COMMENT ON THE GROUNDWATER RESOURCES SURFACE WATER RESOURCES AND WATER SUPPLY OF RAROTONGA, COOK ISLANDS

Report of a visit, including field investigations 13-21 November 1996

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SUMMARY

- A lack of information regarding water supplied to the user and the amount of water used is preventing the wise management of the water supply system.
- Bulk and individual water meters need to be installed to provide information to manage and develop the water supply system.
- The introduction of a "user pays" system for water would encourage the wise use and conservation of water.
- Information regarding surface water resources is required to enable the assessment of sustainable safe water catchment yields and to determine low flow and flood frequency.
- A leak detection and pipeline rehabilitation program is required to locate and fix system losses.
- Information regarding surface water resources is required to enable the assessment of sustainable safe water catchment yields, and to determine low flow and flood frequencies.
- Information regarding groundwater resources is required to locate, develop and assess sustainable water abstractions to supplement surface water resources.
- The proposed legislation to protect the water supply catchments of Rarotonga, by restricting land use, is an excellent step by Government to ensure sustainable water yields and water quality for future generations.

INTRODUCTION

This report has been compiled following a field mission carried out by the SOPAC Water Program staff from 13 to 21 November to Rarotonga, Cook Islands. The objectives of the field mission were as follows:

- to assess the actual exploitation of groundwater resources;
- to arrange a plan for the development and management of existing aquifers;
- to carefully assess the general hydrogeological situation, and to ensure that exploitation of this limited resource did not cause consequent risks of saline intrusion or other environmental problems;

- to measure the flows in the various streams in Rarotonga that are used for the water supply on the island;
- to provide training of Water Works staff in the use of stream flow measuring equipment;
- to comment on surface water resources, the existing water supply system, and groundwater resources.

SUMMARY OF MORPHOLOGY, HYDROGEOLOGY AND GEOLOGY OF RAROTONGA

The volcanic island of Rarotonga covers a total area of 67 km^2. Population is concentrated in the coastal plain, which is less than 1 km wide.

The actual water supply is provided by a double ring distribution network, fed by the capture of surface runoff water by catchments installed on the main streams of the island.

Because of the difficulty in dissociating the basic water requirements from husbandry, wastage, market gardening etc., the total requirements, including agricultural demand, which increases during droughts, cannot be covered through the existing network.

As many sources have confirmed, there is a good quantity of groundwater resources in coastal plain aquifers, at present unexploited, which could provide a valuable source of water supply for agricultural purposes.

The major risk for the hydrogeological exploitation of coastal aquifers would be a saltwater intrusion. Careful attention to groundwater exploitation is therefore required.

Because of the lack of information on the geology and hydrogeology of the coastal plain sedimentary deposits, a data collection phase had to be carried out.

A geophysical survey (geoelectrical methods) and some exploratory borehole (rotary rigs) were considered necessary.

The completed boreholes would be equipped as monitor boreholes to collect data and monitor the exploited aquifer.

The island of Rarotonga is a typical Pacific-basin volcano now extinct. The oval shape of the island is formed by a central mountain dissected by erosion, a non-active volcano of late Tertiary age, surrounded by Quaternary sediments, deposits of gravel fans, coastal terraces, mud swamps, coral sands and reefs.

This structure is rather complex, like every volcano. The following is a summary from Wood and Hay (1970) from which a schematic geological map with a cross section is shown in Figures 1 and 2.

Volcanic Rocks

Old Caldera Complex (Late Pliocene)

This complex (Avatiu Caldera Complex, Te Manga Group, Pue Ash) is composed by basaltic eruptive rocks, breccias, pyroclastic deposits as scorias and ash. With its explosive genesis and its age, this complex has been intensively weathered. This weathering has altered rocks mostly into clay minerals.

Phonolitic Eruptive Rocks (Late Pliocene-Early Pleistocene)

More recent lavas, breccias and massive volcanic rocks (basalt colonnades) intruded in the older caldera complex. Generally, these rocks appear to be less weathered than the previous complex. The massive basalt rocks of this geological unit show a well developed fracture pattern.

Sedimentary Deposits

Nikao Gravels

Weathered volcanic gravels and sands of coastal terraces and fans. The older and higher deposits (Nko) are more weathered.

Aroa Sands

The Aroa Sands form a low bench around the edge of the island between the foot of the Nikao Gravels and the inner edge of the lagoon. This sedimentary deposit is made of coral sands, gravel and cemented beach deposits.

Stream Alluvium

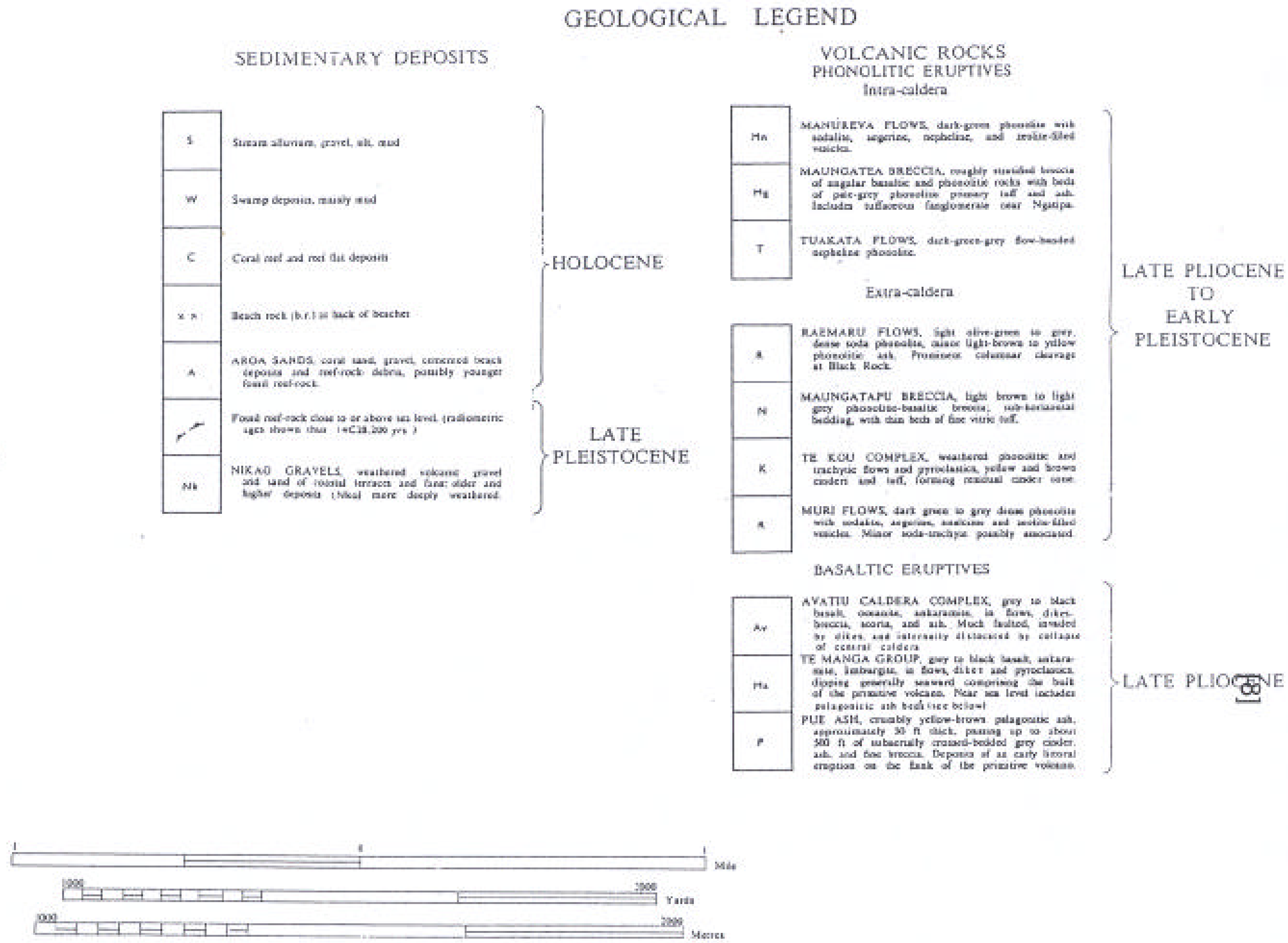
Fans consisting of volcanic gravels and debris deposited by streams.

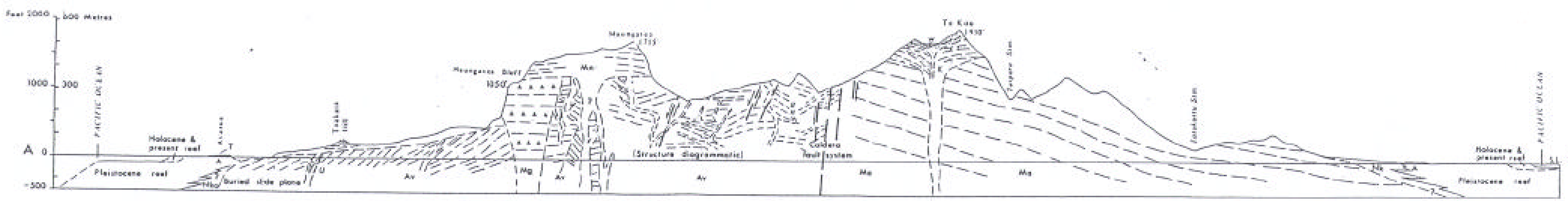
Figure 1

Geological map of Rarotonga Island
(Source: Waterhouse & Petty, 1986)

Figure 2

Geological cross section of Rarotonga Island
The section (A - B) is indicated in figure 1
(Source: Wood & Hay, 1970)





GEOLOGICAL CROSS SECTION (A-B), RAROTONGA ISLAND.

GROUNDWATER RESOURCES

Volcanic Complex

There is not enough data to understand the deep circulation of groundwater in the volcanic rocks. However, the data collected during the 122 m cored-hole drilled by DSIR for a seismic survey showed the existence of rock fractures. These fractures allow the deep circulation of water through the volcanic rocks. The older volcanic complex however, was of very low permeability because of sealing of fractures by clayey weathering products.

The finding of permeable fractured zones in the fractured basalt unit (basalt colonnades late Pliocene-early Pleistocene), requires higher cost survey than a usual groundwater development plan for sedimentary aquifers.

Nikao Gravel

All previous work shows that almost all streams lose either part or all of their flow when crossing the coastal plain before reaching the lagoon.

Volcanic rocks are favourable to an immediate runoff of rainwater because of their low permeability. The Nikao Gravels deposit, forming terraces at the foot of volcanic hills, have a variable permeability depending to their weathering grade.

In general the clayey weathering products seal the pores and fractures of these deposits.

Where the weathering process has not been so developed, runoff water can infiltrate into these deposits and flow in permeable strata.

Nko (older Nikao Gravels), due to their age, have a lower permeability than the younger Nikao Gravels.

Old hand dug Maori wells in these deposits supplied good quality groundwater (150-350 µS/cm at 25º C), but with disappointing results in terms of yield.

Recently, no more wells have been developed in these strata.

Since the Nikao Gravels are sometimes deeply weathered, they may be highly permeable from place to place. Thus, the major problems in exploiting these deposits consist of finding high permeable sites with a low weathering grade.

Water Quality and Use

Piggeries are scattered all around the terrace at the foot of the volcanic hills. This factor has probably caused a deterioration of the aquifer water quality.

The nitrate content as well as bacteriological pollution is supposed to be quite high.
However, before every exploiting plan, we suggest a chemical and bacteriological analysis of groundwater.

Because of the poor water quality, the primary use of this resource should be agricultural, except for sites where a good hydrogeological protection from pollution is verified.

Having been derived wholly from basaltic rocks, the release of relatively large amounts of iron in Nikao Gravels groundwater is expected.

Aroa Sands

Aroa Sands have a better hydraulic uniformity, compared to the Nikao Gravels.
In general the permeability is quite good and does not change much from place to place.
These sediments have not been affected by any kind of alteration process, except for some cemented beds, as shown in a section through a trial pit drilled at the Transiting Station (Figure 3).

The major risk for the hydrogeological exploitation of this aquifer consists of a saline intrusion.

Some field results suggest that these deposits contain a good quantity of water. The New Zealand Department of Civil Aviation at the airport have constructed a horizontal collector well on the southern side of the Airport runway near the inner edge of the Aroa Sands. This well is currently yielding approximately 200 m^3/day.

Data collected during the field mission in November 1996 showed that conductivity of the water in the well has decreased from 1000 µS/cm (July 1992, French Report) to 600 µS/cm.
The decrease in the conductivity value suggests that the recharge rate from the aquifer exceeds pumped yield in the well.

The value measured during the mission by the French was due to a seawater intrusion following to a big storm.

This high value of recharge is likely due to rain precipitation. High permeable sands favour this recharge, although a certain amount of water flows through Nikao Gravels directly to Aroa Sands.

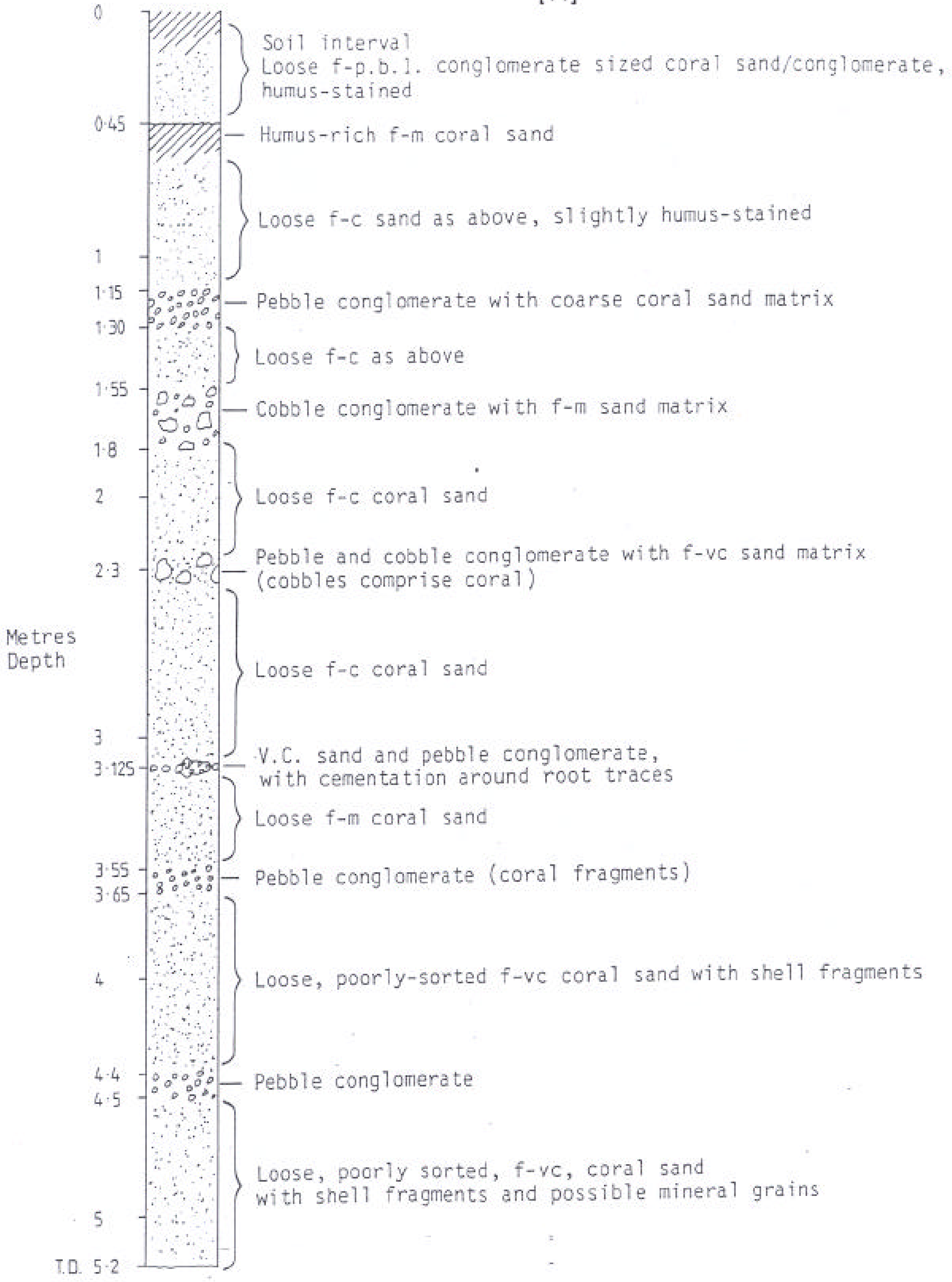


Figure 3 Aroa Sands Section through Trial Pit-Trasmitting Station Avarua) (Source: Binnie & Partners, 1984)

It is important in aiming at future use of the Aroa Sands aquifer to find a site where both thickness and distance from the sea are a maximum, so that there is the least risk of saline intrusion and loss of yield in drought periods.

The sites favourable for exploitation are located on the immediately seaward side of swamp areas for the following reasons: maximum possible distance from the seashore and least interference in swamp areas groundwater recharge.

Figure 4 shows the geological relationships and groundwater paths of the deposits forming the coastal plain.

Water Quality and Use

All the conductivity measurements carried out during the field mission of November 1996 show values between 200 and 600 µS/cm. The biggest value at the airport well was due to the storm of 1993 but this value has decreased since that time.

Although some wells show a salinity (calculated from conductivity measurement) lower than the WHO limit for drinking water (250 mg/l of Cl^-, equivalent to more or less 340 µS/cm 25º C), other chemical values (for example nitrate) could be over-limits for human consumption.

Because of the calcareous nature of the Aroa Sands, a medium-high value in hardness and alkalinity is expected. An agricultural use is suggested for this water, as it is not possible to avoid easy contamination of groundwater by human activity (for example from fertiliser, waste landfills, etc.).

Also for this aquifer, before every exploiting plan, we suggest a chemical and bacteriological analysis of the groundwater.

Stream alluvium

Stream alluvium deposits can contain moderate water quantities because of their high permeability. In the past, these deposits have been exploited with infiltration galleries located in the bed of watercourses. Possible exploitation of this limited aquifer requires finding sites where deposit thickness is sufficiently large. Possible areas are located at the outlet of the larger river valleys.

Because of the permeability and the location of these deposits, a serious hazard of pollution is possible.

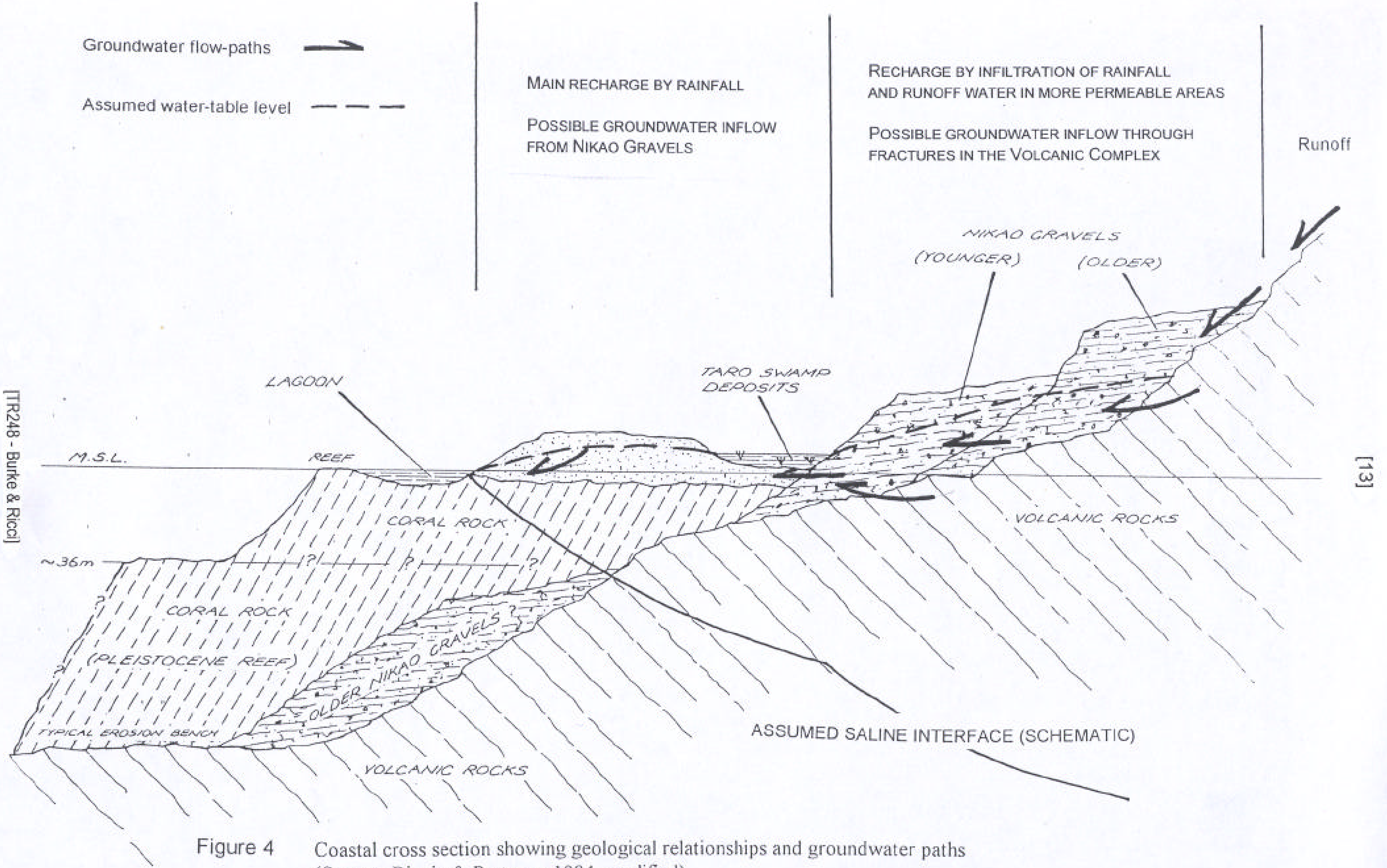


Figure 4 Coastal cross section showing geological relationships and groundwater paths (Source: Binnie & Partners, 1984, modified)

Data Collecting

With the lack of available data on the deep geology and hydrogeology, the collecting data phase should provide information on the geometry and thickness of sedimentary deposits. Moreover, more precise information about the water content of the sedimentary deposits should be collected.

Geophysical Survey

Geoelectrical methods provide an economical way to get useful information on sedimentary deposits. In order to provide data useful for groundwater exploitation, some profiles (Wenner array) and vertical soundings (Schlumberger array) in the most interesting sites are suitable. However to better calibrate field results, at least one exploratory borehole per site is required.

Drilling

Assuming that a drilling rig with skilled crew is available, we suggest drilling as many boreholes as possible, to get the largest quantity of data concerning the geology and hydrogeology available.

Rotary rigs (core-boring) are well suited for sampling sedimentary formations. Completed boreholes should be equipped as monitor boreholes to collect data and to monitor the aquifer water head, salinity and other chemical and physical parameters.

Nikao Gravel

Groundwater occurrence in these deposits could be located at various depths. In general, a good system to intercept permeable strata is a vertical well with a slotted lining to full depth. Drilling must be carried out to 15-20 m deep depending on elevation.

Aroa Sands

Since the watertable in this deposit is located about 3 to 5 metres depth, the best exploiting system is a large diameter well with horizontal collectors. This technology allows a good yield with a minimum of drawdown (Figure 5) to be obtained. Minimising drawdown is also very important in deposits where exploiting groundwater could cause risk of seawater up-coning.

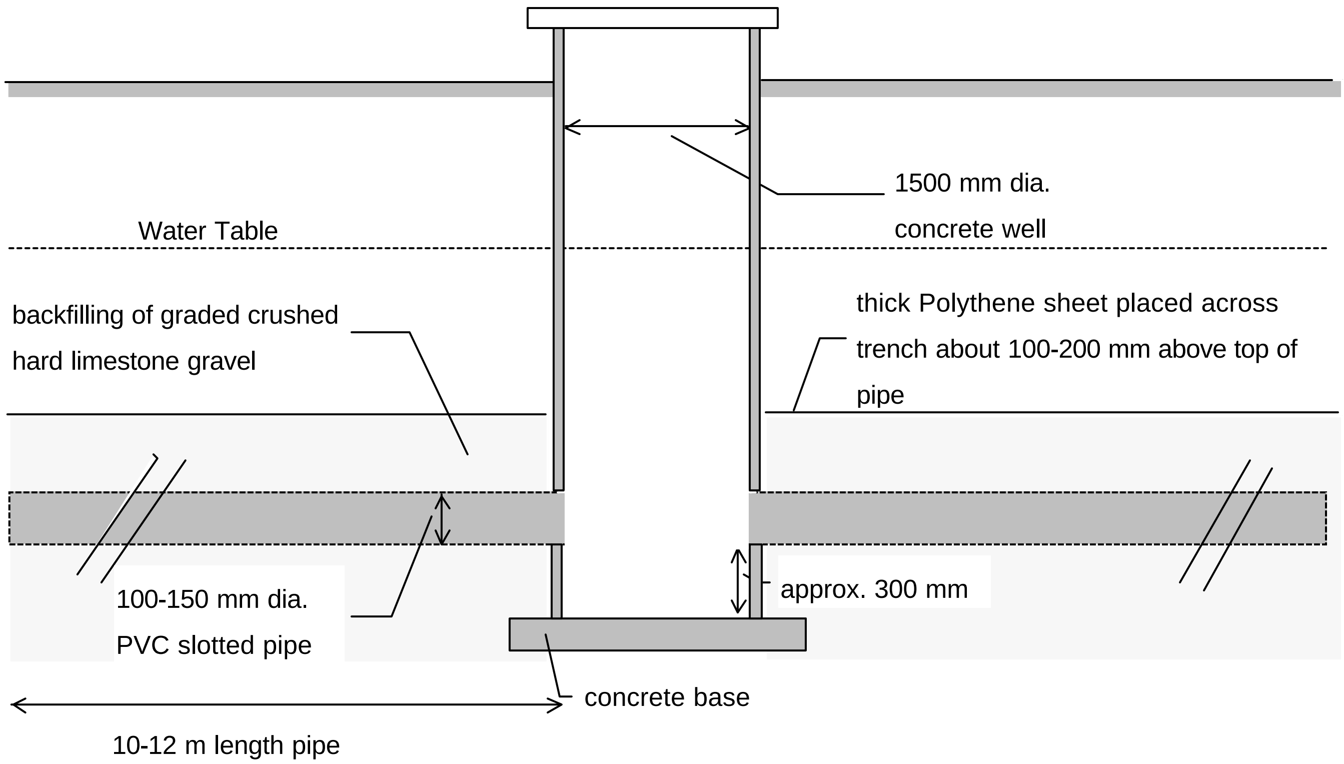


Figure 5. Schematic drawing of a typical horizontal gallery well

During the field mission in November 1996 a horizontal gallery well built by a local farmer (Sam Napa) was visited. Measurement of conductivity showed that water quality is good for agricultural use (irrigation).

The introduction of a user pays system for water, as well as the building of some sample wells in chosen sites around the island could be a good way to encourage the farmers to use groundwater for irrigation. Technical building features should be published and available for everyone interested in developing this technology.

A possible problem could be the over-exploiting of the Aroa Sands aquifer with consequent risk of saline water intrusion.

Although an agricultural use of water should recover a part of the water exploited, a preliminary study on the water balance must be carried out, before beginning to exploit the aquifer.

A possible solution to the over-exploitation risk could be the limitation of water pumped. Definition of the amount which can be pumped sustainably will be the aim of a follow-up study on the possible development of water consumption.

In a second phase of the project, after enough data has been collected, a water balance study should be carried out. The aim is to calculate net recharge of the sandy aquifer in order to optimise use of the Aroa Sands.

First Phase

- Geophysical survey of the Nikao Gravels and Aroa Sands carried out with geoelectric methods in selected sites (profiles and vertical soundings).
- Trial boreholes (one for each site if possible) with rotary rig to get geological information, to calibrate results collected from geoelectric survey and eventually simple slug tests to determine hydrogeological parameters.
- Equipping trial boreholes to monitor water table, conductivity and chemical parameters.
- Collecting data for monitoring groundwater.
- Data processing and interpretation of results.

Second Phase

- Choosing of appropriate technology for groundwater development of different sedimentary deposits.
- Building demonstration wells to encourage farmers to follow the same technology.
- Collecting data for monitoring groundwater.
- Water balance study to better calibrate water exploitation.

SURFACE WATER RESOURCES

Stream flow measurement training and field survey results

The WASP pygmy current meter, current meter counter and 50m measuring tape were taken to Rarotonga to use to measure stream flows and for training. The following Water Works staff were instructed in the standard use and care of the equipment to measure and calculate stream flows:

- Ben Parakoti
- Enua Bishop
- Tavaupoo Bates
- Terence Bishop
- Adrian Teotahi

After one morning of "class" instruction the team went into the field for practical hands-on training in the use of the equipment and the calculation of stream flows. Eighteen stream flow measurements were made over a four day period with at least one measurement made at each of the existing water supply stream sources. During this period the Water Works staff developed skills in stream gauging encountering a variety of site conditions to practice gauging techniques. Various forms were prepared to assist with making, recording and calculating the flow measurements.

The equipment was left in Rarotonga, on loan to the Water Works Section, so the staff could continue to measure stream flows during a very dry period that was being experienced during and after the field mission. This type of low flow information is very important in assessing water resources and for managing the water supply.

Table 1 shows the results of the stream flow measurements.

Table 1: Stream flow measurement results

Stream	Flow (l/s)	Date	% of combined flow
Avatiu	10.2	13/11/96	5
	9.2	18/11/96	
Takuvaine	15.9	13/11/96	7
Tupapa	14.2	13/11/96	6
Matavera	17.5	13/11/96	8
Turangi	36.8	13/11/96	17
	35.4	18/11/96	
Avana	27.8	16/11/96	12
Totokoitu	13.3	14/11/96	6
Taipara	34.3	14/11/96	15
	30.9	18/11/96	
Papua	20.9	14/11/96	9
Ngatoe	12.5	14/11/96	6
Rutaki	8.3	14/11/96	4
Muriavai	11.9	14/11/96	5

Each of the streams measured are a water supply source that feeds into the distribution system servicing Rarotonga. All flow measurements were made upstream of the water supply intakes (except for Tupapa that was measured entering the filter). Thus by summing all the measured flows the potential amount of water available for Rarotonga at the time of measurement is indicated. During this exercise a combined flow of 223.6 l/s or 19,319 m^3/day was measured. Naturally this amount changes depending on climatic conditions such as rainfall intensity, duration and distribution. However, not all this water enters the water supply system due to intake over flows, intake leaks, blocked screens and filter beds, system hydraulics and lack of demand.

The flow measurements were taken during a dry period where substantial rainfall had not occurred for 40 days. Newspaper headlines of “Low water levels striking home” and “Pray for rain” were appearing daily. (See Appendix 1).

Water supply catchment and intake observations

The following are observations regarding each of the water supply sources.

Avatiu Stream

It appears that during low flow periods water infiltrates into the stream bed and does not reach the main intake structure that consists of a concrete weir with buried drainage pipes covered with selected gravel and sand materials (locally called a Ramos intake) To overcome this problem, approximately 100 m of 150 mm diameter PVC pipe has been installed to capture the water before it disappears into the stream bed. Sand bags and stream bed material are used to divert the stream flow into the PVC pipeline that was fitted with a wire mesh screen.

This low flow arrangement should be made more permanent to utilise the full potential of this water source.

Although an old gallery system (a series of porus pipes buried below the groundwater table running parallel with the stream leading to a collection chamber) exists, it is however understood that it is not used much.

Takuvaine Stream

Similar to the Avatiu intake, low flow conditions result in no flow reaching the Ramos-type intake. However, about 30 m upstream of the intake structure water is diverted using gabions (rock filled wire baskets) into the distribution system via a 2500 m^3 reservoir.

During the field investigation period two temporary 100 mm diameter PVC pipes were installed to capture flows about 50m upstream to supplement the diverted intake flows. A more permanent intake arrangement is required to best utilise the water resource.

It was noted that there is extensive agriculture development and thus human activity within this catchment take diverts stream flow for irrigation use. Thus this catchment is more susceptible to pollution.

An old gallery system exists, however it is understood that it is not used much.

Tupapa Stream

An intake weir dams and diverts water through a 200 mm diameter steel pipe to a filtration chamber. (It is the same as the Ramos-type filter except that the filter is constructed out of the stream bed). The water must first pass through a wire mesh screen that is fitted to the inlet of the pipe. The filtration chamber is designed to distribute water evenly over the entire surface of the filter and percolates through the filter media to collection drains at the base of the filter. The filtered water then enters the distribution system.

The wire intake screen is subject to blocking by leaves and other water borne debris. This may restrict the flow that enters the filter. This was observed on most intake screens visited. Also it is difficult to achieve a uniform flow over the surface of the filter. What appears to happen is that the water finds a “weak spot” in the filter material and “short circuits” the filter. Thus the filter is not performing as designed. On site cleaning of the filter media also appears to be a problem due to algae growth and fine silt deposits.

Due to operational, as well as maintenance problems, and limited availability of suitable filter media material the filter mainly improves the appearance of the water rather than reduces bacteria contamination.

Matavera Stream

This intake and filter system is identical to the Tupapa Stream system. The problems with the intake screen and filter are also identical. Water was observed flowing through the scour pipe (estimated at 0.5 l/s) thus this amount is not available for water supply.

This system also supplies water to a freshwater prawn farm that consists of four unlined artificial ponds. On the day this intake was visited water was flowing freely into each of the four ponds at an estimated combined rate of 10 l/s which was more then half the measured flow at the water supply intake.

This was during a time when there was a shortage of water for domestic use. Details of any water agreement to supply the prawn farm were unknown to the writer, however commonsense would suggest that the domestic water supply would take preference during water short periods. Lining the ponds with an impermeable material would reduce the water requirements of the prawn farm.

Turangi Stream

This water source comes from one of the higher yielding catchments in Rarotonga and is currently providing the most water to the distribution system on Rarotonga. The intake is a Ramos-type with its filter media and collection system constructed in the stream bed directly behind the concrete intake weir. It is understood that there is very little human activity within the upper catchment area thus the water quality should be relatively good compared to catchments like Takuvaine where plantations exist.

At the time of visiting the Turangi intake an estimated 0.5 l/s was flowing over the intake weir.

Avana Stream

Access to this intake requires 23 stream crossings using a robust vehicle. The intake pipe is enclosed in a roofed structure constructed of concrete blocks jointed so that water may enter but water borne debris does not. The intake structure is located behind a concrete intake weir that dams the stream. It was noted that the upstream edge of the intake pipe structure had been damaged by flooding waters and should be repaired before further damage that may jeopardise the intake structure and water supply.

Water was observed flowing under the intake dam apparently through an old diversion pipe that runs under the dam. A stream gauging made downstream of the dam measured a flow of 9 l/s which should be flowing into the distribution system. This catchment has been identified as a potential storage dam reservoir site. Two possible sites have been selected. However, further geotechnical and hydrological investigations would be required to assess the feasibility of a reservoir site. It is understood that the existing gallery system is operational but cannot supply as much as the stream intake.

Totokoitu Stream

This intake consists of a concrete weir to dam and divert water into a 150 mm diameter steel pipe with a wire mesh screen fitted to its inlet. The screen and inlet pipe are surrounded by large stream rocks that offers a degree of protection from debris flowing down the stream. However leaves still enter the protected inlet from above (falling from trees). On inspection the screen was completely blocked with leaves. Once the leaves were removed the flow into the pipe increased.

The inlet area should be covered to prevent leaves from entering. This may be accomplished by covering with a shade cloth or similar more permanent material.

About 500 m downstream of the intake the remains of a recording water level gauging station was seen. This was used to collect about 4 months of water level data in 1989/90 that was converted to stream flow data. The compound V-notch weir and stilling well appeared to be in fair condition. On 14 November 1996, an estimated flow of 3 l/s was flowing over the weir.

Taipara Stream

This intake is a Ramos-type with the collector drains and filter material located in the stream behind a concrete weir.

The Taipara source is one of the higher yielding catchments and water supply producers on Rarotonga with very similar yields and supply rates as the Turangi catchment.

Water was observed flowing under the right side of the weir as well as through the weir scour device.

Papua Stream

The intake consists of a concrete dam located on top of a 15 m (approximate) waterfall where water is diverted into a 150 mm diameter steel pipe with a screen fitted to the inlet. All the stream flow was entering the pipe with no spillage over the waterfall.

A gallery system was seen between the base of the waterfall and the 450 m^3 reservoir. It is understood that neither the gallery system nor reservoir is being used.

Ngatoe Stream

This intake is a Ramos-type with the filter located out of the stream similar to the Tupapa and Matavera intakes. The intake screen is subject to blockages due to leaves and other debris and the water entering the filter was short circuiting through the filter media.

This catchment has been identified as a potential storage dam reservoir site. However, further geotechnical and hydrological investigations are required to assess the feasibility of the reservoir site.

Rutaki Stream

The intake is a Ramos-type. The filter bed requires attention. The intake was not connected to the distribution system on the day of inspection.

Muriavai Stream

A concrete intake weir dams and diverts water directly into the distribution system through a 100 mm diameter steel pipe. A wire mesh screen has been fitted to the inlet of the pipe to prevent water borne debris such as leaves and sticks from entering the system. This intake has the ability to convey water into the Akava 10,000 m^3 reservoir if required. (Note that the Akava reservoir is not connected to the water supply distribution system due to objectionable water quality).

A deposit of organic material has built up behind the intake dam. Gas bubbles were observed surfacing from this deposit indicating its state of decomposition and resulting poor water quality.

Table 2 summarises all the flow measurements and meter readings made during the visit plus information regarding all the water supply catchments and intakes on Rarotonga.

Table 2: Summary of data collected and catchment details

RAROTONGA WATER RESOURCES INVESTIGATION

Surface water data collected 13-18 November 1996, upstream of intakes except where indicated

Catchment	Intake Area (ha)	Intake Elevation *(m amsl)*	Meter Readings Spot *(l/s)*	Meter Readings Average *(l/s)*	Stream Gaugings Intake *(l/s)*	Stream Gaugings Intake *(l/s)*	At Filter *(l/s)*	Catchment Yield *(l/s/ha)*
Avatiu	135	80.3	10.2	10.1	10.2			0.076
			7.7	7.7		9.5		
Takuvaine	157	69.4			15.9			0.101
Tupapa	104	61.0			14.2		14.2	0.137
Matavera	95	68.0	17.7	17.0	17.5		16.4	0.184
Turangi	116	71.6	43.0	42.7	36.8			0.317
			37.0	38.3		35.4		
Avana	243	80.9			27.8		(9.0 DS)	0.096
Totokoitu	67	64.0			13.3			0.199
Taipara	94	61.0	23.0	22.2	34.3			0.365
			22.2	22.1		30.9		
Papua	161	49.3			20.9			0.130
Ngatoe	99	53.0	2.9	3.8	12.5			0.126
Rutaki	106	51.0			8.3			0.078
Muriavai	144	67.0			11.9			0.083
TOTAL	1568				223.6			0.143
					(19,319 m^3/day)			

DS = flow measured downstream of intake

Suggested improvements to water supply intakes

The following are general suggestions to improve the operation and maintenance and may not apply to all intakes.

Access

Access is generally poor to most intake sites with many stream crossings involved. This makes routine inspections and maintenance more tedious and time consuming and it also causes additional wear and tear on the limited selection of vehicles available to Water Works. Each intake should be visited at least once a week to ensure that there are no problems (blocked screen, dead animals, broken pipes, open valves, etc.) and to carry out maintenance tasks (clean screens, clean filter beds, maintain access tracks, trouble shooting, etc.)

It is also important to have good access after a flood or when emergency attention may be required to reinstate damaged water supplies.

Most access roads to water supply intakes require upgrading with special attention to stream crossings. Some roads just require filling of holes, clearing of logs, trees, rocks and other debris that prohibit vehicle access.

Stream crossings may be dealt with by constructing fords using gabion mattresses (rock-filled wire baskets.). With minimum cost and effort, stream bed materials can be used to construct gabion mattresses across a stream thus providing a suitable surface for vehicle crossing. The mattresses are permeable and flexible so water passes through them and they conform to any bed movement without failure.

Intake Leakage

Most of the intakes leak in one way or another. During most of the year this is not a problem as there is sufficient stream flow to meet the water demands of Rarotonga. However during “dry” periods any water that leaks through the intakes is water that could have been used in the distribution system. If each of the twelve intakes leaked 1 l/s then this would equal the “dry” weather flow (12 l/s) of one intake similar in yield to the Ngatoe or Avatiu streams.

Simple repairs to leaking scour devices located in each intake would reduce the amount of water lost. Note that a measured flow of 9 l/s was observed flowing under the Avana intake and an estimated flow of 3-4 l/s around the Taipara intake.

Intake Screen Design

The blocking of intake screens with leaves and other debris appears to be a problem especially where intakes cannot be visited on a daily basis. There may be a more appropriate screen design available for the covering of the intake.

Silt and Debris Traps

The installation of “check dams” located strategically upstream of intake structures would be useful in trapping silt and debris that otherwise would be deposited at the intake. These could be constructed at minimum cost and effort in existing pools and other suitable locations using rock-filled gabions and/or steel fence posts (tied with wire) driven across the stream. These “check dams” would trap a portion of flood driven stream bed materials as well as logs and debris thus protecting the intakes. The “check dams” may require periodical cleaning especially after flood events.

WATER SUPPLY

Water Demand

Table 3 shows the water demand estimates made by various consultants in the past:

Table 3: Estimates of Water Usage (m^3/day) on Rarotonga

USAGE	Binnie (1) 2000	WMI (2) 2000	Sakaru (3) 1992
Domestic	5,680 (8,100)	3,000	7,200
Industrial & Commercial	3,420 (4,200)	4,400	2,100
Agriculture	800 (2,900)	18,000	1,200
Unaccounted for Water	1,800 (2,800)	6,880	3,500
TOTAL	11,700 (18,000)	32,380	14,000

(1) Binnie & Partners 1984 Resources and Water Supply of Rarotonga, June 1984 NOTE: Binnie provides two demand estimates; a “best estimate” and a “high estimate” which is given in the brackets.

(2) WMI & BURGEAP 1992, Outline Scheme for Water Development and Management.

(3) Sakaru 1992, Report on Rarotonga Water Supply Network Analysis.

As can be seen from Table 3 there is little agreement between the domestic water demands. There is over a 50% difference in Binnie’s best and high estimates. In calculating domestic demand Sakaru (1992) uses 660 litres per consumer per day, Binnie’s uses 560 litres per consumer per day and WMI uses 250 litres per consumer per day while all figures are said to be based on water meter readings.

Water for agriculture varies as well. WMI allow for the irrigation of 900 ha at 20 m^3/ha/day whereas the others are much less. It is believed that the high domestic demand rates use by Binnie and Sakaru have a component of irrigation.

Unaccounted for water is another big unknown, mainly consisting of reticulation losses and illegal connections. Binnie uses 15% while WMI and Sakaru assume 25% for unaccounted water. However, night flow losses up to 70% were measured by both Binnie and WMI resulting from water wasted through leaky distribution pipes, leaky individual plumbing systems and taps not turned off. Unaccounted for losses in the order of 40-60% are normal in the region.

It is interesting to note that if the water from all the stream flows, that was measured by the team, was available for use (19,319 m^3/day) then both Binnie and Sakaru's demand estimates would be satisfied.

Any reduction in unaccounted for water losses would have direct impact on water resources providing additional water for future growth and developments and/or for in-stream users. An example would be that if a water supply system provided 10,000 m^3/day and 50% of the water was unaccounted for then actual demand is only 5,000 m^3/day. If through leak detection, pipe line rehabilitation, water conservation and education, the unaccounted for water was to be reduced to zero, then the potential capacity of the water supply is doubled. In reality there will always be unaccounted for water in any water supply system but the point is by minimising water losses the capacity of the water supply is increased.

The only reliable way to assess and control water usage is by universal water metering and a "user pays" system.

Dealing with water losses may be more economic than providing for additional water sources and/or constructing new storage reservoirs.

Universal Water Metering

The installation of bulk (reticulation system) and individual (all used connections) water meters are very beneficial to the operation, maintenance and water consumption of a water supply system. The main benefits are as follows.

- How much water being supplied by each water source and flowing through the distribution system can be determined.
- How much water each consumer uses can be measured.

- An assessment of where water losses occur in the system by monitoring water meters can be undertaken.
- A water charging system that encourages consumers to use water wisely can be determined.
- The management of the water supply system based on hard data instead of guessing can be implemented.

During the visit, only four out of twelve intake water meters were operational. Thus it was impossible to assess how much water was entering the distribution system.

If the amount of water was being supplied by the twelve water sources, and the amount of water used was known (by water meter readings), then it becomes easier to assess if a problem is caused by either (i) water shortage; (ii) water conveyance; or (iii) water usage.

It is strongly suggested that bulk water meters are installed (fixed or replaced) within the distribution system and that all water connections are metered to enable the sustainable management of the water supply.

User Pays System

It is suggested that a user pays system be initiated to generate funds necessary to supply water throughout Rarotonga for domestic, commercial, industrial, and limited agricultural use. Water is essential for the existing and developing tourism industry which Rarotonga heavily relies on. Rarotongans pay for their electrical, their petrol and other consumables so why not pay for their water?

All non-domestic users should be targeted first. Most commercial and industrial user already have water meters installed. Therefore, the balance of non-domestic users should be metered at once and water supplied paid for. Non-domestic users all financially benefit from the water supply so why shouldn't they contribute to the operation, maintenance and capital improvements of the supply?

Along with providing revenue, overseas experience has shown that water consumption also decreases when users have to pay. Paying for water will reduce water demands and therefore reducing the need for alternative water sources, storage facilities and other capital works. The environment also benefits by providing reducing stream abstractions that enhances in stream users.

SURFACE WATER RESOURCES

Very little information exists on the surface water resources of Rarotonga. Stream flow data is essential to be able to analyse sustainable catchment yields, low-flow and flood-flow conditions. The following is a list of known periods of stream measurements.

- 1950/51 Spot gaugings at intake sites using temporary rectangular weirs.
- 1960/61 Spot gaugings at intake sites.
- 1979/80 Four months of recorded daily flows on the Totokoitu Stream located approximately 400 m downstream of the water supply intake.
- 1991/92 Spot gaugings at proposed intake sites on Matavera and Tupapa Streams using a temporary V-notch weir by Sakaru.
- 1996 Spot gaugings taken by SOPAC upstream on the 12 water supply intakes using a standard current meter.

Copies of the above mentioned flow measurements appear in Appendix 2 and Table 2

Other “flow measurements” are mentioned in various reports but most were made from water meters located on intake pipelines (not all stream flow enter the intake pipeline) and are estimates only.

The Binnie and WMI/BURGEAP reports use water balance methods to assess surface water resources. Both consultants used existing average rainfall and average expected evapotranspiration losses to generate average runoff values. However, without any hard stream flows data to compare their results with, the exercises are only academic, based as they are on the only data available to the consultants.

Stress on the existing surface water resources will only get worse in the future thus it is important to know the sustainable safe yield from the water supply catchment areas of Rarotonga. The only way this can be achieved is by the installation of continuous stream gauging stations to build up a database that can be used to analyse stream flows.

Its is suggested that three or four continuous long term gauging stations be established on selected streams to best assess the surface water resources on Rarotonga. Appendix 3 contains a proposal to establish a surface water resource study on Rarotonga.

Water Supply Distribution System

The existing distribution system consists of a network of various pipes of all types, sizes and conditions that are gravity fed by twelve surface water intakes that have been constructed over the last forty years. Four infiltration gallery systems exist but are not used on a continuous basis. A number of reservoirs exist ranging from a 10,000 m^3 HDPE-lined reservoir, to a 150 m^3 steel panel tank. It is understood that only the Takuvaine supply reservoirs are operational. As previously stated, it is estimated that 50% of the water entering the distribution system is lost through leaks.

In the past the water supply development pattern appeared to be "if more water is needed therefore put in another intake." This approach has generally worked until there is a dry period. The approach now should be, "how much water is available and how best to utilise this water?".

If this approach is to be adopted then the following information is required:

- water resource data
- water demand data

Water resource data will enable an assessment to be made on the available of the water resource. Water demand data will enable an assessment on current water usage noting domestic, commercial, industrial, agricultural demands. This can only be achieved by the installation of water bulk and individual water meters. Unaccountable for water then can be assessed and a method employed to minimise water wastage.

A leak detection and pipeline rehabilitation program is urgently required to reduce wastage through defective pipes.

Other improvements to the distribution system would include storage reservoirs located adjacent to individual intakes. Also computer modelling of the distribution network could assist in the management of the system but the unavailability of water meters, leak detection and pipeline rehabilitation are the urgent issues to deal with first.

DISCUSSION

Basic data is required to be able to manage any resource in a sustainable manner. An example is a bank account. To know how much money can be spent (with out going into overdraft) you need to know how much money is going into the account. This is true with water resources. How can a water supply system be managed if you do not know how much water is available and how much is being used? Currently in Rarotonga there is no way to assess water supply and demand. Only when the supply and demand of the water supply system is known can the system be managed in a sustainable manner.

As a priority, bulk and individual water meters must be installed and monitored to assess water entering and exiting the water supply system. Once this information is available the system can be analysed thus allowing management decisions to be made to improve the service and to conserve the limited water resources.

Existing information suggests that there is considerable wastage of water within both the distribution system and individual private systems. Because most connections are not metered and there is no charge for supplying water, there is no means to monitor or to control water usage.

It is very likely that with water meters installed and a “user pays” system in place that water wastage will reduce through leakage repairs and water consumption rates will decrease due to water charges. The end result will be a more efficient water supply system, reduction in water usage as well as funds to operate, maintain and improve the water supply system for future development. The need for large storage reservoirs and additional water sources may not be needed or postpone a real need.

Since there is very little existing data regarding surface water resources an investigation of Rarotonga’s water resources (as proposed in Appendix 3) is most appropriate. With the data generated by the proposed study the safe sustainable catchment yields can be assessed with confidence.

Protection of the water supply catchments is most important to ensure both water yield and quality for generations to come. The proposed Rarotonga water supply catchment zone legislation (as per Progress Report on the Rarotonga Water Catchment Committee, October 1996) that restricts land use in all areas located above the 150 m contour is strongly supported.

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APPENDIX 1

Newspaper Headlines

Cook Islands NEWS

PO Box 15 Ph. 22-999 Fax 25-303 60c

Monday 18 November 1996 Rarotonga

Low water levels striking home

The current dry weather has meant low water pressure on Rarotonga's western side and despair for some families.

The low water pressure in inland areas meant at least one family deciding to move to the low-lands.

A number of residents in the Nikao and Arorangi area have contacted the Water Supply Division over the situation.

Water Supply Director, Ben Parakoti, says some families are without a drop of water.

One resident said his family planned to shift to stay with his father because there wasn't any water, and a water tank hadn't been installed yet.

Homes with water storage tanks that need filling can contact the Ministry of Works, Environment & Physical Planning (MOWEPP) who can supply water for domestic requirements at $50 a 1000 gallon load of water or $25 for 500 gallons.

However for commercial users, MOWEPP is charging $100 per 1000 gallon load.

CONSERVATION

Parakoti is also urging the public including farmers not to waste water.

Farmers using irrigation methods are urged to use water only at night.

Parakoti said "If you run the water during the day time you need lots and lots of water to soften the soil. And because it's very hot the water evaporates faster [during the day time] and it won't go in to the plant, and you'll just be wasting your time."

He says it's better to run the water at night for about three to four hours.

While urging sensible use of water, Parakoti warns that if people continue to waste water, then Water Supply staff will have no choice but to disconnect their water supply.

The director is calling on the public to report any leaking or broken water pipes.

Water Supply checks of Rarotonga's intakes reveal that only two of them are more than half full. *—AS/NB*

Cook Islands NEWS

PO Box 15 Ph. 22-999 Fax 25-303 60c

Tuesday 19 November 1996 Rarotonga

Pray for rain

Another month or so of sunny weather could mean a state of emergency being declared because of Rarotonga's plummeting water supply.

And while a backlash of public opinion slams the sudden fees for water carted on request, MOWEPP's Water Supply director Ben Parakoti says all the public can do is pray for rain.

"The rates had not been advertised because we were still deciding on Friday," he says after some Arorangi residents phoned CINews yesterday to slam the rates beginning from $10 for 200 gallons or $25 for 500 gallons of water — estimated to be around three days supply for a small household.

INTAKES LOW

Yesterday Parakoti was part of a team doing daily monitoring of the water levels in intakes across the island — most of them lower than ever for this time of the year.

The Arorangi area, which has many tourist properties including the Rarotongan and Edgewater resorts, has seen some residents moving to second homes or extended families in villages where the water supply is better.

Edgewater Resort General Manager Paul Boyce says the hotel's large underground water tank has come in handy.

DELIVERIES

"With the hotel occupancy at 74% last week, we were higher than expected so we had water deliveries," he says, "we were never in an emergency situation — we've taken precautions, monitored usage daily and arranged everything satisfactorily."

And Rarotongan Resort GM Adi Narayan says there hasn't been a problem there either.

But others, especially the majority of households without tanks or the cash to fill them, are not so happy.

"It's not fair," says one resident of the charges, "we weren't told about this and everybody's suffering."

"We had to come up with charges to recover costs to maintain the tanker," says Parakoti.

He admits the problem of the majority not having containers or tanks, "but some of them have been talked to long ago about the need for tanks and have ignored that, they don't have a right to blame the department."

Parakoti says with the water situation reaching critical levels in Takuvaine and Avatiu, planters and pig-owners need to wait until demand is lowest before irrigating or cleaning out with water. — *Lisa Vainerere*

APPENDIX 2

Available Flow Measurement Data

(from Binnie & Partners, 1994)

Table 3.1 GAUGINGS AT INTAKE SITES (1960/61)

DATE	Flows converted to l/s							
	AVATIU	TAKUVAINE	TURANGI	AVANA	TOTOKOITU	PAPUA	MURIAVAI	TOTAL
30.4.60	13	22	23	64	4	0	0	106
24.6.60	64	21	64	24	19	0	0	128
4.7.60	6	17	17	71	14	13	2	113
8.7.60	3	0	64	26	129	11	0	104
15.7.60	4	3	43	60	2	19	0	104
22.7.60	15	23	20	34	7	13	0	112
29.7.60	5	0	34	·100	31	20	0	190
2.8.60	15	13	26	126	12	0	0	110
19.8.60	26	21	24	3	0	36	0	106
26.8.60	17	24	36	60	17	23	3	180
2.9.60	64	23	64	24	13	0	0	188
9.9.60	54	11	160	206	144	190	121	886
16.9.60	17	*	40	100	24	46	0	–
23.9.60	–	43	35	64	4	7	0	–
30.9.60	13	26	24	64	3	0	0	118
7.10.60	19	22	57	*	*	7	0	–
14.10.60	19	24	64	–	–	0	0	–
20.10.60	8	0	24	57	34	34	0	140
28.10.60	19	0	54	64	13	7	0	116
2.12.60	71	314	171	371	131	229	100	1387
9.12.60	45	171	100	200	86	54	20	685
15.12.60	*	*	200	400	*	*	126	*
23.12.60	13	60	37	129	51	100	20	510
13.1.61	19	143	100	64	100	37	20	483
20.1.61	26	109	80	24	64	20	16	339
27.1.61	–	114	71	51	111	20	7	374
3.1.61	13	0	46	64	*	126	24	–
7.2.61	13	109	126	64	114	31	37	494
10.2.61	8	64	43	40	21	64	37	277
Minimum	3	0	17	3	0	0	0	

* means flow was too large to be assessed
– means flow not measured

Table 3.2 GAUGINGS AT TEMPORARY WEIRS IN 1950

DATE	Flows converted to l/s		REMARKS
	AVATIU	TAKUVAINE	
16.8.50	-	14.6	
18.8	-	11.5	Takuvaine rebuilt
31.8	-	30.0	25/8
4.9	16.7	-	
14.9	27.4	40.5	
21.9	37.9	60.6	
28.9	45.3	66.4	
5.10	17.7	20.1	
12.10	167	235	Weirs overtopped
19.10	27.0	31.8	by 'about 1.5 inches'
26.10	weirs submerged		
28.10	50.0	73.2	
2.11	21.6	27.0	
9.11	18.1	18.6	
16.11	15.9	16.4	
23.11	12.1	14.2	
30.11	16.8	19.5	Weirs washed out or
7.12	10.8	13.4	dismantled because of heavy rain by 11.12.50
Mean	35.0	43.0	

Table 3.3 GAUGINGS AT TEMPORARY WEIRS IN 1951

DATE	Flows converted to l/s					
	TURANGI	AVANA	TITIKAVEKA (TOTOKOITU)	VAIMAANGA (PAPUA)	RUTAKI	ARORANGI (MURIAVAI)
6.6	34.9	–	–	–	–	–
7.6	–	28.3	11.3	22.9	–	–
8.6	–	–	–	–	8.0	10.5
13.6	–	–	–	–	–	9.7
14.6	34.3	30.7	10.5	20.2	8.0	–
20.6	–	–	9.7	19.2	7.4	8.8
21.6	33.7	26.7	–	–	–	–
28.6	–	37.2	12.1	30.7	11.9	17.7
29.6	37.4	–	–	–	–	–
4.7	33.7	31.3	10.8	21.8	–	–
5.7	–	–	–	–	8.0	8.5
12.7	32.5	25.0	9.2	19.2	–	6.2
13.7	–	–	–	–	6.1	–
20.7	37.4	28.9	10.0	26.7	4.9	8.5
27.7	40.0	41.3	11.3	25.0	8.6	7.6
3.8	36.8	60.2	18.7	36.2	11.1	18.3
10.8	32.5	37.2	17.7	30.2	10.4	11.3
15.8	30.7	35.7	9.2	28.3	8.6	8.8
22.8	27.8	31.3	13.4	22.3	7.4	20.8
30.8	15.8	30.7	11.7	20.2	6.5	13.4
6.9	o/topped by 1.4 inches	–	–	–	–	–
7.9	–	o/topped by 4.4 inches	–	o/topped by 4.7 inches	–	–
14.9	–	55.5	–	–	–	–
15.9	–	–	19.2	38.1	11.5	26.1
19.9	27.2	35.6	16.3	28.3	–	–
20.9	–	–	–	–	10.1	21.2
28.9	32.5	43.9	15.8	33.1	14.6	15.8
5.10	27.2	32.0	–	–	–	–
6.10	–	–	13.9	26.1	8.6	8.8
11.10	30.2	44.6	13.0	30.7	11.5	10.5
18.10	25.6	23.9	10.5	18.3	–	–
19.10	–	–	–	–	10.4	7.0
27.10	23.3	17.7	8.8	14.9	5.8	5.2
1.11	22.3	17.7	8.1	13.9	–	–
2.11	–	–	–	–	5.3	4.6
7.11	20.2	20.2	8.8	13.0	4.7	3.9
14.11	–	17.7	7.0	10.8	4.5	3.0
15.11	20.8	–	–	–	–	–
22.11	22.2	13.0	6.2	8.8	3.7	2.3
30.11	21.2	13.9	6.2	12.6	3.9	2.6
5.12	21.8	11.7	5.9	10.8	3.4	3.0
12.12	32.5	–	10.8	24.4	5.8	3.4
13.12	–	25.0	–	–	–	–
Mean (l/s)	29.0	30.3	11.3	22.5	9.9	7.8
Median (l/s)	31	30.7	10.5	22.3	8.5	8.0

Table 3.5 TOTOKOITU DAILY FLOWS (1979/80)

DAY	DEC 1979	JAN 1980	FEB 1980	MAR 1980	APR 1980	
1	-	10	240	10e	35	
2	-	*	90	*	26	
3	-	*	48	*	26	
4	record started	*	49	*	25	
5	*	*	pen failed	*	19	
6	*	*	clock stopped	*	15	
7	*	*	" "	*	13	
8	*	10e	67	*	12	
9	129	*	73	9e	12	
10	317	*	40	9e	10	
11	900e	26	28	*	*	
12	chart said	22	22	*	*	
13	to have	17	35	*	*	
14	been	19	25	*	*	
15	distorted	22	41	*	*	
16	over	193	35	*	54	
17	this	52	19	33	48	
18	week.	179	14	10e	23e	
19	19e	180	12	*	15e	
20	17	149	11	*	13e	
21	16	86	*	*	12e	
22	15	65	*	12	10e	
23	12	555	*	43	No further	
24	15	133	*	48	chart	
25	10e	128	*	223	records	
26	*	164	9e	64e	kept	
27	11e	964	*	70e		
28	10e	229	*	535		
29	10e	130		597		
30	23	80		127		
31	14	48		62		
Total (l/s x days)	1,558 over 20 days	3,525	914 (25 days)	1,980e	393 (22 days)	129 days total
Mean (l/s)	78	114	36.6	63.9	17.9	64.9
Runoff (mm on 0.66 km^2)	240	461	120	259	51	1095

* means less than 10 l/s (assume 8 l/s on average)

Flows taken midnight to midnight

e means estimate from evidence

STREAM FLOW SURVEY IN MATAVERA AND TUPAPA

Stream flow was measured in Matavera and Tupapa stream on proposed intake site using temporary Vee-notch weirs. Flow rate is shown as the following formula:

Q = 1.337 * h - 2.48
Q = Flow rate (Ton/m-3)
H = Water depth (m)

<u>Matavera Stream on Proposal Intake Site</u>

DATE	TIME	READING (mm)					Average (mm)	Notch (mm)	H (mm)	Q (l/s)
2/12/91	11:00	270	275	285	280	290	280.0	442	162	14.6
3/12/91	9:10	285	292	287	285	288	287.4	442	155	13.0
4/12/91	10:30	305	290	295	290	295	295.0	442	147	11.5
9/12/91	9:00	291	295	289	300	295	294.0	442	148	11.7
11/12/91	9:00	275	274	268	262	266	269.0	442	173	17.2
19/12/91	12:00	300	309	304	299	301	302.6	442	139	10.1
22/1/92	11:30	265					265.0	442	177	18.2
30/1/92	11:20	270	271	273	278	280	274.4	442	168	15.9
4/2/92	10:10	261	267	266	267	272	266.6	442	175	17.8

<u>Tupapa Stream on Proposal Intake Site</u>

DATE	TIME	READING (mm)					Average (mm)	Notch (mm)	H (mm)	Q (l/s)
4/12/91	12:55	297	299	294	300	296	297.2	434	137	9.6
9/12/91	9:30	285	284	285	292	289	287.0	434	147	11.5
11/12/91	9:45	269	262	278	274	275	271.6	434	162	14.7
19/12/91	12:55	303	297	288	296	301	297.0	434	137	9.7
30/1/92	10:00	286	276	290	295	284	286.2	434	148	11.7
4/2/92	9:00	285	280	283	278	283	281.8	434	152	12.5

Sakaru Tsuchiya, Report on Rarotonga Water Supply Network Analysis, March 1992.

RAROTONGA WATER RESOURCES INVESTIGATION

Surface water data collected 13-18 November 1996

Catchment	Intake Area (ha)	Intake Elevation *(m amsl)*	Meter Readings Spot *(l/s)*	Meter Readings Average *(l/s)*	Stream Gaugings US Intake *(l/s)*	Stream Gaugings US Intake *(l/s)*	At Filter *(l/s)*	Catchment Yield *(l/s/ha)*
Avatiu	135	80.3	10.2	10.1	10.2			0.076
			7.7	7.7		9.5		
Takuvaine	157	69.4			15.9			0.101
Tupapa	104	61.0			14.2		14.2	0.137
Matavera	95	68.0	17.7	17.0	17.5		16.4	0.184
Turangi	116	71.6	43.0	42.7	36.8			0.317
			37.0	38.3		35.4		
Avana	243	80.9			27.8		(9.0 DS)	0.096
Totokoitu	67	64.0			13.3			0.199
Taipara	94	61.0	23.0	22.2	34.3			0.365
			22.2	22.1		30.9		
Papua	161	49.3			20.9			0.130
Ngatoe	99	53.0	2.9	3.8	12.5			0.126
Rutaki	106	51.0			8.3			0.078
Muriavai	144	67.0			11.9			0.083
TOTAL	1568				223.6			0.143
					(19,319m^3/day)			

DS = flow measured downstream of intake

APPENDIX 3

Water Resources Study Proposal

COOK ISLANDS

LOGICAL FRAMEWORK OF PROPOSED PROJECT

PROJECT NAME: Hydrological Network for Rarotonga

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Main Assumptions
Goals or Broad Objectives			
To provide hydrological information to enable the sustainable development and management of the water resources in Rarotonga	Hydrological reports on selective stream catchments in Rarotonga	Installation of recording equipment and development of a hydrological database	Land access is not a problem. Equipment is maintained and made secure
Purpose or Narrow Objectives			
• To install water level and rainfall recorders on three streams in Rarotonga. • To carry out stream flow gaugings • To collect, store and analyse hydrological data • To train staff on use of hydrological equipment and computer software	Good quality flow and rainfall data for selective stream catchments.	Check gaugings carried out at each site visit. Audit of hydrological data using quality control methods.	Technical staff available to carry out installation, monitoring and data handling.
Outputs			
• Stream level and rainfall recording stations. • Reports on the hydrological data of the catchments • Trained staff in hydrological data collection			Funding available for installation and maintenance of all recorders
Inputs			
• Hydrological recorders, computer equipment and associate software • Training of staff			Funding available to purchase equipment

PROJECT COST ESTIMATES

DONOR COST	($NZ)
EQUIPMENT COSTS	
• 3 water level recorders with associate equipment	$15,900.00
• 3 tipping bucket rain gauges with associate equipment	$7,500.00
• Computer system plus software to donwload, enter, store, analyse and retrieve hydrological data	$13,000.00
• Pygme current meter and associate equipment	$5,500.00
Sub-Total	***$41,900.00***
INSTALLATION COSTS	
• 3 water level recording stations	$9,000.00
• 3 rain gauge stations	$1,500.00
Sub-Total	***$10,500.00***
CONSULTANCY COSTS	
• Design, supervise installation of hydrological sites and equipment plus staff training in the use of equipment (30 man-days)	$15,500.00
• Hydrological data collection, storage, analyses and retrieval training (one week)	$8,100.00
Sub-Total	***$23,600.00***
TOTAL	**$76,000.00**
COOK ISLAND GOVERNMENT COST	
TECHNICAL STAFF SALARIES	
• Technical Supervisor (one) 5 years @ 10% of the time	$15,000.00
• Technicians (two) 5 years @ 25% of the time	$35,500.00
Sub-Total	***$50,500.00***
PROJECT OPERATION AND MAINTENANCE COSTS	
• Vehicle Operation	$5,000.00
• Equipment Maintenance	$2,000.00
Sub-Total	***$7,000.00***
TOTAL	**$57,500.00**
GRAND TOTAL	**$133,500.00**