

1993-94 DROUGHT

NORTHLAND REGION

Report Prepared
for the
Northland Regional Council
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1.0 INTRODUCTION

Northland, like most other regions of the world, is prone to experiencing dry spells and drought relative to what may be considered average rainfall or river flows. For the last four years (1990-1994) most localities in Northland have experienced lower than average annual rainfall. Low severity droughts have been experienced in 1990-91 and in 1991-92, which have disrupted general farming practice. What is unusual about these droughts is that autumn and spring rainfall has generally been lower than average. Hence, low rainfall and low flow periods during summer (generally an expected climatic condition for Northland) have lasted well into the autumn winter period.

The 1993-94 drought includes some of the lowest winter rainfalls that have ever been recorded in Northland. It is not restricted spatially to Northland, but is also being experienced in Auckland causing a disruption of the municipal water supply, as well as east coast areas such as Gisborne and the Hawkes Bay. Dry conditions have also been reported in the Australian States of New South Wales and Queensland (Bureau of Meteorology 1994). The 1993-94 drought, then, is not just a localised phenomenon confined to Northland.

The increasing demands on available water resources in Northland, predominantly by large farming ventures such as pasture irrigation, make the quantification and prediction of drought essential to water resources planning.

The aim of this report is to:

- A. Provide an indication as to the severity and frequency of the 1993-94 drought, with respect to rainfall and river flows, throughout Northland
- B. Evaluate the spatial pattern of drought severity throughout Northland for the 1993-94 drought
- C. Provide an indication as to what could be causing the 1993-94 drought

2.0 METHODOLOGY

2.1 Definition of drought

The definition of drought used in this analysis is the same that was used in Keyte (1993). That is, that drought, as a working definition, is defined quantitatively as two or more months of rainfall below the long term 25th percentile of that month. Such a deficit of rainfall is likely to have a significant effect on water resources and agriculture (Martin and Waugh 1972) inevitably leading to economic and social impacts. It should be noted that when the term "drought" is used in this report, it refers specifically to meteorological or rainfall drought. A simplistic view is taken, where a lack of rainfall is

considered to be the "cause" of drought and low flows are considered to be the "effects" of drought.

2.2 Rainfall

- I. A drought index, based on the index devised by Martin and Waugh (1972) was used to determine the severity the 1993-94 drought throughout Northland. This index uses rainfall as the only indicator of drought and is described in Keyte (1994). Only monthly rainfall prior to May 1994 was used in this analysis, as rainfall totals for May 1994 were not available when this analysis was undertaken.
- II. Drought frequency was calculated using the theory of probability by fitting the double exponential distribution to the distribution of drought severities.
- III. Drought severity maps were constructed for the 1993-94 drought using drought severities calculated for 61 rainfall stations throughout Northland, providing a visual basis for spatial drought comparison.
- IV. Monthly cumulative rainfall graphs were constructed showing the cumulative lowest monthly rainfall, cumulative monthly median rainfall and 1993-94 cumulative monthly rainfall, for four rainfall stations in Northland.

A full description of the drought index used, frequency distributions and methodology of constructing the drought severity maps is given in Chapter Four of Keyte (1993). All assumptions and limitations of using the drought index and frequency analysis are as described in Keyte (1993).

2.3 Flows

- I. A low flow frequency analysis was used to determine the recurrence interval of annual low flows for selected rivers, in order to evaluate the effects of drought on river flow. A 1-day averaging period for the flow data was chosen for the low flow frequency analysis, as the 1-day minimum low flow is most used by the Northland Regional Council in the allocation of river flows. Annual minimum series were constructed as outlined in Chapter Six in Keyte (1993) using hydrological years.

The Weibull Distribution (type III distribution of smallest extremes) was chosen to represent the distribution of annual minimum flows, and the graphical method (using the Gringorton plotting position formula) was used to fit the Weibull distribution to the annual minimum flow series, as described in Chapter Six of Keyte (1993).

3.0 DATA USED

Rainfall from 61 rainfall stations throughout Northland was used in the drought index to calculate severities and in the drought severity map (see Table 1). The rainfall stations with asterisks beside them are those whose rainfall time series were also used to calculate drought frequency. The Mangonui, Kawakawa, Dargaville and Wairua Falls rainfall time series were used to construct the cumulative rainfall graphs.

Station Location	Station No.	Station Location	Station No.
Parengarenga	A42582	Dargaville *	A53982
Waiharara	A43921	Waitangi	542010
Rangiputa	A43931	Russell	A54201
Mangonui *	A43951	Kawakawa *	A54301
Aupouri	530204	Waiotu	545111
Kaingaroa	A53031	Puhipuhi	545201
Ahipara	A53111	Hukerenui	545213
Kaitaia *	A53121	Whakapara	545310
Victoria Valley	531411	Matapouri	A54551
KerkeriMaf	A53191	Jordan Valley	546212
Laurensons	531910	Hikurangi	A54622
Herekino	A53222	Ruatangata	A54623
Takahue	532311	Glenbervie	546301
Omahuta	A53253	Ngunguru *	546412
Taus Falls	A53281	Riponui	546510
Tyrees	532810	Wairua Falls*	A54701
Waikimihia	532910	Otaika	547219
Kerkeri Aero	A53293	Whau Valley	A54735
Waihou	533610	Onerahi *	A54737
Omapere	533812	Mangapai	A54821
Puhata	A53321	Tauraroa	548310
Opononi	A53442	Monymusk	549010
Rawene	A53453	Manganui *	549310
Kaikohe DSIR	A53482	Arapohue	A63091
Waipoua	A53651	Waihoihoi	640411
Waimatenui	A53672	Waipu *	A64051
Kaihu *	537611	Ruawai *	A64112
Parakao	A53791	Maungataroto *	A64132
Mamranui	A53881	Hakaru	641413
Awakino	538810	Pukehau	A64221
Baylies Beach	539710		

Table 1 Rainfall stations used

Flows from six different rivers were used to calculate low flow frequencies (see Table 2). River flows were calculated from continuous water level measurements using standard rating equations by NRC hydrologists.

RIVER	SITE NUMBER
Awanui	1316
Kaihu	46611
Wairua	46644
Ngunguru	4901
Waihoihoi	6016

Table 2 Flow stations used

A full summary of the characteristics of the rainfall and flow stations used (such as altitude and grid reference) is included in Keyte (1993).

4.0 RESULTS

4.1 Rainfall Analysis

4.1.1 Drought severity

The 1993-94 drought can be classified as a regional drought. Another words, the drought was detected in rainfall time series for most localities throughout Northland. The 1993-94 drought is also low magnitude and long duration in nature. This means that the magnitude of the rainfall deficit is low, but the duration of the drought event is lengthy. It should be noted that this drought may still not have ended, as only rainfall totals up to May 1994 were analysed. From recent discussions with the NRC hydrologist, Dale Hansen, it would appear that the rainfall total for May for most east coast areas is still well below average.

The 1993-94 drought was most severe at coastal locations, on both the west coast from Herekino to Dargaville, and east coast from Kawakawa to Onerahi, as well as southern Northland around Waipu and Maungataroto (see Figure 1). The drought index severity designations are given, in Table 3. The 1993-94 drought was also was also severe at some inland locations for example around Wairua Falls and Parakao, and Kaikohe. The drought was mild over most of northern Northland, from Kerikeri north. No drought was detected at the higher altitude rainfall stations, for example those stations located in the Tutumoe or Mangamuka ranges, or the Hikurangi Hills. This is due to the large falls of rain in these high altitude locations.

It should be noted that the rainfall total for July 1993 is the lowest or second lowest on record, for all stations analysed. Eight rainfall stations (Mangonui, Dargaville, Russell, Wairua Falls, Waipoua Forest, Kaitaia, Waimatenui and Kawakawa) have record lengths of greater than 67 years.

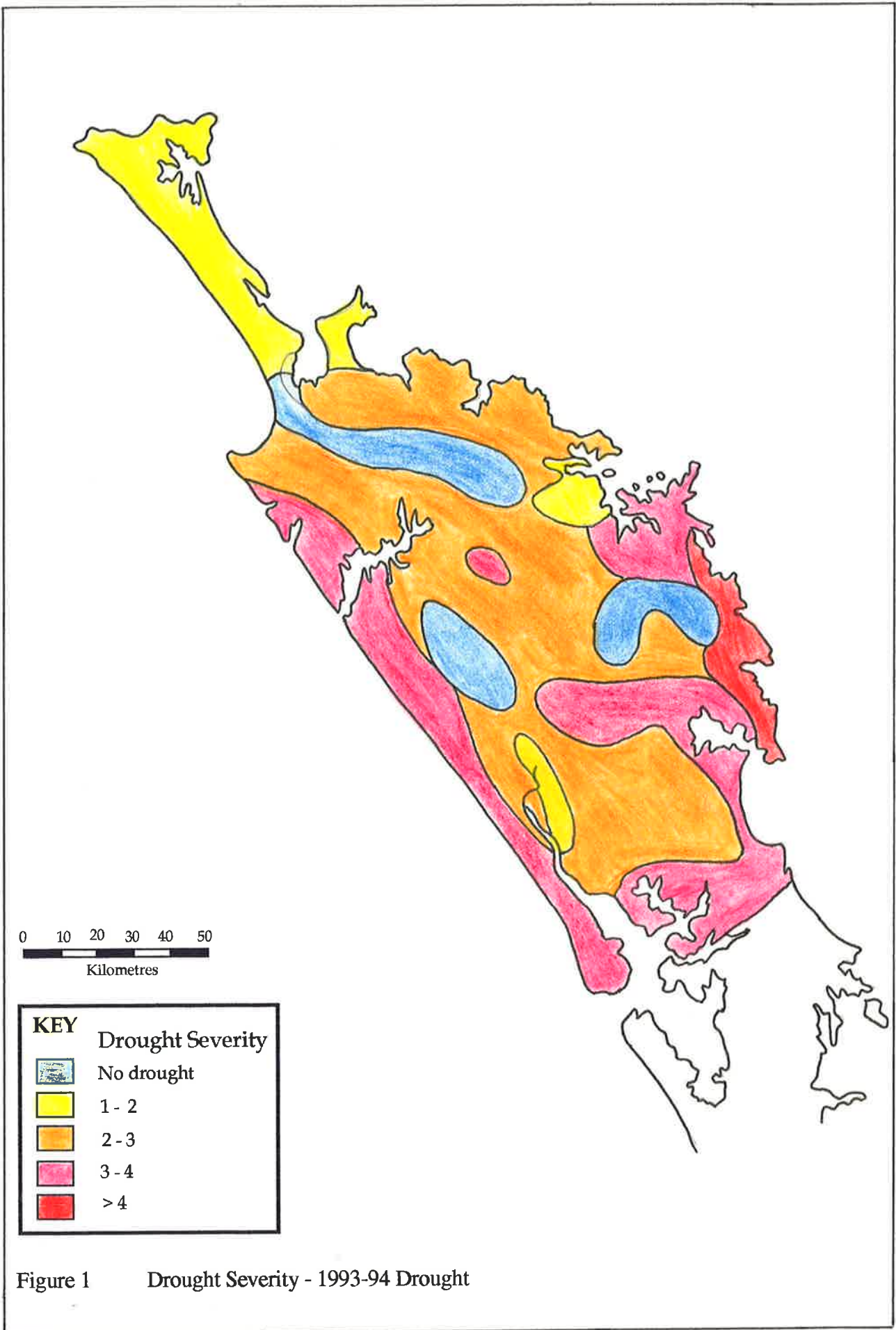


Figure 1 Drought Severity - 1993-94 Drought

Drought Severity Category (S)	Drought Severity Description	Approximate Return Period (years)
0 to 1	No drought	
1 to 2	Mild	2.33 to 5
2 to 3	Medium	5 to 10
3 to 4	Moderately severe	10 to 30
4 to 5	Severe	30 to 50
> 5	Extremely severe	> 50

Table 3 Drought index severity designations (determined from the drought frequency analysis).

In comparison with other droughts that have occurred in the last 15 years, the 1993-94 drought is more severe than the 1990-91 or 1991-92 drought, with quite different spatial patterns (see Figures 4.11-4.14 in Keyte (1993)). In east coast, west coast and southern Northland locations it was as severe as the 1982-83 and 1986-87 droughts, which have been the most severe droughts experienced in Northland in the last 30 years. The 1993-94 drought was more severe than the 1982-83 drought for rainfall stations at Ngunguru, Onerahi and Kawakawa and more severe than the 1986-87 drought at all rainfall stations on the west coast. Table 4 shows the drought severity rank for the 1993-94, 1982-83 and 1986-87 droughts for 12 rainfall stations. For all stations except Mangonui and Kawakawa, the 1993-94 drought is the second, third or fourth most severe drought in station history.

Rainfall Station	Record Length (years)	Rank of drought		
		1993-94	1982-83	1986-87
Mangonui	102	26	4	6
Kaitaia	97	No drought	6	21
Kawakawa	76	7	10	1
Ngunguru	26	2	4	1
Onerahi	45			
Wairua Falls	78	3	6	2
Kaihu	26	2	1	No drought
Manganui	27	4	1	6
Dargaville	72	2	1	No drought
Ruawai	26	2	1	No drought
Maungataroto	45	3	2	1
Waipu	44	3	2	4

Table 4 Severity rank of the 1993-94, 1982-83 and 1986-87 droughts. The severity rank is 1 to n, where 1 denotes the most severe drought on record and n denotes the least severe drought on record. The second column shows the record length of the rainfall station.

The rainfall cumulative departure graphs, for four long term rainfall stations, also show how severe the 1993-94 drought period is (figure 2a-d). These graphs show the cumulative lowest monthly rainfall, the cumulative median monthly rainfall and the cumulative 1993-94 monthly rainfall using a hydrological year (June-May). In particular the deficit of the 1993-94 cumulative monthly rainfall from the cumulative median monthly rainfall should be noted.

The cumulative lowest monthly rainfall was calculated by: (a) finding the lowest rainfall total in June for a particular site and plotting this for June (b) finding the lowest consecutive rainfall total for June and July and plotting this for July (c) finding the lowest consecutive rainfall total for June, July and August and plotting this total for August and so on. The cumulative median rainfall is simply the median rainfall for each month summed and plotted as such.

As shown in Figure 2 (a-d), cumulative monthly rainfall from June 1993 has been significantly below the cumulative monthly medians for the 11 ensuing months for the four rainfall stations used, and has indeed, for Dargaville, Kawakawa and Wairua Falls, been near the lowest cumulative rainfall recorded for consecutive months. For Mangonui, the deficit of rainfall from average over the last 11 months, has clearly not been as severe as at the other three aforementioned stations, although is still considerably below average.

Figure 2 a-d Cumulative monthly rainfall graphs

A

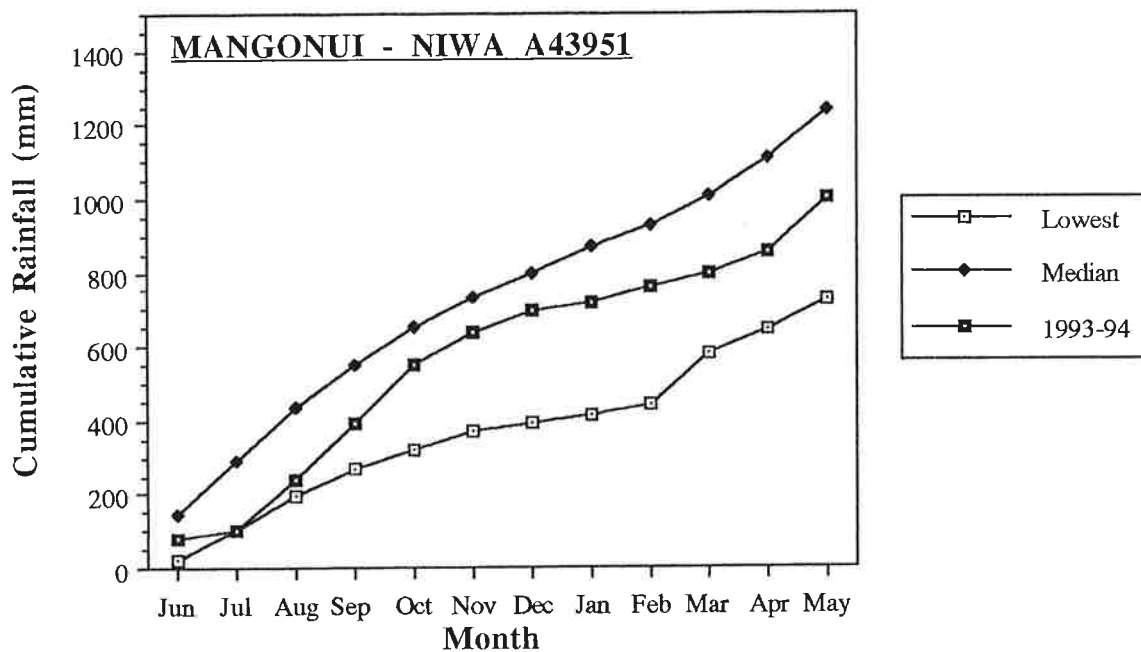
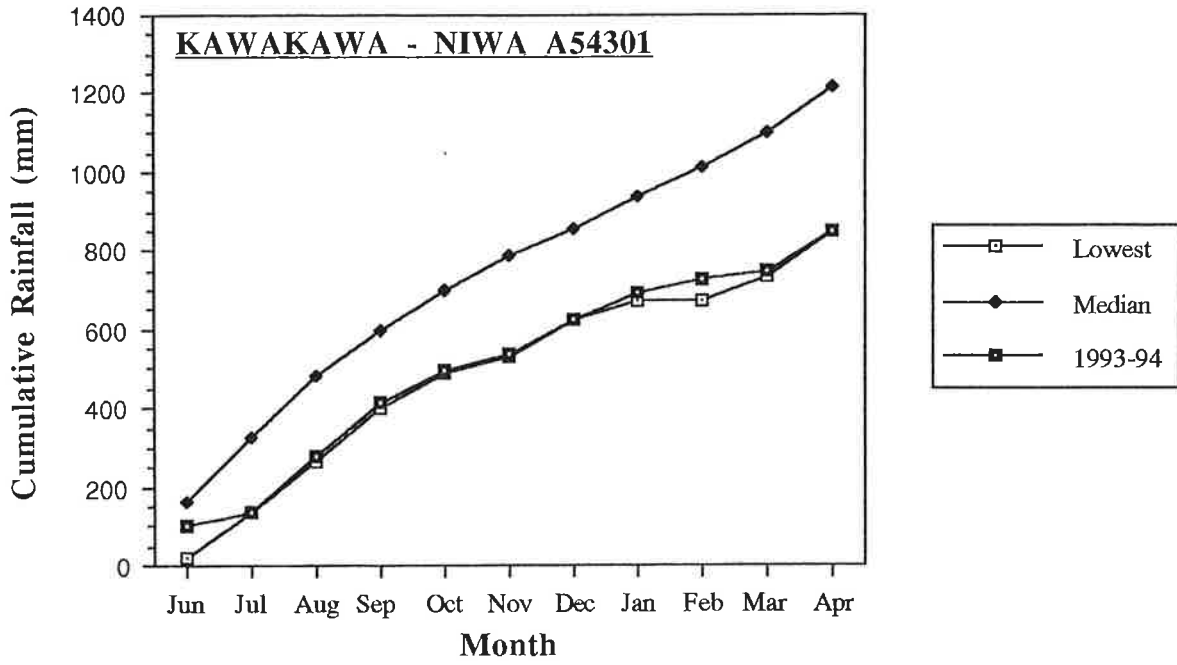


Figure 2 -cont-

B



C

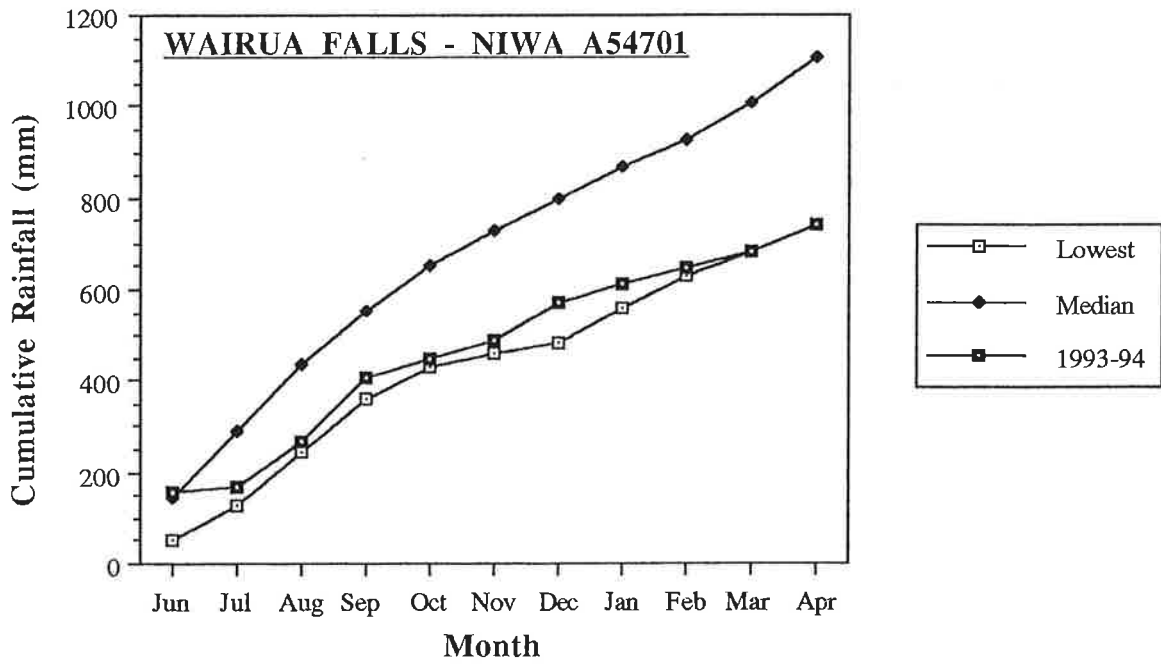
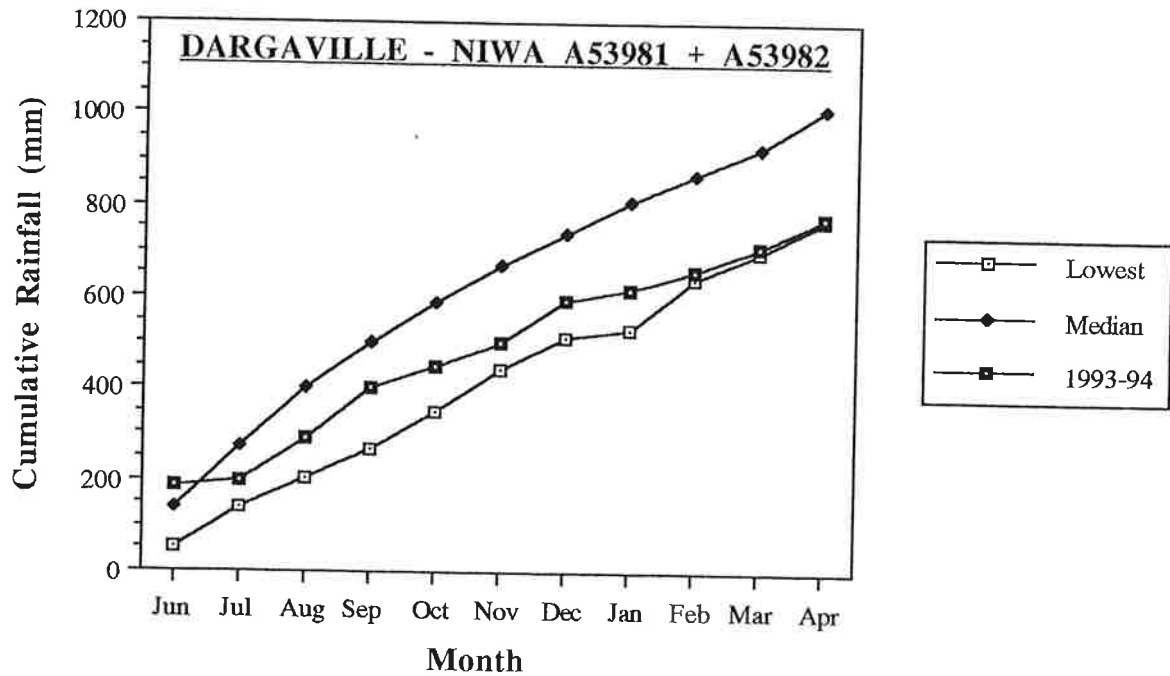


Figure 2 -cont-

D



4.1.2 Drought Frequency

The calculated 1993-94 drought return periods for rainfall stations used in the drought frequency analysis are given in Table 5 along with the return periods of other severe drought events for comparison. Drought severity frequency plots are shown in Appendix A.

Rainfall Station	Return Period (years)		
	1993-94	1982-83	1986-87
Mangonui	5	25	14
Kaitaia	No drought	15	5
Kawakawa	16	10	50
Ngunguru	11	7	33
Onerahi	16	8	41
Wairua Falls	22	16	39
Kaihu	19	22	No drought
Manganui	7	14	6
Dargaville	21	77	No drought
Ruawai	18	21	No drought
Maungataroto	16	17	37
Waipu	17	18	14

Table 5 Return periods of the 1993-94, 1982-83 and 1986-87 droughts for different localities

For most locations, the 1993-94 drought has an average return period of around 16 to 20 years. This means that a drought of this severity will only occur, on average, once every 16-20 years. The return period of the drought is less in Far North sites. For example, at Mangonui, the calculated return period is 5 years and at Kaitaia no drought was detected at all. The return period of the drought was also comparatively low for Mangonui, being 7 years. The drought had the highest return period at Wairua Falls, of 22 years. The return period of the 1993-94 drought is similar with that of 1982-83 for many rainfall stations, but is considerably less than the return period of the 1986-87 drought for most stations analysed.

4.2 LOW FLOW FREQUENCY

The annual low flow frequencies for the 1993-94, 1982-83 and 1986-87 droughts are shown in Table 6, for the rivers analysed. The low flow frequency plots for each river are given in Appendix B.

RIVER	RETURN PERIOD (YEARS)		
	1993-94	1982-83	1986-87
Awanui	14	46	2.33
Wairua	17	69	12
Kaihu	3	*	*
Ngunguru	20	5	34
Waihoihoi	37	*	16

Table 6 Return period for 1 day minimum flows associated with the 1993-94, the 1982-83, and 1986-87 droughts. The asterisk (*) signifies missing flow record where a 1 day minimum flow (and therefore return period) could not be calculated.

The 1993-94 minimum flow for the Waihoihoi River had the highest return period, at 37 years. However, it is considered that this high return period is not representative of this drought because of the shortness of the Waihoihoi flow record, which started in 1984. The drought severity return period calculated from the Waipu rainfall record (record length = 45 years) is probably more indicative of the true severity of this drought, being around 18-20 years. The 1993-94 annual minimum flow for the Kaihu River was not particularly severe, with a return period of around 3 years. The 93-94 annual low flows for the Wairua, Awanui and Ngunguru Rivers flows are calculated as occurring once every 15-20 years.

The lowest annual 1 day minimum flows associated with the 1993-94 drought occurred in early April for all rivers concerned.

Table 7 shows the comparison of return periods calculated from (a) annual low flows and (b) drought index severity from calculated rainfall records. The rainfall stations listed in this table are those located in or near the river catchment concerned.

The low flow return periods are generally different to that calculated from the rainfall records using the rainfall index. This is because (a) the rainfall records are considerably longer than the flow records and therefore include more drought events (b) rainfall is only one factor determining to river flows, which are dependent on baseflow, evaporation and human influences such as abstraction (c) rainfall records used may not be representative of river catchment rainfall, particularly for larger catchments.

River and Rainfall	Return Period (yrs)
Awanui River Kaitaia Rain	14 no drought
Wairua River Wairua Rain	17 22
Kaihu River Kaihu Rainfall	3 19
Ngunguru River Ngunguru Rain	20 11
Waihoihoi River Waipu Rain	37 17

Table 7 Drought severity frequency and low flow frequency comparison

5.0 POSSIBLE CAUSES OF THE 1993-94 DROUGHT

The likely cause of the 1993-94 drought is the El Nino phase of the Southern Oscillation. The Southern Oscillation Index has been negative since August 1990, signifying an El Nino event. Generally El Ninos do not last for longer than a year to 18 months, however, the present El Nino has lasted three years. The last time an El Nino lasted three years was from 1939 to 1941. This long duration El Nino could explain the drier than average conditions experienced in Northland over the last 3 years.

The effects of an El Nino on Northland's weather, is that the subtropical anticyclonic highs which generally cross Northland during summer are located more northwards than normal. This generally results in an increased frequency of southwesterly winds which carry little moisture, and often more settled climatic conditions for Northland during the summer and autumn months. The large subtropical highs are often anchored over Northland for many days at a time. During summer and autumn, the largest rainfalls are generally brought by moist northwesterly and northeasterly winds.

In November 1993, the Southern Oscillation Index went back to zero, which generally signifies the end of the El Nino event. However, in March 1994 the index went significantly negative again (-9.4), and in April 1994 it was still negative at -19.3. If the the negative trend of the index persists over the next few months, this could signal the continued development of the present El Nino and drier than average conditions for Northland over the next year. Generally, there is a three to six month time lag between the Southern Oscillation Index and rainfall in Northland. The Bureau of Meteorology (1994) state that atmospheric and oceanic conditions in the Pacific do not indicate the continued development of a significant El Nino episode within the next three to six months. However, the continued development of an El Nino event should not be discounted.

To statistically quantify the above statements, more research would have to be undertaken.

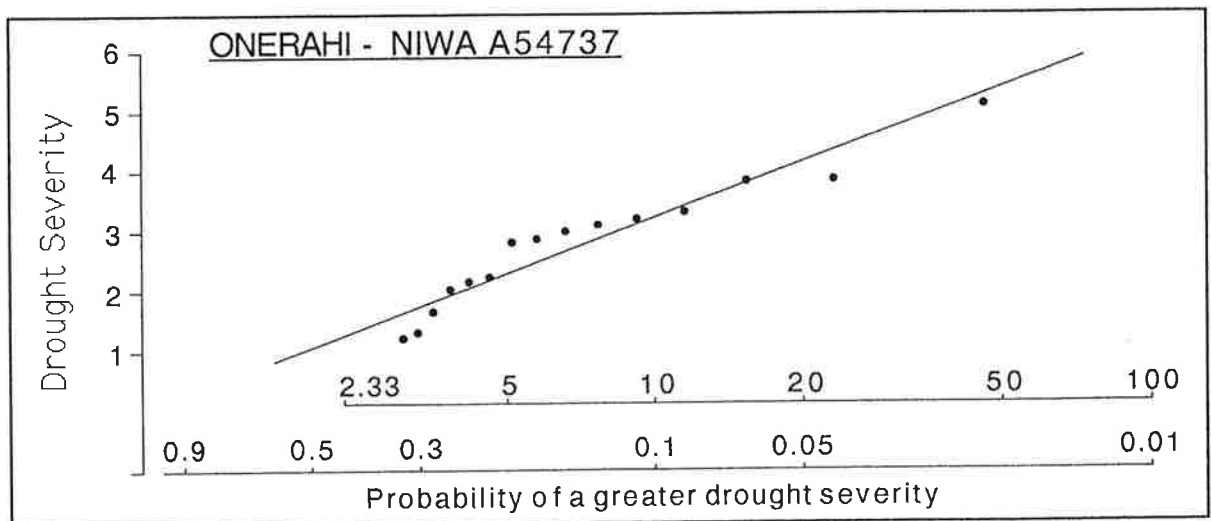
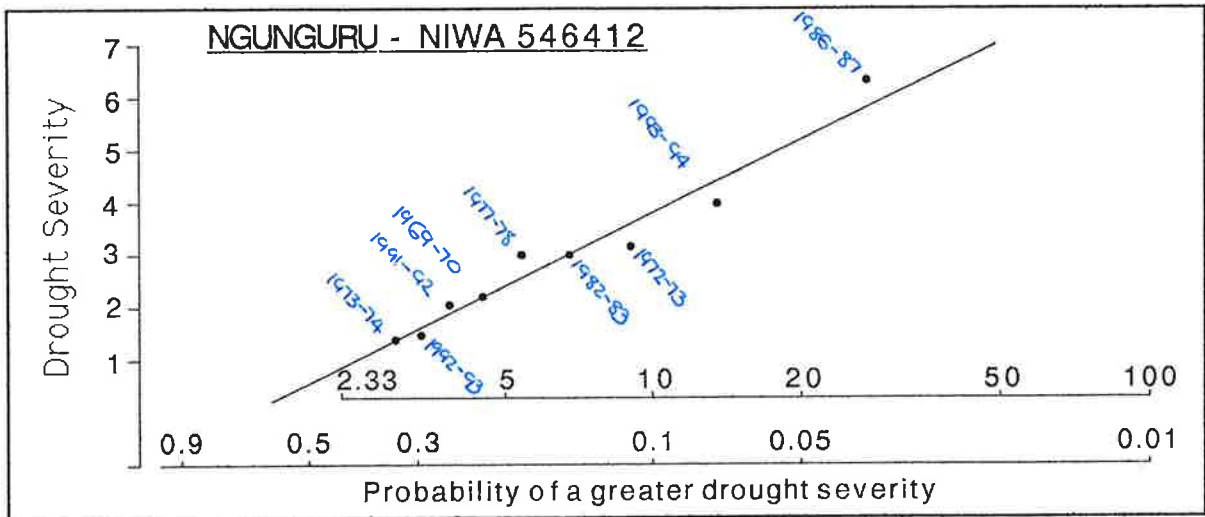
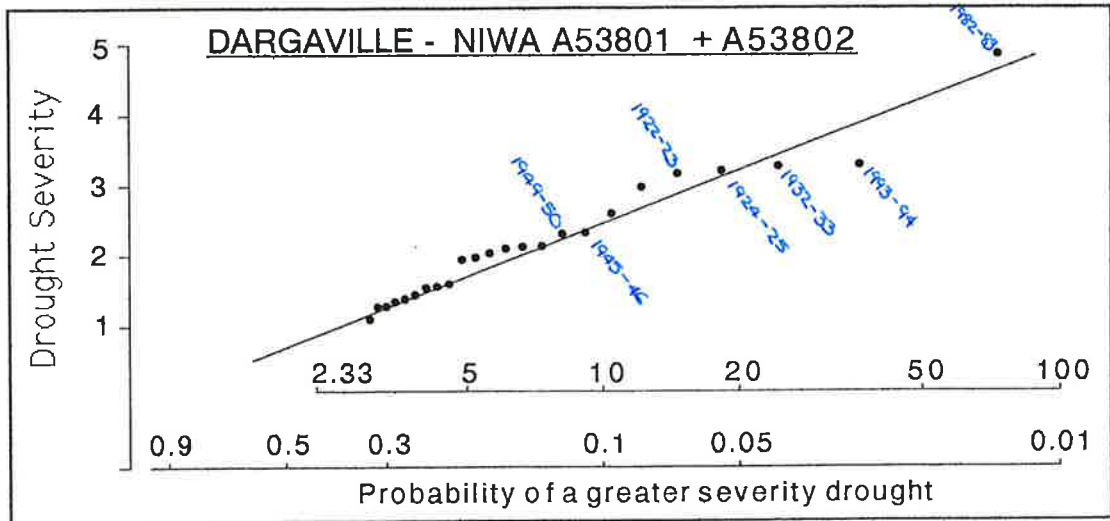
6.0 CONCLUSIONS

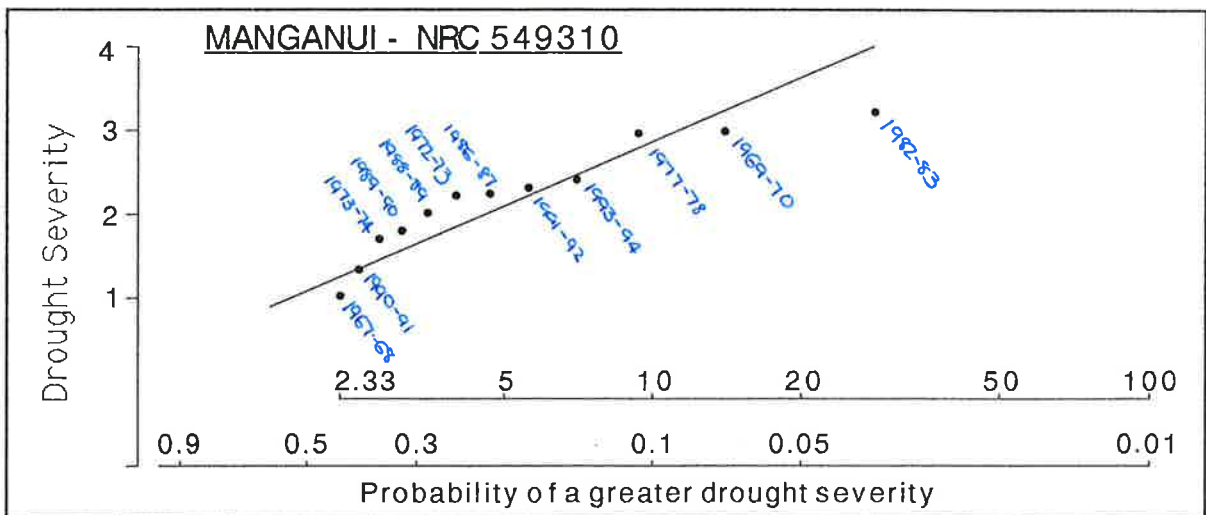
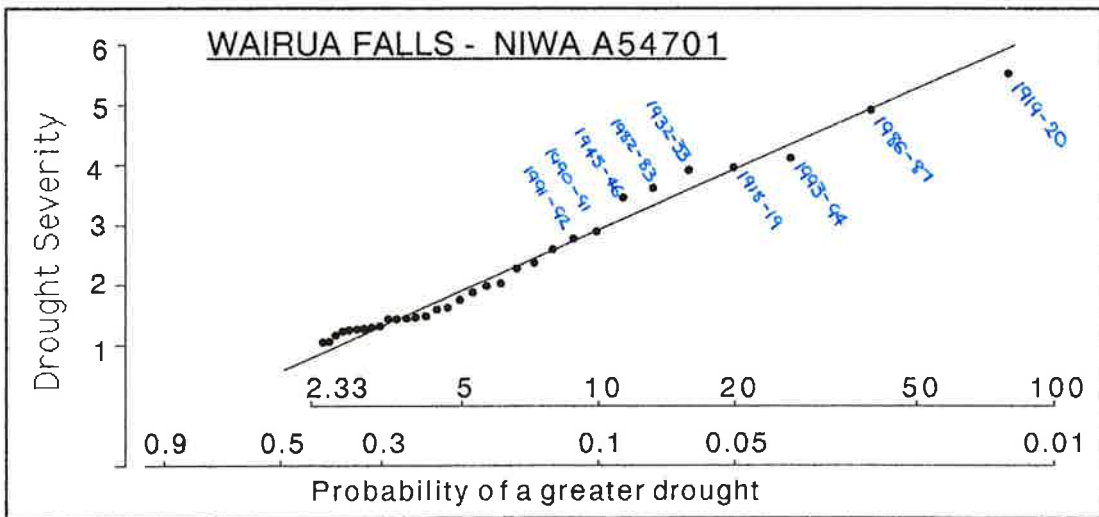
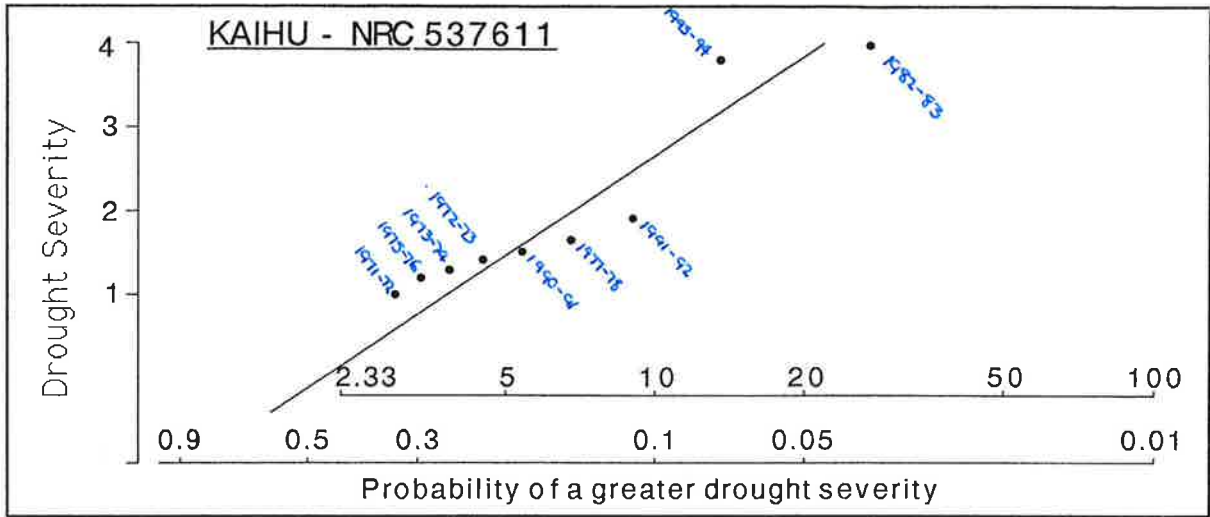
The following conclusions have arisen from this research

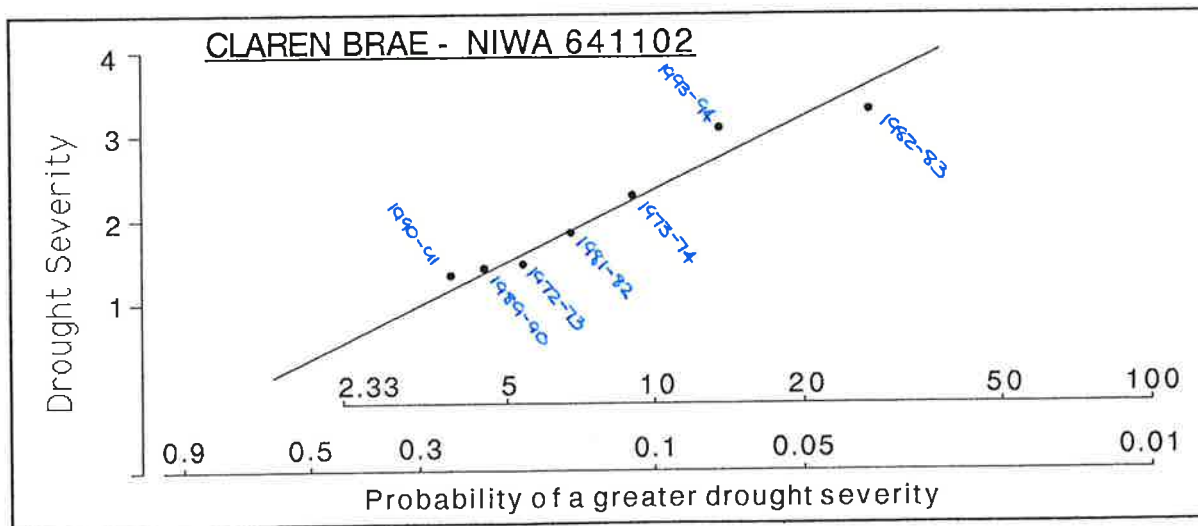
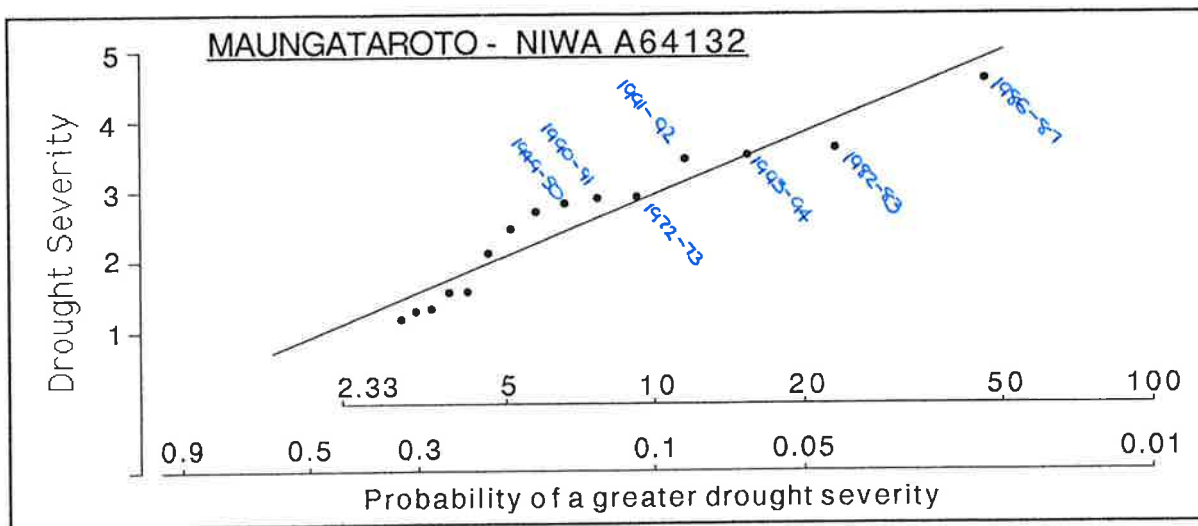
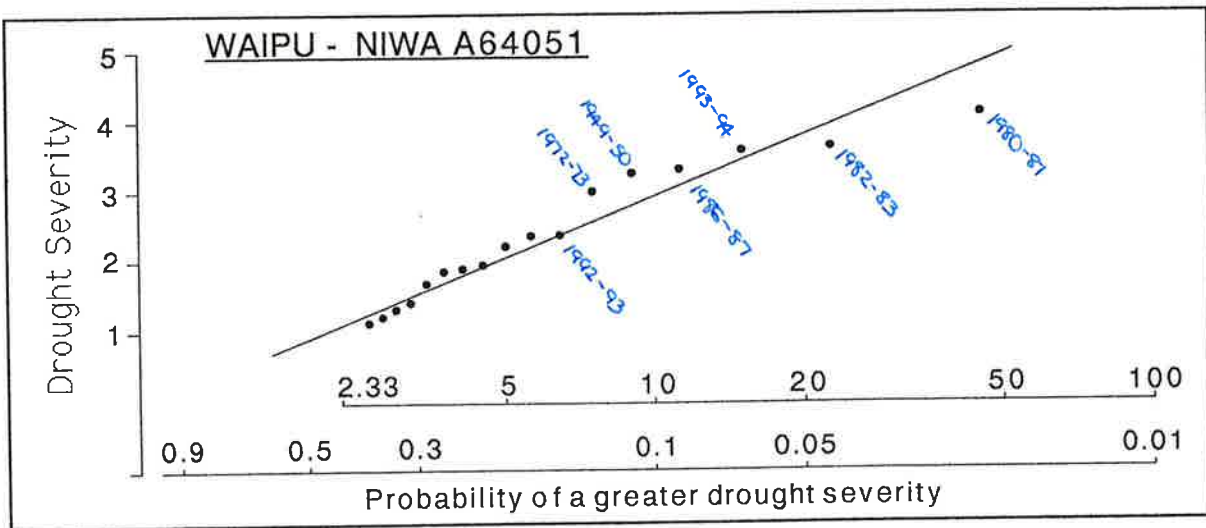
- The 1993-94 drought in Northland is regional in nature and is classified as a low magnitude, long duration event.
- The 1993-94 drought is one of the most severe droughts experienced in the last 30 years at most rainfall sites analysed.
- The 1993-94 drought was most severe on the east and west coast, south of Kerikeri, as well as inland around the Wairua-Parakao area. The return period for the drought along the west coast from Ruawai to Opononi is approximately 20 years. The return period for the drought along the east coast from Ruakaka to Kawakawa is approximately 16-20 years. The return period for the drought at southern Northland locations, such as Waipu and Maungataroto is approximately 17 years. The return period for the drought at locations north of Kerikeri is around 5-10 years. The drought was not detected at high altitude locations, such as the Mangamuka and Tutumoe ranges and the Hikurangi Hills.

The 1993-94 drought affected river flows considerably. Annual minimum flows for the rivers analysed were between a 14 to 20 year drought. Except for annual minimum flows for the Kaihu River which were not significantly affected by this drought.

- The 1993-94 drought is the result of large scale, atmospheric circulation patterns, that are hemispheric in nature, likely to be caused by the effect of the El Nino phase of the Southern Oscillation. If this El Nino phase continues to develop, below average rainfalls could be expected at most locations throughout Northland (the east coastal areas are particularly susceptible, however) for the 1994 winter and spring, and possibly the 1995 summer.

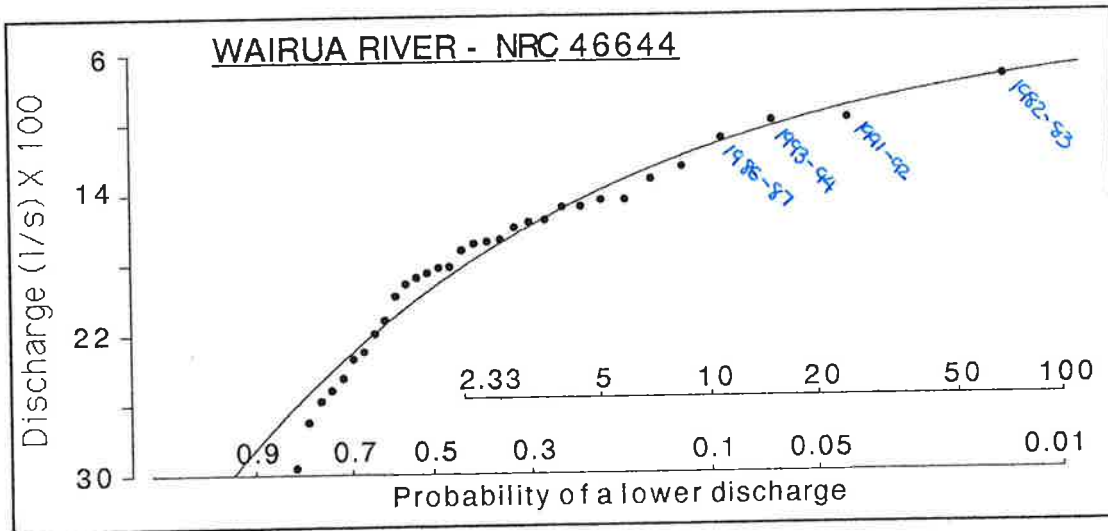
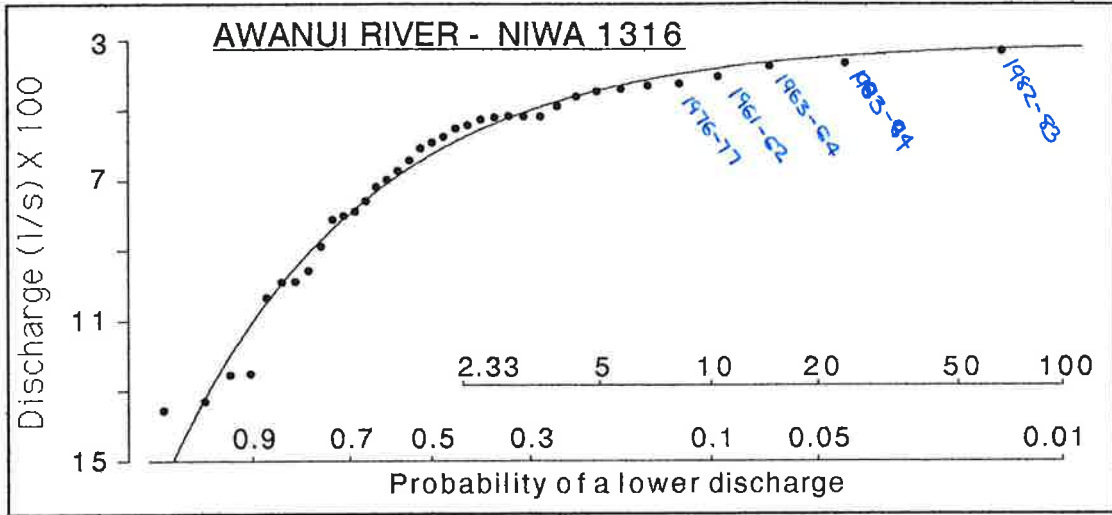


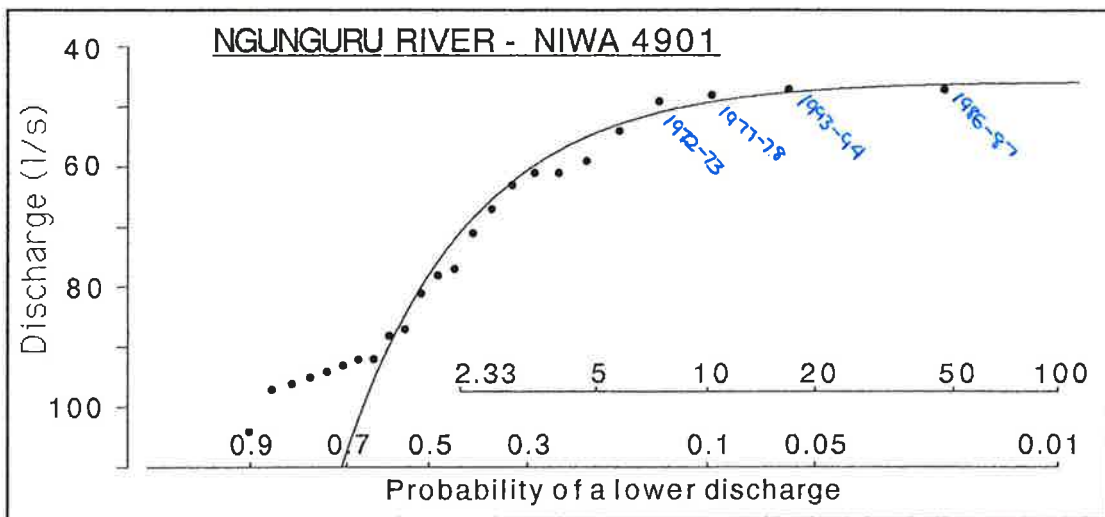
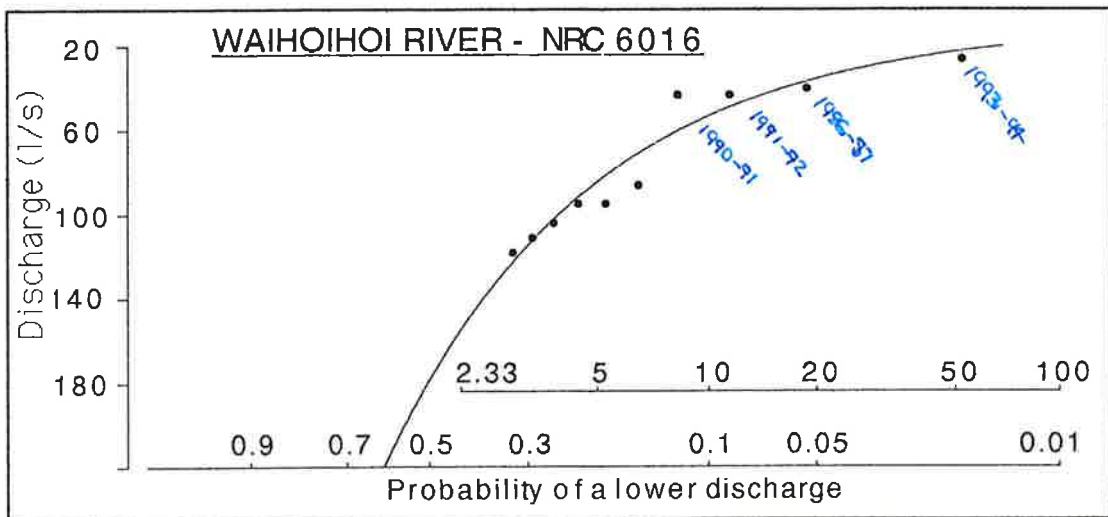
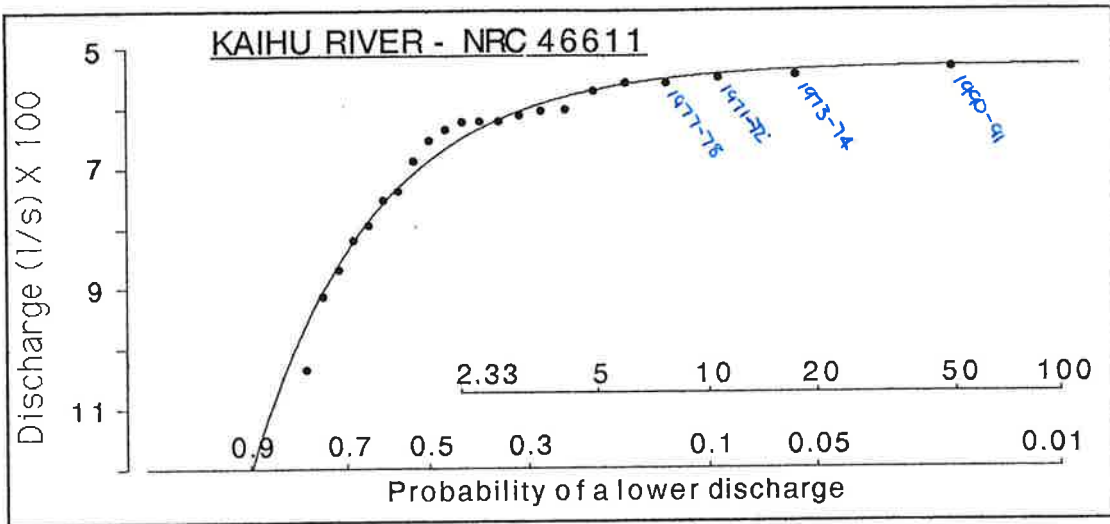




APPENDIX B

LOW FLOW FREQUENCY PLOTS





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