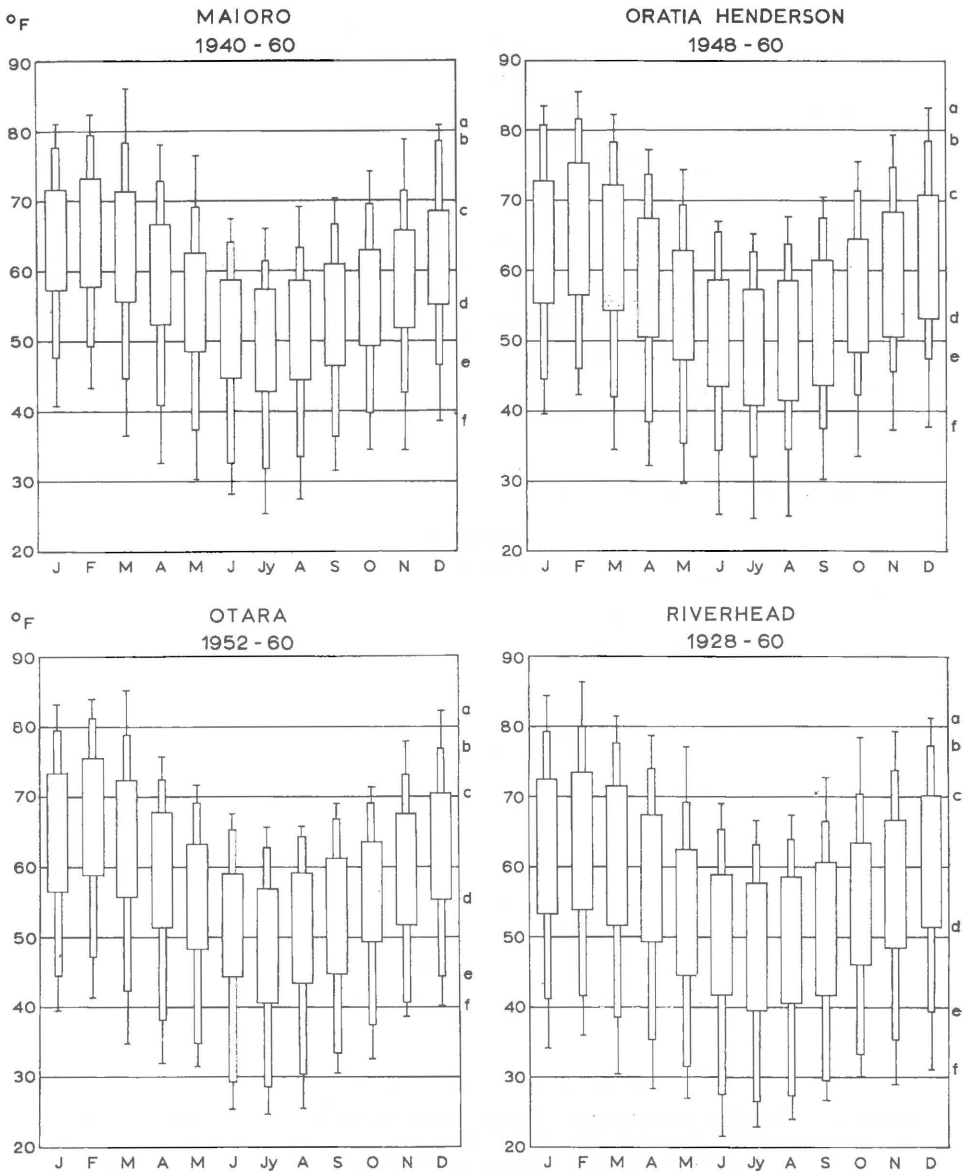

Figure 4. Monthly temperatures. Temperatures shown are: (a) highest recorded; (b) mean monthly maxima; (c) mean daily maxima; (d) mean daily minima; (e) mean monthly minima, and (f) lowest recorded.

Temperature inversions occur as a result of radiation cooling in the rural Auckland area particularly in autumn and winter. De Lisle (1966) has shown that multiple inversions are common and that most inversions are less than 660 feet deep. The frequency of temperature inversions is of obvious significance when considering the location of industrial plants in the Auckland rural area such as the steel mill at Glenbrook or the gas turbine electricity generating station at Otara.

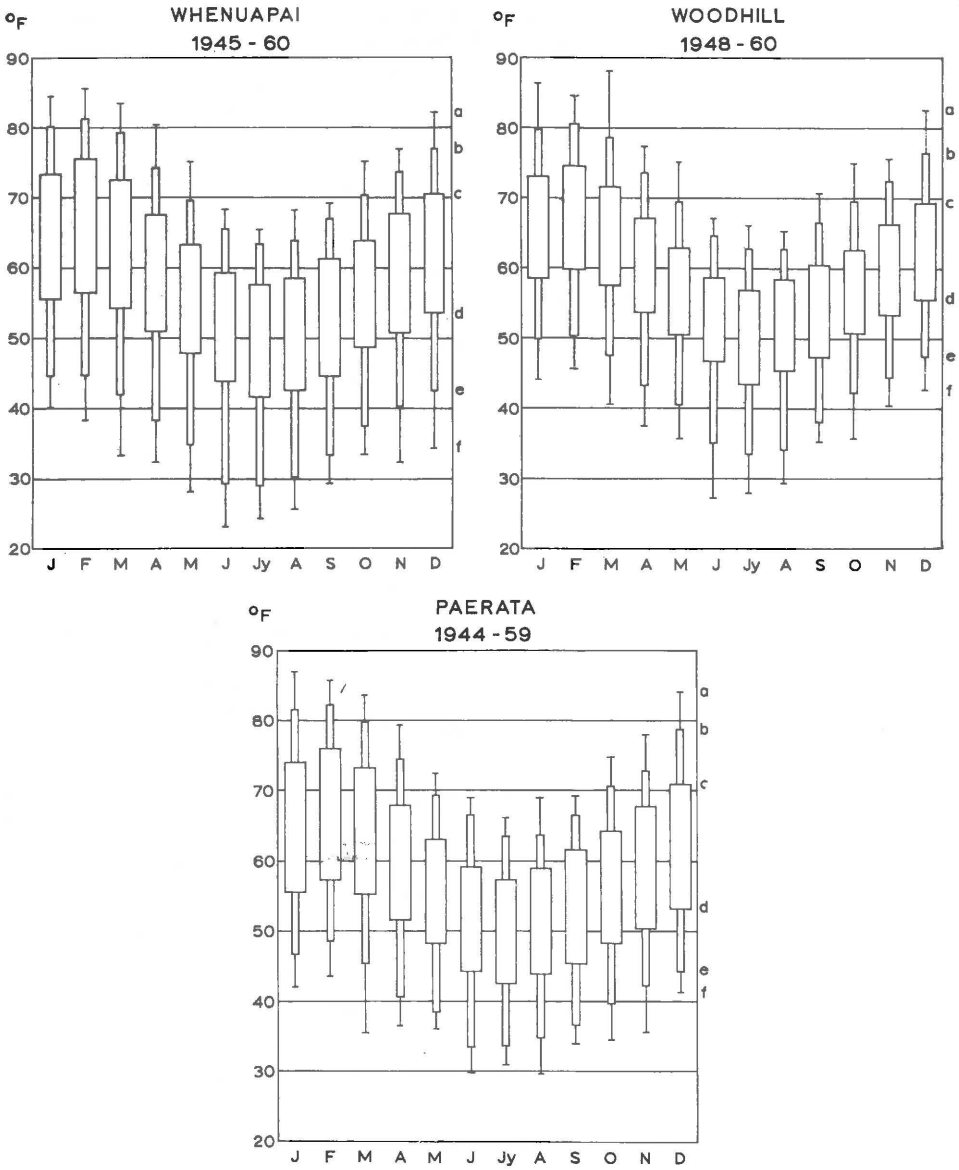

Figure 5. Monthly temperatures. Temperatures shown are: (a) highest recorded; (b) mean monthly maxima; (c) mean daily maxima; (d) mean daily minima; (e) mean monthly minima, and (f) lowest recorded.

FROST

Because the Auckland area lies to the north of latitude 37° 22′ it is not surprising to find that frosts occur on far fewer occasions than in regions in the south of New Zealand. Ground frosts are recorded when the grass minimum thermometer reads 30.4° F. or below while a screen or air frost is reported when the minimum temperature in the Stevenson Screen reaches 32° F. or less. Table 12 shows the occurrence of screen and ground frosts for the rural Auckland reporting stations. The maximum number of screen frosts recorded on average is at the forestry headquarters at Riverhead State Forest while the minimum number is at Paerata on the gently rolling ash covered South Auckland lowlands. Ground

Table 12. Average number of days on which a ground frost (a) and a screen frost (b) is recorded at selected stations.

Selected Stations	Period	J	F	M	A	M	J	JY	A	S	O	N	D
Maioro	1940–60 (a)	—	—	0.2	0.4	2.1	3.2	4.9	1.8	0.4	—	0.1	—
	(b)	—	—	—	—	0.1	1.0	1.6	0.8	0.1	—	—	—
Paerata	1944–59 (a)	—	—	0.1	0.6	0.6	4.9	9.2	6.0	3.6	0.6	—	—
	(b)	—	—	—	—	—	0.1	0.2	0.3	—	—	—	—
Otara	1952–60 (a)	—	—	0.6	1.1	3.7	8.2	11.2	8.2	5.3	0.8	0.2	—
	(b)	—	—	—	—	0.1	1.9	4.2	1.1	0.3	—	—	—
Oratia Henderson	1948–60 (a)	—	—	0.2	1.2	2.5	5.4	8.8	7.2	3.5	0.5	—	—
	(b)	—	—	—	—	0.2	2.0	3.8	1.8	0.7	—	—	—
Whenuapai	1945–60 (a)	—	—	0.2	1.4	2.7	6.2	7.6	7.3	4.9	1.4	0.4	0.4
	(b)	—	—	—	—	0.2	2.3	3.0	1.2	0.4	—	—	—
Riverhead	1928–60 (a)	0.1	0.1	0.5	1.4	4.5	7.2	9.9	8.9	6.1	2.6	0.8	0.1
	(b)	—	—	0.1	0.4	1.7	4.6	6.2	5.2	2.6	0.5	0.1	—
Woodhill	1952–60 (a)	—	—	—	0.1	0.2	2.4	4.3	3.9	1.0	0.6	—	—
	(b)	—	—	—	—	—	0.9	1.4	0.8	—	—	—	—

frosts occur more frequently with over 30 per year being recorded at Riverhead and Whenuapai and 42 at Otara. Maioro and Woodhill near the West Coast each record approximately 13 frosts per annum. July is the frostiest month throughout the area and the summer months are frostless except for very occasional ground frosts at Whenuapai and Woodhill. In sheltered areas, and in areas influenced by cold air drainage, the incidence of frost is higher than apparent from the figures in Table 12. The maximum number of frosts recorded is considerably above the average and at Oratia Henderson, for example, up to 56 frosts in one year have occurred with 20 in August 1950 being the maximum for a single month (Figure 6).

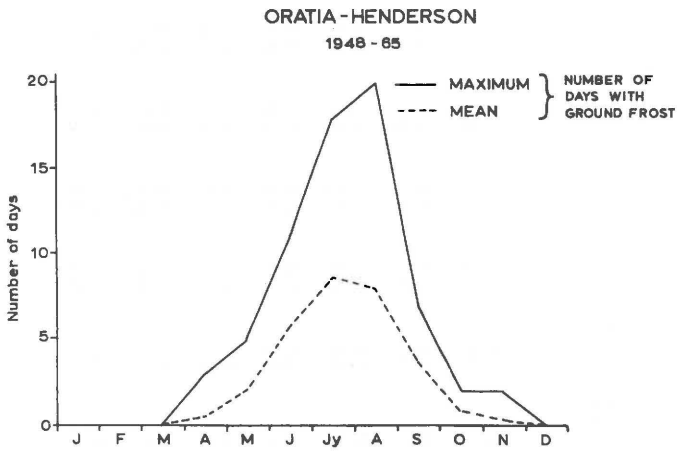

Figure 6. Maximum and mean number of days on which a ground frost has been recorded at Oratia Henderson, 1948-65.

OTHER CLIMATIC FEATURES

Data referring to hourly wind velocity and direction is available only from Whenuapai in the Auckland rural area . Information concerning wind direction is published for all the climatological recording stations in the area under consideration as is the average wind velocity at Woodhill, Oratia Henderson, Otara and Maioro. Average 24-hour wind speeds range from 3.6 miles per hour at Oratia Henderson to 6.1 miles per hour at Woodhill over the period 1950-65. Average maximum daily velocities vary from 19.4 miles per hour at Woodhill to 11.6 miles per hour at Oratia Henderson. Wind roses from Whenuapai and Tiritiri are shown in

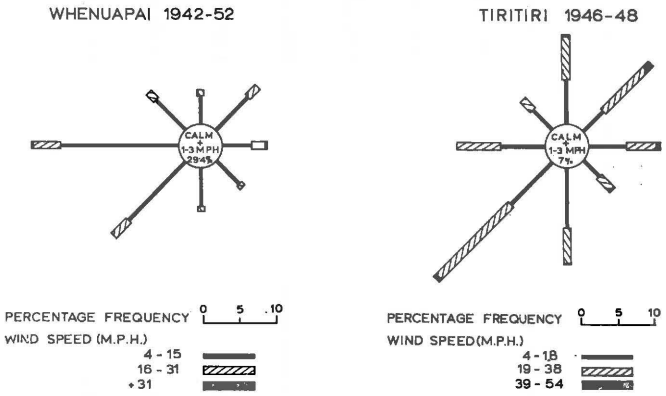

Figure 7. Mean annual percentage frequency direction of wind at Tiritiri and Whenuapai from hourly mean winds at three-hour intervals.

Figure 7 illustrating the prime importance of winds from a westerly quarter. North-easterly and easterly winds are also significant and account for the greatest frequency of winds in excess of 39 miles per hour at the exposed east coast station of Tiritiri (Healy, 1967). Wind directions for eight climatological or synoptic recording stations are shown on Figure 8. This map indicates that in the entire rural area winds from a westerly quarter predominate. South-westerlies are most

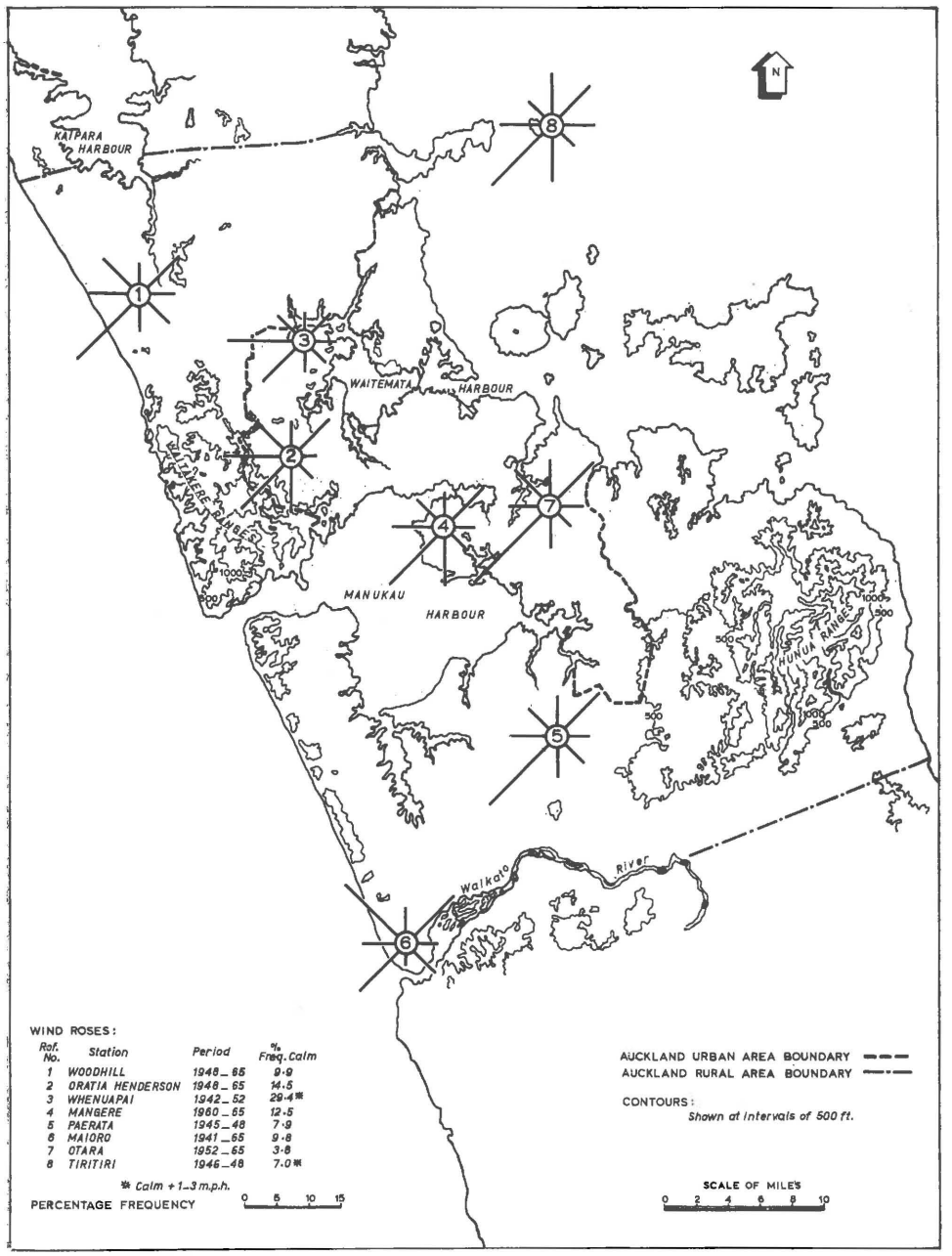

Figure 8. Located wind roses for eight recording stations in the Auckland rural area.

important except at Whenuapai where westerlies occur most often and at Maioro which is most frequently affected by north westerlies. Easterlies and north-easterlies are also important at all stations and it is generally winds from this quarter that cause structural and other damage in the area and have speeds of up to 40 miles per hour. Gusts of over 65 miles per hour occur in the area from time to time (Gluckman, 1963: p. 26).

Calms occur from less than four per cent of the time at Otara to 29 per cent of the time at Whenuapai. Oratia Henderson is also sheltered by the Waitakere Ranges from the prevailing westerlies and has 15 per cent calms at the time observations are made.

Tornadoes occur in this part of New Zealand from time to time. Seelye (1945) grouped the Auckland and Taranaki provinces and the West Coast of the South Island as the areas most affected in the country. The majority of tornadoes appear to be associated with the passage of a front and are particularly notable in south-westerly conditions, although in the Auckland area tornadoes occur most frequently in December and accompany gale-force winds from the north-east (Gluckman, 1963: p. 32). The tornadoes which occur in New Zealand are only small-scale systems with diameters measured in tens of yards and have tracks of very limited length.

Thunderstorms are more common in the Auckland area than in many other parts of the North Island (Kidson and Thompson, 1931). Oratia Henderson records less than one a year on average while Otara may record a dozen with a slight tendency for thunder to occur most frequently in autumn, early summer and winter.

Soil temperatures are recorded at 0900 hours N.Z. Standard Time at one foot depth at all climatological stations except Riverhead and at three feet at Maioro, Oratia Henderson and at Woodhill. At the one-foot depth variations occur from 72° F. in February at Woodhill to 50° F. at Oratia Henderson in July. These temperatures are 5° F. and 1° F. above the average daily air temperature at the same time. Three feet below the ground surface temperatures reach 70° F. in February at Maioro and Woodhill and 54° F. at Oratia Henderson in August. The temperatures at three feet below the surface are 2 - 3° F. higher from March to September than those at one foot and colder for the months October to February (Figure 9).

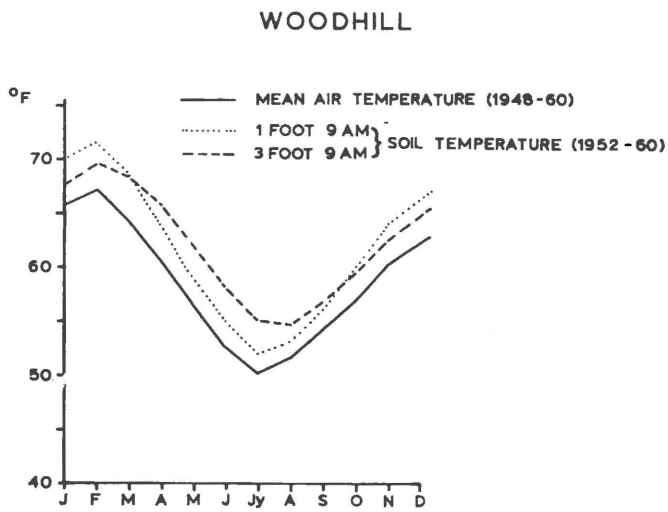

Figure 9. Mean air temperatures and soil temperatures at Woodhill.

SUMMARY

As has been seen, the climate of the Auckland rural area is not as distinctive as that of some regions of New Zealand and is not marked by dramatic extremes of climatic elements. However, the area does possess characteristics of rainfall, temperature, wind and other climatic elements which make it of interest and different from the rural areas to the south and north and from the urban area of Auckland. Variations occur within the area defined and one of the main contrasts is in the average annual rainfall of the area which ranges from over 90 inches in the Hunuas to less than 40 inches at Tiritiri. Temperatures are generally warm throughout the year and frosts are not recorded as frequently as in the Waikato Valley to the south for example although occasionally up to 60 ground frosts per annum may occur. Tornadoes and thunderstorms occur in the area and the importance of north-easterly winds and associated heavy rainfalls are further distinctive features of the climate of the Auckland rural area. High annual sunshine amounts and high humidities are also well-known attributes of the climate of this area of Northern New Zealand.

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REFERENCES

Coulter, J. D., 1966: Flood and drought in northern New Zealand: *N.Z. Geogr.*, 22 (1): pp. 22-34.

de Lisle, J. F., 1965: The climate of Auckland in *Science in Auckland.* ed. L. O. Kermode, Auckland: pp. 2-6.

————, 1966: Temperature inversions over South Auckland. *Unpub. report, N.Z. Met. Serv.*

————, 1967: The climate of the Waikato Basin. *Earth Sci. Jnl,* 1 (1): pp. 2-16.

Department of Statistics, 1967: *Monthly abstract of statistics, October, 1967.* Department of Statistics, Wellington: p. 15.

Finkelstein, J., 1961: Estimation of open water evaporation in New Zealand. *N.Z. J. Sci.*, 4 (3): pp. 506-522.

Garnier, B. J., 1958: Northern New Zealand in *The climate of New Zealand.* London: pp. 71-86.

Gluckman, Ann J., 1963: *Climates of Auckland.* Unpub. M.Sc. thesis, Univ. of Auckland: 205 pp.

Healy, T. R., 1967: *The shore platforms of the Whangaparaoa Peninsula.* Unpub. M.Sc. thesis, Univ. of Auckland: pp. 12-14.

Kerr, I. S., 1950: The duration of fogs at Whenuapai. *Unpub. report, N.Z. Met. Serv.*

Kidson, E., and Thompson, A., 1931: The occurrence of thunderstorms in New Zealand. *N.Z. J. Sci. Tech.*, 12 (4): pp. 193-206.

Moir, R. W., 1944: Radiation fogs at Whenuapai, and associated meteorological phenomena. *Unpub. report, N.Z. Met. Serv.*

N.Z. Met. Service, 1964: Maximum recorded rainfalls of given durations. *N.Z. Met. Serv. Misc. Pub.*, 121: 4 pp.

Robertson, N. G., 1960: The frequency of high-intensity rainfalls in New Zealand. *N.Z. Met. Serv. Misc. Pub.*, 118: 84 pp.

Seelye, C. J., 1940: The variability of annual rainfall in New Zealand. *N.Z. J. Sci. Tech.*, 22: pp. 18B-21B.

————, 1945: Tornadoes in New Zealand. *N.Z. J. Sci. Tech.*, 27B: pp. 166-174.

Wright, L. W., 1966: The Muriwai debris-avalanche: some aspects of its form and genesis. *N.Z. Geogr.*, 22 (1): pp. 90-93.