THE WATER RESOURCES of the MAUNU – MAUNGATAPERE – WHATITIRI AREA

Water Resources Report No 5

Prepared By The

NORTHLAND CATCHMENT COMMISSION

and

REGIONAL WATER BOARD

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ERRATA

Since the printing of this report further consideration of the data available from the Whatitiri catchment has led to the rewriting of pages 74 and 75 (attached).

This alteration does not change any of the conclusions drawn originally but it is felt that it provides a better explanation of the conclusions that have been drawn.

The major change is the use of the total flow from Poroti Springs (Cutforths) as the mean cross-sectional flow rate (Q) of the aquifer instead of the flow rate from "Fig Tree."

Pumping from the Poroti Abstraction Site probably only indicates the characteristics of the aquifer whose flow is represented by the flow at "Fig Tree." However, it was initially assumed that the cross-sectional area of the aquifer was represented by the total width of basalt perpendicular to the groundwater flow direction in the vicinity of Poroti Springs. For this reason, the total flow through this cross-section should be considered in the calculation of Km.

ACKNOWLEDGEMENT

It may not have been immediately apparent in the original text that the work done in preparation for chapter 4 was largely the result of efforts by the Geology Department of the University of Auckland. In fact, the largest share of this work was borne by the University and their assistance is gratefully acknowledged.

4.5.1 Whatitiri

An assessment of the magnitude of K and Km of the aquifer at the Poroti Abstraction Site is given in Table 19. The width (l) of the cross-sectional area of the flow section, perpendicular to the inferred groundwater flow direction, was taken as 1 500 metres (Figure 21). Assuming an aquifer thickness of 10 metres, as indicated by the stratigraphic section (ie thickness of fractured basalt), this gives a cross-sectional area at mean flow of 15 000 square metres.

As shown in Table 19, the value of Km is 87 m/day, whereas pumping tests carried out at this site indicate a value of 400 m/day, ie about five times greater.

From the small elevation difference between the springs and the present abstraction site it can be inferred that the aquifer is also limited in vertical extent. In fact, from the linear regression formula on page 45 it can be shown that if the springs were at mean flow and the piezometric level dropped by 2 metres then the flow would be approximately halved. Assuming all this flow reduction can be attributed to a reduction in cross-sectional area (S), the aquifer thickness at mean flow must be approximately 4 metres. This approach also indicates K to be five times higher than Km (see Table 19).

Since the errors in Q and dz/dx are probably not greater than 30%, the fact that K is five times Km implies that the effective cross-sectional area (S) of the highly permeable aquifer at the Poroti Abstraction Site must be smaller by a factor of about five than that assumed so far. This indicates that the aquifer at the Poroti Abstraction Site forms a "channel" approximately 300 metres wide within the basalt. However, as previously discussed (page 64) indications are that there are two "channels" with similar discharge rates and that taking from the Poroti Abstraction Site only influences the channel that surfaces upstream of "Fig Tree" (Poroti Channel). A Km value for an aquifer thickness of 4 metres and width of 150 metres is also calculated for the Poroti Channel in Table 19 and shows this model to best fit the observed data. The present of a second channel with similar dimensions would also be in keeping with observed data.

This model also explains the absence of any significant groundwater flow in the downstream exploratory holes at Adams and Poroti West. The aquifer structure in the Poroti sub-catchment area is therefore significantly different from that of the basaltic catchment area at Mt Wellington (Auckland) where similar studies have shown that there is a good agreement between K and Km (about 100 m/day) assuming a constant conductivity for the whole cross-sectional area of the basalts (MSc thesis by G Roberts, 1980, University of Auckland).

TABLE 19

HYDRAULIC CONDUCTIVITIES FROM WELL DATA AND FROM ASSUMED UNIDIRECTIONAL FLOW IN WHATITIRI CATCHMENT AREA

Well	Poroti Abstraction	Poroti Abstraction	Poroti Abstraction	Poroti Abstraction	Clarkson (N20/664944)	Whatitiri Wines (N20/676935)
Subcatchment	Poroti	Poroti	Poroti	Poroti	Poroti	Kauritutahi (?)
Observed transmissivity T (m^2/day)	4×10^3	4×10^3	4×10^3	4×10^3	2.7×10^1	2.5×10^1
Assumed aquifer thickness b (m)	10	10	4	4	20	30
Hydraulic conductivity K (m/day)	400	400	1 000	1 000	1.35	0.85
Inferred aquifer width (m)	1 500	300	300	150	1 750	1 000
Inferred cross-section S (m^2)	1.5×10^4	3×10^3	1 200	600	3.5×10^4	3×10^4
Mean hydraulic gradient $\frac{dz}{dx}$	1/50	1/50	1/50	1/50	1/100	1/75
Mean cross-section flow rate Q (m^3/day)	2.6×10^4	2.6×10^4	2.6×10^4	1.4×10^4	2.6×10^4	1.03×10^4
Mean theoretical hydraulic conductivity K_m (m/day)	87	433	1 083	1 166	74	26

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P R E F A C E

This report is intended to provide an assessment of the available water resource in the area comprising the quaternary volcanics to the west of Whangarei.

It is intended that it will provide a framework within which the limited resources can be shared amongst competing uses in as objective and equitable manner as possible.

TECHNICAL SUMMARY AND CONCLUSIONS

(a) The climate of the study area is summarised below :

mean annual rainfall	1 630 mm
mean daily wind run	approx 220 km
mean annual sunshine	2 041 hrs
mean annual temperature	15°C
mean number of frosts	approx 10 per year
mean annual evaporation	900 mm

(b) The high quality soils and warm temperatures of the study area make it highly suitable for horticultural production, however, high evaporation rates and variable summer rainfalls make irrigation a necessity for such a land use.

(c) Surface water resources in the study area total 445 l/s during a five year return period drought. This is about a third of that required to irrigate the suitable horticultural soils in the area.

(d) The lack of local water resources is hindering horticultural development in the area, however, the proposed Maungatapere Irrigation Scheme will allow horticulture to develop to its full potential and most of the small, heavily committed streams to return to their natural state.

(e) A geophysical study aimed at determining possible groundwater yields from the volcanics revealed the following :

(i) The Maunu-Maungatapere-Whatitiri catchment is made up of six concealed catchment areas :

1	Whatitiri	(31.5 km^2)
2	West Whatitiri	(4.5 km^2)
3	South Whatitiri	(2.5 km^2)
4	Southeast Maungatapere	(3.2 km^2)
5	Maunu West	(6.2 km^2)
6	Maunu East	(10.0 km^2)

The catchment areas are separated by concealed ridges of relatively impermeable, subvolcanic sediments.

(ii) A buffer storage volume of groundwater of about 66 million cubic metres is indicated for the Whatitiri catchment area, which is about six times that of the average annual groundwater output of this catchment. The ratio of buffer volume to total annual output appears to be smaller for the other catchment areas although exact figures cannot be given because of uncertainties in the mean piezometric level and mean porosity of the reservoir rocks in these areas.

(iii) Average hydraulic conductivity in the Maunu East catchment is closer to that observed in test wells, thus indicating that the aquifer is more homogenous in the Maunu area. This could be the case throughout the areas of Taheke Basalt.

INTRODUCTION

The Water and Soil Conservation Act 1967, sections 20(5), 20(6) detail the functions, rights, powers and duties of the Regional Water Board.

A number of the functions and duties are as follows :-

(a) The Board shall promote the protection of water supplies of local authorities and the conservation and most beneficial uses of natural water within the region including the planning for and promotion of works and projects for the conservation of natural water and projects for the multiple use of natural water.

(b) The Board shall have the function of recommending maximum and minimum levels, and minimum standard of quality to be sought or permitted for the natural water in lakes, both natural and artificial, and the minimum acceptable flow and minimum standard of quality of the natural water of any river or stream within the region.

(c) The Board shall investigate and record all significant resources of natural water within the region, and its quality and availability, and shall check so far as possible upon the effects of damming, abstractions, diversions, pollution and other factors affecting the volume, quality and availability of natural water above and below ground within the region.

(d) The Board shall collect, sort and record data on resources and availability of natural water, and shall supply to public authorities and the public, information so collected.

(e) Every Board shall have due regard to recreational needs and the safeguarding of scenic and natural features, fisheries and wildlife habitats, and shall consult the appropriate authority controlling fisheries and wildlife where they are likely to be affected.

As a result of existing demands for public and rural water supplies and the rapid change of land use from traditional pastoral farming to intensive horticulture in the Maunu, Maungatapere, Whatitiri areas the Commission embarked on a programme to determine the potential of the surface and underground water resources.

In investigating the underground resources, the Commission was guided and assisted by the Geology Department, University of Auckland.

This report is the result of that investigation. While further more detailed studies may be desirable, the information available to date describes the availability, distribution, quality, uses and other related factors in the area. It forms the basis upon which the resources can be managed in the best public interest having regard to all the competing demands being made upon it.

Identifiable costs associated with the investigation and production of this report total approximately \$56 500, of which \$55 500 came directly from grants by the National Water and Soil Conservation Organisation.

1 PHYSICAL FEATURES OF THE STUDY AREA

1.1 LOCALITY

The survey area comprises 59 square kilometres of volcanic soils to the west of Whangarei dominated by the Maunu, Maungatapere and Whatitiri volcanic cones. Because of an emphasis on groundwater and the fact that surface and groundwater catchment boundaries do not always coincide, the report varies from a pure catchment approach and considers the volcanic region instead. Consequently, some of the sedimentary soils surrounding the volcanics are also discussed. This involves comments on a number of different catchments.

The surface catchment boundary between the Maungatapere and Maunu cones runs across the plateau area on which the Maungatapere township is sited. This boundary is the watershed between the east and west coast, east trending flows drain to the Whangarei Harbour, while west trending flows become tributaries of the Northern Wairoa River. The names and locations of the streams relative to roads and volcanic cones are shown in Figure 1.

1.2 RELIEF

Figure 2 shows a map of the surface contours of the area. Apart from the three volcanic cones: Whatitiri (347 metres); Maungatapere (375 metres); and Maunu (397 metres); the majority of the area is of low relief and lies between 100 and 200 metres above sea level. However, some of the volcanic slopes do present the possibility of large quantities of top soil being displaced downslope by rilling and sheet wash during heavy storms. However, as mentioned in the chapter on erosion, the surrounding sedimentary land is the more erosion prone.

The geophysical survey has resulted in an assessment of the relief prior to the volcanic activity in the area. Naturally the lava laid down followed the course of the ancestral valleys in the sedimentary lithology, building up to the present day contours. An example of the degree of in-filling can be seen in the Whatitiri area where the volcanic cone, now standing at 347 metres above sea level, in-fills a basin with a lowest level at present day sea level. The sub-volcanic relief is shown in 40 metre contours in Figure 2a and the thickness of basalt over the area is shown by overlaying Figures 2 and 2a.

1.3 GEOLOGY - LITHOLOGY

The dominant, most recent surface features of the Maunu-Maungatapere-Whatitiri area are the Quaternary volcanic plateaux. These partially overlay and conceal a wide range of older, complexly folded, weathered and dissected sediments. Table 1 outlines the relationship of the various rock groups according to age. Figure 3 shows the location of broadly classified surface formations.

1.3.1 The Volcanic Plateaux

These are basaltic and sometimes scoriaceous lava flows which have erupted from the three volcanic cones of the area. Maungatapere and Maunu are the most recent and contain the most scoria.

The lava flows around these are Taheke Basalts, a formation dated at Kerikeri at 17 000 years but which may range in age from Pliocene to Recent. The Horeke Basalts from the third cone, Whatitiri, are about 500 000 years old. Both of these formations are medium-gray olivine basalts. The presence of red scoria in the Taheke Basalts is common. Vesicular basalt is also common. Many of the vesicles are infilled by clay deposited from the groundwater percolating through many of the interconnected pore spaces.

The Quaternary basalts cover an area of 59 square kilometres. The Whatitiri flow has an aerial extent of 23 square kilometres and the Maungatapere-Maunu flows cover a surface area of 36 square kilometres. The Horeke Basalt has a greater thickness than the younger flows, indicating that eruptions from Whatitiri were much greater than those from Maungatapere and Maunu.

In several districts the lava flows have created depressions, particularly along the contact with older sedimentary rocks. Those areas are shown as Recent alluvial deposits on Figure 3.

1.3.2 Sedimentary Rocks

These vary widely in age and have a complex surface distribution not yet completely resolved in detail. They are eroded into radially formed catchments partially concealed by the lava flows.

Rocks of sedimentary origin can best be described under these headings of progressively more recent groups found in the study area :-

1.3.2.1 Waipapa Group (Permian/Jurassic Age) :

These are the most ancient rocks in the area. They are dark grey and green indurated greywackes and argillites. The Western and Otaika Hills, located in the Maunu area, are formed from fault bounded blocks exposed by uplift and erosion of more recent sediments.

The rocks are intensely deformed, jointed and sheared. Most are highly weathered to a 20 metre deep reddish-brown or yellow clay (Marua soils).

1.3.2.2 Mangakahia Group (Upper Cretaceous/Paleocene Age) :

Intensely folded dark-grey or black siliceous claystones or mudstones outcrop to the west of Whatitiri, in the Wharekohe area. When weathered, these become light mauve or white in colour, have a high silica content and commonly show a sulphur coloured efflorescence. This formation is known as Ngatuturi Claystone.

South of Whatitiri, in the Wheki Valley, massive micaceous sandstone (Punakitere Sandstone) overlays the claystone. This, in turn, is covered by a finely fractured calcareous shale (Titoki Shale) in the Poroti district. There may also be outcrops of Karaka Sandstone, the youngest rock in this group, northeast of Poroti.

1.3.2.3 Opahi Group (Eocene Age) :

At the head of the Otaika Valley and north of Maungatapere near Kara, green and chocolate shales (Aponga Shale), argillaceous limestone and greensands (Pahi Greensand) outcrop in association. A "window" of brown shale also occurs in the volcanic area to the north of Maungatapere cone.

Between the Western Hills and the Maunu lava flows, a glauconitic calcareous sandstone is exposed. This is Ruatangata Sandstone, the youngest formation in this group.

1.3.2.4 Motatau Group (Oligocene Age) :

To the south of Maunu, below the volcanic area, there are small areas of argillaceous and crystalline limestone (Whangarei Limestone) but this group is generally not well represented in the study area.

1.3.2.5 Onerahi Chaos Breccia (Miocene Emplacement) :

East of Maunu also occur sheared, crushed, calcareous mudstones, sandstones and argillaceous limestones emplaced on Whangarei Limestone. These sediments are older than Whangarei Limestone. They were formed principally in the Upper Cretaceous to Oligocene Age but have since been emplaced over younger beds due to geological processes not yet resolved. The formation has poor engineering stability characteristics.

TABLE 1

GEOLOGY - LITHOLOGY (AFTER HAY 1960)

Era	Age (Millions of Years B P)	Series (Stage)	Group	Formation	Content
	Recent (< 0.02)				Undifferentiated alluvium
Quaternary	Pliocene - Recent (< 13)		Kerikeri Volcanics	Taheke Basalt Horeke Basalt	Olivine basalts with scoria cones Olivine basalts without scoria cones
	Lower Miocene - Pleistocene (25 - 0.5)			Onerahi	Superimposed, slumped rocks of Cretaceous to lower Tertiary age
Tertiary	Lower and Middle Oligocene (36 - 30)	Landon (Whaingaroan to Waitakian)	Motatau	Whangarei Limestone Pokapu Limestone Otai Greensand	Crystalline and Argillaceous limestone Argillaceous limestone Not found in area
	Upper Eocene (40)	Arnold (Runangan)		Ruatangata Sandstone	Brown-grey massive glauconitic calcareous sandstone
	Middle Eocene (45)	Arnold (Bortonian)	Opahi	Aponga Shale Pahi Greensand	Shale and argillaceous limestone Glauconitic sandstone
	Paleocene - Middle Eocene (63 - 45)	Dannevirke (Waipawan - Porangan)	Waiomio		Not found in area
Mesozoic	Paleocene (60)	Dannevirke (Teurian)	Mangakahia	Karaka Sandstone Titoki Shale	Micaceous sandstone Calcareous shale and argillaceous limestone
	Upper Cretaceous (100)	Mata (Haumurian)		Punakitere Sandstone Ngatuturi Claystone	Micaceous sandstone Siliceous claystone
Paleozoic	Permian - Jurassic (250 - 150)		Waipapa		Greywackes and argillites

1.4 SOILS

Five major soil groups are found in the Maunu-Maungatapere-Whatitiri area. These are :-

(a) Volcanic : Red and Brown Loams

(b) Northern Yellow-Brown Earths

(c) Northern Podzolised Yellow-Brown Earths

(d) Northern Rendzinas

(e) Northern Recent : Gley and Organic

The district relationship between these groups, the soil suites into which they are divided, and the parent lithologies are set out in Table 2. Figure 4 defines their distribution in the study area.

1.4.1 Volcanic Soils

The red loams (Papakauri Suite) are derived from rocks containing scoria. They occur on and to the east of the Maunu and Maungatapere cones. The brown loams (Kiripaka Suite) are derived from denser rocks of the basalt flows. They make up the majority of the volcanic soils in the area.

Topsoils of both types are very friable and have a fine granular structure. Natural drainage is generally good.

While much of the stone has been removed, subsurface stone and boulders can still provide limits to the depth and extent of cultivation. Examples of soils with these limitations are Kiripaka bouldery silt loam and Ohaeawai shallow bouldery silt loam which occur around Maungatapere and in the Poroti area.

Natural fertility varies with the degree of leaching and development of the soil profile. Papakauri silt loam (hill soil) and Maunu silt loam are examples of weakly leached red loams formed under broadleaf forest at Maunu. These have high total phosphorus content but natural availability is low, due to a high level of phosphorus fixation. The physical and chemical properties of these soils are otherwise good. Whatitiri clay loam, another important soil extending over all the Whatitiri cone area is an example of a moderately leached brown loam. The ability of this soil to store water is probably lower than the "young" volcanic soils which in turn have lower available water capacities compared with soils from sedimentary rocks. Whatitiri clay loam also has a high level of phosphorus retention.

1.4.2 Soils Derived from Sedimentary Rocks

1.4.2.1 Yellow-Brown Earths :

This group of soils is found in catchments extending from the volcanic shield areas, in the Wheki Valley, Maunu and Kokopu areas including the Otaika and Western Hills. The soil suites represented are Omu, Waiotira and Marua.

Waiotira clay loam from sandstone, is an example of a moderately leached typical mid-Northland hill country soil in this group. A large area of it occurs in the Wheki Valley.

The soil has a moderately high natural fertility but with generally inferior physical properties, such as poor drainage characteristics, compared with the volcanics. The topsoil is dark greyish-brown clay, friable, moderately developed with medium to coarse granular structure. Waiotira clay loam supports a high level of pasture production but is not well suited to more intensive use.

1.4.2.2 Podzolised Yellow-Brown Earths :

Soils of this group are present on hills below Maungatapere and on the Wharekohe flats northwest of Whatitiri. They are mainly of the Omu Suite.

Wharekohe silty loam is a classic "gumland" soil The soil was formed under trees with an acid litter such as kauri and rimu. It has a thin grey topsoil and little or no structure. Iron, aluminium and clay have been removed, leaving silica and oxidised humus. The soil has low natural fertility and poor drainage characteristics. Because of high available moisture capacity the soil can, however, provide good summer growth conditions. Agricultural management is complex and capital intensive but excellent dairy units with this soil type have been developed.

1.4.2.3 Rendzinas :

Konoti clay (Konoti Suite) is the only major soil type of this group in the district. It is found at Maunu and occupies a small area only. The soil has excellent physical and chemical properties but is often limited by the presence of surface or subsurface crystalline limestone.

1.4.2.4 Recent, Gley and Organic :

These soils derive from sediments laid down in catchments where drainage has been impeded by intersecting lava flows (Waipapa Suite) as well as in the floodplains of valley systems radiating from the area; (Mangakahia, Whareora Suites).

1.4.2.4 Continued

Kamo peaty silt loam is an example of a heavily gleyed soil found west of Maungatapere. This soil derives from volcanic alluvium in which peat has formed due to a high and fluctuating water table.

Whakapara mottled clay loam is a recent soil found in the Wheki Valley floodplain. Like other soils of the group, it has a high natural fertility but is limited by frequent flooding and a fluctuating water table.

The podzolisation process can also occur on alluvial soils. Kara silt loam (Whareora Suite) is an example found in the district.

1.4.3 Elite Horticultural Soils

The red and brown loams formed on the quaternary volcanics of the study area are extremely well suited to a wide range of horticultural crops. The Whangarei County Council, under it's proposed District Scheme Change No 40, is proposing to incorporate most of these horticultural soils in the County into a new zone. This "Rural H" zone would include the soils that have the best characteristics for horticultural production, based on such criteria as slope, drainage and access-ibility.

For the purposes of this report the soils within this proposed Rural H zone are termed "elite horticultural soils."

Within the Maunu-Maungatapere-Whatitiri area there are 4 100 hectares of these elite soils. These are the soils which were investigated for inclusion in the Maungatapere Irrigation District which is discussed later in the report.

The location of elite soils coincides roughly with the red and brown loams shown on Figure 4.

TABLE 2 - SOILS OF THE STUDY AREA

PARENT ROCK FORMATION	SUITE	REPRESENTATIVE SOIL TYPES	SOIL GROUP
Taheke Basalts	Papakauri	Maunu silt loam	Red & Brown Loams
Horeke Basalts	Kiripaka	Kiripaka bouldery silt loam/Whatitiri clay loam	
Waipapa Greywackes	Marua	Marua clay loam Rangiora clay, clay loam & silty clay loam	Northern Yellow-Brown Earths
Punakitere Sandstone Greensand Ruatangata Sandstone Onerahi Chaos-Breccia Karaka Sandstone	Waiotira	Waiotira clay loam Pukewaenga sandy loam Puketitoi sandy loam Riponui clay & sandy clay	
Ngatuturi Claystone Aponga Shale Onerahi Chaos-Breccia	Omu	Aponga clay Omu clay loam	
Whangarei Limestone	Konoti	Konoti clay	Northern Rendzina
Ngatuturi Claystone Aponga Shale Titoki Shale	Omu	Hukerenui silt loam	Northern Podzolised Yellow-Brown Earths
Pahi Greensand Karaka Sandstone	Waitemata	Wharekohe fine sandy loam, ash variant	
Recent Alluvium	Whareora	Whakapara mottled clay loam	Northern Recent Gley & Organic
Peaty Volcanic Alluvium	Waipapa	Kamo peaty silt loam	

1.5 EROSION

Figure 5 indicates the relative level of potential erosion hazard under pasture cover and if cultivated. The map provides an indication of any rise in potential hazard with intensification in land use.

Soil loss and general erosion damage arising from existing use is of a relatively minor nature on the volcanic areas. This is likely to continue to be the case, with foreseeable diversification, provided common sense management precautions are taken on the steeper slopes. The surrounding sedimentary land is more prone to erosion however. In particular, groundwater flows at the volcanic sedimentary interface can cause large scale mass movement and deep entrenching of channels in unstable formations. The Onerahi Chaos Breccia formation below Maunu is an example.

1.5.1 The Volcanic Plateaux

Red and brown loams in this area are stable soils due to their high infiltration rate and corresponding minimum surface runoff. The soils can be dispersed when cultivated on footslope areas at the base of the steep volcanic cones and on very long slopes of moderate grade such as occur around the Whatitiri cone. In these situations, during heavy storms, large quantities of topsoil have been displaced downslope by rilling and sheet wash when precautions such as strip cultivation have not been taken.

The prevention of accelerated erosion in the brown loams, in particular, is important because of the rapid fall off in beneficial physical and chemical properties as topsoil horizons are eroded.

1.5.2 Maunu - Maungatapere

The upper part of the Whakapai and Otaika Stream catchments below the Maunu shield is an area of complex geology in which intermittent and large scale mass movement has occurred over a long period. The movements affect farmland and other assets. Their activity is related to erosion and its control in the deeply entrenched channels dissecting the area as well as incident groundwater flows.

The Otaika hills further down the catchment include a fault scarp with steepland greywacke derived soils, erosion of which would greatly increase bed load in the stream, if the present bush cover were removed.

Changes in vegetation and land use on the Western Hills above Maunu may also affect duration, peak and low flows on urban Whangarei catchments.

1.5.2 Continued

Further west, the Maungatapere State Forest area consists of steepland podzolised (gumland) soils which are Northland's second most erosion susceptible group and are normally difficult to stabilise. Podzolised soils have no aggregation and structure. They are prone to rilling and sometimes severe gully erosion. Great care is required in cultivation and tillage techniques on these soils on all slopes and advice should be taken where drainage is essential.

1.5.3 Maungatapere - Poroti

Sandstone derived soils in the Wheki Valley are susceptible to mass movements and to tunnel gullies, particularly on slopes of 7 - 15 degrees range. Soil conservation work here has been directed at controlling some large movements but these soils are generally more tolerant of management abuse than other hill country soils in the area.

Gumlands to the west of Whatitiri and north of Poroti are of generally easier slope than near Maungatapere. Installation of systems of safe surface drainage, such as graded banks, require particular consideration.

Erosion of banks of channels in alluvial soils is not a great problem in the study area. Most channels are undersized for the catchment they drain and a careful balance has to be maintained between channel capacity and stability. New types of willow are available to achieve this purpose.

1.6 LAND USE CAPABILITY CLASSIFICATION

The system of classification used in Figure 6 is that described in the Land Use Capability Survey Handbook published by Ministry of Works and Development. The map has been extracted from Sheets N19, N20, N23, N24 of the N Z Land Resource Inventory Worksheets published by the department.

The classification does not indicate specific recommended uses but simply provides a guide to the diversity of use to which any area may be put, having regard to the various physical limitations imposed by soil type, catchment situation and climate. Most of these factors have been described in previous sections.

The easy soils around Maunu are Class II, the highest district classification, because of their physical suitability for uses ranging from market gardening to forestry. In comparison with Class I areas elsewhere in New Zealand, slight limitations exist due to the vagaries of Northland's summer climate and the high phosphorous retention of the soil types involved. These limitations are only slight however, and the land involved only narrowly falls short of Class I criteria. These Class II areas are therefore some of the best land in NZ and should be protected (saved) for intensive horticultural use.

The Whatitiri area has a lower classification (III) because of further limits due to the slightly lower natural fertility, lower summer water content and the presence of surface stone in soils of this area. A wide range of uses is still possible but greater capital outlay may be required to overcome these limitations than for the Maunu area.

No soils derived from sedimentary rocks offer the diversity of use of the volcanics in this district. The gumlands of easy contour of the Wharekohe district and the weakly podzolised clay soils in the Otaika Valley are assessed as Class IV because of several severe restrictions to intensive use. The restrictions are poor natural drainage, low natural fertility and susceptibility to soil erosion, during extended periods of cultivation on slopes as low as four degrees. The soils in this group are, however, well suited to pastoral production. Tree crops where no extended periods of cultivation are necessary may be suited to some areas of Class IV land.

There is a small area of Ohaeawai shallow bouldery silt loam which is assessed as Class V. The presence of stone excludes cultivation in this area, which is otherwise similar to the Class III land around it.

The clay hill country soils in the Wheki Valley, Western Hills and the Otaika Valley are assessed as Class VI. Cultivation is severely limited by topography and/or erosion susceptibility. Limited tillage methods, such as ripping and bedding (for forestry) can still safely be carried out in most areas. Once only cultivation for pasture renewal is also possible provided this does not coincide with a major storm.

1.6 Continued

Gumland hill country south of Maungatapere and steep greywacke hill country at Otaika and in parts of the Western Hills are assessed as Class VII because these soils are very susceptible to erosion damage when vegetation is removed or the soil disturbed. Effective use for agriculture could only be achieved with difficulty and much expense. Development could easily be reversed with the onset of erosion which would be difficult to correct. These areas are best suited to uses involving minimal disturbance of land including protection/production forestry and recreation.

2 CLIMATE

The climate of the Northland peninsula including the Maungatapere region has been described as a "Mediterranean" type climate. One of the major features of this climatic type is the occurrence of drought in summer. Northland is also more prone to cyclones than other parts of New Zealand.

There are two climate stations in the Maungatapere region from which information was obtained. These are detailed in Table 3.

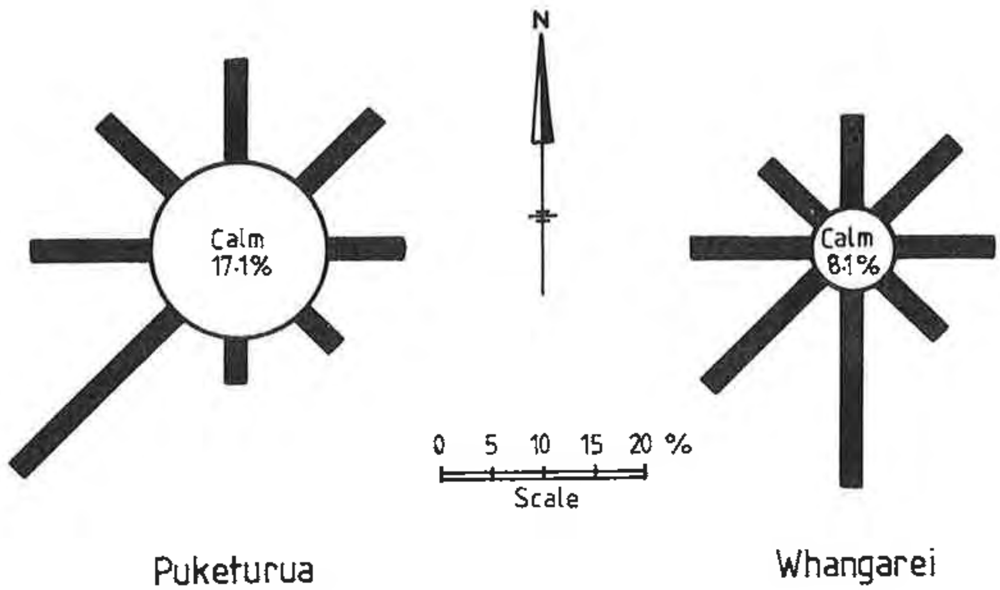
TABLE 3 - Showing Climate Stations in the Maungatapere Region

Station Name	Station No	Map Reference	Elevation (masl)	Period of Record
Puketurua	A 54601	N19/595028	101	1965 - 1975
Whangarei Hospital	A 54734	N20/814951	29	July 1970 - 1978

The Puketurua Station is situated approximately 15 km northwest of Maungatapere township and the Whangarei Hospital station 10 km east

2.1 WIND

FIGURE 7 - Showing Percentage Frequency of Surface Wind Directions at Puketurua (1965 - 75) and Whangarei (1971 - 78) from Daily Observations at 9.00 am



2.1 Continued

Figure 7 above shows that southerlies and southwesterlies are the predominant winds at Whangarei, while southwest winds are the most frequent at Puketurua.

The mean daily wind run at Puketurua is 220 km, the windiest month being October with a mean wind run of 253 km per day, the smallest daily run is 188 km during June.

2.2 SUNSHINE

At Whangarei Hospital the average number of sunshine hours per year is 2 041 hours (1971 - 78). January is the sunniest month with an average of 237 hours, while June has the least, 119 hours.

2.3 TEMPERATURE

TABLE 4 - Showing Mean Daily Temperatures at Whangarei and Puketurua (°C)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Whangarei (1970 - 78) :												
Max	24.6	24.8	23.6	20.9	18.3	16.1	15.3	16.1	17.0	18.9	21.0	22.9
Min	14.5	14.9	14.3	12.5	9.5	8.0	6.8	7.7	8.3	10.0	11.7	13.0
Mean	19.6	19.9	19.0	17.0	14.0	12.1	11.0	11.9	12.8	14.7	16.3	18.0
Mean Annual = 15.5												
Puketurua (1966 - 75) :												
Max	24.7	25.2	23.7	20.9	18.2	15.8	14.9	15.9	17.3	19.0	21.4	23.1
Min	13.1	13.7	13.2	10.7	8.6	6.9	5.5	6.7	7.8	9.0	10.5	12.0
Mean	18.9	19.5	18.5	15.8	13.4	11.4	10.2	11.3	12.6	14.0	16.0	17.6
Mean Annual = 15.0												

A good indication of temperatures over the Maungatapere region can be obtained from Table 4 which shows daily mean temperatures from Whangarei and Puketurua.

2.3 Continued

At both stations the annual temperature trend is very similar, both having February as the warmest month and July the coolest. At Whangarei the mean daily maximum for February is 24.8 °C dropping to 15.3 °C in July. Daily maxima are practically the same at Puketurua. However, at Puketurua there is a larger diurnal fluctuaion and the daily minima are on average about 1 °C cooler than at Whangarei.

Whangarei has a mean temperature of 15.5 °C and Puketurua a mean temperature of 15.0 °C.

Table 5 shows that ground frosts are not uncommon in the area, there being an average of 20 per year at Puketurua and 7 at Whangarei. They occur most frequently during July which has an average of 6.7 at Puketurua and 2.0 at Whangarei. Air frosts on the other hand occur less frequently - 10 times per year at Puketurua, but only about once every three years at Whangarei.

TABLE 5 - Showing Mean Number of Frosts Monthly at Whangarei and Puketurua

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Whangarei (1970 - 78) :												
Ground	-	-	-	-	0.4	2.0	2.0	1.6	0.6	0.3	-	-
*Air	-	-	-	-	-	0.1	0.2	-	-	-	-	-
Puketurua (1965 - 75) :												
Ground	-	0.1	-	0.1	1.5	3.7	6.7	4.5	1.8	1.2	0.3	-
*Air	-	-	-	-	1.2	2.3	3.3	2.6	0.5	0.3	-	-

*Air : Days frost on screen at 1.2 m

2.3 Continued

A table of mean daily soil temperatures at various depths at Puketurua appears below :

TABLE 6 – Showing Daily Mean Soil Temperature (°C) at Puketurua for Depths of 0.1 m, 0.2 m, 0.3 m & 1.0 m (1966 - 70, 1972 - 75)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.1 m	20.2	20.1	18.7	14.9	12.4	10.3	9.0	9.9	11.6	14.1	17.0	18.6
0.2 m	20.6	20.8	19.7	16.6	13.7	11.5	10.3	10.9	12.3	14.4	16.8	18.9
0.3 m	20.8	21.1	20.0	17.1	14.3	12.3	10.9	11.5	12.8	14.8	17.3	19.3
1.0 m	19.2	20.0	19.9	18.3	16.1	14.2	12.9	12.7	13.3	14.5	16.2	17.8

At 0.1 m, 0.2 m and 0.3 m, the maximum temperature occurs during February and the minimum in July, there being a general increase in temperature with depth to 0.3 m. At 1.0 m the temperature is cooler than at 0.3 m during the summer and warmer during the winter. At this depth February is the warmest month and August the coolest.

2.4 RAINFALL

Rainfall records have been obtained from eleven sites in the Maungatapere region. A summary of the rainfall stations appears as Table 7.

TABLE 7 - Showing Summary of Rainfall Stations in Maungatapere Area

Site No on Fig 8	Station Name	Elevation (masl)	Map Reference	Mean Annual Rainfall (mm)	Period of Record
1	Titoki	37	N19/582962	1372	1962-78
2	Wairua Falls	15	N19/585928	1393	1916-78
3	Moerangi	107	N23/648894	1495	1973-75
4	Suester	88	N20/671951	1482	1972-75
5	Nioka	134	N20/675935	1457	1973-75
6	Totara Grove	125	N20/687921	1576	1973-78
7	Maungatapere	122	N20/721929	1729	*1934-78
8	Watson	152	N20/715913	1756	1976-78
9	Kara III	244	N20/751956	1849	1971-78
10	Whau Valley	152	N20/803990	1848	1971-78
11	Whangarei	29	N20/820960	1651	1971-78

* Closed 1938-48

Wairua Falls and Maungatapere are two long term stations in the area having 63 and 35 years of record respectively. The other nine stations have much shorter records and the mean rainfalls for these staions were calculated by correlation with one of the long term stations.

Using the mean annual rainfall at these eleven stations a rainfall map of the area was drawn (Figure 8). This map shows that there is general increase in rainfall from west to east over the region with the highest rainfalls in the Western Hills to the northeast of the study area.

From Figure 8 the mean annual rainfall for the region was calculated to be 1 630 mm.

2.4 Continued

The rainfall distribution at the Wairua Falls and Maungatapere stations are summarised in Table 8 and Figure 9.

Table 8 compares the mean and median (50 percentile) rainfall for each month, and also shows the 10 to 90 percentile values. The 10 percentile is the value which is exceeded 90% of the time and the 90 percentile is the rainfall exceeded 10% of the time. The 10 percentile therefore also shows the low rainfall that can be expected once every 10 years.

TABLE 8 - Showing Monthly Rainfall Distribution for Wairua Falls and Maungatapere (mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Maungatapere :													
10 %ile	16	19	26	55	79	92	79	93	70	36	46	47	1339
Median	77	109	115	108	158	181	172	177	120	103	109	105	1675
90 %ile	212	357	256	271	272	297	313	281	256	191	190	194	2083
Mean	96	143	137	139	166	189	186	189	140	117	117	110	1729
Wairua Falls :													
10 %ile	19	17	21	50	59	70	64	70	61	46	36	33	1058
Median	72	70	74	102	128	149	147	127	104	93	89	80	1361
90 %ile	197	207	197	191	241	238	240	223	156	178	169	162	1704
Mean	94	99	92	119	143	157	155	138	111	103	94	90	1395

The two long term rainfall stations have similar annual rainfall distribution with June and July being the wettest months at both stations, with August being equally wet at Maungatapere. The driest month is January at Maungatapere but at Wairua Falls the mean rainfall is practically the same through all the summer months. At both stations 50% of the annual rainfall occurs during the five months from May to September.

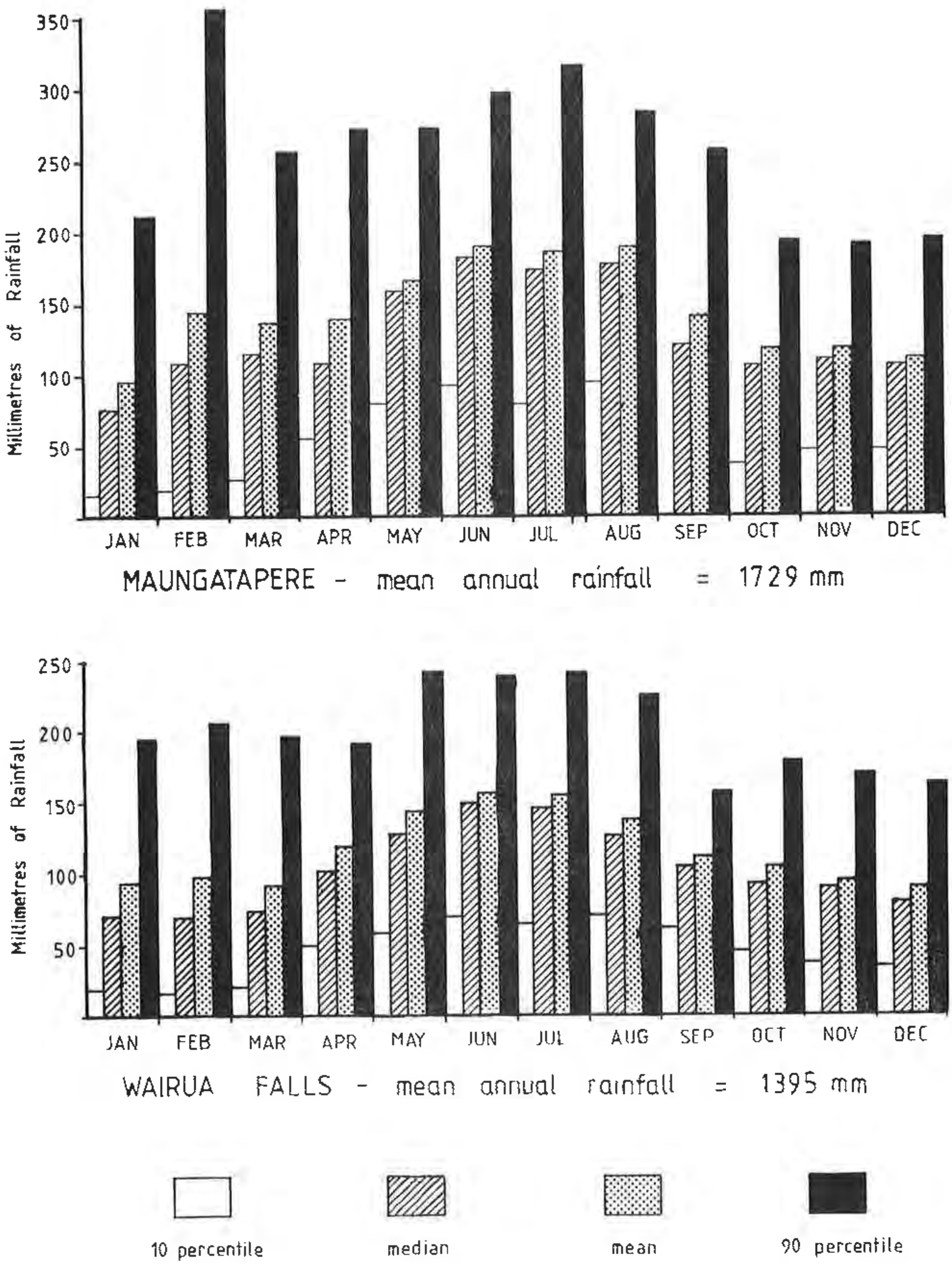


FIGURE 9 RAINFALL AT MAUNGATAPERE AND WAIRUA FALLS STATIONS

2.4 Continued

By studying Table 8 and Figure 9 the rainfall variability of each month can be seen. The summer months show the most variability, with not only the lowest but some of the highest rainfalls occur during the summer months. High rainfall totals during these months are usually the result of intense cyclonic storms, of tropical or subtropical origin that can occur once or twice a year or not at all.

2.4.1 Assessment of Drought from Rainfall

Drought severity and return period were calculated from the rainfall of Maungatapere and Wairua Falls. This was done using the method outlined by G N Martin and J R Waugh in "Assessment of Drought from Rainfall Data." This method defines a drought as :

"being two or more months in the summer period (December - March) when the individual monthly rainfalls are less than 50% of the long term average monthly rainfall."

This method also takes into account the conditions prior to the drought, since a relatively dry spring would lead to a much more severe drought than if the spring were wet. Based on these parameters a drought index is assigned to each drought. This drought index compares relative drought severity at a site for the period of rainfall record on an arbitrary scale. In this instance (see Figure 10) all records lie within a range from one to six. Droughts were ranked from most severe to least severe and return period found using the Gringorten formula :

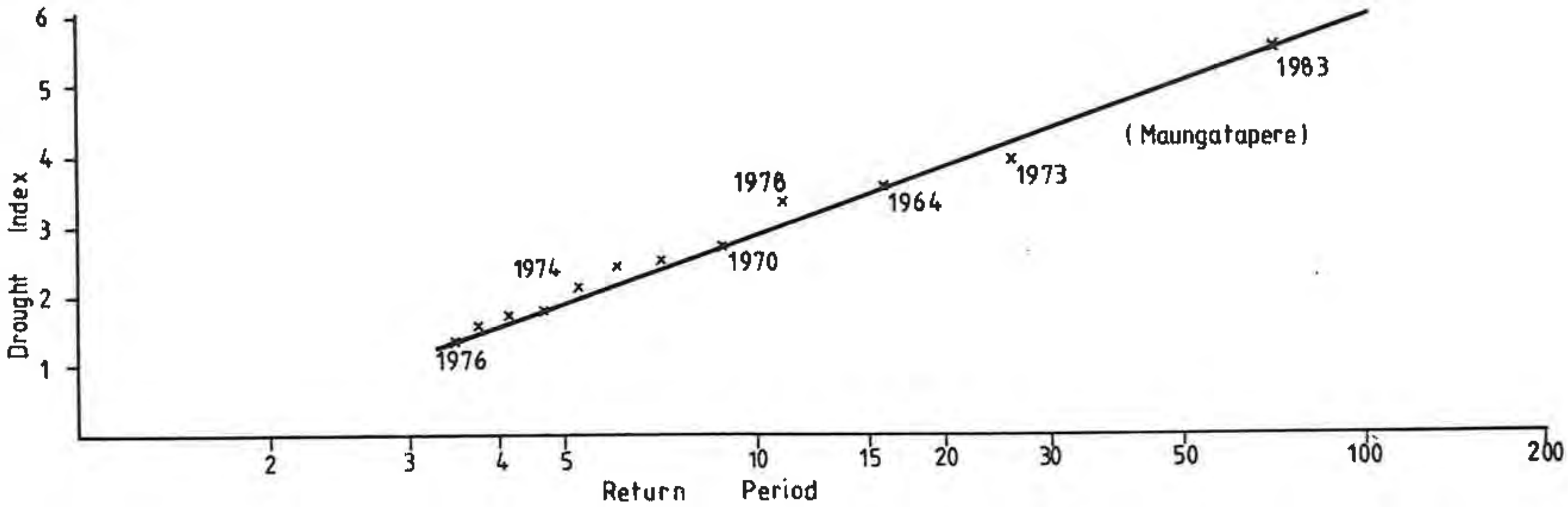
$$R = \frac{n + 0.12}{m - 0.44}$$

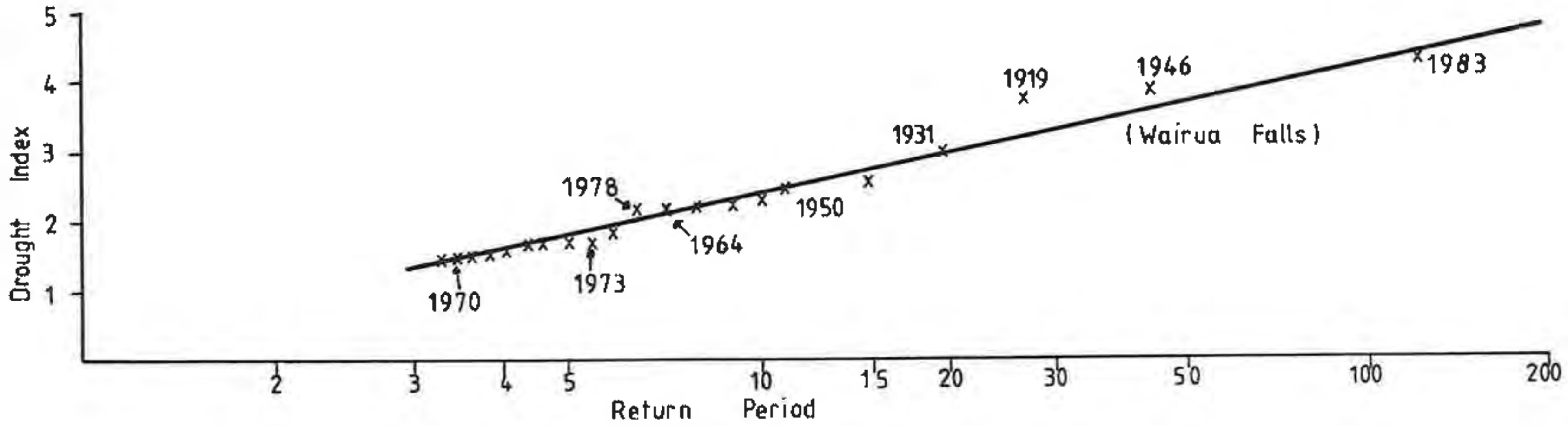
where R = Return period in years
n = Total number of years record
m = Rank of drought index where the ranking is counted from the most severe drought to the least severe drought

The drought indices were plotted against return period on Gumbel probability paper, as shown in Figure 10.

By this method the 1982-83 drought is the most severe on record at both stations, having a return period of 120 years at Wairua Falls and 70 years at Maungatapere. Although some differences occur, mainly due to the varying length of the records, there is reasonable agreement between the return periods of the same drought at the two sites. The most severe droughts in recent years were those of 1964, 1973, 1978 and 1983. The return periods assigned to the Wairua Falls record are therefore reasonably indicative of the drought severity throughout the region.

FIGURE 10 Drought Index vs Return Period Maungatapere 1934 – 38 1949 – 83
Wairua Falls 1916 – 83





2.5 EVAPOTRANSPIRATION

Daily pan evaporation measurements were made at Puketurua from 1966 to 1975. These data were corrected to give open water evaporation, (factor = 0.7) which approximates potential evapotranspiration (ET). Table 9 shows monthly ET and compares it to mean monthly rainfall and the rainfall during a 1:10 dry month. This shows the annual ET to be 851 mm which is in accordance with figures usually quoted for Northland (760 - 930 mm). French (1980), using several different methods determined the annual ET for the study area to be 900 mm.

TABLE 9 - Showing Evapotranspiration at Puketurua and Mean Monthly Rainfall and Rainfall for 1:10 Dry Month at Wairua Falls in Millimetres

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
ET	132	101	83	59	36	22	25	39	56	79	99	120	851
Monthly Rainfall	96	143	137	139	166	189	186	189	140	117	117	110	1729
1:10 Dry Month	16	19	26	55	79	92	79	93	70	36	46	47	1339

The summer (Nov - March) ET figures total 535 mm, this is approximately equal to the mean rainfall for this period. During the majority of years, however, the summer rainfall is less than the mean and consequently moisture stress caused by ET is more severe than indicated by summer mean rainfalls. From November to March the mean monthly ET exceeds the 1:10 year low rainfall by 50 - 100 mm every month.

Coulter (1973) used a daily water balance for the Whangarei rainfall station to determine the frequency of water surpluses and deficits. The number of months during which there has been at least one day of moisture deficit, or surplus, is shown in Table 10 as a percentage of the total months in the record.

2.5 Continued

TABLE 10 - Showing Frequency of Occurrence of a Daily Moisture Deficit and Surplus at Whangarei as Percentage of Months of Total Record

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Deficit	89	100	67	22	-	-	-	-	-	-	33	56
Surplus	11	22	33	56	90	100	100	100	100	78	33	22

The frequent low rainfalls and high evapotranspiration during the summer months result in the very frequent water deficits shown in Table 10. Since the record began there has been a water deficit at some stage during every February. Deficits are also very common during January and during both months surpluses are uncommon. Records show that deficits can occur any time from November to April and confirms accepted irrigation practice in the area. It is also not uncommon during February for there to be a moisture surplus and a moisture deficit in the same month.

3 SURFACE HYDROLOGY

The study area is located on Northland's main divide and therefore has a rather complex drainage pattern with many small streams leading in every direction (see Figure 11). All the streams within the area originate as springs, either within or on the perimeter of the basaltic lava flows which dominate the region. The largest of these springs, Poroti Springs (Map Reference : N20/652954) has a low flow of 165 l/s. Significant flows are also produced by Maunu Springs (Map Reference : N20/732932) at the head of the Whakapai Stream and Gunsons Spring (Map Reference : N20/765930) in the Mokupara Stream catchment, which have low flows of 70 l/s and 35 l/s respectively.

Because the catchments are small and significant flow contributions are made by springs it is difficult to separate surface hydrology from groundwater hydrology.

A study of the groundwater hydrology and a water balance is presented later in the report, this section will deal with surface water resources only.

3.1 WAIPAO STREAM

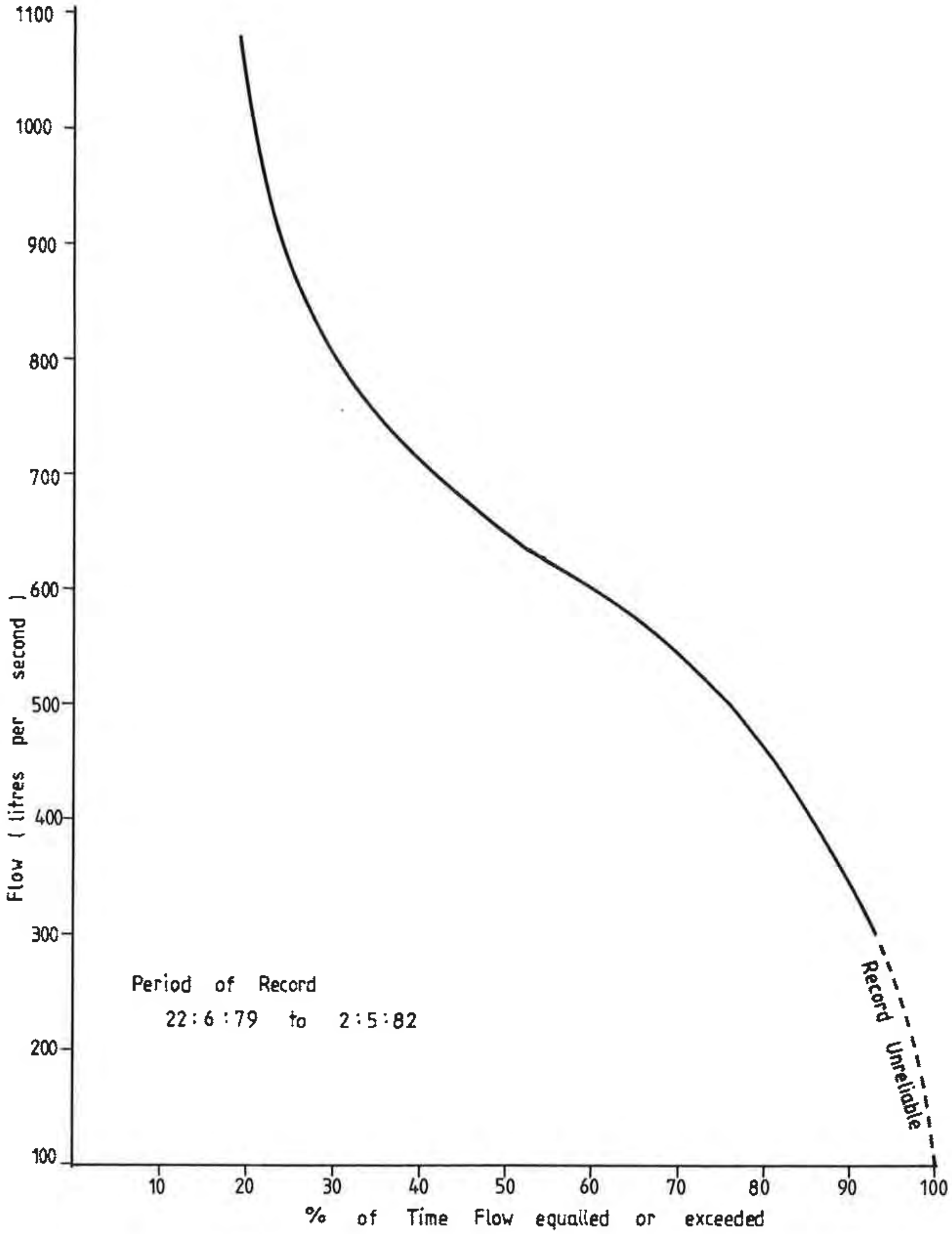
The largest surface water resource within the study area is the Waipao Stream. An automatic water level recording station was established on this stream at Draffin Road during 1979. This is shown as Site 1 on Figure 11. The catchment area at this site is 30 square kilometres.

Data from this station is incomplete and although mean annual base flow has been calculated (see Section 3.2) for the Waipao Stream, it is not possible to accurately determine the total annual discharge.

However, isolated gaugings and correlation with nearby recorder stations indicate the mean annual discharge from the Waipao Stream to be 750 l/s.

The flow duration curve for low flows of Waipao Stream at Draffin Road is shown in Figure 12.

The curve is steeper at the ends and flatter in the middle with the stream flowing at between 500 l/s and 700 l/s for 40% of the time. Much of the steepness at the lower end can be attributed to taking from upstream.



Flow Duration Curve — Waipao Stream at Draffin Rd. for flows up to 1100 l/s.

FIGURE 12

3.2 POROTI SPRINGS

The groundwater level adjacent to Poroti Springs (Map Reference : N20/655946) has been measured weekly by the Whangarei City Council since 1972 (see Figure 16).

Ministry of Works and Development have plotted these groundwater levels against stream flow measurements at Cutforths (see Table 11) and carried out a regression analysis. Using the least squares method, the following linear regression equation was found to best fit the plotted data :

$$Y = 0.084 X - 5.77$$

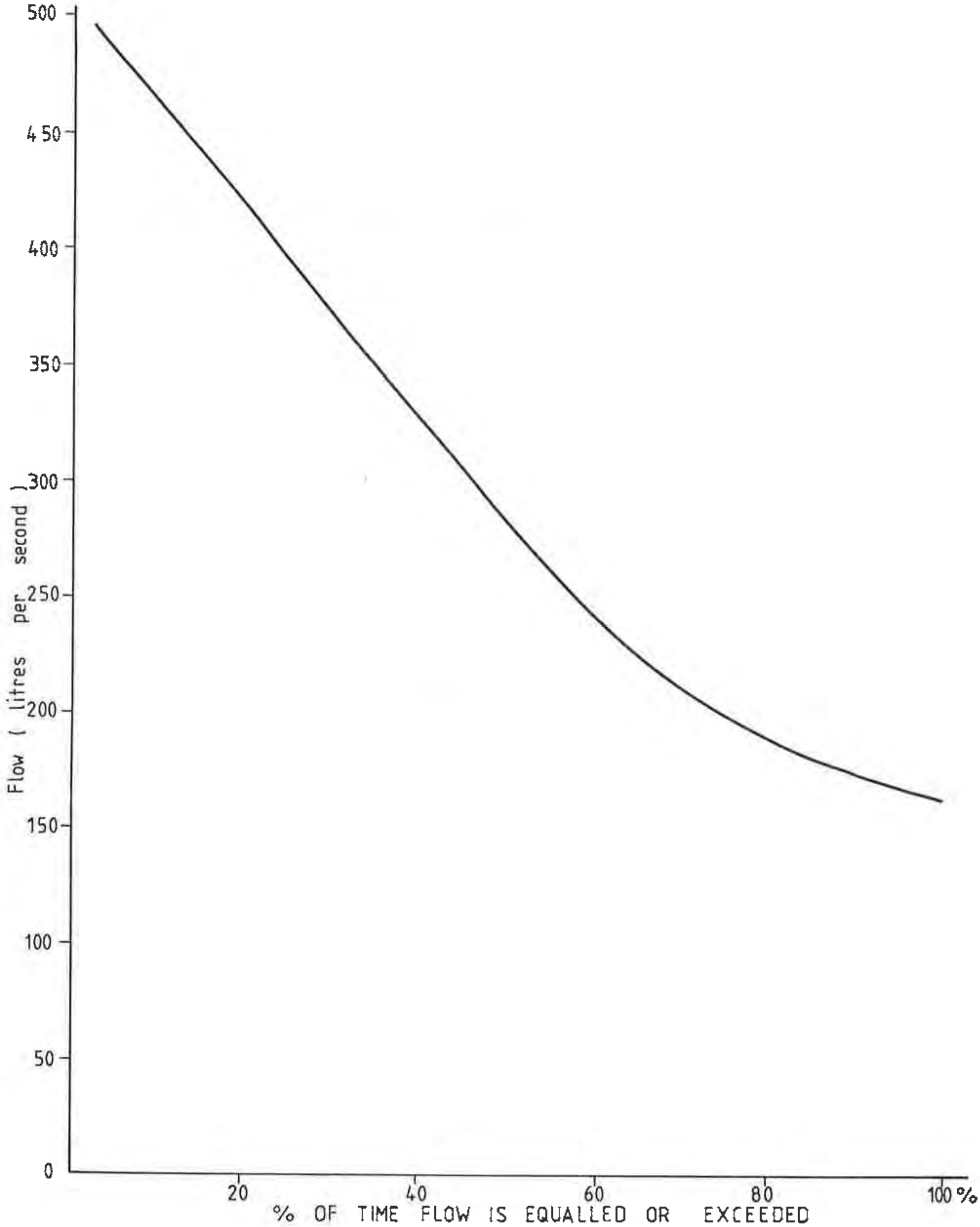
where Y = flow at Cutforths in l/s
X = groundwater level at Poroti in mm above datum
(datum = 72.018 masl)

This equation was used to generate a continuous flow record for Poroti Springs from February 1972 to October 1981 when pumping at Poroti Springs seriously disrupted the data.

Daily flows determined by this method are shown in Appendix I and the flow duration curve is shown in Figure 13. The flow duration curve shows the percentage of time that a given flow is exceeded, for example the springs are flowing at more than 200 l/s for 73% of the time. The daily flow tables show that the minimum flow during the period of analysis was 143 l/s and the maximum 505 l/s.

TABLE 11 - Showing Gauged Flows of Poroti Springs at Cutforths (Map Reference : N20/652954) in Litres Per Second

Date	Flow	Date	Flow	Date	Flow
10.02.72	313	10.01.74	293	26.02.81	200
30.01.73	193	30.01.74	291	27.08.81	280
13.02.73	165	01.05.74	214	26.11.81	309
02.03.73	201	10.05.74	230	21.01.82	245
30.03.73	188	10.07.74	331	25.01.82	234
19.04.73	155	21.08.74	364	28.01.82	241
04.05.73	139	27.09.74	370	18.02.82	201
22.05.73	158	21.05.75	157	02.12.82	200
29.05.73	146	30.10.75	462	15.12.82	214
02.10.73	348	22.08.80	361	28.01.83	192
14.11.73	310	22.09.80	361	11.02.83	147
26.11.73	282	22.12.80	271	10.03.83	122
10.12.73	264	05.02.81	294	05.10.83	204



Flow Duration Curve — Poroti Springs at Cutforths

FIGURE 13

3.2 Continued

From Appendix I the following table was produced showing monthly discharge from Poroti Springs :

TABLE 12 - Showing Monthly Flows from Poroti Springs at Cutforths in Litres Per Second and Mean Monthly Rainfall at Maungatapere for the Same Period

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1972		292	232	194	205	254	300	334	379	376	345	292
1973	235	198	178	161	149	153	211	329	353	350	319	292
1974	266	224	195	188	202	232	299	349	376	365	325	265
1975	218	194	176	158	147	170	232	233	271	416	499	494
1976	489	469	404	331	257	209	228	314	480	503	502	496
1977	480	432	327	231	185	203	323	458	479	456	385	297
1978	230	190	170	155	150	189	328	479	489	483	478	444
1979	297	189	167	171	155	164	289	353	416	420	415	403
1980	375	323	363	395	374	328	385	421	391	410	344	255
1981	193	191	153	134	155	168	217	275	388	414		
Mean Monthly Flow Poroti	309	270	237	219	180	207	281	355	402	419	401	360

Mean Annual Flow = 303

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Mean Monthly Rainfall Maungatapere (mm)	96	143	137	139	166	189	186	189	140	117	117	110

Mean Annual Rainfall = 1729 mm

3.2 Continued

Table 12 shows that the lowest monthly flow occurs during May and begins to rise in June to reach a peak in October.

The maximum and minimum monthly discharge/groundwater levels at the springs lag behind the extreme monthly rainfall by approximately four months.

Mean annual discharge for the period of record is 303 l/s. The mean annual rainfall for the same period is 95% of the long term mean, so 300 l/s is assumed to be the long term mean discharge from the springs.

Correlation with groundwater levels has shown that the minimum flow at Cutforths occurs during June, however, observations show that flow at this site increases significantly soon after the onset of rain. Therefore the flows shown in Appendix I represent only that portion of flow that comes from groundwater (ie base flow) and does not take into account any runoff.

3.3 MAUNU SPRINGS

In the upper catchment of the Whakapai Stream, there are a series of springs flowing from the southern slopes of the Maunu volcanic cone. These are known collectively as Maunu Springs. The Whangarei City Council have utilised this resource for public water supplies since 1929 and has made weekly measurements of the flow from individual springs since 1970. The two major springs have been called "Tunnel" and "Chamber." The weekly flow readings from these springs are plotted in Figures 14 and 15 and monthly flows from the Tunnel site are shown in Table 13. From the plot of rainfall it can be seen that the fluctuations in spring flow lag behind rainfall by a few weeks at most. The plots also show that there is little seasonal variation in discharge with the mean flow being only 4 l/s greater than a five year drought flow. Table 15 shows that there is virtually no difference between the five year and the 20 year drought flows at the Tunnel site. Flow parameters for three of the Maunu Springs are shown in the summary of gauging sites (see Table 16).

3.3 Continued

TABLE 13 - Showing Monthly Flows in Litres Per Second
Maunu Springs at Tunnel

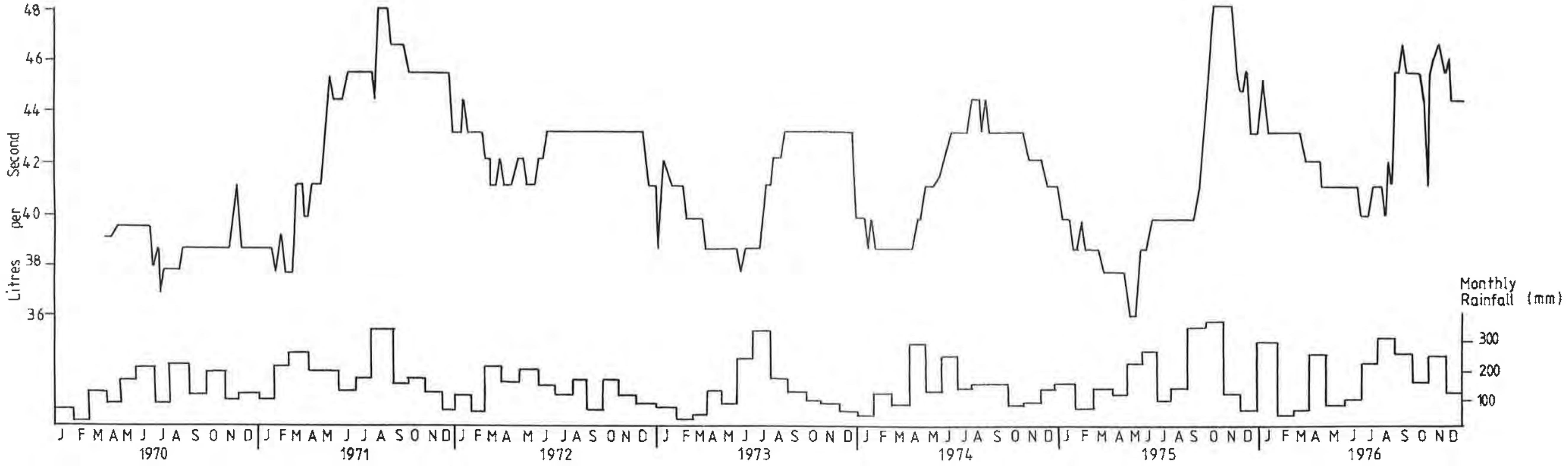
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1970	-	-	-	39.2	39.4	39.0	37.6	38.4	38.5	38.5	39.2	38.5
1971	38.6	37.9	40.2	41.0	44.2	45.0	45.3	47.0	46.7	45.5	45.5	44.3
1972	43.6	43.0	41.2	41.5	41.3	42.8	43.1	43.1	43.1	43.1	43.1	42.2
1973	40.6	40.8	39.6	38.6	38.5	38.3	39.4	42.3	43.1	43.1	43.1	41.8
1974	39.5	38.7	38.6	38.8	40.9	42.5	43.2	44.0	43.1	43.1	42.5	41.5
1975	40.1	39.0	38.5	37.7	37.1	38.0	39.8	39.8	40.8	46.8	47.2	44.4
1976	43.7	43.3	43.2	41.9	41.1	40.8	40.5	41.9	45.7	44.1	45.9	44.8
1977	43.9	43.5	42.1	41.8	41.0	41.8	43.2	44.1	45.5	44.4	42.7	41.6
1978	41.0	40.8	38.9	38.6	38.1	39.2	42.2	45.1	45.2	45.3	43.4	42.1
1979	42.1	40.5	41.0	42.1	41.5	39.9	43.9	43.5	42.4	44.4	44.8	45.4
1980	42.4	42.6	44.1	43.7	42.6	42.8	43.1	41.7	42.6	39.6	41.4	41.0
1981	39.2	39.5	39.1	38.2	39.6	39.7	40.5	40.6	41.5	41.6	40.8	40.5
1982	39.3	38.9	39.3	38.9	38.9	38.5	38.9	40.6	40.1	39.6	39.8	38.6
1983	38.1	37.5	37.0	36.3	36.9	37.8	38.9					
Mean	40.9	40.5	40.2	39.9	40.1	40.4	41.4	42.5	43.0	43.0	43.0	42.1

Mean Annual Flow = 41.4 l/s

Mean Monthly Rainfall Maungatapere (mm)

96	143	137	139	166	189	186	189	140	117	117	110

Mean Annual Rainfall = 1729 mm



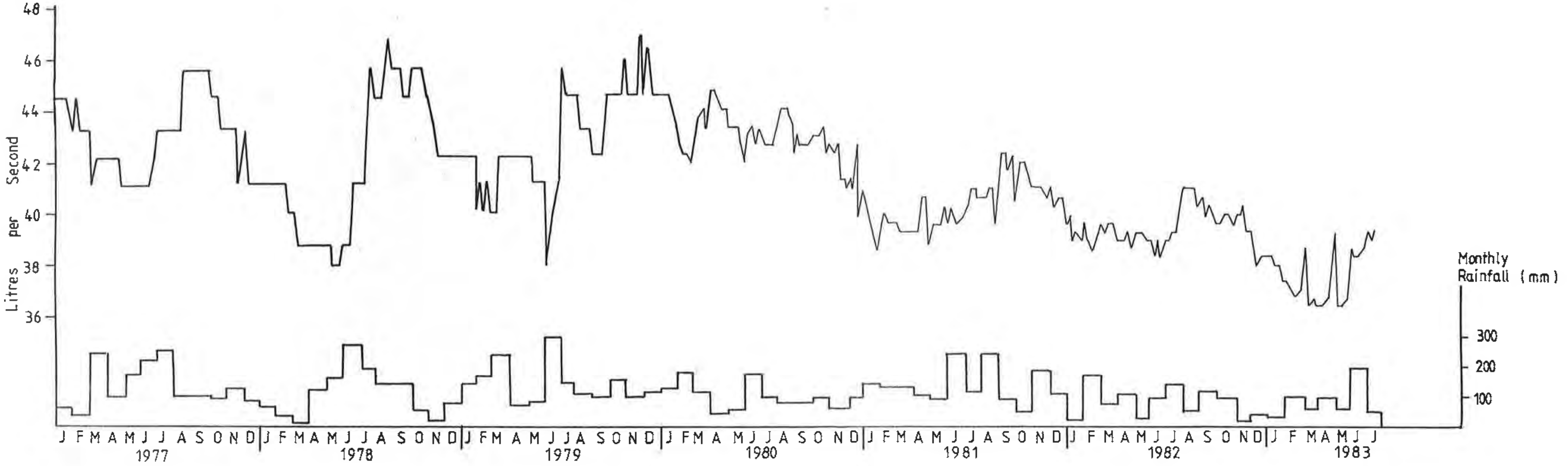


FIGURE 14 Flow — Maunu Springs at Tunnel
Rainfall — Maungatapere

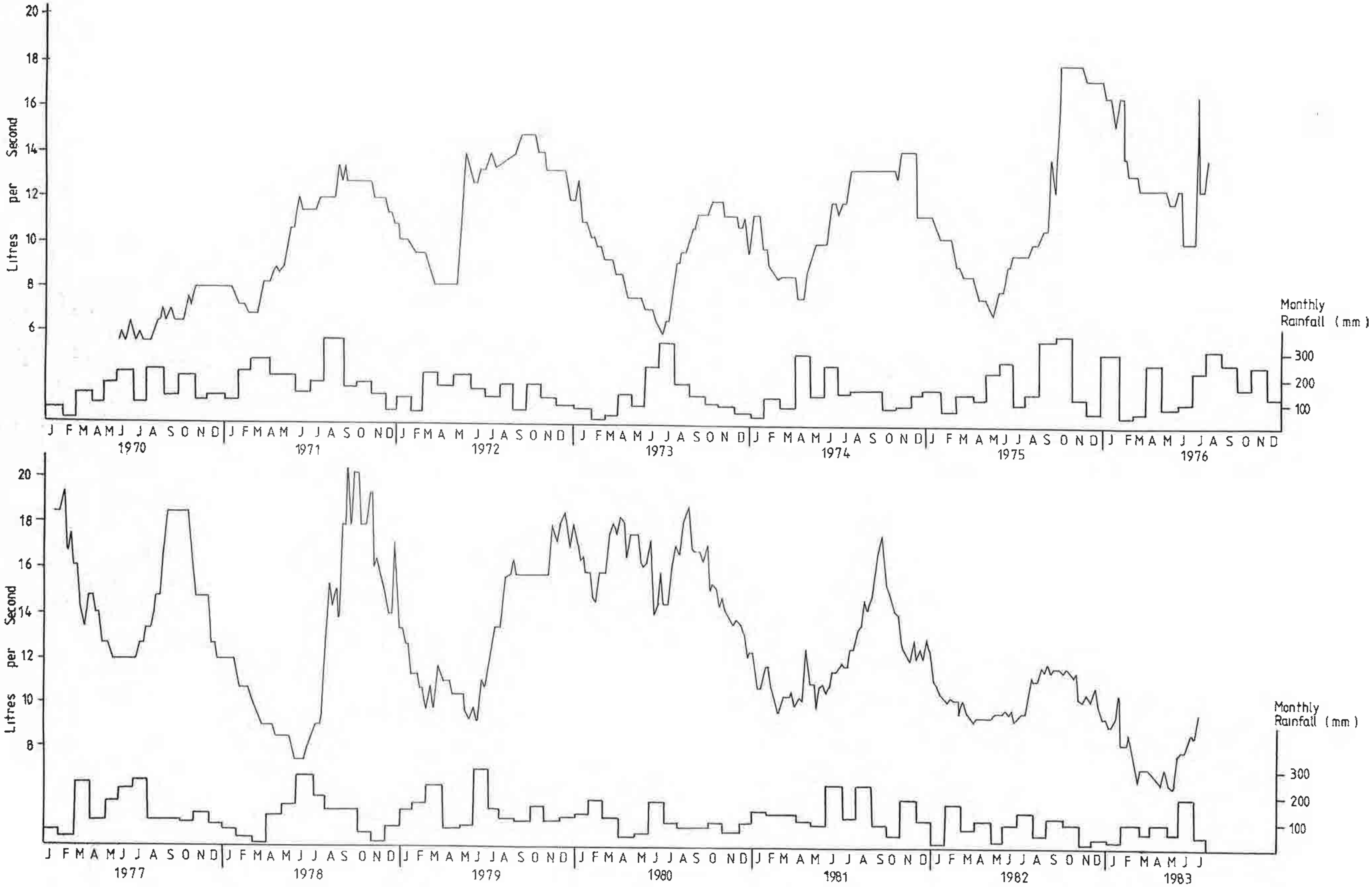


FIGURE 15 Flow — Maunu Springs at Chamber
Rainfall – Maungatapere

3.4 SECONDARY GAUGING SITES

In addition to the major gauging sites previously discussed, there are 32 other sites in the study area where a reasonable record of stream flow has been obtained. The location of all gauging sites are shown on Figure 11 and the site information is summarised in Table 16.

3.5 DROUGHT FLOWS

A frequency analysis has been performed on the flow data generated at Poroti Springs (MWD 1983). Minimum recorded flows for each month from November to March were ranked in ascending order and assigned a return period using the Gringorten formula (see Page 38).

The return period for each low flow event was then plotted against return period on Gumbel probability paper and the line of best fit assessed by eye. The results are shown in Table 14.

TABLE 14 - Showing Low Flows with Various Return Periods for Poroti Springs at Cutforths from November to March in Litres Per Second

Return Period :	2.33 Years (average)	5 Years	10 Years	20 Years
November	325	280	245	210
December	270	240	220	200
January	210	205	200	195
February	200	180	170	170
March	175	165	160	155

3.5 Continued

Gaugings carried out before March 1983 are used in the frequency analysis and in all cases, the 1982/83 flows were the lowest recorded for their respective months. The analysis indicates that these flows have return periods greater than 20 years. The record is not long enough to accurately assign return periods greater than this. A complete list of gaugings from Poroti Springs at Cutforths is shown in Table 11. This shows that flows dropped to 120 l/s during March and April 1983. These figures were not used in the frequency analysis and therefore a return period cannot be assessed. However, the rainfall total for 1982 at Maungatapere is the lowest in the 40 years of record, therefore the 1982/83 low flows at Poroti Springs could have a return period as high as 50 years.

TABLE 15 – Showing Minimum Gauged Flows and Low Flow Return Periods for Major Sites in the Maunu-Whatitiri Area

Site	Lowest Gauged Flow (l/s)	Date	Return Period 5 Years	10 Years	20 Years
Waipao @ Draffins Road	160	11.2.83	210	185	172
Poroti Springs @ Cutforths	122	10.3.83	165	160	155
Karukaru @ Farm Crossing	36	11.3.83	45	43	41
Kauritutahi @ McBeths Road LH	17	27.1.83	20	19	18.5
Otaika @ Quarry	100	11.2.83	105	103	100
Maunu Springs @ Tunnel	36	30.5.75	37	36	36
Mokupara @ Bottom of Scarp	31	10.4.78	34	32	30
Te Hihi @ Health Camp	7.1	2.2.79	6.2	5.6	5.2
Raumanga @ City Weir	24	6.4.78	26	25	24

3.5 Continued

The affect of low rainfall on flows from Maunu Springs can be seen in Figures 14 and 15. The discharges have been steadily diminishing since 1980 and there has been little increase over the winter. At the Tunnel site the highest flow during 1982 was 40 l/s, whereas in four out of five years immediately prior to 1980 the peak annual flow reached 46 l/s.

The gauged flows at all sites were plotted against the flow on the same day at Poroti Springs obtained from Appendix I or from actual gaugings. Gaugings had been carried out only after several days without rain so that only base flow was being measured (ie no runoff). The plotted measurements generally showed good correlation and a line of best fit was drawn through the points. The minimum annual flows for Maunu Springs at Tunnel were also ranked and analysed in the same way as Poroti Springs and in some cases, gauged flows in the Maunu area where plotted against flows from Maunu Springs instead of Poroti.

From flows of known return periods at the major site, return periods at all gauging sites were determined. Table 15 shows low flows of various return periods for the more important sites and Table 16 shows mean flows and five year drought flows for all gauging sites. The mean annual flow for each site was assumed to be made up of two components. One being the annual groundwater flow (base flow) which was determined from the correlation mentioned above. The other is the runoff component which was obtained from a runoff factor of 8.4 l/s/sq. km. The derivation of this factor is explained in section 4.3. Although this factor is derived from the volcanic area it is used for all gauging sites even though some have catchments with a portion of sedimentary lithology.

TABLE 16

GAUGING SITES - MAUNU/WHATITIRI AREA

Site As On Figure 11	Stream	Site	Map Reference	Catchment Area (km²)	Number of Gaugings	Minimum Recorded Flow (l/s)	Date	5 Year Drought Flow (l/s)	Mean Annual Groundwater Flow (l/s)	Mean Annual Discharge (l/s)
1	Waipao	Draffin Rd	N19/642963	30	30	160	25.01.83	210	390	642
2	Tapahina	Draffin Rd	N19/640962	3.2	3	0.76	7.02.83	0.8	2	29
3	Karukaru	Farm Crossing	N19/627904	5.0	15	36	11.03.83	45	93	135
4	Karukaru	Harris Spring	N19/646907	0.8	14	6.0	15.04.83	9	19	26
5	Poroti Springs	Cutforths	N20/652954	2.9	19	122	10.03.83	165	300	324
6	Poroti Springs	Fig Tree	N20/653950	1.4	16	45	10.03.83	60	154	166
7	Kauritutahi Trib	McBeth Rd	N20/684954	5.3	3	27	21.10.83	Insufficient Data		
8	Kauritutahi Trib	Kokopu Block Rd	N20/724940	-	16	0.1	12.02.71	Insufficient Data		
9	Kauritutahi	McBeth Rd LH	N20/668953	16	22	17	23.03.78	20	40	174
10	Kauritutahi Trib	McBeth Rd RH	N20/669954	7.3	18	8.2	28.01.83	13	25	86
11	Kauritutahi	Poroti Rd	N20/688929	8.3	17	8.2	11.02.83	11	33	103
12	Kauritutahi	Tatton Rd	N20/688922	7.9	19	20	12.02.71	11	33	99
13	Kauritutahi Trib	Stonewall LH	N20/691918	2.2	10	5.1	17.02.82	3.8	8.7	27
14	Kauritutahi Trib	Stonewall RH	N20/692918	5.0	10	12	17.02.82	8.5	26	68
15	Kauritutahi Trib	Groves RH	N20/701917	2.4	5	5.6	11.01.80	1.5	2	22

16	Kauritutahi Trib	Groves LH	N20/701916	0.8	6	6.8	14.01.80	2.5	3.5	10
17	Wheki	Wheki Rd	N24/679889	2.8	4	4.2	11.01.80	2.5	8	32
18	Maunu Springs	Tunnel	N20/735934	-		36	30.05.75	37	41	41
19	Maunu Springs	Chamber	N20/732934	-	weekly since 1970	5.4	30.07.70	6	9.5	9.5
20	Maunu Springs	Above Pump	N20/738932	-		3.4	26.04.83	4	8	8
21	Whakapai Trib	Stevens Yards	N20/727924	0.2	14	3.8	17.02.82	2.5	17	19
22	Whakapai Trib	Waltons Spring	N20/722927	0.1	5	5.5	7.01.71	5	22	23
23	Otakaranga	Pukeatua Rd	N24/721896	1.3	15	2.7	2.02.79	2.0	6.2	17
24	Otakaranga	Sterlings	N20/731903	1.1	5	4.3	3.02.82	2.3	9.0	18
25	Otaika Trib	Fabers Intake	N20/726917	0.6	4	25	24.02.78	25	33	38
26	Otaika Trib	Concrete Slab	N20/746914	3.1	13	17	11.02.83	28	40	66
27	Otaika	Quarry	N20/754912	11	10	120	11.02.83	130	180	272
28	Mokupara	Hawken downstream	N20/750938	0.6	6	9.0	18.02.82	6.3	16	21
29	Mokupara	Cemetery Rd RH	N20/751928	1.7	10	8.5	26.01.83	6.5	21	35
30	Mokupara Trib	Cemetery Rd LH	N20/761933	1.6	45	0.8	27.02.73	1.4	5.0	17
31	Mokupara Trib	Gunsons Spring	N20/764926	0.5	2	42	26.11.81	25	55	59
32	Mokupara	Bottom of Scarp	N20/765924	5.1	7	31	10.04.78	34	84	127
33	Nihotetea	Austin Road (1)	N20/781928	0.5	3	1.8	30.03.71	Insufficient Data		
34	Nihotetea	Austin Road (2)	N20/790929	4	10	14	6.04.73	11	33	67
35	Raumanga	City Weir	N20/808945	13	26	24	6.04.78	26	45	154
36	Te Hihi	Health Camp	N20/795950	5.0	10	7.1	2.02.79	6.2	31	73
37	Kaitara (Takahie)	Kara Road	N20/721976	3.1	4	10	10.03.83	13	Insufficient Data	

4 GROUNDWATER HYDROLOGY

4.1 INTRODUCTION

Regular groundwater levels are measured in six bores in the study area. The locations of these bores are shown on Figure 11 and the particulars of each site are shown in Table 17. Five of the bores are in the Whatitiri groundwater catchment while Puriri Park bore is some distance away in the Maunu East groundwater catchment.

From Figure 16 it can be seen that the Poroti Springs bore fluctuates in a cyclic manner with the lowest grounwater level occurring in May each year, rising through June to a peak in October. These fluctuations lag approximately 4 months behind rainfall.

The pattern of the Poroti Road bore (Figure 17) is the same as at Poroti Springs. Each of the five other bores also fluctuate in a similar manner to the Poroti Springs bore differing only in the amount the water level varies and the lag behind rainfall. The Poroti West and the Whatitiri Wines bores (Figures 18 and 19) take appoximately one month to respond to changes in rainfall. The Maddever bore shown in Figure 20 lags behind rainfall by approximately two months.

Prior to mid 1983 data had been collected irregularly from the Puriri Park bore since it was drillled in 1981. It is therefore inadequate to determine any long term trends.

The flow from Maunu Springs in the Maunu West groundwater catchment originates almost entirely from groundwater from the southern slopes of the Maunu volcanic cone. Therefore it is not surprising to see the cyclic fluctuations observed in bore levels also present in the seasonal discharge of these springs (Figures 14 and 15).

A noticeable trend observed in the bores is the decreasing water levels since the beginning of 1982. The Poroti Springs bore in particular (Figure 16) shows a much reduced peak in 1982 than would normally be expected for October. This is largely a consequence of the low rainfall experienced over this period.

TABLE 17 - Showing Groundwater Level Recording Sites in Maunu - Maungatapere - Whatitiri Area

No on Fig 11	Bore Name	Map Reference	Year Recording Began	Recording Frequency
1	Poroti Springs	N20/655946	1972	Weekly
2	Poroti Road	N20/661944	1979	Continuous
3	Poroti West	N19/645953	1980	Continuous
4	Whatitiri Wines	N20/676935	1980	Continuous
5	Maddever	N20/687905	1977	Approx Fortnightly
6	Puriri Park	N20/801949	1981	Irregular*

* Continuous since June 1983

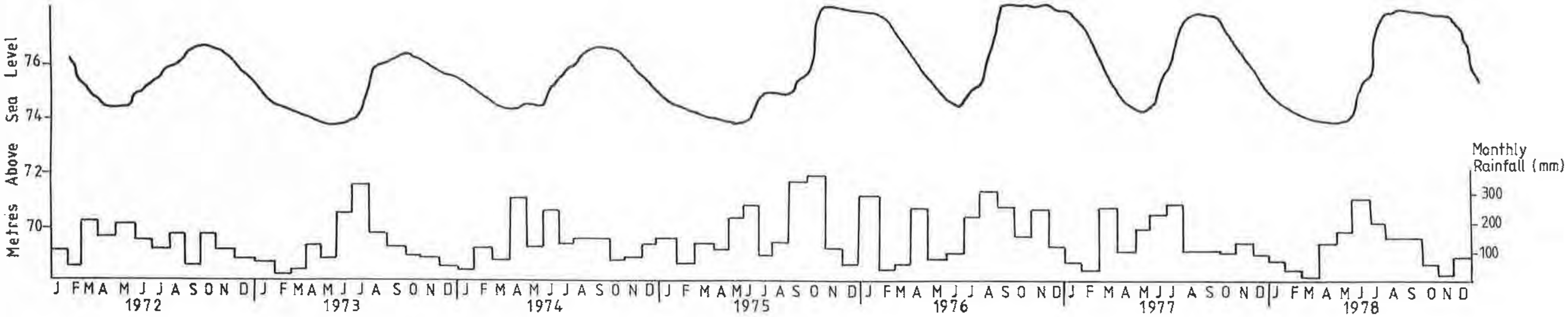
A combined geophysical-hydrological study was started by the Northland Regional Water Board and Auckland University in 1976 to obtain the following information :

1 The geohydrological structure of the catchment, ie boundaries of individual subterranean catchments which control the magnitude and direction of the groundwater flow and therefore the base flow of the streams in the area;

2 Overall balance of annual input and output of groundwater for individual catchment areas;

3 Feasibility of groundwater abstraction in various parts of the catchment away from the natural springs.

All this information was required to obtain a representative hydrological model of the volcanics which could be used for an efficient management of the groundwater resources. The geophysical study was started, with an airborne magnetic survey and a pilot gravity survey in an attempt to determine the thickness of the volcanics. These methods were found to be unsuitable. However, later DC-resistivity soundings were successful in determining the thickness of the basalts, and a systematic resistivity survey was started in 1978 which produced a representative picture of the geohydrological structure of the catchment. This information, together with existing meteorological data and spring and stream discharge data, was used to derive a hydrological balance and a hydrological model for the area.



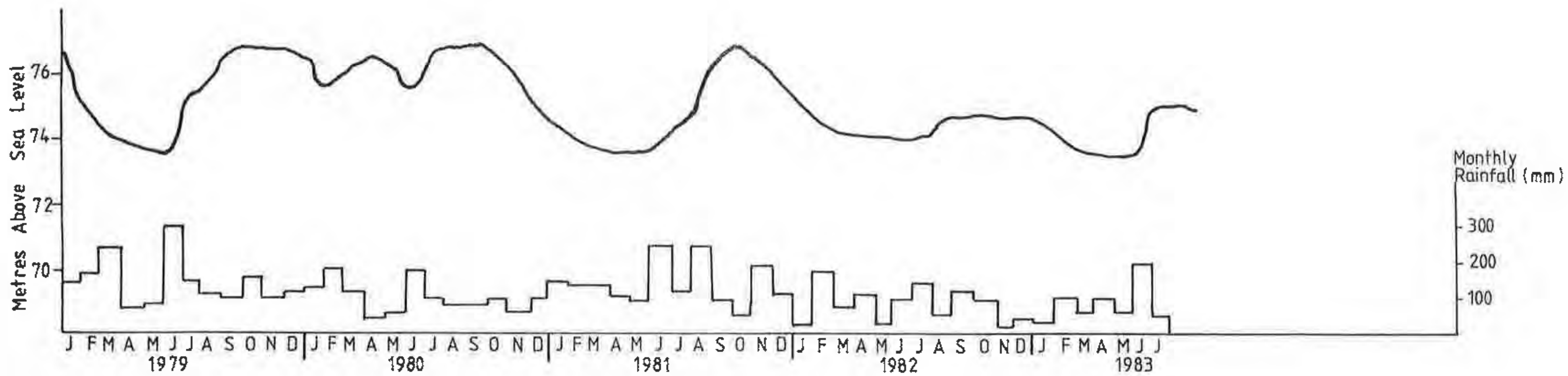


FIGURE 16 Groundwater Levels – Poroti Springs
Rainfall – Maungatapere

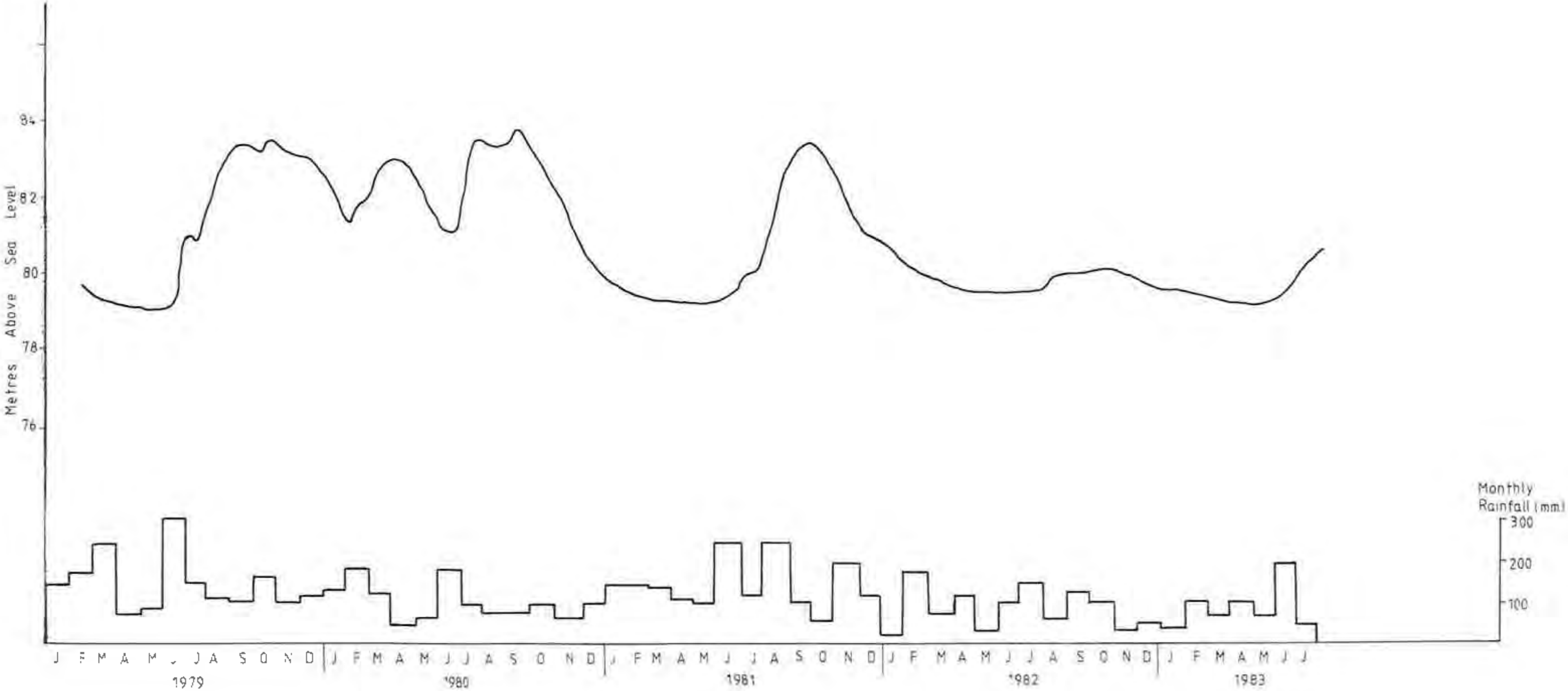


FIGURE 17 Groundwater Levels — Poroti Road Bore

Rainfall — Maungatapere

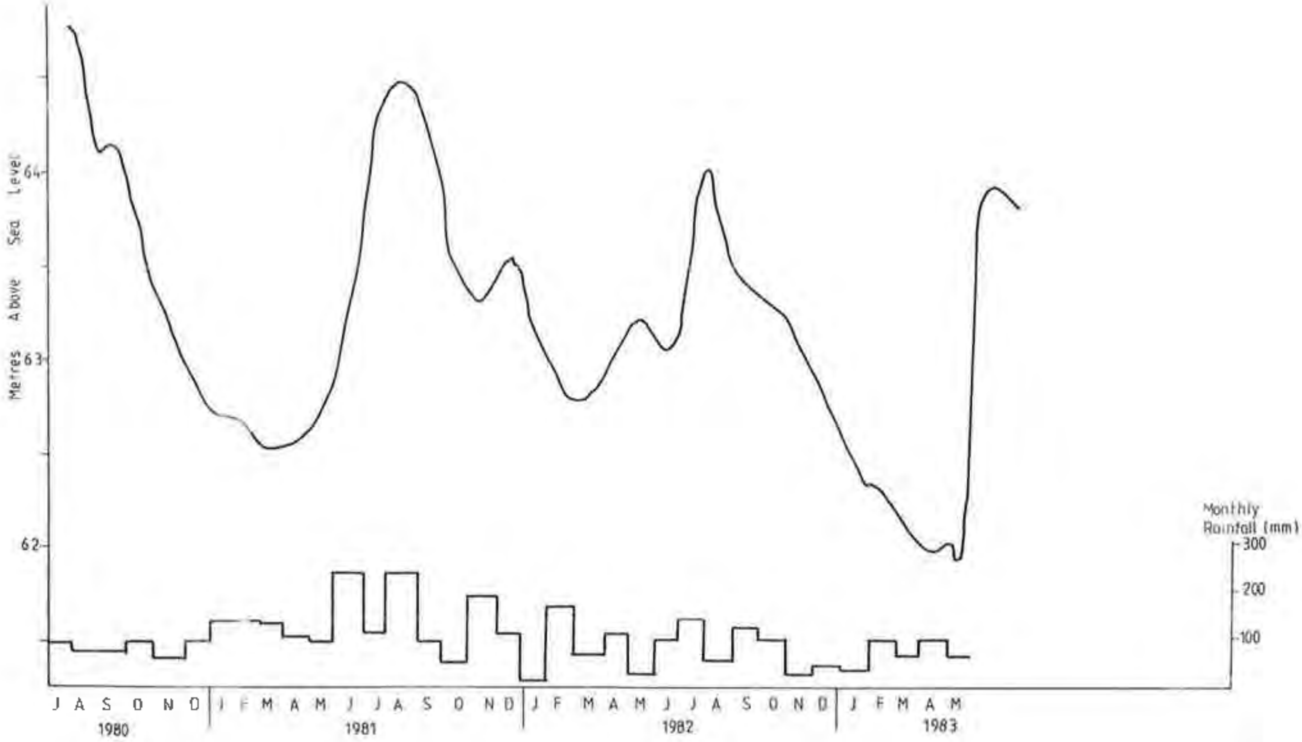


FIGURE 18 Groundwater Levels – Poroti West Bore
Rainfall – Maungatapere

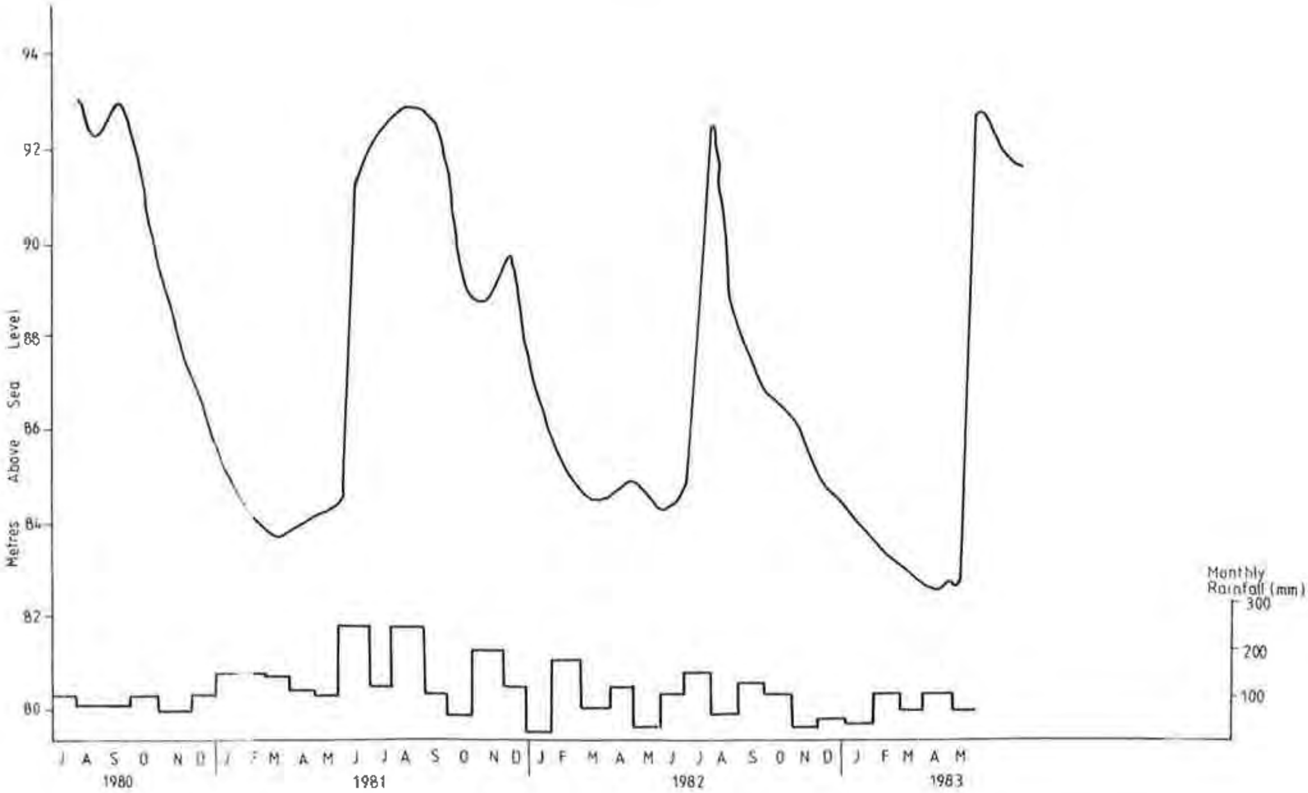


FIGURE 19 Groundwater Levels – Whatitiri Wines Bore
Rainfall – Maungatapere

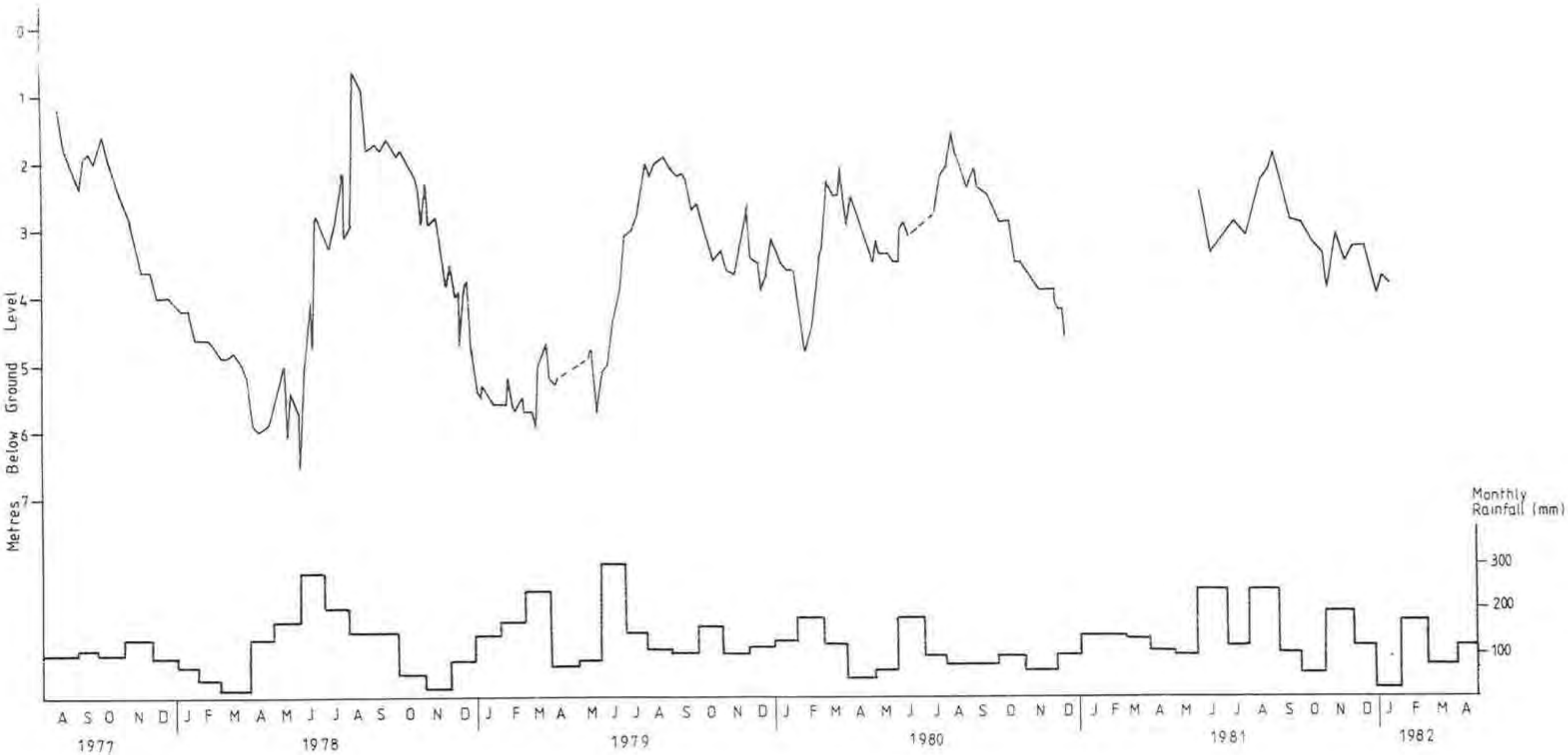


FIGURE 20 Groundwater Levels — Maddever Bore
Rainfall — Maungatapere

4.1 Continued

Some information about parameters which control the groundwater flow and storage capacity of individual catchment areas, was obtained from the analysis of widely spaced existing bores, some of which had been drilled during the study to test the predicted geophysical structure of the area. This information is still incomplete but indicates that the volcanic aquifers have highly variable hydraulic properties.

4.2 GEOHYDROLOGICAL STRUCTURE OF THE VOLCANICS

The DC-resistivity soundings, together with drillhole data of some bores which had penetrated the basalts, allowed the construction of a map showing the thickness of the volcanics. Allowing for the surface elevation, a contour map of the rather impermeable underlying sediments was compiled (see Figure 2a). The contour map of these subvolcanic sediments, together with piezometric (groundwater) level data from existing wells, allowed the definition of six individual catchments which were given the following names :

1 Whatitiri

2 West Whatitiri

3 South Whatitiri

4 Southeast Maungatapere

5 Maunu West

6 Maunu East

The piezometric contours and the boundaries of these catchments are shown in Figure 21.

In most cases, these catchment areas are separated by concealed ridges that have been covered by the overlying volcanics but in a few cases; for example separation of Whatitiri and Maunu West catchment areas, the boundaries are less well defined. The individual catchment areas are described in more detail in the following paragraphs. A summary of important parameters of these areas is given in Table 18.

4.2.1 Whatitiri

This is the largest coherent catchment (31.5 ± 1.2 square kilometres) and constitutes the reservoir for all groundwater discharged around the base of Mt Whatitiri; for example at the Poroti Springs. The main feature of this area is the large subvolcanic depression (remnant of explosion crater?) now infilled by basalts (Whatitiri depression), beneath the Whatitiri cone (see Figure 2a). The bottom of the depression lies at present-day sea level and the basin is ringed by a concealed sedimentary ridge that rises to about 140 metres above sea level. The ring structure is breached to the northeast and allows groundwater to pass from the basin into a northwest trenching channel (referred to from now on as the Whatitiri Channel).

This situation occurs when the piezometric level beneath Whatitiri cone is higher than about 100 metres above sea level. The inferred intermittent buffer flow from the Whatitiri depression can be represented in a schematic model if one subdivides the Whatitiri catchment area into three sub-catchments, namely Poroti, Whatitiri Central and Kauritutahi. Using the hydrological balance approach described later, and assuming that all groundwater of the catchment is discharged by springs and streams, the flow of groundwater between the sub-catchments was obtained for the periods of mean flow and low flow (see Figures 22 and 23). The data shown in these figures are based on the correlations with Poroti Springs previously discussed.

The results shown in Figures 22 and 23 indicate that all groundwater from the Whatitiri Central sub-catchment flows into the Poroti sub-catchment. This quantity varies between 89 l/s and 164 l/s from low to mean flow. The groundwater flow from the Kauritutahi sub-catchment into the Poroti sub-catchment varies between 65 l/s and 119 l/s. This is 65% of the total groundwater flow from this sub-catchment; the remaining 35% goes into the Kauritutahi Stream directly.

Therefore almost 80% of the groundwater flow within the Whatitiri catchment surfaces at Poroti Springs. Of the net rainfall in this catchment, 60% infiltrates to groundwater.

The large increase in flow between the gauging sites at "Fig Tree" and "Cutforths" (see Table 15) indicates that the groundwater flow from the Whatitiri Central sub-catchment surfaces upstream of Fig Tree, whereas the flow from the Kauritutahi and Poroti sub-catchments surface between the two sites so that all groundwater flow from the Whatitiri catchment is measured at Cutforths. At mean flow the quantity contributed by each sub-catchment as shown in Figure 22 is in good agreement (less than 10% error) with the quantities determined by gaugings at Fig Tree and Cutforths (Table 15). At low flow the quantities do not compare as well but the errors (30%) are within acceptable limits.

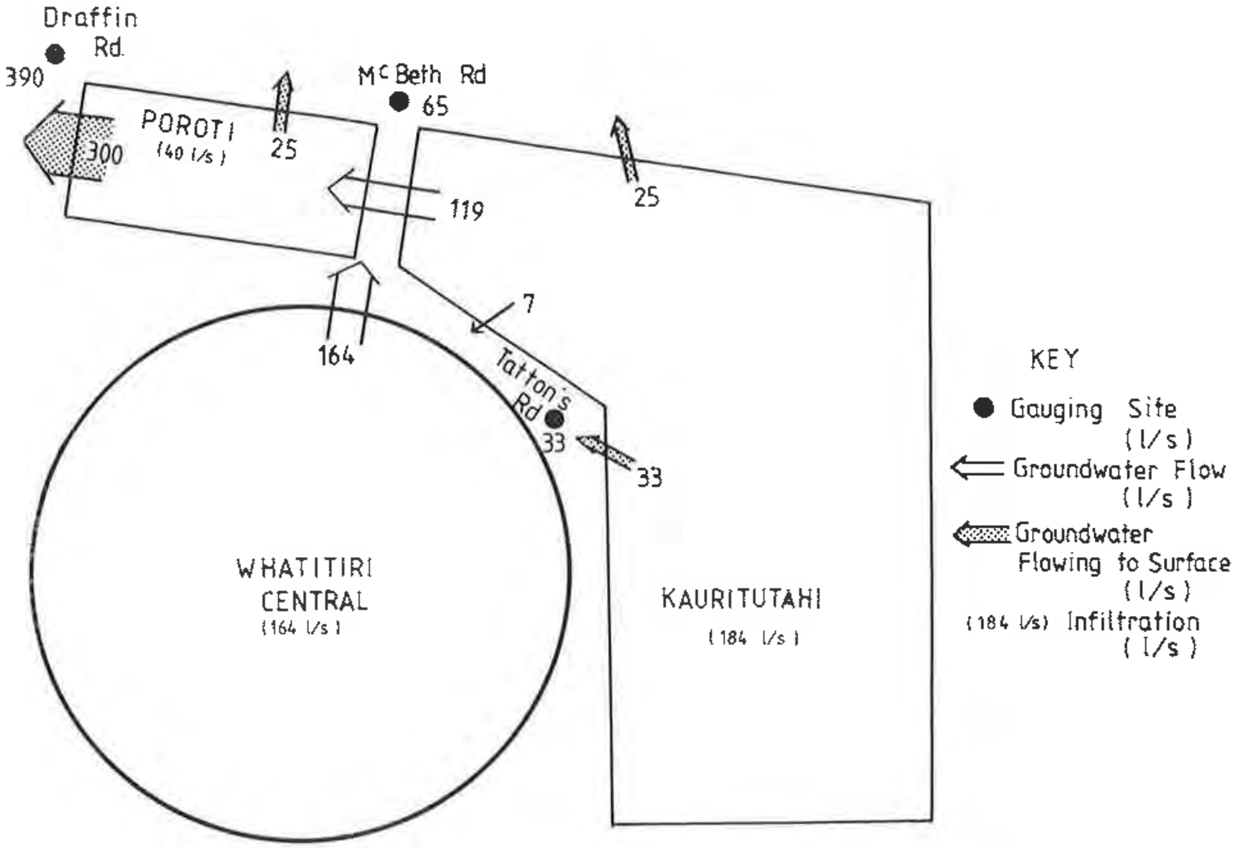


FIGURE 22 GROUNDWATER FLOW (mean annual) OF WHATITIRI CATCHMENT AREA

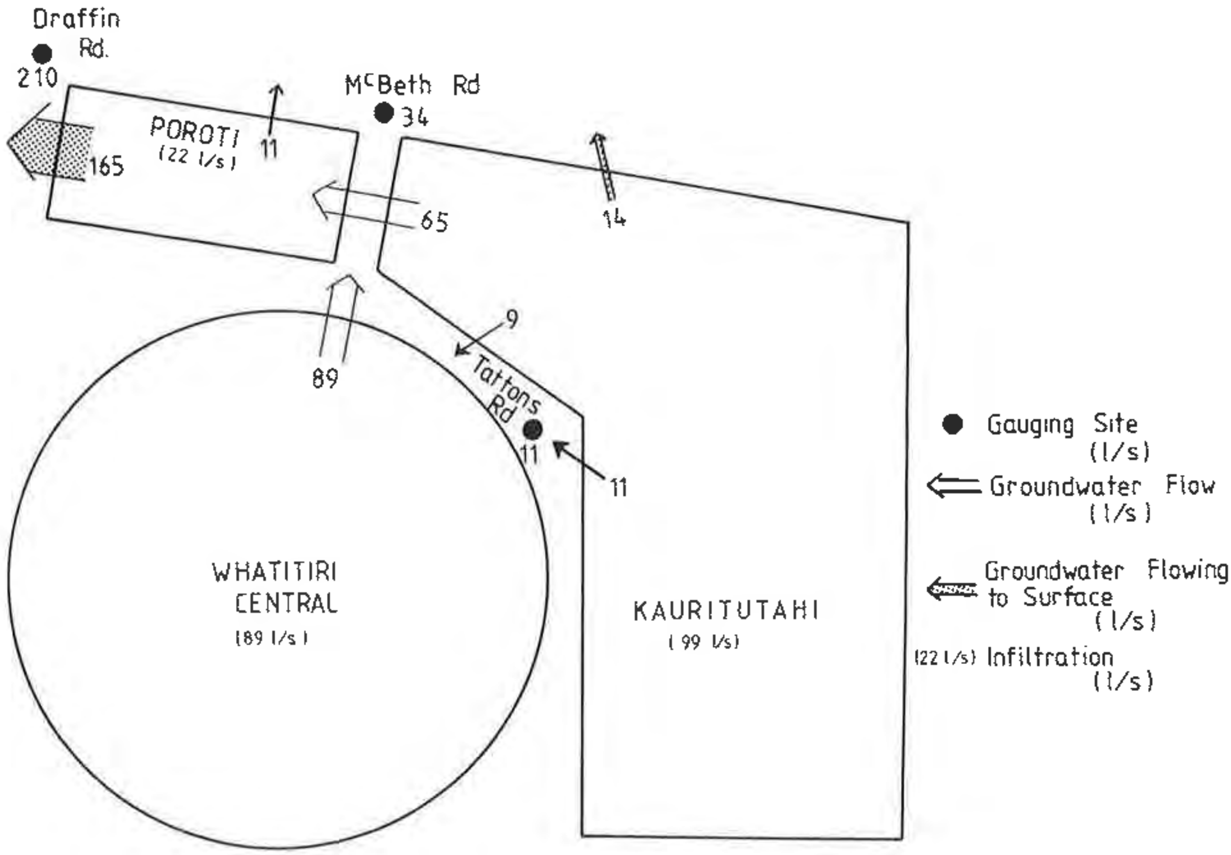


FIGURE 23 GROUNDWATER (1:5yr low flow) OF WHATITIRI CATCHMENT AREA

4.2.1 Continued

The Whangarei City Council takes a water supply from groundwater adjacent to the Poroti Springs bore (see Table 11). Any water taken from this site (Poroti Abstraction Site) reduces the flow at Fig Tree and Cutforths by the equivalent amount. This implies that the taking at the Poroti Abstraction Site intercepts the groundwater flow from the Whatitiri Central sub-catchment only.

The Kauritutahi sub-catchment area is not entirely covered by volcanics but encloses an area of impermeable sedimentary and alluvial material lying to the north of Maungatapere cone (see Figure 3). The eastern boundary of the Kauritutahi sub-catchment is not well defined but is assumed to lie near the north-south catchment divide indicated by the surface topography.

4.2.2 West Whatitiri

This small catchment area (about 4.5 square kilometres) lies to the west of the Whatitiri shield volcano and feeds the springs that discharge into the Karukaru Stream catchment. The discharge rates measured appear to be similar to both calculated discharge rate and groundwater flow, indicating that all net rainfall in this catchment infiltrates to groundwater.

4.2.3 South Whatitiri

This small catchment area (about 2.5 square kilometres) lies to the south of the Whatitiri catchment area. The discharge rates of the small springs and seepages at the southern margin are significantly smaller than the inferred discharge rate (see Table 18). The difference could be due to some sub-surface losses or a slight misplacement of the boundary with Whatitiri resulting in an over-estimation of the catchment area.

4.2.4 Southeast Maungatapere

This small catchment area (about 3.2 square kilometres) lies to the southeast of the scoria cone of Maungatapere and feeds the springs at the head of the Otakaranga Stream. Total infiltration rates and natural spring disharge rates for this areas show a similar imbalance to those for the South Whatitiri area; the explanations given for the differences at South Whatitiri might also hold for the Southeast Maungatapere area.

4.2.5 Maunu West

This is the third largest catchment area (about 6.2 ± 1.2 square kilometres) of the survey area. The position of the western boundary is uncertain, as stated previously in connection with the (common) eastern boundary of the Kauritutahi sub-catchment. The Maunu West catchment provides buffer storage and feeds the Maunu Springs at the southeastern boundary of the volcanics which flow to the Whakapai Stream.

There is good agreement between the calculated discharge, the measured discharge and the groundwater flow. Thus it appears that all net rainfall infiltrates to groundwater. Therefore it is unlikely that any significant sub-surface losses occur to the south of the volcanic boundary.

4.2.6 Maunu East

This catchment area (about 10 square kilometres) is the second largest in size of the catchments and supplies the water discharged by numerous springs and seepages to the Mokupara, Nihotetea and Te Hihi Streams.

As with the Whatitiri catchment, the groundwater flow is 60% of the calculated discharge rate, that is, 60% of the net rainfall infiltrates to groundwater. However, unlike the Whatitiri catchment the measured discharge rate is similar to the groundwater flow. This is most likely a result of inaccuracies in the method of determining mean natural flows (Qd).

4.3 WATER BALANCE

A water balance study was carried out for each catchment. This was based on the formula :

$$Q = A (R - ET)$$

where

Q = Annual Outflow from Catchment
R = Annual Rainfall
ET = Annual Evapotranspiration
A = Area of Catchment

The theoretical annual outflow (Qt) from each catchment as determined by the above formula was then compared to measured natural flows (Qd).

The mean annual rainfall was taken from the rainfall map (Figure 8). The mean annual evapotranspiration of 900 mm was used, as determined by French (1980).

TABLE 18

HYDROLOGICAL BALANCE

Catchment Areas	1 Whatitiri	2 West Whatitiri	3 South Whatitiri	4 S E Maungatapere	5 Maunu West	6 Maunu East
Area (km^2)	31.5 ± 1.2	4.5	2.5	3.2	6.2 ± 1.2	9.95
Mean measured natural discharge Q_d (l/s)	748	108	2.5 (?)	17.5 (?)	173	187
Mean groundwater flow (l/s)	390	93	10	15	180	150
Mean specific net rainfall (mm/yr)	660	580	640	812	786	805
Mean theoretical discharge Q_t (l/s) calculated from net rainfall	686.5	83	50.5	82.5	175	253.5
Maximum of Q_t (5 year period) (l/s)	799.5	100	59	94	205	289
Minimum of Q_t (5 year period) (l/s)	299	46.5	23	32	81	132.5
Difference $Q_t - Q_d$ (l/s)	-61.5	25	48	65	2	66.5

Means and Sub-totals for Catchment

Area of catchment: 59 km^2

Mean annual groundwater flow: 838 l/s

Measured mean annual natural discharge (Q_d): 1 236 l/s

Theoretical mean flow (Q_t): 1 331 l/s

Mean specific infiltration rate: 448 mm/yr

4.3 Continued

In the absence of any deeper outflow, the mean theoretical discharge (Qt) for the whole study area and for the individual catchments should be the same as the natural discharge rate (Qd) given by the mean discharge of springs at the volcanic perimeter and the mean stream discharges within the catchment fed by these springs (for example, Kauritutahi Stream). Mean natural discharge rates of individual discharge features were obtained from the mean of measured maximum and minimum discharge rates. The sites that were gauged are shown on Figure 11 and Table 16. Because of fluctuations in the mean annual precipitation and the incomplete gauging data, it is likely that the error of some of the sub-total discharge rates obtained might be as large as 30%, constituting the largest component of error in the balance study.

All data used for the balance study are listed in Table 18. It can be seen that there is a good agreement between the theoretical mean discharge of the catchment (Qt) (1 331 l/s) and the measured mean discharge (Qd) (1 236 l/s).

The difference between mean theoretical discharge (1 331 l/s) and the mean annual groundwater flow (838 l/s) is 493 l/s or 8.4 l/s/sq. km. It is assumed that this difference is runoff. Discrepencies between Qt and Qd for some sub-catchments may be partially explained by the fact that Qt values are related to the underground catchment boundaries, whereas it is the surface catchments which are relevant to runoff.

The agreement between Qt and Qd for the greater catchment areas of Whatitiri, Maunu West and Maunu East also implies that the areal extent of the individual catchments (A), as inferred from the geophysical study, is quite realistic. Furthermore, it can be inferred that any deeper sub-surface outflow from the catchment, if present, is rather small and does not constitute any significant water resource.

From the geohydrological setting, some sub-surface outflow had been postulated downstream from the Poroti Springs where the valley is infilled by coherent thin basalt flows (10 to 25 m thick). Subsequent drilling of two wells (Adams : N19/634964 and Hollier Poroti : N19/644954) showed however, that the groundwater flow in the volcanics is not significant. The same holds for the eastern end of the Maunu East catchment area where some potential outflow of groundwater could take place. Subsequent drilling and testing of one well (Puriri Park : N20/802948) however, indicated a rather poor hydraulic conductivity which would restrict any such outflow. For the management of the Maunu-Maungatapere-Whatitiri catchment, the contribution of outflows beyond the boundary of the volcanics can therefore be disregarded.

4.4 STORAGE CAPACITY

The "mean flow condition" concept used for the balance study is an idealised condition; in reality the mean annual infiltration rate can vary significantly between succesive years. The extreme values for the resulting total infiltration rates Qt for each catchment area, based on existing climatological records for a five yearly period, are listed in Table 18. For any enhanced management of the catchment, the storage buffer capacity of the volcanics at mean flow would be of importance. This parameter was derived from the estimated mean porosity of the volcanics and the volume of the saturated volcanics of a certain catchment area at mean flow where the upper boundary is given by the piezometric level at mean flow (Figure 21) and the lower boundary by the level of the sub-volcanic sediments (Figure 2a).

The mean porosity was obtained from measurements of core samples from three wells, namely Poroti (N20/653947), Clarkson (N20/664944) and Whatitiri No 2 (N20/686937) which gave a mean porosity of 10.7%. This value is similar to that of 11% determined from the interpretation of the true resistivity of the volcanics obtained from the resistivity soundings. The main uncertainty in determining the volume of the buffer capacity comes from the uncertainty of the piezometric level at "mean flow." This parameter is known only from one set of measurements (September 1979) in existing wells (see Figure 21). Additional information from the interpretation of sounding curves, which in many cases allowed the definition of the level of water-saturated volcanics, has also been used for the compilation of Figure 21; these soundings were taken during the autumn of 1979. In the following it will be assumed that the piezometric level at mean flow is similar to that shown in Figure 21.

Using this information it was found that the volume of the saturated volcanics of the Whatitiri sub-catchment is about 400 million cubic metres and that of the Kauritutahi sub-catchment about 260 million cubic metres. With a mean porosity of 10% for the volcanics, this indicates a total buffer storage at mean flow of about 66 million cubic metres for the Whatitiri catchment area (disregarding the contribution from the much smaller Poroti sub-catchment). The total average annual output of groundwater from the Whatitiri catchment is about 12 million cubic metres, ie about one sixth of the total buffer storage volume. The difference between total average output and total buffer volume appears to be smaller for the other catchment areas. More information about the mean piezometric level and mean porosity in these areas is however, required before representative buffer storage figures can be cited for the other catchment areas.

4.5 AQUIFER STRUCTURE

At present only up to one third (ie about 300 l/s) of the mean annual groundwater flow potential of the Maunu-Maungatapere-Whatitiri catchment is being produced and utilised (see section 6) and the balance study indicates that in theory, a greater usage rate of the groundwater in the catchment is possible, especially in view of the inferred buffer storage.

The question of whether any additional production is feasible away from the present major abstraction sites is rather complex and cannot clearly be answered from the data available at this stage. For a full discussion of the feasibility of groundwater production of the catchment, away from the present major production sites, the following information would be necessary :

a Average thickness (b) and average cross-section (S) of aquifer for a given piezometric level (say, at mean flow);

b Average cross-sectional flow rate (Q), or mean hydraulic conductivity (K)*, and hydraulic gradient (dz/dx) perpendicular to flow section;

c Actual hydraulic conductivity (K) or transmissivity (T)ǂ from representative test well sites.

In this report only a two-dimensional treatment of an idealised mean cross-sectional flow is attempted. It does however, allow a discussion of the magnitude of various parameters for which a one-directional "Darcy Flow" will be assumed.

* Hydraulic Conductivity (K) = the rate at which water can pass through a unit area of an aquifer under a unit gradient in m/day or $m^3/day/m^2$.

ǂ Transmissivity (T) = the rate at which water can pass through a unit width of an aquifer under a unit gradient in m^2/day or $m^3/day/m$. T = Kb (where b is the aquifer thickness)

4.5 Continued

The problem of a realistic model of the aquifer structure again is quite complex. Initially it was assumed that the whole section of the volcanics has similar hydrological properties, at least the section of the solid and partly fractured basalts which seem to be dominant in the test holes in the Whatitiri catchment. If this assumption holds, one would expect some agreement between the observed hydraulic conductivity (K), as given by the ratio of transmissivity (T) and total thickness of solid basalts (b), and the mean conductivity (Km) computed from one directional cross-sectional flow given by Darcy's Law, ie :

$$Km = \frac{Q}{S(dz/dx)}$$

where

Km = Mean Conductivity
Q = Flow Rate Through Aquifer
S = Cross-sectional Area of Aquifer
dz/dx = Hydraulic Gradient

At present the Whatitiri and Maunu East catchments are the only ones from which sufficient data is available to attempt an analysis.

4.5.1 Whatitiri

An assessment of the magnitude of K and Km of the aquifer at the Poroti Abstraction Site is given in Table 19. The width (l) of the cross-sectional area of the flow section, perpendicular to the inferred groundwater flow direction, was taken as 1 500 metres (Figure 21). Assuming an aquifer thickness of 10 metres, as indicated by the stratigraphic section (ie thickness of fractured basalt), this gives a cross-sectional area at mean flow of 15 000 square metres.

As shown in Table 19, the value of Km is 47 m/day, whereas pumping tests carried out at this site indicate a value of 400 m/day, ie nine times greater.

From the small elevation difference between the springs and the present abstraction site it can be inferred that the aquifer is also limited in vertical extent. In fact, from the linear regression formula on page 45 it can be shown that if the springs were at mean flow and the piezometric level dropped by 2 metres then the flow would be approximately halved. Assuming all this flow reduction can be attributed to a reduction in cross-sectional area (S), the aquifer thickness at mean flow must be approximately 4 metres. This approach also indicates K to be nine times higher than Km (see Table 19).

Since the errors in Q and dz/dx are probably not greater than 30%, the fact that K is nine times Km implies that the effective cross-sectional area (S) of the highly permeable aquifer at the Poroti Abstraction Site must be smaller by a factor of about 9 than that assumed so far. This indicates that the aquifer at the Poroti Abstraction Site must form a "channel" 150 metres - 200 metres wide within the basalt. A Km value for an aquifer thickness of 4 metres and width of 150 metres is also calculated in Table 18 and shows this model to best fit the observed data. The "channel structure" (from now on referred to as the "Poroti Channel") presumably outflows in the vicinity of the Poroti Springs.

This model also explains the absence of any significant groundwater flow in the downstream exploratory holes at Adams and Poroti West. The aquifer structure in the Poroti sub-catchment area is therefore significantly different from that of the basaltic catchment area at Mt Wellington (Auckland) where similar studies have shown that there is a good agreement between K and Km (about 100 m/day) assuming a constant conductivity for the whole cross-sectional area of the basalts (MSc thesis by G Roberts, 1980, University of Auckland).

TABLE 19

HYDRAULIC CONDUCTIVITIES FROM WELL DATA AND FROM ASSUMED UNIDIRECTIONAL FLOW IN WHATITIRI CATCHMENT AREA

Well	Poroti Abstraction	Poroti Abstraction	Poroti Abstraction	Clarkson (N20/664 944)	Whatitiri Wines (N20/676 935)
Subcatchment	Poroti	Poroti	Poroti	Poroti	Kauritutahi (?)
Observed transmissivity T (m^2/day)	$\sim 4 \times 10^3$	$\sim 4 \times 10^3$	$\sim 4 \times 10^3$	2.7×10^1	2.5×10^1
Assumed aquifer thickness b (m)	10	4	4	~20	~30
Hydraulic conductivity K (m/day)	~400	~1 000	~1 000	~1.35	~0.85
Inferred aquifer width (m)	1 500	1 500	150	1 750	1 000
Inferred cross-section S (m^2)	$\sim 1.5 \times 10^4$	$\sim 6 \times 10^3$	600	$\sim 3.5 \times 10^4$	$\sim 3 \times 10^4$
Mean hydraulic gradient $\frac{dz}{dx}$	1/50	1/50	1/50	1/100	1/75
Mean cross-section flow rate Q (= mean flow at "Fig Tree") (m^3/day)	1.4×10^4	1.4×10^4	1.4×10^4	1.4×10^4	1.03×10^4
Mean theoretical hydraulic conductivity K_m (m/day)	~47	116	~1 083	~40	~26

TABLE 20

HYDRAULIC CONDUCTIVITIES FROM WELL DATA AND FROM ASSUMED UNIDIRECTIONAL FLOW IN MAUNU EAST CATCHMENT AREA

Well	G Jeeves N20/787 034	Wade N20/761 945	Noonan N20/766 938	Hawken N20/781 942
Observed transmissivity T (m^2/day)	200	200	72	244
Assumed aquifer thickness b (m)	4	2.3	1	1
Hydraulic conductivity K (m/day)	50	87	72	244
Inferred aquifer width l (m)	1 500	1 500	1 300	3 500
Inferred cross-section S (m^2)	6 000	3 450	1 300	3 500
Mean hydraulic gradient $\frac{dz}{dx}$	$\frac{1}{50}$	$\frac{1}{20}$	$\frac{1}{7}$	$\frac{1}{30}$
Mean cross-section flow rate Q (m^3/day)	10 000	10 000	10 000	10 000
Mean theoretical hydraulic conductivity (m/day) K_m	84	60	54	86

4.5.1 Continued

If the large hydraulic conductivity in the Poroti sub-catchment were limited to a "channel" one could postulate that the conductivity in areas of the sub-catchment outside the Poroti Channel should be significantly less. Indeed this holds for the Clarkson bore (N20/664949) where pumping tests indicate a conductivity (K) of only 1.3 m/day, whereas a homogeneous aquifer with a thickness of about 20 metres should exhibit a mean conductivity (Km) of a least 40 m/day. Similar results also hold for the Whatitiri Wines bore (N20/676935) which lies at the western margin of the Kauritutahi sub-catchment (see Figure 11). These results clearly confirm that the permeability of the volcanics in the whole catchment is highly variable.

4.5.2 <u>Maunu East</u>

The hydraulic parameters for four bores tested in the Maunu East catchment are shown in Table 20. In this case the bore logs indicate thinner aquifers than was assumed in the Whatitiri catchment, with thickness ranging from 1 to 4 metres.

It can been seen that in three out of four bores tested, there is good agreement between K and Km. In the fourth instance the observed conductivity is larger by a factor of three. It is unlikely that errors in the determination of the conductivity values can explain all this difference. Therefore the implication is that the effective cross-sectional area (S) of the aquifer has been over-estimated by three times. However, a reduction in the effective width of the aquifer by a factor of three would make it 1 200 metres wide which is too wide to be termed "a channel" of the type apparent at Poroti. These results are similar to those obtained by Roberts at Mt Wellington.

The close agreement between K and Km points to a generally more homogeneous aquifer structure than in the Whatitiri catchment. Therefore the groundwater in this catchment is probably more easily accessible than in the Whatitiri catchment.

4.6 EXTENT OF GROUNDWATER RESOURCES

The annual flow of groundwater within the study area has been calculated as 26 million cubic metres. This is assumed to be the annual input to groundwater by rainfall. Within the Whatitiri catchment the annual groundwater flow is 12 million cubic metres, and the buffer storage has been calculated to be equivalent to six times this amount. However, the buffer storage calculation was made assuming that the saturated volcanics were homogeneous, and it was subsequently shown that this is not the case.

Taking all points into consideration, it appears that a more dynamic management of the catchment, which is more tailored to the annual mean flow of groundwater within the catchment rather than to low flow, could be feasible. From the data of the balance study, additional abstraction from the Whatitiri sub-catchment, the Maunu West area and probably the Maunu East catchment appears to be possible. A better understanding of the aquifer structure in these catchments is required, however, before any such plans can be realised.

5 WATER QUALITY

Over the periods March/April, September/October 1980, and December/January 1981-82, the waters from 11 selected sites of the study area were sampled to assess basic water quality. The sites chosen represent a cross section of typical land use and geomorphology. The location of these sites is shown in Figure 24.

The parameters tested included field measurements of temperature and dissolved oxygen, and laboratory analysis of pH, conductivity, turbidity, nitrate, phosphate, ammonia and the coliform bacteria (both total and faecal). Methods of analysis are shown in Appendix II.

Based on the criteria contained in the schedules to the Water and Soil Conservation Act 1967 (see Appendix III) each site was sampled five times within a thirty day period. Median values were then extracted to form a summary of data. This is the data reproduced on the accompanying Table 21. Also in accordance with these schedules, an attained standard, labelled A, B, C, or D has been given to each site for that particular sampling run.

In general, the water quality appears to be of a fairly high standard - either B or C, which is consistent with the land use of the area and comparable to similar regions of Northland.

An exception noted was the December/January 1981-82 series of the Kauritutahi Stream, where a discharge of cowshed effluent resulted in a depressed oxygen level and high coliform count. All the other free running streams however showed well saturated oxygen levels.

The nutrients, ammonia and phosphate appear only in trace quantities, but nitrate levels varied considerably from 1.6 mg/l in the Wheki Stream to a relatively high 11 mg/l in the Otaika Stream tributary. This variation could be explained by differences in land use.

TABLE 27 - SHOWING WATER QUALITY IN THE MAUNU - MAUNGATAPERE - WHATITIRI AREA

Site	1 Raumanga Stream @ City Weir			2 Te Hihi Stream @ SH 14			3 Otaika Stream @ Cemetery Road			4 Mokupara Stream @ Otaika Valley Road			5 Kauritutahi Stream @ Poroti Road			6 Wheki Stream @ Wheki Road		
Map Reference	N20/808945			N20/797951			N20/754911			N20/783906			N20/688929			N24/679 69		
Sampling Period*	a	b	c	a	b	c	a	b	c	a		c	a	b	c	a	b	c
Temperature °C	15.5	14.0	18.0	15.0	13.5	18.0	15.0	15.5	19.0	14.5		17.5	15.5	14.0	20.0	15.0	13.5	20.0
Dissolved O_2 mg/l			9.4			8.5			7.9			9.2			1.7			3.8
pH	6.9	7.1	7.8	7.0	7.3	7.4	7.1	7.3	7.5	7.2		7.7	6.8	7.2	6.9	6.3	7.1	6.6
Conductivity umho /cm @ 25°C	170	153	200	130	118	161	165	145	210	180		207	140	123	161	105	85	127
Turbidity NTU			2.3			3.5			4.8			3.6			4.7			12.5
NO_3 mg/l	10.3		7.5	6.5		6.2	10.5		7.1	11.7		8.2	10.9		7.9	1.6		3.3
PO_4 mg/l	tce		-	tce		-	tce		-	tce		-	tce		-	0.04		-
NH_3 mg/l	tce		-	tce		-	tce		-	0.05		-	0.05		-	0.1		-
Total Coliform No/100 ml	760	1080	600	900	1000	2400	1140	1000	2440	1020		1520	860	740	2640	1060	980	750
Range) High	980	2000	2660	1120	3750	20K	1440	3300	4480	1660		1780	2380	1800	TNTC	1440	1600	1480
Range) Low	560	550	220	500	400	118	820	800	760	620		360	520	550	1150	380	500	260
Faecal Coliform No/100 ml	180	200	360	400	700	1360	440	500	580	340		300	260	200	225	40	650	120
Range) High	540	850	440	640	2150	15.4K	1500	3000	3180	420		700	2060	400	10K	100	1050	550
Range) Low	120	150	140	220	300	1240	240	380	220	180		220	160	100	50	40	100	20
Attained Standard (coliforms)	C	C	B	B	B	B	B	B	B	B		B	B	C	B	C	B	C

TABLE 21 - Continued

Site	7 Karukaru River @ Farm crossing			8 Waipao Stream @ Draffin Road			9 Kauritutahi Stream Tributary @ McBeth Road			10 Kaitara Stream @ Kara Road			11 Otaika Stream Tributary @ Concrete Slab		
Map Reference	N19/627904			N19/640963			N20/669954			N20/721976			N20/746914		
Sampling Period*	a	b	c	a	b	c	a	b	c	a	b	c	d	e	f
Temperature °C	16.0	14.5	20.0	15.5	14.5	19.0	16.0	13.5	20.0	15.0	13.5	19.5	15.5	19.0	19.0
Dissolved O_2 mg/l			8.0			7.4			8.0			8.3	9.3		8.1
pH	7.1	7.2	7.2	6.9	7.2	7.1	6.9	7.3	7.3	7.0	7.3	7.4	7.1	6.8	7.3
Conductivity umho/cm @ 25°C	130	115	149	130	120	155	140	115	155	115	100	140	172	170	200
Turbidity NTU			6.0			2.2			6.3			5.3			11
NO_3 mg/l	2.1		3.5	9.8		7.2	5.5		3.5	5.6		5.1			
PO_4 mg/l	tce		-	0.04		-	tce		-	tce		-			
NH_3 mg/l	tce		0.05	tce		tce	0.08		0.08	tce		-			
Total Coliform No/100 ml	560	1100	1060	900	750	940	1560	1900	1700	760	780	640	4000	4700	4050
Range } High	680	9200	3020	1080	4100	2260	2960	2250	9520	1120	1650	2160	11.2K	TNTC	TNTC
Range } Low	380	550	760	400	200	500	900	400	1260	580	350	62	350	1200	1020
Faecal Coliform No/100 ml	60	240	300	60	200	200	580	1100	620	180	300	360	350	1700	1100
Range } High	180	6000	340	140	1250	360	640	1680	980	480	650	400	6100	12.8k	8400
Range } Low	40	100	120	40	150	20	280	400	460	60	200	360	150	450	440
Attained Standard (coliforms)	C	B	B	C	C	C	B	B	B	C	B	B	B	B	E

*Sampling Periods : a) 31.03.80 to 30.04.80
b) 10.09.80 to 16.10.80
c) 17.12.81 to 14.01.82
d) 31.10.79 to 26.11.79
e) 18.02.80 to 26.02.80
f) 15.02.82 to 22.03.82

Notes : 1) Values given are median values of 5 samples taken over each period shown.
2) tce = trace quantity < 0.02 mg/l K = x1000
- = below limits of detection
TNTC = Too Numerous To Count

6 PRESENT WATER USE

The quantity of water authorised to each water use category within each catchment of the study area is shown in Table 22. This shows that the total amount allocated at present is 626 l/s, 534 l/s of this is from stream flow, 57 l/s from bores and the remaining 35 l/s from dams.

The largest user of water within the area is horticultural irrigation which takes 152 l/s. This quantity is sufficient to irrigate 525 hectares. The other major user is public water supplies which takes 116 l/s. Most of the remaining allocation is used by industry with statutory (farm/domestic) users taking the least.

6.1 IRRIGATION

6.1.1 Regional Water Board Policy

The Regional Water Board policy on allocation of water for irrigation is detailed in Appendix IV. However, the points most relevant to this section are :

- Allocations are made on the basis of 25 cubic metres per day per hectare
- Allocations are made in line with immediate requirements but with provision for upwards variations in quantity in line with development
- The potential needs of existing right holders are taken into account when considering subsequent applications
- Storage of irrigation water is encouraged in areas of high demand relative to available water
- Groundwater extractions are encouraged providing it has been demonstrated that surface flows are not detrimentally affected

6.1.2 Irrigation Demands

The Regional Water Board considers the potential needs of existing right holders before adjudicating on subsequent applications. Consequently, although this section is considering "Present Irrigation Demands" the discussion centres around the quantity that is committed to existing right holders, ie their potential needs. The quantity actually allocated under existing rights is often less. The difference between that currently allocated and that committed is shown in detail in Table 23.

6.1.2.1 Waipao Stream Catchment

Table 22 shows that a maximum of 384 l/s is committed from this stream. The 269 l/s committed to horticulture includes 245 l/s which the Whangarei County Council is authorised to provide for this purpose via a water right held by the Whangarei City Council at Poroti Springs.

Upon implementation of the Maungatapere Irrigation Scheme (see section 7.1) the authority held by the Whangarei County Council to provide irrigation water within the Maungatapere Irrigation District will be transferred to the Minister of Works and Development.

A further 19 l/s is committed from groundwater within the catchment and 7 l/s from dam storage bringing the total water committed to horticulture in the Waipao Stream catchment to 295 l/s, sufficient to irrigate 1 020 hectares.

6.1.2.2 Karukaru Stream Catchment

The Karukaru Stream has its origin as a series of strong springs around the western base of the Whatitiri volcanic cone. Table 22 shows that water committed to horticulture accounts for 16 l/s in this catchment.

No bores in this catchment supply irrigation water and dam storage contributes only a small amount. Table 22 shows a total of 17 l/s committed to irrigation, this being adequate for 59 hectares of horticultural crops.

6.1.2.3 Wheki Stream Catchment

The Wheki Stream headwaters have proven to be an unreliable source of water for irrigation. Consequently all such needs are supplied from groundwater or dam storage.

These are 4 l/s committed from bores and 2 l/s from dams. This is sufficient to irrigate a total of 21 hectares.

6.1.2.4 Otakaranga Stream Catchment

Similarly flows in the headwaters of the Otakaranga Stream are insufficient for horticultural irrigation and none has been allocated from the stream itself. On the other hand 5 l/s have been committed from bores and 8 l/s from storage. Thus the area able to be irrigated from these sources total 45 hectares.

6.1.2.5 Otaika Stream Catchment

Table 22 shows that 13 l/s is committed to horticulture from the Otaika Stream, sufficient to irrigate 45 hectares. A further 6 l/s is used for pasture irrigation. Bores and dams also provide 2 l/s for irrigation within this catchment.

6.1.2.6 Mokupara Stream Catchment

From Table 22 it can be seen that the Mokupara Stream has committed from it 7 l/s, this being sufficient to irrigate 24 hectares. No dams in this catchment supply irrigation water, but one bore supplies approximately 1 l/s towards horticultural needs.

6.1.2.7 Nihotetea Stream Catchment

The Nihotetea Stream itself as shown in Table 22 has only 2 l/s committed to irrigation. However, the amount committed from bores is substantially greater at 13 l/s. These two sources are capable of irrigating 52 hectares. There is no dam storage of irrigation water in this catchment.

6.1.2.8 Te Hihi Stream Catchment

The Te Hihi Stream is committed to supply irrigation water at the rate of 5 l/s. A further 3 l/s is committed from bores and combined these two sources can irrigate 28 hectares.

6.1.2.9 Kaitara (Takahie) Stream Catchment

The Kaitara Stream has 5 l/s committed from it for irrigation, this is sufficient for 17 hectares of horticulture. A dam in this catchment will also supply water to a further 50 hectares of horticulture, although most of this will be in the Mokupara Stream catchment.

TABLE 22 - Showing Water Use from Various Sources in Each Catchment within the Maunu-Maungatapere-Whatitiri Area with Values in Litres Per Second

	Stream	Bore	Dam	Total
Waipao :				
Public Water Supply	* 110	0	0	110
Irrigation - Horticulture	* 269	19	7	295
Statutory	5	5	0	10
	384	24	7	415
Karukaru :				
Irrigation - Horticulture	16	0	1	17
Statutory	9	1	0	10
	25	1	1	27
Wheki :				
Irrigation - Horticulture	0	4	2	6
Statutory	1	1	0	2
	1	5	2	8
Otakaranga :				
Irrigation - Horticulture	0	5	8	13
Statutory	1	1	0	2
	1	6	8	15
Otaika :				
Public Water Supply	† 66	0	0	66
Industrial	13	0	0	13
Irrigation - Horticulture	13	1	1	15
- Pasture	6	0	0	6
Statutory	2	1	0	3
	100	2	1	103

TABLE 22 Continued

	Stream	Bore	Dam	Total
Mokupara :				
Irrigation - Horticulture	7	1	0	8
Statutory	1	1	0	2
	8	2	0	10
Nihotetea :				
Irrigation - Horticulture	2	13	0	15
Statutory	1	1	0	2
	3	14	0	17
Te Hihi :				
Irrigation - Horticulture	5	3	0	8
- Greens	0	0	1	1
Statutory	1	0	0	1
	6	3	1	10
Kaitara (Takahie) :				
Irrigation - Horticulture	5	0	‡ 15	20
Statutory	1	0	0	1
	6	0	15	21
TOTAL FOR ALL CATCHMENTS	534	57	35	626

* Whangarei City Council maximum combined groundwater/surface take at Poroti Springs

¥ Whangarei City Council Maunu Springs Take

‡ Mostly used in Mokupara Catchment

TABLE 23

DESIGN DROUGHT FLOW LESS AUTHORISED DRAWOFF FOR VARIOUS STREAM CATCHMENTS

Catchment	Whatitiri	West Whatitiri	South Whatitiri	Southeast Maungatapere	Maunu West	Maunu East		
Site	Waipao @ Draffin Rd	Karukaru @ Farm Crossing	Wheki @ Wheki Rd	Otakaranga below confluence	Otaika @ Quarry	Mokupara @ bottom scarp	Nihotetea @ Austin Rd 2	Te Hihi @ Health Camp
Map Reference	N19/642963	N19/627903	N24/679889	N20/795950	N20/754912	N20/765924	N20/790929	
Design Drought Flow (l/s)	210	45	4.0	4.3	130	34	11	6.2
Statutory (l/s)	5	9.3	0.5	0.7	1.8	0.8	0.7	0.8
Requirements of Existing right holders (l/s)	162*	4.5	0	0	88.4	4.3	2.1	3.7
Remaining Flow (l/s)	143	31.2	3.5	3.6	39.8	28.9	8.2	1.7
Potential Requirements of Existing right holders (l/s)	379*	15.5	0	0	97.1	6.9	2.1	5.0
Remaining Flow (l/s)	78	20.0	3.5	3.6	31.1	26.3	8.2	0.4
Percentage Remaining Flow	37% ‡	45%	88%	84%	24%	77%	75%	7%
Groundwater Commitment (l/s)	24	1	5	6	2	2	14	3

Total Surface Resource 445 l/s   Total Remaining Flow 171 l/s (38%) Groundwater Committed 57 l/s

* Includes WCC Poroti Springs Groundwater Take   ‡ Minimum Flow Requirement

6.2 PUBLIC WATER SUPPLY

Within the study area there are two sites from which water is taken for public water supply.

The Whangarei City Corporation has recently been granted water rights which allow the taking of a maximum total of 360 l/s from the Poroti Springs abstraction site and from Poroti Springs at Cutforths for public water supplies within the Whangarei City and County. The quantity authorised for these purposes is reduced to about 100 l/s during the summer months.

The total quantity taken by the Whangarei City at Poroti is shown under "surface" in Tables 22 and 23, although some is taken from groundwater. This is because the pumping from groundwater directly affects stream flow.

The Whangarei City Corporation also holds a water right to take water at a maximum rate of 94 l/s for public water supply from Maunu Springs. However, the mean flow from these springs is approximately 66 l/s and is the figure included in Tables 22 and 23.

6.3 INDUSTRIAL

The only industrial user in the area is the Northland Co-op Dairy Company Ltd taking a maximum of 13 l/s in total from two tributaries of the Otaika Stream for general dairy factory use. After use in the Dairy Company plant, almost all the waste water is spray irrigated onto Company farm land in the Waipao Stream catchment.

6.4 WASTE DISPOSAL

The largest user of water for waste disposal is the dairy industry. There are approximately 4 400 cows in 31 herds in the study area. Approximately 50% of the dairy farms and also the dairy factory dispose of their waste water using land application methods. However, the remaining dairy farms discharge waste to streams after treatment. Based on a rate of 45 litres/cow/day, 100 cubic metres per day is discharged to streams in the area.

The Regional Water Board requires this waste to be substantially free of suspended solids, grease and oil. This standard is usually obtained by treating the waste in oxidation ponds before discharging.

6.4 Continued

Generally waste disposal is not a major user of water resources within the study area. This coupled with improved treatment methods means that no major problems are envisaged in the future. However, should there be any significant processing of horticultural crops, particular attention would need to be given to waste disposal in order to maintain water quality.

6.5 FISHERIES, RECREATIONAL AND ECOLOGICAL NEEDS

No surveys have been carried out in the study area to determine a detailed inventory of the flora and faunu present in the various streams. Taking into account accessibility and suitability of the streams themselves it is unlikely that any game fish are taken by recreational fisherman. However, eels are taken from some streams on a commercial basis.

In catchments of high demand relative to available water resources the Regional Water Board dictates that a minimum of 40% of the design drought flow remains in the stream at any one time to satisfy ecological and recreational demands.

Very little recreational use is made of the streams in the study area. This is probably due to the fact that most of the streams are relatively small and inaccessible as most flow through private farm land. A scenic walkway exists in bush adjacent to parts of the Otaika Stream on the Otaika Valley Road.

6.6 IMPACT OF PRESENT WATER USE

6.6.1 Surface Resources

Table 23 shows the quantity currently allocated from resources in the study area. Also shown is the quantity committed to existing right holders to allow for planned further development. These quantities are then compared to the design drought flow of the respective streams.

From the table it can be seen that there is 171 l/s uncommitted from streams in the study area. This is 38% of the design low flow. It is considered that the reduction in stream flow results in no significant detriment to the stream ecology.

The Te Hihi Stream has almost all the drought flow already committed. But of the larger streams, the Otaika Stream has the least flow remaining during droughts (24%). The Karukaru Stream has 45% remaining and the Waipao Stream 37%.

6.6.2 Groundwater Resources

At present there is 57 l/s committed from bores in the study area. This figure does not include the 50 l/s taken from the Poroti Springs bore by Whangarei City Corporation during low flow periods because this directly influences spring flow and therefore has been treated as a surface take.

In fact all groundwater takes will affect stream flow eventually. The hydraulic conductivity figures discussed in the "Geohydrology" chapter indicate that groundwater is flowing at rates ranging from 1 m/day to several hundred metres per day in the Whatitiri catchment and less that 100 metres per day in the Maunu area.

Therefore depending on the distance from a stream of a groundwater take the stream flow will be influenced either days or months later. It appears likely that streams in the Maunu area will be influenced approximately two weeks after the onset of groundwater pumping. Therefore during extended drought periods the affect of groundwater takes on stream flow in the area is likely to be significant.

The quantity of groundwater taken is only a small portion of the buffer storage of the area.

7 FUTURE WATER USE

7.1 IRRIGATION

Within the Maunu-Maungatapere-Whatitiri area there are 3 000 hectares of soils which are considered highly suitable for horticulture. The lack of sufficient water in the area is hindering horticultural development and consequently landowners of the region have requested that Ministry of Works and Development investigate the viability of an irrigation scheme.

A Feasibility Report has been published and approval in principle of the Scheme by Government is now awaited. The Feasibility Report states that the proposed Scheme will require a maximum of 1 030 l/s. It also proposes that as much of this as possible will be pumped from the Poroti Springs at Cutforths (N20/652954). However, it is now planned to take from the Waipao Stream near its confluence with the Wairua River. The flow in the Waipao Stream at this point is about the same as at Draffin Road.

In a report assessing the water availability at Poroti Springs and predicting the increase in irrigation demand within the proposed Maungatapere Irrigation District, the Ministry of Works and Development has produced Table 24 showing the increase should the Scheme go ahead.

Table 24 is based on an increase of horticultural development of 200 hectares per year and assumes irrigation water is taken at a constant rate over 24 hours.

TABLE 24 - Showing Cumulative Flow Rate in Litres Per Second Determined For :
i Daily Irrigation Demand Spread Evenly Over 24 Hour Period
ii Land Development Rate of 200 hectares/year

Irrigation Season	Nov	Dec	Jan	Feb	Mar
1982/83	9	18	21	18	9
1983/84	19	32	36	31	18
1984/85	35	51	57	50	30
1985/86	56	76	85	73	47
1986/87	98	123	135	119	80
1987/88	143	173	189	166	116
1988/89	191	228	248	219	154
1989/90	249	294	318	281	200
1990/91	307	360	388	344	246
1991/92	365	425	459	407	292
1992/93	424	491	529	470	338
1993/94	482	557	600	533	384

Should the Maungatapere Irrigation Scheme not be approved or be delayed for a substantial period, development of horticulture in the Maungatapere area would be limited by the lack of adequate water resources.

7.2 PUBLIC WATER SUPPLY

The Whangarei City Council has produced Table 25 showing the anticipated summer demand from Poroti Springs.

TABLE 25 - Showing Whangarei City Council Anticipated Public Water Supply Demands from Poroti Springs in Litres Per Second

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1983	69	81	84	81	69	64	52
1985	73	86	88	86	73	66	54
1987	76	89	91	89	76	69	58
1989	81	93	96	93	81	73	60
1991	84	97	101	97	86	76	64
1993	88	102	105	102	90	81	66
1995	93	107	109	107	95	84	69
1997	97	111	116	111	100	88	73
1999	102	118	122	118	104	93	76
2001	107	124	127	124	109	97	81

This table is based on a 2.5% annual increase and shows that the maximum demands from Poroti Springs occur during December. The demands during that month are currently 84 l/s with an anticipated increase to 127 l/s in 2001. This does not take into account the possibility of a major water using industry being connected to the City supply.

Areas of potential horticultural development are also potentially areas of high demand for a public water supply of potable water as the population in these areas increase. It is estimated that for every 100 hectares of horticulture that is developed, 10 cubic metres per day of potable water is needed.

Within the proposed Maungatapere Irrigation District, increased demands for potable water may fall on the Whangarei City Corporation's Poroti Springs supply. However, the quantities of water required for domestic supply in the County will always be dwarfed by the need of Whangarei City.

7.3 INDUSTRIAL USE

It is likely that the Northland Co-op Dairy Co Ltd will move its operation from Maungatapere in the future. However, it is possible that a food processing industry will develop along with horticulture in the area. Therefore, it is unlikely that there will be a decline in the amount of water used by industry in the area.

7.4 IMPACT OF FUTURE DEMANDS

Table 24 and 25 show that should the Maungatapere Irrigation Scheme proceed immediately the amount of water required for irrigation and Whangarei City will equal the design drought flow of the Waipao Stream by 1988. Thus the Maungatapere Irrigation Scheme will result in a huge increase in water demand. This demand will be placed on the Wairua River and would result in significantly reduced summer flows from the Waipao Stream confluence to the Mangakahia River confluence 10 kilometres downstream. The Power Station, owned by Wilson's Portland Cement Ltd, 2 kilometres downstream of the Waipao Stream confluence would have a reduced generation capacity over summer, however, a minimum flow condition on any water right would limit any impact.

The implementation of the Maungatapere Irrigation Scheme will reduce irrigation demands almost totally in the other catchments of the study area. Some demands will still exist on the Te Hihi and Kaitara Streams.

8 FURTHER WORK REQUIRED

The most useful further work that could be done, would be an attempt to locate the areas where maximum quantities of groundwater can be extracted, ie "channels." The best way to do this would be to determine an accurate piezometric contour of the area since the piezometric level would be slightly depressed over a channel. This would be a very time consuming and costly exercise especially if it became necessary to sink further bores.

Further pump testing of aquifers in the area would also be useful in understanding the groundwater of the area.

It is unlikely that further work would be cost effective unless, as yet unforseen demands for groundwater make it necessary.

ACKNOWLEDGEMENTS

The assistance of the following organisations in the preparation of this report is gratefully acknowledged :

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Geology Department - University of Auckland

N Z Meteorological Service

Water and Soil Division - Ministry of Works and Development (Whangarei Residency)

Whangarei City Council

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Appendices

APPENDIX I

Mean Daily Discharge from Poroti Springs at Cutforths

determined from groundwater levels

DAY	JAN	FEB	MAR	APR	MAY	JUN	JLY	AUG	SEP	OCT	NOV	DEC	
1	396	330	341	389	395	343	340	421	419	427	386	320	
2	395	320	341	390	394	341	343	422	415	426	384	325	
3	393	311	342	391	393	339	346	422	397	425	382	321	
4	392	301	343	391	391	337	348	423	378	423	380	316	
5	391	295	344	392	390	335	351	424	359	422	378	311	
6	389	298	346	393	389	334	354	424	340	420	376	306	
7	388	303	347	393	388	332	357	424	321	419	375	301	
8	387	307	348	394	387	330	360	424	302	419	373	296	
9	384	312	350	394	386	328	363	424	290	418	371	291	
10	382	316	351	394	385	327	367	424	306	418	369	281	
11	379	321	352	394	384	325	370	424	325	417	368	272	
12	377	325	354	395	383	323	374	424	344	417	366	263	
13	375	325	357	395	382	321	377	423	363	416	365	253	
14	372	326	359	395	380	319	381	423	382	416	363	244	
15	370	326	361	395	378	317	384	422	400	414	362	234	
16	370	327	363	396	376	315	388	422	416	413	360	226	
17	371	327	365	396	374	314	391	421	419	412	358	222	
18	371	328	367	397	372	315	394	420	421	410	355	218	
19	372	328	369	397	371	318	397	420	423	409	343	214	
20	372	329	370	398	369	320	400	420	425	407	331	210	
21	373	331	371	398	367	322	403	419	427	406	319	206	
22	373	332	373	399	365	324	406	419	428	404	307	202	
23	371	333	374	399	363	326	408	418	430	403	295	201	
24	369	335	376	399	361	328	410	418	430	401	283	209	
25	367	336	377	399	359	330	411	417	430	400	274	218	
26	365	337	379	398	357	332	413	417	430	398	281	227	
27	363	338	381	398	355	333	415	417	429	396	289	236	
28	361	339	382	398	352	335	416	418	429	395	297	244	
29	357	340	384	398	350	337	418	418	429	393	304	253	
30	348		386	397	348	338	419	418	429	390	312	256	
31	339		387		346		420	418		388		234	
MIN	339	295	341	389	346	314	340	417	290	388	274	201	201
MEAN	375	323	363	395	374	328	385	421	391	410	344	255	364
MAX	396	340	387	399	395	343	420	424	430	427	386	325	430

(pumping) — FEB, days 4–9
(pumping) — SEP, days 5–10
(pumping) — DEC, days 20–25

TIDEDA 14/01/83

DAILY MEANS YEAR=1973 SITE=5471001 ITEM= 1 RATING NOT APPLIED
DSN=WTMND0.SFLOW.DATA VER= 1 14/01/83

DAY	JAN	FEB	MAR	APR	MAY	JUN	JLY	AUG	SEP	OCT	NOV	DEC	
1	262	211	187	169	154	144	166	306	342	359	335	303	
2	260	211	187	168	154	144	166	309	343	359	333	302	
3	258	210	187	168	154	144	167	311	344	359	332	301	
4	256	209	187	167	154	143	167	314	345	358	331	300	
5	254	209	186	166	153	143	168	317	346	358	330	299	
6	252	208	186	165	153	143	168	320	347	358	329	298	
7	250	206	185	164	153	144	169	322	347	358	328	297	
8	248	205	184	164	153	144	169	323	348	357	327	296	
9	246	204	183	163	152	144	170	325	349	357	325	296	
10	245	202	182	162	152	144	170	326	349	356	324	295	
11	243	201	181	162	151	145	173	327	350	355	323	294	
12	242	199	180	161	151	145	175	329	351	355	322	293	
13	241	198	179	161	150	147	178	330	352	354	321	293	
14	239	197	178	160	149	149	180	331	352	353	320	292	
15	238	196	177	160	149	151	182	331	353	353	319	292	
16	237	196	177	159	149	153	185	332	354	352	317	291	
17	234	195	176	159	149	155	189	332	354	351	316	290	
18	232	194	175	159	149	157	198	332	355	350	315	290	
19	230	194	175	158	148	159	208	332	356	348	314	289	
20	228	193	174	158	148	160	218	333	356	347	313	289	
21	225	192	174	158	148	160	228	333	357	346	312	288	
22	223	191	173	158	148	161	238	334	357	345	311	288	
23	221	191	173	157	148	161	248	335	358	344	310	287	
24	220	190	172	157	147	162	258	335	358	343	309	286	
25	219	189	172	157	147	162	264	336	359	342	309	286	
26	217	189	171	156	146	163	271	337	359	341	308	286	
27	216	188	171	156	146	164	278	337	359	340	307	285	
28	215	188	171	155	145	164	284	338	359	339	306	285	
29	214		170	155	145	165	291	339	359	338	305	284	
30	213		170	154	145	165	297	340	359	337	304	284	
31	212		169		144		303	341		336		283	
MIN	212	188	169	154	144	143	166	306	342	336	304	283	143
MEAN	235	198	178	161	149	153	211	329	353	350	319	292	244
MAX	262	211	187	169	154	165	303	341	359	359	335	303	359

-TIDEDA 14/01/83-

DAILY MEANS YEAR=1974 SITE=5471001 ITEM= 1 RATING NOT APPLIED
DSN=WTMND0.SFLOW.DATA VER= 1 14/01/83

DAY	JAN	FEB	MAR	APR	MAY	JUN	JLY	AUG	SEP	OCT	NOV	DEC	
1	283	243	206	183	201	198	272	318	375	374	350	296	
2	282	242	205	182	202	198	274	320	375	374	349	294	
3	281	240	205	183	202	197	277	321	376	374	347	292	
4	280	238	204	183	203	197	279	323	376	374	345	289	
5	279	237	203	184	204	199	281	325	376	373	344	287	
6	279	235	202	184	204	201	283	326	376	373	342	285	
7	278	234	201	185	205	203	286	329	377	373	341	283	
8	277	233	200	185	205	205	288	331	377	373	339	280	
9	275	231	199	186	205	207	290	333	377	372	338	278	
10	274	230	199	185	205	209	292	335	377	371	336	276	
11	273	228	198	185	204	212	294	338	377	370	334	274	
12	271	227	197	184	204	216	296	340	377	369	333	272	
13	270	226	196	184	204	221	298	342	377	368	331	270	
14	268	224	196	183	204	225	300	345	376	367	329	268	
15	267	223	195	182	203	230	301	347	376	366	327	266	
16	266	222	195	182	203	234	303	350	376	365	325	265	
17	265	220	194	184	202	239	304	352	376	364	323	263	
18	263	219	193	185	202	243	305	354	376	363	322	261	
19	262	218	193	187	201	246	306	357	376	362	320	259	
20	261	217	192	188	200	248	307	359	376	362	318	257	
21	260	215	191	190	200	251	308	361	375	361	316	255	
22	259	214	190	192	200	254	309	363	375	360	314	253	
23	257	213	189	193	200	256	310	365	375	359	312	252	
24	256	211	189	194	200	259	311	367	375	358	310	250	
25	254	210	188	195	199	261	312	369	375	358	308	248	
26	253	209	187	196	199	263	312	370	375	357	306	246	
27	251	208	186	197	199	265	313	372	375	356	304	245	
28	249	207	185	198	199	267	314	373	374	356	302	243	
29	248		185	199	199	269	314	373	374	355	300	241	
30	246		184	200	198	271	315	374	374	353	298	239	
31	245		183		198		317	374		352		238	
MIN	245	207	183	182	198	197	272	318	374	352	298	238	182
MEAN	266	224	195	188	202	232	299	349	376	365	325	265	274
MAX	283	243	206	200	205	271	317	374	377	374	350	296	377

TIDEDA 14/01/83

DAILY MEANS YEAR=1975 SITE=5471001 ITEM= 1 RATING NOT APPLIED
DSN=WTMND0.SFLOW.DATA VER= 1 14/01/83

DAY	JAN	FEB	MAR	APR	MAY	JUN	JLY	AUG	SEP	OCT	NOV	DEC	
1	236	204	187	166	152	144	217	233	238	300	498	498	
2	235	203	186	165	152	144	219	232	239	302	499	498	
3	233	202	185	165	152	144	221	232	241	305	499	498	
4	232	201	185	164	152	144	223	231	244	307	500	498	
5	230	200	184	164	151	145	225	231	247	309	500	498	
6	228	199	183	163	151	145	227	231	250	312	500	497	
7	227	199	181	162	151	145	228	231	253	317	500	497	
8	226	198	180	162	150	145	230	231	256	331	500	497	
9	225	197	179	161	150	146	231	230	259	346	500	497	
10	223	197	178	161	149	147	232	230	262	361	500	497	
11	222	196	177	160	149	150	232	230	265	376	500	496	
12	221	195	177	160	148	154	233	230	267	391	500	496	
13	220	194	176	159	148	157	234	230	270	406	500	496	
14	219	193	176	158	148	161	234	231	273	420	500	496	
15	218	192	175	158	147	164	235	231	276	430	500	495	
16	217	191	175	158	147	168	235	231	278	439	500	495	
17	216	190	174	157	147	171	236	231	279	448	500	495	
18	215	189	174	157	147	174	236	232	280	458	500	494	
19	214	189	173	156	146	177	236	232	281	467	500	494	
20	213	189	173	156	146	180	236	232	282	477	499	493	
21	212	189	172	155	146	183	237	233	283	485	499	493	
22	211	189	172	155	145	186	237	233	284	487	499	492	
23	211	189	171	155	145	189	237	234	285	488	499	492	
24	210	189	170	154	145	192	236	234	287	489	498	492	
25	210	189	170	154	145	196	236	235	289	491	498	491	
26	209	188	169	154	144	200	235	235	290	492	498	491	
27	208	188	169	154	144	203	235	235	292	494	498	490	
28	208	187	168	153	144	207	234	236	294	495	498	490	
29	207		168	153	144	210	234	236	295	496	498	489	
30	206		167	153	144	214	234	237	297	497	498	489	
31	205		166		144		233	237		497		488	
MIN	205	187	166	153	144	144	217	230	238	300	498	488	144
MEAN	218	194	176	158	147	170	232	233	271	416	499	494	268
MAX	236	204	187	166	152	214	237	237	297	497	500	498	500

DAILY MEANS YEAR=1976 SITE=5471001 ITEM= 1 RATING NOT APPLIED
DSN=WTMND0.SFLOW.DATA VER= 1 14/01/83

DAY	JAN	FEB	MAR	APR	MAY	JUN	JLY	AUG	SEP	OCT	NOV	DEC	
1	486	482	442	362	285	228	194	251	410	505	504	503	
2	485	482	440	359	282	226	196	251	417	505	504	502	
3	484	481	437	356	280	225	197	253	424	505	503	502	
4	482	481	435	353	278	223	199	256	430	505	503	501	
5	481	480	433	350	277	222	201	259	437	505	502	500	
6	481	480	431	349	276	220	202	262	443	504	502	500	
7	484	480	428	350	275	218	205	265	450	504	501	499	
8	487	480	426	352	274	217	208	268	457	503	500	499	
9	490	479	424	353	274	216	211	271	464	503	500	499	
10	494	479	421	355	273	214	214	275	471	502	500	499	
11	497	477	418	357	271	213	217	280	478	501	500	499	
12	500	476	416	358	269	212	220	286	485	501	500	499	
13	502	475	413	359	266	210	223	291	492	501	500	499	
14	500	473	410	352	263	209	226	296	498	502	500	499	
15	498	472	407	346	260	208	229	302	499	502	500	498	
16	496	470	405	339	257	207	232	307	500	503	500	497	
17	494	469	402	332	254	206	235	313	501	503	501	496	
18	491	467	399	326	251	206	238	319	502	504	501	495	
19	489	465	397	319	249	205	240	326	502	504	502	495	
20	487	463	394	313	247	204	243	332	503	504	502	494	
21	487	461	391	310	245	204	244	339	504	504	503	493	
22	487	459	388	307	243	203	245	345	504	504	503	493	
23	487	458	386	305	241	201	245	351	504	503	504	493	
24	486	456	383	302	240	199	246	358	504	503	504	493	
25	486	453	381	299	238	198	247	364	505	503	504	492	
26	486	451	378	296	236	196	247	371	505	503	504	492	
27	486	449	375	294	235	194	248	378	505	503	504	492	
28	485	447	373	291	234	192	249	384	505	503	504	492	
29	484	444	370	289	232	191	249	391	505	503	504	492	
30	484		368	287	231	193	250	397	505	504	504	491	
31	483		365		229		250	404		504		491	
MIN	481	444	365	287	229	191	194	251	410	501	500	491	191
MEAN	489	469	404	331	257	209	228	314	480	503	502	496	390
MAX	502	482	442	362	285	228	250	404	505	505	504	503	505

-TIDEDA 14/01/83-

DAILY MEANS YEAR=1977 SITE=5471001 ITEM= 1 RATING NOT APPLIED
DSN=WTMNDO.SFLOW.DATA VER= 1 14/01/83

DAY	JAN	FEB	MAR	APR	MAY	JUN	JLY	AUG	SEP	OCT	NOV	DEC	
1	491	468	386	265	203	176	258	419	479	477	424	339	
2	491	466	382	262	201	177	261	424	479	476	421	336	
3	490	464	378	259	199	178	265	428	479	475	419	333	
4	490	461	374	256	198	180	269	431	479	475	416	330	
5	490	458	370	254	196	181	273	435	480	475	413	327	
6	489	456	366	251	195	183	277	438	480	474	411	324	
7	489	453	362	249	194	184	281	442	480	474	408	321	
8	488	451	358	246	192	186	285	445	480	473	406	318	
9	488	446	354	243	191	187	289	448	480	473	403	315	
10	487	445	350	241	190	189	293	450	480	472	401	312	
11	487	443	346	238	189	190	297	453	480	471	398	309	
12	486	440	343	236	187	192	301	455	480	469	395	306	
13	486	437	339	234	186	194	304	457	480	466	393	304	
14	485	434	335	231	185	195	306	459	480	464	390	301	
15	485	432	331	229	183	196	308	461	480	461	388	299	
16	484	429	327	227	182	197	310	463	480	458	385	296	
17	483	426	323	225	181	198	313	464	480	455	382	293	
18	483	423	319	223	180	199	315	466	480	453	379	291	
19	480	420	315	221	179	200	319	467	480	451	376	288	
20	478	417	311	220	179	201	327	468	480	449	373	286	
21	476	414	307	219	178	203	337	470	480	447	370	283	
22	474	411	303	217	177	209	346	471	480	445	368	280	
23	471	407	299	216	177	215	355	472	480	443	364	278	
24	469	404	295	215	176	222	365	473	479	441	361	275	
25	467	400	291	214	176	228	374	474	479	439	358	272	
26	467	397	286	213	175	234	383	475	479	437	355	269	
27	468	393	282	211	175	240	389	476	479	434	352	267	
28	468	390	278	209	175	246	395	476	478	432	349	265	
29	468		274	207	175	250	401	477	478	430	346	263	
30	468		271	205	174	254	407	478	477	428	342	261	
31	469		268		174		413	478		426		259	
MIN	467	390	268	205	174	176	258	419	477	426	342	259	174
MEAN	480	432	327	231	185	203	323	458	479	456	385	297	354
MAX	491	468	386	265	203	254	413	478	480	477	424	339	491

DAILY MEANS YEAR=1978 SITE=5471001 ITEM= 1 RATING NOT APPLIED
DSN=WTMNDO.SFLOW.DATA VER= 1 14/01/83

DAY	JAN	FEB	MAR	APR	MAY	JUN	JLY	AUG	SEP	OCT	NOV	DEC	
1	257	203	179	156	152	155	264	460	491	486	480	475	
2	256	201	178	157	152	156	266	462	491	486	480	475	
3	254	200	178	157	151	156	269	464	491	486	480	474	
4	252	199	177	158	151	157	271	466	491	485	480	474	
5	250	197	176	158	150	157	273	468	491	485	479	474	
6	248	196	176	157	150	158	274	470	491	485	479	472	
7	246	195	175	157	149	159	276	472	490	485	479	470	
8	244	194	176	157	148	160	277	474	490	485	479	468	
9	243	194	176	157	148	160	279	475	490	484	479	466	
10	241	193	177	156	148	161	281	476	490	484	479	464	
11	239	193	177	156	148	162	282	476	490	484	478	463	
12	237	192	178	156	148	162	283	477	489	484	478	460	
13	235	191	178	155	149	164	284	478	489	484	478	457	
14	233	191	179	155	149	167	286	478	489	484	478	454	
15	231	190	177	155	149	171	287	479	489	483	478	450	
16	229	189	175	155	149	175	288	480	489	483	477	447	
17	227	188	173	154	149	178	289	480	488	483	477	443	
18	225	187	171	154	149	182	293	481	488	483	477	440	
19	224	186	169	154	149	186	309	481	488	483	477	437	
20	223	185	168	154	148	191	327	482	488	482	477	436	
21	221	184	166	154	148	199	344	482	488	482	477	435	
22	220	183	164	154	148	208	361	483	488	482	476	433	
23	218	183	162	154	148	218	379	484	487	482	476	432	
24	217	182	161	154	149	227	396	486	487	482	476	431	
25	215	182	159	154	150	236	411	487	487	482	476	430	
26	213	181	157	154	151	245	419	488	487	481	476	427	
27	211	180	155	153	152	253	426	490	487	481	475	418	
28	209	180	154	153	152	256	433	491	486	481	475	408	
29	207		155	153	153	258	440	492	486	481	475	398	
30	206		155	153	154	261	447	492	486	481	475	388	
31	204		156		155		454	492		480		378	
MIN	204	180	154	153	148	155	264	460	486	480	475	378	148
MEAN	230	190	170	155	150	189	328	479	489	483	478	444	316
MAX	257	203	179	158	155	261	454	492	491	486	480	475	492

TIDEDA 14/01/83

DAILY MEANS YEAR=1979 SITE=5471001 ITEM= 1 RATING NOT APPLIED
DSN=WTMND0.SFLOW.DATA VER= 1 14/01/83

DAY	JAN	FEB	MAR	APR	MAY	JUN	JLY	AUG	SEP	OCT	NOV	DEC	
1	368	226	147	179	160	151	217	310	396	422	421	412	
2	360	210	146	179	160	150	225	313	399	422	423	411	
3	362	195	145	179	159	150	233	315	401	422	424	410	
4	364	179	145	179	159	150	242	318	404	422	425	410	
5	367	163	144	179	158	150	250	321	406	422	426	409	
6	370	151	145	179	158	150	259	324	407	421	426	409	
7	372	155	152	179	157	149	267	327	408	421	423	408	
8	375	160	159	179	157	149	276	330	410	421	419	408	
9	372	166	167	179	157	149	284	334	411	421	415	407	
10	349	171	175	179	156	149	292	337	413	421	411	406	
11	324	176	183	177	156	148	294	341	414	421	407	406	
12	300	181	190	176	156	149	297	344	415	421	403	405	
13	275	187	195	174	156	151	299	348	416	421	401	404	
14	250	195	190	173	155	154	301	351	418	421	403	404	
15	226	202	184	171	155	157	303	353	419	421	406	403	
16	208	210	177	169	155	160	305	356	420	421	409	402	
17	219	217	171	168	154	163	307	358	421	421	412	402	
18	232	225	165	167	154	165	307	360	422	420	415	401	
19	245	232	158	167	154	168	308	362	422	420	417	401	
20	258	236	154	166	154	169	308	364	423	419	420	401	
21	271	225	157	166	153	170	308	366	423	419	419	401	
22	284	212	161	165	153	172	308	369	424	418	418	400	
23	294	199	165	164	153	173	309	371	424	418	417	400	
24	290	186	169	164	152	174	309	374	425	418	416	400	
25	285	173	173	163	152	175	309	377	425	419	416	400	
26	280	160	177	163	152	177	308	379	425	418	415	399	
27	275	150	180	162	152	185	308	382	424	419	414	399	
28	270	148	180	162	151	193	308	384	424	419	413	398	
29	264		180	161	151	201	308	387	423	419	413	398	
30	257		180	160	151	209	307	390	423	419	412	397	
31	242		179		151		308	393		420		396	
MIN	208	148	144	160	151	148	217	310	396	418	401	396	144
MEAN	297	189	167	171	155	164	289	353	416	420	415	403	287
MAX	375	236	195	179	160	209	309	393	425	422	426	412	426

(pumping) [beside JAN days 16–21]
(pumping) [beside FEB days 15–19]
(pumping) [beside MAR days 17–22]
(pumping) [beside NOV days 12–16]

TIDEDA 14/01/83

DAILY MEANS YEAR=1980 SITE=5471001 ITEM= 1 RATING NOT APPLIED
DSN=WTMNDO.SFLOW.DATA VER= 1 14/01/83

DAY	JAN	FEB	MAR	APR	MAY	JUN	JLY	AUG	SEP	OCT	NOV	DEC	
1	396	330	341	389	395	343	340	421	419	427	386	320	
2	395	320	341	390	394	341	343	422	415	426	384	325	
3	393	311	342	391	393	339	346	422	397	425	382	321	
4	392	(pumping) 301	343	391	391	337	348	423	378	423	380	316	
5	391	295	344	392	390	335	351	424	(pumping) 359	422	378	311	
6	389	298	346	393	389	334	354	424	340	420	376	306	
7	388	303	347	393	388	332	357	424	321	419	375	301	
8	387	307	348	394	387	330	360	424	302	419	373	296	
9	384	312	350	394	386	328	363	424	290	418	371	291	
10	382	316	351	394	385	327	367	424	306	418	369	281	
11	379	321	352	394	384	325	370	424	325	417	368	272	
12	377	325	354	395	383	323	374	424	344	417	366	263	
13	375	325	357	395	382	321	377	423	363	416	365	253	
14	372	326	359	395	380	319	381	423	382	416	363	244	
15	370	326	361	395	378	317	384	422	400	414	362	234	
16	370	327	363	396	376	315	388	422	416	413	360	226	
17	371	327	365	396	374	314	391	421	419	412	358	222	
18	371	328	367	397	372	315	394	420	421	410	355	218	
19	372	328	369	397	371	318	397	420	423	409	343	214	
20	372	329	370	398	369	320	400	420	425	407	331	(pumping) 210	
21	373	331	371	398	367	322	403	419	427	406	319	206	
22	373	332	373	399	365	324	406	419	428	404	307	202	
23	371	333	374	399	363	326	408	418	430	403	295	201	
24	369	335	376	399	361	328	410	418	430	401	283	209	
25	367	336	377	399	359	330	411	417	430	400	274	218	
26	365	337	379	398	357	332	413	417	430	398	281	227	
27	363	338	381	398	355	333	415	417	429	396	289	236	
28	361	339	382	398	352	335	416	418	429	395	297	244	
29	357	340	384	398	350	337	418	418	429	393	304	253	
30	348		386	397	348	338	419	418	429	390	312	256	
31	339		387		346		420	418		388		234	
MIN	339	295	341	389	346	314	340	417	290	388	274	201	201
MEAN	375	323	363	395	374	328	385	421	391	410	344	255	364
MAX	396	340	387	399	395	343	420	424	430	427	386	325	430

TIDEDA 14/01/83

DAILY MEANS YEAR=1981 SITE=5471001 ITEM= 1 RATING NOT APPLIED
DSN=WTMND0.SFLOW.DATA VER= 1 14/01/83

DAY	JAN	FEB	MAR	APR	MAY	JUN	JLY	AUG	SEP	OCT	NOV	DEC	
1	209	203	178	164	156	155	188	238	351	412	?	?	
2	185	202	177	163	156	155	190	239	355	412	?	?	
3	161	202	176	163	156	156	191	239	359	412	?	?	
4	137	201	176	162	155	156	193	239	362	412	?	?	
5	112	200	176	162	155	157	195	234	366	413	?	?	
6	97	199	176	161	155	157	196	228	369	413	?	?	
7	114	198	176	161	155	158	198	223	373	413	?	?	
8	134	197	176	161	155	158	201	217	376	414	?	?	
9	154	196	176	161	156	159	204	211	378	414	?	?	
10	174	195	174	161	156	160	207	206	381	415	?	?	
11	194	194	162	160	156	161	210	204	383	415	?	?	
12	214	193	149	160	156	162	213	216	385	416	?	?	
13	230	192	137	160	156	163	215	230	387	416	?	?	
14	230	191	124	157	156	164	218	244	389	415	?	?	
15	229	190	112	142	156	165	220	258	391	415	?	?	
16	228	189	99	127	155	166	222	271	393	414	?	?	
17	226	188	91	111	155	168	223	285	394	414	?	?	
18	225	187	101	95	155	169	225	297	396	413	?	?	
19	223	187	112	79	155	170	227	302	397	412	?	?	
20	222	186	124	64	155	172	228	306	399	?	?	?	
21	219	186	135	54	155	173	230	310	401	?	?	?	
22	217	185	147	67	155	175	231	314	402	?	?	?	
23	214	184	158	82	155	176	232	318	403	?	?	?	
24	212	184	167	98	155	178	233	322	405	?	?	?	
25	210	183	167	113	155	179	234	326	406	?	?	?	
26	207	182	167	128	155	180	234	330	407	?	?	?	
27	205	180	166	144	155	182	235	334	409	?	?	?	
28	205	179	166	156	155	183	236	337	410	?	?	?	
29	204		165	157	155	185	237	341	411	?	?	?	
30	204		164	156	155	186	237	344	411	?	?	?	
31	203		164		155		238	348		?		?	
MIN	97	179	91	54	155	155	188	204	351	412	?	?	54
MEAN	193	191	153	134	155	168	217	275	388	414	?	?	222
MAX	230	203	178	164	156	186	238	348	411	416	?	?	416

APPENDIX II

LABORATORY METHODS

Temperature	50°C mercury thermometer
Dissolved Oxygen	YSI temperature compensated dissolved oxygen meter
pH	Triac pH meter
Conductivity	Radiometer CDM 2 e conductivity meter Samples corrected to 25°C
Turbidity	Hach ratio turbidity meter
Nutrients	NO_3^-; PO_4^{3-}; NH_3 Colourimetric methods using Baush and Lomb Spectronic 20 Spectrophotometer - Nitrate by cadmium column reduction method - Phosphate by ascorbic acid reduction method - Ammonia by direct nesslerisation method as laid down by the procedures in "Standard Methods for the Examination of Water and Waste Water" 15th Edition APHA 1980
Coliform Bacteria	Membrane filter method, plated on M endo Agar LES and incubated at 37°C & 44.5°C Methodology as laid down by the procedures in "Standard Methods for the Examination of Water and Waste Water" 15th Edition APHA 1980

A P P E N D I X III

WATER CLASSIFICATION STANDARDS

Standards for Class A Waters

The waters shall in all respects be maintained in their natural state, and no waste shall be permitted to enter them.

Standards for Class B Waters

The quality of Class B waters shall conform to the following requirements :

(a) The natural water temperature shall not be changed more than 3 degrees Celsius;

(b) The acidity or alkalinity of the waters as measured by the pH shall be within the range of 6.0 to 8.5 except when due to natural causes;

(c) The waters shall not be tainted so as to make them unpalatable, nor contain toxic substances to the extent that they are unsafe for consumption by humans or farm animals, nor shall they emit objectionable odours;

(d) There shall be no destruction of natural aquatic life by reason of a concentration of toxic substances;

(e) The natural colour and clarity of the waters shall not be changed to a conspicuous extent;

(f) The oxygen content in solution in the waters shall not be reduced below 6 milligrams per litre;

(g) Based on not fewer than five samples taken over not more than a 30 day period, the median value of the faecal coliform bacteria content of the waters shall not exceed 2 000 per 100 millilitres and the median value of the total coliform bacteria content of waters shall not exceed 10 000 per 100 millilitres;

A P P E N D I X III Continued

Standards for Class C Waters - more stringent than Class B

The quality of Class C waters shall confirm to the following requirements :

(a) The natural water temperature shall not be changed by more than 3 degrees Celsius;

(b) The acidity or alkalinity of the waters as measured by the pH shall be within the range 6.5 to 8.3 except when due to natural causes;

(c) The waters shall not be tainted so as to make them unpalatable, nor contain toxic substances to the extent that they are unsafe for consumption by human or farm animals nor shall they emit objectionable odours;

(d) There shall be no destruction of natural aquatic life by reason of a concentration of toxic substances;

(e) The natural colour and clarity of the waters shall not be changed to a conspicuous extent;

(f) The oxygen content in solution in the waters shall not be reduced below 6 milligrams per litre;

(g) Based on not fewer than five samples taken over not more than a 30 day period, the median value of the faecal coliform bacteria content of the waters shall not exceed 200 per 100 millilitres;

APPENDIX III Continued

Standards for Class D Waters

The quality of Class D waters shall conform to the following requirements :

(a) The natural water temperature shall not be changed by more than 3 degres Celsius;

(b) The acidity of alkalinity of the waters as measured by the pH shall be within the range of 6.0 to 9.0 except when due to natural causes;

(c) The waters shall not be tainted so as to make them unpalatable, nor contain toxic substances to the extent that they are unsafe for consumption by farm animals, nor shall they emit objectionable odours;

(d) There shall be no destruction of natural aquatic life by reasn of a concentration of toxic substances;

(e) The natural colour and clarity of the waters shall not be changed to a conspicuous extent;

(f) The oxygen content in solution in the waters shall not be reduced below 5 milligrams per litre.

APPENDIX IV

NORTHLAND CATCHMENT COMMISSION

AND

REGIONAL WATER BOARD

Policy on Allocation of Water for Horticulture in Catchments of High Demand Relative to Available Water Resources

1 Priority to be given to statutory farm/domestic supplies and existing water rights.

2 Maximum limits of total allocation to be set in each catchment as a proportion of five year return period design drought flows. Due regard shall be had to recreational needs, the safeguarding of natural features, fisheries, and wildlife habitats. This proportion shall generally be less than and would rarely exceed 60% of the design drought flow.

3 Irrigation applications shall generally be considered in the order in which applications are received.

4 In considering applications the Board must be satisfied that the proposal is genuine and that, if irrigation water were available, development would proceed.

5 Allocations will be made in line with immediate needs but with provision for upwards variations pursuant to section 24B of the Act to eventually meet the potential needs of one "economic unit." In considering subsequent applications within the same catchment the potential needs of existing right holders will be taken into account.

6 Allocations shall be on a uniform basis of 25 mm per unit planted area per 10 day period. This is equivalent to 25 cubic metres per day per planted hectare.

7 In areas where stream flows are known to be inadequate for potential horticultural development the location of storage dams in suitable sites will be encouraged. This will particularly be the case in considering water resource demands on subdivisions of pastoral land suited to the growing of horticultural crops.

8 The taking of groundwater, where pumping tests have demonstrated no detrimental impact on surface flows and other statutory groundwater users, will be encouraged.

APPENDIX IV Continued

9 In assessing potential irrigation demands in areas of significant size and suitable soils to justify a communal irrigation scheme, forward planning of the water resource will generally be on a 10 year basis.

10 In granting water rights for irrigation the term of the right shall generally be not longer than five years but shall be arranged to coincide with expiry of other existing rights to allow for overall water resource reviews within the same catchment.

11 In the event of irrigation schemes proceeding the Regional Water Board will take such action as is available to it under the Water and Soil Conservation Act 1967 to phase out water rights for irrigation of properties as and when scheme connections become available.

Note : In implementing these policies the Regional Water Board will continue to recognise that the adjudication of water right applications is a quasi-judicial procedure. It must therefore consider each and every application on its merits and in accordance with the Water and Soil Conservation Act 1967 and that its decision must be able to be supported before the Town and Country Planning Tribunal.