DUPLICATE

AUPOURI PENINSULA WATER RESOURCES ASSESSMENT

NORTHLAND REGIONAL COUNCIL

CARING FOR NORTHLAND AND ITS ENVIRONMENT

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1991

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Department of Conservation	Biological values of freshwater wetlands
GCNZ	Groundwater investigations
Local Welldrillers	Bore logs and subsurface geology
Stephen McIntosh	Geophysical investigations

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AUPOURI PENINSULA - WATER RESOURCES ASSESSMENT

1 INTRODUCTION

1.1 Background to Report

This final report details the findings of the Northland Regional Council (NRC) (and previously Northland Catchment Commission (NCC)), investigation into the nature, quantity, quality and use of the water resources of the Aupouri and Karikari Peninsulas.

The region covered by this report includes the Aupouri and Karikari Peninsulas as well as the area north of the Kaitaia - Ahipara road and west of the Awanui River. The area is shown in Fig 1.1.

In the early to mid 1980's both the NCC and the Mangonui County Council (MCC) were faced with making decisions on water rights and planning consents for proposed developments on the Aupouri and Karikara Peninsulas. These included the subdivision of farmland for orcharding and vegetable growing, development of forestry, possible forest processing industries, tourist resorts and such things as the kauri gum mining proposal.

It was known that the main source of water supply on the peninsulas was groundwater. However, at that time there was little information available on the water resources of the area and there were concerns about the sustainability of the ground water resource. In particular concerns were expressed about the impact the substantial plantings of exotic forest on the sand country of Aupouri peninsula might have on the quantity of ground water available and that there may not be enough water available to meet both existing farm water supply needs and the extra demands and use for irrigation and other proposed developments. There were also concerns that heavy localised use of ground water could lead to sea water intrusion into the ground water and loss of the resource.

As a consequence of these concerns, it was acknowleged that a better understanding of the water resources would enable informed resource management decision making and would provide both existing resource users and potential developers with water resource information. Neither the NCC or the MCC wanted a lack of information on the water resources of the area to hold up or prevent what might be sustainable development.

To this end, the NCC resolved to undertake a study of the water resources of the Aupouri peninsula, starting in 1986, to collect the information needed to develop management policies for the water resources.

1.2 Objectives

The main objectives of this project were to determine the location, and characteristics, quantity and quality, of the water resources of the Aupouri and Karikari Peninsulas, assess existing and potential uses and demands on the resource and prepare management policies for those water resources.

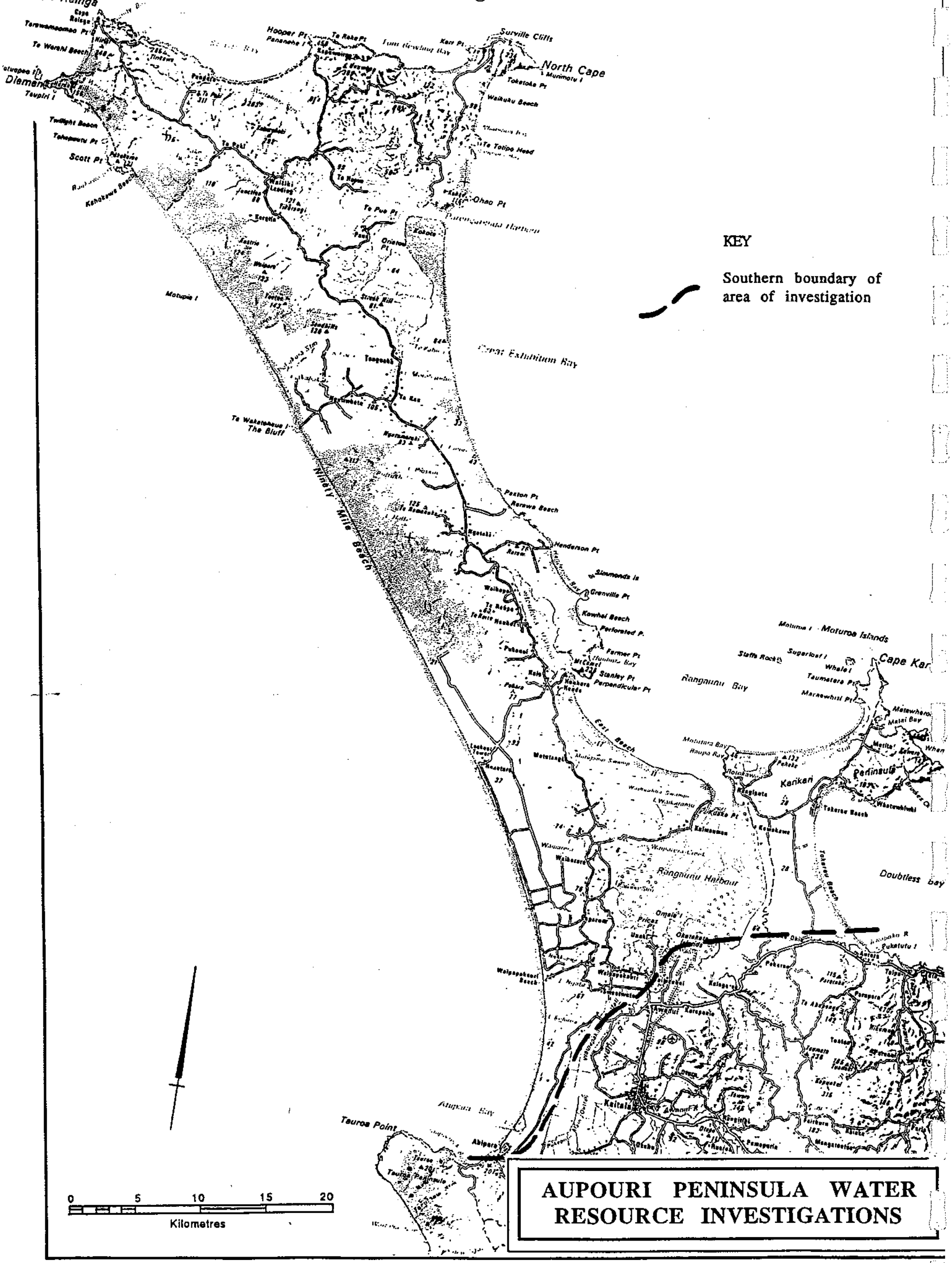


Fig. 1.1 AREA OF INVESTIGATION

These objectives were originally stated as follows:

(a) To determine the extent and magnitude of the water resources of the Aupouri (and Karikari) Peninsulas.

(b) To determine the existing quality of the resource.

(c) To determine the effects of land use changes on the resource, particularly forestry.

(d) To ascertain the likelihood of sea water intrusion into coastal aquifers.

(e) To determine likely demands on the water resources.

(f) To provide the NCC (now NRC) with resource management guidelines to enable sound and equitable management of the water resources.

(g) To determine the significant (freshwater) wildlife habitats of the study area and the likely effect of water resource utilisation on such habitats.

1.3 Investigations Carried Out

Considerable effort has been put into investigation drilling, geophysical surveys, monitoring of rainfall, groundwater levels, lake levels, stream flow and water quality. Particular emphasis has been placed on the investigations of the groundwater resources as for large areas of the peninsulas groundwater is the major source of water. A summary of these investigations is given in Table 1.1.

Table 1.1 Investigations Carried Out;

TYPE	PURPOSE	DATA STORAGE/REPORT LOCATION
Investigation Drilling: - Pukenui-Hukatere transect, Paparore Rd., L Heather, Te Hapua, Ahipara landfill.	- locate and determine geology of water bearing material - install ground water level monitoring wells	WELAR database GCNZ (1987) Sec.
Geophysical Surveys: - Ngataki to Ahipara and Karikari Pen.	- Locate and investigate nature of aquifers - detection of seawater intrusion	McIntosh (1988) GCNZ (1987) (1990) Sec.
Pumping Tests:	- determine hydraulic characteristics of aquifers, examine interference effects between bores	NRC pump-test reports Sec.
Groundwater Level Monitoring:	- estimate direction of flow and quantities of groundwater - examine pumping effects, rainfall recharge and longer term climatic and land use change effects.	GCNZ (1987) Sec. TIDEDA database.

Rainfall Recording: - at NRC and NZMS sites.	- measure rainfall input to water resources - determine rainfall patterns	TIDEDA database NZMS database Sec.
Stream Low Flow Gauging:	- estimate stream water resource	TIDEDA database Sec.
Lake Water Level Monitoring: - Lakes Waipareara, Ngatu, Heather, Rotoroa	- examine water balance and effects of abstractions, climate and land use changes	TIDEDA database Sec.
Water Quality: - of groundwater, lakes, streams	- determine existing quality and suitability for various uses - examine potential problems: sea water intrusion into groundwater and eutrophication of lakes	QUALARC database Sec.
Water Use Survey: - of farm water supplies, irrigators, domestic and industry - for effluent disposal - freshwater wildlife habitat	- determine existing and estimate potential water demands - location, nature and value of freshwater as wildlife habitat	Sec. DOC records.

Table 1.1 The type and purpose of the resource investigations carried out on the Aupouri and Karikari peninsulas.

1.4 Limitations

This report is limited to the freshwater resources of the area and it was not part of the objectives to examine the quality and uses of harbour and coastal waters.

2. FEATURES OF THE STUDY AREA

2.1 General Description and Relief

The topography and drainage of the study area are shown in Fig 1.1

The Aupouri Peninsula is a 75 km long by approximately 10 km wide tombolo type sand spit liking the main body of Northland to North Cape and Mt Camel. The Karikari Peninsula is a similar but smaller tombolo, approximately 14 by 5 km linking the main land to what were offshore hard rock island of Cape Karikari, Puheke and Rangiputa. Over much of the study area the land rises gently to approximately 80 to 100m above mean sea level as low rolling dune country with various terraces, interdunal flats, lakes and swamps.

From Te Kao north the land surface becomes more elevated and dissected, rising to a maximum height of 310 m above sea level. Other rugged and higher level land occurs at Mt Camel (235m above sea level) and at Karikari Peninsula (160m above sea level). In the southern portion of the study area (Waipapakauri, west of Awanui, Ahipara), the land reduces to low level plain of only 5-10m above sea level with a narrow (1km) west coast dune strip.

More comprehensive descriptions of the topography and landforms can be found in Brook (1990), Hay (1975), (1981) and (1983).

2.2 Surface Drainage

The southern plain, east of the coastal dune ridges is drained by a series of ditches and canals to the Awanui River catchment.

The drainage pattern of the sand country is irregular and contrasting. With dune ridges being well drained and generating little surface runoff, while interdunal flats are naturally poorly drained due to the presence of pans. It is on these interdunal areas where numerous swamps and lakes have formed. Many of the swamps and lakes on Aupouri Peninsula are formed at the inland, eastern edge of the most recent (now stabilised) west coast dunes on top of the older eroded dune surface on which pans have formed. Many of these swamp areas have had drains put through them with runoff being channelled to Rangaunu or Houhora Harbours or to the open east coast. The uplands of the northern part of both Aupouri and Karikari peninsulas have well developed but generally short, stream cut valleys.

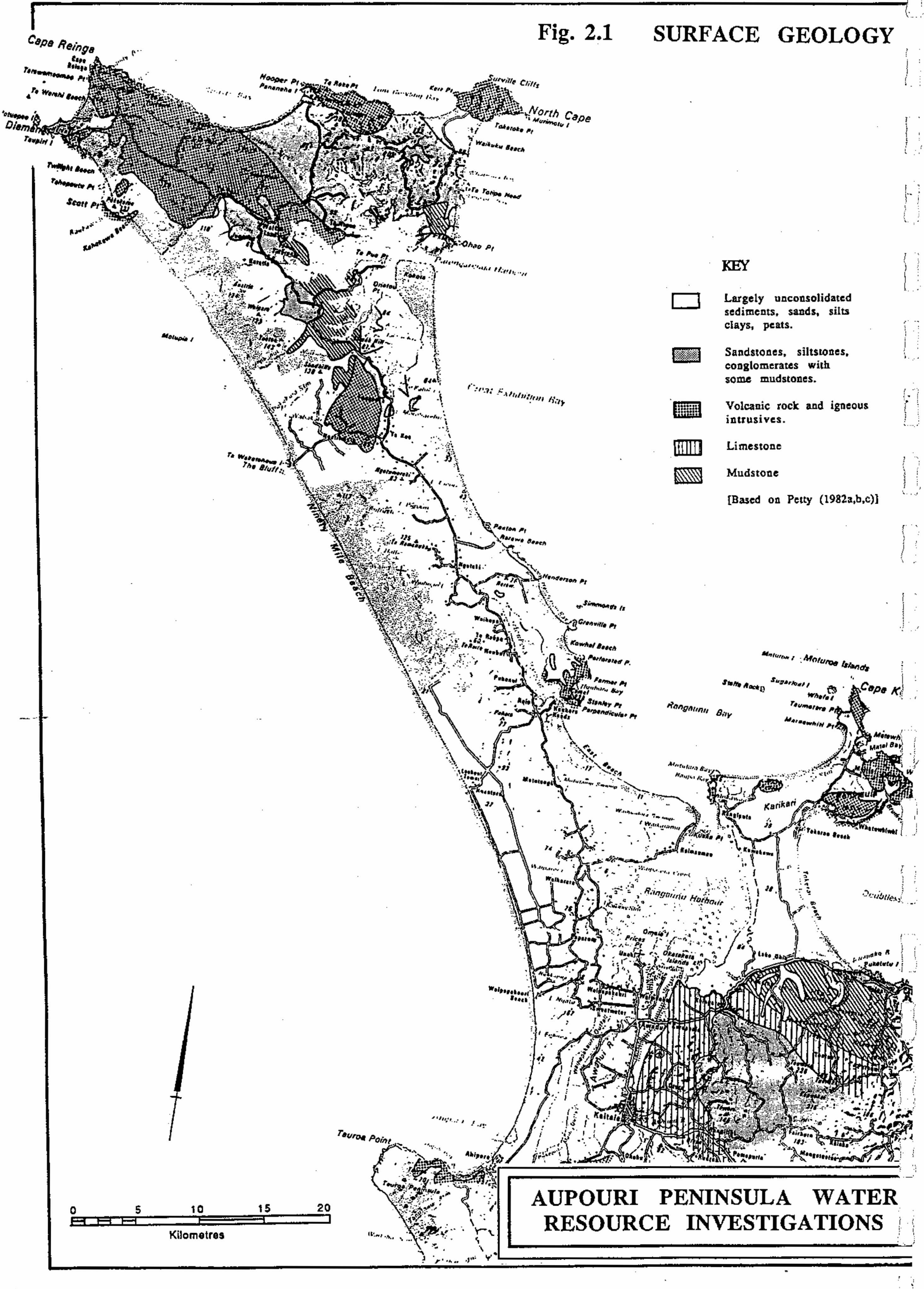
2.3 Geology

Geological materials in the study area form into two main groups, ie. unconsolidated materials and hard rocks.

Unconsolidated Materials

These materials are comprised of fine grained sands, interspersed with gravels, peats (and lignites), silts and shell beds. They are formed as beach and estuary deposits, dune sands, swamp and lagoon deposits. These deposits cover approximately 80% of the study area and their distribution is shown on Figure 2.1

Fig. 2.1 SURFACE GEOLOGY



Hard Rock Materials

Underlying the unconsolidated materials and outcropping over much of the area north of Te Kao, at Mt Camel, Cape Karikari, Pukete and Rangiputa are hard rocks. These comprise sandstones, conglomerates, mudstones, limestones and rocks of volcanic or igneous origin. These rocks are frequently fractured and jointed with weathering extending from 5 to 30m below the ground surface. The surface distribution of these rocks is shown on Figure 2.1.

More detailed descriptions of the surface geology of the area can be found in Brook (1990), Hay (1975), (1981) and (1983) and Petty (1982).

2.4 Soils, Vegetation and Landuse

The current pattern of vegetation and landuse is shown in Figure 2.2.

Vegetation

(Refer: DSIR 1986-87)

Land cover in the catchment can be grouped into the following five categories; pasture (37%), scrub (23%), exotic forest (25%), lakes and wetlands (7%) and unconsolidated bare sand (7%). There are small areas of urban settlement and horticultural plantings (approx. 150ha currently).

Soils and Landuse

(Refer: Sutherland et al., 1979 a,b,c, DSIR 1990)

The study area can be broadly divided into three main groups of soils. Firstly the flats close to Awanui and Kaitaia have soils derived from marine muds and alluvial material. The Aupouri peninsula, to just south of Te Paki stream is comprised of sands of varying ages with peat/sand complexes, as is the Karikari peninsula. The northern ends of both the Aupouri and Karikari Peninsulas have soils formed on older volcanic and sedimentary rock.

1. The estuarine flats are generally Kaitaia clay loam and are versatile for agricultural production. These areas are used primarily for dairying and cropping, with small areas in horticulture.

2. The peninsula can be sub-divided into two distinct areas;

    (a) The western edge which is comprised of younger sand dune complexes, which have only been stabilised over the last 30 years, overlying older more consolidated dunes. Aupouri Forest, predominantly Pinus radiata, was established in the 1970's on this area, to both stabilise the windblown sand dunes and serve as a production forest covering some 30,000 hectares. The land was initially stabilised with marram grass and lupin then planted in pines 5 years later. The forest runs from Waipapakauri along the west coast to Te Paki in the north and is an

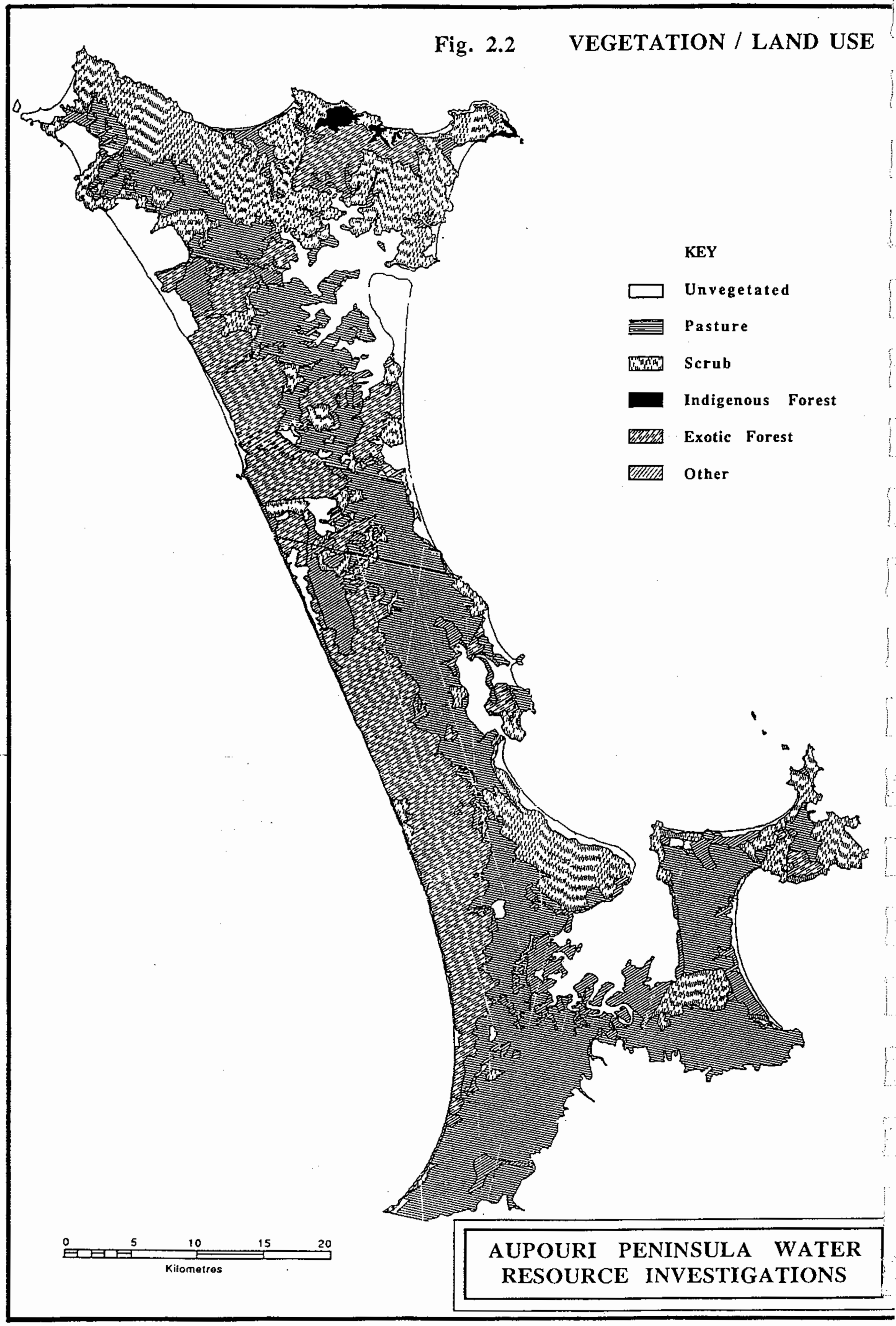


Fig. 2.2 VEGETATION / LAND USE
KEY
Unvegetated
Pasture
Scrub
Indigenous Forest
Exotic Forest
Other
0 5 10 15 20
Kilometres
AUPOURI PENINSULA WATER RESOURCE INVESTIGATIONS

average of 4km wide. (Refer to Sale 1985 for a history of Aupouri exotic forest planning).

(b) This runs from the edge of the forest to the east coast where there are older and more fertile peat/sand complexes. The soils, of which Tangitiki sand is typical, are used for sheep and beef farming, dairying, and some horticulture. The major limitation on these soils is an iron pan which may be from centimetres to metres below the surface, which can lead to poor drainage and restrict root growth. Some horticulturists have used mechanical 'ripping' to break up the pan and increase drainage and tree rooting. The moderately to well drained Houhora sand soils are, however, drought prone and require irrigation. The Karikari peninsula has soils similar to this, although they are in general older, more weathered and limited by iron pans and poor drainage. Sheep and beef farming is the primary current landuse on those soils.

3. The northern tip of the peninsula and the eastern tip of Karikari comprise soils formed on deeply weathered ancient volcanic and sedimentary rock. These soils are strongly leached tending towards podzolisation, and on strongly rolling to steep topography. The steeper and more podzolised areas have reverted to manuka scrub with sheep and beef farming on the better land .

3. CLIMATE

3.1 General

In general the climate of the north of Northland is mild and humid (Moir 1986). The area experiences few frosts and a relatively small range of temperatures. For Kaitaia, the average daily minimum for July is 7.2 degrees C while the average daily maximum for February is 25.6 degrees C.

3.2 Evapotranspiration (ET)

ET is the loss of water to the atmosphere by a combination of evaporation from open bodies of water, soil and other surfaces and transpiration by plants. ET is very difficult to measure directly and is normally estimated from pan evaporation or temperature, solar radiation and wind measurements. A list of the sites where pan evaporation or other measurements used to estimate potential evapotranspiration (PET) within the study area are given in Table 3.1.

Table 3.1
Evaporation and Other Data Available for the Estimation of Potential Evaportranspiration

Site No.	Name	Map Reference	Length of Record
1. Raised Pan Evaporation			
A43922	Waiharara	8/83 - 1/86	
A53024	Aupouri Forest	N04:288-879	1/85-3/87
A53125	Kaitaia Observatory	O04:349-742	6/85
2. Temperature, Solar Radiation and Wind Run			
A42461	Cape Reinga	M02:816-525	1951 - (temperature)
A42581	Te Paki Station	M02:922-440	1931-73 (temperature)
A53024	Aupouri Forest	N04:288-879	1/85-3/87 (no radiation)
A53021	Kaitaia Aerodrome	O04:369-815	1950-85 (no wind run)
A53123	Kaitaia	O04:344-772	19-79 (temperature)
A53124	Kaitaia	O04:345-770	1980 - (temperature)
A53125	Kaitaia Observatory	O04:349-742	6/85 - (no wind run)

The NZMS Kaitaia Observatory is the only site for which pan evaporation data is available for the period of this investigation. The average raised pan evaporation for that site for the period 1986-90 is given in Table 3.2. Also given for comparison is the PET calculated (using Priestly-Taylor method: Linsley et al. 1985) for the Kaitaia Aeroport site (1969-80), 1986 figures for pan evaporation at Aupouri Forest, Kaitaia Obs. and the PET calculated for Kaitaia Obs.

Table 3.2
Evaporation and Potential Evaportranspiration Data

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Pan Evaporation													
Kaitaia (A531205)													
1986-90	163	149	126	92	64	47	54	63	83	116	131	160	1248
1986	154	127	139	91	52	39	62	57	89	114	142	154	1220
Aupouri Forest (A53024)													
1986	140	119	133	81	51	32	40	48	68	108	137	150	1107
Potential Evapotranspiration (Priestly-Taylor method) Kaitaia Aero. (A530201)													
1969-80	170	125	100	60	34	19	25	39	68	99	126	162	1027
Kaitaia (A531205)													
1986	133	112	105	54	31	18	22	34	66	87	120	140	922

3.3 Rainfall

3.3.1 Rainfall Stations

Table 3.3
Rainfall Stations in and Around Aupouri and Karikari Peninsulas

Ref No. (fig 3.1)	Site Name	Site No. *	Map Reference (NZMS 260)	Altitude (m)	Period of Record #	Average Annual Rainfall (mm/yr)
1	Cape Reinga	A42461/2	M02:816-525	191	1919-	1033 (1940-88)
2	Te Paki	A42581	M02:922-440	64	1931-73	1443 (1931-73)
3	Paua Block	A42592	M02:011-369	55	1970-	1268 (1970-86)
4	Cape View Sta	A43701	N03:136-222	37	1967-	1243 (1967-85)
5	Waiharara	A43921	N04:287-948	30	1956-	1176 (1956-90)
6	Aupouri Forest	A53024	N04:288-878	69	1967-86,89-	1176 (1967-86)
7	Waipapakauri	A53022	O04:331-860	6	1955-	1291 (1955-86)
8	Ahipara	A53111	N04:252-708	5	1961-	1213 (1961-86)
9	Kaitaia-Vincent	A53121	N04:345-766	8	1951-	1377 (1951-86)
10	Kaitaia Obs	A53125	O04:349-742	85	1985-	1337 (1985-90)
11	Kaitaia Aero	A53021	O04:369-815	80	1921-78	1430 (1921-77)
12	Kaingaroa Nth	A53031	O04:414-844	30	1962-	1433 (1962-86)
13	Rangiputa	A43931	O03:427-006	8	1970-	1290 (1970-86)

* These are NZ Meteorological Service site numbers.

\# Sites with a "-" and no second year given are still operating. Aupouri Forest is now an NRC site (No. 530204).

The main rainfall measurement sites on and around the Aupouri and Karikari Peninsulas are listed in Table 3.3. All the sites listed are manual collection gauges read daily with the exception of the NZ Meteorological Service Kaitaia Observatory (A53125) and Cape Reinga (A424362) which are automatic. The distribution of the mean annual rainfalls are shown in Figure 3.1. Much of the area has a mean annual rainfall of between 1100 and 1300mm per year. However, slightly higher annual rainfall occurs in the northern hills and adjacent to the hills south of the study area.

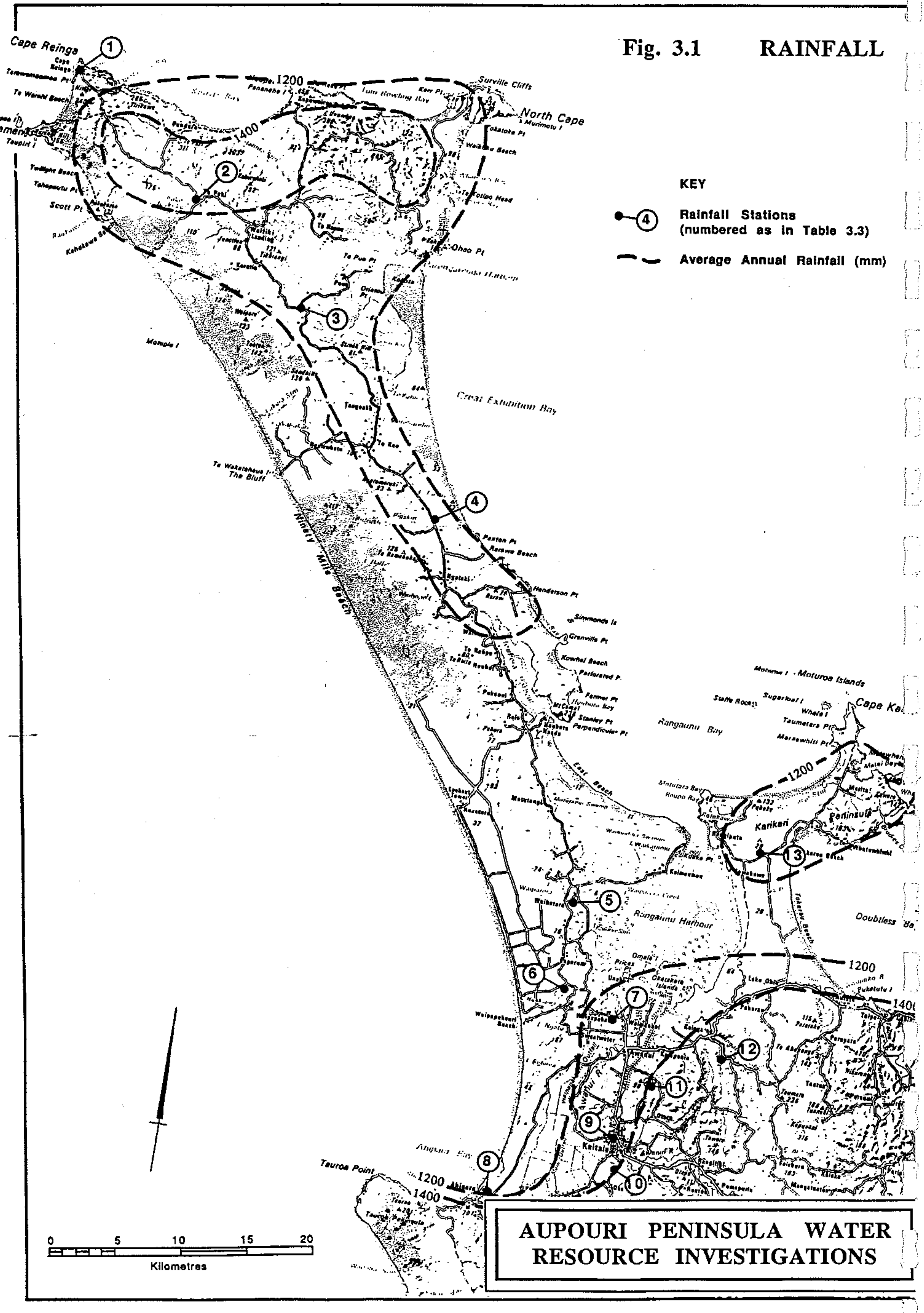


Fig. 3.1 RAINFALL

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3.3.2 Rainfall During Investigation (1986-90)

The monthly rainfalls for Waiharara (site no. A43921) for the period of this investigation ie 1986 through 1990, are listed in Table 3.4.

Table 3.4
Monthly rainfalls for Waiharara

Period	Jan	Feb	May	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Year
1986	138	71	176	26	113	83	141	150	94	52	47	53	985
1987	33	18	136	146	39	57	129	51	101	110	121	129	1068
1988	5	188	159	30	297	77	151	77	185	70	82	52	1372
1989	261	52	14	73	48	205	89	235	160	120	84	46	1387
1990	63	4	73	104	107	84	143	149	57	118	56	16	974
1986-90	99	67	80	76	121	101	131	132	119	94	78	59	1157
1956-90	68	83	80	94	108	138	131	132	106	85	76	74	1176

Table 3.4 Rainfall (Site No. A43921) for the period Jan 1986 to Dec 1990 and the average monthly rainfalls for the period 1986 to 1990 and 1956 to 1990.

From the rainfall figures in Table 3.4 the average rainfall at Waiharara for the study period was similar to the longer term average. This was the case for most of the rainfall stations within the study area.

While, the spring and summer (Oct-Feb) of 1986-87 was particularly dry, having only 53% of the longer term average rainfall. The winter of 1989 was particularly wet with 140% of the long term average (1988 and 1989 winters being respectively the 7th and 6th wettest periods since 1956). In addition, 1985 the year prior to the study period was also a wetter than average year.

3.3.3 Long Term Rainfall Patterns

Long term rainfall trends have been examined with two smoothing procedures:

(i) cumulative departure - where the differences between actual monthly rainfalls and monthly means are summed; and

(ii) five year running mean - where the mean annual rainfall of each five years of records is calculated.

Plots of the cumulative departures and five year running means for selected stations are shown on Figures 3.2 and 3.3 respectively.

The 5 year running means show a somewhat cyclic pattern of 4 to 6 wetter years followed by a similar length dryer than average period. Two further trends are apparent in the 5 year mean plots. The Mangonui, Kaitaia and possibly Waipapakauri data indicate a possible long term reduction in rainfall, with the running mean curve lying below the long term for much of the time since 1972, while generally being above the mean from about 1960 to 1972.

For the Waiharara site, the 5 year mean is above the long term mean from 1960 to 72, then below or close to the long term mean except for 1988-89.

Figure 3.2: Cumulative departure for the Cape Reinga rainfall site

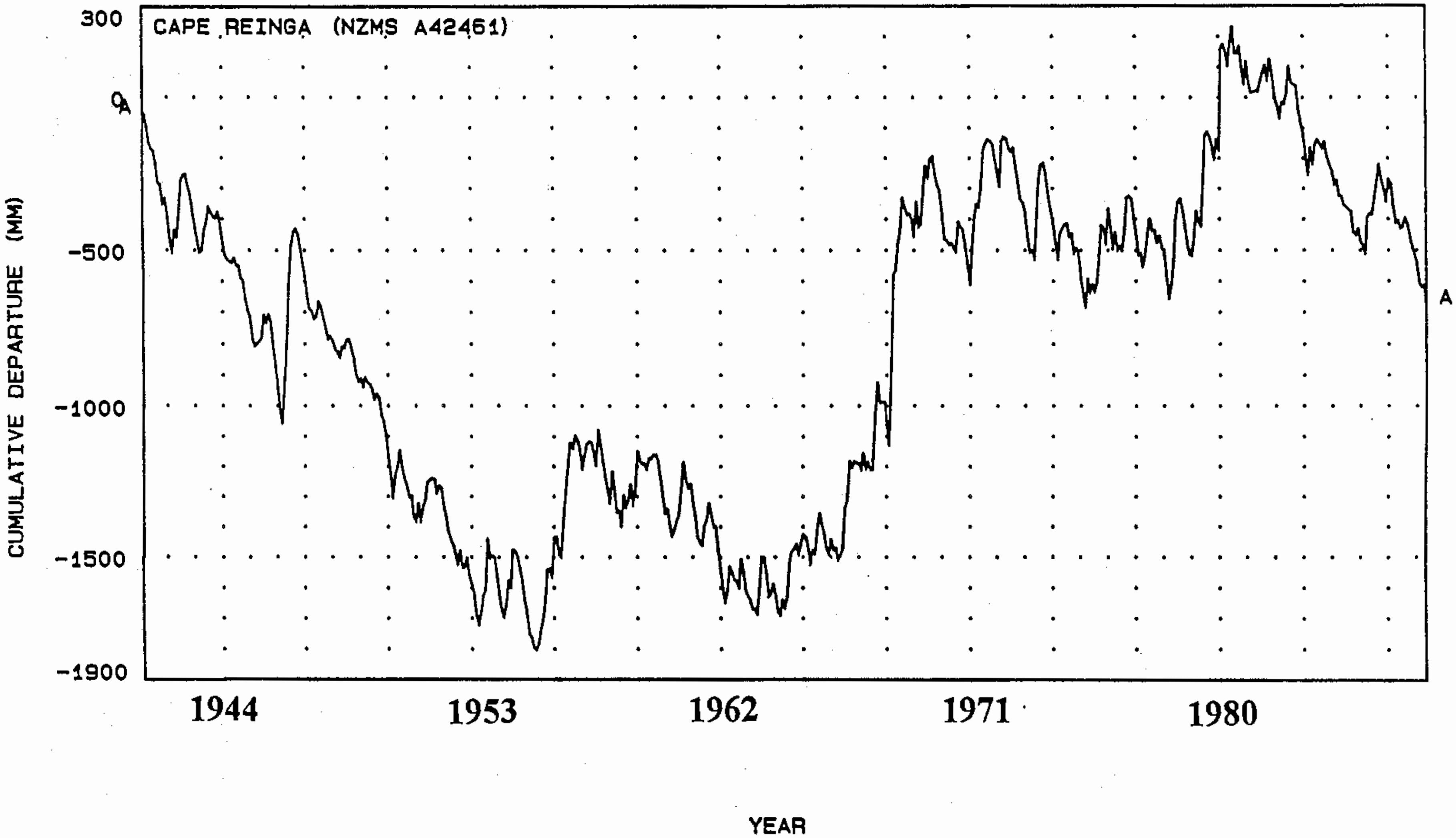

Figure 3.2: Cumulative departure for the Mangonui rainfall site

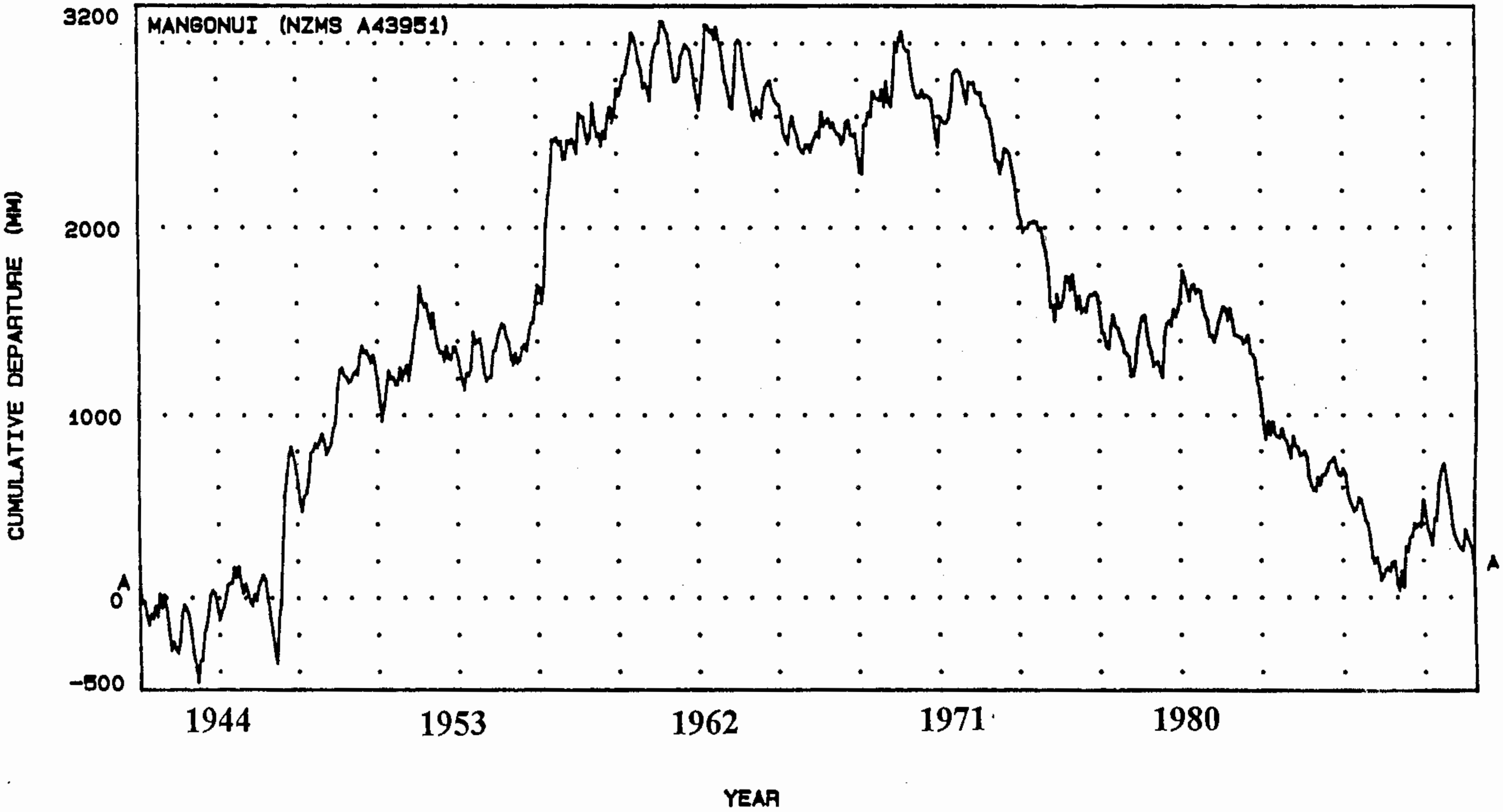

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Figure 3.2: Cumulative departure for the Waiharara rainfall site

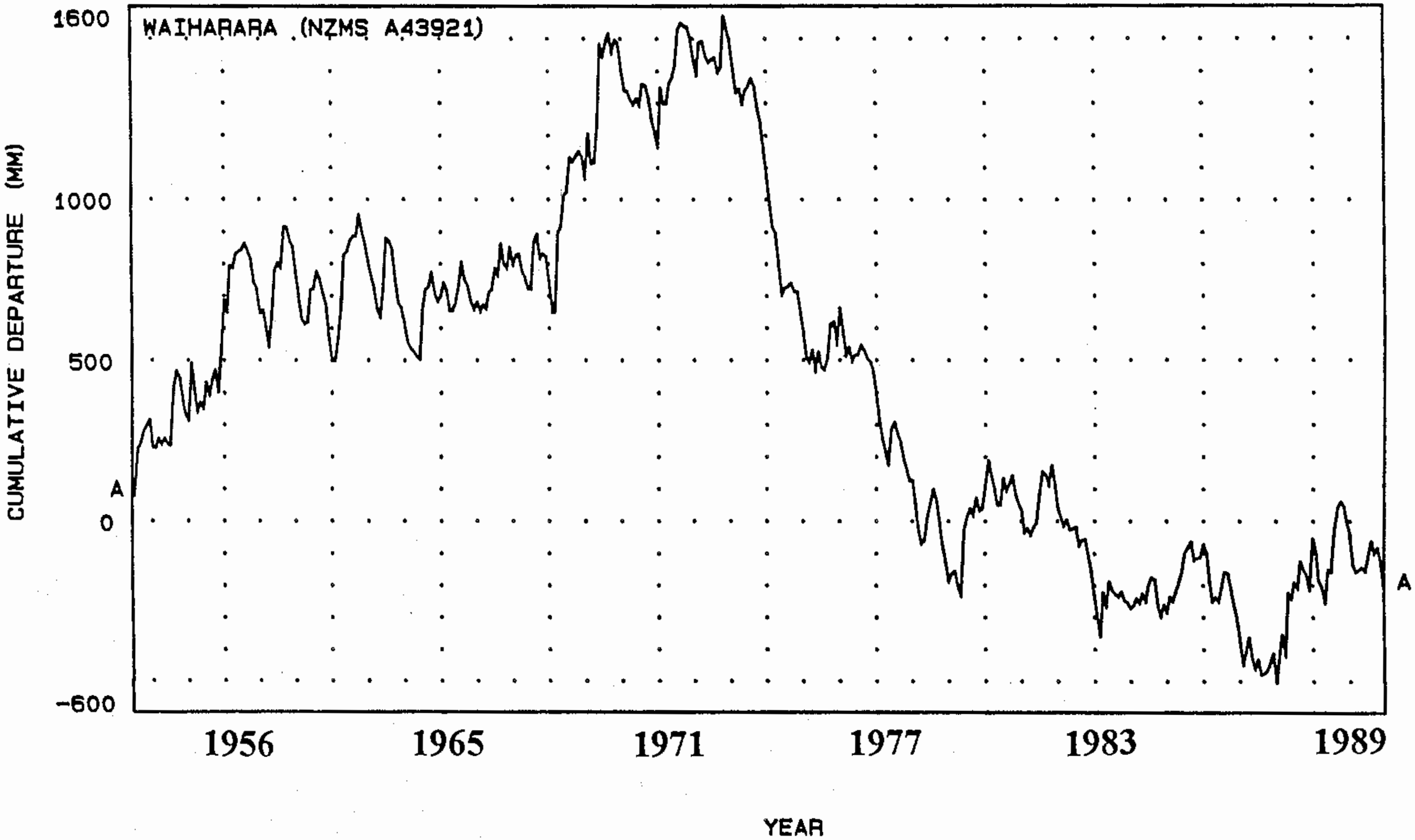


Figure 3.2: Cumulative Departure for the Ahipara rainfall site

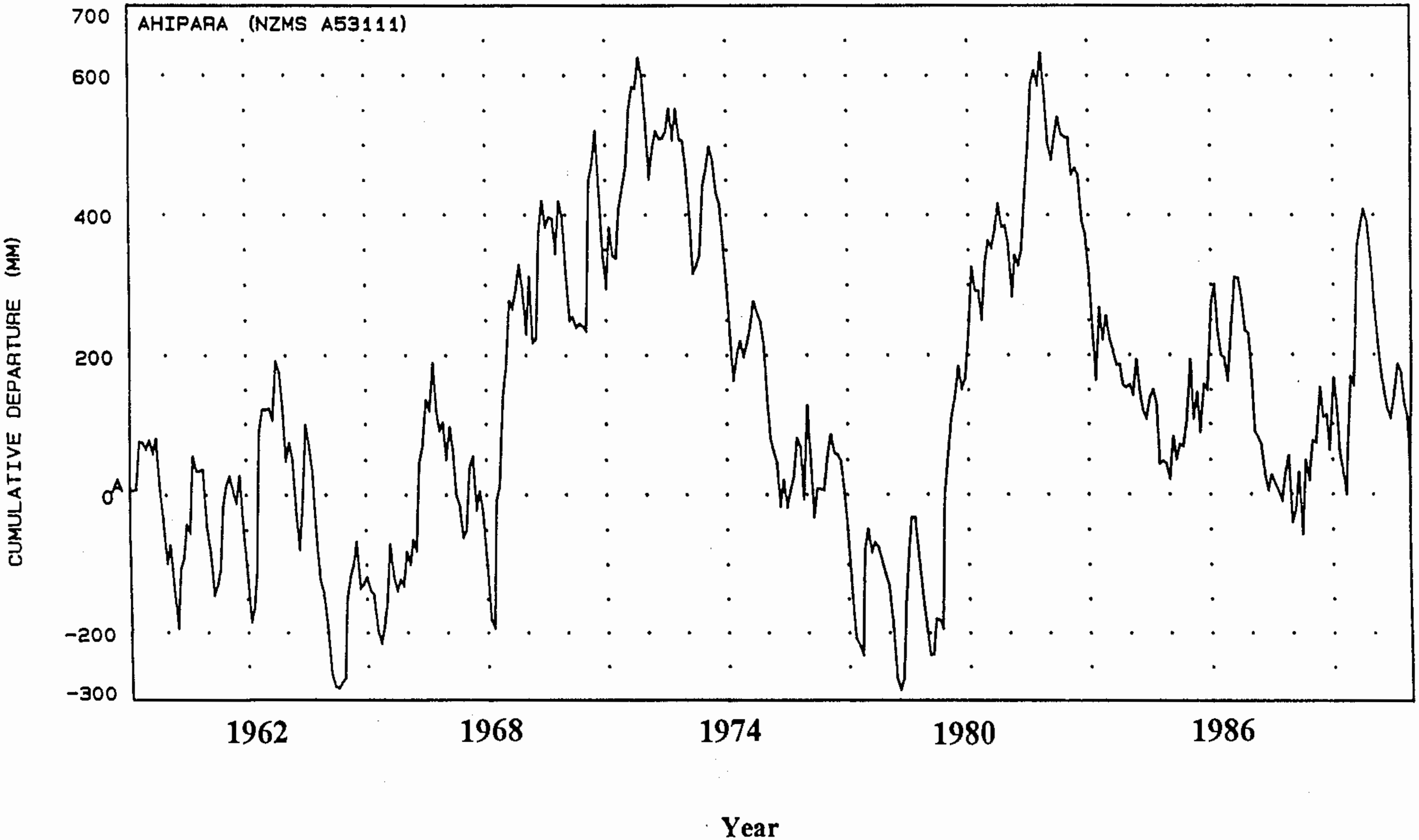


Figure 3.2: Cumulative departure for the Cape View Station rainfall site

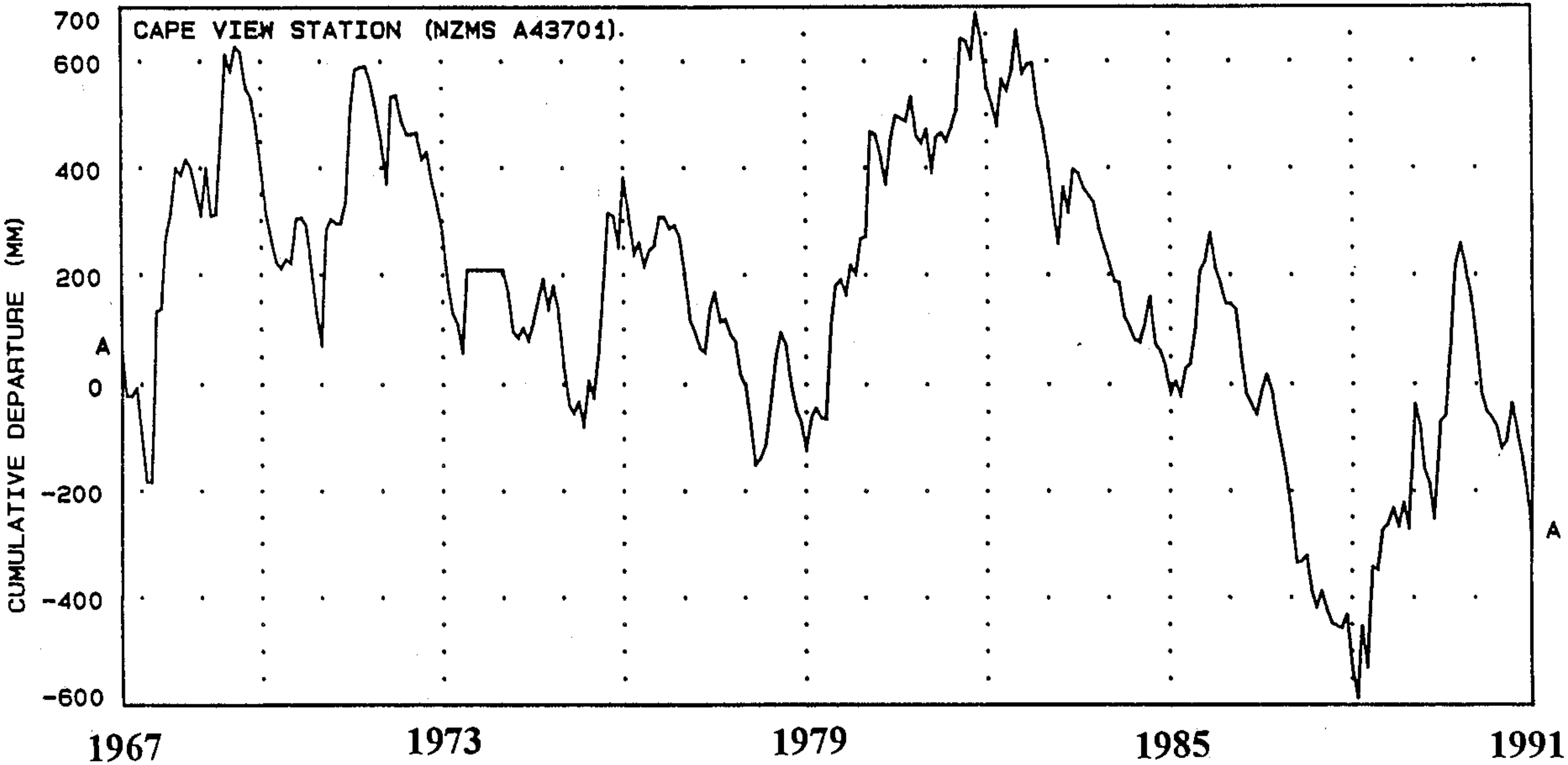


Figure 3.2: Cumulative Departure for the Kaitaia rainfall site

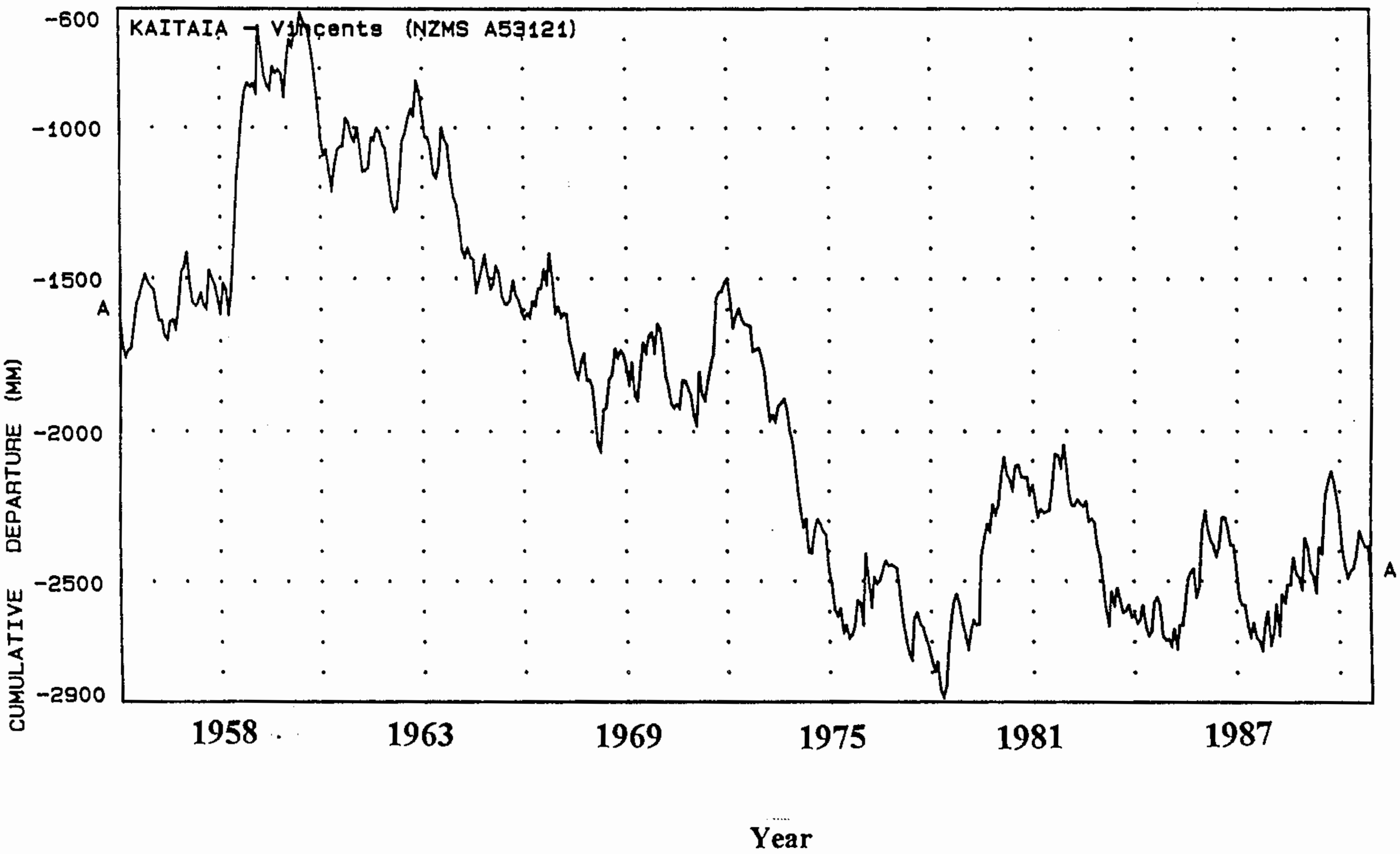


Figure 3.3: 5 year running means of annual rainfall Waiharara

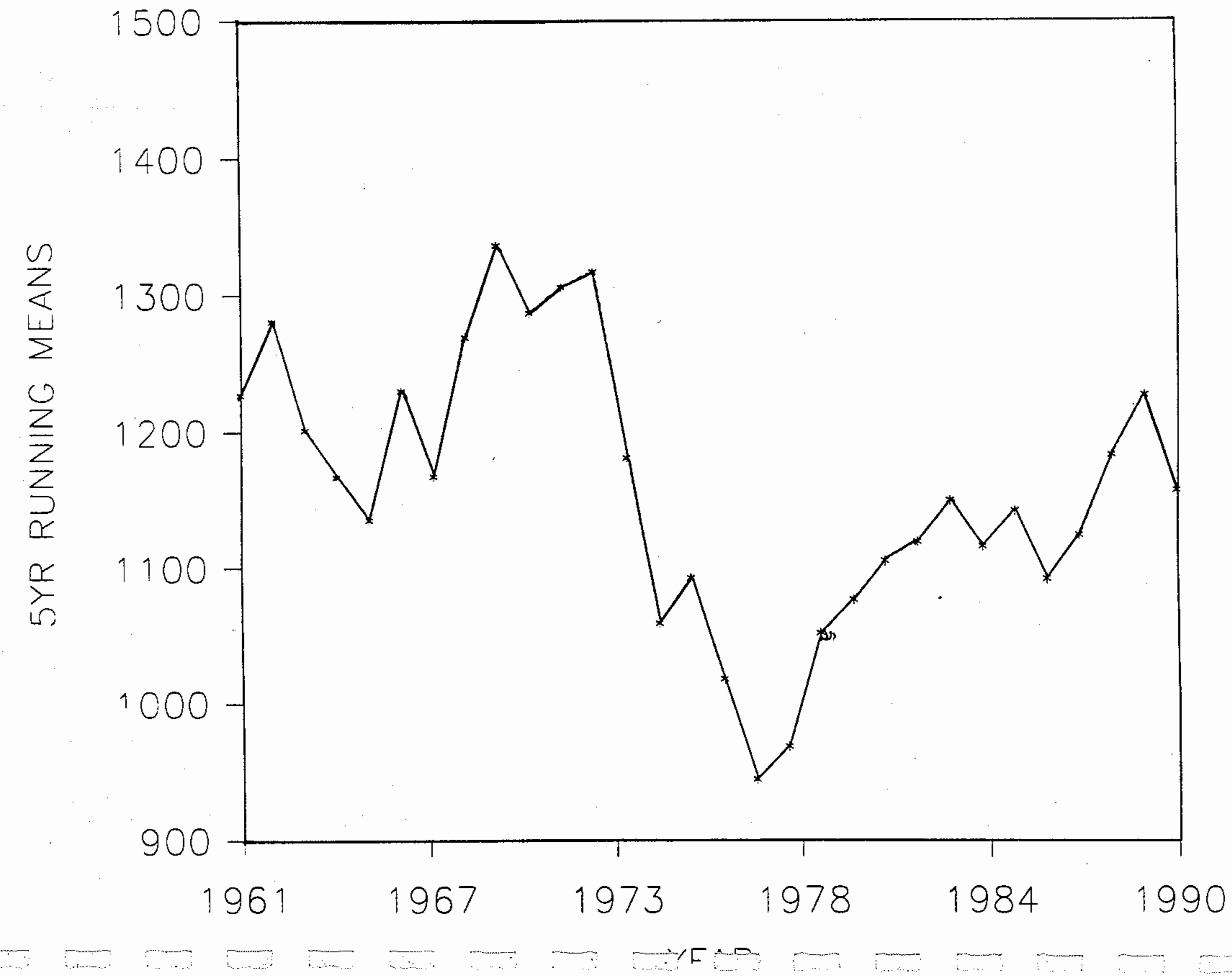


Figure 3.3: 5 year running means of annual rainfall Kaitaia and Mangonui

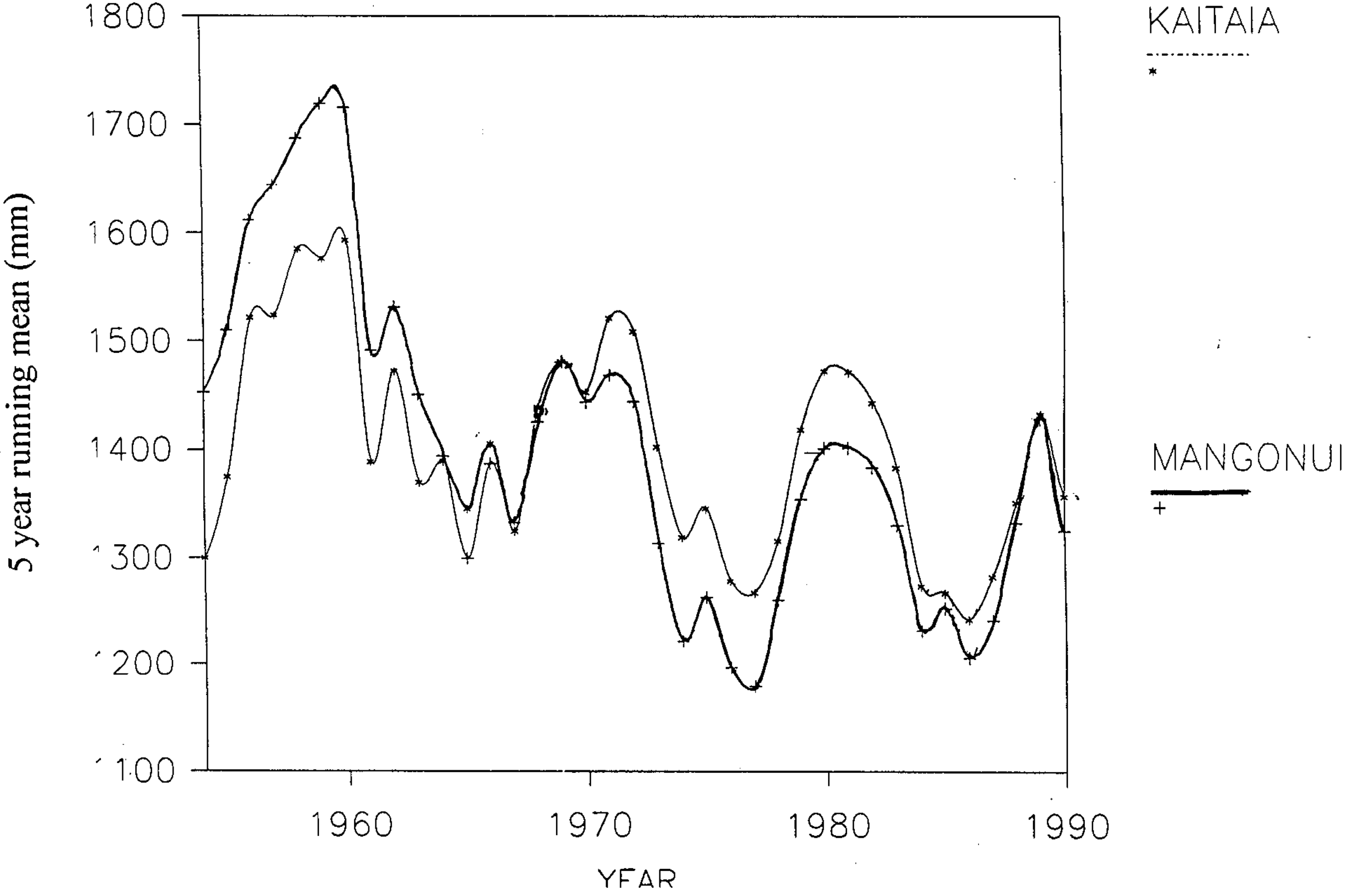
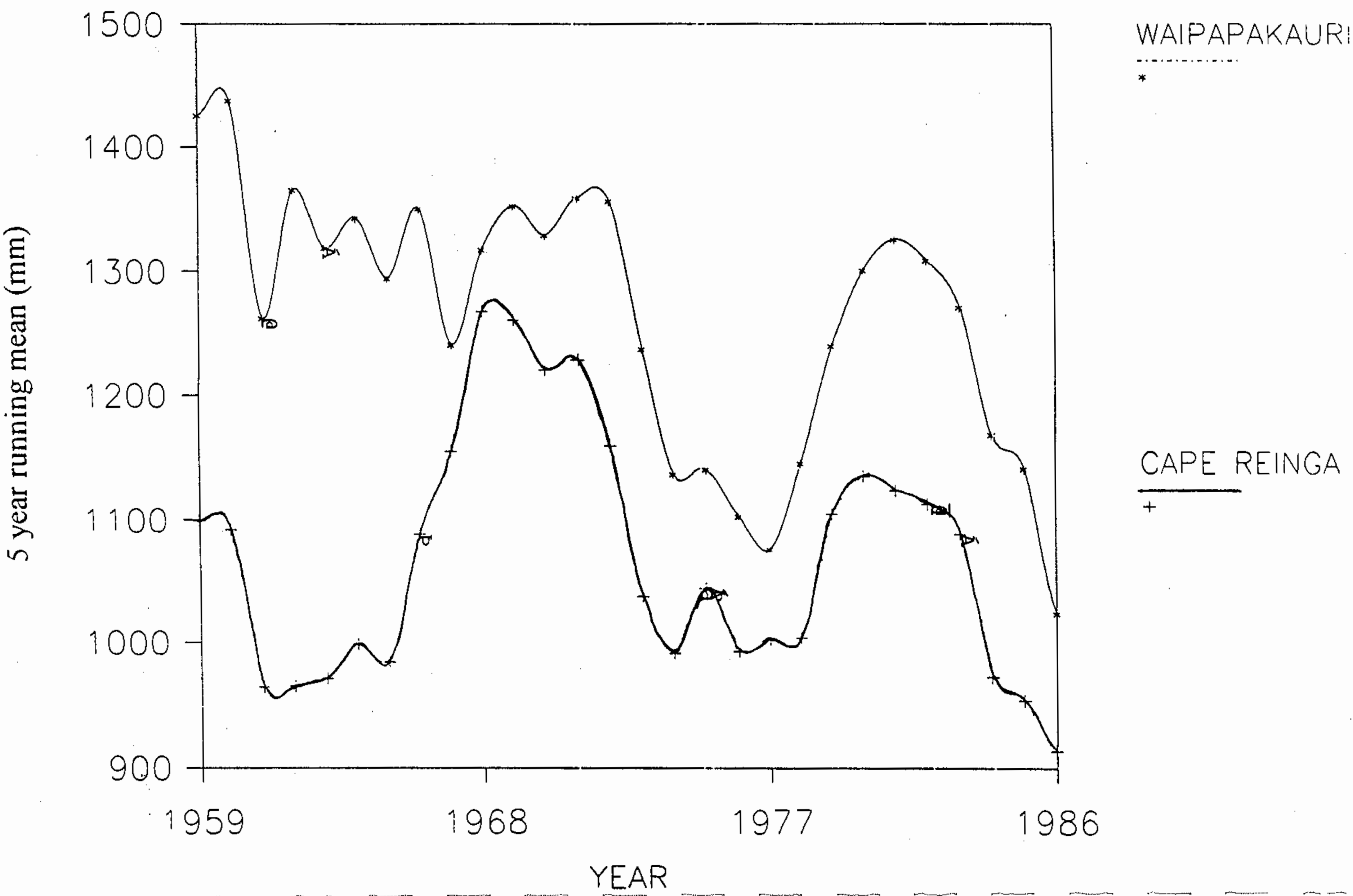


Figure 3.3: 5 year running means of annual rainfall
Cape Reinga and Waipapakauri



The Cape Reinga record, which unfortunately stops in 1988, shows a similar 4 to 6 year cycle of relatively wet and dry periods, but without apparent long term reduction, and with at least half of the period since 1972 being above the long term mean.

The cumulative departure plots for Mangonui and Waiharara show a similar pattern of decline in rainfall since about 1972. However, other sites such as Kaitaia, and to a lesser extent, Ahipara, show a significant increase in the 1979-81 period followed by a decrease from 1982 to 87.

4 GROUNDWATER INVESTIGATIONS

4.1 Introduction

It was a major objective of this project to investigate the nature of the groundwater resources of the area and a substantial part of the project expenditure and effort was directed towards hydrogeological investigations. Sections 4 and 5 contain a summary of the findings of those investigations.

4.2 Geological Maps and Geophysical and Hydrogeological Investigation Reports

A number of reports produced both before and during this project detail particular aspects and findings. These reports are referred to in the relevant sections of this report and include:

Hay 1975, 1981 and 1983 and Brook 1989: a series of detailed geological maps (scale 1:63360) with accompanying texts which describe the physiography, startigraphy (age relationships of various strata) and rock types, covering the Aupouri Peninsula north of Waipapakauri and Karikari Peninsula present. These maps are based largely on the interpretation of surface outcrops.

Petty 1975: a report on the drilling, sampling and pump testing of bores at five sites from Kaitaia to Hukatere, including three sites within the sand country of the Aupouri Peninsula. The location of the sites and details of the bore logs, water quality and pumping test results are given in the appropriate sections of this report.

Petty 1982a, b and c: a series of maps (scale 1:100,000) showing and describing the basic rock types of the whole study area. This series of maps is useful for assessing likely hydrogeological conditions in those parts of the study area where there is little or no hydrogeological data from bores as it lists such things as the hardness, fracturing, bedding and weathering of the rock types.

GCNZ 1987a: Describes the drilling, construction and hydraulic testing of five multi-level monitoring bores (piezometers) across the Aupouri Peninsula between Hukatere and Pukenui, including an initial evaluation of the ground water resource in that area.

GCNZ 1987b: Describes a seismic refraction survey of sites at Hukatere and Sweetwaters used to determine the thickness of the sands.

McIntosh 1988: Reports on the use of various geophysical survey methods to determine the geometry of water bearing strata, sub-surface geology and detection of possible sea water intrusion into aquifers and findings of those surveys.

GCNZ 1990: Describes the geophysical investigations of sites in the Ahipara, west Awanui and Karikari areas to assist with the determination of the hydrogeological features in this area.

All of the above are available at the NRC Whangarei offices for examination.

4.3 Bore Log Data

Bore logs from drill holes are an important component of the investigation of ground water resources. Provision of bore logs for private bores is done on a voluntary basis by well drillers. The NRC keep copies of logs submitted and references and locates each bore on a series of maps.

NRC have logs for about 250 water bores from the study area. The amount of data returned on the bore logs ranges from minimal (eg owner, driller, bore depth, map reference) to full descriptions of material drilled, bore construction details and an estimate of the water yield from the bore. A selection of the more complete logs for bores representative of those in a particular area or of special interest are listed in Appendix 1, along with a location map.

As part of this investigation bores were drilled at 9 sites (as shown on Figure 4.1) to determine the subsurface geology and monitor groundwater levels. The detailed geological and construction logs of those bores are given in Appendix 2.

4.4 Investigation Drilling Programme

4.4.1 Purpose of Drilling Programme

The purpose of the investigation drilling programme for this groundwater resource survey were to:

(1) Determine the geology, presence and type of potential aquifers;

(2) Install piezometers for the monitoring of groundwater levels, and hence gradients and directions of flow. Multi-level piezometers were used at a number of sites to determine vertical gradients;

(3) Two sets of multi-level piezometers were installed near high yielding irrigation bores (at Hukatere Rd and Paparore Rd) to be monitored during pumping tests to determine the hydraulic characteristics of the aquifers and monitor longer term effects of pumping on groundwater levels;

(4) Enable the sampling of groundwater for water quality determination.

4.4.2 Choice of Location of Investigation Drilling Sites

Investigation drilling was targeted to areas of greatest potential groundwater use; Pukenui-Hukatere and Paparore Rd (Waiharara) (irrigation and farm water supply) and adjacent to Lake Heather (Sweetwaters) (proposed forest processing).

Investigation/monitoring bores were also drilled around the FNDC Sandhills Rd, Ahipara landfill tip site and one investigation bore was drilled at Te Hapua to examine the potential of any groundwater resource in that area.

Initially it was planned to drill one or two bores on Karikari Peninsula. However, with the demise of the major tourist development proposal the priority for investigation was changed to Ahipara and Te Hapua, areas of existing problems.

Table 4.1: Summary of bore pumping tests

BORE NO (WELARC)	LOCATION	MAP REF.	BORE DIAM. (mm)	DEPTH (m)	SCREEN (m)	AQUIFER	TEST TIME (hrs)	Q (m3/d)	DRAWDOWN m.b.g.l (m.a.m.s.l)	T (m2/d)	COMMENTS
43	Pukenui	N03:225-088	150	55	52-55	f.sand	19	330	9.3-12.4 (3.2-0.1)	240 p 280 r	recov. in 90mins
48	Hukatere	N03:196-016	150	67	19-20.5	m.sand	2x4	250	5.3-13.2 (17.6-9.7)	80 - 300	S= 0.01 to 0.0001
184	Burnage Rd	N03:211-074	150	110	101-110	sh.sand	24	260	17.2-20.9	140 p 340 r	
60	Hukatere Rd	N03:217-063	150	60		f.sand	20	708	14.9-25.0 (11.7-1.6)	220- 850 o 525 r 480 ro	
59	Hukatere Rd	N03:218-059	150	55	49-55	f.sand	22	235	13.4-19.7 (13.4-7.1)	190 p	
	Hukatere Rd	N03:221-071		6	none	f.sand	21	130v	2.8-4.8 (18.2-17.0)	140 p/r	2 obsrv. bores
229	Paparore Rd	N04:300-905	150	79	70-79	sh.sand	24	864	2.6-24.6 (7.0--15.0)	140 p/o	S= 0.00014 to 0.0018
230	Kaimaumau Rd	004:303-972	100	88	63-69	sh.sand	10	270	4.8-7.2	310 d 240 r	
81	Ogle Dr	N04:285-898	150	32	31-32	f.sand	6	37	20.9-21.7 (14.7-14.0)	12 to 28	S= 0.07 to 0.03
152	Far Nth Rd	N04:281-889	150	66	60-66	f.sand	20	320	30.1-38.6 (10.6-2.1	260 p/o	2 observ. bores
1007	L.Ngatu	N04:283-858	150	50	45-50	f.sand	21	150v	33.3-43.1 (11.8-2.0)	305 d 275 r	

continued

BORE NO. (WELARC)	LOCATION	MAP REF.	BORE DIAM. (mm)	DEPTH (m)	SCREEN (m)	AQUIFER	TEST TIME (hrs)	Q (m^3/d)	DRAWDOWN m.b.g.l (m.a.m.s.l)	T (m^2/d)	COMMENTS
1025	Sweetwaters	004:315-844	100	30	27-30	f.sand	6	300	+1.55-13.1 (5.53--9.12)	60 to 103	S= 0.00025 to0.0005
1002	Ahipara	N04:255-711	150	32	28-32	m.f.sand	22	160v	7.3-25.9	-	variable Q prob.
	Awanui	004:342-849	100	34	32-34	sand					

KEY:

Aquifer types:- f:fine, m:medium, sh:shelly.

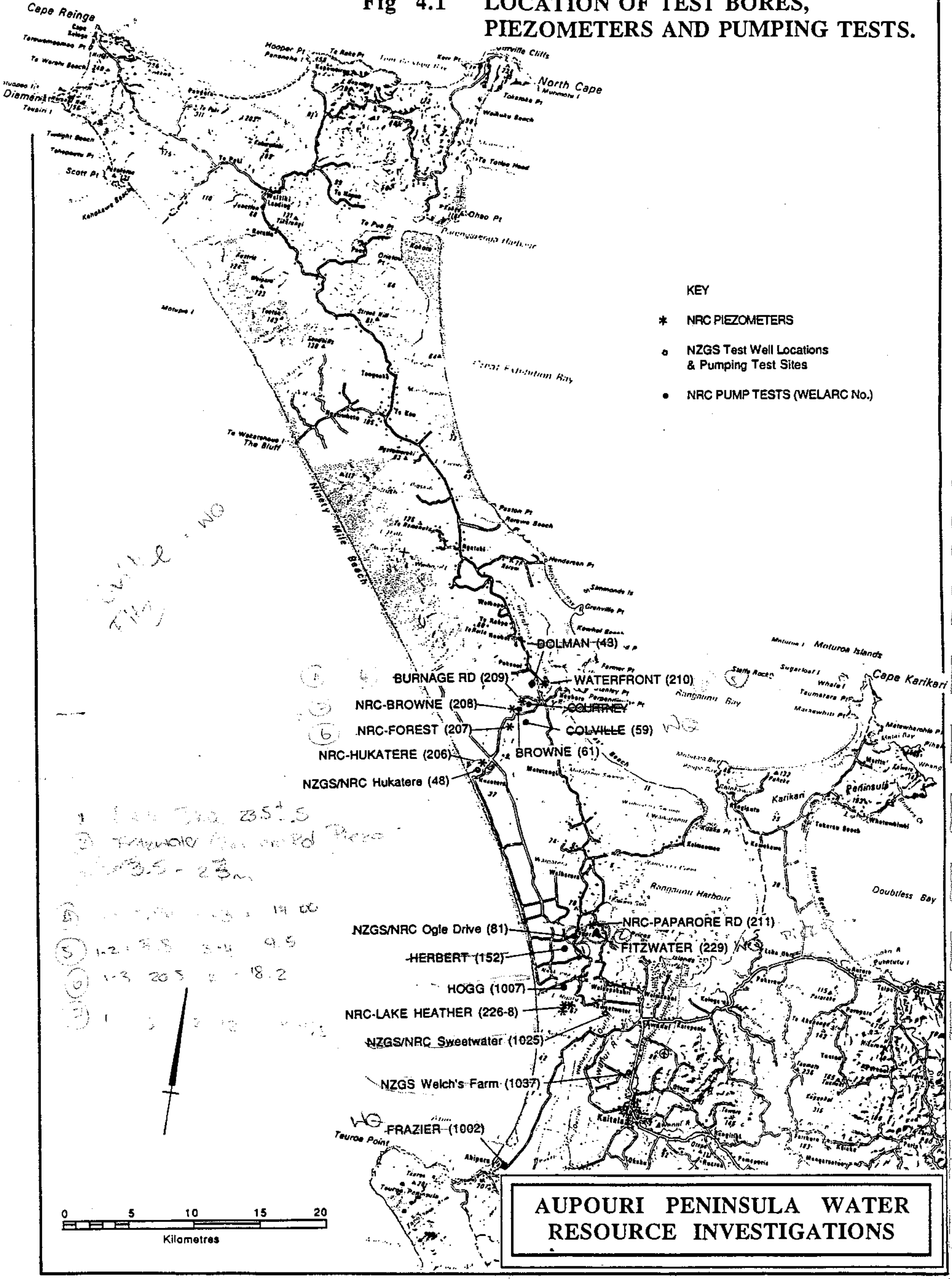
m.b.g.l :- metres below ground level; m.a.m.s.l :- metres above mean sea level

Q :- pumping rate, discharge

T :- transmissivity; p:calculated from pumped bore drawdown data: r:calculated from pumped bore recovery data; o:calculated from observation bore data.

S :- storativity calculated from observation bore data.

Fig 4.1 LOCATION OF TEST BORES, PIEZOMETERS AND PUMPING TESTS.



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The location of the investigation drilling sites are shown in Fig 4.1, the detailed geological and construction logs of those bores are given in Appendix 2.

4.5 Geophysical Surveys

Geophysical surveys, reported in GCNZ 1987b, McIntosh 1988 and GCNZ 1990, were carried out to help locate drilling sites and allow the extrapolation of the findings of the drilling to other areas, helping to define aquifer geometry and look for possible sea water intrusion inland into aquifers.

Two geophysical methods were used, electrical (DC) resistivity and seismic refraction. See Fig 4.2 for location of geophysical surveys

4.6 Pumping Tests

The Council has data on 13 pumping tests carried out on bores in the study area to evaluate the hydraulic characteristics of aquifers, ie the ability of the aquifer to store and transmit water. A summary of the bores tested and the test results are given in Table 4.1 and the locations of the bores tested are shown Fig 4.1.

For the purposes of this report the results of the pump tests will be referred to where relevant in the discussions of the groundwater resources of particular areas and will not be discussed in detail here. The detailed pumping test data may be obtained from the NRC.

4.7 Groundwater Level Monitoring

The monitoring of groundwater levels is done to determine the response of the groundwater resource to climatic events and development activities and to estimate flow directions and volumes.

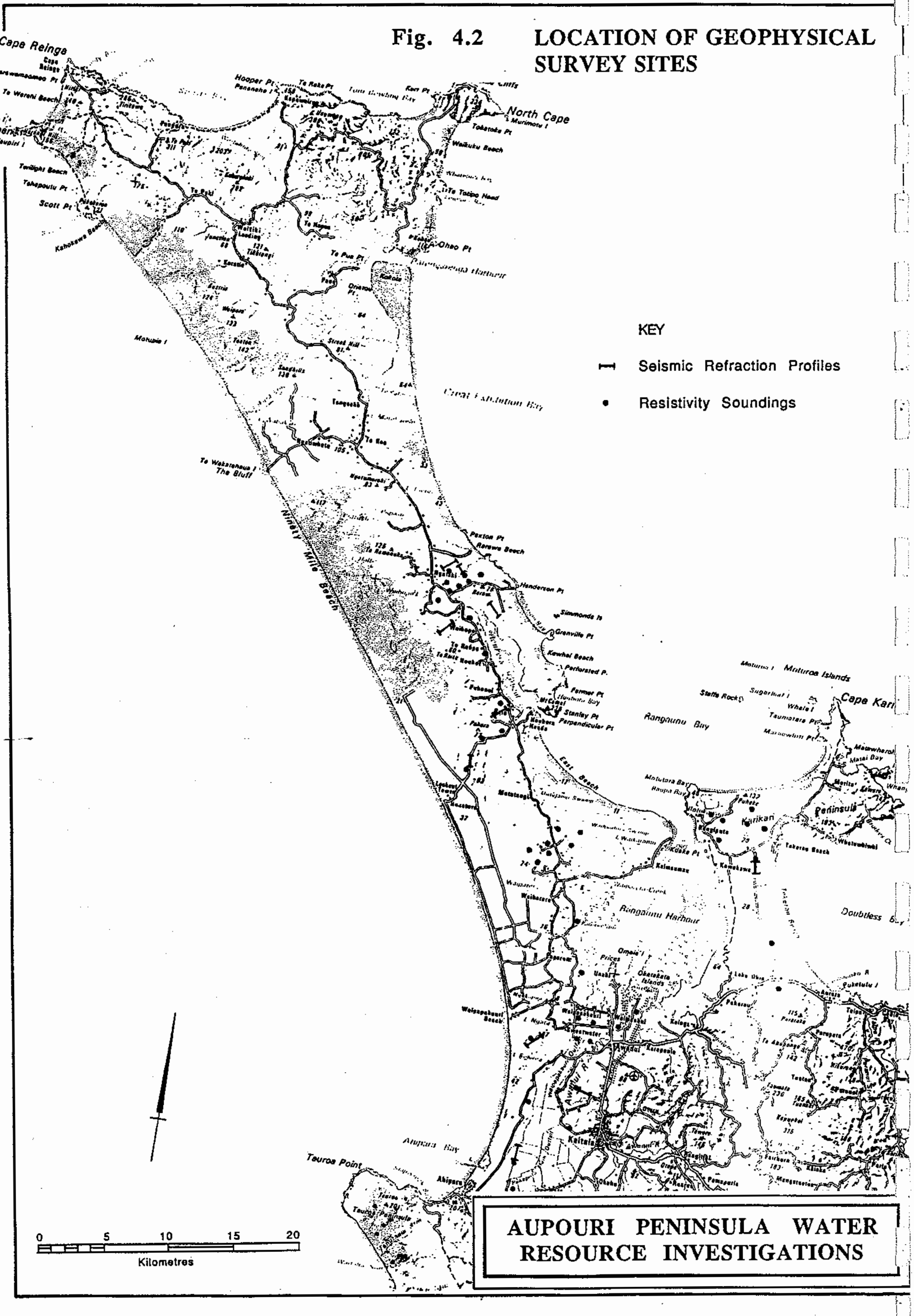
Prior to this investigation the only measuring of groundwater levels had been those recorded by MWD between 1975 and 1978 for the ex-DSIR (Petty 1975) bore at Hukatere (No. 48) and from 1975 to 1976 for the Ogle Drive (No. 81) and Sweetwaters (No. 1025) bores.

As part of this investigation, water level monitoring bores were installed across the Aupouri Peninsula from Pukenui to Hukatere and at Paparore Rd and adjacent to Lake Heather. These were multi-level piezometers in which the water levels were measured monthly from the beginning of 1987. Groundwater level recorders were re-installed on the ex-DSIR bores at Hukatere, Ogle Drive and Sweetwaters at that time. The location of the groundwater level monitoring bores are shown on Fig 4.1.

Surveys of the water levels in a selection of irrigation bores were also carried out to help determine directions and volumes of groundwater flow.

Plots of the water levels measured and recorded in the multi-level piezometers are given in Figure 5.10.

Fig. 4.2 LOCATION OF GEOPHYSICAL SURVEY SITES



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5 GROUNDWATER RESOURCES

5.1 Introduction

For the purposes of discussion of the findings of the groundwater resource investigations, it is convenient to divide the study area into four sub-areas:

(1) Sweetwaters to Waihopo;
(2) Ahipara to Sweetwaters;
(3) Waihopo-North;
(4) Karikari Peninsula.

The division into sub-areas is based on actual hydrogeological differences. The approximate boundaries of these areas are shown on Fig. 5.1

5.2 SWEETWATERS TO WAIHOPO

This is the area of the Aupouri Peninsula north of Lakes Rotoroa and Heather and south of Waihopo, excluding the Mt Cambel, Henderson Bay peninsula. This is the area with the largest available groundwater resources, highest current demand for water and in which most of the detailed investigations were carried out. This area is approximately 33 km long and encompasses about 297 km^2.

5.2.1 Groundwater Bearing Strata - Type and Distribution

From the surface geology maps, summarised in Fig 2.1, it can be seen that the area between Sweetwaters and Waihopo is covered by unconsolidated sediments, mainly fine sands, with no outcrops of hard rock.

Two main aquifer types are represented in the sediments, namely sands and shell beds. The subsurface geology as determined from bore logs and interpreted from geophysical surveys is a thick sequence of fine sands, 70-100m thick over much of the eastern side and southern end of this area thickening westward to greater than 200m at Hukatere, with a basal shell bed overlying hard rock basement.

The sequence of fine sands is separated by thin (relative to thickness of sands) peats (lignites), silts and clay layers or lenses on the eastern side of the Aupouri Peninsula. The frequency of these finer grained materials is shown by the resistivity data (McIntosh 1988) to reduce westward. Grain size analysis of the sands (Petty 1975) shows the sands to be uniformly graded fine sands (0.1 to 0.3mm, 40% retention at 0.2mm, effective size: 0.15mm, uniformity coefficient 1.4).

A bed of shell hash (broken shell fragments of various sizes in a sand matrix) occurs at the base of the sands and immediately on top of the underlying hard rock basement and from bore logs is known to occur over much of the eastern half and south of this sub area. The known occurrences of the shell bed from bore logs are shown on Fig 5.2, its thickness varying from 2m to 20m.

Some bore logs indicate that shell beds can also occur at higher levels in the sedimentary sequence (Bore log 200).

Fig. 5.1 SUB AREA BOUNDARIES

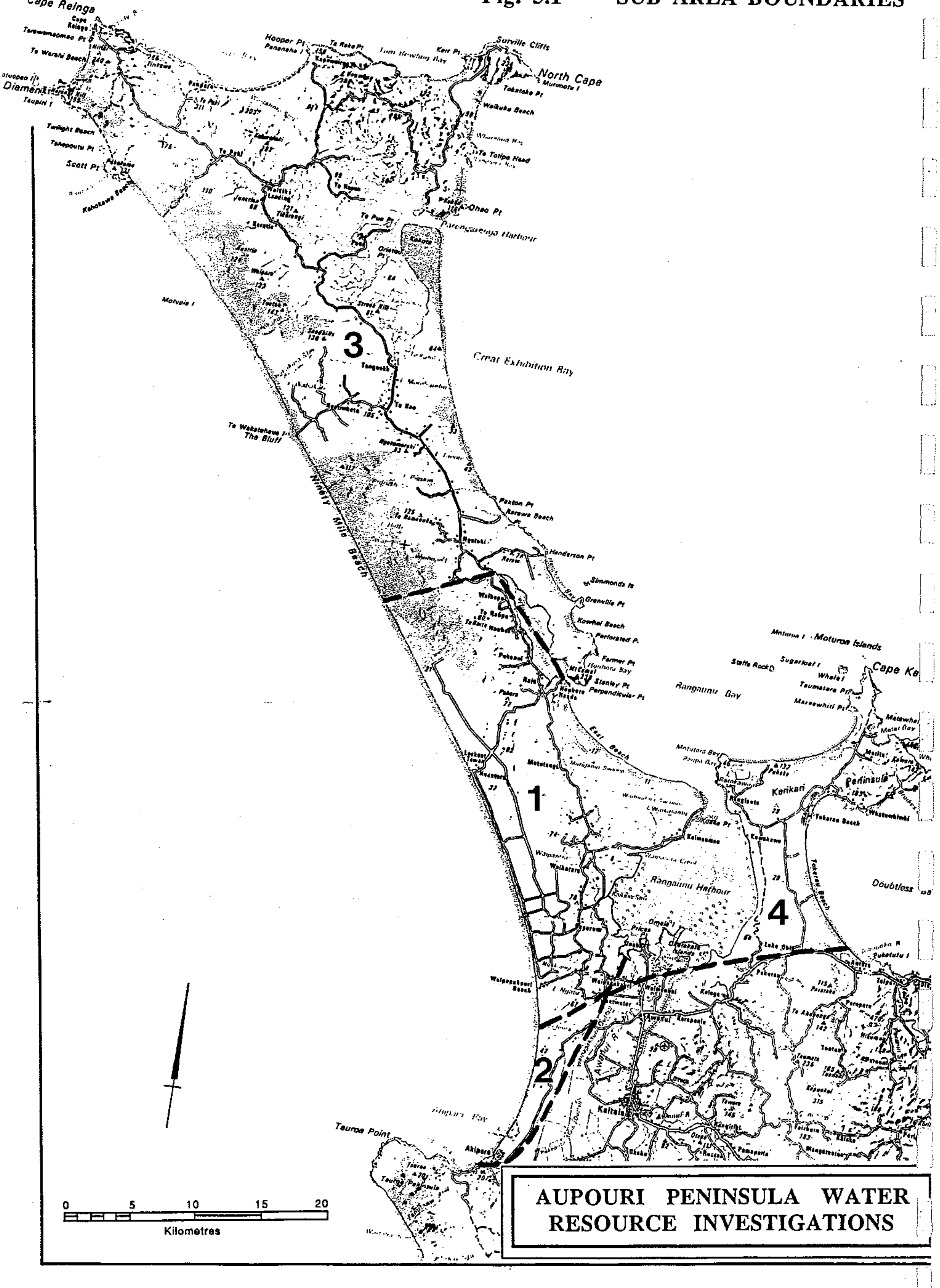

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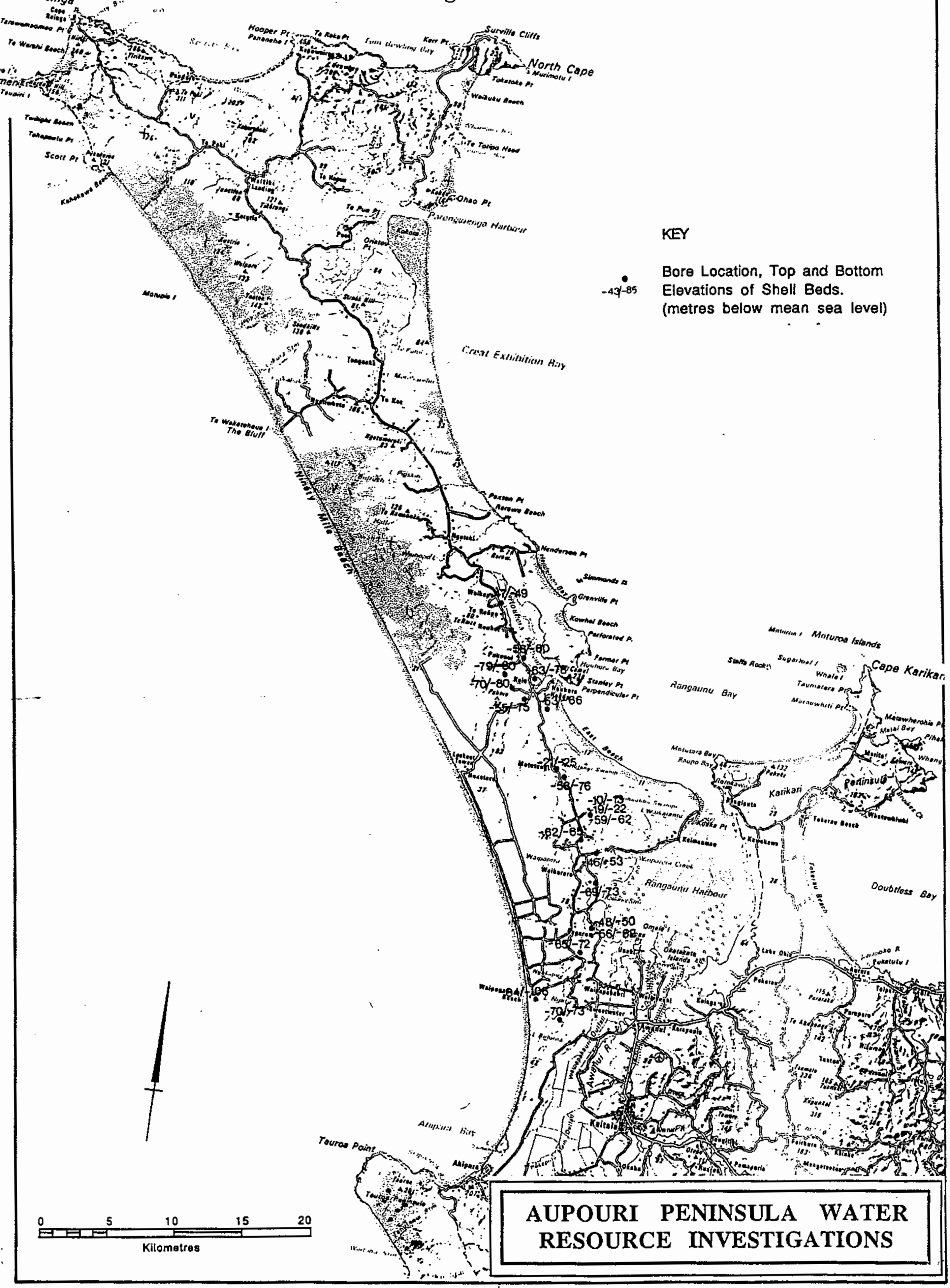
Fig. 5.2 SHELL BED INTERCEPTIONS



The depth to hard rock basement and hence the thickness of the sand sequence, or of other unconsolidated sediments, is shown in Fig 5.3.

Several major geological structural features can be inferred from the bore log and geophysical data:

(a) A major break in sediment thickess immediately north of Waihopo Landing. This is shown as a ENE trending line on Figure 5.3 and is interpreted as the lineation of a significant fault. North of this line the base of the sediments generally lie above sea level.

(b) A major break in sediment thickness across Houhora Harbour. This is interpreted as a northwest trending fault.

(c) A basement rock surface of considerable relief. The main features are:
a rapid change in gradient resulting in deepening of the rock contact between Houhora and Hukatere and:
a deep basin in the Awanui-Sweetwater locality which is likely to extend south westward and a north-east trending ridge in the basement extending from between Waipapakauri Beach and Waipapakauri towards Waiharara.

The reasons for the high relief on the basement rock surface are not clear from the available data. The steep gradients and the possible lineations suggest that faulting (block faulting) may have been responsible for the gross structure.

5.2.2 Geological Cross-sections

Further details of the sub-surface structures are shown in a series of cross sections, Figs 5.4 to 5.7. These cross-sections are a composite from bore logs and resistivity soundings. The locations of the sections are shown on Fig 5.3.

Ngataki Section (Fig 5.4)

The Ngataki section shows a high resistivity basal layer. This is interpreted by McIntosh 1988 as basement rocks (indurated sandstones of Tupou formation) which outcrop to the east at the coast. These basement rocks apparently dip westwards. Overlying these basement rocks is a moderate to high resistivity layer which McIntosh (1988) interprets as a younger sandstone unit similar to others which outcrop in the north. (Some drillers bore logs refer to this material as "basalt"). A thin veneer of fine sand (or other sediment) overlies these rock units (refer to bore logs Nos. 0172, 0181 and 0188).

Hukatere-Houhora Section (Fig 5.5)

Data forming the Hukatere-Houhora section is interpreted to show a fault in the Houhora Harbour and a second fault close to the centre of the peninsula. Resistivity values are moderately high and are indicated as increasing from east to west. This suggests that the sands may contain less silt and clay or fewer peat beds in the west.

Big Flat Section (Fig 5.6)

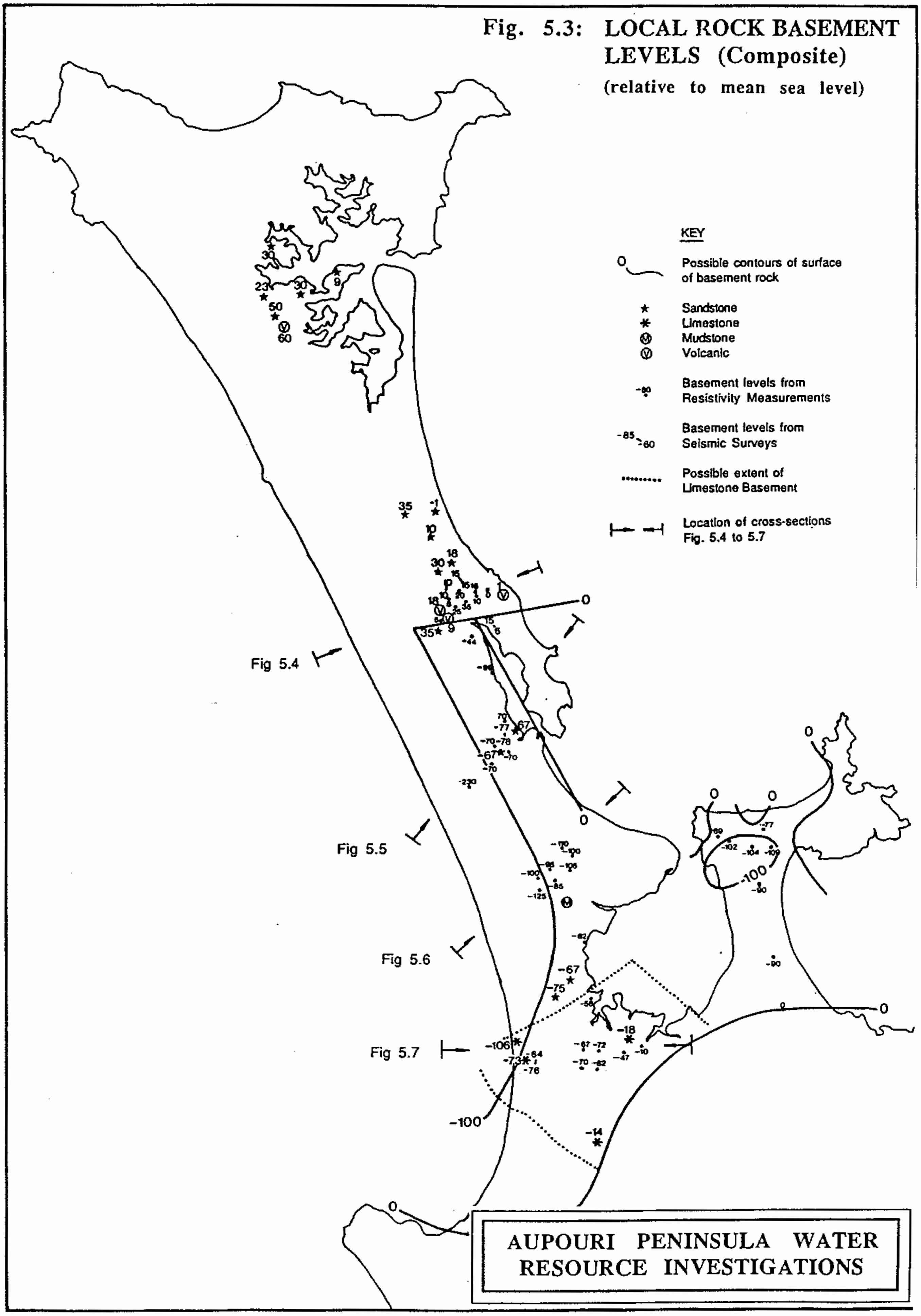


Fig. 5.3: LOCAL ROCK BASEMENT LEVELS (Composite)
(relative to mean sea level)
KEY
Possible contours of surface of basement rock
Sandstone
Limestone
Mudstone
Volcanic
Basement levels from Resistivity Measurements
Basement levels from Seismic Surveys
Possible extent of Limestone Basement
Location of cross-sections Fig. 5.4 to 5.7
Fig 5.4
Fig 5.5
Fig 5.6
Fig 5.7
-100
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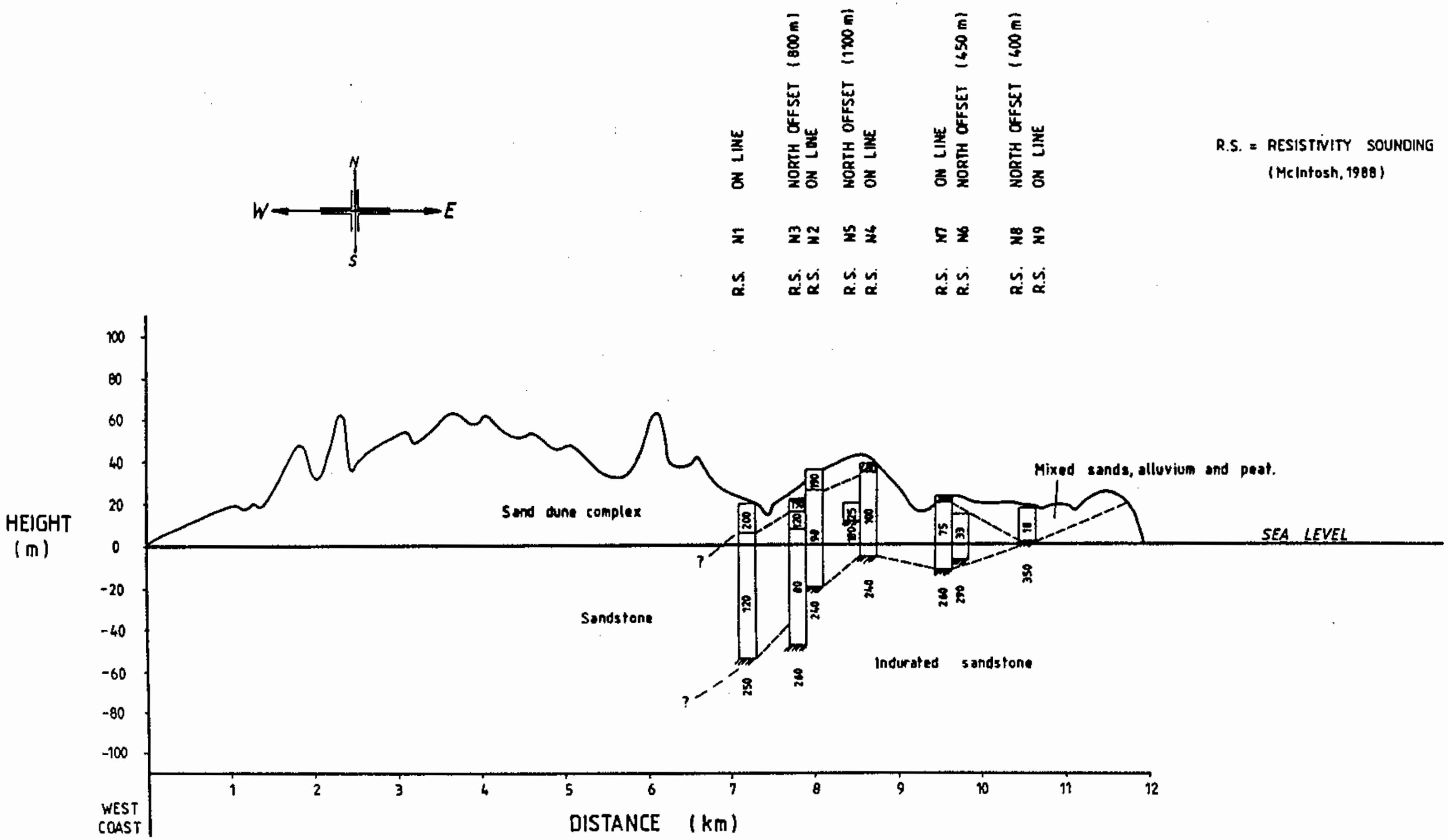

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Fig. 5.4 NGATAKI CROSS SECTION

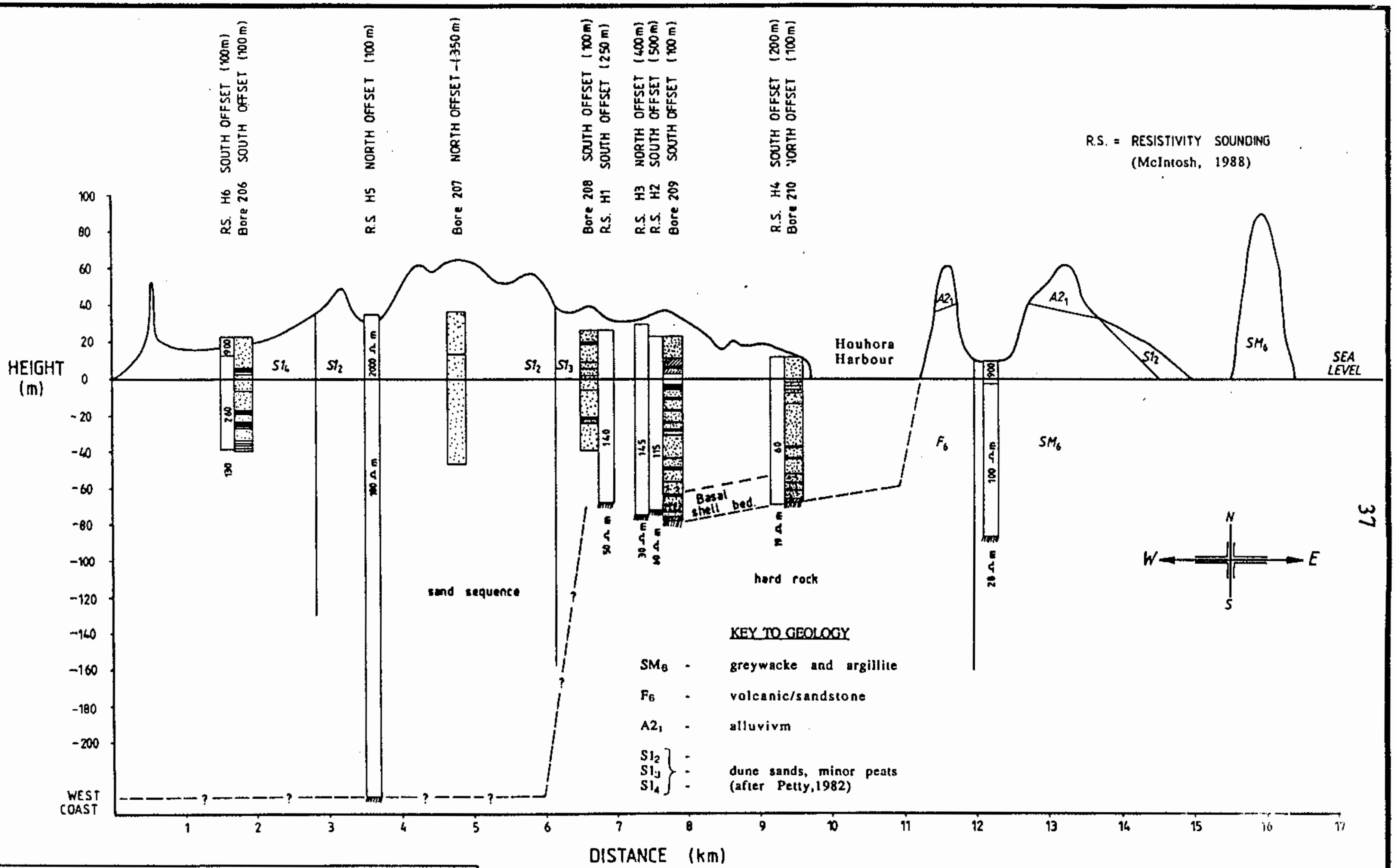

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Fig. 5.5 HUKATERE HOUHORA CROSS SECTION

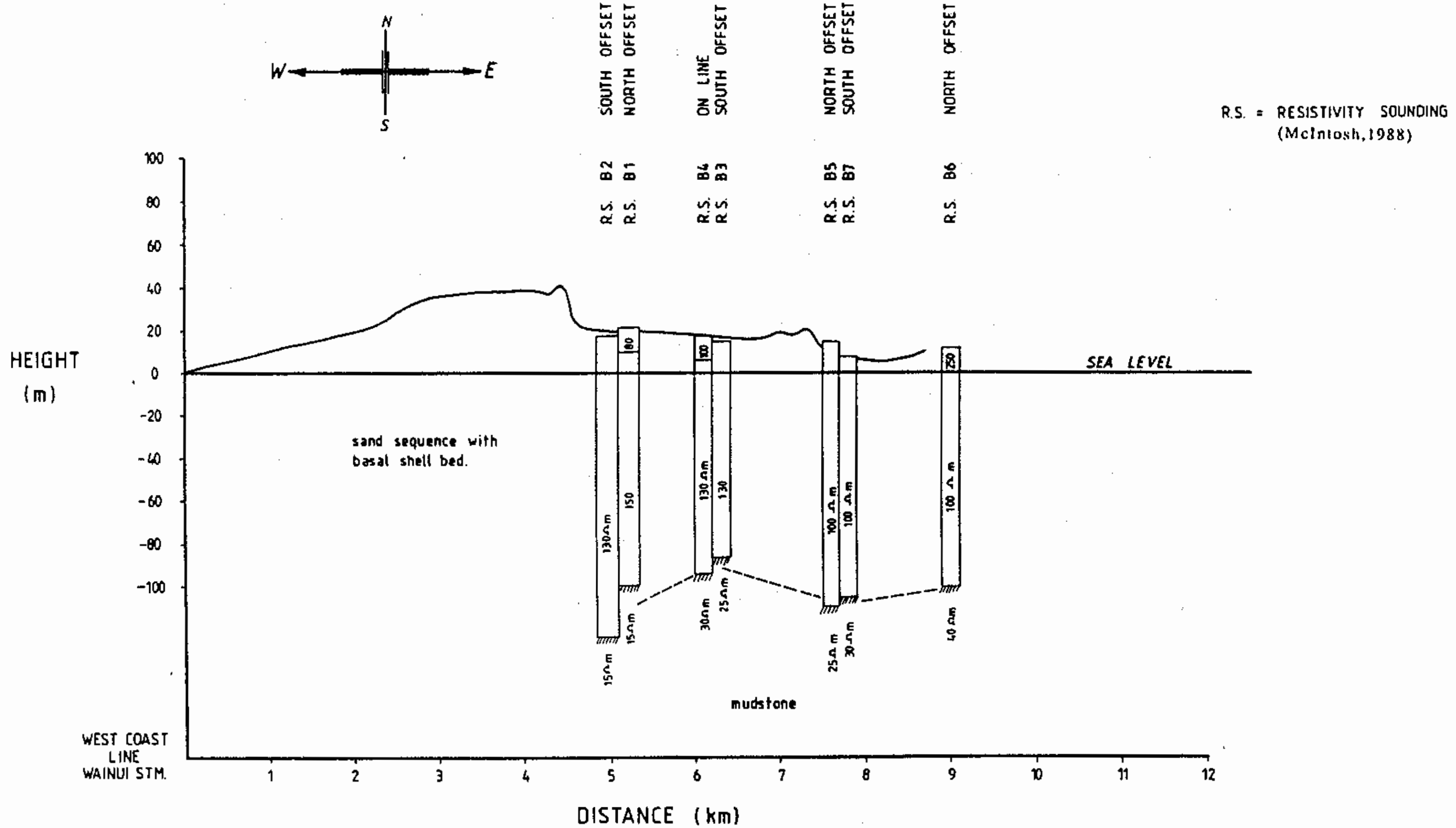

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Fig. 5.6 BIG FLAT CROSS SECTION

The section of Big Flat shows a thick layer of moderate to high resistivity material and is likely to be similar to the Hukatere - Houhora section.

Waipapakauri Beach-Awanui Section (Fig 5.7)

The sand sequence is about 70-80m thick from the west coast to mid-way across the Awanui flats shallowing to where weathered muddy limestone outcrops at the surface to the east of SH1. The decreasing resistivity of the sand sequence from west to east is likely to represent an increasing proportion of silts, clays and peats, which may be lensoidal and more prevalent than in the Hukatere-Houhora section.

5.2.3 Groundwater Flow and Storage

Flow Direction

Groundwater levels rise gently inland from both east and west coasts to about 20 m.a.m.s.l. under the crest of the peninsula. The dominant direction of groundwater flow will therefore be towards both coasts from the crest of the peninsula. This is shown in the water levels for the bores in the Hukatere - Pukenui transect. The water level (head) in the piezometers adjacent to Houhora harbour (bore No. 210, Waterfront Rd) are between 2.3 and 5.3 m.a.m.s.l., increasing with depth. In the piezometer near the crest of the peninsula (bore No. 207) the heads are 17.5 to 21 m.a.m.s.l. and decreasing with depth.

In some low lying areas the head of the groundwater is higher than the ground surface being confined by either a continous area of iron pan, clay or some other very low permeability layer. Shallow bores in those areas may have artesian flow. Currently the head in bore No. 1025 at the old Sweetwater nursery is approximately 0.4m above ground level.

The measurement of water levels in the multi-level piezometers indicates that under the crest of the peninsula and for some distance, to the west coast and several kms towards the east coast, the head in the groundwater decreases with depth indicating predominant downward movement of groundwater, the groundwater recharge zone. On either side of that zone there is a zone where horizontal flow is likely to dominate. Towards the coast, particularly on the east coast further away from the high ground, the gradient is reversed and head increases with depth indicating groundwater discharge zones. The pattern of distribution of groundwater potentials (heads) in a cross-section of the peninsula along the line of the Hukatere-Pukenui transect is shown on Fig 5.8. This pattern is illustrated schematically in Fig 5.9.

Flow Volume

The quantity of groundwater flow can be estimated given the hydraulic conductivity of the aquifer, the hydraulic gradient (head difference in the direction of flow) and the cross-sectional area of the aquifer (Darcy's law). These have all been estimated from pumping test results, water level monitoring and bore logs for the Hukatere-Houhora transect. Estimated groundwater flow towards each coast is about 4000m3/day per kilometre length of peninsula, assuming a hydraulic conductivity of 10m/day. Given that the sand aquifer is thicker and has less fine material towards the west, it is likely that the flow to the west coast is greater than to the east. The flow to the east could

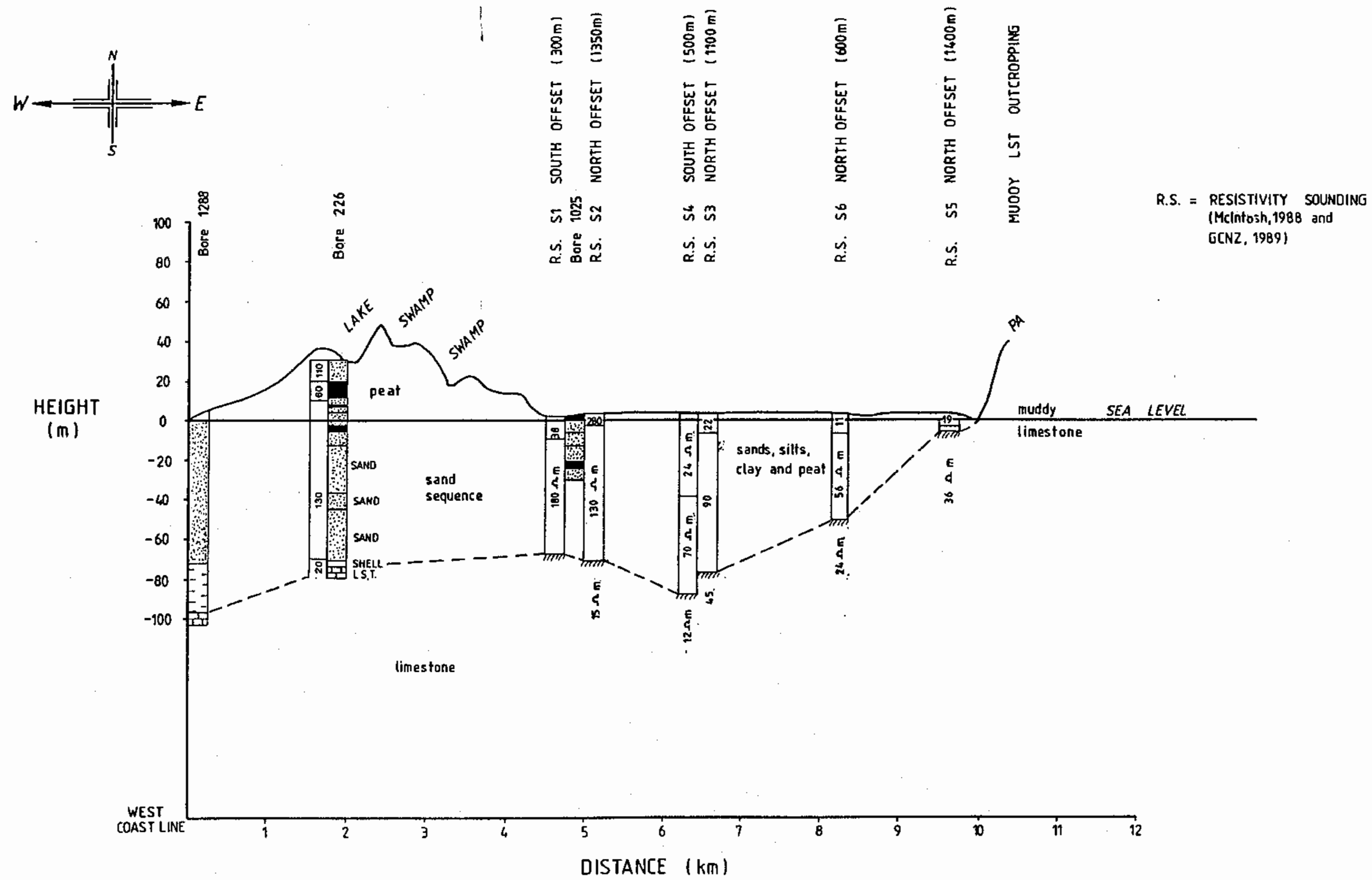

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Fig. 5.7 WAIPAPAKAURI - AWANUI CROSS SECTION

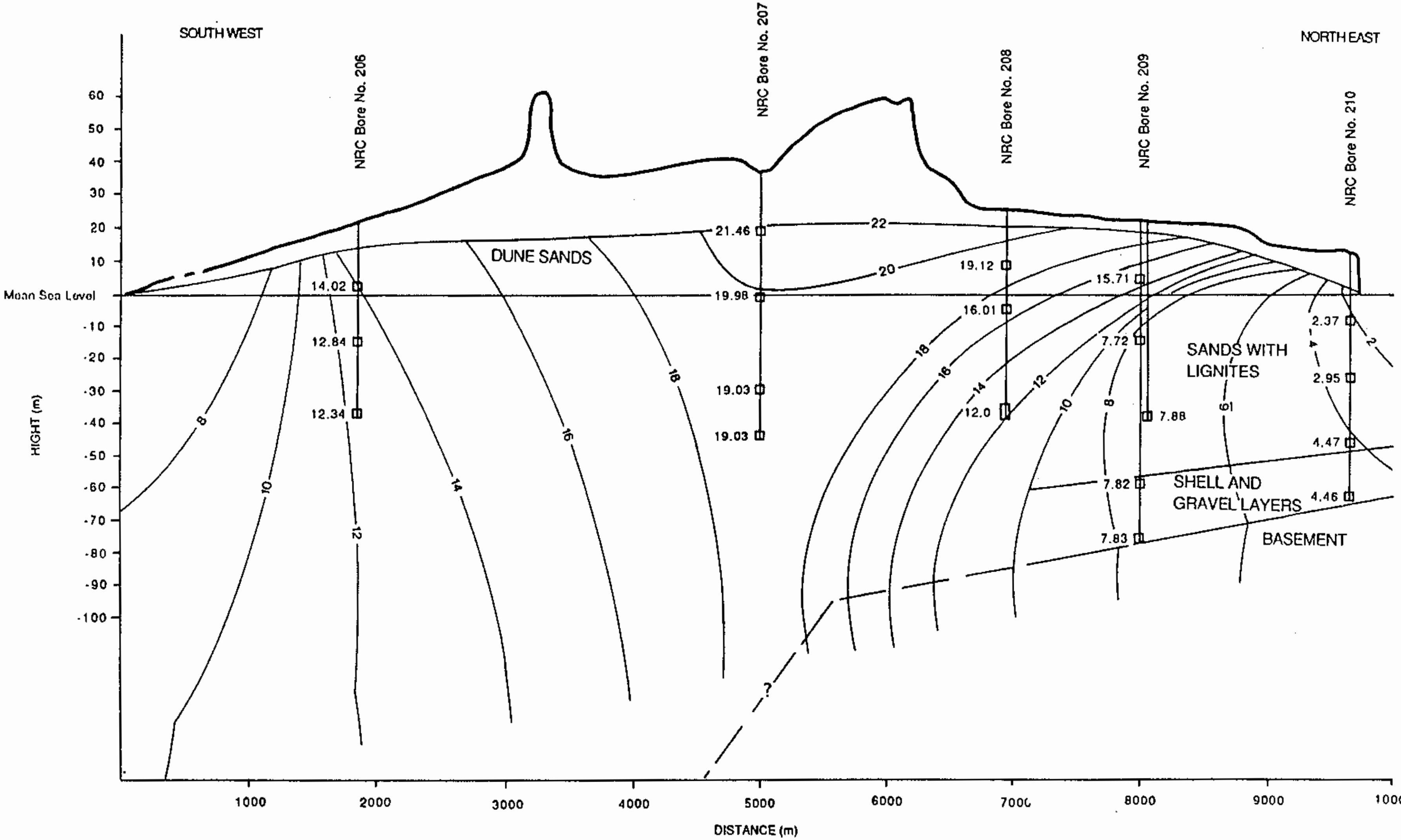

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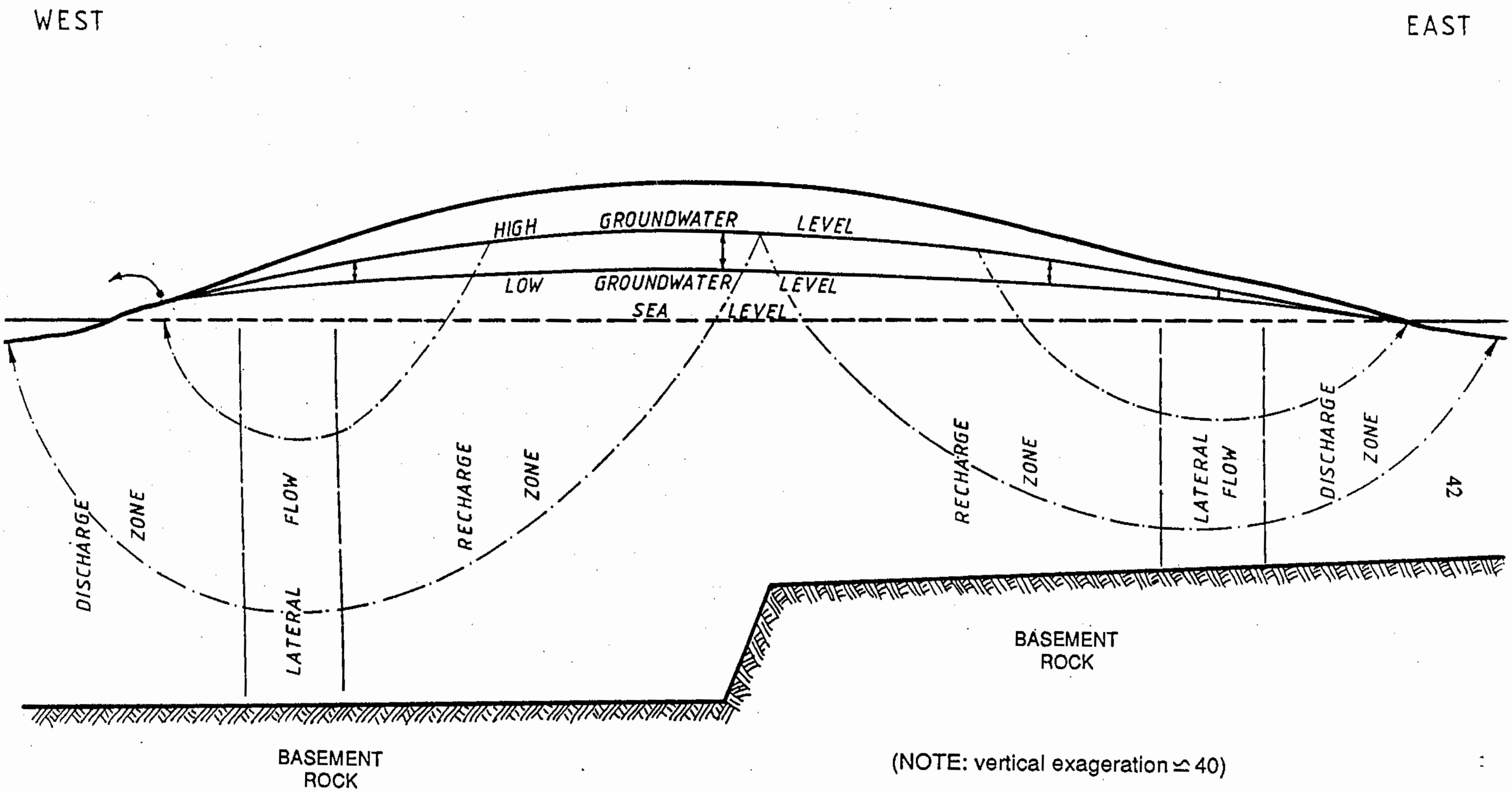
Fig. 5.8 GROUNDWATER POTENTIAL (m.a.m.s.l.) HUKATERE - PUKENUI CROSS SECTION (Jan. 1987) (after GCNZ, 1987)

Fig. 5.9 SIMPLIFIED CONCEPTUAL GROUNDWATER FLOW SYSTEM LOWER AUPOURI PENINSULA



be an order of magnitude lower, say 400m3/day per kilometre given an hydraulic conductivity of 1m/day.

Such flow volumes, 400-4000 m3/day per kilometre, would likely apply to all of the Sweetwaters - Waihopo sub-area.

Storage Volumes

The quantity of freshwater stored in the sand is large. At any one time the volume stored in the sand above sea level will be of the order of 600 million cubic metres ie . 34km x 8km x 7 m (average groundwater level above sea level) x 0.3 (porosity). The volume stored in the total thickness of the sand and shell bed formation could be ten times that volume.

However, the estimated stored volume is far larger than the volume that can actually be pumped from the aquifers or safely used without causing some significant detrimental effect to the resource, such as significant intrusion of seawater. The volume that can be taken without causing significant problems is discussed further below.

5.2.4 Recharge and Discharge of Groundwater

In the long term, unless we wish to mine all or part of the volume of water in storage, the volume of water withdrawn from an aquifer cannot exceed the volume of recharge (replenishment) of the aquifer.

However, it is technically difficult to gain a precise estimate of the recharge to many types of aquifers as in this case. Estimates can be made from water balance calculations and from examining the water level records from the piezometers. These methods are discussed below.

The bulk of the sand aquifers system is recharged directly by infiltrating rainfall. There is also likely to be leakage from the numerous lakes and wetlands and streams perched above the main body of groundwater. Active recharge of the sand aquifer system is evident from the rise in the groundwater level with distance inland, the significant vertical decrease in head with depth in the inland piezometers and can be seen in the rise in groundwater levels during the relatively wet period of winter 1989. However, the continuing decline in the water levels in the 'Forest' piezometers near the crest of the peninsula indicates that recharge may not currently be keeping up with discharge from the system in that area and perhaps a significant area of the sand aquifer system. The reasons for this are discussed in sections 5.6.2 below.

Based on soil water balance calculations using data from the Aupouri Forest climate station Moir et al (1986) estimate that the average annual quantity of water available for runoff or groundwater recharge is equivalent to 460mm. How much is discharged as surface flow and how much is available for groundwater recharge is difficult to assess and will be spatially variable depending on the permiability of the materials. In areas with high permiability sandy soils and no pan at shallow depth there will be little direct surface run-off and much of the water will percolate to groundwater. In such areas groundwater recharge may be close to that suggested above ie 460mm/yr average. These soils typically occur on the younger dune complexes of the western half of the peninsula. Water that enters the upper part of the groundwater system may be discharged via springs and seeps to incised streams and interdunal wetlands. This occurs particularly at the boundary of the younger dunes where they overly older dune surfaces with older podzolised soils.

In areas with podzolised soils and pans at shallow depths there may be significant surface run-off and lateral flow of shallow groundwater, discharging as springs and seepage into wetlands streams and drains. In such areas recharge of the main body of groundwater will be significantly less than the 460 mm/yr discussed above. To accurately assess the recharge is not possible with the data available and a conservative figure of 10 to 15% of the mean annual rainfall, approximately 130 to 200 mm/yr is considered to be realistic. That is equivalent to an average recharge of 1300 to 2000 m^3/ha/yr.

recharge — 2970km^2 2.97×10^4 ha $2\times10^3 * 3\times10^4 = 6\times10^7$ m^3 yr^{-1}

The annual recharge will vary from year to year with rainfall. The variation from a particularly dry year to a wetter than average year will be considerable, however, this will be buffered by the large storage volume of the aquifers of the Waihopo - Sweetwaters area and it is longer term trends that are more important.

5.2.5 Bore Yields

The range in yield from bores in the sand and shell bed is largely related to bore construction ie bore depth, diameter, size and type of screen openings. Bore log data shows that water production from bores in the sands ranges between 14 and 800m^3/d. Properly designed and constructed larger wells with efficient screens yield the higher water volumes.

Shell hash being coarser grained has the ability to yield large volumes of water. Bore log data indicates discharges from bores tapping shell beds to vary from 130 to more than 1000 m^3/d, again depending on well construction.

5.2.6 Bore Construction

To obtain larger volumes of water from bores, multiple screens, filter packs or multiple wells could be used.

Several individual layers of sand, particularly the cleaner coarser sands could be screened with intervening peats and finer layers cased out. In finer sands filter packs may be an economic method of increasing the effective diameter and efficiency of the bore. Increased well efficiency means less energy (less power cost) required to pump the equivalent quantity of water.

Bore logs show that most irrigation bores in the sand aquifers have 3 to 6m lengths of 0.15 to 0.2mm slot width screens and are typically capable of producing 200 to 800 m3/day. The grain size analysis reported in Petty (1975) indicate that screen slot widths of 0.15 to 0.25mm are appropriate.

Effective development of the bore by the welldriller is essential for well efficiency and high volume production, particularly from the shell beds.

5.3 SWEETWATERS - AHIPARA

5.3.1. Topography and Geology

This is the south western corner of the Aupouri Peninsula sand dune country, south of the Sweetwaters dune lakes and largely west of Sandhills Road area 2 on Figure 5.1 covering approximately 22 km^2.

The surficial geology of the area is largely unconsolidated fine sands forming low dune ridges interspersed with peat, which are usually less than 4 metres but can extend up to 11 metes thick.

The information on the groundwater resources of this area is restricted to a few bore logs (eg No.s 1002, 1038, 1042 and 1307 (Appendix 1) and the geophysical survey reported in GCNZ (1990). The results of the investigation drilling adjacent to L Heather can be applied to the northern part of this area. Some useful data was also obtained from the driling of the monitoring bores around the Ahipara tip site.

5.3.2 Hydrogeology

The results of the geophysical survey and bore log data indicate that to the NW of this area a sequence of mainly fine sands, contains at least one peat layer several metres thick, with possibly a shelly layer at the base. This sequence has a total thickness of about 100 metres and overlies limestone (at RL-75 metres). The depth to basement rock shallows rapidly east from the coast towards Awanui and Kaitaia with the overlying sediments containing more silts, clays and peats. Towards the eastern and southern boundary of this area the bulk of the sediments will be peat, silts and clays, with little clean sands. The basement rock possibly shale and sandstone appears to be at a depth of about RL - 40 metres, with limestone near RL - 70 metres.

The hydraulic characteristics of the bulk fine sands will likely be similar to those of the area of the north. As the sediments get finer in the east and south of the area the ability of the sediments to yield significant quantities of groundwater lessens markedly.

5.3.3 Bore Yields

The few bores within this area indicate that yields are likely to be small, in the range of 0-100m^3/day. The one pump test that was carried out within this area (bore 1002) gave a yield of 160m^3, however existing bores within this area indicate that smaller yields are more common. These are given below:

Bore no.	Location	s.w.l.	Q m^3/day	Depth
1002	Ahipara (Frazier)	7.3	160	32
1003	Kaitaia golf club	6	49	25
1289	Ahipara	7	16	19.5
1307	Ahipara	7	1.5	114

5.4 WAIHOPO - NORTH

5.4.1 Introduction

This section is a brief discussion of the groundwater resources of the area of Aupouri Peninsula north of Waihopo and the Mt Carmel Peninsula area 2 on Figure 5.1. Information about sub-surface geology and the water storage and transmitting capacity of the rock types present is restricted to the geophysical survey results for the Ngataki area, a small number of brief welldrillers bore logs, and the information provided by published geological maps. The only investigation drilling undertaken was one investigation bore at Te Hapua. A selection of bore logs from this area, No. 0022, 0035, 0170 and 0198 are given in Appendix 1.

5.4.2. Hydrogeology

5.4.2.1 Unconsolidated Material

From the surface geology maps, summarised in Figure 2.1, it can be seen that much of the area south of Te Kao, the western side of the Peninsula adjacent to Ninety Mile Beach and Kokota sandspit, is covered by various unconsolidated or partially consolidated sediments, dominated by sand dune complexes of various ages and associated marine, estuarine, alluvial, swamp and estuarine terrace deposits, refer to Hay (1983).

The results of the geophysical survey (McIntosh, 1988) indicated a major change in thickness of the sand aquifer sequence across the peninsula at about Waihopo Landing. North of that line, hard rock, and hence the base of the sands, generally lies above, or close to sea level. However, there is no data to indicate the thickness of the sands along the western side of the peninsula and a significant thickness of sand could exist, particulary between Ngatake and the bluff. If a significant thickness of sand was present, it would likely have similar hydrogeological features to the sands south of Waihopo, with significant groundwater storage and flow to the west coast.

A cross-section of the sub-surface geology immediately south of Ngataki is shown in Figure 5.4 and described in Section 5.2.7.

There are a number of permament streams with substantial flows (not yet gauged) to the west coast eg. Kauaeparaoa (Te Paki) Stream, Waikanae Stream and Pukekura Stream, north of the Bluff. These streams originate as the outflow from lakes, are incised into the dune sand and likely receive groundwater being discharged from the sands. The existence of these streams could indicate the presence of a small thickness of sand north of the Bluff and that hard rock dips westward from the surface, to just below the current sea level along the coast.

In the middle and eastern side of the peninsula south of Te Kao, the sands are deposited as as thick veneer (less than 30 metres) overlying various hard rocks and weathered hard rock, the boundary being above or close to sea level. Well-drillers bore logs and bore users report that these sands yield little water and may be dry during prolonged dry spells.

5.4.2.2 'Hard' Rock

The hilly country inland north of Te Kao and at Mt Camel is formed by various sedimentary rocks, claystones, siltstones, conglomerates, and igneous rocks, mainly old basalts and spillites. Hard rock also outcrops on both sides of the Mt Camel peninsula, indurated sandstones, mudstones, and at the Bluff, volcanic rocks. These rocks also underly the unconsolidated sediments discussed above.

The potential for these rocks to yield groundwater depends largely on the degree of weathering (decomposition into clays) and extent of fracturing of the rock. The hard rocks underlying the sands, where they are largely unweathered and well fractured, may yield substantial quantities of water from individual bores eg. bore number 0181 (Appendix 1), approximately 250 m^3/day from indurated sandstone. Good yields are more likely from sandstones and indurated sandstones. In mudstones and calcareous rocks, fractures and joints tend to be infilled.

Over much of the area the rock is typically deeply weathered to depths of 10 to 30 metres, and altered to soft clays with infilled fractures which contain and transmit little groundwater.

Again sandstones are more likely to yield useable quantities of groundwater. There are a number of bores driilled into sandstone in the Ngatuwhete area that reportedly yield quantities useful for farm water supplies, 20-100 m^3/day. However, some are also reported to be "dry".

5.5 KARIKARI

5.5.1 Introduction

This section is a brief discussion of the groundwater resources of the area of Karikari Peninsula area 4 on Figure 5.1.

Information about the hydrogeology of this area is restricted to the geophysical survey results, a small number of brief welldrillers bore logs, and the information provided by published geological maps.

5.5.2 Topography and Geology

The Karikari Peninsula is a 4 to 8km wide, 15km long low lying tombolo of dunes, inter-dune wetlands and lakes, connecting the mainland to a group of former islands. Most of the tombolo lies at less than 20 m.a.m.s.l., with large areas at less than 10m. The former islands which form the hills and headlands rise to 195m.

The geology map (Hay, 1975) shows the surface of the tombolo to be formed of a complex of mainly moving, semi-fixed and fixed dune sands with alluvium, flat wetlands and peat areas between dune ridges.

The former islands are formed of various indurated (hard) sedimentary and volcanic rocks. The hills to the immediate south of the peninsula are formed of rather soft calcareous mudstones and glauconitic sandstones, with some hard calcareous siltstones and siliceous sandstone to the south east.

5.5.3 Hydrogeology and Groundwater Availability

Low Lying Area

Based on observation of the surface hydrology, soils and surface, geological descriptions and geophysical surveys (McIntosh 1988 and GCNZ 1990) the potential for obtaining large quantities of groundwater from the low lying areas of Karikari Peninsula is not high.

The area is low lying, with little potential storage volume above sea level, and because of the presence of podzolised soils with associated iron and silica rich pans, much of the area is poorly drained. This means that most of the rainfall runs off to the interdune wetlands and associated drains resulting in little groundwater recharge.

The geophysical survey results indicate that basement rock lies at approximately -90 metres RL (depth) over much of this area. The basement type appears to change from possibly local volcanic rock types at the north end of the peninsula to limestone in the south, indicating a major structural feature passing through the peninsula.

The basement is overlain by a thick sequence of either clay rich sediments and/or sediments containing brackish water. The sand content and/or water quality in the sediments appears to increase towards the surface. There is also a trend to what might be a significant thickness of cleaner sand with better water quality towards the north west, Puheke Road which could be on a similar sand sequence to that found across the harbour at Papaore. However, this sequence is much more confined in area due to the nearby rock outcrops at Rangiputa and Puheke Hill and consequently has a reduced recharge area and little above sea level storage volume. However, the presence of such a potential aquifer would need to be confirmed by the drilling of an investigation bore(s) to check the geophysical survey results.

A bore log for a 122 metre deep bore (No. 0220) at Tokerau Beach shows a 58 metre sequence of estuarine sediments (peat, mud ,some shell and a couple of thin gravels overlying indurated sandstone or similar (probably Tokerau formation).

Hills

The hills of the Karikari Peninsula, as described above, are formed of various old volcanic and sedimentary rocks. Over much of the area, the rock is deeply weathered to depths of 10 to 30 metres which has been altered to soft clays, with unfilled fractures. These rocks generally contain and transmit little groundwater.

Where there are significant deposits of cleaner dune sands, particularly with some thickness above sea level, there may be useable quantities of good quality groundwater. Two such areas are behind Matai Bay, and some areas immediately behind Tokerau Beach.

5.5.4 Bore Yields

There are few existing bores and little documented yield detail, and no pumping test for bores in this area. The yields from individual bores in this area are likely to be small, in the range 0 to 100m^3/day, most toward the lower end of that range.

Here are some examples of useful quantities obtained from bores:

Bore No.	Location	Aquifier	Depth	Estimated Yield
0194	Tokerau Beach	sands/shell	22m	$50m^3$/day
*0220	Tokerau Beach	fractured basement rock	122m	$600m^3$/day
0155	Whatuwhiwhi	volcanic rock	41m	$30m^{3+}$/day
0103	Matai Bay	sand/gravel	26m	$20m^3$/day

* This was only pumped for 8 hours and it is not known if pumping of that quantity is sustainable, particularly given its depth and proximity to the coast.

5.6 POSSIBLE CAUSES FOR GROUNDWATER LEVEL FALLS

5.6.1 Impacts of Variation in Rainfall

The long term rainfall trends discussed in Section 3.9 suggest a changing rainfall pattern from south to north and possibly east to west.

A comparison of the longer term rainfall record and the groundwater level records show a rather conflicting picture.

The record of the groundwater levels for the Ogle Drive and Hukatere recorders during the study period 1987-90, reflect changes in the rainfall cumulative departure plots (Figure 3.3) well. The drop in groundwater levels through 1987 reflects the decline in the cumulative departure curves. Similarly, the rise in levels from 1988 through to the 98/90 summer, reflect rises in the cumulative departure curves. A 400-500mm rise in the cumulative departure results in a 1 to 1.2m rise of the groundwater level for the same period.

However, there is a big difference in the changes in groundwater levels at the two sites when comparing the level records from the 1975-79 period to 1987 onwards (see Figure 5.10). Firstly, the groundwater level at Hukatere is approximately 4.5 metres lower in 1988 than in 1976, while at Ogle Drive, the difference was only about 0.9 metres (with the level then rising to above the 1976 level in 1990). Secondly, there are significant differences in the cumulative departure curves (see Figure 3.3) with the south and easterly sites (Manapouri, Waiharara and Kaitaia) indicating large negative cumulative departures on the order of 1000 to 500mm, which could explain some of the fall in the Hukatere groundwater level.

The western and northern rainfall stations (Ahipara, Cape View and Cape Reinga) tend to indicate that the groundwater level in 1987 should have been close to or above the 1076 level, more like that recorded at Ogle Drive. This problem is discussed further below.

5.6.2 Impact of Afforestation

Development of forest on the western portion of the Aupouri Peninsula is likely to have resulted in greater evaporation of water intercepted by the tree canopy, and transpiration. The increases in these components of the water balance have the potential to restrict recharge.

Figure 5.10: Groundwater levels for bores at Ogle drive and Hukatere (bores 81 and 41 respectively) for the period from Aug 1975 to Aug 1991

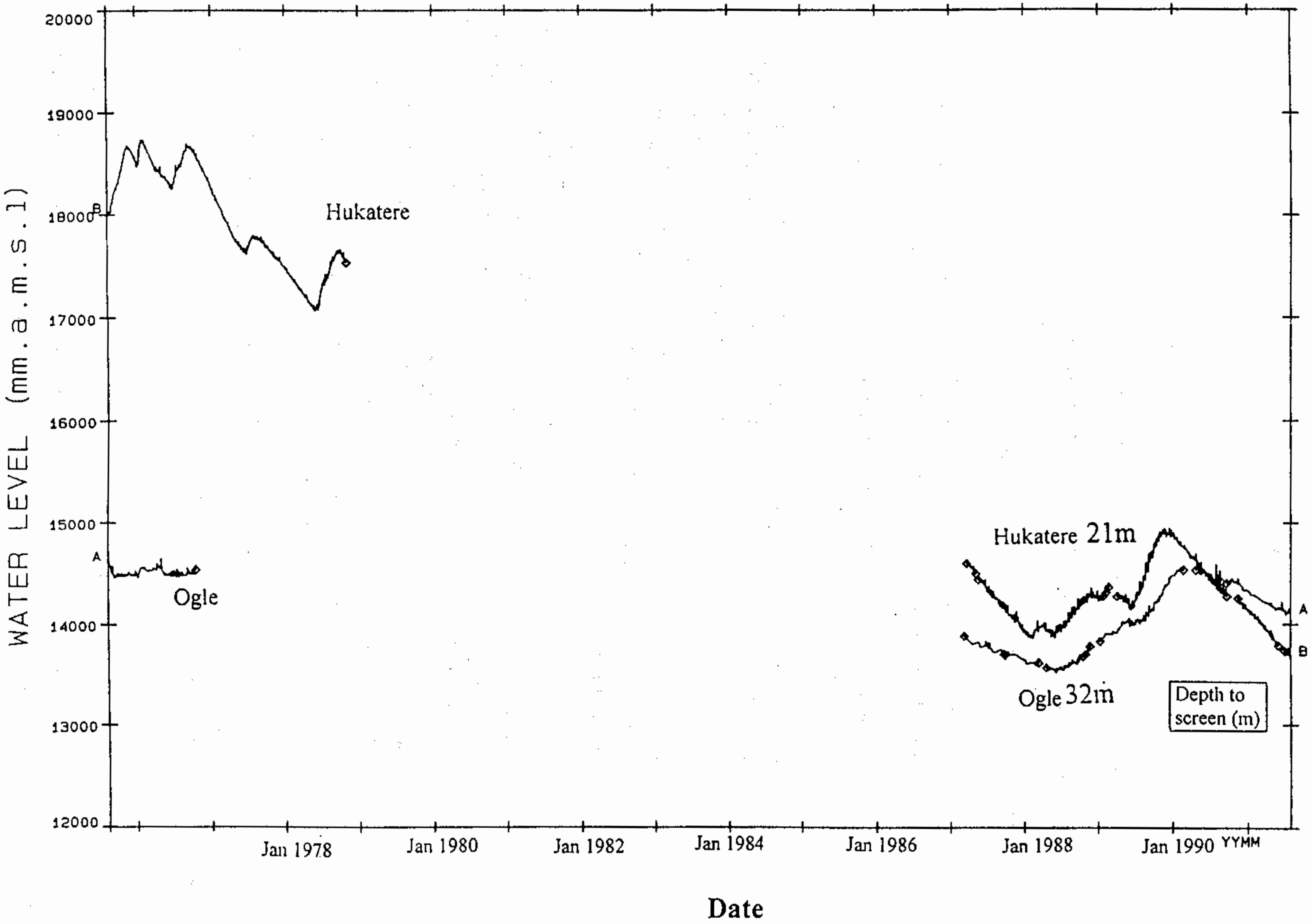


Figure 5.10 Groundwater levels at Hukatere (bore 206)for the period Jan 1987 to Aug 1991

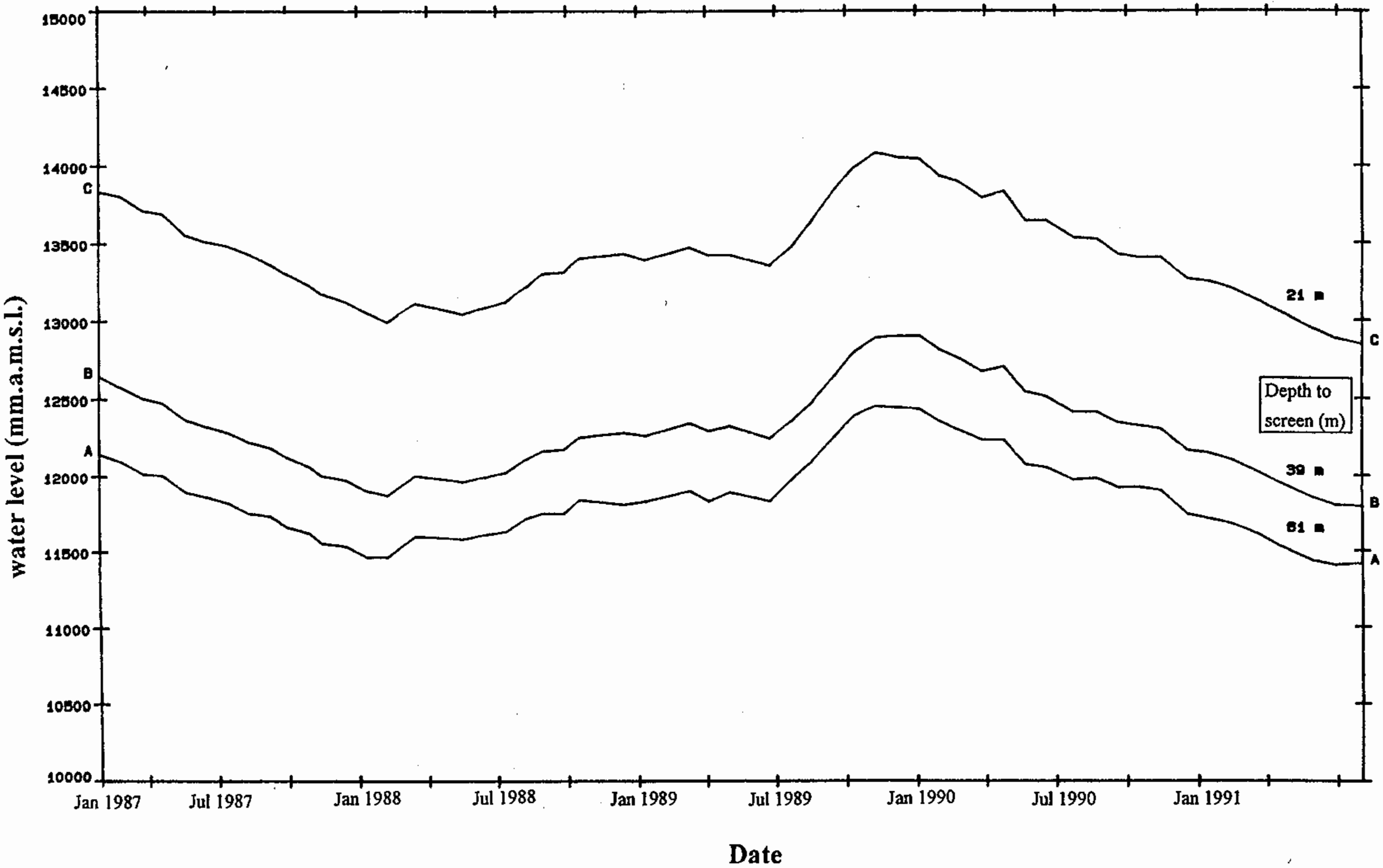


Figure 5.10: Groundwater Levels for bores at LakeHeather (bores 226, 227 and 228) for the period from May 1988 to Aug 1991

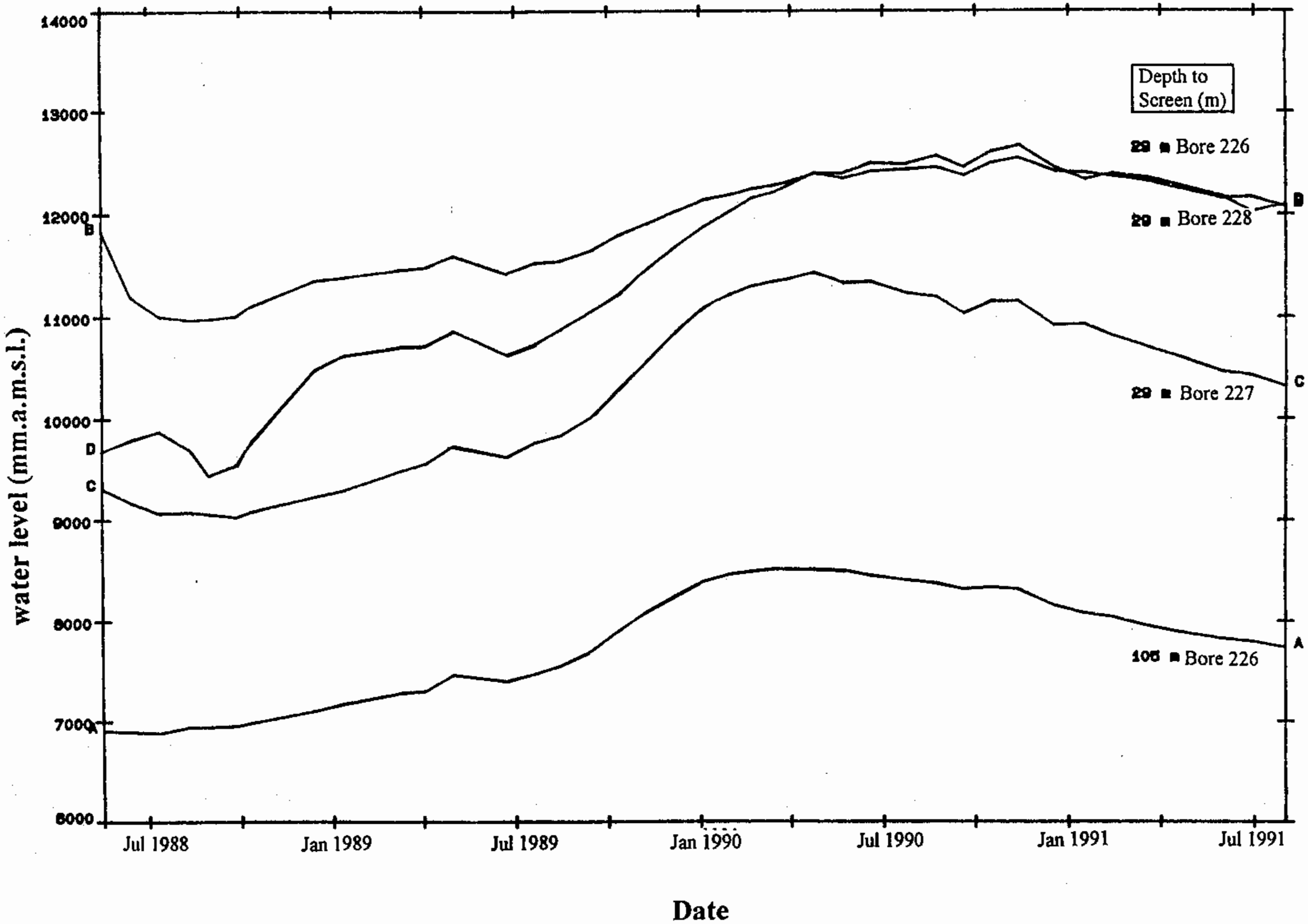


Figure 5.10 Groundwater levels at Burnage Rd (bore209) for the period from Jan 1987 to Oct 1991

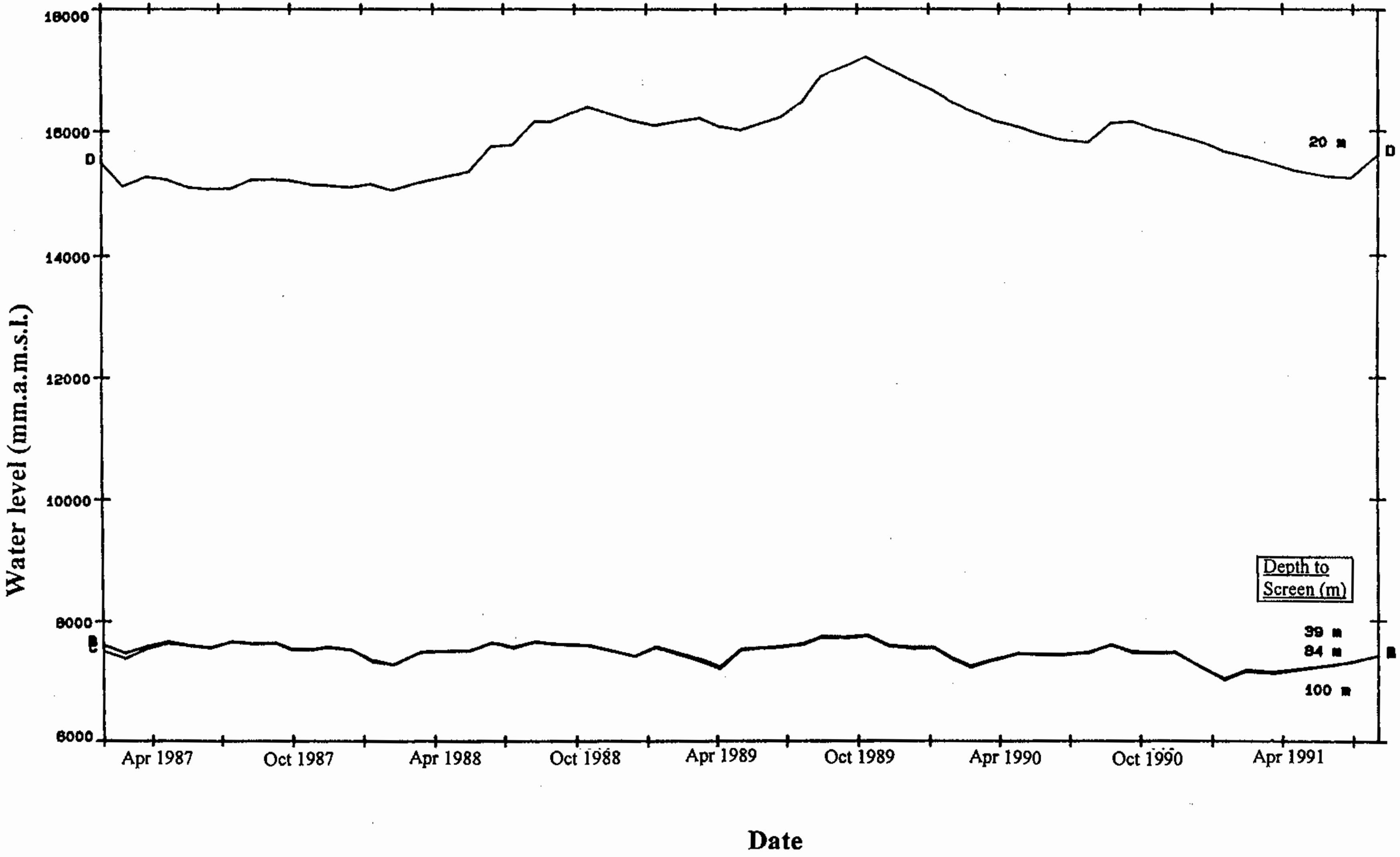


Figure 5.10 Groundwater levels at Waterfront (bore 210)for the period from Jan 1987 to Aug 1991

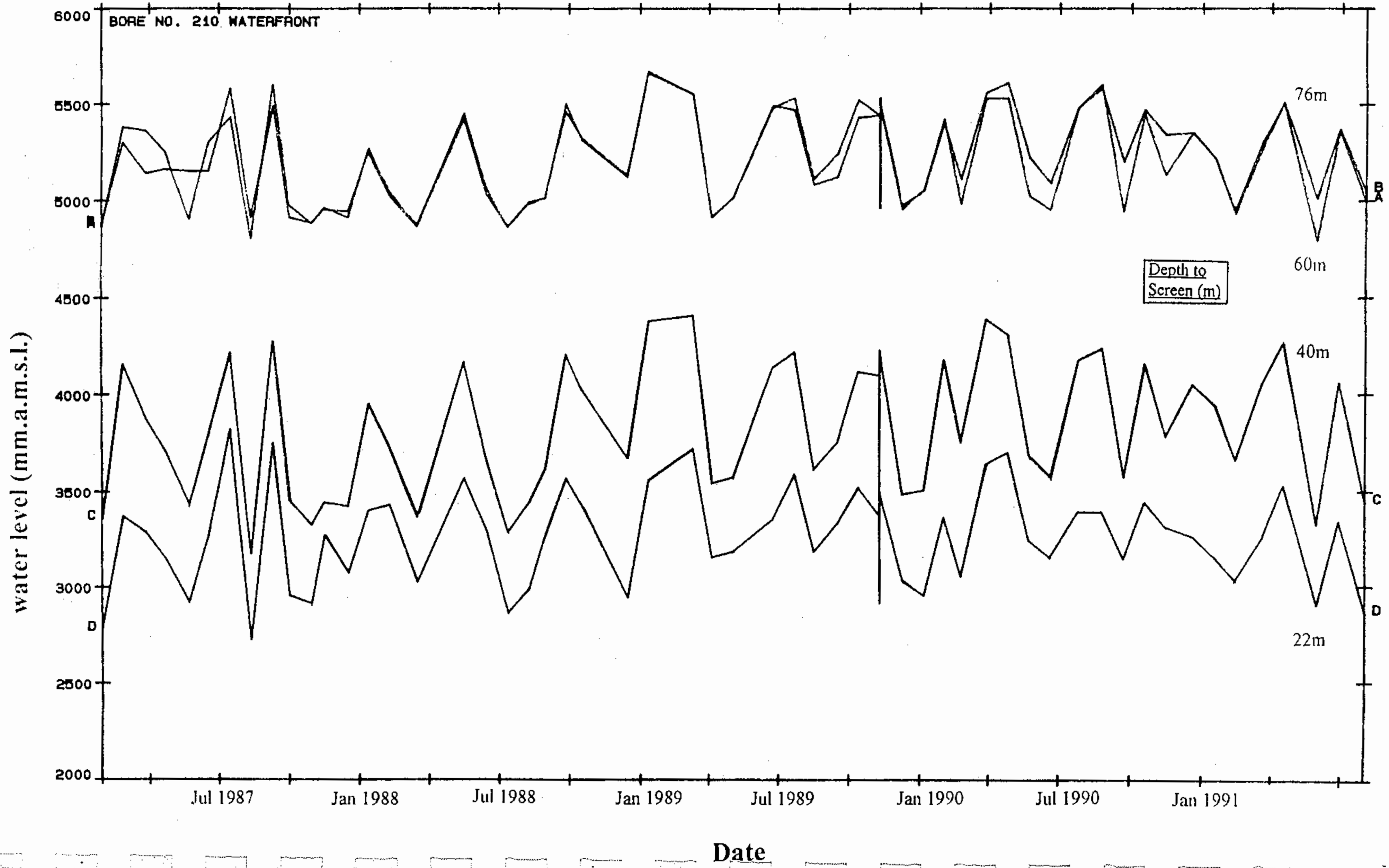


Figure 5.10: Groundwater Levels for the bore at Forest(bore 207) for the period from Jan 1987 to Aug 1991

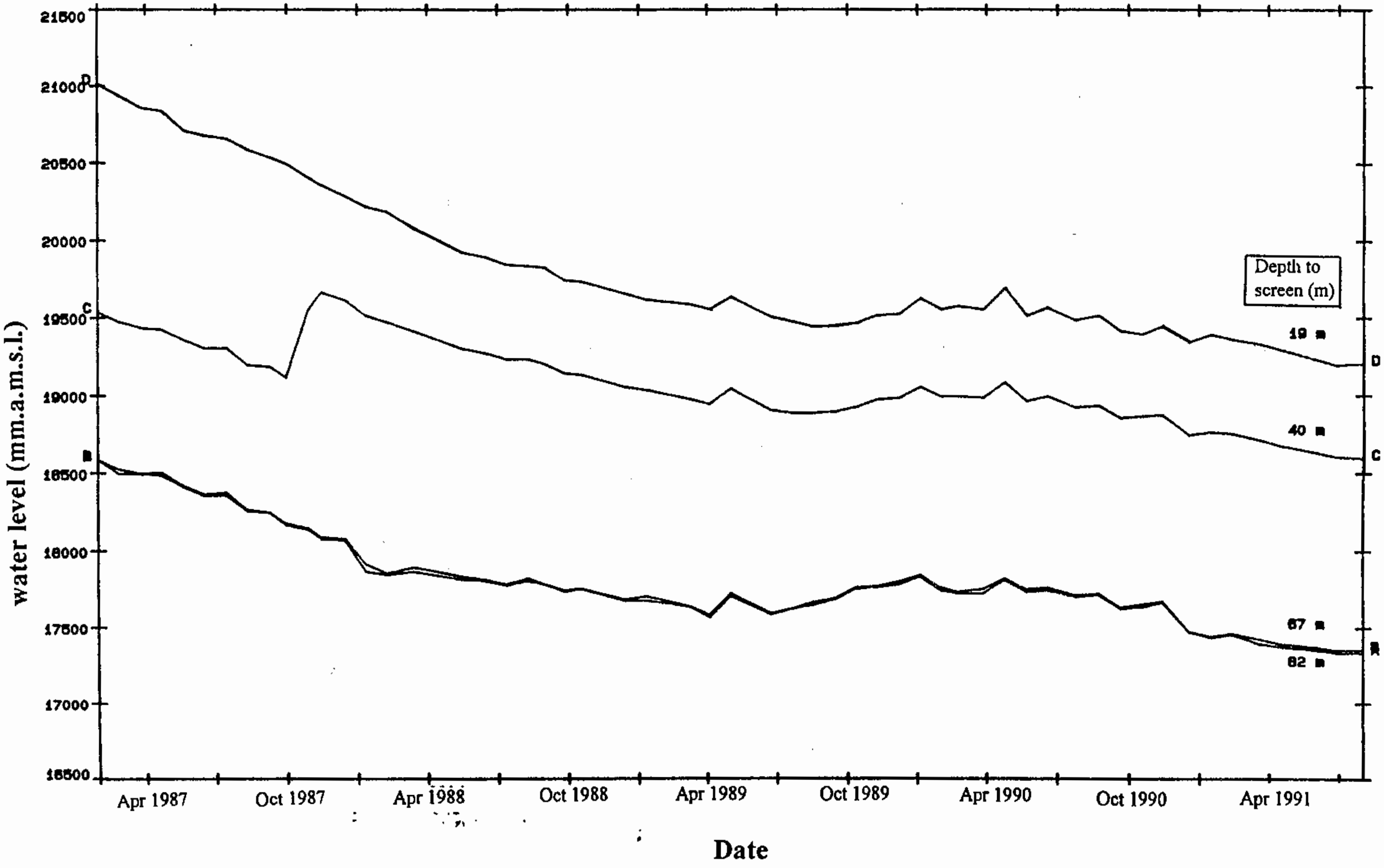


Figure 5.10: Groundwater levels for the bore atPaparore Rd (211) for the period from Feb 1987 to Aug 1991

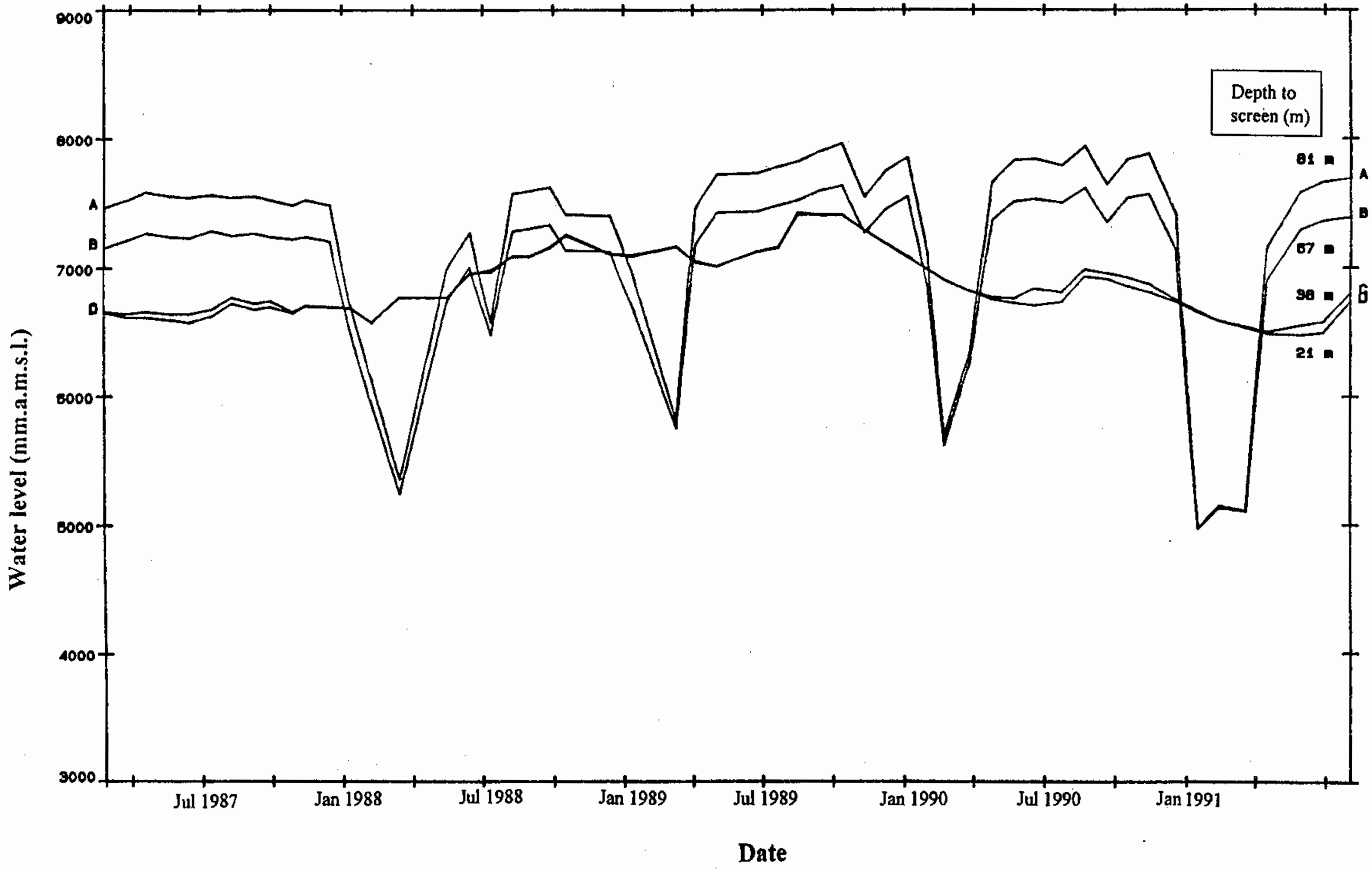


Figure 5.10: Groundwater levels for the Sweetwaters bore (1025) for the period from Jul 1987 to Feb 1991

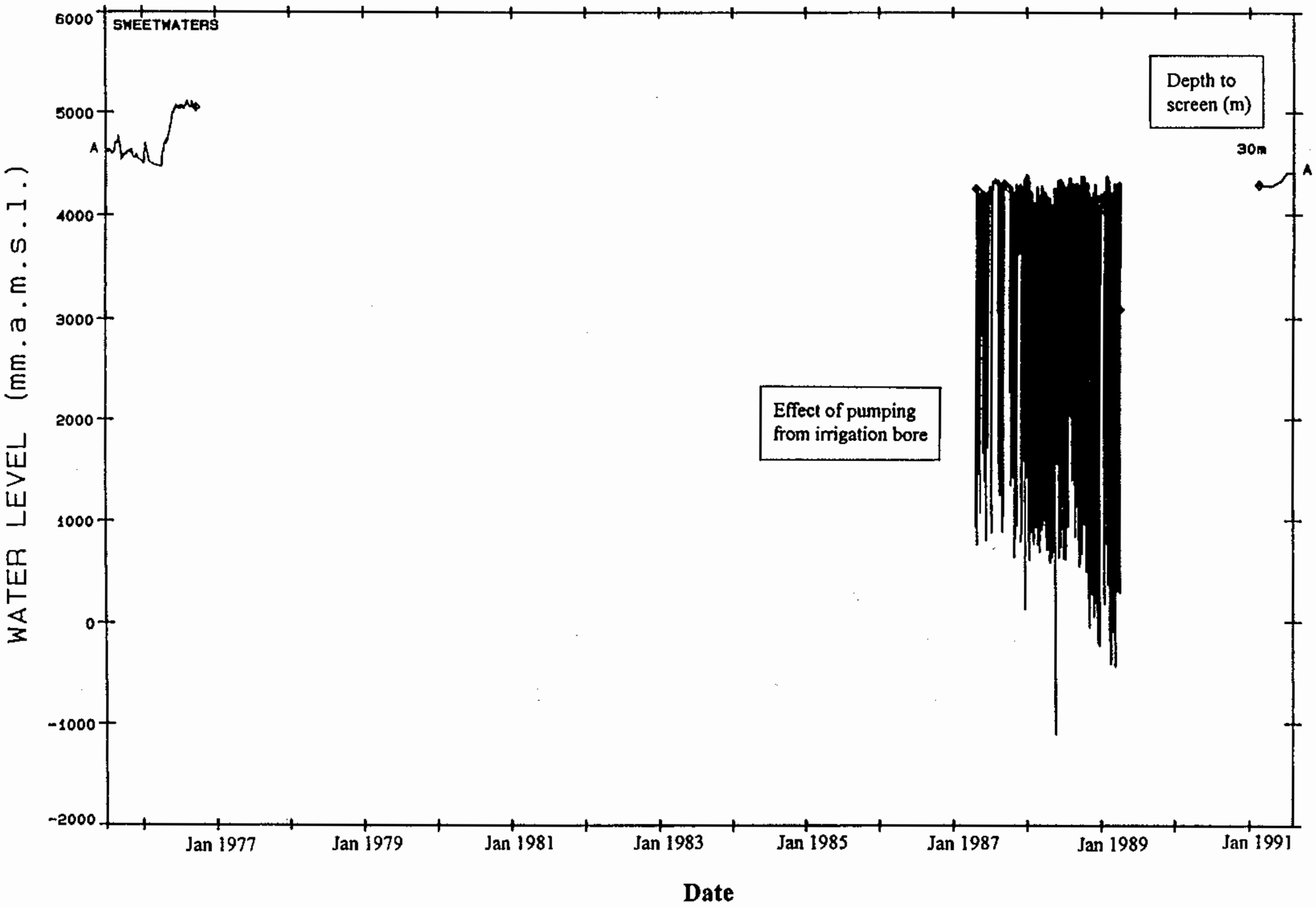
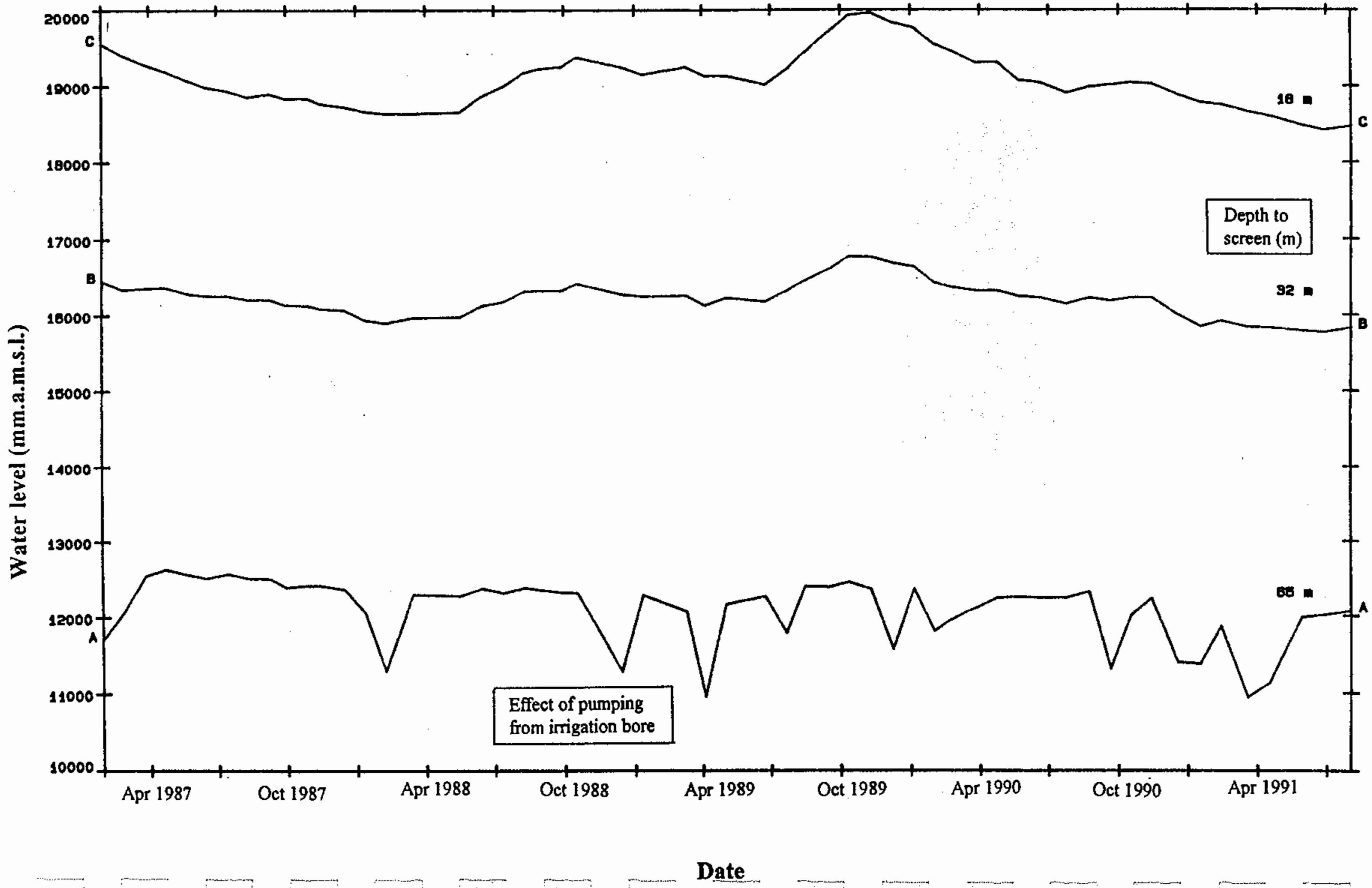


Figure 5.10: Groundwater levels for the Browne bore (208) for the period from Jan 1987 to Oct 1991



Groundwater level measurement show a 4.54m fall in water levels at Hukatere, see Fig 5.10 which is not well explained by rainfall variations. Plantings in the vicinity of this site took place in 1973 to the south of Hukatere Road and in 1978 to the north of the road. Other blocks east of this site were planted between 1977 and 1980. Significant impact from this afforestation probably did not occur until the early to mid-1980's when fuller canopies were developing. Unfortunately, this time period falls between the earlier and later automatic water level records. However, reduction in recharge due to afforestation is likely to be responsible in part for the large fall in water level measured at this site.

Forest planting adjacent to the Ogle Drive site occurred before 1970. At that site, the magnitude of the groundwater level fall between 1976 and 1988 was smaller, see Fig. 5.10. Therefore impact on recharge is likely to have been well advanced before water level measurements commenced at the Ogle drive site. That could explain the smaller fall in water levels was measured between 1976 to 1988.

The Sweetwaters site is some distance from forested areas. It is probably that the recharge area for this site may not have been greatly influenced by forestry. Certinly little change has taken place in water levels from the earlier to the later period, and that which had occurred is more likely due to the relatively lower rainfall discussed above or possibly due to unrestricted flow from artesian bores.

Although the evidence for linking afforestation to falling groundwater levels is not conclusive, it is certainly coincidental. Monitoring of groundwater levels over a longer period of time (10-20 years) is necessary to deterine the relationship of groundwater levels to afforestation and whether water levels have stabilised or are still falling.

5.6.3 Impact of Irrigation Development

Irrigation from groundwater supplies is a recent development in the area starting in the mid 80's. The quantities taken, although locally significant are small in relation to the size of the groundwater resource.

Impacts on water level (pressure within the aquifers) from pumping are observed in the water level records for the eastern Hukatere Rd (bore No. 208), Paparore Rd (bore No. 211) and Sweetwaters (bore No. 1025) piezometers (see Fig 4.3). The Hukatere Rd piezo. is only 30m from an irrigation site and the Sweetwaters piezo only 17m from an irrigation bore that pumped at up to 360 m^3/day during the irrigation season (this bore is no longer used for irrigation).

The data shows that pumping only affects the level adjacent to that being tapped by the pumping wells and that recovery of water levels follows cessation of pumping. The records do not show any long term impact from pumping. The current irrigation usage therefore appears to have little impact on the resource.

5.7 Sea Water Intrusion

Seawater intrusion was not detected during this investigation and resistivity surveys indicated no evidence for seawater intrusion for the areas of the Aupouri Peninsula surveyed. However, the resistivity survey of the Karikari Peninsula indicated a low resistivity layer (10-12 ohm.m) which although more likely to be clay rich sediments, limestone or shale, could indicate interstitial water. Drilling and water quality sampling would be required to prove this.

The potential for sea water intrusion in the study area is low under current flow conditions. Groundwater heads lie 10m above sea level over much of the study area rising to 20-40m above sea level in a significant portion of the area. Groundwater flow therefore is from the land towards the sea. For example, the water levels in the piezometers (bore No. 210) on the shore of Houhora harbour are 2.3 to 5.3 m.a.m.s.l. suggesting that the freshwater body extends into the sediments beneath the harbour.

The fall in water levels since 1976 has not greatly changed the groundwater flow condition and hence had little impact on the potential for sea water intrusion.

Sea water intrusion may occur in wells, or areas with a number of wells, close to or at the coast. This is particularly applicable to shallow wells tapping unconfined aquifiers close to sea level. When such wells are pumped, the groundwater gradient may reverse, sloping towards the well from the sea. Saline water will then move towards the well. If pumping is continued for a long period, saline water may enter the well and contaminate the supply. When pumping ceases, the natural groundwater gradient (which generally slopes seawards) is re-established and the seawater is flushed away from the well.

The water levels in some irrigation wells are drawn down to below mean sea level during pumping eg. bore 229, where the water level in the pumped bore draws down to about 15m below mean sea level, but remains more than 5m above mean sea level in the monitoring bore, No. 211, only, 95m away.

In confined aquifers, the seawater-fresh water interface is likely to be well off-shore (eg. at Houhora). Intermittent pumping, such as seasonal irrigation pumping, is less likely to result in contaminated supplies.

Wells tapping fractures in hard rock near the coast are at risk from seawater intrusion if pumped heavily for moderate to long periods. Such rocks have lower porosity than sands and seawater can move much more rapidly through the fractures toward a pumping well.

5.8 Ground Water Quality

Samples of groundwater have been taken from a selection of existing production bores for analysis to determine the suitability of the water for various uses. A small number of the more heavily used bores sampled can be located from their bore (WELARC) numbers as shown on Fig 4.1, or from the map reference. The detailed results of the analyses are contained in Table 5.1

The results show that the groundwater quality is often good and suitable for most uses. However, a significant number of bores from all over the study area yield water with iron concentrations of 1 to 4.5 g/m^3, with some particularly high concentrations, 13.6 to 24 g/m^3, in samples from bores at Te Hapua. Those iron concentrations can give the water an unpleasant taste, cause staining and may lead to blockages of pipes and irrigation equipment. The iron concentration can be significantly reduced through treatment such as aeration and filtration.

Based on the sampling to-date, there is little discernible pattern to the occurrence of elevated iron concentrations in bore water, except that none of the samples taken from the deeper bores screened in the shelly bed at the base of the sand aquifer system had elevated iron concentrations. The elevated iron concentrations in the sand aquifer system may be related to the presence of acid peat and localised deposits or iron rich minerals.

Table 5.1 Bore water quality analysis results

Bore No. (WELARC)	Sample No. (QUALARC)	Date Sampled	Location	Depth (m)	pH	Cond. (mS.m-1)	Na	K	Ca	Mg	Cl (g.m-3)	SO4	HCO3	Fe	Mn	B	NO3-N
-	901169	080390	Te Hapua School (N02:027-427)		6.3	41	61	2.2	3.0	8.4	84	24	63	24.0	0.30	-	0.25
-	901164	080390	Te Hapua (N02:022-423)		10.2	34	57	0.1	2.2	0.1	56	9	28	0.1	<0.02	-	0.98
-	901168	080390	Te Hapua (N02:024-429)		5.5	41	60	4.8	1.3	5.8	112	15	7	13.6	0.17	-	0.43
-	901167	080390	Te Hapua (N02:024-430)		5.1	54	74	9.6	3.7	7.2	136	32	5	0.4	0.04	-	0.16
-	901166	080390	Te Hapua (N02:026-425)	w	5.8	51	76	2.7	3.2	7.8	112	55	15	2.9	0.06	-	0.20
-	901165	080390	Te Hapua (N02:022-423)	s	7.1	52	61	1.4	19.6	10.5	108	9	100	2.3	0.08	-	0.24
0188	893559	151189	Ngataki (N03:164-166)	135	6.7	27	29	1.3	14.9	5.2	33	11	85	4.4	0.16	-	0.01
-	893557	151189	Houhora (N03:193-132)		6.6	28	37	1.5	8.0	6.0	59	12	26	0.3	<0.02	-	-
-	911438	230491	Houhora (N03:209-117)		6.6	25	33	1.8	7.8	3.3	40	14	51	2.1	0.04	<0.1	0.02
0196	911426	230491	Pukenui (N03:217-097)	75	7.9	48	41	3.4	48	5.8	44	9	200	0.1	0.07	<0.1	0.02
0055	911429	230491	Pukenui (N03:217-094)	13	6.0	44	58	2.1	7.3	10.3	98	25	27	2.7	<0.02	<0.1	0.18
-	911428	230491	Pukenui (N03:226-089)	s	6.6	40	54	2.5	12.5	5.8	84	24	33	0.7	0.02	<0.1	0.03
0210	-	011087	Pukenui (N03:226-089)	76	7.6	62	105	4.9	24	6.5	71	9	221	1.1	-	0.14	-
0043	893561	151189	Pukenui (N03:225-087)	54	7.0	22	33	1.9	8.0	3.3	31	7	65	2.4	0.06	-	<0.01
0043	911427	230491	Pukenui (N03:225-087)	54	6.9	25	36	2.3	10.2	3.7	34	5	83	2.6	0.07	<0.1	0.02
-	893558	151189	Pukenui (N03:227-077)		6.7	26	35	1.5	9.0	5.4	36	12	73	4.1	0.04	-	0.04
-	911431	230491	Pukenui (N03:224-074)	w	5.6	47	49	2.3	14.9	5.3	90	48	11	0.1	<0.02	<0.1	3.5
-	-	011087	Pukenui (NO3:215-058)	65	6.2	20	26	1.2	7.9	3.1	35	<2	56	1.4	-	<0.05	-
0184	-	011087	Pukenui (N03:211-072)	110	7.4	28	32	2.0	26	3.9	33	8	101	0.2	-	<0.05	-
0184	90314	160191	Pukenui (N03:211-072)	110	-	-	26	1.9	22.5	3.5	23	6.4	105	0.2	-	<0.1	-
0214	911433	230491	Houhora Heads (N03:233-071)	76	7.8	50	50	3.7	44	4.9	62	10	171	0.3	0.07	<0.1	0.03

Bore No. (WELARC)	Sample No. (QUALARC)	Date Sampled	Location	Depth (m)	pH	Cond. (mS.m-1)	Na	K	Ca	Mg	Cl (g.m-3)	SO4	HCO3	Fe	Mn	B	NO3-N
-	911432	230491	Houhora Heads (N03:233-070)		6.4	26	27	1.8	10.3	6.2	48	25	12	0.3	<0.02	<0.1	0.27
0060	911430	230491	Pukenui (N03:217-063)	70	6.8	28	38	2.4	10.4	4.3	42	<1	78	2.1	0.06	<0.1	0.02
0208	-	011087	Pukenui (N03:216-062)	65	6.8	30	40	1.9	16.3	4.2	48	5	107	2.5	-	0.06	-
0044	893562	151189	Pukenui (N03:218-058)	41	6.8	24	32	1.7	7.4	5.6	30	10	88	2.9	0.11	-	<0.01
-	893560	151189	Pukenui (N03:216-057)		6.7	20	28	1.2	5.8	3.5	27	13	50	4.1	0.12	-	0.01
0207	-	011087	Hukatere (N03:204-046)	82	6.6	38	62	2.5	18.3	5.0	24	6	176	0.9	-	0.14	-
1034	893563	151189	Motutangi (N03:248-017)	26	7.2	19	30	1.4	4.6	3.2	20	9	63	1.8	0.03	-	<0.01
0206	-	011087	Hukatere (N03:197-016)	61.2	7.2	26	37	1.6	15.7	2.9	33	11	84	0.4	-	0.06	-
0048	DSIR	130875	Hukatere (N03:196-013)	20.5	7.0	13	16	1.0	1.1	1.7	25	9	12	0.23	0.04	-	0.18
0229	-	011087	Paparore (N04:297-906)	79	7.2	46	59	3.3	25	8.2	68	9	133	0.3	-	0.07	-
0229	-	280988	Paparore Rd (N04:297-906)	79	8.0	-	43	2.3	37.0	6.0	55	11	152	<0.05	0.08	<0.1	-
0229	911434	230491	Paporore Rd (N04:297-906)	79	8.0	41	42	2.7	34	5.9	50	9	155	<0.05	0.10	<0.1	0.04
0081	DSIR	040875	Ogle Dr (N04:285-897)	32	6.6	29	33	1.4	4.4	7.1	44	17	66	0.08	<0.02	-	0.46
0205	911436	230491	Paparore (N04:286-886)	96.5	8.1	32	31	1.8	29	3.7	32	9	115	0.2	0.06	<0.1	0.02
1269	900496	310190	Ngatu (N04:295-856)	52	6.7	26	32	1.6	8.1	5.2	46	9	44	0.3	-	<0.1	0.16
1288	900495	310190	Waipapakauri Bch (N04:265-848)	108	7.9	28	34	2.2	16.2	3.8	39	11	85	0.1	-	<0.1	0.20
1288	911435	230491	Waipapakauri Bch (N04:264-848)	108	8.4	28	32	1.9	17.3	4.5	42	10	76	<0.05	0.03	<0.1	0.02
-	900501	310190	Ahipara (N04:253-712)		6.1	17	19	1.2	6.4	3.7	26	12	23	<0.05	-	<0.1	2.36
-	900500	310190	Ahipara (N04:257-712)		5.8	16	20	0.9	2.8	3.2	27	13	17	0.1	-	<0.1	1.12
-	900502	310190	Ahipara (N04:251-707)		5.9	15	19	1.5	4.2	2.7	31	10	21	1.8	-	<0.1	0.57
1028	900497	310190	Waipapakauri (O04:318-863)	27	7.6	25	28	1.6	17.5	3.4	27	6	79	0.2	-	<0.1	0.19
1045	NDC	0285	Awanui (O04:343-846)	33	6.7	38		-	24	8.3	51	<2		1.0	-	-	-
-	NDC	0285	Awanui (O04:343-846)		7.2	56		-	28	8.3	78	<2		0.5	-	-	-

Bore No. (WELARC)	Sample No. (QUALARC)	Date Sampled	Location	Depth (m)	pH	Cond. (mS.m-1)	Na	K	Ca	Mg	Cl (g.m-3)	SO4	HCO3	Fe	Mn	B	NO3-N
1032	900498	310190	Waipapakauri (O04:319-845)	26.5	6.7	25	31	1.6	11.6	5.3	37	2	67	2.9	-	<0.1	0.16
1025	DSIR	170775	Sweetwaters (O04:315-844)	30	7.4	26	30	1.7	5.4	4.6	50	6	49	2.1	0.06	-	<0.05
-	900499	310190	Waipapakauri (O04:314-833)	26	7.0	30	38	1.5	14.6	4.9	37	3	90	2.4	-	<0.1	0.14
-	911437	230491	Puheke, Karik (O03:426-029)		7.3	87	146	7.2	33	10.7	48	91	370	0.9	0.09	0.7	0.02
0180	911439	230491	Rangiputa (O03:380-022)	53	6.6	25	48	5.3	22	7.3	80	24	76	15.3	0.22	<0.1	0.02

6 LAKES AND WETLANDS

6.1 Introduction

This section includes a description and discussion of the major features of the lakes of the Aupouri and Karikari Peninsulas, including their location and dimensions, hydrology, water quality, flora and fauna, uses and management. Their wildlife habitat value is described further in Sec. 7.

There are many small shallow freshwater lakes and associated wetlands on this area. The location of many of these are shown in Fig 6.1. Most of the lakes are less than a few hectares in area and less than 4m in depth. The dimensions of some of the larger lakes are given in Table 6.1.

It seems likely (Hicks 1975 and Hay 1981) that water is retained in the dune lakes and wetlands largely due to the presence of pans (or lignite beds) at shallow depths. The hard pans could have formed as groundwater podzols at times of higher sea level. The blocking of pre-existing valley outlets has led to the formation of lakes and wetlands.

Bathymetry maps (NZOI 1976 and 1982) are available showing depth contours for lakes Ngatu, Waiparera, Heather and Wahakari. Simplified contours and a cross section through the long axis of each of these lakes is shown in Figure 6.3. Spot depths associated with sampling of other lakes are shown in Table 6.1. Even though the lakes investigated are deeper than the more abundant smaller lakes in the area, they are still shallow lakes by New Zealand standards.

Table 6.1 Location and Dimensions of Some Larger Lakes

LAKE	MAP REFERENCE	AREA (ha)	DEPTH (m)	ELEVATION (mamsl)
Te Kahika	N02:110-311	13	-	15*
Morehurehu	N03:109-291	35	-	15*
Kihona	N02:020-304	5	6	45*
Wahakari	N03:040-278	83	12.0*	50*
Bullrush	N03:107-215	6	1.3	65*
Salt	N03:132-217	1.5	3.2	20*
Waiparera	N04:274-952	112	6.5*	30.3
Unnamed (Forest HQ lake)	N04:283-873	2	5	45*
Ngakapua	N04:287-869	9	5.2	45*
Ngatu	N04:289-855	53	6.5*	32.6
Heather	N04:285-834	8	4	27
Rotoroa	N04:287-825	28	8.0*	22.6
Rotokawau (Karikari)	O03:393-034	6.7	1.6	10*
Unnamed (Karikari)	O03:402-033	23	1.2	10*
Waiporohita	O03:427-001	7	2.8	18*
Waimimiha	N04:263-728	10	1.3	12*

* DEPTHS: These approximate maximum depths. Depths marked * are the maximum depth from Irwin 1976 and Irwin 1982. Other depths are the

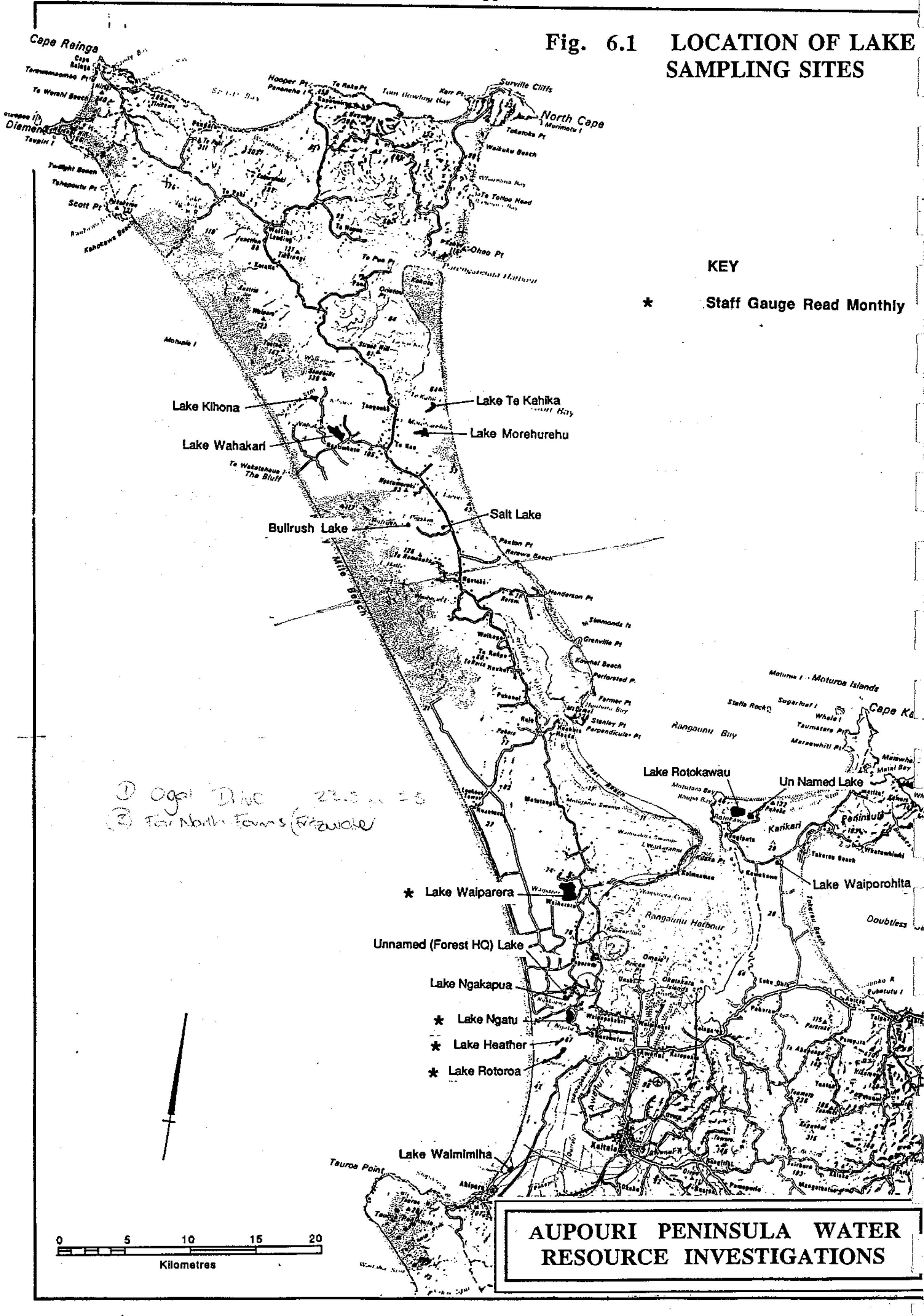


Fig. 6.1 LOCATION OF LAKE SAMPLING SITES

AUPOURI PENINSULA WATER RESOURCE INVESTIGATIONS

deepest measured during water quality sampling and may not be maximum depths. Depths vary with time, see Sec. 6

ELEVATIONS: Approximate water surface elevations in metres above mean sea level. Elevations marked * are estimates only from topographical maps (NZMS 260, 1:50000 series).

6.2 Lake Levels and Water Balance

Lake surface water level was measured for four lakes: Ngatu, Waiparera, Heather and Rotoroa.

Recording consisted of monthly readings of water level on a staff gauge installed in each lake. Recording started in March/April 1987 and levels (to June 1991) are plotted in Figure 6.2. A continuous recorder was also installed on Lake Ngatu in June 1990 to detect any water level changes that would otherwise be missed by monthly readings. Monthly readings were found to give an adequate representation of water level changes occurring in Lake Ngatu and this is likely to apply to the other lakes which were measured monthly.

These four lakes are geographically close to each other and similar changes in water level are seen to occur in each lake. Over the period of measurement the water levels in the lakes varied over a range of approximately 1m with the highest levels occurring during the wet winter of 1989 and the low in April 1991 at the end of a prolonged dry spell. Annual highs occur about September/October and lows around April.

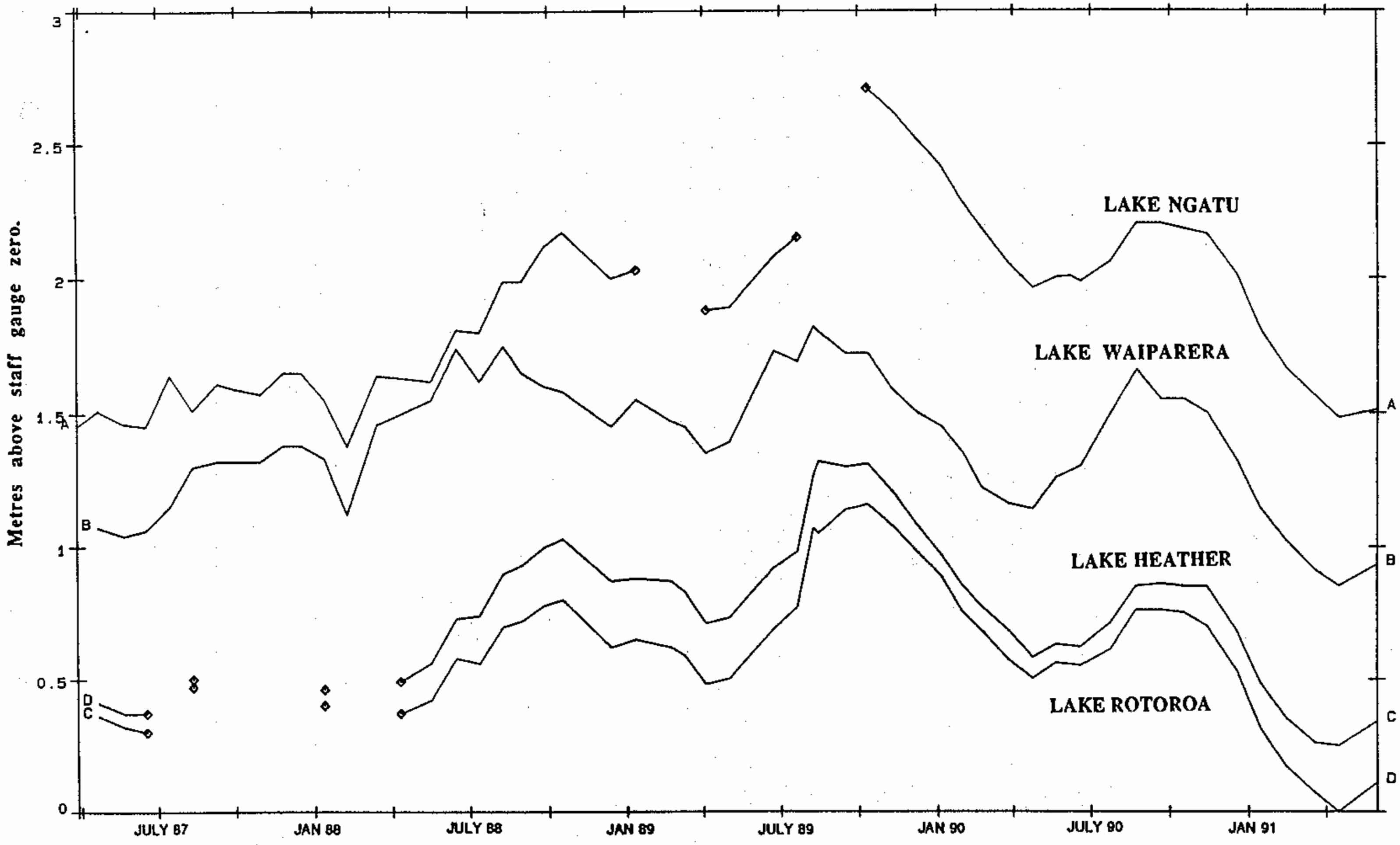
Many of the lakes formed in the sand of the Aupouri and Karikari peninsulas do not have well defined streams flowing into or out of them. Some notable exceptions to this are: L. Kihona which has a significant outflow to Pukekura Stream to the west coast, L. Wahakari has an outflow to the Te Kao Stream, except during prolonged dry spells, and as with L TeKahika and L Morehuehu may have significant stream inflows, L Waiparera may have some significant stream inflows and outflows during wet periods, from and to drains.

Some inferences can be made on the probable lake water input and output pathways by comparing rises and falls in lake level with rainfall and evaporation. This is imprecise mainly because of the uncertainty in estimating the evaporation component. From the water level record of Lake Ngatu the rises of water level over a number of months cannot be accounted for simply by subtracting evaporation from rainfall, for instance:

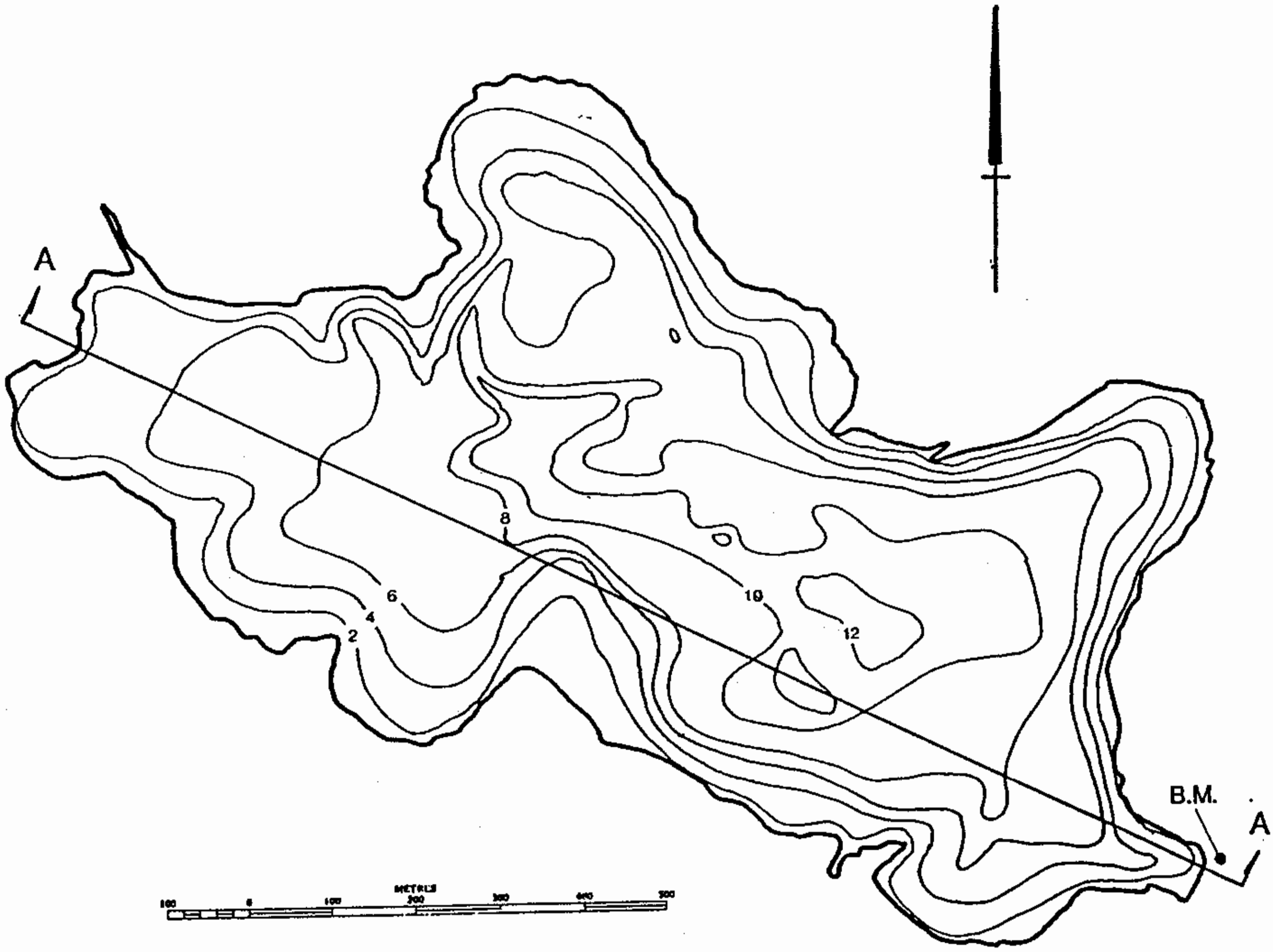
rise in water level 16.5.88 to 17.10.88	= 550 mm
rainfall over period (site 439201)	= 700 mm
estimated open water evaporation	= 240 mm

If water level was solely determined by rainfall and evaporation acting directly on the lake surface then the expected water level rise over the period in question would be 700 mm - 240 mm = 460 mm. As the observed water level rise is actually 550 mm the inference is that additional water enters the lake as surface runoff from the surrounding catchment or by groundwater input. The difference is relatively small, 90mm, some of which may be accounted for due to inaccuracies in estimating evaporation, the rest coming from surface runoff during particularly wet periods.

Fig. 6.2 LAKE WATER LEVELS (Height in metres)



LAKE WAHAKARI



SECTION A-A

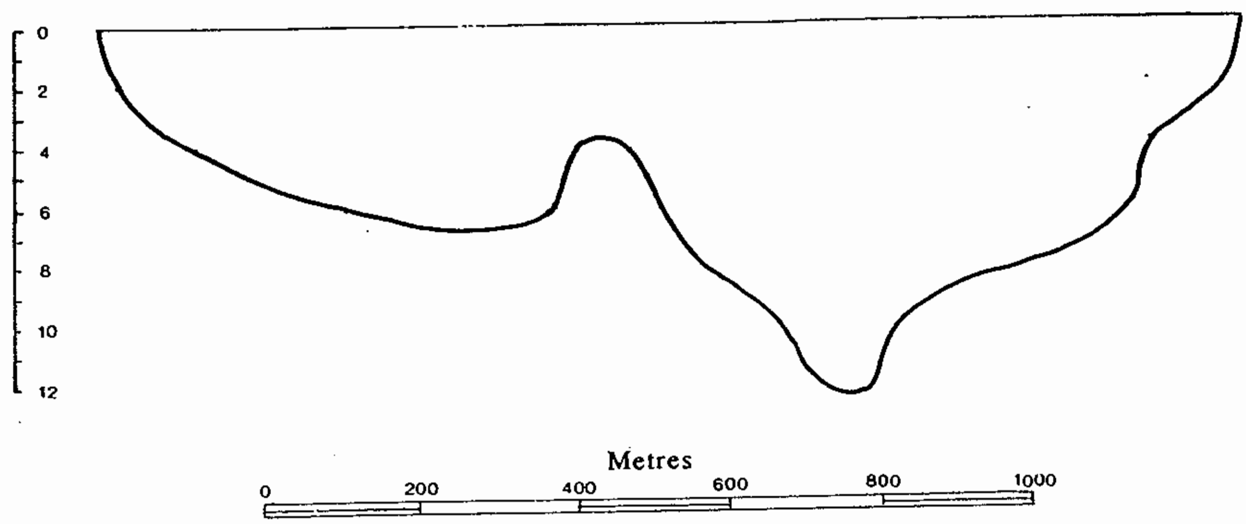
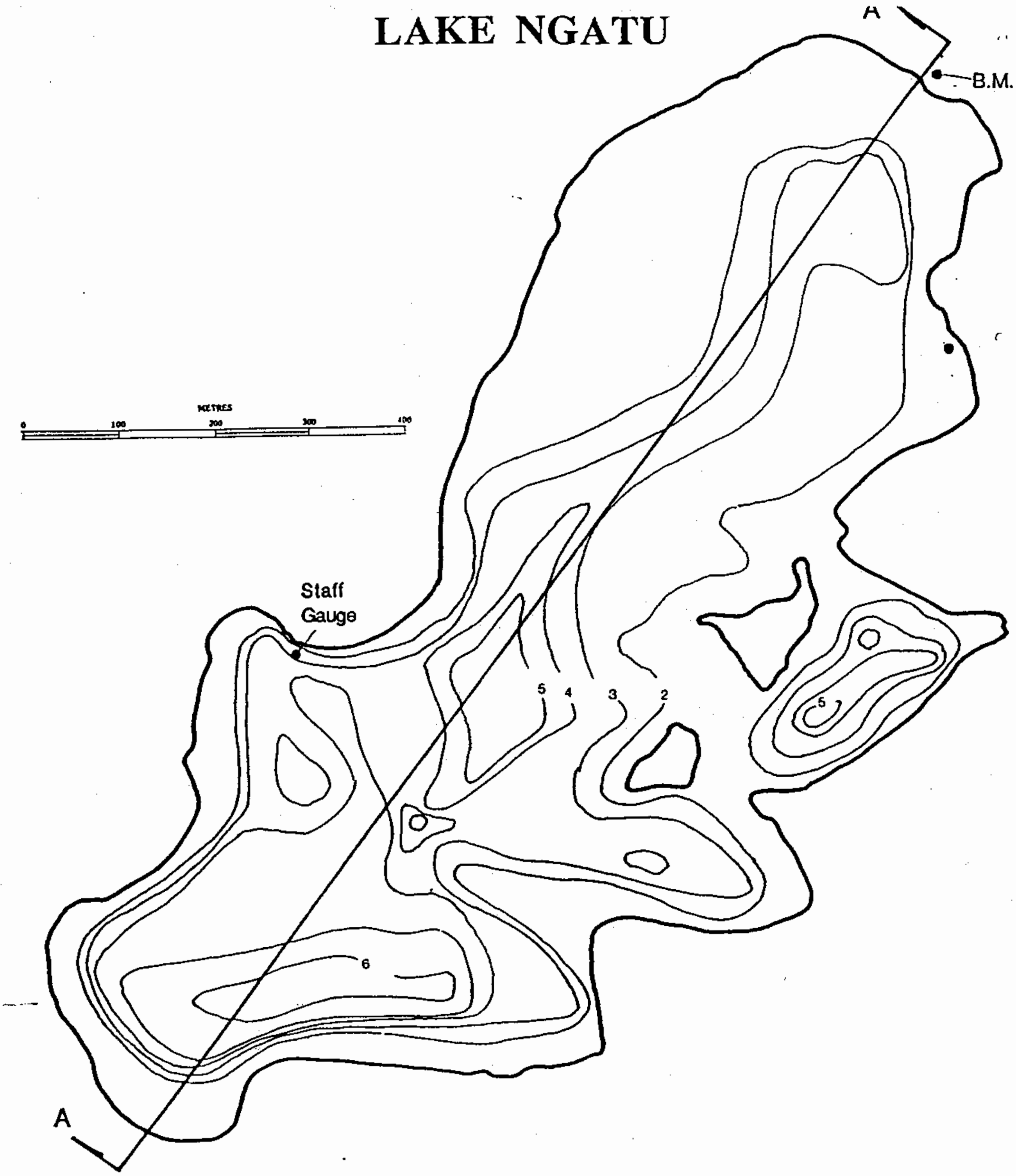


Fig. 6.3: Bathymetry and Cross Section

LAKE NGATU



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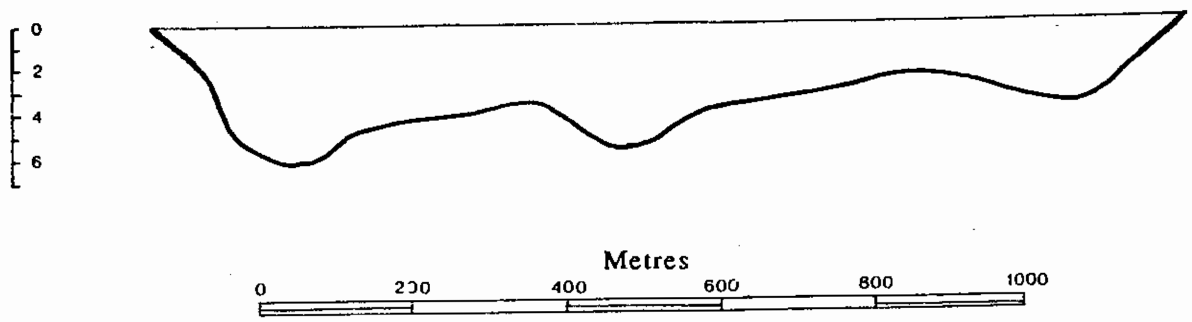


Fig. 6.3: Bathymetry and Cross Section

LAKE WAIPARERA

SECTION A-A

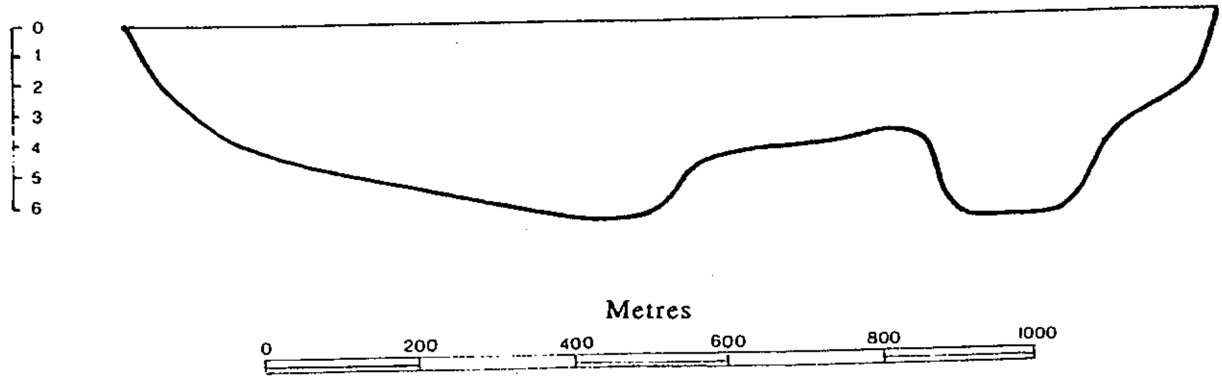


Fig. 6.3: Bathymetry and Cross Section

LAKE ROTOROA

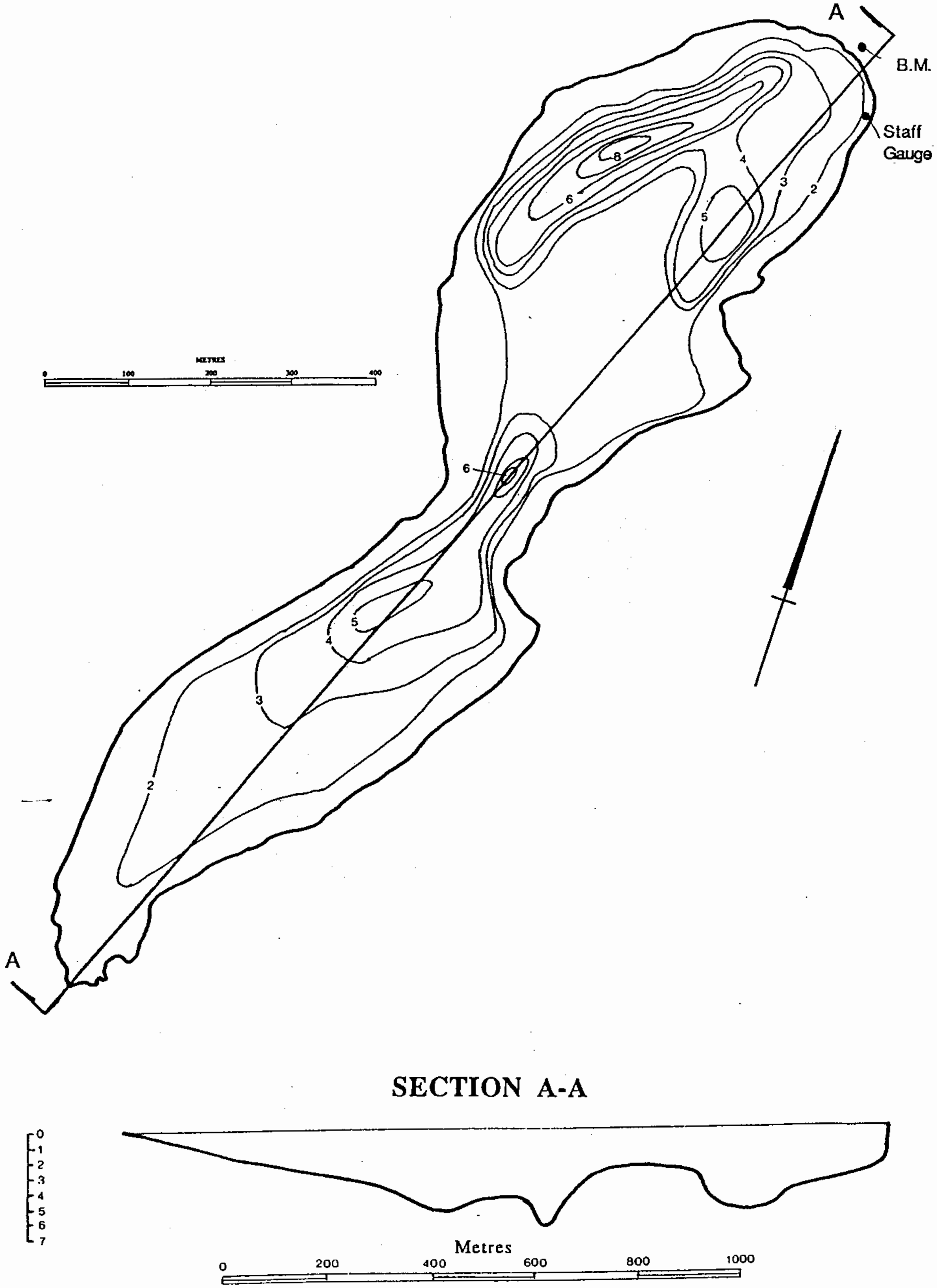


Fig. 6.3: Bathymetry and Cross Section

The groundwater levels in bores surrounding the lake are between 8 and 9 m.a.m.s.l., some 15 to 20m below the lake surface. Indicating that, if anything, water from the lake will be recharging groundwater, rather than groundwater supplying the lake. The same relationship of groundwater levels to lake levels exists for lakes Heather and Waiparera. There may, however, be some localised flow to the lakes of shallow groundwater perched above a pan at shallow depths.

Falls in the water level of Lake Ngatu cannot satisfactorily be explained by the excess of evaporation over rainfall, for instance:

fall in water level 11.10.89 to 23.04.90	= 750 mm
rainfall over period (site 530204)	= 405 mm
estimated open water evaporation	= 750 mm

Rainfall and evaporation acting alone would indicate that the water level change should be 405 mm - 750 mm = -345 mm where in fact it was actually 750 mm. As Lake Ngatu does not have an outlet and no significant quantities of water are taken from it, this would suggest that water is lost or 'leaks' through the bed of the lake. Given that adjacent groundwater levels are lower than the lake then this view is reasonable and indicates that water from Lake Ngatu recharges local groundwater.

The water level records for the other three lakes in Figure 6.2 also show similar rise and fall changes as Ngatu both in time and in magnitude suggesting that the pathways of water inflow and outflow inferred above probably also apply to Lakes Waiparera, Heather and Rotoroa.

6.3 Lake Water Quality

The water quality of a number of lakes on the Aupouri and Karikari Peninsulas were investigated as part of this project. The lakes sampled are shown on Figure 6.1 and listed in Table 6.1

Lakes numbered 1,2,3,5,6,8,9,15, and 16 in Table 6.1 were sampled only once.

The lakes investigated were chosen for a number of reasons which included:

- geographical spread over the study area
- examples from major landuse types, forest, scrub and pasture
- ease of sampling access (for most lakes anyway)
- generally larger lakes
    - other lake use features:
    - public recreation (eg., Waiparera, Ngatu).
    - water supply (stock water, irrigation, public water supply).
    - potential for contamination (eg., proposed forestry processing zone next to Lake Heather).

Water quality measurements and sample analysis results are given in Appendix 3.

6.3.1 Faecal Bacteria

The presence of faecal coliform and streptococci bacteria is an indication of faecal contamination from warm blooded animals, and while they are not necessarily disease causing themselves, they indicate the possible presence of pathogens of similar origin. In the Aupouri and Karikari peninsula dune lakes investigated, sources of faecal coliforms are likely to be from birds or farm animals. Faecal bacteria from stock can be from dung dropped directly into the lake margins by cattle standing in the lake or be contained in runoff from pasture.

Generally, shore locations have higher levels of faecal chloroforms and faecal streptococci than open water sites. This is to be expected and reflects the greater use made of the shoreline area by domestic stock and waterfowl. Faecal bacteria counts in lakes are often elevated by faecal contamination in runoff from surrounding pasture, especially so when pastures are heavily grazed and ground conditions are already wet and/or rainfall is intense. The degree to which stock have access to the lakes sampled is reflected in the level of faecal bacteria found. For instance, of the lakes repeatedly sampled, Lakes Wahakari, Ngatu and to a lesser extent, Rotokawau and Waiparera have moderate bacteria counts which is consistent with these lakes having restricted or partial stock access to the shoreline. The unnamed lake on Karikari and Lakes Heather and Rotoroa, which are wholly or partially surrounded by pasture and allow stock access to the shoreline, have a much higher faecal bacteria count. Similarly so for the once only sampled Lakes Salt, Bullrush, Ngakapua and Waimimiha. This is in contrast to levels found in lakes surrounded entirely by forest or non-pasture land where counts are very low, eg., Lakes Waiporohita, Kihona, Morehurehu, Te Kahika and the unnamed (Forest HQ) lake.

Generally speaking, the faecal bacteria results are consistent with the surrounding land use, reflecting varying levels of faecal contamination related to input mainly from domestic stock. There are no known inputs of domestic sewage or cowshed waste to any of the lake sampled.

6.3.2 Phytoplankton - Algal Blooms

Phytoplankton is the term given to microscopic planktonic "plants" or algae in water. In high numbers these colour the water green and, in terms of light and nutrients, compete with submerged aquatic plants.

Phytoplankton can, in certain circumstances, have an impact on water use. This often occurs when nutrients become high enough to promote "excessive" growth. Other factors such as temperature, wind and sunshine also play a part and can be used to explain why phytoplankton may be a nuisance one year and not in another, especially in a water body that would appear not to be nutrient limited. Present in large numbers and for long enough duration algae can shade out, displace and become dominant over bottom growing aquatic plants. This has probably occurred in two of the lakes sampled, Lake Waimimiha and the unnamed lake on Karikari.

Samples were taken just below the surface and in many instances centrifuged to concentrate the algae before viewing under the microscopic. Algae were identified to the generic level in most cases. Samples for algae were taken along with those for water chemistry, ie., August 1987, February 1989, August 1989, January 1991. This sampling was insufficient to detect any long term changes.

Most natural water bodies contain algae and when not detected in a sample indicates that algae are likely to be present in the water in low or very low numbers rather than being absent altogether. All species observed in this investigation have been found in other water bodies elsewhere in Northland.

No algae were detected in samples taken from Lake Wahakari. Low numbers were found in Lake Ngatu, Peridinium was seen. Lake Rotoroa also had low levels, observed on occasion were Monoraphidium, Ulothrix, Dichtyosphaerium, and possibly Oocystis. A greater variety was found in Lake Waiparera, Peridinium, diatoms, and several other species. Microcystis aeruginosa, a blue green alga, was the most common species found in all samples taken from Lake Waiparera and on one visit was found as pale green millimetre sized chunks in the water column and formed a bottom film at the waters edge. Lake Rotokawau (on Karikari) on all but the last time sampled showed fairly low levels of algae which included Cryptomonas, Staurastrum, and the copepod, Diattomas. In January 1991 the lake was found to be undergoing what is termed an "algal bloom" with high levels of Anabaena flos-aquae and Aphanocapsa elaschista. Several species were found in Lake Heather and general levels were higher than in the lakes outlined above. Algae in Lake Heather included Staurastrum, Closterium, Ulothrix, Westella, Anabaena flos-aquae, Aphanocapso, Peridinium, Trachelomonas, Synedra, Cosmarium and Euglena. The unnamed lake sampled on Karikari was at all times distinctly green and turbid with significant amounts of algae in the water.

Algae included Pediastrum, Scenedesmus, Aphanocapsa, Anabaena flos-aquae, Anabaena circinalis, Actinastrum, Cosmarium, Ankistrodesmus, Clasterium, Dichtysphaerium and the copepod, Diattomas. Aphanocapsa and Peridinium were the dominant algae in this unnamed lake.

It was noticeable that all of the lakes mentioned above had lower water clarity when visited in January 1991 compared to previous visits. This lower water clarity was attributed to increased algal content.

Cunningham et al., (1953) in their study found no algae in samples from lake Ngatu and only Dinobryon and Peridinium in Lake Waiparera.

The other lakes, sampled only once in January 1991, also varied in the quantity of algae and the number of species found. A number of these lakes were low in algae, these being Lakes Waiporohita, Morehurehu, Te Kahika, Kihona, Ngakapua and in the unnamed lake ("Forest HQ"). Found in one or more of these lakes was Staurastrum, Ceratium, Peridinium, Trachelomaonas, Stauradesmus, Phacus and Diatoms. Algal mats in the sand were observed at Lake Morehurehu (in the shallows) and on the damp shore at Lake Waiporohita. Wells et al., (1988) observed similar algal mats in the sand at the Kai Iwi dune lakes north of Dargaville. Algal levels in Bullrush Lake and Salt Lake were higher with the presence of Certaium, Trachelomonas, Euglena, Chlamydomonas and Diatoms. Lake Waimimiha was the most green coloured and turbid lake sampled, containing a wide variety of algae, Westella, Anabaena flos-aquae, Scenedesmus, Monoraphidium, Pediastrum, Dichtyosphaerium, Aphanocapsa and Diatoms.

Of direct consequence to various uses made of lake water, many nutrient enriched water bodies develop algal blooms. This is where conditions come together to produce sudden prolific growth of algae in the water. In some cases a part of the cycle from bloom to die off of the algae is accompanied by the formation of a surface scum which may be observed to coat the surface when calm or may form a fringe when blown against the shore. Colour can vary, depending on the species involved, shades of red, green and blue-green are not uncommon.

Scum forming species are often "blue-green" algae and some of these, or strains of these species, can be toxic to animals when ingested in large enough quantities. The literature gives accounts of waterfowl, dogs and domestic stock dying after drinking algal contaminated water (eg., Flint, 1966, McBarron and May, 1966). As "ill thrift" in farm animals resulting from drinking algal contaminated water can easily be overlooked or wrongly attributed to other causes it is possible that such cases are more common than currently thought. In the study area there are numerous small takes and it is in such water bodies, often muddied by trampling and enriched by stock defecation, that blue-green algae tends to proliferate. Blue-green algae, most of which are widespread throughout the world, were found in this investigation in a number of lakes and were the dominant alga in some of them. Blue greens observed were Microcystis auruginosa, Anabaena flos-aquae, Anabaena circinalis, and Aphanocapsa. Lakes considered to contain algae in bloom proportions were Lake Waimimiha and two lakes on Karikari, Rotokawau and the adjacent unnamed lake.

Analysis of the level of the green photosynthetic pigment contained in the algae, chlorophyll"a", gives a rough measure of the abundance of algae in the water. These values can be found in Appendix 3 and are low in most cases.

However, the water colour of some lakes was distinctly green at the time of sampling, this observation agreeing with elevated chlorophyll a levels found for Lakes Heather, Waimimiha and the unnamed lake on Karikari peninsula. Waimimiha was very high at 0.418 g/m3. Between these lakes and the ones flow in algae, intermediate values of 0.015-0.019 g/m3 of chlorophyll a were found in Lakes Waiparera and Bullrush. As mentioned above, the algal content of the water can change through the year and vary from one year to the next. Compared to previous samples, Lake Rotokawau (on Karikari) was unexpectedly high at 0.078 g/m3 when sampled in January 1991.

To summarise, the dune lakes sampled varied from having little or no algae in them to being highly turbid due to the presence of significant amounts of algae. The species of algae observed were common species. The brown coloration of water in some of the lakes having low algal content was assumed to be tannins and humic substances from the breakdown of vegetation detritus. Those lakes surrounded by other than pasture were generally found to be low in algal content.

6.3.3 Water Clarity

Water clarity is an important aspect in lakes from a biological and recreational point of view. People prefer to swim and use water that is not discoloured by suspended sediment or algae. Clear water is important for bottom growing aquatic plants such as the low growing charophytes (non-vascular aquatic plants) which are dominant in many of the lakes. The bottom rooted charophytes require light to grow and being low growing are susceptible to phytoplankton or sediment in the water column that reduces light penetration for significant periods. Clarity is determined by a combination of algae, suspended solids and dissolved colour (eg., tannins and humic compounds) in the water.

The secchi disc, a circular, weighted black and white disc, is used as a measure of water clarity. Simply stated, the secchi value is the depth at which the disc disappears from view when lowered into the water. Appendix 3 shows secchi readings, on occasions readings were taken at more than one point on the lake.

The clearest lakes sampled were Lakes Ngatu, Wahakari, Waiporohita, Kihona, and the unnamed (Forest HQ) lake. These lakes had secchi values from around 2.0 metres to more than 3.6 metres. Lakes Morehurehu and Te Kahika, though not measured (due to no boat access), had low chlorophyll and suspended solid levels and casual visual observation indicated a similar water clarity to Lake Kihona. Less clear were Lakes Rotokawau, Rotoroa, Waiparera, Salt, Bullrush and Ngakapua with secchi values generally in the one to two metre range. There were exceptions to this, Waiparera was measured at 3.4 metres in August 1987 while Rotokawau was very low at 0.41 metres when sampled in January 1991. Less clear again on average was Lake Heather, ranging from 0.8 metres to 1.2 metres. Poorest water clarity in the lakes sampled was found in Lake Waimimiha (0.23 metres) and the unnamed lake on Karikari (0.2-0.6 metres), both these lakes having high algal levels and high suspended solids. Both are very shallow and wave action may disturb bottom sediments.

Cunningham et al., (1953) obtained secchi readings in February 1950 of 2.5 metres in Lake Waiparera and 4.0 metres in Lake Ngatu.

Secchi values from a number of the dune lakes at Pouto, North Kaipara Head (NRC., 1991) are comparable to those found in this investigation. However, the Aupouri lakes are not as clear as the Kai Iwi lakes in the Taharoa Domain, north of Dargaville where secchi values ranged from 3.6 metres to 11.0 metres.

It is notable that the lakes having elevated faecal bacteria levels are lakes to which stock have greatest access and are the same lakes which show higher levels of planktonic algae and reduced water clarity. This suggests that these lakes are becoming enriched with nutrients from farming operations, most likely from direct dung and urine input, and runoff or groundwater from pasture containing nutrient from dung, urine and fertiliser.

6.3.4 Plant Nutrients

Two important nutrients required for plant growth are phosphorus and nitrogen which are only directly available to plants in certain inorganic forms. A partial measure of this availability in the water is the nitrogen concentration derived from ammonia, nitrite and nitrate and the phosphorus concentration from dissolved reactive phosphorus (DRP). Nitrogen and phosphorus levels from these sources are shown in Appendix 3 from lake water samples filtered in the field to remove algae and other solids.

The four sampling occasions were not frequent enough to give more than an indication of nutrient levels and there is little in the tables to suggest a positive link between nutrient and planktonic algal levels (as measured by chlorophyll a). Interpreting dissolved nutrient levels in the water as a measure of lake productivity in isolation from other factors can be misleading. This is partly due to the ability of algae to take up more nutrient than they can immediately use ('luxury' uptake) and, when rapidly growing, to quickly strip the available nutrient from the water. Lake Waimimiha did in fact have high levels of nutrient and a high algal content though other lakes on occasion appeared to have sufficient nutrient but low levels of algae.

Overall, nutrient levels varied from not detectable to a maximum of 0.111 g/m3 for dissolved reactive phosphorus, 0.645 g/m3 for ammoniacal nitrogen, 0.190 g/m3 for nitrite+nitrate nitrogen. Results were variable between samples within a lake and between lakes.

6.3.5 Temperature and Dissolved Oxygen (DO)

Some of the dune lakes could reasonably be expected to become thermally stratified in most years, particularly the deeper lakes like Wahakari or those now more sheltered by maturing pine trees. Sampling has not been sufficient to determine which lakes stratify on a regular basis. Wahakari was only sampled once during the summer period (February 1989) and was not found to be stratified. A number of lakes were found to have some degree of stratification present when sampled in January 1991, namely Lakes Heather, Kihona, Salt, and the unnamed (Forest HQ) lake. The dissolved oxygen and temperature profiles for those lakes, for January 1991 sampling, are shown in Fig. 6.4.

The lakes with profiles shown in Fig. 6.4 are shallow and it was somewhat unexpected that they were found to be stratified. The separation into top and bottom layers of water is not distinct, temperature in each of these lakes drops off after a certain depth and continues this trend to the bottom. While the profiles shown may not represent true stratification, it is obvious that the water bodies are not uniformly mixed in terms of temperature and dissolved oxygen. Lake Kihona which was sheltered by surrounding hills and pines is the most strongly stratified.

In most lakes the dissolved oxygen levels of surface waters was in the range of 6.5 to 8.5 g/m3 which is normal for such water bodies and will sustain fish life (providing temperature is not too high). Higher oxygen levels were observed in Wahakari, Waiporohita, and Morehurehu (9.2, 9.5, 9.6 g/m3 respectively) probably due to wind action, whereas the highs in Lake Rotakawau, Bullrush and Waimimiha (9.5, 10.0 g/m3 respectively) may have been due to algae (photosynthesis releases oxygen to the water). High levels of dissolved oxygen were not measured in the algal dominated unnamed lake on Karikari peninsula as might have been expected. Similarly it is not obvious why the unnamed (Forest HQ) lake had low oxygenated surface water of 3.3 g/m3 when sampled.

6.3.6 Major Ions

Sampling of the lakes was not comprehensive. However, the results shown in Appendix 3 does give an indication of what "average" values might be.

Alkalinity measures the ability of water to resist or "buffer" changes to the pH. The higher the alkalinity the more difficult it is to change the pH. Alkalinity varied from low values of less than 5 g/m3 up to 50 or so g/m3 CaCO3. The suggestion by Wells

Fig. 6.4: Dissolved oxygen and Temperature profiles for selected lakes sampled 21-January 1991.

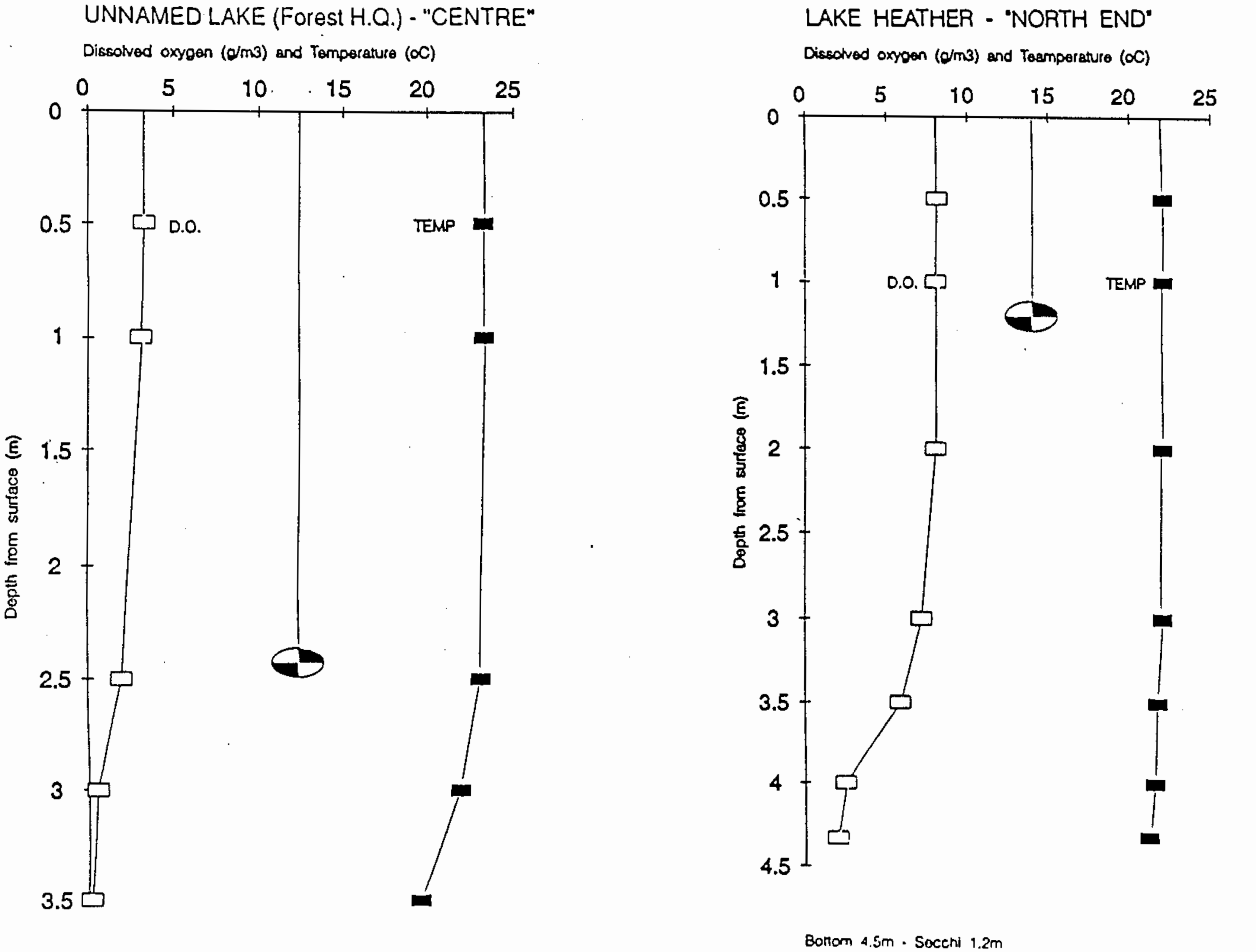
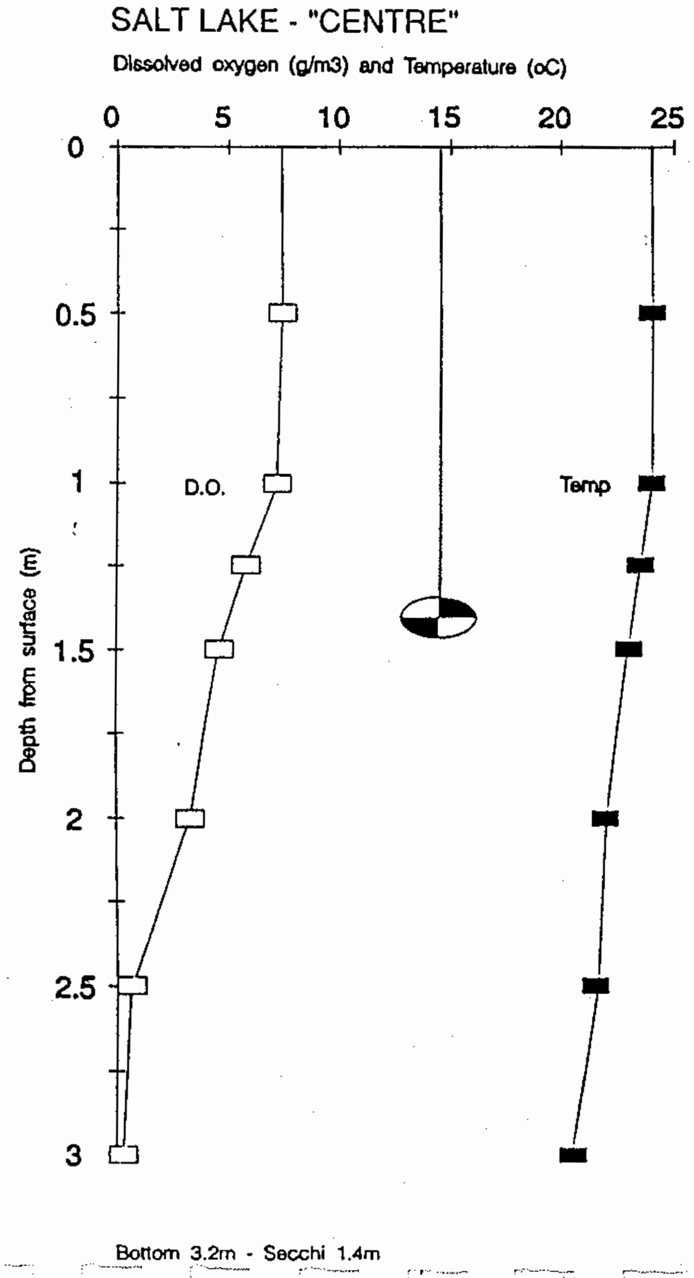
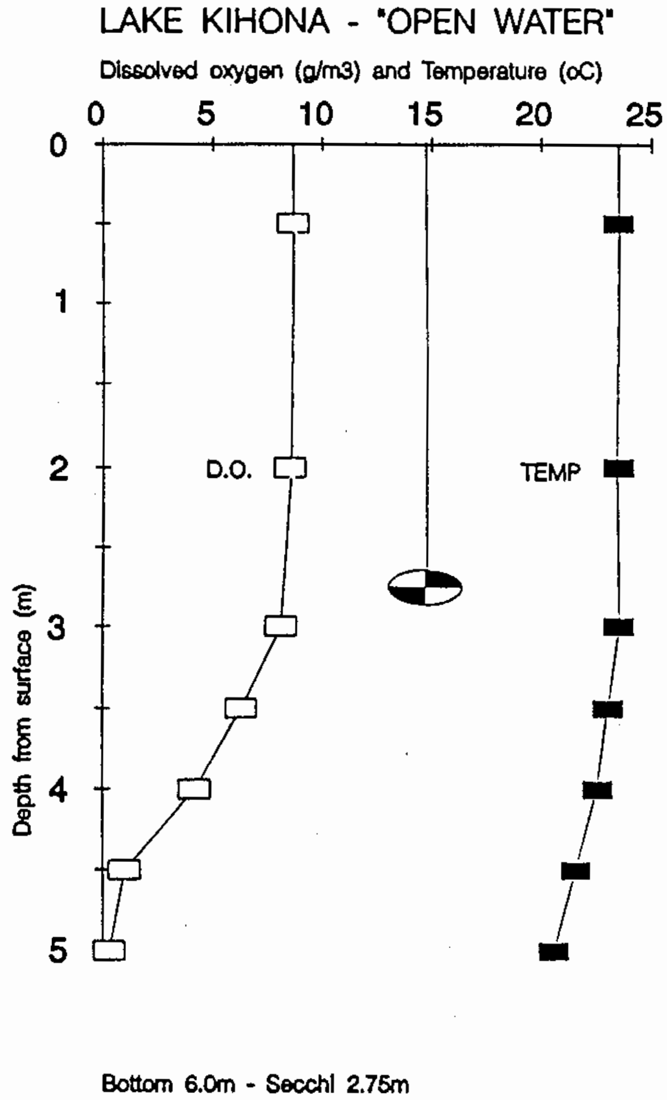


Fig. 6.4: continued





et al., (1988 - Kai Iwi lakes study) that low alkalinities may restrict algal growth through carbon limitation does not appear to hold in the case of Lake Rotokawau and the adjacent unnamed lake on Karikari where algal levels were high and alkalinities low, ranging from 2 to 7 g/m3.

Total hardness in the majority of lakes sampled were in the 20 to 40 g/m3 of $CaCO_3$ range. Values obtained in Lakes Waiparera, Salt and Waimimiha were higher, up to 75 g/m3.

6.3.7 Lake Water Quality and Suitability for Various Uses

Although the lakes have only been sampled a few times and in some cases only once, the following comments on the general state of the lake water quality and suitability for various uses can still be made.

Domestic Water Supply

Although a few samples from some lakes did not contain detectable numbers of Faecal Coliform bacteria, samples from all the lakes sampled more than once had significant counts. Which means that the water was not within the NZ Drinking Water guideline standard for untreated drinking water supplies. The risk of Giardia infection from drinking or food preparation with untreated lake water is unknown.

The water from most of the lakes would require filtering to remove algae and other organic matter.

The lakes with high algae contents could experience blooms of potentially toxic blue-green algae species which would render them totally unsuitable for domestic water supply use.

In conclusion, all lake waters to be used for drinking or food preparation should first be treated, filtered and disinfected. The limited sampling shows that water from some lakes, namely lakes Wahakari, Kihona, Morehurehu and Te Kahika would require only minimal treatment.

Stock Water and Irrigation

The lakes sampled are of a suitable water quality for stock drinking. However, there is a risk to stock from blooms of potentially toxic blue-green algae in lakes Waimimiha, Rotokawau and the unnamed neighbouring lake on Karikari Peninsula, and possibly other lakes not sampled.

The lake waters sampled are generally suitable for irrigation except again lakes with high algal contents which could cause clogging and purification in pipes.

Recreation

The previous generally used bacterial standard for contact recreation/swimming, 200 faecal coliforms per 100 ml, was only exceeded in one sample from the unnamed lake on Karikari Peninsula. However, the algal and suspended organic matter content of some lakes makes the water quite murky and unattractive and unsafe.

Wildlife Habitat

The suitability of the lake waters for wildlife is a wide and technically complex topic, particularly given the lack of knowledge of the habitat requirements of many species. A more comprhensive discussion of this is contained in Sections 6.4 to 6.6 and in Section 7.

As a generalisation the dominance of algae in some lakes will severely limit many native species found in other dune lakes. The lack of dissolved oxygen in the lakes that become stratified or partially stratified will also be limiting to some species found in well mixed lakes.

6.4 Aquatic Plants

Discussion in this subsection is restricted mainly to submerged and emergent aquatic plants in the lakes themselves. Section 7, provided by the Department of Conservation, gives greater detail on the flora in wetlands and swamps associated with or separate from the lakes.

Cunningham et al., (1953) in surveying 26 dune lakes of the west coast of the North Island investigated Lakes Waiparera and Ngatu on the Aupouri peninsula. The bed of both lakes were extensively covered with chara species and the reeds around portions of the lake shores consisted of predominantly Eleocharis sphacelata and to a lesser extent, Baumea huttoni, Baumea articulata, Schoenoplectus validus and raupo, Typha orientalis. Raupo was typically found associated with swampy areas draining into a lake rather than in the lake itself. In describing the dominant shoreline vegetation, Cunningham et al., noted that they had the common feature of propagation by rhizomes and were limited to growing in water depths of two metres or less. They also observed that vegetation density around the shore was related not only to depth but also to exposure to wind and waves and to the proximity of drifting sand. Vegetation was absent in the more exposed situations in Lake Waiparera while Eleocharis sphacelata extended to a limiting depth of two metres in sheltered areas of Lakes Waiparera and Ngatu.

The aquatic macrophyte survey of 26 northern New Zealand lakes by Tanner et al., (1986) included 12 lakes in the study area, Lakes Ngatu and Waiparera being in common with the survey by Cunningham et al., in 1950. Limited diving was carried out allowing a subjective assessment to be made on the abundance of each species present. The results of Tanner et al., relating to Aupouri are reproduced below in Tables 6.2 and 6.3.

The description of the emergent vegetation by Tanner et al., (1986) is similar to that given by Cunningham et al., (1953) though the latter survey notes the presence of more exotic species, namely the adventive Palustris ludwigia and to a lesser extent Glyceria maxima, Juncus articulatus and Polygonum species.

Tanner et al., found the submerged vegetation of lakes on the Aupouri peninsula to be comprised of native species in most cases. The low growing native charophytes most often dominant were Chara corallina and Chara fibrosa. The exotic 'oxygen weeds' Ceratophyllum demersum, and Egeria densa were noted in Ngakeketa and Lake Rotoroa respectively where they formed dense growths which excluded other species.

Table 6.2: Species code used by Tanner et al., (1986)

Table 2 Species codes and frequencies (number of lakes) for aquatic plants recorded in surveys of 26 northern New Zealand lakes.

Species code	Species	No. of lakes
AP	*Azolla pinnata* R. Br.	7
BA	*Baumea articulata* (R. Br.) Blake	8
BH	*B. huttoni* (Kirk) Blake	5
BJ	*B. juncea* (R. Br.) Palla	5
BR	*B. rubiginosa* (Spreng.) Boeck	6
CC	*Chara corallina* Kl. ex Willd. em. R.D.W.	21
CD	*Ceratophyllum demersum* L.	1
CF	*Chara fibrosa* var. *acanthopitys* (A. Br.) Zanev	18
CG	*C. globularis* Thuill	6
CU	*Cyperus ustulatus* A. Rich.	2
EA	*Eleocharis acuta* R. Br.	2
EC	*Elodea canadensis* Michx.	1
ED	*Egeria densa* Planchon	3
EG	*Elatine gratioloides* A. Cunn.	1
ES	*Eleocharis sphacelata* R. Br.	19
GE	*Glossostigma elatinoides* Benth.	8
GM	*Glyceria maxima* (Hartm.) Holmb.	1
GS	*Glossostigma submersum* Petrie	11
HI	*Hydatella inconspicua* Cheeseman	5
IK	*Isoetes kirkii* A. Braun.	1
JA	*Juncus articulatus* L.	2
JB	*J. bulbosus* L.	4
JP	*J. pallidus* R. Br.	1
KS	*Callitriche stagnalis* Scop.	1
LL	*Lilaeopsis lacustris* Hill.	12
LM	*Lagarosiphon major* (Ridley) Moss ex Wager	*
LN	*Limosella lineata* var. *spathulata* Gluck	2
LP	*Ludwigia palustris* (L.) Ell.	9
LS	*Leptocarpus similis* Edgar	5
LX	*Lemna* sp.	2
MP	*Myriophyllum pedunculatum* Hook. f.	3
MQ	*M. propinquum* A. Cunn.	13
MR	*M. robustum* Hook. f.	2
MT	*M. triphyllum* Orchard	8
MV	*M. votschii* Schlindler	*
NH	*Nitella hookeri* A. Br.	9
NL	*N. leptostachys* A. Br. em. R.D.W.	6
NP	*N. pseudoflabellata* A. Br. em. R.D.W.	14
NY	*N. hyalina* (DC.) Ag.	6
OO	*Otellia ovalifolia* A. Br. em. R.D.W.	5
PC	*Potamogeton cheesmanii* A. Benn.	20
PO	*P. ochreatus* Raoul	15
PP	*P. pectinatus* L.	1
PX	*Polygonum* sp.	2
RX	*Ruppia* sp.	3
SL	*Scirpus lacustris* L.	8
SM	*Salvinia molesta* Mitchell	1
SP	*Spirodela punctata* (G. Meyer) C.H. Thompson	6
SR	*Scirpus prolifer* Rottb.	1
TO	*Typha orientalis* C.B. Presl	10
TT	*Triglochin striatum* Ruiz et Pav.	2
UP	*Utricularia protrusa* Hook. f.	8
WA	*Wolffia australiana* (Benth.)Hartog & van der Plas	1

Note: The species codes above are those used in the Ministry of Agriculture & Fisheries, Aquatic Plant Section, Aquatic Vegetation Database.
* Species not recorded in the present study but recorded by other authors for lakes in the present study — see Table 3.

Source: Tanner C.C., Clayton J.S. and Harper L.M. 1986. Observations on aquatic macrophytes in 26 northern New Zealand Lakes. New Zealand Journal of Botany. Vol. 24:539 to 551.

Table 3 Aquatic macrophytes recorded from exploratory surveys of 26 northern New Zealand lakes in December 1984, January 1985, and July 1985. The areas of the lakes which were sampled and other published records are also noted. Charophytes are noted first and vascular plants second.

Species[1]	Depth range (m)	Abundance[2]
1. *Ngakeketa* (whole)		
CC	0.1–3	c
NH	1–4	o
NL	1	o
NP	0.1–1.5	o
BA	0–1	o
CD*	0–4.5	a
GS	0.3–1	o
LN	0.2	o
LP*	0–0.2	o
MQ	0–0.5	o
PC	0.2–3.5	o
PO	0.1–4	c
SP	+	o
TO	0–1.5	a
2. *Wahakari* (S end)		
CC	1–7	a
CF	0.3–3	a
NP	0.5–1	o
BJ	0–0.5	o
ES	0–1	
LL	0.5–2	c
LS	0–0.3	o
MT	1	o
PC	1–4.5	o
PO	1–4	o
SL	0–1	o
TO	0–2	o
TT	1	o
UP	+	o
3. *Waihopo* (whole)		
CC	0.1–3	a
BR	+	o
CU	+	o
ES	0–1.25	a
MQ	0–0.5	c
PC	1–2.5	o
SL	+	o
SP	+	o
UP	0.1–3	a
4. *Waiparera* (N & E shores)		
CC (i)(ii)	0.5–4	a
CF (i)(ii)	1–3	c
CG (ii)	0.1–3	c
NH (ii)	0.5–4	o
NL (ii)	0.2	o
NP (ii)	0.2	o
NY (ii)	0.1–0.5	o
BH (i)	0–0.5	c
BR	0–0.5	o
ES (i)	0–0.75	c
LL	0.1–1.5	c
LP*	0–0.2	o
LS	0–0.3	o
PC	0.1–2.25	c
SL (i)	0–0.75	c
(i) BA, TO, (iii) MT, MV; (v) HI, (viii) LM		
5. *N6/695806* (whole)		
CC	1–3.5	a
CF	2	o
BA	0–0.3	c
ES	0–1.2	a
PC	1–3.5	c
SM*	+	c
SP	+	o
UP	0.5–3.5	a
6. *Ngakapua* (W end)		
CC	0.1–5	a
CF	1.5–4.5	c
AP	+	o
BA	0–0.5	o
ES	0–2	a
PO	1.5–2	o
TO	0–0.5	o
UP	0.2–5	a
# 7. *Rotokawau*[5] (whole)		
CC	0.1–3	c
CF (ii)	0.1–3	a
NL (ii)	0.5–2	o
BJ	0–0.2	o
BR	0–1	c
ES	0–1.5	a
GS	0–0.1	o
MQ	0–0.1	o
PC	0–3	o
UP	0.1–3	o
(ii) NH		
8. *Carrot* (whole)		
CC	0–2.5	a
BA	0–0.5	c
LX	+	c
MQ	0–0.1	o
PC	0–2	o
PO	1.5–2.5	o
TO	0–0.5	c
UP	0–2.5	o
WA	+	c
9. *N9/688787* (whole)		
NL	+	o
AP*	+	c
BA	+	o
CU	+	o
EA	+	o
ES	+	c
GM*	+	o
JA*	+	a
LP*	+	c
MQ	+	c
MR†	+	c
PC	+	c
SL	+	o
SR	+	c
UP	+	c
10. *Ngatu*[3] (whole)		
CC (i)	0.2–5	c
CF (i)(ii)	0.2–5	a
NL (ii)	0.5–5	c
NP	0.3–3	o
BA	0–1.5	o
BH (i)	0–1.25	c
ES (i)	0–2.25	a
GS	0.5–1	o
HI† (v)	0.3–1	o
JA*	+	o
LL	0.5–2	o
LN	0.4–1.5	o
MP (iii)	0.4–1.5	o
MQ	0.1–1	o
LS	+	o
PC	0.1–3	o
SL	+	o
TT	0.5	o
UP	0.5–3.5	o
(i) TO; (ii) NH		
11. *N9/700767* (S end)		
CC	0.3–2.5	a
CG	0.5	o
AP*	+	o
BR	+	c
ES	0–1	c
LP*	+	o
LX	+	o
MQ	+	c
MR†	+	o
PC	0.3–0.5	o
PO	0.5–3	a
PX*	+	c
TO	0–0.5	c
12. *Rotoroa* (N end)		
CC	0.5–4.5	c
CF (ii)	0.3–3.5	a
NH	0.1–0.5	o
BJ	0–1	a
BR	0–0.75	o
ED*	1–4.5	a
HI† (v)	0.3–0.6	o
LL	0.3–2	o
MT	0.5–1.5	o
PC	0.3–4	o
PO	0.5–4.5	o

[1]See Table 2 for species codes. Other published records: (i) Cunningham et al. (1953), (ii) Wood & Mason (1977), (iii) Orchard (1979), (iv) Fish (1966), (v) Edgar (1966), (vi) Rawlings (1974), (vii) Pledge (1974), (viii) Mason (1975).
[2]a = abundant, c = common, o = occasional, + = present.
[3]Colonised by macrophytes to maximum depth sampled in the present study.
[4]Sampled at Pine Beach, Nob Point, Hauhatoki Bay, and Western Bay.
[5]Shoreline survey only — eastern shore.
*Exotic species.
†Rare and endangered species.

Lake Rotokawau located N6 / 710803 not to be confused with Lake Rotokawau on Karikari Peninsula.

Source: Tanner C.C., Clayton J.S. and Harper L.M. 1986. Observations on aquatic macrophytes in 26 northern New Zealand Lakes. New Zealand Journal of Botany. Vol. 24:539 to 551.

Largarosiphon major, another oxygen weed, which had been found in Lake Waiparera in 1970 was not found by Tanner et al., (1986). The presence of exotic oxygen weeds is of some concern because of their ability to colonise many of the habitats currently occupied by native species. By comparison to the charophytes which seldom cause problems, oxygen weeds often form dense beds of surface reaching vegetation. Such growths can interfere with boat access, water intakes, swimming and result in onshore accumulation of weed strands broken or dislodged by storms.

Egeria densa is palatable to waterfowl and in Lake Omapere near Kaikohe black swan numbers increased markedly each year until the weed collapsed in 1985 (NRC, 1986). Fragments of Egeria densa have been found (by NRC staff) washed ashore at Lake Waiparera in 1990, indicating that it has established in this lake, presumably in recent years. Egeria densa is extensively found in the nearby Awanui River and tributaries.

A finding of Tanner et al., was that shallow water submerged plant communities were largely excluded from lakes with swampy or cattle trampled shores. Hydatella inconspicua, an endangered species which grows in shallow water, was recorded from Lakes Ngatu and Rotoroa. The vulnerable adventive plant Myriophyllum robustum was found in two unnamed lakes (lakes 9 and 11 in Tanner et al., 1986). Hydatella inconspicua, of scientific significance in terms of plant evolution, taxonomy and paleobotany, is endemic to New Zealand and known to occur only in dune lakes of Northland. Recommendations have been made for the management and conservation of Hydatella inconspicua (and Myriophyllum robustum) in Northland by Tanner et al., (1988).

An infestation of the noxious floating weed Salvinia molesta was found by Tanner et al., in an unnamed lake (lake No.5); other lakes in the area have been subject to eradication programmes for this species in the past.

In summary, it can be said that most lakes still retain largely native associations of emergent and submerged aquatic plants and that these do not cause as many water use or management related problems as is experienced with certain introduced aquatic plants. Exotic 'oxygen weeds' known to be in some lakes in the area are Egeria densa, Ceratophyllum demersum and Lagarosiphon major. Lagarosiphon and Ceratophyllum appear not to have spread substantially since detection whereas Egeria still appears to be actively colonising new waterbodies. There are other introduced aquatic plants in New Zealand which could be expected to reach the lakes given time and, if environmental conditions prove suitable, to adversely impact on various uses made of the lakes.

6.5 Freshwater Fish

Discussion here has been extended to cover all of the streams, lakes and wetlands of the study area. Discussion is generalised and most of the information has been extracted from the book "New Zealand Freshwater Fishes - A Natural History and Guide", McDowall (1990).

The fish fauna of the streams, swamps and lakes in the study area have not been extensively surveyed. Knowing the type of habitat the various fish species occupy elsewhere in New Zealand does allow reasonable comment to be made as to the likelihood of a particular species being present or not.

Many of the 27 native freshwater fish species require a marine phase to complete their life cycle. As many dune lakes do not have outlets, most of these fish species are excluded from the lakes. Exceptions to this are the short finned eel (Anguilla australis) and long finned eel (Anguilla dieffenbachii) which under moist conditions can move some distance overland between waterbodies. Both species are found in many of the lakes, streams and swamps in the study area. For some species a marine phase is not essential and allows for landlocked fish populations to exist. Thus, inanga (Galaxias maculatus) are able to reproduce in Lake Waiparera and common smelt (Retropinna retropinna) in Lake Ngatu. Similarly, populations of the common bully (Gobiomorphus cotidianus) are present in many landlocked dune lakes in Northland. The Waiparera inanga were initially considered to be a separate species (McDowall, 1967) but study of other landlocked populations since that time indicates that they should be regarded simply as a landlocked population or race of Galaxias maculatus (McDowall, 1990). In streams, inanga juveniles are the most numerous fish forming the annual upstream whitebait runs (migration).

Other native species have been found in streams and swamps of the study area, these being banded kokopu (Galaxias fasciatus), black mudfish (Neochanna diversus), redfinned bully (Gobiomorphus huttoni), giant bully (Gobiomorphus gobioides) and bluegilled bully (Gobiomorphus hubbsi). The swamps and wetlands of the study area support populations of black mudfish which have disappeared from many areas of Northland due to loss of habitat by drainage. it is a secretive fish, having a competitive advantage over other fish by being able to survive in mud or swamp debris when the water dries up. It lives wholly in freshwater and can delay spawning until a dry spell is broken by rain. Black mudfish are thought to favour such areas as the Kaimaumau peatlands and gumland, particularly the water filled holes remaining from old gumdigging operations.

Some introduced fish species are present in the study area, these being rudd (Scardinius erythrophthalmus), rainbow trout (Oncorhynchus mykiss), goldfish (Carassius auratus) and mosquito fish (Gambusia affinis). Rudd, classified as a noxious fish, was reported from Lake Ngatu some four years ago (pers comm. M. Poynter, Manager Northland Fish and Game Council). Its current status in the lake is unknown. Rainbow trout is stocked in Lake Ngatu on an intermittent basis by the Northland Fish and Game Council while stocking of Lake Waiparera was discontinued some five years ago. As spawning is reported not to take place in either lake, there is not likely to be any trout remaining in Lake Waiparera. lake Ngatu is fished by a few local anglers and both lakes are probably marginal as trout habitat due to high summer water temperatures. Goldfish too, have been found in Lake Ngatu (M. Poynter, pers. comm.). Mosquito fish were introduced to Lake Ngatu in the 1930's as an experiment to control mosquito larvae and since that time have extended their range throughout the North Island. They are a small drab fish, tolerant of low oxygen and enriched waters, often observed in shoals feeding close to the shoreline of sluggish streams and lakes. Mosquito fish were noted in the small unnamed lake next to Lake Rotokawau and in Waiporohita, on Karikari Peninsula, in January 1991.

The impact of these exotic fish species on native aquatic ecosystems has seen little study, although the decline of some native species (notably Galaxids) has occurred with the introduction of trout in other parts of New Zealand.

In summary, it can be said that most lakes have a low diversity of fish species, due largely to the exclusion of species that require a marine phase to their life cycle. Native fish known to be in one or more of the dune lakes are the short and long finned eel, smelt, inanga and the common bully. Rudd and rainbow trout may be limited to Lake Ngatu while the mosquito fish is more widespread.

6.6 Bird Life

Many bird species make use of the lakes in the study area as well as the vegetation associated with the shoreline and adjacent swampy areas. Birds may be resident all year or present for only part of the year.

A more thorough discussion of birds and their habitats, especially those considered rare, endangered or threatened, is provided by the Department of Conservation in Section 7.

6.7 Lake Modification

The degree to which the character of a lake has changed depends on many factors such as exposure to wind, lake depth and size, land use in the surrounding catchment and introduction of exotic aquatic plants and animals. The influence of introduced aquatic weeds and fish have been discussed in sections 6.4 and 6.5 respectively.

The following briefly outlines some of the observed changes in lake character and suggests the mechanisms of change that has occurred or is likely to occur in the Aupouri dune lakes.

As the sand is largely stabilised and with most lakes having only ill defined streams flowing into them, infilling by sand is no longer a major process in these dune lakes. The encroachment of emergent vegetation (reeds) growing in from the waters edge, reducing the area of open water is however significant, particularly so for shallow lakes and for lakes that now are sheltered from the wind by maturing pine plantations. Organic detritus is also contributed by the planktonic algae and submerged vegetation. In many instances pines have been planted down to the waters edge (eg., Lake Te Kahika, Lake Kihona). Comparing the existing situation with early aerial photographs shows that some small open water lakes have now become infilled with reeds. Infilling of lakes is a natural process but is likely to have been accelerated by the sheltering effect of the pines, and in some cases the increased evapotranspiration of the forest may have reduced water inflow to lakes, and drainage operations for forestry and farming lowered lake levels.

Some lakes in the forests have "disappeared" since afforestation began and this mechanism may account for their loss, though it is possible that some lakes were deliberately drained during the forestry planting phase.

For larger and deeper lakes (significant area >2 m deep) this process progresses more slowly. Emergent vegetation establishes as a fringe in shallow and sheltered margins and a significant amount of organic matter is produced. These lakes, such as Lake Kihona, had yellow-brown coloured water with a relatively high level of organic detritus. The sheltering of the trees or surrounding hills, allows these lakes to become stratified and combined with the presence of the organic detritus causes deoxygenation of the bottom waters to occur. In turn, prolonged deoxygenation will allow the accumulation of organic detritus on the lake bed, gradually infilling the lake and allowing encroachment of the emergent vegetation.

Where lakes are surrounded by pasture, emergent vegetation growth is restricted by stock grazing and exposure to wind. This combined with the nutrient input from animal waste and fertiliser leads to algal dominance in those lakes. These lakes are quite green in colour, eg., Lake Waimimiha.

The deliberate, accidental or natural spread of exotic plant and animal species into the lake environment has changed the character of some lakes. The most notable is the displacement of native submerged plants by the exotic oxygen weed *Egeria densa*. The exotic oxygen weeds may lead to significant water quality problems. Table 6.4 summarises the current condition and possible future trends for the lakes that were sampled, should conditions in their catchments remain the same.

6.8 Management Options

There are a number of management options which could be used to minimise or reduce adverse impacts to the lakes:

(a) Provision of fenced and vegetated buffer strips between the shoreline and pasture of forestry. Advantages include prevention of stock grazing and trampling, creation and protection of wildlife habitat, reduction of nutrient input and aesthetic improvement.

(b) Prohibiting any point source discharges of effluent to lakes. Advantages are prevention of nutrient enrichment and toxic effects.

(c) Though not yet a proven method, the introduction of algae eating silver carp to already algal dominated lakes may be of benefit by reducing turbidity, improving water clarity and reducing nutrient load if the fish are harvested, reduced risk of toxic algae blooms.

(d) Heightened public awareness of the need to prevent further introductions of water weeds or fish to the lakes. Advantages are lakes retaining their natural character in terms of native species composition and reduce risk of nuisance weed growth.

(e) Heightened land owner awareness or even prohibition of further drainage operations that could lead to reduction of lakes and wetlands. Advantages are the maintenance of the size and quality of natural wetland habitats and preservation of the natural character of the lakes.

Current Local Lake Management Initiative

An environmental group, the Community Business and Environment Centre based in Kaitaia, has proposed a number of measures for the Sweetwater lakes designed to enhance the physical lake and wetland environment in and between Lakes Ngatu, Rotoroa and Heather (C.B.E.C., 1991). Included in the proposal is a walkway linking the lakes, picnic and recreation areas and, in the longer term, the provision of overnight

Table 6.4: Lake location and surrounding land use

Lake name	Location	Surrounding land use	Current status	Possible future trends
Te Kahika	N02:110-311 Tangaoake	pine forest, s. dune and scrub	generally good	Likely to remain good water quality
Morehurehu	N03:109-291 Tangaoake	pine forest, some dune scrub	generally good water quality	Likely to remain good
Kihona	N02:020-304 Ngatiwhetu	pine forest,	average to good water quality	Likely to remain average for some time
Wahakari	N03:040-278 Ngataki	pine forest, scrub and pasture	generally good water quality	Likely to remain good for some time, slow deterioration expected
Bullrush	N03:107-215 Ngataki	pasture, some pine forest	poor water quality	further deterioration expected
Salt	N03:132-217 Ngataki	pasture	poor water quality	further deterioration expected
Waiparera	N04:283-873 Waipapakauri	pasture	good to average water quality, some deterioration	further deterioration expected
Forest HQ	N04:283-873 Waipapakauri	pine forest	average water quality	slow deterioration expected
Ngakapua	N04:287-869 Waipapakauri	pasture	average water quality	further deterioration expected
Ngatu	N04:285-825 Waipapakauri	pasture	generally good water quality, some deterioration	further deterioration expected
Heather	N04:285-825 Sweetwaters	pasture	average to poor water quality	further deterioration expected
Rotoroa	N04:285-825 Sweetwaters	pasture	average water quality	further deterioration expected
Rotokawau	003:393-034 Karikari	pasture and scrub	average water quality	further deterioration expected, probably algal dominated
Unamed	003:402-033 Karikari	pasture and scrub	poor water quality, algal dominated	likely to remain algal dominated
Waiporohita	003:427-001	pasture	good to average water quality	further deterioration expected
Waimimiha	N04:263-728 Ahipara	pasture	poor water quality	likely to remain algal dominated

camping facilities. The financial backing needed for the fencing, planting and walkway construction is intended to be sought from the public, business community, territorial authorities and government departments. Aside from funding, the major problem, as in all such ventures, is the co-ordination and co-operation that is needed from the various owners of the land in the proposed management area as well as meeting the necessary criteria of any local or government bodies having jurisdiction over the proposed development and associated activities.

C.B.E.C, the Bushlands Trust and Kaitaia Conservation Crop have planted an area of Lake Ngatu foreshore with native trees and shrubs as a start to the proposed programme.

7.0 BIOLOGICAL VALUES OF THE FRESHWATER WETLANDS WITHIN THE TE PAKI AND AUPOURI ECOLOGICAL REGIONS

7.1 Summary

A freshwater wetland inventory was undertaken within the Aupouri and Te Paki Ecological Regions during April 1991. Prior to this inventory, surveys had been completed in 1978 by the NZ Wildlife Service within the old Mangonui County, in 1985 on Crown land of the Karikari Peninsula, and by the Department of Conservation in 1987-88 on Crown administered land during government departmental restructuring.

A total of 114 freshwater wetlands within the two Ecological Regions have been identified and ranked for their biological values. The 114 wetlands identified, known as Sites of Special Biological Interest (SSBI) are home to a surprisingly large number of threatened flora and fauna species. With only about 10% of New Zealand's original freshwater wetlands now remaining, it is essential that the existing freshwater wetlands are protected and if necessary enhanced to prevent the further slide towards extinction of the large number of threatened flora and fauna which frequent these habitats.

The survey revealed that continuing wetland modification and drainage, deterioration of water quality and standards due to adjoining land use practices, eg., enriched nutrient runoff, land clearing, afforestation, stock encroachment to the peripheral and littoral margins, weed invasion and fire are all contributing factors impacting upon the natural values of the wetlands recorded.

7.2 Introduction

In April 1991, the Department of Conservation carried out work to identify, survey and record all freshwater wetlands on SSBI located within the Aupouri and Te Paki Ecological Regions.

The purpose of this survey was to update the Department of Conservation's database on the biological values of the wetlands so that a report and schedule of sites identified could be compiled for inclusion into the Northland Regional Council's proposed Water Resources Management Plan. To meet the requirements of the proposed water resources management plan, estuarine and coastal saline wetlands were not included in this survey. Where freshwater wetlands were contiguous with coastal saline wetlands, eg., Kapowairua Wetland No.2, then only those freshwater values were commented on.

Limited funding for the actual field survey meant that a full coverage of the entire area could not be achieved. To overcome this obstacle and complete the gaps on the 1991 resurvey, information from the Department's biological database originating from the 1978, 1985 and 1987-88 surveys has been used.

A total of 114 wetlands were recorded from the survey area consisting of:

1991	78
1987-88	12
1985	7

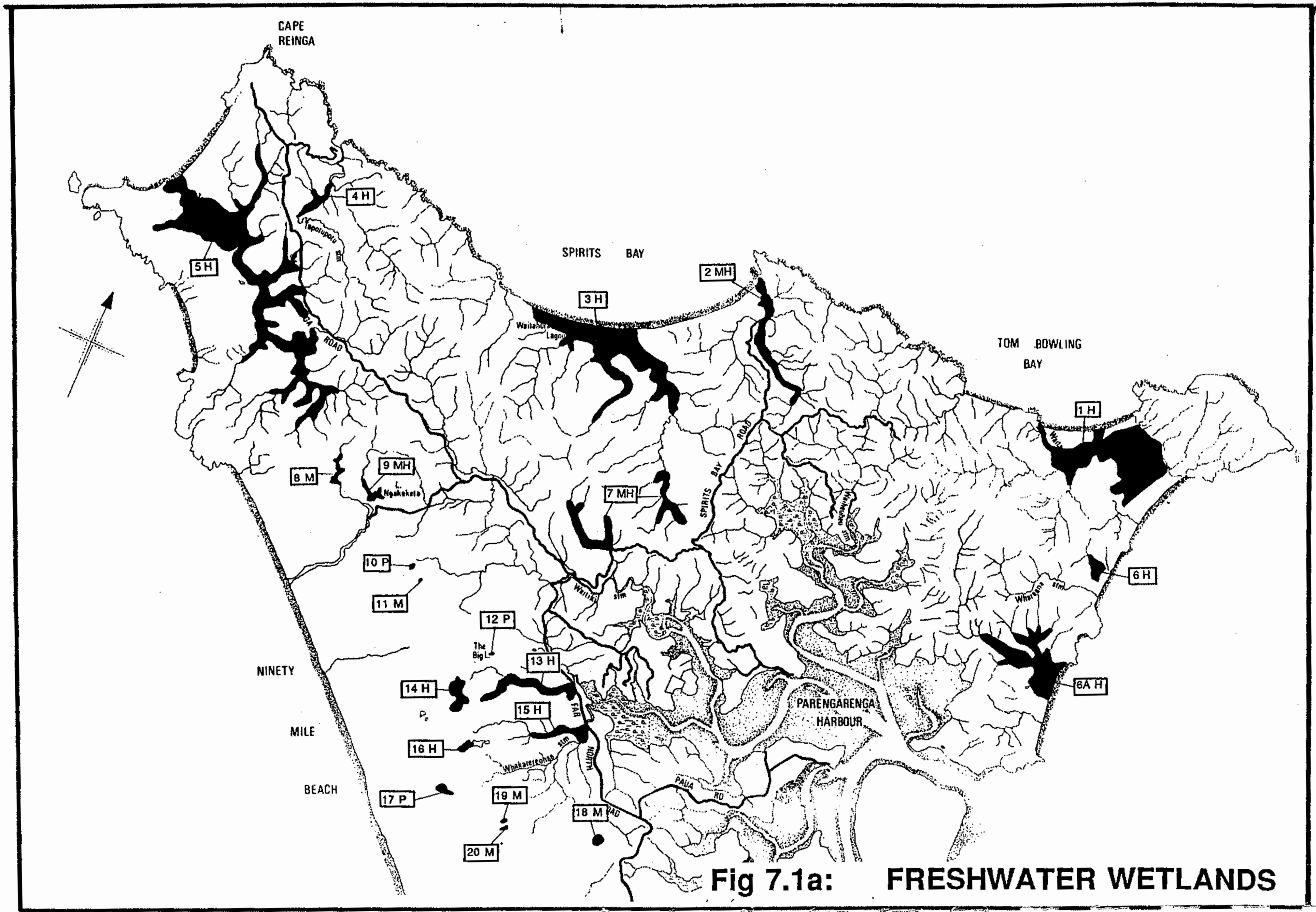


Fig 7.1a: FRESHWATER WETLANDS

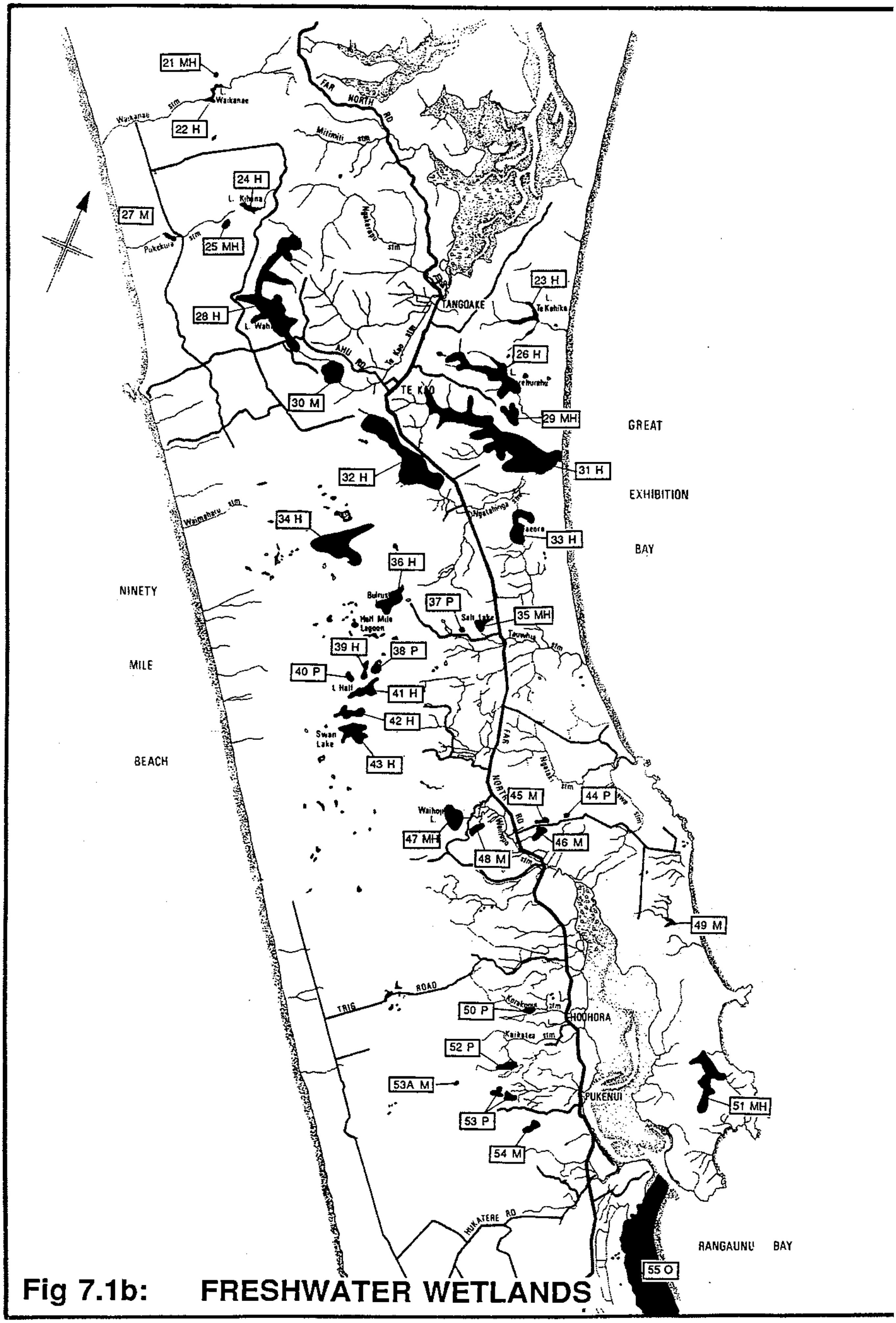


Fig 7.1b: FRESHWATER WETLANDS

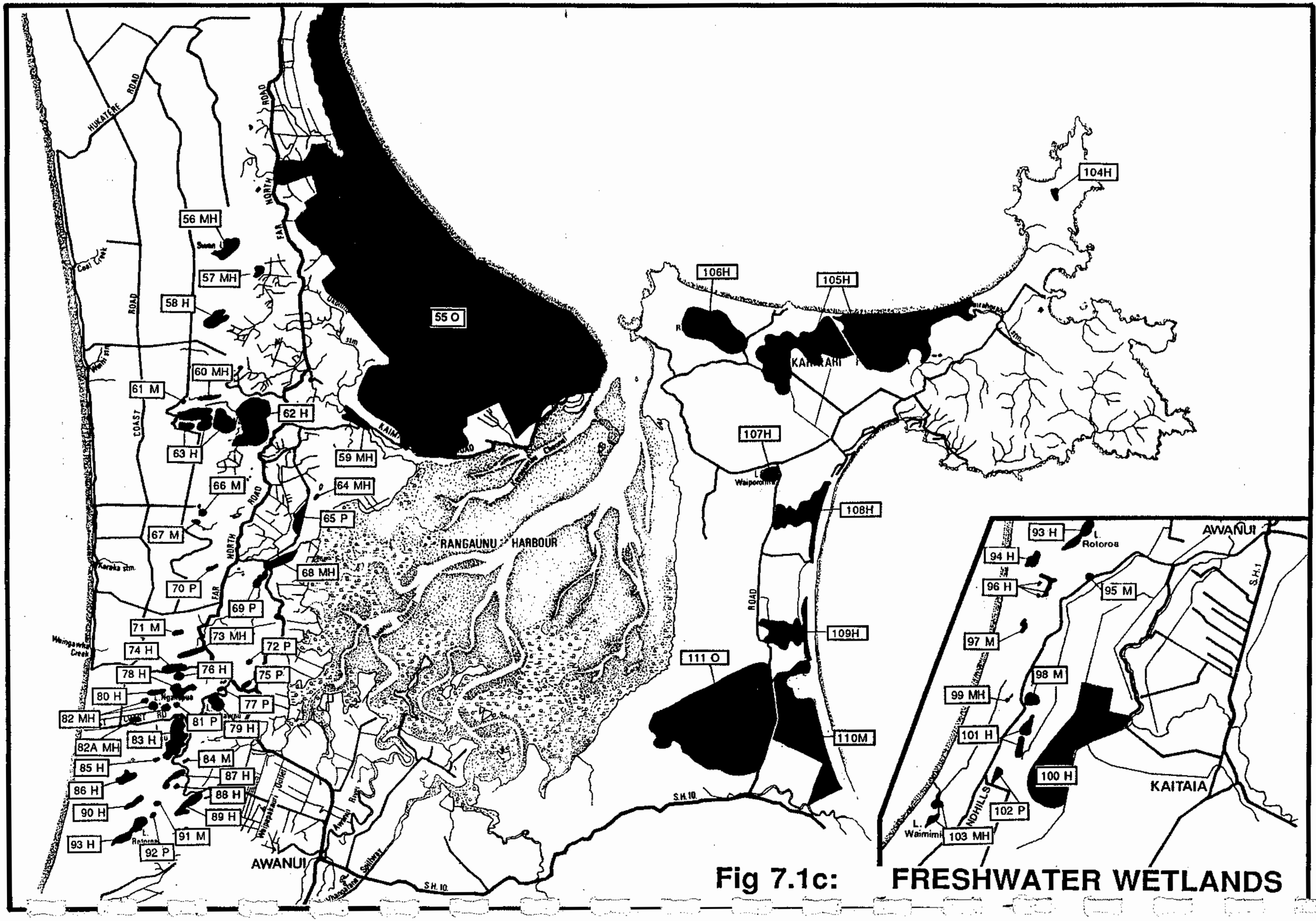


Fig 7.1c: FRESHWATER WETLANDS

1978	16
Total:	**114**

7.3 Methods

7.3.1 Field Work

All wetlands were physically inspected on the ground by a small team of Department of Conservation personnel.

During the inspection, a number of biological factors and criteria were considered to describe and rank each individual site. For sites containing open water, eg., dunelakes, a full count of water birds was undertaken. For wetlands containing a dense sward of vegetation, or those sites containing a mosaic of dense vegetation and open water, a cassette tape recorder would be played with the species call to gain a response from those secretive and seldom seen birds such as North Island fernbird and spotless crake. Whilst total waterfowl counts of conspicuous water birds can be undertaken the more secretive bird species confined to the dense swards of aquatic vegetation can generally only be recorded as being present or absent.

A full plant list was compiled for each wetland, and the vegetation types, sequences and percentages of abundance were also recorded. The plants were listed separately into ferns and fern allies, dicotyledons, monocotyledons and naturalised plants.

Further information and factors such as tenure, adjacent land use, threats, physical and habitat description, ranking, presence of threatened species, species usage, public usage, landscape, archaeological and historic values, and management/reservation options were also gathered and considered during the inspection of each site.

7.3.2. Ranking of Sites

All wetland sites identified and recorded as SSBI were allocated one of five different rankings. A large number of factors are considered before a ranking is given to each site. The SSBI are judged on more than just their capacity to contain species which are known to be at risk. A numerical value for each wetland is calculated where a sum of scores are allocated for each value such as , species diversity and abundance, other habitats situated nearby, presence of corridors and habitat linkages, size, amount of modification, rarity of species and habitat diversity and sequences (Ogle 1987).

The criteria for ranking the wetlands are listed in Appendix 4. The five rankings used and the number of wetlands listed under each ranking is as follows:

Outstanding	2
High	50
Moderate-High	20
Moderate	23
Potential	19
Total:	**114**

7.4 Wetland Types Recorded

The wetland sites recorded from the Aupouri and Te Paki Ecological Regions can be split into six distinct groups. These groups are:

1. Peat Bogs

Acid wetlands lacking diversity and numbers of waterfowl are characterised by dense swards of *Baumea* and *Schoenus* sedges, swamp umbrella fern, wire rush and manuka. These wetlands seldom have flowing water and gain most of their water through precipitation alone. Growth of plants an decay is slow and peat develops underneath the water and plant mass.

These wetlands are important and often essential habitats for a number of threatened plants and animals such as black mudfish, NI fernbird, Australasian bittern, *Thelymitra* orchids, *Cryptostylis subulata* (duck-billed orchid), and *Lycopodium serpentinum*. The greater part of the Kaimaumau wetland (No.55) is a large peat bog.

2. Mineralised or Eutrophic Swamps

These wetlands are characterised by macrophytes, raupo, NZ flax, *Baumea articulata*, rushes, oxygen weeds, cabbage trees, and naturalised broad leaved plants. The swamps have a high biological productivity with a large turnover of organic material and mineral nutrients each year.

Mineralised swamps are generally habitat to large numbers of water birds, eg., black swan, mallard, grey duck, shoveller duck, pukeko, white-faced heron, and spotless crake. Threatened species include, banded rail, Australasian bittern, the marsh ferns *Thelypteris confluens*, *Cyclosorus interruptus* and *Rununculus urvilleanus*.

Truly mineralised swamps were uncommon within the study area, but a good example is the Selwyn Flat wetland (No. 58).

3. Intermediate Wetlands

These wetlands are neither truly mineralised or acid, but are a mixture of both wetland types. They are the most commonly encountered wetlands within the study area and often contain threatened plants and animals common to peat logs or fertile swamps. The large Tangoange wetland (No. 100) is an example of an intermediate wetland type.

4. "Wet" Gumlands

These wetlands are often only seasonally wet. This wetland type is rare within the study area, and often forms the margin or periphery to peat bogs or intermediate wetlands. The largest "wet" gumlands are found within the Kaimaumau wetland complex. This wetland type is habitat to threatened species such as NI fernbird, the hard fern *Todea barbara*, and a number of orchids.

5. Dune Lakes

The dunelakes form a discontinuous chain of "collective wetlands" along the consolidated inner dunes of the west coast within the Aupouri Ecological Region stretching from Ahipara in the south to near Te Paki in the north. These wetlands are often dynamic due to shifting sand dunes, but in recent years nearly all have been consolidated due to the planting of kikuyu and other introduced grasses for farming purposes, or lupin, arram and pine planting for afforestation purposes. With these land use practices occurring, together with the encroachment of stock, the sowing of fertiliser in the catchment areas and the removal of the native peripheral vegetation, both water quality and watertables have been reduced significantly.

The dune lakes are important habitats for some native fish, shags, Australian little grebe, pied stilts, black swan, ducks including scaup, as well as the threatened species NZ dabchick, Australasian bittern, stout water-milfoil (*Myriophyllum robustum*), *Eleocharis neozelandica, Hydatella inconspicua,* and occasionally the two marsh ferns *Thelypteris confluens* and *Cyclosorus interruptus.* Dune lakes are generally characterised by containing a margin of *Eleocharis sphacelata* with occasional *Baumea articulata.* Some dune lakes have swamps adjoining, and generally contain a shallow littoral margin. As well as containing high biological values, the dune lakes have important recreational (duck hunting, boating and bird watching), landscape, scenic and archaeological values.

6. Oligotrophic Lakes

These are deep, steep-sided and fairly acid lakes (eg., Lake Moremurehu (No. 26) and Te Kahika (No. 25) located between Te Kao and the Parengarenga Harbour on the east coast of the northern Aupouri Peninsula. The lakes appear to be older than the west coast dune lakes and are generally lacking in species numbers and diversity.

They are surrounded by old naturally consolidated dunelands which contain NI fernbird - around the lake margins together with the occasional scaup and other waterfowl. *Todea barbara* grows on the lakes margins.

The greatest value of these wetlands, which number only four in total, is their rarity as a wetland ecosystem in Northland. The two lakes situated on the southern Tokerau Beach of Karikmari Peninsula are another example of this lake type.

7. Hard Temporary Pan

Lake Ohia was the only hard temporary pan identified within the study area. The lake bed generally consists of a hard sand pan, but does contain smaller areas of a semi peat-sand bottom strata during winter or occasionally during heavy summer rain, the lake bed is filled temporarily with water, but the bed becomes exposed during the dry summer-autumn period. This wetland type is habitat to a very large number of threatened species which includes: *Thelymitre malvina, Crytostylis subulata, Todea barbara, Thelypteris confluens,* black mudfish, Australasian bittern, North Island fernbird, banded dotterel, golden plover and NZ dotterel. Waders roost on the pans during high tide periods on the adjoining Rangaunu Harbour. The hard temporary pan is also habitat to waterfowl and Northland green gecko and shore skinks.

In recent years the pans have slowly been invaded by sedges, manuka and prickly hakea.

7.5 Biological Values

All wetlands recorded from the study area are either individually important or are important collectively as a chain of wetlands, eg., Sweetwater-Waipapakauri chain as habitat to a wide range and number of both flora and fauna species. Many of these species are today classified as threatened due to the direct or indirect loss of modification of their aquatic habitats.

The wetlands contain a wide range of wetland types for a relatively small area (Aupouri and Te Paki Ecological Regions). Many are of national importance because of the presence of a wide diversity of threatened species, whilst the very large Motutangi-Kaimaumau wetland complex and Lake Ohia (ranked "outstanding") are of international significance.

As a discontinuous chain of wetlands along the Aupouri Peninsula, in particular the dune lakes, their value as a "collective habitat" is actually greater than the individual rankings which have been accorded to each individual wetland. "Collectively" the entire chain may qualify for international status due to the rarity of this habitat type today, and because of the wide range of threatened flora and fauna which they contain. In this respect all of the lakes regardless of their individual rankings an size are important as a "collective" habitat to a wide number of species including those threatened species. For example, the threatened Australasian bittern may require up to 49 ha of wetland to meet its full habitat and breeding requirements (Ogle and Cheyne 1981), and in this study area the 49 ha requirements, may consist of a collection of several small wetlands within fairly close proximity to each other (to accommodate one pair of Australasian bittern).

To fully meet their habitat requirements the trade and dispersal of waterfowl occur, particularly ducks, black swan and the threatened NZ dabchick. This is another example of a habitat use which may cover several individual lakes or wetlands.

Our survey did not cover the freshwater fish within the study area. However, mention is made of the known black mudfish population within the Kaimaumau wetland. This species and other significant native fish fauna probably occur in many of the identified wetlands. The Department of Conservation is presently investigating the need to undertake a native freshwater fish inventory in Northland, particularly within the Northland dune lakes. (This work has started with the dwarf inanga on the Poutu Peninsula dune lakes).

At least 23 species known to be at risk or which have a distribution significance have been recorded from the wetlands within the study area. These species are:

1. Black Mudfish (*Neochanna diversus*)

An endemic freshwater fish which is found in the kaimaumau wetlands. The black mudfish may also occur in other peat bogs or intermediate wetlands within the study area. This species is unique in that it has the ability to aestivate during periods of drought (similar to the lung fishes of Africa and Australia).

The black mudfish continues to decline in numbers and range due to continued loss of habitat. It is classified as an indeterminate species in the Red Data Book of New Zealand, for the rare and endangered species of endemic terrestrial vertebrates and vascular plants (1981).

2. New Zealand dabchick (*Podiceps rufopectus*)

The New Zealand dabchick is endemic to New Zealand. This species has suffered a contraction of range historically and is now confined to the North Island with the greatest numbers now occurring the dune lakes of Northland, and Manawatu - Wanganui, and the volcanic lakes and hydro electric dams of the central North Island. NZ dabchicks now number between only 1100 and 1400 individuals. The dune lakes of the study area are a major habitat to this species. During the 1991 survey 38 NZ dabchick were recorded, and another eight were recorded on lakes in 1988 which were not covered in the latter survey. This represents approximately 3% of the total New Zealand population. This percentage of NZ dabchick would identify the dune lakes collectively as wetlands of international importance. (Conference on Conservation of Wetlands of International Importance, Cagliari, Italy 1980).

The NZ Dabchick is listed as a threatened species in the Conservation Status of New Zealand Wildlife (B D Bell - 1986).

3. Australian Little Grebe *(Podiceps novaehollandiae)*
This is a native species which has recently established in New Zealand from Australia. The Aupouri dune lakes are the stronghold for this species in New Zealand, where it is now successfully breeding and in 1991 numbered approximately 29 individuals. A further six birds were recorded during 1988 in wetlands not covered in 1991. It utilises some lakes in common with the NZ dabchick.

4. *Australasian Bittern* (*Botaurus stellaris poiciloptilus*)
The Australasian bittern is a native species and is classified as threatened. It may now number less than 1,000 individuals nationally (Ogle and Cheyne 1981). Northland, and in particular the wetlands of this study area are a stronghold for this species. Australasian bittern observed during this survey totalled 30, together with a further seven located in the 12 wetlands inspected during the 1987-88 survey. This is approximately 3.5% of the total New Zealand population, a figure which would quality these wetlands "collectively" as wetlands of international importance.

The bittern utilises in some way, virtually all of the wetlands, both large and small in the study area to meet its habitat requirements. This species has declined in number due to loss of its habitat.

5. Brown Teal (*Ana aucklandica chlorotis*)
This is an endemic species, and is now the fourth rarest duck in the world. The brown teal was found to be a breeding species during the 1978 survey (Headquarters Pond, Aupouri Forest) but was not located during either of the 1988 or 1991 surveys. It may now be locally extinct within the study area. Only about 750 brown teal now exist on mainland New Zealand with nearly all of these occurring in Northland. The brown teal is classified as an endangered species.

6. NZ Scaup (*Aythya novaeseelandiae*)
The scaup is an endemic diving duck, which frequents the clean dune lake waters to meet its habitat requirements. It is a species of restricted distribution whose numbers continue to decline in New Zealand. If the water quality of the dune lakes continues to deteriorate within the study area, the scaup numbers will continue to decline accordingly.

7. Banded Rail *(Rallus philippensis assimilis)*
The banded rail is an endemic subspecies. Northland is a stronghold for this species, where it normally frequents the saline mangrove and saltmarsh ecosystems. The

banded rail is now only rarely found in freshwater wetlands. It is, however, occasionally reported from the fertile swamps, and intermediate wetlands of the study area. The banded rail is a shy and secretive species and is classified as a threatened species.

8. NZ dotterel *(Charadrius obscurus)*

The NZ dotterel is an endemic shore wader which generally frequents duneland, sandy beaches, estuaries and sand pits. It is to be found on the Lake Ohia pans (No. 111), but was not observed on any other freshwater wetlands. The total population of NZ dotterel is estimated at about 1400-1500 birds, of which approximately 50% are known from Northland (Parrish 1990). The NZ dotterel is classified as threatened.

9. Marsh Crake (*Porzana pusilla affinis)*
Spotless Crake (*P. tabuensis plumbee)* -

Both these birds are very shy, secretive native species and are confined to the dense swards of aquatic vegetation. They can generally be located only with the use of a cassette recorder by playing their calls and awaiting for a return response. There are only about six records of marsh crake from Northland, with one of these being from the Spirits Bay wetland (No. 3). It may be present elsewhere as it has been sighted near Houhora and in a dune lake swamp near Dargaville (Lake Rehutai). The marsh crake has a regional distribution significance.

The spotless crake, a similar species, was located from several mineralised or intermediate wetlands within the dense swards of aquatic vegetation, particularly raupo and *Baumea articulata*. The spotless crake, although not classified as a threatened species, does have the potential to become at risk, due to modification and development of its habitat type, to which it is solely restricted to on mainland New Zealand.

10. North Island Fernbird *(Bowdleria punctata veateae)*

The NI fernbird, an endemic species is restricted to the dense gumland, peat bog, intermediate, and fertile swamp vegetation types within the study area. The fernbird has suffered greatly throughout the country due to development of its gumland and wetland habitats, and because of this is now considered to be a threatened species. It has weak flight with 100m of continuous flight being exceptional.

11. Northland Green Gecko *(Naultinus grayii)*

This is an endemic gecko and is restricted solely to northern Northland. The stronghold of this species is the Motutangi-Kaimaumau wetland complex. It has also been reported from shrublands surrounding the Te Kao lakes. The Northland green gecko is listed as a species of restricted distribution.

12. Stout Water Milfoil *(Myriophylllum robustum)*

This aquatic water herb is an endemic species which was once widespread throughout New Zealand. However, due to modification or loss of habitat it is known from only about eight individual sites in the North Island and from 15 sites along the west coast of the South Island (Wilson and Given 1989). Our survey recorded this plant from six of the dune lakes, all being located within the collective chain of lakes in the Awanui-southern Aupouri area. It is listed as a vulnerable species and is to be found around the shallow lake margins.

13. *Hydatella inconspicua*

A small grasslike aquatic herb which is now restricted solely to Northland, being found in about 13 dune lakes on the Pouto and Aupouri Peninsulas. Whilst our survey did not identify this species, it is known from some of the dune lakes situated in the southern Aupouri chain. It grows in water of one to two metres in depth.

It is now classified as an endangered species. The Department of Conservation has approved funding to undertake research on this species in Northland, and hopefully this future work may reveal more information on the species to safeguard it from extinction.

14. *Ranunculus urvilleanus*

A slender tufted herb up to 80cm or more. This plant was found in the Kaimaumau wetland and may well occur in some of the other wetlands. It favours damp sites or wet ground along the swamp margins. It appears to tolerate a small amount of disturbance. It is classified as a rare species, ranging from South Auckland to Te Paki.

15. Copper Beard Orchid *Calochilus campestris (C. herbaceus)*

This highly endangered species was presumed to be extinct until rediscovered in the Kaimaumau gumlands in 1986. It was last recorded in 1900. Only about 10 plants are known within its location.

16. Duck-bill Orchid *(Crypotostylis subulata)*

A tall attractive orchid growing up to 130cm high. It was recorded in the Motutangi-Kaimaumau wetland complex and Lake Ohia, where it grows in seasonally wet and low lying areas of peat bogs.

This plant is classified as threatened and in New Zealand is found only in Northland, although it also occurs in Australia.

17. *Thelymitra malvina*

Another attractive orchid which grows seasonally in the Kaimaumau and Lake Ohia wetlands. It requires fungi *(Mycorrhixae)* to break down dead organic materials to supply it with the necessary growth and nutrients. It is an endangered species in New Zealand found only in the Kaimaumau-Karikari Peninsula areas of Northland and in Australia where it is rare.

18. *Uleocharis neozelandica*

A small sedge which grows in the sandy margins of some Aupouri and Te Paki dune lakes located near the coast. The species was classified as endangered, but has recently been reclassified as vulnerable, and occurs as far south as Farewell Spit.

19. Marsh Fern *(Cyclosorus interruptus)*

This fern grows in intermediate wetlands amongst other aquatic sedges and rushes, in very damp or shallow water. It has been found in the Kaimaumau, Lake Ohia and some Aupouri Forest wetlands. It requires a warm and frost free environment and is classified as a vulnerable species. Colonies occur as far south as Taupo but in the colder southern sites it is restricted to the warm waters of the geothermal areas.

20. *Lycopodium serpentinum*

This is a generally prostrate club moss. It is known from the Kaimaumau and Karikari Peninsula peat bogs where it grows in association with other acid loving plants (eg sundews and umbrella fern). The plant may occur in other peat bogs within the study area. It is classified as a vulnerable species growing south to the Waikato.

21. Hard Todea Fern *(Todea barbara)*

This is a large attractive and erect fern growing up to two metres tall. It was recorded from three sites which contain wet gumlands or on the margins of the oligotrophic lakes. This fern is classified as a vulnerable species, growing south to Bay of Islands and Poor Knights.

22. Marsh Fern *(Thelyperis confluens)*

A fern which grows amongst dense stands or swards of other wetland plants eg. sedges. It grows up to 60cm in height, and is frost tender.

Marsh ferns were found growing in six different sites including the Lake Ohia/Kaimaumau wetlands. Its favoured sites were in the intermediate and fertile wetlands, and on some margins of the dune lakes.

The marsh fern is classified as a vulnerable species, with remnant stands occurring south to the Bay of Plenty.

23. *Hibiscus diversifolius*

An attractive sub-shrub plant which grows up to 2m in height. A colony of these plants was found within the Tom Bowling Bay wetland, growing along the damp margin. *Hibiscus diversifolius* is classified as a vulnerable species being found only between North Cape and Whangarei.

7.6 LOSS OF WETLANDS

The re-survey of 1991 has shown that since the original survey of 1978 severe modification or complete development has occurred to several wetlands within the study area, whilst other wetlands, especially the temporary pans (seasonally wet duneland wetlands) have disappeared completely. Although it was generally the smaller wetlands that had undergone the greater degree of development, some of the largest known wetlands eg., the Tangaonge wetlands (No. 100) had also been reduced in size. The Tangaonge wetlands in 1978 were 341 hectares in size, yet our re-survey in 1988 some ten years later revealed a loss of 221 hectares to 120 hectares. The number of waterbirds including those species which are at risk have been reduced markedly w within the Tangonge wetlands and the adjoining drainage patterns are slowly drying out the remaining swamp. As this wetland slowly dries out, it is being invaded by weeds especially blackberry and privet. Even more dramatic is the complete destruction and total loss of the entire western Motutangi wetlands, which in 1978 was a 300ha wetland complex and ranked of High wildlife value. It would have contained a number of threatened species. This large wetland was also linked to the internationally important Kaimaumau wetlands.

At least one dune lake was found to be partly drained since 1978 and many had their important peripheral swampy margins or natural shrubland buffers either modified by stock or land use practices, or had been drained or developed completely. Between 1978 and 1985, one third or approximately 650ha of the Lake Ohia wetland complex was developed for farming purposes by the Department of Lands and Survey as part of its Rangiputa Farm Settlement Block.

This sad loss of wetland habitat corresponds to the overall loss of known freshwater wetlands elsewhere in Northland where 3,176 hectares (or 14.4% of all wetlands) were lost due to development over a five year period between 1978 and 1983 (Anderson et al. 1984).

The Department of Conservation is particularly concerned at the continued modification to the fragile dunelake ecosystems. Deterioration of water quality due to farm run-off containing fertilisers and natural animals wastes leads to enrichment and eutrophication of water; stock encroachment is leading to shoreline erosion, browsing and destruction of the essential littoral zone aquatic plants eg. the sedges and rushes, and dry shoreline vegetation eg. manuka, flax, cabbage tree and rushes. Illegal exotic fish releases is another concern, as recently koi carp, rudd and others have been discovered in some Pouto lakes. These exotic species may have a serious impact upon our native fish, aquatic invertebrates and plants communities.

Pine trees plantings may be having an impact on the dune lakes. Since afforestation commenced on the South Kaipara Heads 20 years ago over half of the dune lakes have now completely dried up. Since the 1978 survey, nearly all of the temporary pan or emphemeral wetlands once present within the natural Aupouri sand dunes have disappeared. This is the loss of a wetland type completely different to the seven already described. Some other smaller more shallow dune lakes have also disappeared since the planting of pines began along the western Aupouri duneland strip.

7.7 CONCLUSIONS

The wetlands identified within the Aupouri and Te Paki Ecological Regions contain a very high number of different flora and fauna species known to be at risk. Seven different wetlands types (an eighth type - soft or duneland temporary (ephemeral) pans, have now all been developed or severely modified) were identified and some of these ecosystems are dynamic and unique in their own right. All of the wetland types recorded represent some of New Zealand's rarest remaining natural ecosystems. Today only about 10% of New Zealand's natural freshwater wetlands remain and even then many of those are in modified condition. When compared to the USA which is concerned that only about 60% of its natural wetlands now remain, New Zealand must have one of the worst records for wetland destruction or modification in the world.

This certainly reflects upon the very high number of threatened species (one of the highest world-wide) which are present in our remaining wetlands.

The Department of Conservation recognises the urgency in obtaining a good rapport with landowners, to have the better dune lakes protected and enhanced. Protection and enhancement can be achieved through protection covenants, fencing of much of the shoreline, and restoration of the important littoral and dry shoreline vegetation. These measures will help reverse deteriorating water quality and shoreline erosion, and will help to re-establish nesting and escape cover for waterfowl and habitat for the secretive and threatened species. These species include: Australasian bittern, rail, fernbird, crakes, NZ dabchick, black mudfish and many threatened plants. Threatened plants in particular can be very vulnerable to any habitat change or modification to their habitat. Unless measures are undertaken within the near future, some lakes may be beyond recovery, and a resultant further reduction of aquatic species so reliant on these fragile ecosystems. Water extraction for horticultural and agricultural purposes will also have to be carefully addressed as the peak extraction of water will almost certainly coincide when the lake levels are at their lowest. Unchecked water extraction, or minimum water levels set too low will lead to the exposure of the important peripheral aquatic vegetation zone and exposure of threatened plant species to browsing by stock or drying out. Pugging of the shoreline by stock will also occur. Waterfowl breeding, escape and feeding cover is then lost, and the food chain is breached.

The Northland Regional Council has the statutory powers and responsibility to address many of these ecological concerns and problems in the water management plan for the Aupouri and Te Paki Ecological Regions.

The Department of Conservation will undertake to work with the Council to assist it in all ways possible to protect and promote the natural values of these wetlands. Department of Conservation can now rank the importance of each wetland in these regions using SSBI data and identify the threats and management requirements facing most of them, as well as assist in carrying out management and restoration work and public education programmes, etc.

The Department of Conservation can carry out monitoring programmes (eg. trend counts of birds, plant health, further surveys for fish, etc) on the Aupouri lakes. In some cases the management needs may be unclear, in which case it may be necessary to carry out research on wetland communities and/or on specific needs to threatened species. Department of Conservation can fund this sort of long-term research, as well as obtain short-term advice from specialist scientists and managers.

8. STREAMFLOW

8.1 Introduction

As a result of the narrow shape, low relief, relatively low rainfall and soil types most of the streams of the peninsulas have small short catchments and little, if any, flow during prolonged dry spells. On the rolling sandy country water enters the ground quickly flowing as groundwater rather than stream flow. Where as the deeply weathered clay and podzolised soils of the elevated areas at the heads of both peninsulas have low permeabilities with rainfall running off quickly with little sustainable low flows.

This combination makes such streams unattractive as a reliable source of water.

However, some streams maintain flows over summer where these are fed by groundwater or from larger lakes and wetlands.

A difficulty in determining the stream yield from the low relief and highly permeable catchments typical of the study area is that the contributing groundwater catchment may be different in area to the surface stream catchment. The boundaries of the groundwater catchments are difficult to define and are unknown for any of the stream gauging sites discussed below. Similarly, even surface catchment areas were difficult to determine using topographic maps and aerial photographs owing to the very small elevation differences between adjacent catchments.

8.2 Stream Flow Gauging Sites

Some 22 stream flow gauging sites, including recorder sites, are listed in Table 8.1 and are shown, together with their surface catchments, in Figure 8.1. The lack of any long term flow recorder in the area means that estimates of low flow frequency is difficult and the estimates given should be used cautiously.

To determine the drought flows listed in Table 8.1, each gauging was compared to the same day flow at the Selwyn Swamp (site 802) recorder and proportioned according to the drought flow determine at Selwyn Swamp (see section 8.3). The rationale is that the flow in the stream varies in a proportional manner with flow at the recorder site. The level of drought listed in the table is the best estimate one in five year drought flow, which is the low flow one would expect to occur on average, over a long period of time, once every five years.

In many cases, the streams dry completely under drought conditions.

Yields from gauged catchments are listed in Table 8.1. These should be treated as indicative only as both the drought flow and the catchment areas used in this case are only approximately. Yield or specific discharge varies from nothing during a drought up to around 2.5 litres per second per square kilometre. An exception to this is the Ariawa Stream (site 807) which appears to have a yield of 4.1l/second/km2 though this may be in error due to inaccuracies in calculating drought flow, catchment area, or if there is groundwater input from outside the catchment. Waugh (1970) gives a specific discharge for the Northland Sands of 2.1l/second/km2 which does agree with yields from several of the catchments listed in Table 8.1. Based largely on the underlying geology, Waugh also mapped a section of the Aupouri peninsula stretching

TABLE 8.1 : AUPOURI AND KARIKARI PENINSULA GAUGING SITES.

Site Number	River	Site	River Number	Map Reference N.Z.M.S. 260	Number gaugings	Lowest flow (l/sec)	(date)	Catchement area (km2)	Design Drought Flow (l/sec)	Specific discharge (l/sec/km2)
350	Waitiki	Te Paki Rd Br		N02:932-445	3	8.40	16.01.91	11.10	10	0.9
351	Waitiki trib.	Recreation area		N02:964-429	3	1.13	16.01.91	1.73	1.0	0.6
401	Mitimiti	Main H'way Br	004080	N02:048-340	5	24.1	16.01.91	6.43	16	2.5
402	Te Kao	Lake outlet	004090	N03:047-271	5	0	16.01.91	8.60	1.3	0.2
404	Te Kao	Ihaka's drive		N03:078-286	5	62.7	15.01.87	18.63	42	2.3
405	Waipararaiki	Behind Ihaka's		N03:075-291	3	0	16.01.91	5.00	0	0
502	Ngatahinga	Far North Rd		N03:114-248	4	41.6	16.01.91	20.40	34	1.7
701	Ngataki	Junction	007020	N03:175-183	1	44.5	03.03.70	15.38	13	0.9
702	Ngataki	Far North Rd		N03:152-185	2	23.3	19.12.90	8.38	15	1.8
802 *	Selwyn Swamp	Big Flat Rd	008015	N04:265-980	-	1.6	08.02.88	1.75 (3.40)#	3	1.7 (0.9)
803	Waihopo	Pines		N03:169-161	6	6.56	17.02.86	4.12	8	1.9
804	Waihopo	Kranenbourg's		N03:168-162	3	0.27	16.01.91	3.77	0.3	0.1
805	Waihopo trib.	Off Far North Rd		N03:178-152	5	0.37	19.12.90	3.45	0.3	0.1
806	Kaikatia	Far North Rd		N03:208-117	4	11.2	16.01.91	3.45	7	2.0
807	Ariawa	Behind sheds		N03:228-067	5	15.1	16.01.91	4.65	19	4.1
808	Ariawa trib.	Whalers Rd		N03:227-068	3	0	16.01.91	0.15	0	0
1002 *	Waiparera trib.	Kaurex detritus	010000	N04:307-967	-	not rated		2.90?	-	-
1602	Wairahoraho	Merita		O03:482-062	4	0.14	15.01.87	3.60	0.4	0.1
1603	Wairahoraho trib.	Wairahoraho Rd		O03:482-062	3	0	17.01.91	1.60	0	0
1604	Waimango trib.	Matai Bay Rd		O03:460-042	3	0	17.01.91	0.38	0	0
1605	Waimango trib.	Beehive v-notch		O03:466-049	4	1.04	08.01.87	1.35	1	0.7
1606	Waimango trib.	Quarry		O03:468-500	3	0	17.01.91	1.15	0	0

* Recorder site, - Selwyn Swamp, (8/65 - 1/74 and 3/87 - 5/91, recorder still operating).
- Kaurex, (7/87 - 6/89, site closed), data not reliable due to build up of sediment above flume, site also not rated.

The catchment area of Selwyn Swamp may be up to 3.4 km2 if adjoining wetlands and depressions are included.

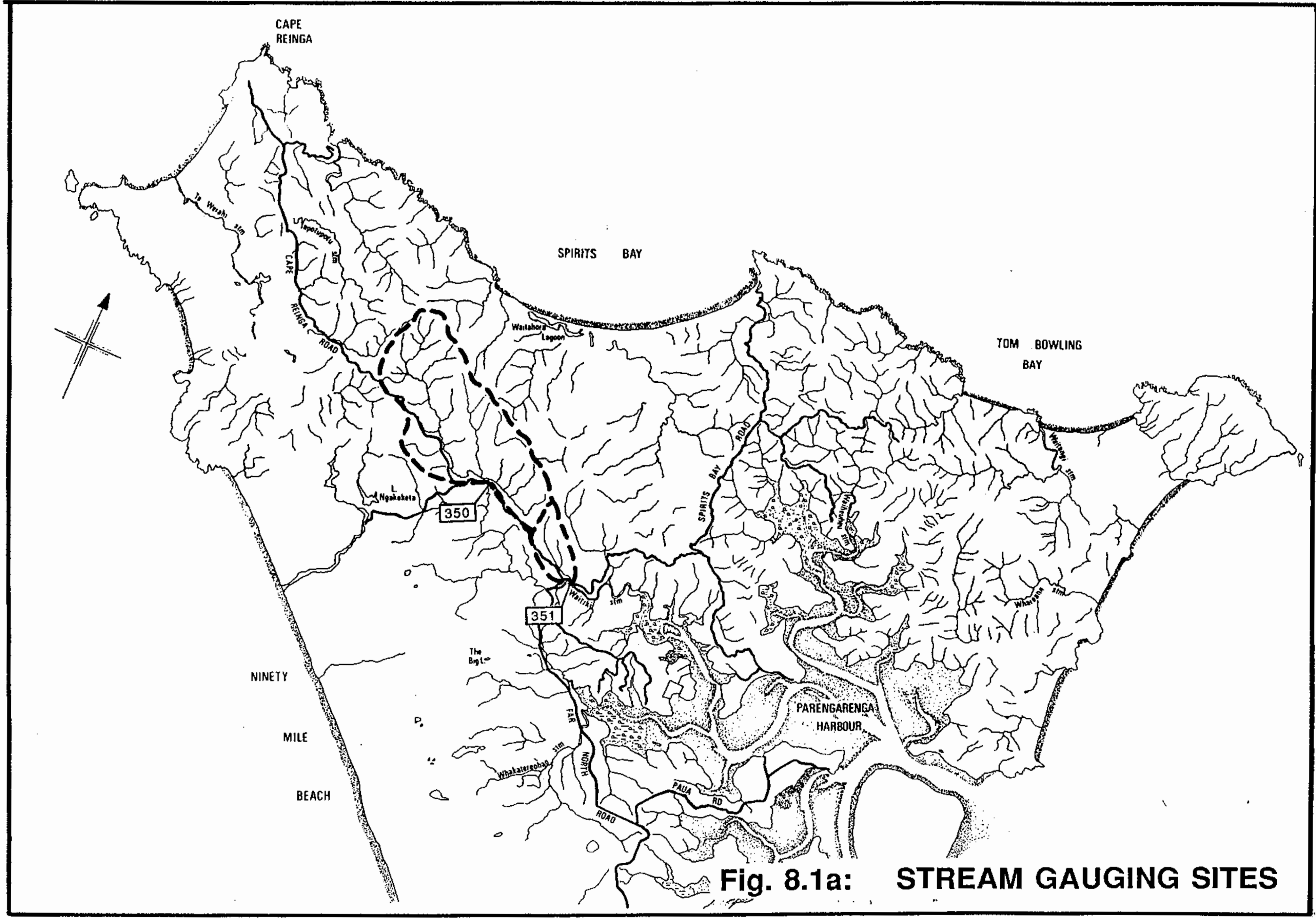


Fig. 8.1a: STREAM GAUGING SITES

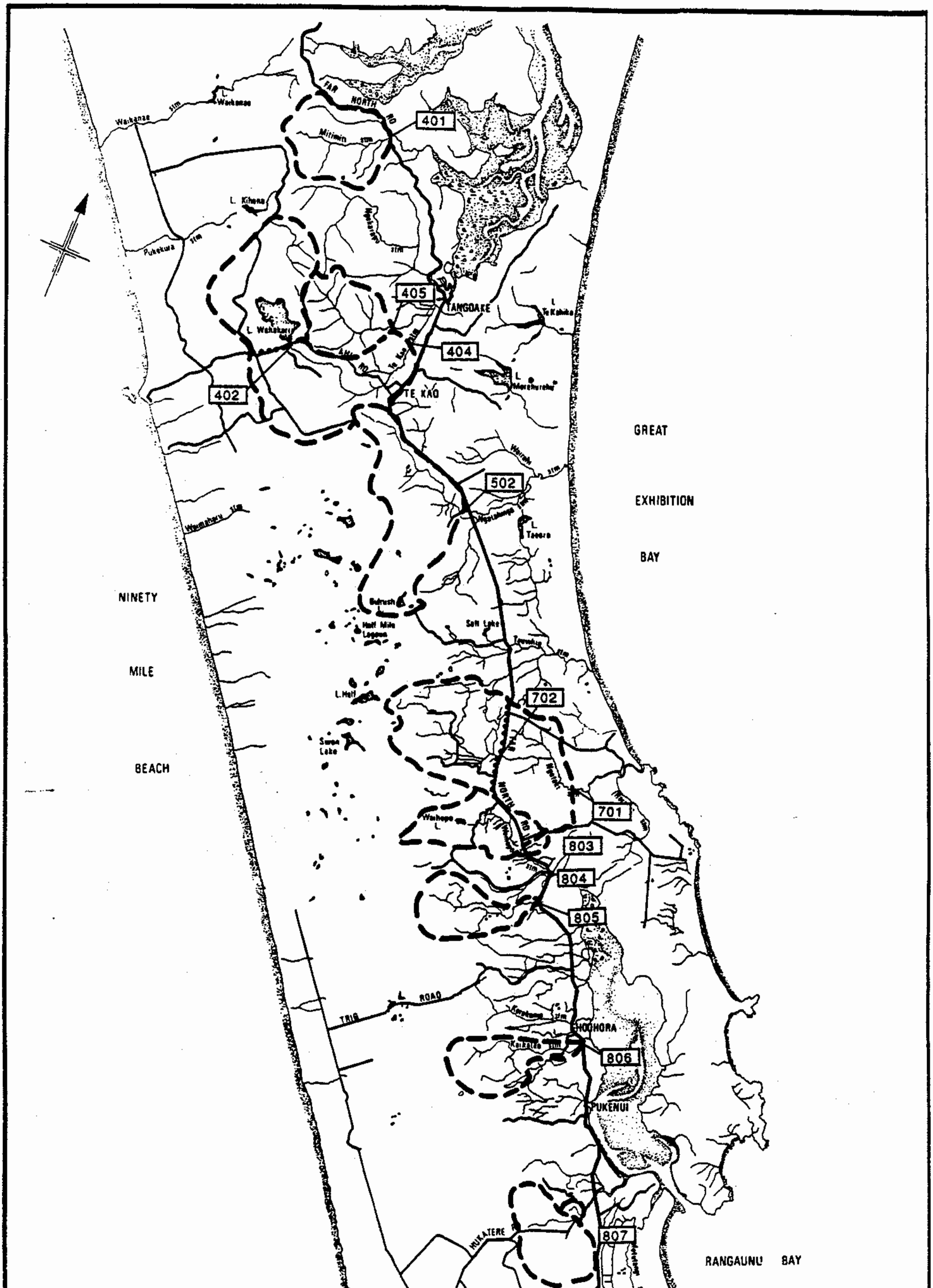


Fig. 8.1b: STREAM GAUGING SITES

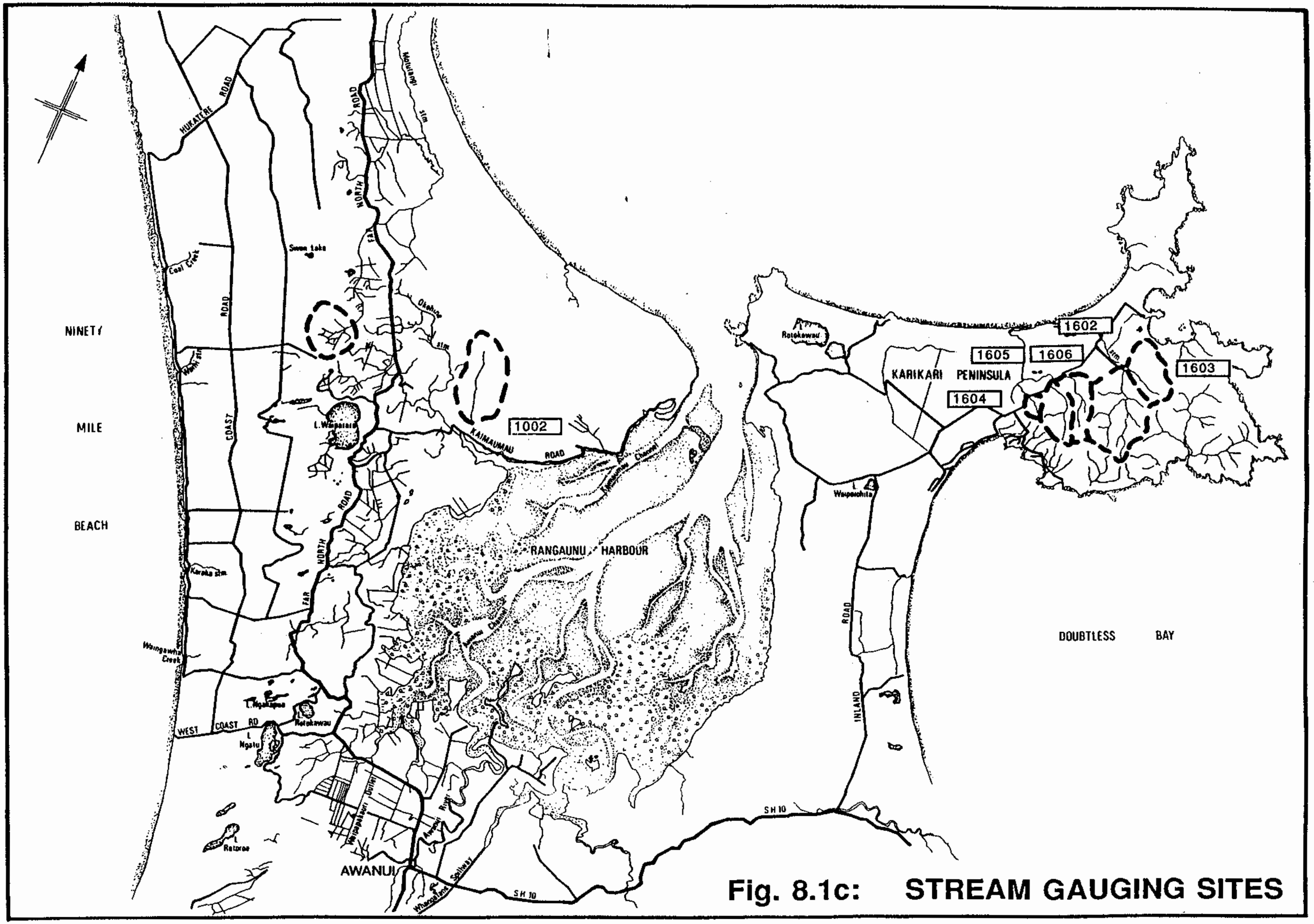


Fig. 8.1c: STREAM GAUGING SITES

southward from Cape Reinga to Te Kao and the eastern tip of Karikari peninsula as having a higher yield, similar to catchments in the Waipoua region with specific discharges around 3.3 litres/second/km2.

8.3 Selwyn Swamp

A weir and recorder were installed on a tributary of the Motutangi Stream at Big Flat Road in late 1965 by the then Ministry of Works and Development (Water and Soil Division) to gather data on a catchment which was, and still is, considered to be representative of streams in the area. The site, known as Selwyn Swamp, was closed in 1974 because it was considered too difficult to define catchment boundaries. As part of this investigation the site was reinstated by the Northland Regional Council in 1987.

Estimates of the catchment area upstream of the recorder vary from as little as 1.35 up to 3.4 km^2. Such uncertainty in catchment area have a marked influence when interpreting low flow yield as is indicated in Table 8.1 above.

The nearest long term stream flow recorder to Selwyn Swamp is Awanui at School Cut in Kaitaia (DSIR, site 1316). Data from the recorder installed in the Kaimaumau swamp (Kaurex debris dam) proved unreliable due to silt build up immediately upstream of the recorder flume and so was not used.

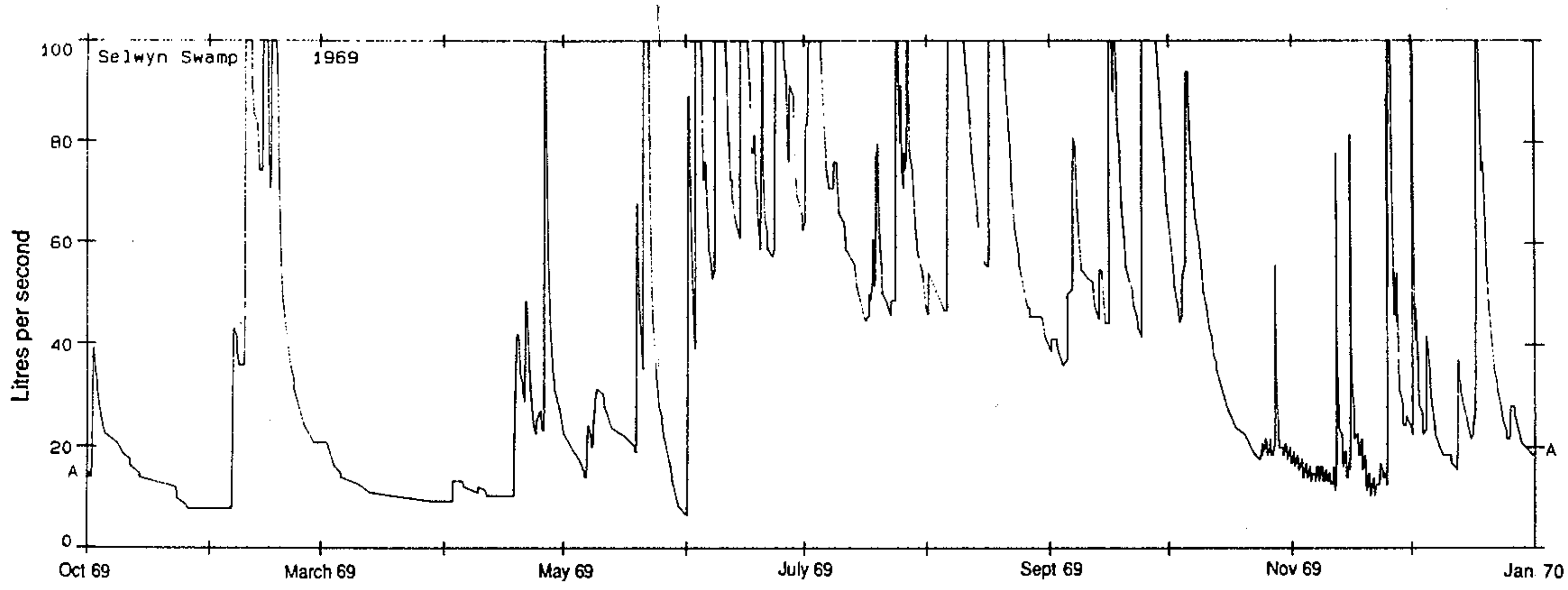
Table 8.2 contains flow statistics for Selwyn Swamp. For 80% of the time, flow from the catchment is less than 19 litres/second. The maximum daily flood flow was 773 litres/second. Flow at Selwyn Swamp can be severely reduced during dry periods, as indicated by the lowest recorded flow of 1.6 litres/second.

The difference between a "dry" year and a "wet" year can be marked and for comparison two such years are plotted in Figure 8.2. The mean flow for 1973 was 22 litres/second whereas 1969 averaged over twice that flow at 52 litres/second.

A low flow frequency analysis (SSS, 1986) was carried out using the minimum daily flows. However, only 11 minimum values could be used and there was a substantial break in the record. The estimate of the one in five year return period drought flow was 3 litres/second.

Daily Flow Variation

A recent low flow period, plotted in Figure 8.3, records flows below 2 litres/second and shows a marked daily variation in flow. Such cyclic changes have been observed in low flows elsewhere (eg., Kobayashi et al. 1990) and are attributed to daily cyclic differences in evapotranspiration (ET) rates, with increased ET during the day reducing the throughflow and groundwater contribution made to the stream flow. Therefore there may be significantly more flow in small streams during the night and early morning than daytime gaugings might indicate. Significant daily changes in flow also make the calculation of drought flows and recession constants more difficult.



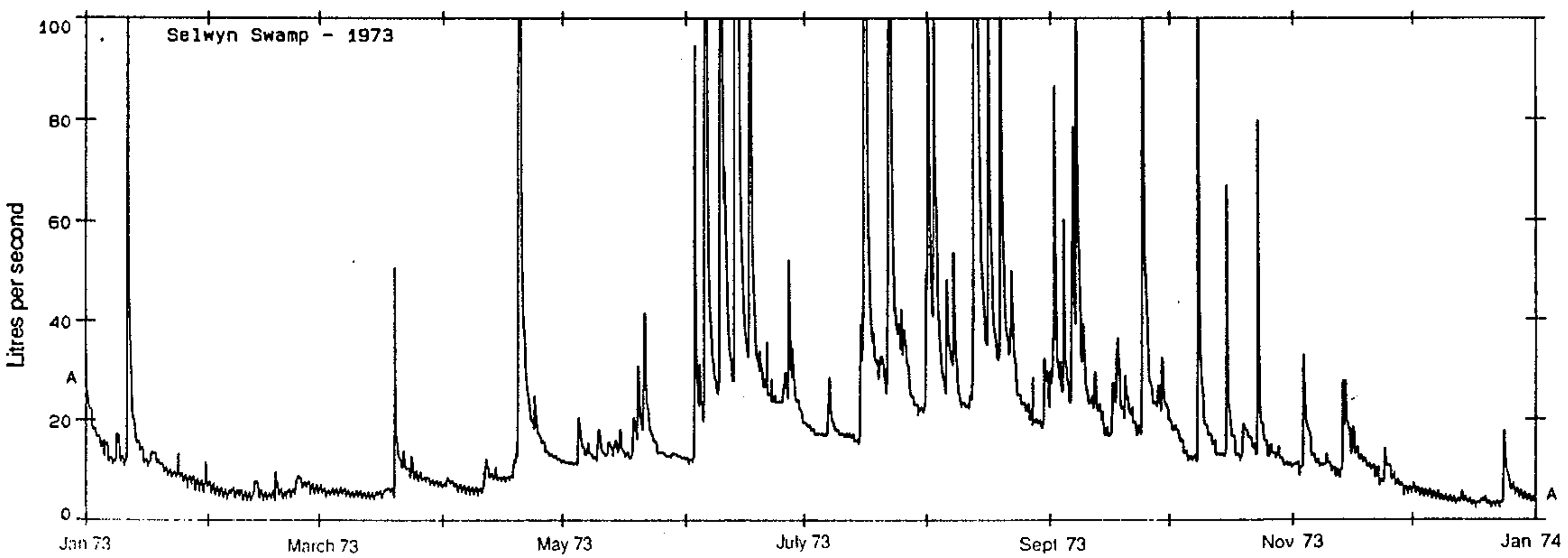
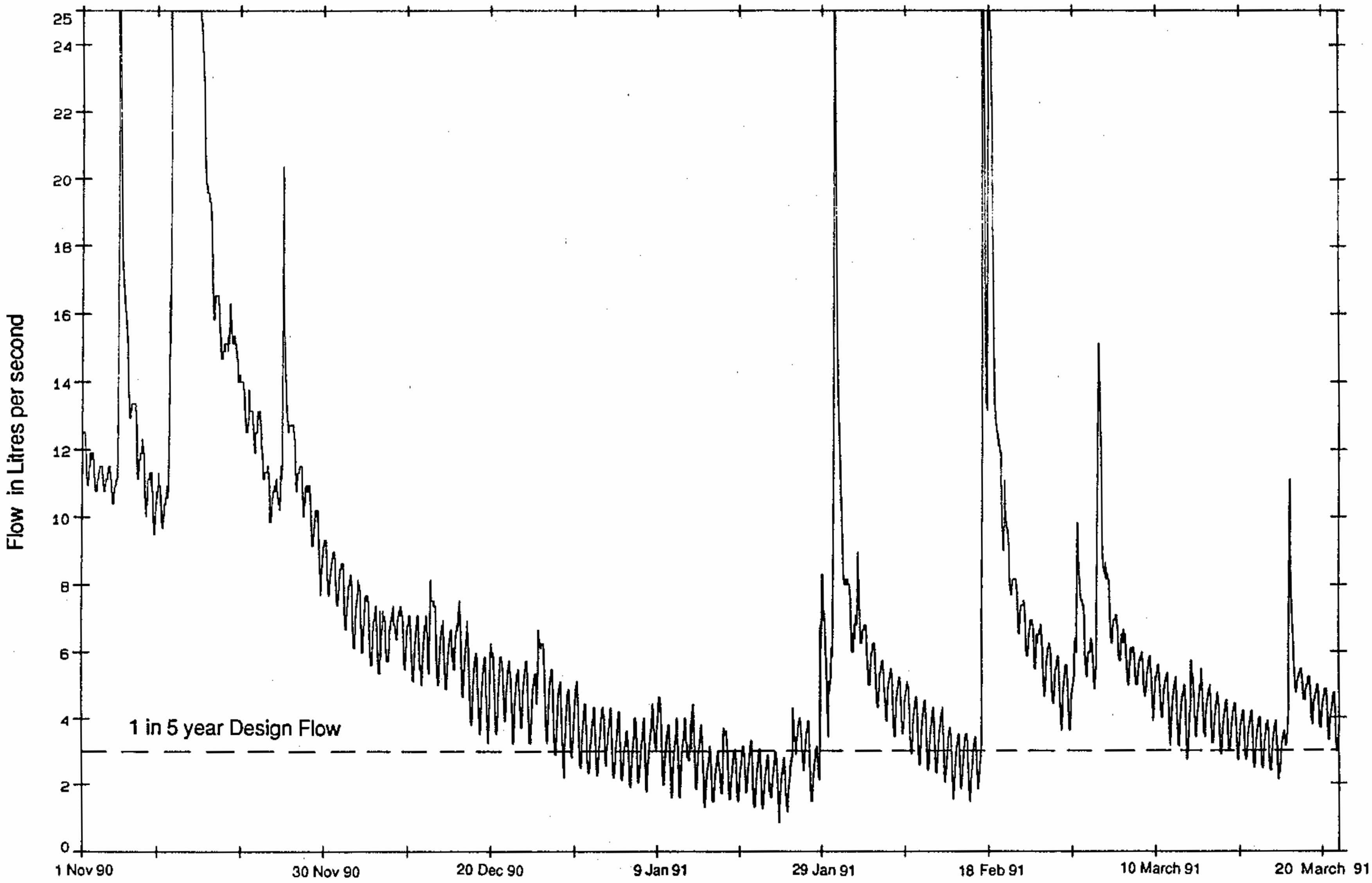


Fig. 8.2: SELWYN SWAMP, FLOW FOR A "WET" YEAR (1969) AND A "DRY" YEAR (1973)

Fig. 8.3: SELWYN SWAMP FLOW (Site 802) - NOVEMBER 1990 TO MARCH 1991



Representatives

Other catchments in the region may have similar hydrogeological characteristics to that of Selwyn Swamp. However, before basing any comparisons between catchments some actual gaugings should be done. For instance, the 500 hectare catchment of the Waipurariki Stream (site 405 in Table 8.1) which is greater in area than Selwyn Swamp, was found to have no flow when visited in January 1991.

8.4 Stream Water Quality

8.4.1 Results of Sampling

This discussion is based on only a few samplings of stream water quality at low flow and experience of stream water quality elsewhere in Northland.

The results of sampling some larger streams on Aupouri Peninsula, generally at a site mid to low down in each catchment, and at low flow, are listed in Table 8.3. Some of the sampling sites were close to the stream mouths and were tidal and saline.

In general terms the results are what might be expected from small streams with rural catchments with significant areas of pastoral farming.

Some relatively high temperatures, 22-27°C, reflect a lack of shading vegetation, while some relatively low pH (<7) and low DO (<8) may result from the streams discharging from swamps and low flows or depletion of oxygen may be caused by excessive growth of aquatic plants and algae.

The faecal coliform bacterial counts are typical for those of small streams from mixed rural catchments and most likely reflect such things as the intensity of recent grazing and access of stock to the stream.

8.4.2 Suitability of the Stream Waters for Various Uses

Public Supply, Farm Supply and Irrigation

Generally, stream water quality is suitable for irrigation and stock water while treatment, filtration, disinfection, and possibly flocculation, would be necessary for public water supplies and many industrial uses. Most on-farm domestic water, where taken from streams, is not treated other than being held in a tank before use.

The quality of water emanating from groundwater springs should be of a similar quality to the groundwater described in Section 5.

Recreational Uses

Levels of coliform bacteria in the few stream samples taken were close to or above the level (200 n/100 ml) generally recommended (NWASCO 1980) for contact recreation. The source of the bacteria is likely to come from pastoral runoff rather than from domestic effluent and therefore the risk associated with higher bacteria levels are not as great as the counts might indicate.

Aquatic Life

No study of the aquatic life of the streams in this area has been made. Much of the Aupouri and Karikari Peninsulas have been modified by man, primarily by clearing forest and drainage of natural wetlands for gum digging and to establish pastoral farming and more recently establishment of exotic forests on sand dune areas. These land use changes will have affected the water quality and will in turn have led to changes in the natural aquatic communities.

8.4.3 Waste Disposal

The low flow of these streams and the relatively high temperatures and low DO indicate that in general the streams of the peninsulas have little capacity to assimilate waste without significant adverse effects on water quality.

9. CONSUMPTIVE WATER USE AND EFFLUENT DISCHARGES

9.1 Introduction

For the purpose of this report consumptive water use is defined as water taken from natural water body for domestic, stock drinking or other farm water needs, irrigation of horticultural crops or pasture, or industrial use.

9.2 Domestic Water Supplies

Groundwater and rain water collected in tanks or a combination of both provide approximately 80% of domestic water supplies in the Aupouri-Karikari Peninsulas. A public water supply from Lake Wahakari supplies the domestic and farm water needs to farms around Te Kao.

9.3 Farm Water Supplies

A farm water supply postal survey was conducted to obtain information on sources of farm water supplies, stock numbers and water supply or water quality problems on the Aupouri and Karikari Peninsulas.

Of the 117 questionnaires sent out, 72 replies were received.

It showed that groundwater is the largest single source of supply, being relied upon solely on 31 farms and contributing to most of the supply on a further 16 farms. Of the 31 farms relying solely on groundwater, 28 are in the Waipapakauri to Houhora area.

Twelve farms used natural lakes or dams as their sole supply while only four relied solely on streams. Twenty-one farms use a combination of either groundwater, dams, lakes, stream (where one or more sources dry up during the dry period) or public water supplies.

Free range drinking from lakes and streams on some farms represent a backup or secondary water supply.

9.4 Irrigation

There are 38 water permits to take water for the purpose of horticultural irrigation, with 31 of those taking from bores. There are two water permits held for the irrigation of golf greens.

The groundwater takes for horticultural irrigation can be grouped into three areas. The Houhora/Pukenui area which includes Burnage Road and Hukatere Road has 13 groundwater water permits with a total allocation of 1835 m3/day. The current water usage estimated from the water use returns is up to approximately 1100 m3/day.

The next area is to the south of Waiharara around Paparore Road and Kauri Flats. There are eight groundwater permits in this vicinity, with a total allocation of 1993 m3/day of which up to approximately 1540 m3/day is currently being used.

There are five groundwater permits located around Lake Ngatu. Of the 315 m3/day allocated, about 100 m3/day is the current usage during the irrigation season. There are three water permits to take a total of up to 50 m3/day for horticultural irrigation from Lake Rotokawau (near Lake Ngatu).

The irrigation season is generally four months long, either from November to February or December to March. The frequency of irrigation is variable with some growers irrigating every day throughout the season and others only irrigating every four days. In general, irrigation takes place every five to seven days initially, reducing to every one to three days, depending on crop type and area.

To calculate a total annual irrigation use of groundwater, an average of 50 days pumping per season was used, giving a current usage of approximately 150 000 m3/year.

9.5 Commercial Uses

Commercial uses include the domestic water supplies of motels, camping grounds, shops and timber treatment plants. There are eight water permits to take water for these purposes, of which two are from lakes and the rest from groundwater. They total up to 191 m3/day.

9.6 Industry

The timber industry on the Aupouri Peninsula, while dominant on the landscape, currently has little consumptive water demand.

Two timber treatment plants currently take small quantities of water from Lake Ngakapua and an adjacent lake for domestic needs and for chemical mixing.

Juken Nissho Limited, which owns the Aupouri Forest timber, is planning to build a mill within the next five years to process its timber. The mill may be sited in the lower Aupouri Peninsula and have water requirements in the order of 400 m3/day. The likely source of water would be groundwater (pers.comm. Mr L Read, Manager, Aupouri Forest, Juken Nissho Ltd).

There are no other known proposals for industrial developments in the area.

There is a small fish processing factory which takes up to 10 m3/day from groundwater for washdown purposes.

The kauri gum resin mining venture at Kaimaumau has ceased operating and all water permits for this development were surrendered in 1988.

9.7 Public Water Supplies

There is a water permit to take up to 250 m3/day from lake Wahakari for rural water supply needs at Te Kao.

9.8 Allocation of the Water Resource to Consumptive Users

The level of water use from each source is shown in Table 9.1.

Table 9.1: Existing Consumptive Water Use (m3/day) in the Aupouri-Karikari Peninsula

Water use	Surface (streams/springs)	Groundwater	Storage (dams/lakes)	Total
Irrigation - hort/golf greens	450	4832	124.2	5397.2
Commercial	62.5	115	13.5	191
Industrial		10		10
Public Water Supply		250	250	
Stock Water Supply	213	1040	499	1752
Total:	**725.5**	**5988**	**886.7**	**7600.2**

Groundwater supplies approximately 80% of the water taken from lakes, streams and groundwater in the Aupouri and Karikari Peninsulas and irrigation accounts for 71% of the total water usage.

9.9 Water Supply Shortages

A few farms experience regular water shortages during the dry period. Around Waiharara the problem stems from the bores not being deep enough to tap the high yielding aquifer. North of Ngataki, some bore supplies dry up, dams become stagnant or dry and stream flows become too low. Water quality at this stage is also becoming a problem. Some farms near Te Kao who get water from the rural water supply scheme do not get an adequate supply from this source because of low pressure in the lines.

The Parengarenga Harbour settlement of Te Hapua has no public water supply and the local people have water for domestic use trucked in to supplement roof runoff collection. There is little or no sustained stream flow in the area and investigations to date have failed to find any significant quantities of good quality groundwater.

The Karikari Peninsula could generally be considered a water short area, particularly coastal settlements water supplies currently being gained from collection of roof runoff, and in a few cases, supplemented by bore supplies. However, any further substantial development on the Peninsula will require either the construction of a water collecting and storage dam, further investigation and proving of a sustainable groundwater supply, or piping water from some distant inland source.

9.10 Discharges

Cowshed Effluent

There are 66 dairy farms in the study area, with approximately 9000 milking cows in total. The dairy farms are spread evenly from Te Kao to Ahipara, with seven farms near the base of the Karikari Peninsula. The estimated discharge of effluent from the cowsheds (including washdown water) is 450 m3/day. This figure is based on 50 litres per day per cow (Vanderholm DH 1984 Agricultural Waste Manual. NZ Agricultural Engineering Institute Report No. 32).

These discharges must comply with the standards set in the Transitional Regional Plan and are inspected for compliance and to check on maintenance.

Domestic Effluent

Almost all rural domestic sewage is treated by way of septic tank and soakage field and when operated property and in compliance with the rules in the Transitional Regional Plan, the discharges from these systems should not result in any significant contamination of groundwater, stream, lakes or coastal waters.

However, in some areas with low permeability soils, soakage fields may not work well and lead to surface discharges of septic tank effluent. This is a problem on some of the low lying terraces, with iron pans at shallow depth, such as parts of Te Hapua, and the Houhora-Pukenui area.

There are a number of domestic effluent discharges for small communities or subdivisions which are authorised by water permits using a number of different treatment systems. These systems are monitored regularly to check that they are functioning properly and in accordance with conditions on the water permits. The details of these discharges are listed in Table 9.2.

Landfill Tips

Landfill tips are located at Te Hapua, Houhora, Kaimaumau, Whatawhiwhi, Awanui and Ahipara. All these sites, except Te Hapua and Ahipara, have now been closed by the Far North District Council and replaced with transfer stations, the refuse from the transfer stations going to the Ahipara site.

In the past these tips were poorly maintained and supervised. However, because of their small size, they are unlikely to cause anything other than minor localised contamination of water.

The Ahipara tip is authorised under a current water permit to discharge up to 1500 m3/day of stormwater from the tip and 5 m3/day of leachate. An application is expected for the Te Hapua tip.

Five ground water monitoring bores have been placed around the Far North District Council Ahipara tip site at Sandhills Road to allow samples of groundwater to be taken for water quality analysis to determine if there is any significant contamination from tip leachate.

Table 9.2: Discharge Water Permits in Aupouri and Karikari Peninsula

Water Permit Number	Permit Holder	Receiving Waters	Quantity m3/day	Treatment System
2635	FNDC - Rangiputa	To ground in the catchment of Rangaunu Harbour	32	Two oxidation ponds to bunded soakage area
2715	FNDC - Whatawhiwhi	To ground in the Waimano Swamp in the Karikari Bay Catchment	100	Aerated lagoon
2877	Ministry of Education - Te Kao School	Te Kao Stream	7	An aeration tank, secondary settlement and cultivated marsh
3607	Brljevich T	To ground in the catchment of Waipapakauri Beach	9	Septic tanks and soak holes
3775	FNDC - Ahipara	Wairoa Stream	160	Oxidation ponds and artificial marsh system
3920	Godwit Centre & Co. Ltd	Waitiki Stream Tributary	31	Oxidation pond and waste treatment ditch
4018*	Courtenay PA - shops/restaurant	Houhora Harbour	6	Septic tank and soakage field
4599	FNDC - Houhora Heads Motor Camp	To ground in the catchment of Houhora Harbour	30	Septic tank and upwards flow stone filter
4716	Te Aupouri Maori Trust Board	Te Kao Stream	27	Transevaporation system to ground by way of forest irrigation
4766*	Department of Conservation	Matai Bay	45	Five septic tanks and soakage fields

Note: * application at the time of writing

10. SUMMARY OF FINDINGS

Groundwater

10.1 Groundwater Availability

There is a substantial groundwater resource contained in a thick (70 to 250 + m) sequence of fine sands and basal shell bed which covers the area between Sweetwaters and Waihopo. This resource should be capable of supplying all current farm water supplies and irrigation demands as well as substantial quantities for any future irrigation or forest processing industry requirements in that area on a sustainable basis.

Other areas of the Aupouri and Karikari Peninsulas have much smaller groundwater resources. The sands contain a lot more peats and clays or form only a relatively thin veneer covering low yielding hard rock. Alternatively deeply weathered (decomposed to clays) rock is exposed at the surface which has low permeability and allows for very little storage or transmission of groundwater. However, there are some localised areas where sufficient groundwater can be obtained for domestic and farm water supplies and small areas of irrigation.

10.2 Groundwater Quality

The groundwater quality is often good and suitable for most uses. However, a significant number of bores from all over the area yield water with raised iron concentrations which gives the water an unpleasant taste, causes staining and may lead to the blockage of pipes and irrigation equipment. In some cases, the iron concentrations are such that, unless treated, using aeration and filtration, the water is practically unusable.

10.3 Seawater Intrusion into Groundwater

Seawater intrusion into the aquifers was not detected. The potential for seawater intrusion into the major groundwater resource south of Waihopo is low while the groundwater levels remain well above sea level, as they are now. Continued monitoring of the groundwater levels would be prudent to give early warning of any significant lowering of groundwater levels in the areas of heaviest groundwater use.

Heavy pumping of bores close to the coast, particularly fractured rock or shallow unconfined sand aquifers, could lead to localised seawater intrusion.

10.4 Impacts of Afforestation on Groundwater Levels

The interception of rainfall by forest canopy and greater transpiration from pine trees will have reduced recharge of the sand aquifers. The degree to which this has resulted in falling groundwater levels is difficult to determine with any accuracy due to the variability in planting history between recorder sites, rainfall patterns during the period of record and the short and interrupted groundwater level record.

It is, however, concluded that there has been a drop in the groundwater level in the sand aquifer due to afforestation but that this drop has not been large enough to threaten the viability of the resource. The groundwater level in the monitoring bore in the forest on Hukatere Track is still falling and monitoring of this should be continued.

10.5 Impacts of Irrigation Use on Groundwater

The monitoring of groundwater levels adjacent to two of the most heavily pumped bores shows that significant reductions in groundwater levels are localised, restricted to depths adjacent to that being pumped and that the levels recover quickly when pumping stops. No long term reductions in groundwater levels due to pumping are evident. However, long term monitoring of this should be continued.

10.6 Abandoned Flowing Artesian Wells

Over some low lying parts of the study area, particularly the south east, the aquifers are confined by impermeable layers near the surface and the head in the aquifer is above ground level. Bores penetrating the impermeable layer flow and if they are abandoned or do not have flow preventers, they will continuously flow to waste lowering the head in the aquifer. Although the extent of this problem does not seem to be large, the sealing of all such abandoned bores should be promoted.

Lakes and Wetlands

10.7 Wildlife Habitat Value

There are numerous dune lakes, most small and shallow, and wetlands on the Aupouri and Karikari peninsulas. These lakes and wetlands provide high value wildlife habitat. Many of the plant and animal communities which are comprised mostly of native species, are unique to dunes, lakes, with some of the species being rare.

10.8 Impacts of Farming and Afforestation

For most lakes, the natural process of lake development and the lake environment itself has become modified by farming or afforestation:

(a) Afforestation has prevented more lakes and wetlands being inundated by moving sand.

(b) The shelter provided by forest, and possibly some reduction of inflows due to increased evapotranspiration have allowed shallow lakes (<2 m) to become dominated by emergent vegetation often to the point of being completely infilled. Deeper lakes may not be infilled but the shelter may prevent mixing resulting in the oxygen depletion at depth.

(c) Where lakes are surrounded by pasture, exposure and stock grazing appear to limit the growth of emergent vegetation. Nutrient input from animal waste and fertiliser leads to algal dominance and a resultant reduction in water clarity and quality.

10.9 Introduced Species

The introduction of exotic species has changed the character of some lakes. The most notable example is the displacement of native submerged plants by exotic oxygen weed, *Egeria densa*.

10.10 Taking Water from, or Discharging Waste to Lakes

A large number of the lakes have little surface inflow or outflow and are fed primarily by rainfall directly onto the lake and surrounding wetlands. Many of the lakes, including lakes Rotoroa, Heather, Ngatu and Waipareara, are perched well above the main body of groundwater. it is therefore likely that these lakes could not sustain anything other than minor farm water supply abstractions without suffering significant water level reductions.

There are some lakes which, because of stream inflows and their larger size, could sustain some more substantial abstractions.

The small size of most of the lakes means that they have very little capacity to assimilate any contaminant and therefore should not receive waste discharges if good lake water quality is to be sustained.

Streams

10.11 Stream Flow and Quality

The streams are typically short with small catchments and few, particularly in the sand country, sustain flows through prolonged dry spells. There are, however, some streams, generally north of Te Kao, that have locally significant sustained flows and could provide for community water supplies, eg., the Te Kao and Waitiki Streams. The few measurements of stream water quality indicate that in general the quality is what would be expected from rural catchments with large areas of pastoral farming, the water being suitable for stock water and irrigation but would require treating to meet a standard suitable for public water supply.

Water Use

10.12 Existing Water Supplies

Irrigation of horticultural crops is currently the largest consumptive use of water, with a current peak usage of approximately 3000 cubic metres per day irrigating 100 hectares, most of which comes from groundwater in the Pukenui and Waiharara areas. Farm water supplies require up to 1800 cubic metres per day, about 60% coming from groundwater, 30% from lakes and dams and 10% from streams.

The only formal public water supply is that from Lake Wahakari for Te Kao.

10.13 Potential Water Demand

At this stage any long term predictions of water demand for the area would be purely speculative. The only likely short term increases in demand are relatively small increases in irrigation and possibly a timber processing plant for the lower part of the Aupouri Peninsula. The water requirement of such a plant could be met from groundwater.

10.14 Waste Discharges

There are no major point source discharges of waste in the area. There are a significant number of minor discharges, namely from about 45 dairy sheds, several small communal sewage treatment systems, septic tanks and rubbish tips.

Given the significance and nature of the groundwater resources of the area, discharges to the ground in the sand country, particularly in the recharge areas of the aquifers, should be avoided or treated to a high standard before discharge.

10.15 Continued Resource Monitoring

The monitoring of rainfall, groundwater and lake levels should be continued to assess any long term impacts of climate, forest management and water use. Bi-annual sampling of selected lakes to examine long term water quality trends and coastal bores to monitor for sea water intrusion is recommended.

10.16 Management Plan

The findings of this project will be used to base management policies and rules to be included in the Council's Regional Policy Statement and proposed Regional (Water and Soil Management) Plan to be prepared pursuant to the Resource Management Act. Both informal and formal public consultation will be part of the process of preparation of the RPS and Regional Plans.