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THE CLIMATE OF THE WAIKATO BASIN

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ABSTRACT

The topography of the Waikato Valley and its position in relation to the large-scale weather systems give it warm humid summers, mild winters and a moderate rainfall with a winter maximum.

Some typical meteorological situations affecting the valley are described and the individual climatic elements are considered in detail.

WEATHER SYSTEMS AFFECTING NEW ZEALAND

The upper atmosphere in the southern hemisphere resembles a gigantic vortex rotating in a clockwise (westerly) direction around Antarctica. This motion is caused by the rotation of the earth and the differences in the amount of solar radiation received in high and low latitudes.

At lower levels the winds in middle and high latitudes still blow mainly clockwise and cyclonic depressions and anticyclones seen on surface weather maps are found in the general westerly flow.

Anticyclones moving eastwards traverse New Zealand at average intervals of 6-7 days. In individual cases the intervals may be anywhere from about 2 days to 2 weeks. The path followed by the centre of an anticyclone may be to the north of New Zealand, across the country or sometimes to the south. The first type of track is more likely in winter and spring and the other two types in summer and autumn.

The air moves anticlockwise around an anticyclone so that on the eastern side of the low pressure trough between two anticyclones the wind is from a northerly or easterly quarter. On the western side the wind is from a westerly or southerly quarter.

When there are differences in temperature and humidity between the air on the eastern and western sides of the trough it contains a cold front generally oriented north-west to south-east. The front may extend to a deep depression centred well to the south of New Zealand.

Sometimes the anticyclones and trough systems move eastwards across New Zealand with little change. As the front passes over an area it gives a period of rain preceded by fresh north to north-west winds and followed by winds from a westerly or southerly quarter and showers.

It is, however, unusual for an anticyclone to move from Australia across the Tasman Sea and out to the east without changing its intensity, speed and direction of movement. These changes are closely related to developments in the low pressure trough which is an unstable region where vigorous storms may form. The storms are low-pressure systems (depressions) in which the wind blows in a clockwise direction. They often form in the north-west Tasman Sea and tend to move in a south-easterly direction growing in intensity as they move.

Tropical cyclones which form in the south-west Pacific in summer and autumn sometimes move towards New Zealand. The air in such storms is still warm and moist by the time they reach New Zealand and the resulting rainfall may be heavy.

WEATHER SYSTEMS AFFECTING THE WAIKATO VALLEY

The weather of the Waikato Valley is determined by the succession of anticyclones, by the fronts and by the cyclonic developments in the low pressure troughs. In most parts of New Zealand the organised weather systems are modified by the topography. The lower Waikato Valley and the Hauraki plains are sheltered to the east by the Kaimai and Coromandel Ranges and to the south by the central North Island plateau. To the north and to the west, the direction from which the prevailing wind blows, they are open.

Settled weather will be associated with the passage of anticyclones across the North Island. In summer such conditions may in extreme cases last up to about 4 weeks.

During the period 7th January-1st February, 1957, a series of anticyclones with centres south of the Waikato crossed the country. Fronts in the troughs between anticyclones were weak giving a wind change and a cloudy period but no rain as they crossed the Waikato Valley. Maximum temperatures were above average on most days and exceeded 80° F. on 5 days.

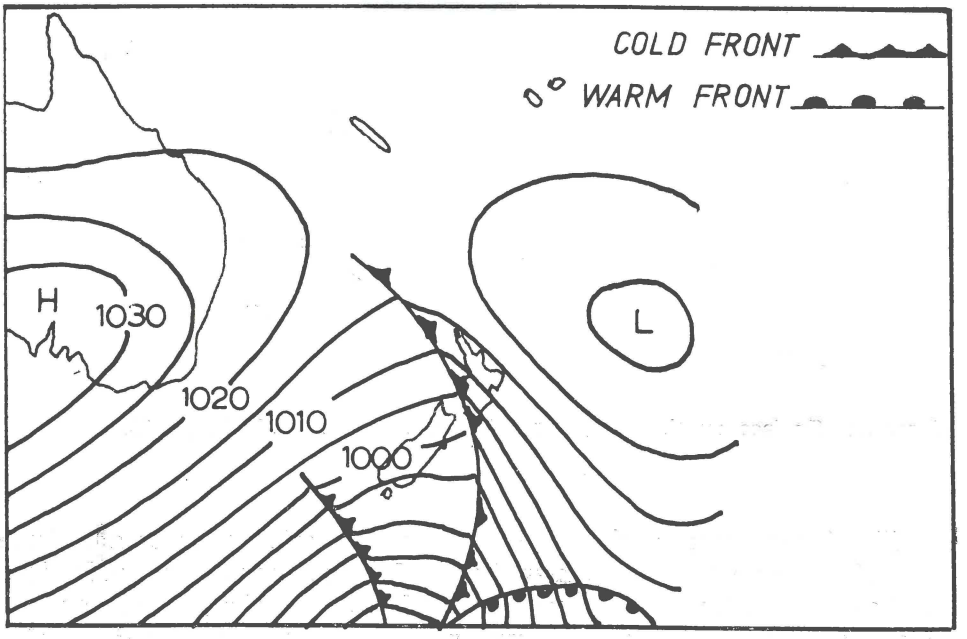

Figure 1: Surface weather map for 1800 hrs NZST on 4th July, 1962. Isobars at 5 millibar intervals.

In autumn and winter fronts are more vigorous. On 4th July, 1962, a front associated with a deep depression to the south of New Zealand passed over the country reaching the Waikato Valley in the evening. The surface weather map for 6 p.m. on 4th July, 1962, is shown in Figure 1. During the day, which had commenced in Hamilton with fog, skies became overcast and the wind a fresh northerly.

With the passage of the front there was $\frac{1}{2}$-$\frac{3}{4}$ inch of rain over most of the valley and a wind change to the west. Over the higher ground the rainfall was increased because of the extra vertical motion imparted to the air flowing up the slopes. At Pirongia there was $1\frac{1}{2}$ inches of rain with the frontal passage.

In situations of this type there are sometimes series of troughs connected with the one depression in high latitudes. In the above case another weaker front had passed over two days previously giving falls of up to $\frac{1}{4}$ inch.

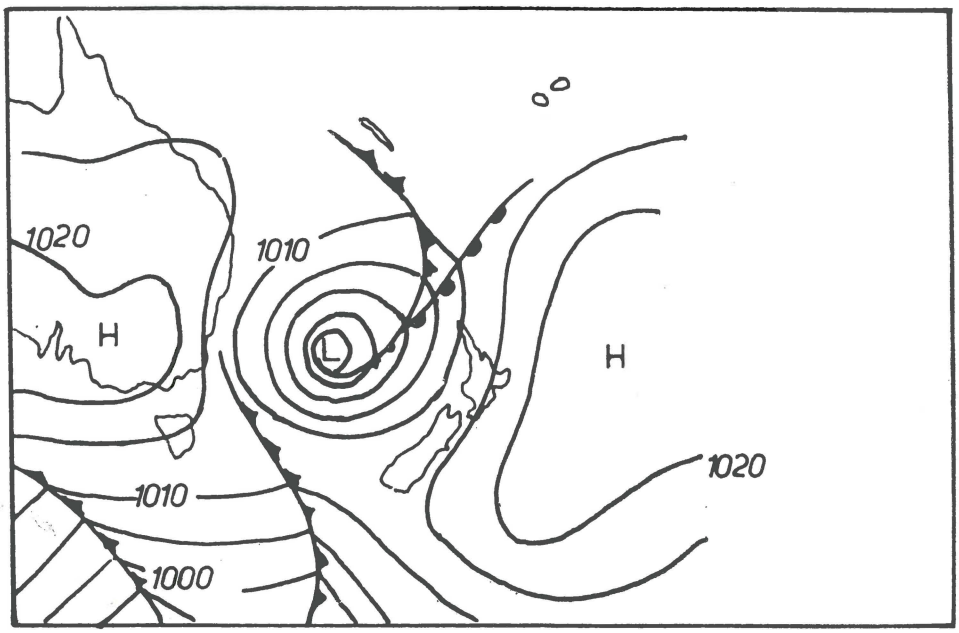

Figure 2: Surface weather map for 1800 hrs NZST on 3rd May, 1962.

Heavier and more prolonged rainfalls are experienced when a cyclonic depression forms in the Tasman Sea and moves south-eastwards. The weather map in Figure 2 for 6 p.m. on 3rd May, 1962, shows such a system which gave 1-$1\frac{1}{2}$ inches of rain over most of the valley. The depression centre crossed the South Island but the frontal systems passed over the Waikato Valley giving a longer period of rain than in the case of a simple cold front passage.

The heaviest rainfalls are produced by depressions moving over the area from the north or north-west and are associated with relatively warm, moist air. Figures 3 and 4 show situations which produced extensive flooding in the Waikato Valley in February 1958 and will be described in a later section.

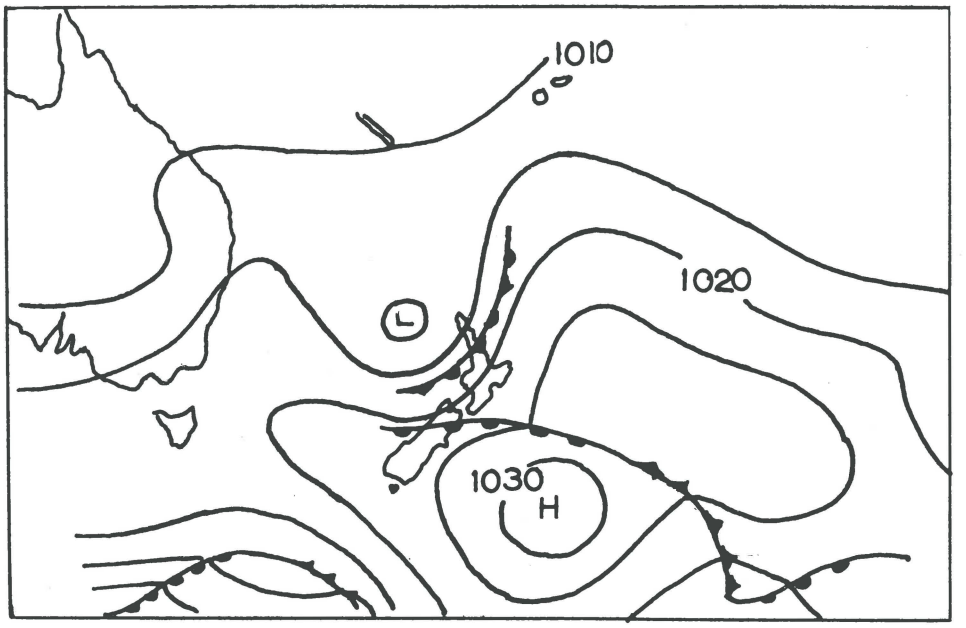

Figure 3: Surface weather map for 1200 hrs NZST on 17th February, 1958.

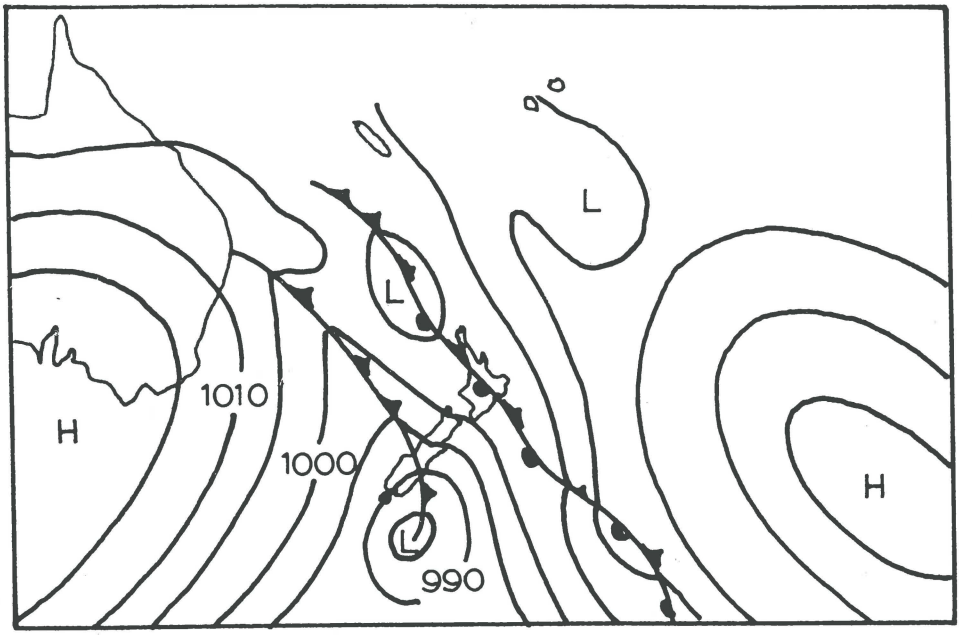

Figure 4: Surface weather map for 1800 hrs NZST on 23rd February, 1958.

THE CLIMATE OF THE WAIKATO VALLEY

The weather systems briefly described above produce in the Waikato a climate in which there are warm, humid summers, mild winters and an annual rainfall over most of the region of 45-60 inches. The rainfall has a winter maximum and is generally adequate for agricultural and pastoral purposes. There are, however, sometimes periods in summer when drought conditions prevail.

The climate is only the long term effect of the passage of the weather systems. The climatic elements which when taken together and considered from this long term viewpoint make up the climate are considered separately below.

Date for the study of climate are provided by:

(a) Climatological stations which record some or all of the elements, pressure, temperature, rainfall, humidity, sunshine, radiation and evaporation. The instruments are read once daily at 09 hours NZST and non-instrumental observations of weather are also noted.

(b) Rainfall stations which record rainfall only, at 09 hours NZST.

(c) Synoptic stations which provide weather reports several times daily for the network from which weather maps are drawn.

The positions of some of these stations are shown in Figure 6.

ELEMENTS OF CLIMATE

Wind

In the free air up to 10,000 ft. winds from a westerly quarter predominate in all seasons. They are most frequent in spring when they make up one half of all winds. At the surface also winds from directions between SW and NW predominate and have their greatest seasonal frequency in spring.

The distribution over the whole year of wind speed and direction at Rukuhia is shown in Figure 5.

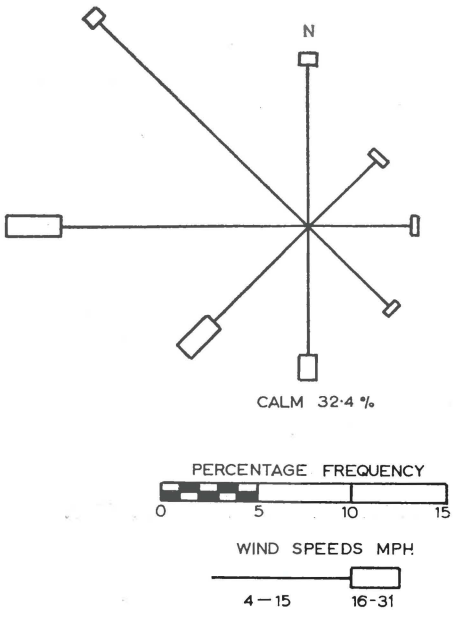

Figure 5: Mean annual percentage frequency of wind at Rukuhia (1946-50) from hourly mean winds at 3-hour intervals.

At Rukuhia the average wind speed for the whole year is 6.6 m.p.h. This is greater than that found in the most sheltered areas in New Zealand but less than that found in west coast areas. The mean wind speeds for a number of places are given in Table 1.

Table 1. Mean annual wind speeds (m.p.h.)

Whenuapai	8.2	Nelson	6.4
New Plymouth	11.5	Christchurch Airport	8.8
Rotorua	4.4	Westport	7.4
Tauranga	8.2	Taieri	8.0
Napier	6.9	Invercargill	9.7
Wellington (Evans Bay)	13.2		

Wind speeds at the surface tend to be greatest in spring and to have another smaller maximum in late autumn.

Some idea of the wind gustiness can be got by considering the average number of days a year with gusts of over 40 m.p.h. and 60 m.p.h.

Data from a continuously recording instrument at Rukuhia show it to be one of the less gusty places in the country having on the average only 23 days a year with gusts over 40 m.p.h. and one day a year with gusts over 60 m.p.h.

The highest gust so far measured is 74 m.p.h. from the WSW.

Calms and light winds occur on 1/2-2/3 of the time during night hours from late spring to autumn and in winter for about 1/3 of the time. On clear calm nights there will be a drainage of cold air down hillsides towards the river valleys.

When thunderstorm activity is associated with the passage of a cold front over western districts of New Zealand a cyclonic vortex sometimes forms in the base of the cloud and a tornado funnel reaches down to the surface. The resulting wind is extremely violent but the path of the disturbance is narrow—tens of yards across—and the length of the track a few miles.

A disastrous tornado cut a path through Hamilton East and Frankton on 25th August, 1948, causing some loss of life and destroying houses. Such occurrences are rare.

Rainfall

Over most of the Waikato Valley the average annual rainfall is 45-60 inches. Greater amounts are found over high ground reaching maxima of 100 inches or more over Pirongia and over the Kaimai Range. The distribution of average annual rainfall is found in Figure 6.

The distribution of the rainfall throughout the year is shown for a number of stations in Figure 7 where the monthly total which is exceeded in 90 per cent, 50 per cent and 10 per cent of years is shown.

It is seen that rainfall is spread fairly evenly throughout the year with a winter maximum and a summer minimum. The ratio of winter to summer rainfall is on the average about 1½ to 1.

Rain falls on 150-175 days a year on the average over the valley but the number of rain days is somewhat higher towards the coast.

Rainfall fluctuates from year to year and in a region where a reliable supply is needed for crops and pasture, low variability in both seasonal and annual amounts is desirable.

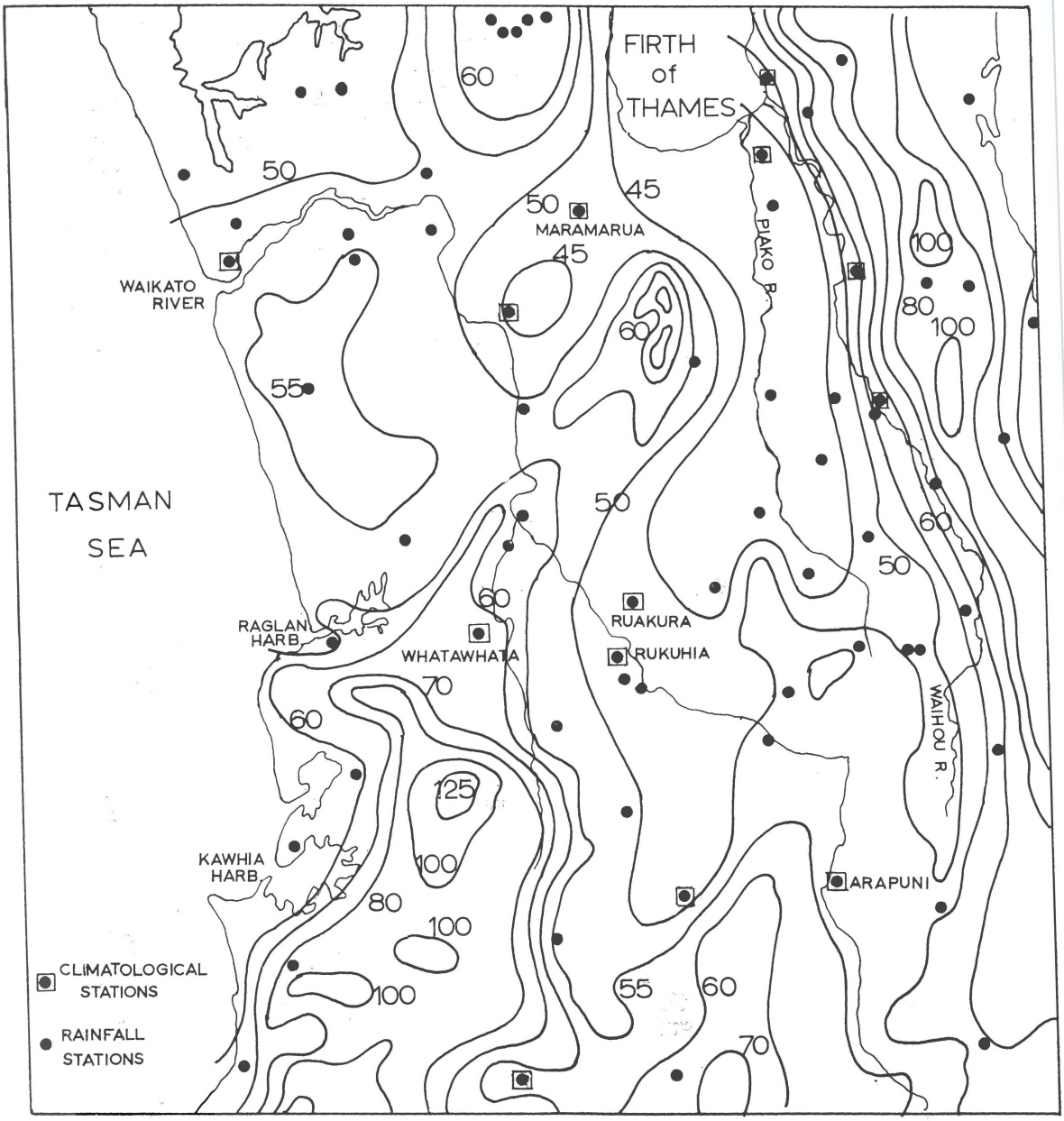

Figure 6 : Distribution of annual normal (1921-50) rainfall over the Waikato Basin. Rainfall in inches. Positions of rainfall and climatological stations marked.

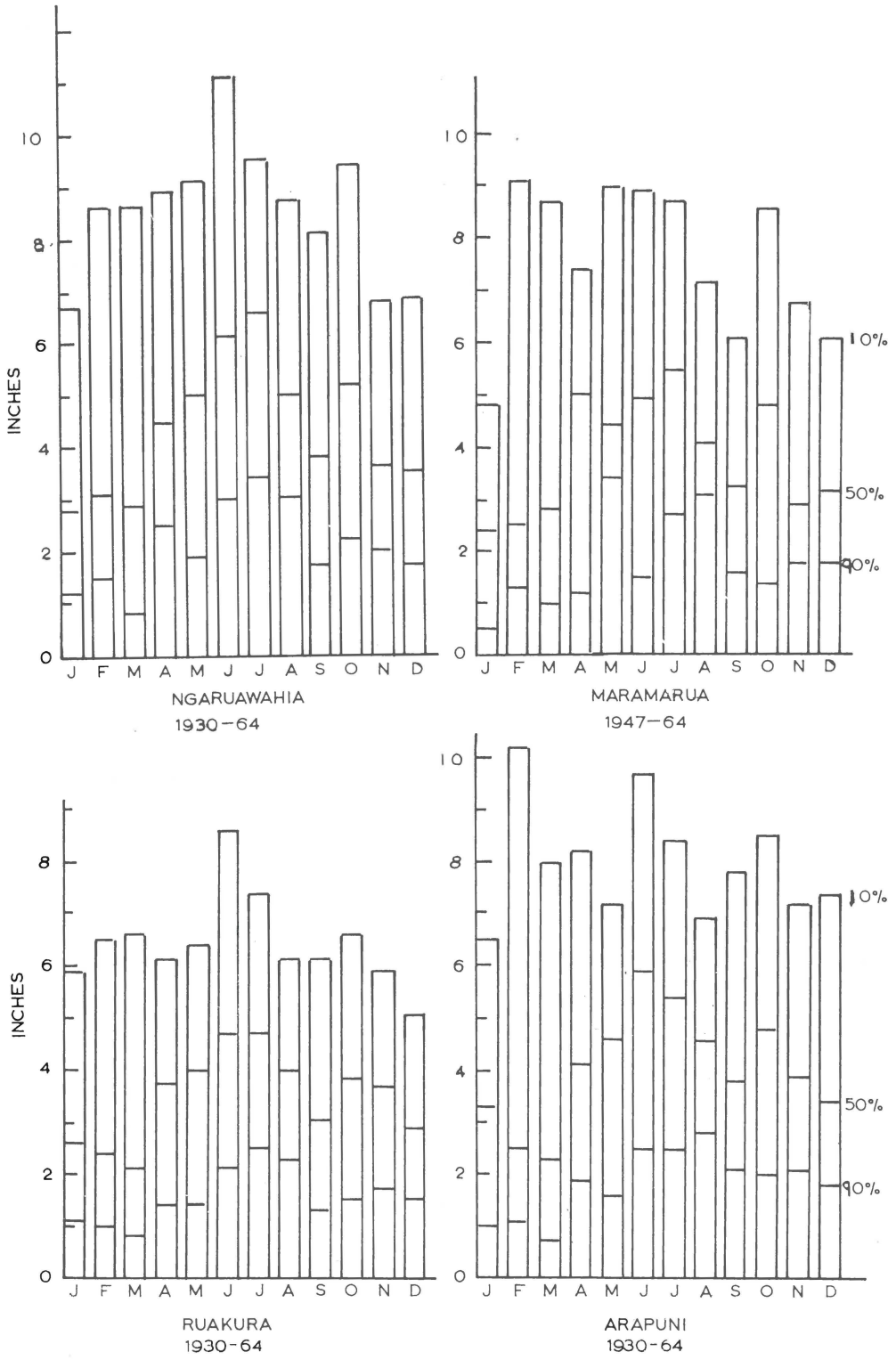

Figure 7 : Rainfall exceeded in 90 per cent, 50 per cent and 10 per cent of months.

The variability of annual rainfall may be defined as the average departure from the mean of the annual total expressed as a percentage of the mean. According to Seelye (1940) the variability of annual rainfall in New Zealand varies from 10 to 20 per cent and in the Waikato it is 12 to 14 per cent.

In a similar manner Seelye (1946) gives the variability of monthly rainfall. For all months and all places it averages 44 per cent while in the Waikato it has its greatest value of 50 to 60 per cent in summer and its lowest values of 30 to 40 per cent in winter.

The annual water need for pasture over most of the Waikato is about 28 inches of rainfall. This need ranges from about 1 inch of rainfall per month in winter to 4 inches per month in summer.

Even though the annual amounts of rainfall are much greater than the water needs there are often months when the rainfall is insufficient to meet the plant requirements. In such cases soil moisture reserves are drawn on. The amount used depends on the soil and plant types. If during dry periods the soil moisture is used up to the equivalent of about 3 inches of rainfall the growth of pasture is seriously retarded.

The percentage of years when the soil moisture would be drawn on to at least the equivalent of 3 inches of rainfall is shown for several stations in Table 2.

Table 2. Soil moisture deficits

Station	Length of Record (years)	Years with deficits (%)	% of years when deficit lasted at least 2 months	3 months	4 months
Morrinsville	26	73	38	15	8
Ngaruawahia	34	44	18	6	0
Maramarua	16	69	50	13	0
Ruakura	34	71	29	12	3
Rukuhia	17	82	53	12	0
Arapuni	34	50	24	3	0
Raglan	21	38	14	0	0

Thus in most places away from the coast, soil moisture deficits occur in at least 50 per cent of years and may last in extreme cases for 4 months.

High Intensity Rainfalls

Although the Waikato Valley is not one of the highest intensity rainfall areas of New Zealand some intense falls of short duration have been recorded during thunderstorm activity. Ruakura has recorded 2.3 inches in an hour.

East Coast districts of the North Island and the west coast of the South Island have received far higher intensities for longer periods than the Waikato Valley.

Statistical methods can be used to get from a record of daily rainfalls an estimate of the frequency with which heavy falls may be expected. Estimates of the maximum 24 hour rainfall which on the average would be at least equalled in every 2 and every 20 years is given for a number of stations in Table 3.

Table 3. Frequency of heavy rainfalls. Expected 24-hour rainfalls (in.) that will be at least equalled once in (a) 2 years and (b) in 20 years.

Station	Years of record	Return period (years) (a) 2	(b) 20
Te Kauwhata	32	2.7	5.2
Ngaruawahia	31	3.3	6.3
Ruakura	32	2.8	5.4
Hamilton ...	53	2.6	4.6
Karapiro	34	2.7	5.2
Arapuni	30	2.7	4.5

From recording raingauge records more detailed rainfall intensity estimates can be found. Robertson (1963) has analysed New Zealand recording raingauge data and in Table 4 are shown for Ruakura and Arapuni, his figures for the maximum falls in 1 hour, 12, 24 and 48 hours expected to be at least equalled every 2, 10 and 50 years.

Table 4. Rainfall intensities (in.) from recording raingauges.
Ruakura (12 years record)

Duration (hrs)	Return periods (years) 2	10	50
1	0.9	1.9	2.8
12	2.2	3.8	5.1
24	2.7	4.7	6.5
48	3.2	5.6	7.7

Arapuni (19 years record)

Duration (hrs)	Return periods (years) 2	10	50
1	0.9	1.5	2.0
12	2.2	3.5	4.6
24	3.0	4.8	6.3
48	3.5	5.6	7.5

Thunderstorms, which are often responsible for short-period intense falls, may occur with the passage of vigorous frontal systems or with convective cloud build up in any month of the year. There are on the average 10-15 thunderstorms per year over most of the area.

Floods

Although the Waikato Valley does not receive such prolonged high intensity rainfalls as are experienced in east coast districts, there is on occasion enough rain to produce flooding.

The dates of the three largest floods in the lower Waikato Valley this century and the peak river discharges at Ngaruawahia are given in Table 5.

Table 5. Most destructive floods since 1900.

Date	Peak discharge at Ngaruawahia
	(Cusecs)
21st July, 1907	66,000
6th July, 1953	33,800
26th-27th February, 1958	54,000

The weather situations which gave rise to these floods had factors common to each.

In each case an anticyclone became practically stationary to the east of the North Island giving a flow for several days of relatively warm moist air over the Waikato Catchment. Widespread rainfall developed with the advance of a slow-moving depression from the north-west.

The flood-producing rain was spread over a period of several days. Prior to this there had been other heavy rainfall sufficient to give a high flow in the lower Waikato and to more or less saturate the catchment. This provided conditions favourable for a high rate of run-off.

According to an unpublished report by Robertson, if there are favourable antecedent conditions a 2-3 day rainfall of 5 inches or more over the greater part of the catchment appears to be sufficient to produce a major flood.

The peak flow depends to a large extent on the relative timing of the rain in the different parts of the catchment. In a simple situation with a band of heavy rain moving slowly from the north-west the falls in the Waipa catchment tend to precede by several hours those in the main part of the catchment. The development of a secondary depression to the north-west, which is not uncommon in this kind of situation, could produce more heavy falls in the Waipa catchment shortly after the main disturbance had crossed the area. This could lead to a substantial increase in the flow from the Waipa about the time the flood crest reaches the lower Waikato.

These principles are illustrated by the floods of February 1958 when for almost two weeks a large intense anticyclone (1025-1030 mb) was centred to the east of the North Island. A series of frontal systems moved over New Zealand and up to the Waikato area where they became stationary. Depressions formed to the north-west of the area and moved towards it.

At some places in the valley there was rain every day from the 16th-25th February and there were two maxima on the 17th and on the 23rd.

The weather maps for noon on 17th February and for 6 p.m. on 23rd February are shown in Figures 3 and 4. The rainfall distributions for the periods 16th-18th February and 21st-24th February, 1958, are given in Figures 8 and 9 and show marked differences.

In the earlier period where the airflow is from the north to north-east the heaviest falls were over the Kaimai Range while the rest of the area received 3-6 inches. During the latter period when the depression moved in from the north-west heaviest falls were in the west from Kawhia Harbour to the mouth of the Waikato River.

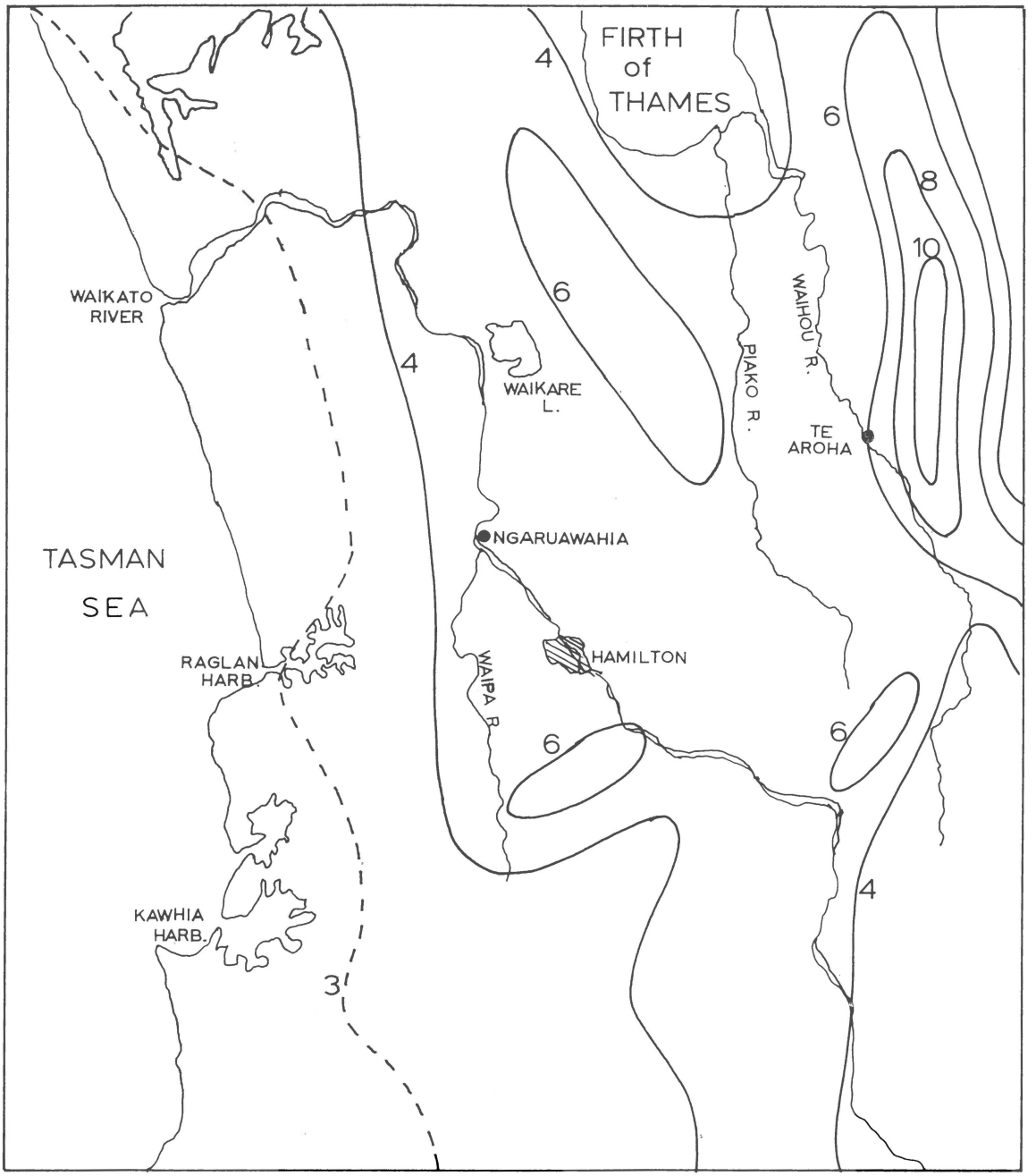

Figure 8: Rainfall in inches during the period 16th-18th February, 1958. Compare with the weather map for 17th February shown in figure 5.

Temperature

Mean annual temperature at sea level in New Zealand ranges from 59°F in North Auckland to 54°F about Cook Strait and 49°F in Invercargill. Temperature decreases with altitude at approximately 3°F per 1,000 ft.

In the Waikato Valley low level temperatures conform to the general scheme being 55-57°F. In the east of the plains area, towards the Kaimai Range mean annual temperatures tend to be 1-2°F higher than those in the west.

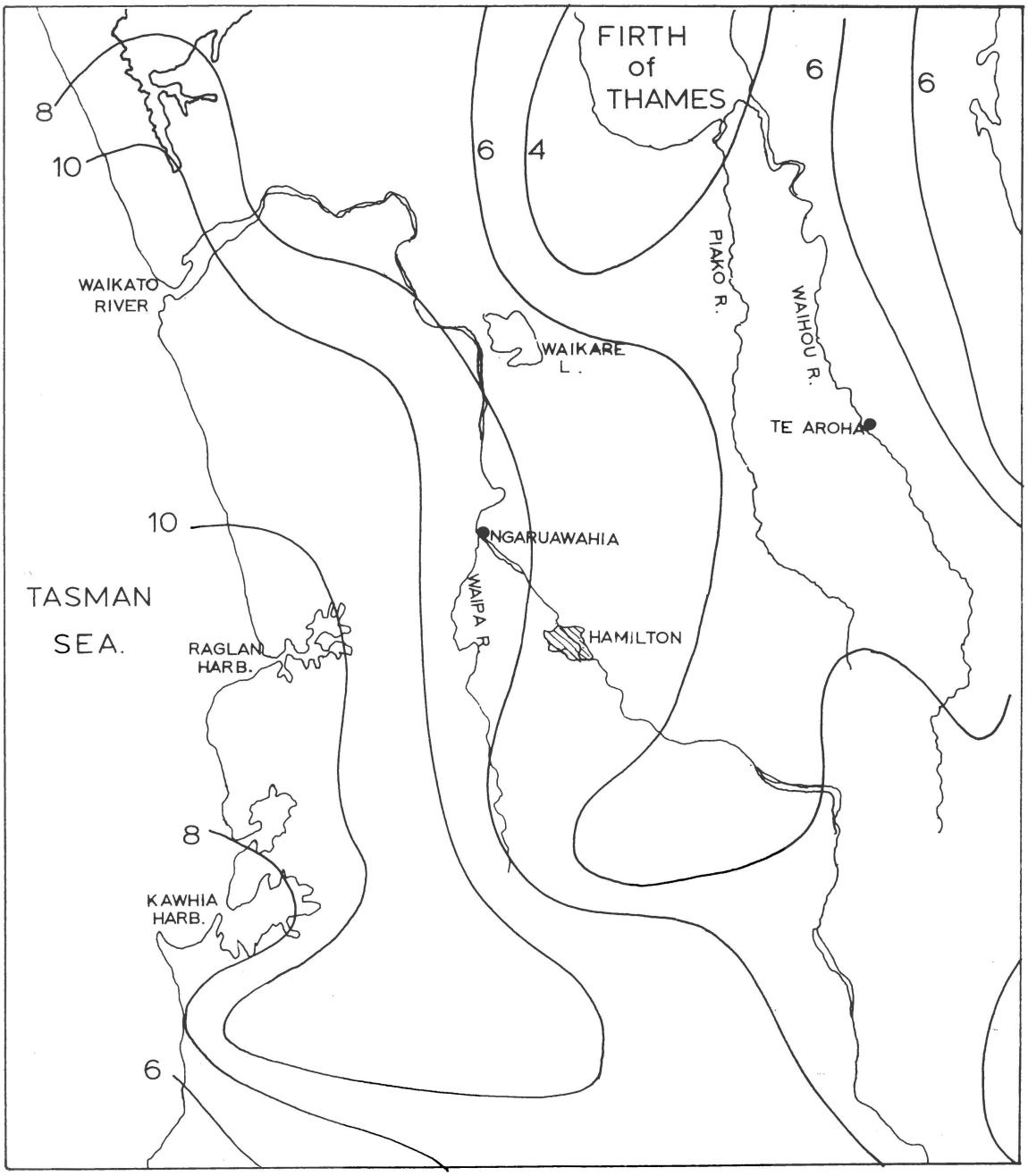

Figure 9 : Rainfall in inches during the period 21st-24th February, 1958 which produced extensive flooding in the lower Waikato. Compare with the weather map for 23rd February shown in figure 6.

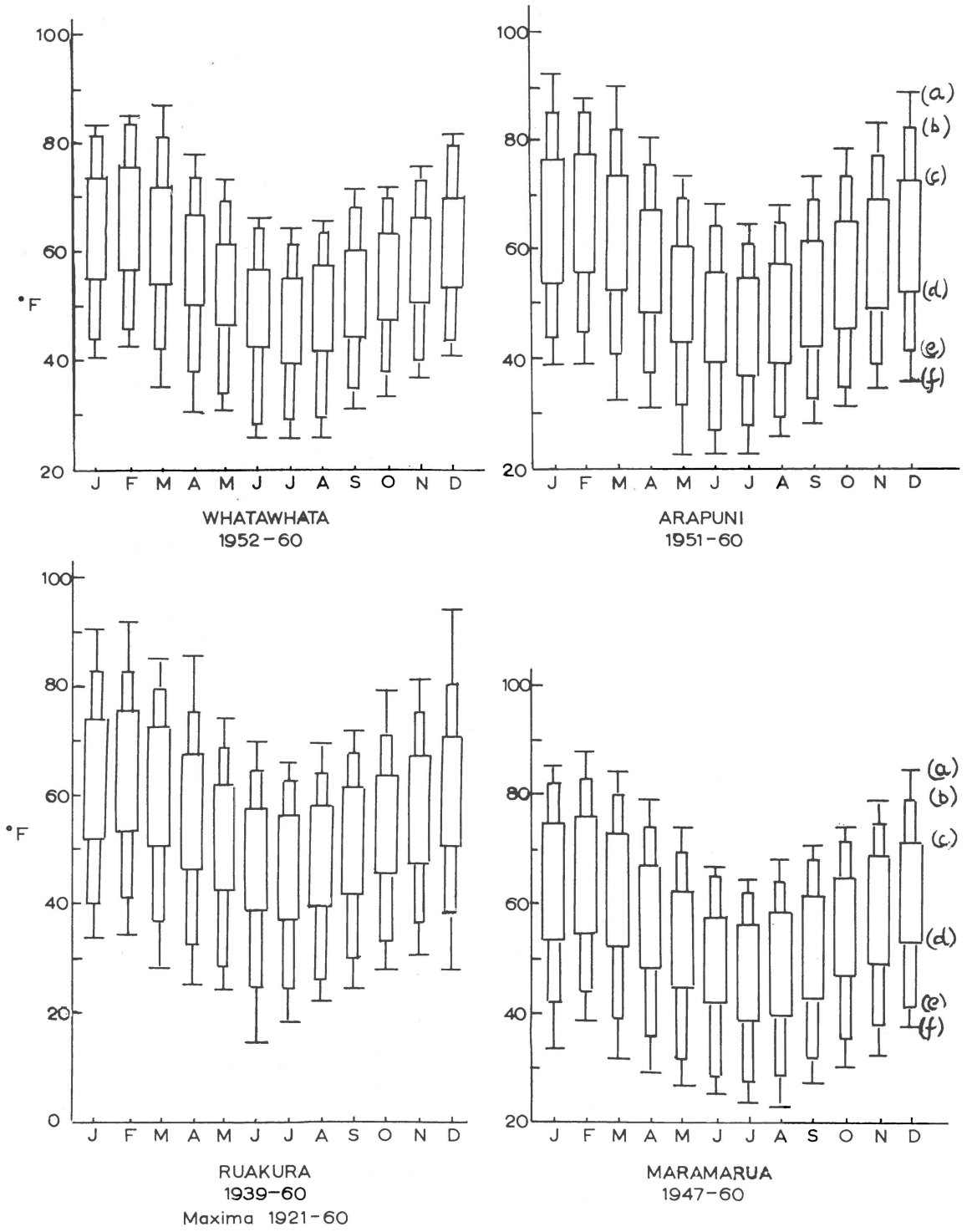

Figure 10 : Monthly temperatures. Temperatures given are: (a) highest recorded, (b) mean monthly maxima, (c) mean daily maxima, (d) mean daily minima, (e) mean monthly minima, and (e) lowest recorded.

In Figure 10 are given for a number of stations, the mean daily maximum and mean daily minimum temperatures each month, the mean monthly maximum and minimum temperatures and the highest and lowest temperatures. The monthly mean is approximately half the sum of the mean daily maximum and mean daily minimum temperatures.

The average daily range of temperature is about 20-22°F in January and 16-18°F in July. This is higher than that found in coastal districts but not as high as in the most sheltered places. In parts of the Wairarapa Valley, for instance, January mean daily ranges of 25°F are found.

Many ground frosts are confined to a very shallow layer of air and they can occur in any month. In sheltered localities there may be on the average 70-80 days a year on which ground frosts occur though in the greater part of the valley the number is much less. Screen frosts occur on the average on about 10-20 days a year.

The lowest temperature recorded in a standard screen is 14°F at Ruakura.

Sunshine

Most of the Waikato Valley receives on the average about 2,000 hours of bright sunshine a year. Less is received over hilly country where increased cloudiness reduces sunshine amount. Whatawhata to the west of Hamilton receives only 1,800 hours a year on the average compared with 1,980 hours at Ruakura. Whatawhata receives 34 per cent of the possible June sunshine and Ruakura 40 per cent.

Most of the valley receives about 50 per cent of the possible January sunshine and 40 per cent of the possible June sunshine. There is a considerable increase in cloudiness in winter.

Humidity

Humidity varies inversely as temperature, falling to a minimum in mid-afternoon when temperature is highest and frequently lying between 90 and 100 per cent on clear nights. The diurnal variation is much greater than the annual difference between summer and winter.

The relative humidity in early morning and mid-afternoon for January and July is given in Table 6 for Rukuhia.

Table 6. Relative humidity at Rukuhia (1965-66)

January		July	
6 a.m.	3 p.m.	6 a.m.	3 p.m.
93	62	95	71

On clear calm nights when radiational cooling produces low temperatures and high humidities there is a tendency for patches of fog to form in areas into which the cool saturated air drains.

The river valley is well suited for this and from Arapuni to Te Kauwhata fog occurs on the average on 30-50 days a year. It is most prevalent in autumn and early winter but may occur in any month.

Near the coast at the mouth of the river where night calms are not as frequent as they are inland, fogs occur on about 20 days a year.

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