LEAST-COST ANALYSIS OF WATER SUPPLY OPTIONS IN NIUE

(Integrated Water Resource Management Technical Report)

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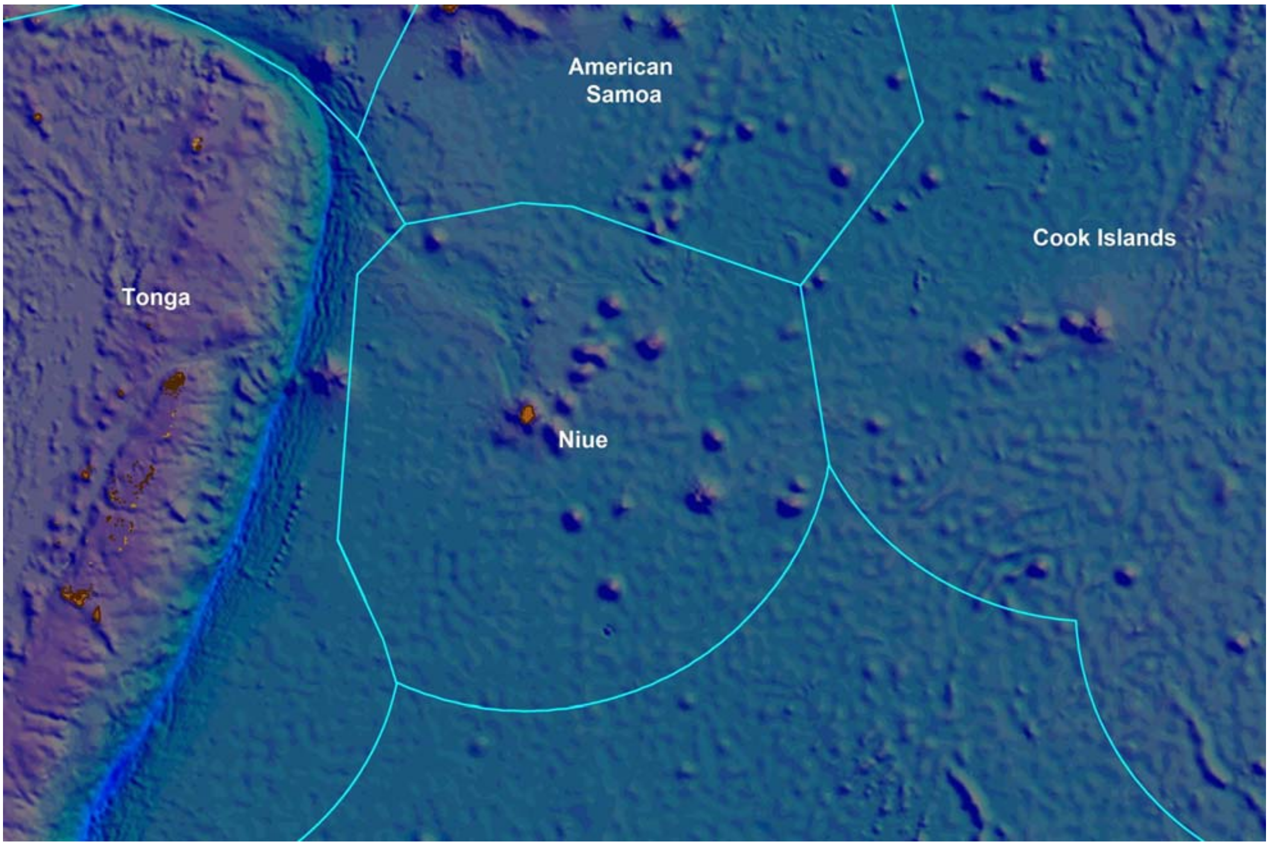

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ACRONYMS

ADB	Asian Development Bank
DWSP	Drinking Water Safety Planning
EEZ	Exclusive Economic Zone
FAO	United Nations Food and Agricultural Organisation
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GoN	Government of Niue
IBT	Increasing block tariff
IWRM	Integrated Water Resource Management
MDG	Millennium Development Goal
NPC	Niue Power Corporation
Pacific-HYCOS	Pacific Hydrological Cycle Observing System
PACTAF	Pacific Technical Assistance Program
PACTAM	formerly Pacific Technical Assistance Program now changed to PACTAF
PIC	Pacific Island Country
PWD	Niue Public Works Department
SIDS	Small Island Developing States
SOPAC	Pacific Islands Applied Geoscience Commission
SPC	Secretariat of the Pacific Community
UNDP	United Nations Development Programme
WASH	SOPAC Water, Sanitation and Hygiene Programme
WBWC	Wide Bay Water Corporation
WDM	Water Demand Management
WQM	Water Quality Monitoring
WSD	Water Supply Division
WUE	Water Use Efficiency
WWD	Niue Water Works Division

GLOSSARY

Discounting	A calculation which transforms future values into present-day terms.
Discount rate	The rate at which future values are transformed into present-day terms.
Exclusive Economic Zone	The sea area surrounding a state over which the state has exclusive fishing rights (Slomanson 2006).
Increasing block tariffs (IBTs)	A tariff scheme in which a subsistence consumption level is identified and water consumption up to that point is free, while water consumed beyond that point is charged a per unit tariff.
Least cost analysis	A comparison of several projects' market and non-market costs, with an identification of which project incurs the least costs (Tietenberg 2000).

CONVERSION RATES

1 kg = 0.001 tonne
1 long ton = 1 016 kg
1 m^3 = 1 000 litres
1 KL = 1 000 litres
1 ML = 1 000 000 litres

EXECUTIVE SUMMARY

Niue's water availability is characterised by groundwater, rainwater and no surface water. While rainwater tanks have sometimes been used in the past to supply water, Niueans have now come to rely almost exclusively on the groundwater lens. In order to access this groundwater, fossil fuel-based pumping is currently used; however, fuel is expensive.

This reliance on costly fossil fuel has provided the impetus for the Government of Niue to begin exploring alternative options for water supply. Among these, Niue has developed a National Integrated Strategic Plan 2009-2013 which specifies targets of rainwater harvesting and renewable energy constituting 20 per cent of total water supply and 20 per cent of electrical power respectively by 2013.

The analysis presented in this paper is an assessment of the least cost of the following three water supply options:

1. existing fossil fuel-based groundwater pumping (the status quo);
2. a combined rainwater harvesting/fossil fuel-based system in which 20 per cent of total water supply comes from rainwater harvesting and the remaining 80 per cent from fossil-fuel based groundwater pumping;
3. a combined solar energy/fossil fuel-based system in which 16 per cent of total water supply comes from solar energy-based groundwater pumping; remaining 84 per cent from fossil-fuel based groundwater pumping. This ratio is specified as 16 per cent to 84 per cent respectively, due to the findings of a 2004 study on solar resource potential.

Niue has had historical experience with both of the proposed alternative water supply options: a solar pumping project was previously trialled in Makefu Village, and rainwater tanks were in widespread use until the 1980s.

Financial and economic analyses were conducted on the grounds of available data. Establishment and operating costs from each water supply option were examined in the financial analysis, including both the specific pumping costs and the costs of maintaining the infrastructure. Under the economic analysis, additional social and environmental factors were considered.

Given the large infrastructure costs any new water supply system would incur, it was found in both the financial and economic analysis that it would be cheaper to maintain the status quo fossil fuel-based system, as the infrastructure to support this is already in place. This is despite the fact that financial and economic per unit operating costs are actually lower for both the solar and rainwater alternatives, the combined rainwater harvesting option offering the lower per unit cost for water supplied. The expense of establishing the new infrastructure required for both these options would be expected to eradicate any supply cost savings for many years.

The only time it would be financially and economically feasible to switch to one of the alternative systems would be if financial assistance was secured to establish the infrastructure required. In this case, a combined rainwater harvesting/fossil fuel-based system would offer the cheapest water supply option. Nevertheless, there remains considerable work to make this option both technically and socially feasible. At a technical level, a detailed analysis of the rainfall to be captured, type and amount of usage, and the storage required for rainwater harvesting would still need to be conducted. There would also need to be strategies developed to ensure that installation of a rainwater harvesting system did not create the perception that there is “more” water available, leading to an increase in per capita water consumption.

At a social level, the implementation of alternative systems would also need to be discussed and elaborated with communities. As an example, any rainwater harvesting based system would potentially require individual households to become responsible for ongoing system operation, maintenance and consequently water quality and safety. Communities would need to commit time

(to maintain tanks, guttering etc.) and money (repairs, extra power costs to pump water from the tanks to the house) to this. Community awareness, support and acceptance of these responsibilities for maintaining rainwater systems to minimise the risk of contamination would be important. If communities did not take on this responsibility, and the WWD was perceived as being responsible for maintaining household rainwater harvesting systems as well as the reticulated supply, this would be a significant additional ongoing cost to the Niue Government which would need to be addressed.

Given these issues, it would appear most appropriate for Niue to retain the current system of fossil fuel-based pumping for the present. Nevertheless, with the potential to reduce operating costs under alternative water supply systems in the future, it would still be wise to keep a watching brief on the costs and development of these alternatives should new opportunities (such as investigations and donor assistance) emerge.

Given the relative feasibility of the fossil fuel-based water supply option presently in Niue, cost-recovery issues for this option were also considered. Currently no cost recovery is conducted for water provision in Niue; however, there is interest in examining the feasibility of water charges. Generally, cost recovery takes the form of per unit tariffs, flat rates or a combination of the two. Two tariff schemes were presented to assess efficiency and equity outcomes: per unit tariff charges and increasing block tariffs (IBTs).

The scheme which maximised both welfare (for households) and revenues (for the Government) was a leakage reduction programme followed by a full cost-recovery IBT: NZ$0.91/KL. This involved a water price of NZ$0.20/KL higher than the price suggested in a previous study (WBWC 2007). With this price, households can be expected to pay an average of NZ$378 per year for their water (or 1 per cent of GDP per capita per year) – as compared to the free water they currently receive.

Furthermore, a leakage reduction programme was considered to assess the impact on supply costs and prices to consumers. Losses in Niue could be significantly reduced from the estimated current level of 40 per cent by implementing water demand strategies (for example, an active leak detection and repair programme). This option was identified as offering a win-win opportunity to the Niuean community by both reducing water supply costs to the Government and reducing the amount which households would need to pay to recover costs.

Niue also has a very high level of per capita consumption – estimated to be 350 litres per person per day – which could also be reduced through education campaigns and retrofit schemes designed to install higher efficiency devices in households (e.g. low-flow shower heads, watertight tap fittings and low-flush toilets).

It is also important to note the inter-dependent relationship between technological change and cost recovery. The analysis considered cost recovery under the status quo situation. If the Government of Niue shifted water supply to rainwater harvesting, it is unlikely that householders would have an incentive to pay water tariffs because rainwater is neither serviced (for example, via water treatment) nor supplied by the Government (as it is the household's rainwater tank). Nevertheless, with 80 per cent of water is still provided by the Government, cost recovery is still important. It might then be necessary to implement subsidies or a loan scheme to share the initial costs of installing rainwater tanks in homes. Households who wish to remain on the status quo infrastructure would meanwhile be charged a tariff.

Depending on one system alone can often be unreliable. For rainwater harvesting, for example, there will be no rainwater during periods of extended drought. The responsibility for the quality and safety of water supply will also be only on the households for rainwater systems. Hence a combination system, where groundwater resources are still utilised and properly managed but supplemented by alternative sources such as rainwater harvesting and/or solar pumps should be explored as a way to reduce the operational costs of World Water Day and provide a safe, reliable water supply to the people of Niue.

A INTRODUCTION

The Pacific Islands Applied Geoscience Commission (SOPAC) currently executes the *Implementing Sustainable Integrated Water Resource and Wastewater Management in the Pacific Island Countries* project. This project is funded by the Global Environmental Facility (GEF) and implemented by the United Nations Development Programme (UNDP). Its main objectives are the promotion and implementation of integrated water resources management (IWRM) (see Box 1) and water use efficiency (WUE). Fourteen Pacific Island countries (PICs) are participating, and each country has designed an IWRM demonstration project which addresses specific needs and vulnerabilities in their local context. A regional component in the project is also being developed: this component will identify cross-linkages between contexts and issues, general lessons from in-country work and opportunities for applying IWRM and WUE principles elsewhere. The duration of the project is from 2006 to 2012.

Box 1: Introducing IWRM

Recognising the interdependent nature of sustainable water supply, Integrated Water Resources Management (IWRM) is a holistic and comprehensive management strategy from water basin to consumer. It aims to manage both land and water resources in an integrated manner, with increased collaboration between sectors as well as between government and civil society (GWP Consultants 2007). It has become an increasingly important concept in sustainable development practice. In 2005, the United Nations adopted IWRM as an integral aspect in achieving the Millennium Development Goals (MDGs) (GWP Consultants 2007).

Overall, IWRM’s guiding principles focus on the carrying capacity of the environment, demand management and integrated cross-sectoral management (IWRM Background FAO). The catchment area or river basin is recognised by IWRM as the “logical unit for water resources management” (Taylor et al. 2008), and the water and land resources are managed from basin to consumer. This is in contrast to traditional water management, which was often ad hoc and sectoral. IWRM is therefore a fundamental paradigm shift: it encourages crosscutting goals and objectives, a focus on the basin rather than the separate rivers, and an inclusive atmosphere between government and community stakeholders (Taylor et al. 2008).

In the Pacific, the Pacific Regional Action Plan (Pacific RAP) on Sustainable Water Management (SOPAC/ADB 2003) was developed in 2002 with IWRM identified as the solution to the governance, management and provision of water and sanitation services (GWP Consultants 2007). Small island developing states (SIDS) are particularly vulnerable to the effects of climate change and increasing population pressures, hence IWRM is believed to generate both financial and economic benefits for the region (IWRM Synopsis).

The types of projects proposed vary according to the country’s needs. For example, in Fiji, a country with abundant sources of groundwater, surface water and rainwater catchment, but with vulnerability both to flooding and drought, the demonstration proposal addresses flood management at the Nadi River Basin (SOPAC 2007a). Meanwhile, Tuvalu, a country which relies almost exclusively on ad hoc privately-managed rainwater collection, has a demonstration project to address wastewater management (SOPAC2007b). SOPAC has been assisting the fourteen countries in the development of their demonstration project proposals.

A.1 SOPAC water projects in Niue

The IWRM demonstration project for Niue is entitled, *Integrated land use, water supply and wastewater management as a protection model for the Alofi Town groundwater supply and nearshore reef fishery* (Government of Niue 2007). Its objectives include implementing land use protection measures for urban and rural/agricultural land, measures for water resource supply and demand management, and the development of an updated water policy (Government of Niue 2007). Given that Alofi exhibits the highest population density in Niue, addressing Alofi's water supply has the advantage both of improving one of the largest water markets on Niue and providing important network effects through learning and adaptation in the other villages.

The IWRM demonstration projects are strongly linked to other water-based sustainable development projects implemented by SOPAC. The Pacific Hydrological Cycle Observing System (Pacific-HYCOS) works to improve management of fresh water resources in PICs through appropriate monitoring and data collection. The Water, Sanitation and Hygiene (WASH) Programme, Drinking Water Safety Planning (DWSP) Programme and Water Quality Monitoring Capacity Building Programme (WQM) implement various activities in water supply, sanitation and hygiene with the common goal of improving access to safe water and adequate sanitation for Pacific people. The Water Demand Management (WDM) Programme focuses on building capacity of Pacific water utilities in various demand management techniques, ultimately enabling them to reduce water losses resulting in positive economic and health benefits for communities.

A.2 Purpose of this study

The purpose in this study, which was requested by the Government of Niue (GoN), is to identify the least-cost water supply option available. Given that Niue does not currently recover water supply charges from households, this study will also consider preliminary cost-recovery options to support the sustainability of the least-cost supply options implemented. Niue's water supply is based on groundwater pumping using fossil fuels. Full Terms of Reference for this study can be found in Annex 1.

A.3 Country background: Niue

A.3.1 Demographics

Located in the South Pacific, approximately 430 km east of Tonga, Niue is one of the world's largest coral islands (Figure 1). Its land area is 259 km^2, with an EEZ of 390 000 km^2. Since 1974 it has been a self-governing state in free association with New Zealand. This means that Niuean citizens also hold New Zealand citizenship. This diplomatic relationship is believed to be an important contributor to the depopulation, which Niue is experiencing (Figure 2). Current population estimates are that 1 625 Niueans are resident in Niue itself (Government of Niue 2006 Census), while 22 500 reside in New Zealand (New Zealand Ministry of Foreign Affairs and Trade 2008). There are 579 households in Niue (WBWC 2007). Household size is estimated to be 3.7 persons per household.

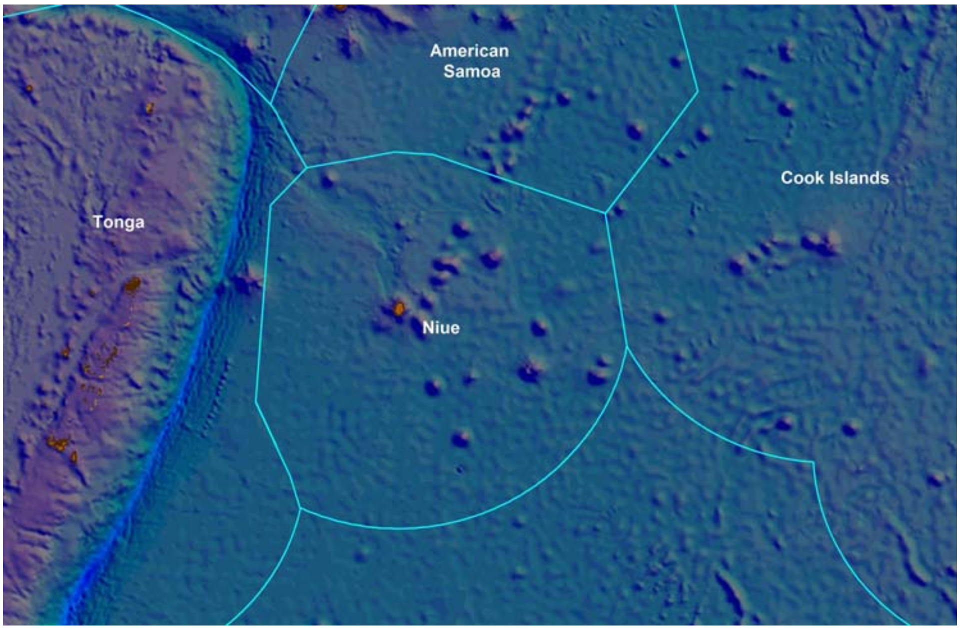

Figure 1: Map of Niue region. Source: SOPAC.

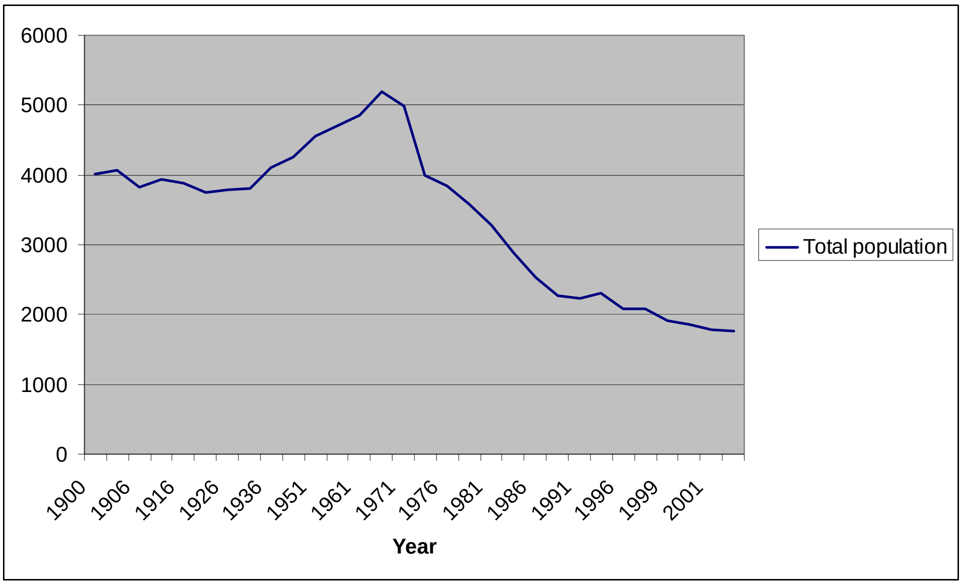

Figure 2: Total population of Niue, 1901-2004. Data source: Government of Niue statistics.

Due to the net outward emigration and the Government of Niue's attempts to retain and attract residents via health, education and social benefits, typical estimates of the population growth rate are zero percent per year (SOPAC 2007c). Importantly for issues of water supply, there is intra-island migration to Alofi Town, as residents from the outer villagers move closer to the capital (Green 1999).

A.3.2 Economic issues

Economic figures are not collected on a regular basis, so the latest data on Niue's Gross Domestic Product (GDP) is from 2003, when it was recorded as NZ$ 17.3 million (Government of Niue statistics 2008). Budget support programs from New Zealand supply approximately half of this (Government of Niue 2004).

The government is the main employer on Niue, while the primary industries are agriculture, fisheries and tourism (Department of Community Affairs 2001).

A.3.3 Environmental issues

The majority of the Niuean coastline is characterised by cliffs and steep, rocky slopes. This allows islanders limited access to the shoreline, and three roads are primarily used to get to the coast: Alofi Wharf, Avatele Cove and Namukulu Landing (Forbes 1996). The wet season is from November to April, while the dry season is from May to October. Niue has suffered from semi-frequent cyclones, with destructive cyclones occurring once every ten years on average (Kreft 1986). The most recent was cyclone Heta (2004) which caused massive destruction.

On initial assessment, several economic and environmental challenges were noted by SOPAC. These challenges included the absence of a protected harbor, limited infrastructure and difficult sea access due to high cliffs surrounding the island (Forbes 1996). Isolation, cyclones and overly wet or overly dry periods are likely to occur in Niue (SOPAC 2005).

A.3.4 Water on Niue

Being a raised limestone atoll, Niue has no surface water. Instead, its groundwater lens has historically been the main source of water on the island. (See Figure 1 for a stylised representation.) The quantity of water available on Niue is a function of rainfall, storage in the limestone, and the rate at which water flows out into the ocean (GWP Consultants 2006). Keeping the water supply safe in Niue is critical because of Niue's isolation and elevated transport costs. Furthermore, the costs of water treatment and health from a tarnished lens would also be elevated (O'Keefe 2007).

The freshwater lens below Niue atoll is considered large and thick, hence providing a substantial aquifer volume. It nevertheless exhibits limited storage capacity due to its rapid recharge and discharge rates (GWP Consultants 2006). Annual average rainfall is approximately 2180 mm, with a range of 810 to 3300 mm (Government of Niue 2008). Of this, it has been estimated that 624 mm is the mean annual recharge rate (GWP Consultants 2006). Since 68 per cent of the annual rainfall comes in torrential downpours during the wet season (Niue Draft DWSP), 85 per cent of the annual recharge occurs between December and April (GWP Consultants 2006). It has been estimated that in an average year, there are 132 million m^3 of recharge (Mosley and Carpenter 2005).

Niue is vulnerable to the effects of El Niño Southern Oscillation and is known to experience extended dry periods and erratic rainfall (SOPAC 2007d).

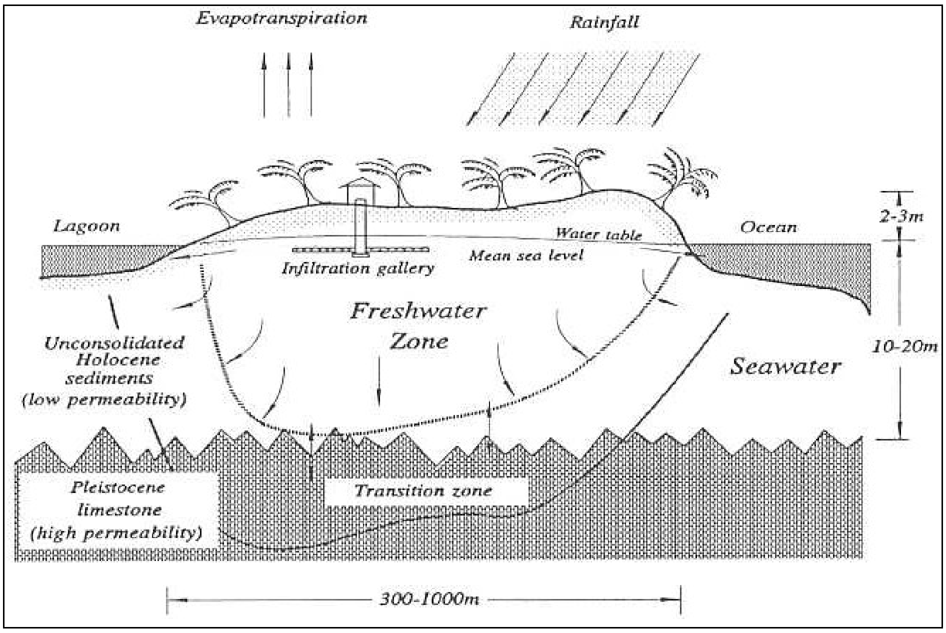

Figure 3: Cross section of a standardised coral island. Source: SOPAC 2009.

Since the atoll is highly permeable karstic limestone, water discharges as fast as it recharges on Niue. The lens is thus vulnerable in the dry season, as it cannot retain water for very long. It has been estimated that if no rain occurred at all, there would only be three months of recharge available before the lens disappeared (Mosley and Carpenter 2005). More generous estimates place storage capacity as lasting a minimum of six months to several years (O’Keefe 2007); however, given Niue’s relative isolation, conservative estimates best suit a precautionary approach to water management.

Due to the rapid discharge rate, it has been suggested that it is irresponsible to define the sustainable yield as 30 per cent of the annual recharge rate, as sometimes used in other contexts, and a lower yield would instead be preferable for Niue (GWP Consultants 2006). Thirty percent of the annual recharge rate would equal 39.7 million m^3 per year (GWP Consultants 2006).

Water for consumption purposes on Niue is currently pumped from the lens to the surface using bore pumps located around the island. These pumps move the water from the groundwater lens to the village water tanks. Pressure pumps then distribute the water from the village water tanks to individual users: mostly households. Fossil fuels are used at both points of pumping: from lens to village tanks, and from village tanks to households. In the past, many households also had their own rainwater tank (Burke 1995); however, the current state of these rainwater tanks is almost uniformly neglected and in disrepair (Burke 1995). Most households now rely on the groundwater lens (Andre Siohane, Niue Water Works Division, personal communication, 9 April 2009).

B WATER MARKET

B.1 Demand

B.1.1 Current

In general, a minimum of twenty to forty litres of water per capita per day are needed to maintain basic hygiene and health (Taylor et al. 2008). However, Mosley and Carpenter (2005) estimate demand for water on Niue to potentially be as high as 500 to 1 000 litres per capita per day. The Niue Water Works Division (WWD), housed in the Public Works Department (PWD), last estimated actual consumption to be 350 litres per capita per day (SOPAC 2007d). The relatively high consumption rates on Niue can be attributed to a perceived abundance of groundwater resources by households and leakages in the infrastructure (Green 1999, Kleppen 2006).

Recently, the population plateaud around 1 625 in 2006 (Government of Niue statistics). Despite the stable population, the rate of electricity consumption for water pumping has been rising, suggesting that water consumption per capita is rising (Kleppen 2006). This is confirmed by past demand assessments – ten years ago, per capita demand was 278 litres per day (Green 1999), compared to 350 litres per day today.

Assuming that water consumption is typically 350 litres per capita per day, this corresponds to national human consumption as 762 650 litres per day or 278 ML per year (SOPAC 2007d). This figure includes human consumption by households, businesses and the government (Table 1).

Table 1: Water demand, disaggregated by sector, in 2006.

Demand		**Share**
Total Residents (2006 Census)	1 625	
Total Visitors 2006	500	
Total Population	2 125	
Water Consumption (litres/capita/day)	350	
Demand (litres)		
• Human consumption (total population + visitors)	271 468 750	80 %
• Industrial	53 428 496	15 %
• Agriculture	17 809 499	5 %
Total demand	342 706 745	

Source: SOPAC 2007d

By comparison, industry and agricultural annual demand are 53 ML and 18 ML, respectively (Table 1) (SOPAC 2007d). Water for human consumption remains the primary use in Niue at 80 per cent (Table 1). Water used in industrial and agricultural production is also notable: at 15 per cent and 5 per cent, respectively (Table 1). The amount of water used for agricultural purposes – 18 ML per year – has only recently been calculated and it is believed that it has not been fully quantified (Davis 2005) and is likely underestimated. Furthermore, it is believed that the water supply to agriculture is currently insufficient (Government of Niue 2007).

B.1.2 Demand by village

There are fourteen villages in Niue. Village water consumption is monitored by meters which are placed on village water tanks (Dawe 2000). When total water demand has been disaggregated by village, the Paliati-Alofi North tank is recorded as having the highest per capita consumption rate in Niue (Table 2). It is probable that this is due to the relatively concentrated population in Alofi. It is also likely that varying tank consumption is related to the relative number of people being served by that tank (for example, Alofi North's tank as compared to the New Zealand High Commission).

Table 2: Average daily water consumption, disaggregated by village tank.

Tank	Average daily consumption (thousands of litres)
Paliati-Alofi North	4 254
Tuapa village	2 992
Tapeu-Alofi South	2 381
Tapeu-Airport	1 938
Tamakautoga village	1 740
Hakupu village	1 614
Avatele village	1 437
Mutalau village	1 258
Vaiea-Talemai	1 181
Liku village	965
Lakepa village	813
Paliat (new tank)	688
Toi village	378
Hikutavake village	236
New Zealand HC	136

B.1.3 Future projected demand

There are two opposing influences on water consumption demand in Niue over time. On one hand, the population is currently constant over time, and there is some belief that it will begin to decrease: growth rate estimates range from - 0.32 per cent to zero (SOPAC 2007c). On the other hand, water demand *per capita* is rising and economic development activities are being planned which will further increase water demand (SOPAC 2007d).

Given these countervailing pressures, assessments of future water demand in Niue are typically based on a constant long-term population, with an increased population density in Alofi as Niueans move from the villages to Alofi (Davis 2005). In this report, a zero growth rate in water consumption is then assumed to reflect the declining population and slightly increasing per capita consumption rates. Thus, with a total population of 2 125 (residents and visitors), the most recent estimate of annual water supply is 356 ML (SOPAC 2007a). (Note that this differs from the annual demand estimates, see Table 1, due to leakages.) It is estimated these figures will remain relatively constant over time. Note that this figure includes both avoidable and unavoidable leakage from infrastructure in the transmission and distribution system. If considerable efforts are made to reduce leakage this would reduce the total amount of water supplied.

B.2 Supply

Initially, Niueans collected water by hand from the deep subterranean caves located around the island (Dawe 2000). Afterwards, rainwater tanks were installed and were the primary source of water supply on the island throughout the 1940s and 1950s. In 1958, the first boreholes were dug to extract freshwater from the lens (Green 1999). These acted as the first permanent water supply to the villages (Dawe 2000). In 1964, pipes were established to transfer water from the bores to village tanks.

Initially, water was pumped from the bores to the village tanks using wind power; however, a cyclone destroyed the infrastructure and, in 1971, diesel engines began to be used to pump the water (Green 1999). Diesel eventually replaced wind power as the primary source of energy for water pumping. By the early 1980s, pipes were extended from village tanks to individual houses. Since then, households have been added in an ad hoc fashion (Mosley and Carpenter 2005). At present, it is estimated that 99 per cent of households are connected to the reticulated water supply (SOPAC 2007d). The number of bore pumps increased and, currently, there are thirty bore pumps – twenty for the public water supply, three for monitoring, six to be used in irrigation and the inactive solar pump at Makefu (SOPAC 2007d). Electricity consumption of these boreholes has been monitored since 2000 (SOPAC 2007d).

The current water infrastructure is believed to be coping with increased per capita demand primarily due to the low population levels (Green 1999). The infrastructure around Alofi is however likely to require strengthening in the face of increasing water demand.

B.2.1 Groundwater pumping using fossil fuels

Most households currently rely on water from groundwater pumping (Andre Siohane, Niue Water Works Division, personal communication, 9 April 2009). There are three pieces of equipment which are key to Niue's groundwater supply: the bore pump (also called a production pump) which brings water from the groundwater lens to the village water tank above ground; the village tank itself; and the pressure or booster pump which powers the distribution of water from the village tank to the end users. This system is currently the predominant method of water supply on Niue, as household rainwater tanks are rarely maintained. In villages on the western side of the island, water is distributed from the village tank to households using gravity.

The complete system operation is therefore a submersible bore pump which extracts water from the aquifer and pumps it to the village storage tank. There, water is distributed to the consumers by pressure pump or it is gravity-fed through the distribution network. Household connections have been constructed in a haphazard and ad hoc fashion (Mosley and Carpenter 2005). The Water Works Division which manages the water supply from bore pump to household (see Figure 4) pays Niue Power for the diesel used in pumping. Water is not directly metered at the household level, though there are meters on the village tanks (Dawe 2000). Typically, water consumption is estimated using electricity consumption data from the bore pumps (SOPAC 2007c). The Niue Power Corporation (NPC) operates the generators which power the pumps, while Niue Bulk Fuel provides the diesel for the electricity production. Both NPC and Bulk Fuel are public operations. The government subsidises fuel used in water supply production through the fuel tax – hence, vehicle owners effectively subsidises the water supply (Andre Siohane, Niue Water Works Division, personal communication, 19 April 2009).

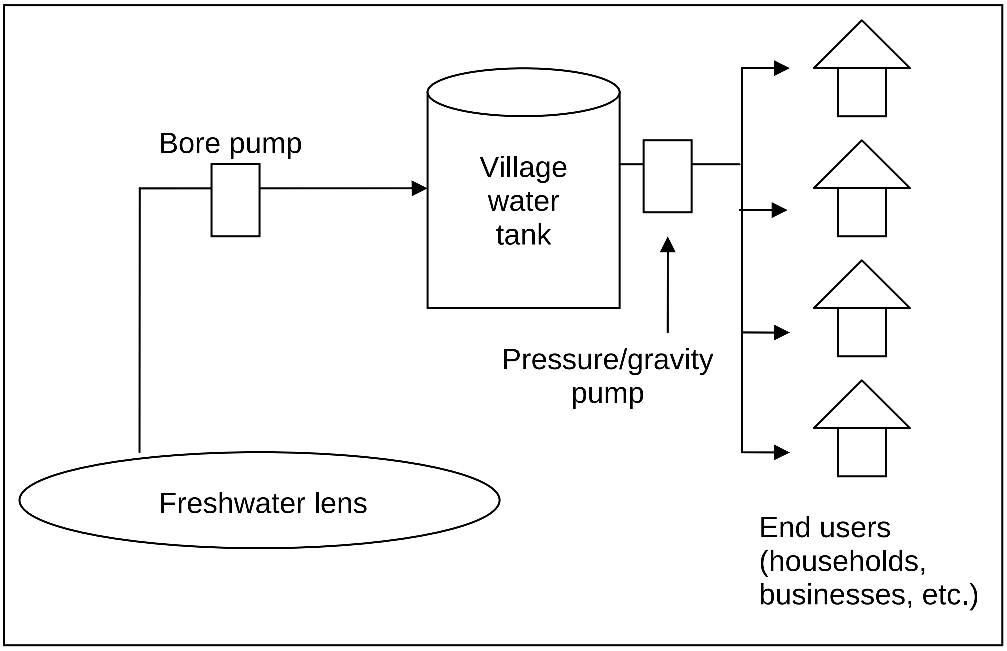

Figure 4: Typical groundwater pumping system in Niue.

The PWD's Water Division currently manages the water supply itself, while the Niue Power Corporation (NPC) provides the electricity to operate the pumps. The PWD conducts regular maintenance of the bore pumps and village tanks.

An updated assessment of seventeen bore pumps currently in use for water supply indicates that the average output of a pump is 106 KL per day (Table 3).

Table 3: Bore pump production.

Bore	Supplies Tank	Output KL/day
SP1	Alofi South (Tapeu tank)	33
SP2	Alofi South (Tapeu tank)	172
SP3	Paliati (Alofi North, Upper and Lower Terraces Tank)	172
SP4	Paliati (Alofi North, Upper and Lower Terraces Tank)	172
SP5	Kaimiti and Alofi South Tanks	172
SP-Tamakautoga	Tamakautoga	73
SP-Avatele	Avatele	90
SP-Vaiea	Vaiea	100
SP-Makefu	Makefu (not currently in use)	No data
SP-Tuapa	Tuapa	89
SP-Namukulu	Vaipapahi and Namukulu	87
SP-Hikutavake	Hikutavake	90
SP-To	Toi	110
SP-Lakepa	Lakepa	86
SP-Liku	Liku	89
SP-Hakupu	Hakupu	83
SP-Mutalau	Mutalau	83

Source: Niue Water Works Division, 2009.

There are some precautions to using bore pumps generally. For example, water supply bores are not drilled within 500 m of the coastline in order to avoid potential pollution from waste disposal of coastal villages (Burke 1995). Furthermore, using narrow boreholes to abstract groundwater from the lens may lead to saline intrusion (GWP Consultants 2006). The risk of this increases when the abstraction rate increases, the borehole gets deeper or nearer to the base of the lens, or rock permeability decreases (GWP Consultants 2006).

The bore pumps move water from the groundwater lens to the village storage tanks. The village tanks vary in size, ranging from 50 m^3 to 450 m^3 capacity (Table 4). There are currently 17 storage tanks in Niue (Table 4).

Table 4: Storage tanks in Niue.

Tank/District	**Capacity m^3**	**Popn Served**	**No. days supply @350 l/p/d**
Alofi South	450	609	3.1
Paliati (Alofi Nth Lower Terrace)	230	427	1.5
Paliati (Alofi Nth Upper Terrace)	195	205	2.7
Tamakautoga	80	157	1.5
Avatele	120	164	2.1
Vaiea	50	59	2.5
Makefu	90	0	0
Tuapa	195	196	2.3
Namukulu	50	22	6.5
Vaipapahi farm	50	12	11.9
Hikutavake	80	56	4.1
Toi	80	31	7.2
Lakepa	80	72	3.2
Liku	80	62	3.7
Hakupu	195	162	3.4
Mutalau	120	81	4.2
Kaimiti	195	100	5.6

Source: Niue Water Works Division, 2009.

Distribution of water from the tank to households is achieved via a pressure pump – which consumes additional energy – or via gravity. At present, ten of the active bore pumps use pressure pumping to distribute the water while eight rely on gravity (Table 5). Six of the pressure pumps are supplying water to villages which could not use a gravity-fed system, implying that the remaining four have the potential to use gravity (Davis 2005). The average lifespan of such a pump is four years (Davis 2005).

Table 5: Distribution type for each bore/production pump.

Bore pump*	**Distribution type**
Hakupu	Pressure pump
Vaiea	Pressure pump
Avatele	Gravity
Tamakautoga	Gravity
Alofi: Maka	Gravity/Pressure Pump
Alofi: Kaimiti	Pressure pump
Alofi: Fonuakula	Gravity/Pressure Pump
Alofi: Lamea	Gravity
Alofi: Lamea	Gravity
Tuapa	Gravity
Hikutavele: Maleuli	Gravity
Hikutavele: Futufutu	Gravity
Mutalau	Pressure pump
Lakepa	Pressure pump
Liku	Pressure pump
Toi	Pressure pump
Makefu**	Gravity
Mutalau	Pressure pump

Source: Niue Draft DWSP
* Submersible pumps (i.e. pumps directly connected to the lens), unless otherwise noted
** Solar pump

The current infrastructure, as described, is capable of supplying up to 731 ML per year (Table 6). Average annual supply is substantially lower: 356 ML per year (Table 6). It should be noted that supply of 356 ML per year exceeds estimated consumption of 343 ML per year by 13 ML per year, suggesting that approximately this amount is lost annually due to leakages or unreported use. At present, there are 579 service connections between village tanks and end users (Table 6).

Table 6: Current water supply statistics.

Data Title	Data	Comment
Total Length of mains (km)	51.2	WBWC 2007
Number of service connections	579	WBWC 2007
Metered residential supply (ML)	0	No flow meters currently installed (WBWC 2007).
Unmetered supply, residential & non-residential (ML)	356	SOPAC 2007d
Maximum supply, current infrastructure (ML)	731	SOPAC 2007d
Marginal cost of water – production ($/ML)	0	No water treatment (WBWC 2007).

Currently, there are meters on the borehole pumps which measure power consumed on a monthly basis. There are also flow meters, installed by SOPAC in 2007 (Kleppen 2007), on all village tank outlets which measure the volume of water supplied from each. Since installation, these meters have been checked monthly.

B.2.2 Groundwater pumping + solar energy

An alternative method of supplying water from the groundwater lens is to use bore pumps powered by solar energy. Niue's relative isolation and limited human capacity makes it an ideal candidate for renewable energy (Argaw et al. 2003). Since electricity demand is high enough to require both Niue Power Corporation (NPC) generators to operate over the midday period, but demand is not high enough to have them operating at full capacity, there is inefficiency in supply. The use of solar pumping would reduce the demand on diesel generation to allow the NPC to power the grid using only a single generator. These midday savings will also contribute to reducing carbon emissions by 24 per cent (McGill 2004).

Solar panels, which generate electricity by converting sunlight using photovoltaic (PV) cells, can be placed near or over bore pumps themselves. It has been suggested that enough solar energy could be generated in Niue to not only address water pumping energy needs, but also to feed energy back into the grid (Phil McGill, Niue Power, personal communication, 17 September 2009). Water can be pumped during the day and stored in the tanks at night (Argaw et al. 2003).

It is generally recommended that the average daily solar radiation, or quantifiable sunlight, should be at least 4 kWh/m^2/day on a horizontal surface in order to merit investigation into the feasibility of solar water pumping (Purohit 2007). Niue's average daily solar radiation is 4.6 kWh/m^2/day (Rupeni Mario, Energy Adviser SOPAC, personal communication, 12 December 2008).

In 2004, a project proposal was drafted to replace 10 kilowatts of diesel-generated energy required for water consumption with solar energy in each of the fourteen villages – amounting to a total of 140 kW (McGill 2004). This amount was based on a previous AusAID-funded pilot project in Makefu Village which found that 2 kW was inadequate to keep the village water tank full (McGill 2004). This project is currently still in the draft proposal phase.

The proposed project aimed to use commercial off-the-shelf solar energy generators, such as BP Solar's 3165 model PV panels, fully integrated into the current infrastructure by being sited on water pumps or community buildings (McGill 2004). Solar pumping will therefore replace 16 per cent of fossil fuel consumption during the midday peak hour, corresponding to a 24 per cent reduction in CO_2 emissions (McGill 2004).

It has been noted that hybrid systems between renewable and traditional energies – for example, solar and diesel – are often the preferred option for their reliability (Argaw et al. 2003). Solar pumping also provides an added safety net in the event of cyclones, since solar pumping can continue during and after strong weather events which might disrupt diesel supply or traditional energy production on the island (McGill 2004). Naturally this depends critically on PV panels being cyclone-proofed. Vandalism is another factor that needs to be considered when placing solar pumps.

Under the proposed scenario of solar pumping, the average annual water supply of 356 ML per year is shared between solar and traditional pumping, with 299 ML being pumped using fossil fuels, and the remaining 57 ML being pumped using renewable energy.

B.2.3 Rainwater tanks

Rainwater tanks provide an alternative source of water supply in a variety of contexts. Annual average rainfall on Niue is 2 075 mm (Aregheore and Misikea 2002). In a place such as Niue, with no surface water and a vulnerable aquifer, rainwater should be considered as an alternative option for water supply. However, insufficient or irregular rainfall could result in a shortage of water supplied from the rainwater tanks. Analysis needs to be undertaken for different scenarios with varying rainfall reliabilities. Just as the case with renewable and traditional energies mentioned above, rainwater and groundwater should both be utilsed to increase reliability, rather than totally relying on only one system.

Historically, rainwater tanks were the primary water supply source for most households, yet they were made redundant in the 1960s with the increasing use of fossil fuel-powered groundwater pumping. As a result, some households still have their old tank, but it is in a state of disrepair (Burke 1995). Many household tanks, for example, are no longer even connected to a roof catchment area (O'Keefe 2007).

The decline of rainwater tank usage escalated in the 1980s, when, due to health-related mosquito-borne illnesses, rainwater harvesting was discouraged (O'Keefe 2007). At present, there is renewed interest in examining rainwater tanks as a sustainable alternative water supply source. Especially in light of planned economic development activities, rainwater has been suggested as a desirable supplementary source of water (SOPAC 2007d).

For example, at present, the SPREP-executed Pacific Adaptation to Climate Change (PACC) project is evaluating the usefulness of providing rainwater tank technology to Niue. This technology would be part of a strategy of climate change adaptation, as changing climate patterns may lead to an increase in the intensity and frequency of cyclones. These cyclones would then have damaging effects on the groundwater pumping system. Rainwater tanks could thus be used to provide water during such periods.

Given the current state of the rainwater harvesting system, it is likely that all tanks will need to be replaced. A new rainwater tank has been established on a trial household for demonstration purposes on Niue (Andre Siohane, Niue Water Works Division, personal communication, 28 January 2009).This new rainwater tank design differs somewhat from the original rainwater tank design used in the 1980s. In the 1980s, rainwater tanks on Niue typically comprised three separate tanks connected to a gravity-fed roof catchment area (Figure 5). Of this, two lower tanks held 800 gallons of water each, which was fed to the header tank (holding 400 gallons) via a pump and fill pipe. Hence the total volume of an old household rainwater tank was 2 000 gallons, or 9.1 m^3. Water was fed back into the house via gravity. This tank design was required for all new house construction under the housing loan, until it was discovered that these concrete tanks encouraged mosquito breeding due to improper operation and maintenance (Andre Siohane, Niue Water Works Division, personal communication, 19 April 2009). Hence this design was discouraged after the 1980s.

The new rainwater tank which is being trialled comprises a single, 5 m^3 tank connected to a roof catchment area (Figure 6). Water which moves from the roof to the tank must first pass through a "first flush" device; that is, a container or valve which, when a certain amount of rainfall has occurred, passes the water into the tank. First flush devices are used in order to collect the initial debris and contaminants which accumulate in roof catchments. Other design specifications, such as a man-hole for tank cleaning, a drainage pipe, screened inlet, and increased cyclone-resistance, can also offer useful methods of tank maintenance.

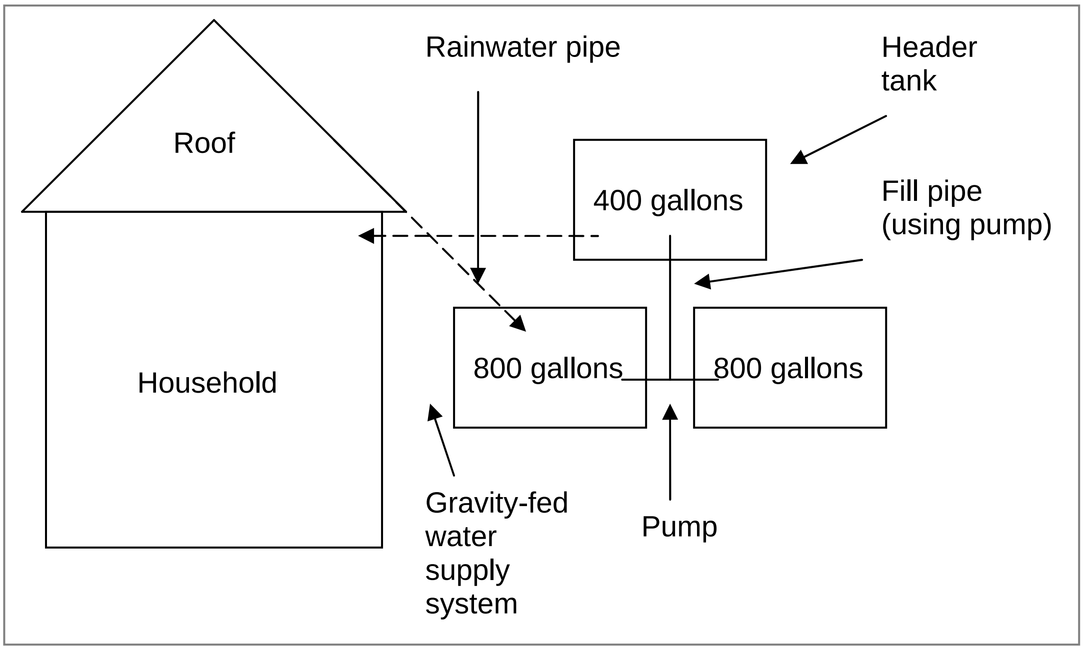

Figure 5: Old household rainwater harvesting system.

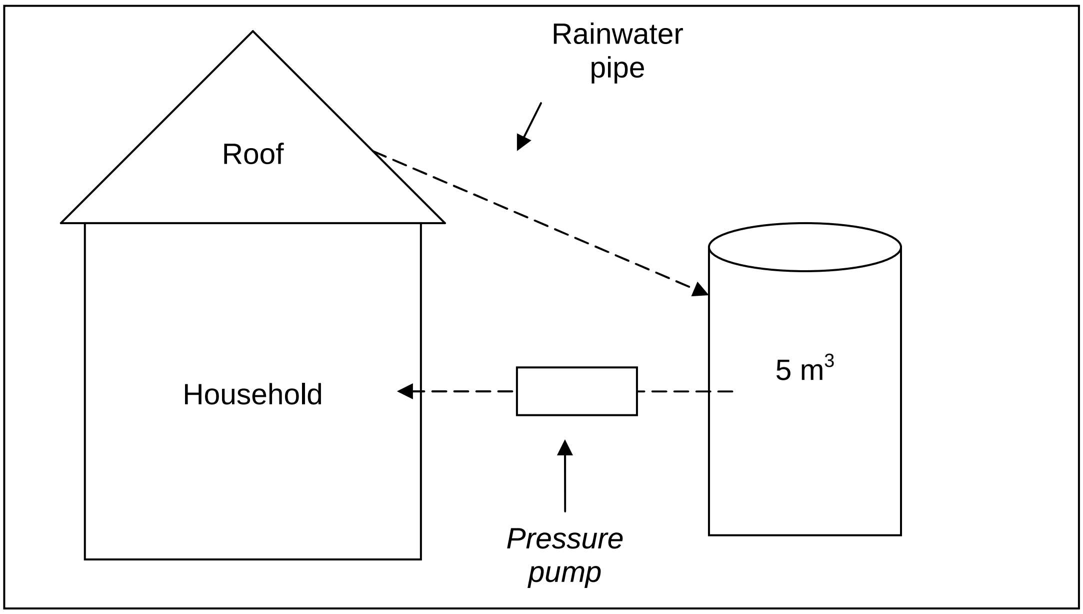

Figure 6: New household rainwater harvesting system.

The current draft National Integrated Strategic Plan for 2009-2013 for Niue targets an increase of 20 per cent in rainwater harvesting for total water supply by 2013. There are a number of motivations behind allowing 20 per cent of Niue's water supply to come from rainwater tanks. One primary motivation is allowing Niue a buffer against system failure in the groundwater pumping system. For example, rainwater tanks would be used in the case of temporary cyclone damage to the groundwater pumping system. An additional benefit of incorporating rainwater tanks would be the promotion of a relatively "cleaner" water supply option with lower operational costs.

In order to ensure the success of this goal, community attitude towards rainwater will need to be supportive. At present, it is believed that there is general community support for rainwater – which is considered acceptable for drinking and cooking (Andre Siohane, Niue Water Works Division, personal communication, 28 January 2009). In most instances, rainwater is, indeed, considered of higher quality than groundwater; however, Niue's aquifer enjoys particularly high water quality, so the quality benefits of rainwater may not be so great. Furthermore, mixed consumption of groundwater and rainwater may risk water quality. In such cases, the maintenance of the household's rainwater harvesting system is of great importance. If the trial is successful, new housing construction would require rainwater harvesting of this kind (Andre Siohane, Niue Water Works Division, personal communication, 19 April 2009).

Analysis is required to ensure correct tank sizing for households given a certain rainfall reliability, roof catchment area and level of demand. For calculation purposes in this report, a tank size of 5 m^3 has been chosen. The following figures are based on the assumption that there is sufficient rainfall and roof catchment area to fill this size tank completely. The total daily supply of a full rainwater harvesting system (that is, one which fully replaces groundwater pumping) would be 5 m^3 x 579 households, or 2 895 m^3 when all rainwater tanks are full. This corresponds to 2 895 000 litres. Assuming that rainwater tanks will be full for 150 days of the year – corresponding to the wet season, which runs from December to April – the total annual supply capacity from rainwater tanks will be 434 250 000 litres, or 434 ML.

If only 20 per cent of water demand is targeted using rainwater harvesting – as recommended in the National Integrated Strategic Plan – the total annual supply from rainwater tanks will only need to be 71 ML (with fossil fuel-based groundwater pumping supplying the remaining 284 ML of demand).

B.3 Losses

The previous sections demonstrated that, while 356 ML is typically supplied per year at present, only 348 ML of water was consumed in 2006 (SOPAC 2007a). This discrepancy can be partly attributed to leakages.

Dawe (2000), supplemented by recent investigations, identified the main problems relating to water markets in the region as leakages and irresponsible consumption – for example, leaking household taps account for 30 per cent of leakages (Table 7). As a result, Dawe (2000) argued that it is an inefficient solution to invest in costly infrastructure revamping – instead, it might be more useful to address these issues using demand management. It might instead be more practical to address these issues using demand management and repair the already existing infrastructure (Dawe 2000, Davis 2005). Typical techniques for water demand management are: leakage control, consumer education, incentive schemes and water use charge (Kleppen 2006).

There are three major categories of leakages: raw water losses (that is, between abstraction and treatment), losses in transmission from treatment to storage reservoirs, and losses in the distribution system from the reservoirs to users (WBWC 2007). Since there is currently no household metering or treatment of the water supply in Niue, all losses can be attributed to physical leaks in the distribution system.

The Pacific Technical Assistance Program (previously PACTAM, currently PACTAF), which examined Niue's water demand from 1997 to 2000, revealed that the main sources of leakages were found to be taps and toilet cisterns in households (Table 7). It has been suggested that the introduction of push tap technology would minimise these types of leakages in the future (James Dalton, Project Adviser IWRM, personal communication, 2 April 2009). This type of technology would be particularly applicable to public buildings (Clinton Chapman, Niue Water Works Division, personal communication, 24 June 2009). This would presumably require a trial first before introduction to assess impact.

Table 7: Leakages on Niue currently identified.

Source of leakage found on leak detection programme 2007/08	Total number of leaks identified and repaired	Estimated percentage of total water wastage
Taps in dwellings (including external taps)	166*	30
Toilet cisterns	20*	10
Domestic pipe-work (including service lines and showers)**	198*	45
Overflowing domestic tanks	8	5
Overflowing village reservoirs	3	5
Leakage on Public Water Supply system (including valves)	10*	5

* Clinton Chapman, Niue Water Works Division, personal communication, 24 June 2009, supplementing the PACTAF/PACTAM programme.

** The majority of faults to service lines have been caused by accidental damage.

Currently, average losses are estimated to total as much as 92 ML per year, of which 15 ML are unavoidable (Wide Bay Water Corporation 2007). This 92 ML is derived from the difference between total supply and average total human consumption. Thus, under 2006 estimates, this would have been 85 ML (see Table 1 for demand, Table 6 for supply). Wide Bay Water Corporation, conducting an updated assessment, estimated further that up to 92 ML was lost, with up to 15 ML being unavoidable (WBWC 2007). That is, 33 per cent of water supplied is lost and – of these losses – 28 per cent are recoverable (WBWC 2007). In terms of pumping costs, this amounts to an annual avoidable expenditure of NZ$ 18 548 on water leakages. Tuapa Village experienced the most daily losses per kilometre of water main (Table 8).

Table 8: Losses disaggregated by village.

Village	Estimated Losses (litres/km water main/day)
Tuapa	24 772
Tapeu-Alofi South	17 443
Paliati-Alofi North	16 541
Tapeu-Airport	10 196
Avatele	9 809
Tamakautoga	9 222
Mutalau	7 962
Hakupu	4 393
Toi	4 191
Lakepa	3 363
Liku	3 305
Vaiea-Talamaitoga	1 432
Hikutavake	No Data*
Fualahi/Kaimiti/Toa	No Data
Makefu	No Data
Nmaukulu	No Data

Source: WBWC 2007

* Meters have since been placed on these village tanks, under the SOPAC water demand project (Andre Siohane, Niue Water Works Division, personal communication, 19 April 2009).

C METHODOLOGY

The purpose of the least-cost analysis is to identify which water supply option is most cost-effective for Niue. Cost-effectiveness can be described in both financial and economic terms. The financial analysis is concerned with the commercial costs. The economic analysis incorporates social and environmental concerns.

A least-cost analysis of three water supply options will be considered for Niue:

i. Groundwater pumping using fossil fuels (status quo).
ii. Groundwater pumping using solar energy.
iii. Rainwater tanks (accounting for 20 per cent of total water supply).

Present as well as future costs are examined, including infrastructure and operating costs. Cost effectiveness was considered in terms of cheapest overall cost of water supply as well as cheapest per unit cost of water supply. Discount rates of 3 per cent, 7 per cent and 10 per cent are used to convert future values into present day terms.

Both financial (Section D) and economic (Section E) least-cost analyses are conducted. Sensitivity analyses are conducted under both the financial and economic analyses. These examine how changing the assumptions may affect the results and policy implications. For example, examined are assumptions about the rate of replacement by solar energy of fossil fuel pumping, as well as the expected change in population.

Under Section F, cost-recovery options are considered for the least–overall-cost water supply. Two tariff schemes are considered, both based on household meters:

- Per unit tariffs; and
- Increasing block tariffs (IBTs).

When considering cost recovery, the previously suggested water price of NZ$ 0.71/KL is examined (WBWC 2007). Cost-recovery tariffs are calculated for each scheme. Alternative sources of cost savings are examined; for example, the use of a leakage reduction programme and its effects on the cost recovery tariff level required. The policy implications of each option are discussed.

C.1 Assumptions

A number of assumptions are used in the calculation of costs and benefits associated with each water supply option. These are based on current evidence from Niue; however, the weaker assumptions have been examined under the sensitivity analyses in each section.

C.1.1 Assumptions for the financial least-cost analysis

The assumptions used in the financial least-cost analysis are:

- The rate of population change is zero. Furthermore, the population is assumed to include both residents and visitors, which therefore includes total consumption per year. Given the countervailing influences of native emigration, increasing water consumption and projected slight increases in tourism, it is assumed that population and water consumption remain constant.
- Prices of fuel, electricity and other supplies are assumed to remain constant over time.
- Total unmetered supply, 356 ML, is used to estimate costs of supply for each option (SOPAC 2007d).

- The unit cost of groundwater pumping using fossil fuels is NZ$0.24/KL (WBWC 2007). This applies to the expenditure by the PWD's Water Division to the Niue Power Corporation (NPC).
- Solar pumping is able to replace 16 per cent of fossil fuel usage (McGill 2004). This is 57 ML per year.
- The annual maintenance cost associated with the water supply infrastructure will be the same under solar pumping as under a solely fossil fuel-based groundwater pumping system, since the bore pumps, pressure pumps, village tanks and so forth will need to be maintained. McGill (2004) suggests that the maintenance costs for the solar panels will be relatively negligible. Furthermore, maintenance experience has already been gained during the AusAID-funded Makefu solar pumping project.
- Rainwater tanks are full for 150 days out of the year, corresponding to the rainy season from December to April, while also accounting for some days when it does not rain.
- Rainwater tanks are used to supply 20 per cent of the total water supply, while the remaining 80 per cent is supplied by groundwater pumping.
- The pressure pumps used in rainwater tanks are assumed to consume a negligible amount of energy, which cannot be accurately predicted with the data available.
- Rainwater tanks must be replaced every 15 years (James Dalton, personal communication, 3 April 2009).
- A rate of 10 per cent is used to discount future costs to present-day terms.

C.1.2 Additional assumptions for the economic least-cost analysis

Several assumptions from the economic analysis are the same as in the financial analysis. Nonetheless, there are key differences as well. The *additional* assumptions used in the economic least-cost analysis are:

- The untaxed, wholesale price of fuel is used.
- The price of carbon is based on market prices from December 2008.
- Solar pumping leads to a 24 per cent reduction in carbon emissions, as compared to fossil fuel-based pumping (McGill 2004).

C.1.3 Assumptions for the cost-recovery analysis

The cost-recovery analysis examines the financial costs and revenues associated with implementing various tariff schemes. The assumptions used in this analysis are:

- Total demand, 271 ML, is used to estimate the expected revenues (WBWC 2007).
- Tariffs are charged on a per-household meter basis.
- All tariffs are paid; i.e. there are no enforcement problems.

C.2 Data generation

The original dataset for the least-cost analysis was mostly derived from:

- interviews with government and community stakeholders;
- past SOPAC reports; and
- Government of Niue documentation regarding water usage and supply.

D FINANCIAL LEAST-COST ANALYSIS

D.1 Costs

D.1.1 Fossil fuels

Given that household water consumption is not currently metered, and the village tank meters are checked irregularly, the electricity costs for water pumping are used as a measure of water consumption. Water pumping is one of the most significant sources of electricity consumption on the island – it is typically the fourth largest consumer of energy on the island (Table 9).

Table 9: August 2008 electricity consumption, disaggregated by sector.

Consumer	Expenditure on electricity (NZ$)	%
Domestics (households)	56 717	42
Government	38 749	29
Commercial (business)	26 697	20
Water pumping	***10 839***	***8***
Streetlights	1 398	1
Private air conditioning	1 270	1
Total	135 670	

Source: Niue Power Corporation, August 2008 data

Similarly, electricity consumption is the largest cost for the PWD's Water Division. This is typical, as demonstrated by other countries where the bulk of operating costs also come from electricity tariffs (Argaw et al. 2003). In a country such as Niue, where the transport costs of importing fuel are substantial, it is not surprising that electricity consumption accounts for the largest expenditure by the Water Division.

Davis (2005) estimated that the pressure pumps generate 20 per cent of pumping costs, while borehole pumps generate the remaining 80 per cent. The per unit electricity cost of supplying water has been estimated to be approximately NZ$0.24/KL (WBWC 2007). Given current estimates of total population (visitors and residents), as well as the per capita water consumption patterns, this amounts to a typical annual expenditure of NZ$ 85 799 on electricity for water pumping. In 2008, this was slightly elevated due to the Forum Leaders' Meeting held in August which raised electricity usage for water consumption beyond the average level. It is expected that future water pumping levels will return to their former values.

There are other costs associated with providing water under the current system. These are largely maintenance costs incurred for the upkeep of the infrastructure. They include maintenance of the bore pumps and pressure pumps, household leakage detection and repair service, freight charges for all repair equipment, salaries and miscellaneous expenditures (WWD Budget 2008). Nevertheless, these will not generally vary greatly in the calculation of the unit cost of providing water as they address the general water supply infrastructure which would be in place regardless of whether fossil fuel pumping or solar powered pumping were used (e.g. the main lines, household leakages).

Table 10: Annual PWD Water Division operating costs: current.

Item	**Cost (NZ$)**	**% total annual cost**	**Notes**
Personnel	104 000	42 %	Salaries for PWD Water Division staff
Maintenance of infrastructure	19 100	7 %	Includes maintenance of buildings, equipments and tools, motor vehicles and maintenance of the village water supply (bore pumps, pressure pumps and village tanks)
Materials, supplies and services	20 100	8 %	Includes expenditures on fuel/oil, office supplies, contract services and so forth
Other operating expenditure	17 800	7 %	Includes water bore rental and miscellaneous expenditures
Water pumps	85 799	35 %	The WWD receives an annual payment from Bulk Fuel, which is then transferred to the Niue Power Corporation for the payment of monthly electricity bills. This figure is based on annual water supply of 356 ML at an electricity cost of NZ$ 0.24/KL (WBWC 2007)
Total	246 799	100 %	

Source: 2008-2009 Annual Budget, Water Works Division

The total annual operating cost for the entire water infrastructure is therefore NZ$246 799 with the total annual electricity cost for groundwater pumping accounting for approximately NZ$85 799, or 35 per cent, of the total (Table 10). These costs vary from year to year, as the electricity cost depends on actual water supplied and the budget is also revised every year to accommodate changing needs. For the purposes of this analysis, the figure of NZ$246 799 is used (Table 11).

Table 11: Financial costs of water supply using fossil fuel-based groundwater pumping per year.

Year	**1**
Total population	2 125
Total supply (L)	356 189 978
Cost of water pumping (NZ$)	85 799
Other infrastructure cost (NZ$)	161 000
Total annual cost (NZ$)	246 799

In order to calculate the unit cost for water supply under the fossil fuel-based pumping system, the following formula was used:

$$\textit{Cost per KL} = \textit{Pumping cost per KL} + \textit{Infrastructure maintenance cost per KL}$$

The pumping cost per megalitre (ML) using fossil fuels was already reported as NZ$240.88 (WBWC 2007). This corresponds to NZ$0.24 per KL. The infrastructure maintenance cost, instead, was based on the average annual costs for maintaining the infrastructure divided by the total amount of water that such an infrastructure could provide. The annual maintenance costs were already calculated as NZ$161 000, and it is known that the current infrastructure can support as much as 731 ML of water supply (SOPAC 2007d). Hence, the per unit maintenance cost is NZ$0.22 per KL. The total per unit cost of supplying water using fossil fuel-based groundwater pumping is therefore NZ$0.46 per KL.

D.1.2 Solar energy

The costs of installing the infrastructure necessary for solar energy-powered groundwater pumping have been estimated to be NZ$973 473 (Table 12*). As outlined in McGill (2004), solar energy would not yet be capable of replacing the entire groundwater pumping energy requirement; however, it is possible that as much as 16 per cent of fossil fuel savings could be achieved with 150 kW solar cogeneration at the midday peak (McGill 2004). Given that the unit costs of solar energy-powered groundwater pumping are expected to be substantially less than the unit costs of using fossil fuels, these amount to considerable annual savings (Purohit 2007, Argaw et al. 2003).

Table 12: Installation costs for solar energy groundwater pumping.

Component	Cost (USD)
Personnel	40 000
Subcontracts	30 000
Training	5 000
Equipment	550 000
Travel	10 000
Miscellaneous	5 000
Total	640 000*

Source: McGill (2004)
* According to the July 2004 exchange rate, US$640 000 = NZ$ 973 473, as quoted in the text.

In calculating the annual cost of water supply, the use of a combination of fossil fuel- and solar-based groundwater pumping means that several costs must be considered:

- The annual maintenance cost associated with the water supply infrastructure. There may be some slight differences in this cost – for example, the establishment of PV panel array may necessitate increased land usage around bore pumps – however, given that these differences are small and unknown, the infrastructure maintenance costs from the previous scenario are used.
- The electricity cost of groundwater pumping. The current estimate is that fossil fuel savings of 16 per cent will accrue with the introduction of solar energy. The remaining 74 per cent of pumping will therefore be fossil fuel-based, and this amounts to NZ$72 071 per year, or 299 ML (Table 13).
- The installation costs for solar pumping, previously noted as NZ$973 473 (Table 12, converted from US$).

The total annual cost of water supply using this mixed system is therefore likely to be NZ$1 206 544 in the first year when an investment in solar pumping is made, and NZ$233 071 in the years thereafter (Table 13). It should be noted that these costs are a rough approximation, as establishing a hybrid system would incur small additional costs (for the purchase of an inverter/converter) as well as some efficiency losses during the transfer of energy (Paul Fairbairn, Community Lifelines Programme, SOPAC, personal communication, 2 June 2009).

Table 13: Financial costs of water supply using mixed fossil and solar systems per year.

Year	**1**	**2+**
Total population	2 125	2 125
Total supply: fossil fuel	299 199 582	299 199 582
Total supply: solar	56 990 397	56 990 397
Cost of water pumping (New Zealand$)	72 071	72 071
Other infrastructure cost (NZ$)	161 000	161 000
Installation cost: solar	973 473	0
Total annual cost** (NZ$)	1 206 544	233 071

The unit cost of supplying water under this system is a weighted sum between the marginal cost of using fossil fuel-based pumping and the marginal cost of using solar pumping. This amounts to NZ$0.46/KL.

D.1.3 Rainwater harvesting

Given the current state of disrepair of infrastructure, the rainwater harvesting system would require a reinvestment and total refurbishment in order to become an option for widespread water supply. The PWD is currently pilot testing a new rainwater tank design (Andre Siohane, Niue Water Works Division, personal communication, 30 January 2009). Assuming that the rainwater tank design is found to be suitable for Niue’s conditions, each household will require the installation of a new tank. Current installation costs for a single tank are NZ$2 237 (Table 16) (Andre Siohane, Niue Water Works Division, personal communication, 30 January 2009).

Installing new tanks in all 579 households on Niue would cost NZ$1.3 million. This would be a one-off investment, as normally polyethylene tanks have a lifespan of 15 years (James Dalton, Project Adviser IWRM, personal communication, 1 April 2009). In order to account for possible decay, it is assumed that the tanks will need to be refurbished or replaced after fifteen years.

Table 14: Installation costs for a rainwater tank.

Item	**Cost (NZ$)**
5 m^3 polyethylene tank	1 415
Freight (15% of tank cost)	212
Tank-to-household pump	370
First-flush device	40
Concrete pad	200
Total	2 237

Source: Andre Siohane, Niue Water Works Division, personal communication, 30 January 2009.

The main financial benefit of rainwater harvesting is the relatively low operational cost once installed. That is, rainwater harvesting can potentially generate substantial savings from avoided pumping costs. The overall maintenance of the infrastructure, however, remains an annual cost which must be incurred. Under a system of rainwater harvesting, this amounts to NZ$161 000 per year (Table 4). This is the same cost which is incurred under a system of fossil fuel-based groundwater pumping or solar pumping. This is because the water supply infrastructure which would support rainwater tanks is the same as in the other scenarios.

One of the targets of the draft National Integrated Strategic Plan for Niue 2009-2013 is that Niue should achieve, by 2013, 20 per cent increased use of rainwater harvesting. Given that, at present, levels of rainwater harvesting are negligible; this represents a full 20 per cent increase in rainwater tank use. The total annual supply of water is estimated to be approximately 356 ML per year. If rainwater tanks displaced 20 per cent of water supply, while fossil fuel-dependent groundwater pumping addressed the remaining 80 per cent, then the annual operating costs of supplying water would be NZ$ 229 639 (Table 15).

These costs can be itemised according to the known annual unit cost of water supply using each type of technology. The infrastructure maintenance cost as the other component of total annual water supply costs, would be shared across both technologies. In other words, the PWD would maintain both the pumps and household tanks. Normally, with rainwater tanks, water can be supplied to the household using a separate faucet, or it can be integrated into the current plumbing. The latter option is generally more expensive, and would lead to higher infrastructure costs as households would need to be adapted. The former option, hence, has been considered in the cost analysis.

In some instances, it is likely that rainwater would need to be pumped from the tanks to the homes (when it cannot be gravity-fed). The operational costs of such pumps have not been included in the analysis, as they are dependant on the physical set-up of each household tank. These costs are likely to be low, and hence not affecting the analysis.

The different amounts of water supply each technology would provide must then be estimated. Based on the National Integrated Strategic Plan for Niue 2009-2013 targets, rainwater harvesting would address 71 ML (20 per cent of total supply) per year, while groundwater pumping would address the remaining 285 ML (80 per cent of total supply) per year. The electricity cost for pumping this amount of water would be NZ$68 639 per year (Table 15). Summing this with the other operating costs, as well as the cost of installing a rainwater harvesting system in Niue, results in the annual cost of supply: NZ$1 525 007 in the first year, and NZ$229 639 for the years thereafter (Table 15).

Table 15: Financial costs of water supply using rainwater harvesting and groundwater pumping per year.

Year	**1**	**2+**
Total population	2 125	2 125
Total supply: groundwater pumping	284 951 982	284 951 982
Total supply: rainwater tanks	71 237 996	71 237 996
Cost of water pumping (NZ$)	68 639	68 639
Other infrastructure cost (NZ$)	161 000	161 000
Installation cost	1 295 368	0
Total annual cost** (NZ$)	1 525 007	229 639

The unit cost of supply was calculated using a weighted sum of the two technologies. From previous sections, it is known that the unit cost of supply using fossil fuel-based groundwater pumping is NZ$0.46/KL. Also, the cost of supply using rainwater tanks is NZ$0.31/KL. A weighted average cost of supply, based on relative rates of use – 80 per cent and 20 per cent, respectively – is NZ$0.43/KL.

It should be noted that the SPREP Pacific Adaptation to Climate Change Project aims to provide a number of rainwater tanks for free. This would naturally affect the costs of this option, as a certain number of households would face only operational and maintenance costs. At present, however, it is unknown how many rainwater tanks would be provided under this project.

D.2 Least-cost analysis

When considering the total cost of supplying water, the current supply system for water on Niue is the cheapest. This is because fossil fuel-based infrastructure is already established and only maintenance and operational costs need to be incurred in supplying water. Any effort to move away from this infrastructure will involve new establishment costs which are high.

By comparison, the *per unit cost* of supply per KL of water is lowest for the mixed rainwater harvesting and pumping system. This system incurs a cost of NZ$0.43 per KL of water supplied compared to the other two options which both cost NZ$0.46/KL of water (Table 16). If rainwater harvesting was already established on Niue, annual supply costs would be around NZ$230 000 (Table 16) compared to fossil fuel-based groundwater pumping which has the highest annual cost of supply at NZ$ 247 000 per annum (Table 16).

Table 16: Per unit marginal cost of supply, by technology.

Technology	Annual cost of supply (NZ$)	Cost per KL
Fossil fuel-based groundwater pumping	246 799	0.46
Solar energy-based groundwater pumping mixed with fuel-based pumping	233 071	0.46
Rainwater harvesting mixed with pumping	*229 639*	*0.43*

If Niue was required to pay the establishment costs of alternative water supply, fossil fuel would remain the cheapest option as it would take a considerable time to recoup establishment costs from savings in water pumping. A combined rainwater harvesting and pumping system would only be viable for Niue in the short to medium term if assistance could be secured to establish the new system. Since this is not presently the case, fossil fuel remains the cheapest option.

D.3 Sensitivity analysis

D.3.1 Solar replacement rate

A sensitivity analysis has been conducted around the assumption that solar energy will replace 16 per cent of fossil fuel usage in groundwater pumping. McGill (2004) estimates that, with 150 kW of energy generated by solar panels, 16 per cent of fossil fuel use would be avoided during the midday peak. Most of these savings accrue from the NPC running only a single generator at full capacity, rather than two generators at low capacity during the midday peak (a relatively inefficient method). It can therefore be assumed that, given the midday peak is the period of most energy use and the period of savings, this figure is a rough estimate of total daily savings (Rupeni

Mario, Adviser Energy, personal communication, 16 March 2009). It should be noted that these savings may vary based on actual solar radiation (i.e. cloudy days) and seasonality.

Yet there is a possibility of variance in fossil fuel savings per day, given that consumption patterns vary from hour to hour and day to day (Figure 7). For example, if there was a spike in energy demand in the evening, this would necessitate running the two generators as well.

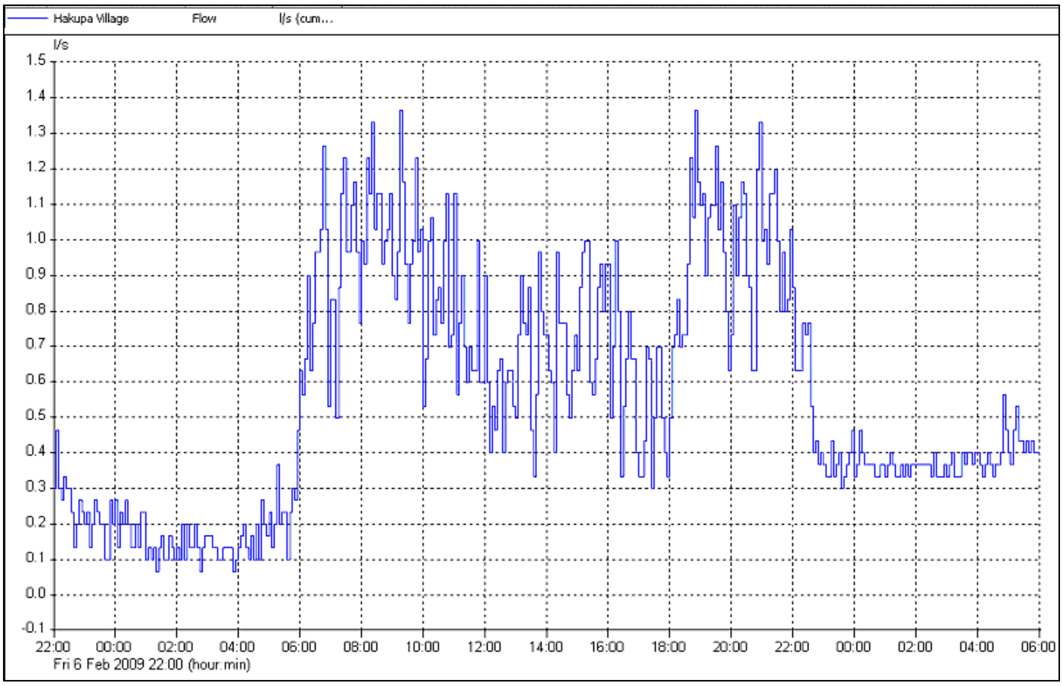

Figure 7: Daily load profile for the Hakupu Village tank. Source: Niue PWD 2009

The unit cost of supply, the annual and unit costs of supply are both affected by increased solar energy and reduced fossil fuel usage (Table 17). It is useful to note that the unit cost of supply does not fall below NZ$0.45/KL, even when renewable energy replaces 95 per cent of energy use (Table 19). This can be attributed to the fact that much of the cost is made up of maintaining the current infrastructure rather than pumping power costs. Also, it must be noted that the annual cost of supply is substantially less when solar energy replaces 95 per cent of fossil fuel usage – lower even than a rainwater harvesting system (Table 16). Such a replacement rate, however, may not be feasible in the short term.

Table 17: Sensitivity analysis around renewable energy's replacement rate.

Replacement rate	**Unit cost (NZ$/KL)**	**Annual cost of supply (NZ$)**
16% (base case)	0.46	233 071
5%	0.46	242 509
50%	0.46	203 900
95%	0.45	165 290

D.3.2 Population growth

The rate of population growth affects the annual cost of water supply; however, it does not affect the unit costs so that the rainwater harvesting and pumping system option remains the cheapest option. Whether the population increases or decreases, the unit cost of supply remains the same as it is based on the technology and infrastructure used which can, in all three cases, sustain a significantly larger population. Therefore it is likely that no further establishment costs would be incurred in the case of population growth. Nevertheless, the total cost of supply is affected as the amount changes.

The same principle applies in the case where per capita demand changes. The unit cost of supply does not change as it depends on the technology used. Therefore, with rising population or rising per capita demand, rainwater harvesting supplementing pumping remains the least-cost option.

D.3.3 Costs

It is possible that fuel prices will rise in the future. An increase in fuel prices would have indirect effects on other costs as well: transport costs, pumping costs, electricity generation costs and so forth. It is therefore useful to examine the effects of rising costs on the least-cost analysis. Over time, the costs of both infrastructure maintenance and fossil fuel-based water pumping will increase (Table 18). If fuel costs will rise by 5 per cent per year, the total annual costs per year for groundwater pumping using fossil fuels would rise to over NZ$400 000 by the tenth year (Table 18). Over ten years, the total costs of supply under this technology would be over NZ$ 3.5 million (Table 18).

Table 18: Sensitivity analysis around rising fuel costs: Groundwater pumping + fossil fuels.

Year	**1**	**2**	**…5**	**…10**
Total population	2 125	2 125	2 125	2 125
Total supply: groundwater pumping (ML)	356	356	356	356
Cost of water pumping (NZ$)	85 799	90 089	109 503	139 758
Other infrastructure cost (NZ$)	161 000	169 050	205 481	262 252
Total annual cost (NZ$)*	246 799	259 139	314 985	402 010
Total costs, after ten years (NZ$)*	3 506 221			

* Undiscounted

Using the same conditions, total annual costs for the solar pumping option would be NZ$1.2 million in the first year (including establishment costs for the solar pumping technology), falling to NZ$244 725 in the second year (when only operational and pumping costs are accrued) and rising to NZ$379 648 by year ten (due to the rising fuel costs) (Table 19). The total costs of supply over ten years are around NZ$4.3 million (Table 19).

In the event that external funding was secured by Niue to cover initial investment costs for the new technology, total operation supply costs for solar pumping would be around NZ$3.3 million over 10 years (Table 19).

Table 19: Rising fuel costs: Solar pumping.

Year	**1**	**2**	**…5**	**…10**
Total population	2 125	2 125	2 125	2 125
Total supply: groundwater pumping (ML)	299	299	299	299
Cost of water pumping (NZ$)	2 071	75 675	91 983	117 396
Total supply: solar pumping (ML)	57	57	57	57
Cost of solar pumping (NZ$)	$ 0	$ 0	$ 0	$ 0
Other infrastructure cost (NZ$)	161 000	169 050	205 481	262 252
Installation cost (NZ$)	973 473	$ 0	$ 0	$ 0
Total annual cost (NZ$)	1 206 544	244 725	297 464	379 648
Total costs, after ten years (NZ$)*	4 284 665			
Total costs, after ten years (NZ$) – With initial funding*	3 311 193			

* Undiscounted

The costs of rainwater tanks (Table 20) vary similarly to those of renewable energy. In the first year, investment in the new technology costs NZ$1.5 million (Table 20). In the second year, when only operational and pumping costs are accrued, costs of supply are NZ$241 121 (Table 20). Costs of supply would rise with increasing fuel costs to NZ$374 058 annually by year ten, when the increased fuel costs are incorporated (Table 22). The total cost of supply over ten years would be around NZ$4.6 million. If development funding was provided to cover the costs of the new infrastructure required, total costs over 10 years would be closer to NZ$.3 million (Table 20).

Table 20: Sensitivity analysis around rising fuel costs: Rainwater tanks.

Year	**1**	**2**	**…5**	**…10**
Total population	2 125	2 125	2 125	2 125
Total supply: groundwater pumping (ML)	285	285	285	285
Cost of water pumping (NZ$)	8 639	72 071	87 603	111 806
Total supply: rainwater tanks (ML)	71	71	71	71
Other infrastructure cost (NZ$)	161 000	169 050	205 481	262 252
Installation cost (NZ$)	1 295 368	$ 0	$ 0	$ 0
*Total annual cost** (NZ$)*	1 525 007	241 121	293 084	374 058
Total costs, after ten years (NZ$)*	4 557 803			
*Total costs, after ten years** (NZ$) – With initial funding*	3 262 436			

Given the nature of changing per year costs due to the rising fuel prices, it is useful to compare the total costs of supplying water for ten years. Groundwater pumping using fossil fuels infrastructure is already established and therefore does not require a major reinvestment. On the other hand, any alternative energy such as solar pumping or rainwater harvesting requires an investment. This increases the overall costs.

If operational costs only are considered, rainwater harvesting supplementing pumping is the least-cost option over a 10-year period (Table 21) with fossil fuel-based groundwater pumping as the most expensive option (Table 21); however, this result depends on the acquisition of external funding for initial investment in the new technologies.

Table 21: Comparison of total costs over ten years for each technology; rising fuel costs.

Option	**Total cost of supply for ten years* (NZ$)**
Fossil fuel-based groundwater pumping	3 506 221
Solar energy-based groundwater pumping	3 311 193
Rainwater harvesting	*3 262 436*

D.3.4 Replacement rates

Niue is vulnerable to cyclones (Kreft 1986). In 2004, for example, Cyclone Heta caused damage costing over NZ$ 37.7 million (Government of Niue 2004). Furthermore, it is likely that general weather conditions in Niue will necessitate a higher replacement rate.

It is therefore critical that any new water supply infrastructure is made severe weather-proof to prevent costly reinvestment over time. To examine the effects of disaster vulnerability on water supply infrastructure, it is assumed for demonstration purposes that every five years a 25 per cent reinvestment in solar panels must be made as a result of weather damage. In this case, solar pumping becomes the most expensive option after ten years (Table 22). Rainwater harvesting would be the cheapest option both in terms of annual cost as well as total cost after ten years (Table 22). It should be noted that it is likely that some reinvestment will be required after fifteen years. This sensitivity analysis does not incorporate rising fuel prices.

Table 22: Sensitivity analysis around solar panel replacement rates.

Technology	**Annual cost of supply (NZ$)**	**Total cost of supply for ten years* (NZ$)**
Fossil fuel-based groundwater pumping	246 799	2 714 789
Solar energy-based groundwater pumping	233 071**	3 050 520
Rainwater harvesting	*229 639*	*2 526 032*

* Undiscounted.

** In a year when there is no reinvestment in solar panels. In years 5 and 10, when there is such reinvestment, the annual cost rises to $ 476 439.

E ECONOMIC ANALYSIS

E.1 Economic costs

In contrast to the financial least-cost analysis, an economic least-cost analysis aims to capture the resource costs of items involved in alternative water supply options. This is in contrast to examining only the market costs, which may or may not capture environmental and/or social effects attributable to each technology.

Adjustments need to be made to reflect the true cost of fuel and the environmental impacts of water supply. First, the untaxed price of fuel is used rather than the retail price. In Niue, taxes of approximately NZ$0.34[1] are levied on each litre of diesel and petroleum (NZ$0.17 for kerosene) (Table 23). As a result, Niue consumers pay an artificially inflated price for fuel which does not match the world market price.

Table 23: Untaxed and retail fuel prices (NZ$/litre).

Fuel type	**Retail price**	**Untaxed price**
Kerosene	2.07	1.88
Diesel	2.10	1.71
Petrol	2.10	1.74

Source: PIFS 2006[2].

The second issue is the environmental consequences of alternative water supply options. Diesel is a fossil fuel whose consumption contributes to CO_2 emissions and thus climate change. Under the Kyoto Protocol and the Clean Development Mechanism, a world market for carbon trading is underway and an associated carbon price now exists. This value can be used to gauge the economic cost of generating carbon emissions. Essentially, each ton of carbon generated is potentially a lost opportunity for carbon trading. This opportunity cost acts as a proxy for the environmental damages associated with emitting CO_2. At present, the carbon price is NZ$28.37[3] per ton (Point Carbon 2009).

E.1.1 Fossil fuels

Using the economic cost of fuel has direct effects on two types of cost: the per unit price for fossil fuel-based water pumping, as charged by the Niue Power Corporation, and the expenditure on fuel by the Water Works Division. In terms of the former, the financial cost of electricity used in groundwater pumping was NZ$240.88 per ML, while the economic fuel-adjusted cost is NZ$195.47 per ML. This is a reduction of NZ$45.41 per ML. The annual expenditure on electricity is NZ$85 799 in financial terms and NZ$69 624, when adjusted to economic terms (Table 24). This is a reduction in cost of NZ$16 175 per year on electricity charges for groundwater pumping.

In terms of the Water Division's budgeted expenditure on fuel and oil, this annual expenditure falls from NZ$20 100 in financial terms to NZ$15 150 (Table 24). The total annual economic cost of water supply if resource economic values are considered instead of financial ones would thus by NZ$225 674 (Table 24).

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[1] Original reported as US$0.20, converted using the 8 April 2009 exchange rate (OANDA 2009).

[2] Prices originally reported in US$, converted using the 8 April 2009 exchange rate (OANDA 2009).

[3] Originally reported as €12.25, converted using the 1 December 2008 exchange rate (OANDA 2009). Using that rate, €12.25 = NZ$28.37.

Table 24: Annual economic operating costs: fossil fuel-based groundwater pumping.

Item	**Cost (NZ$)**	**Percentage of total annual cost**	**Note**
Personnel	104 000	46 %	Same as the financial cost. See Table 10.
Maintenance of infrastructure	19 100	8 %	Same as the financial cost. See Table 10.
Materials, supplies and services	15 150	7 %	NZ$4 950 less than the financial cost, due to the replacement of retail fuel prices with untaxed fuel prices.
Other operating expenditure	17 800	8 %	Same as the financial cost. See Table 10.
Water pumps	69 624	31 %	NZ$16 175 less than the financial cost, due to the replacement of retail fuel prices with untaxed fuel prices.
Total	225 674	100 %	

Carbon emissions associated with fossil fuel-based pumping vary throughout the day, based on variable water consumption. Therefore it is difficult to generate a daily rate of carbon emissions. Nevertheless, given that renewable energies would replace peak hour carbon emissions, it is useful to examine the total annual peak hour emissions under different technologies. Under fossil fuel-based groundwater pumping, the total peak hour emissions per year are 110 486 kg, or 109 tons. Using the world market price for carbon, this amounts to a cost of NZ$3 085.

Thus, the total economic cost of supply is the annual operating cost plus the cost of generating carbon emissions. This amounts to NZ$228 759 per year, or NZ$1 634 383 (discounted) after ten years (Table 25). The per unit economic cost of supply would be NZ$0.64/ML (Table 26).

Table 25: Economic costs of water supply using fossil fuel-based groundwater pumping.

Year	**1+**
Total population	2 125
Total supply: groundwater pumping (litres)	356 189 978
Cost of water pumping (NZ$)	NZ$69 624
Other infrastructure cost (NZ$)	NZ$156 050
Cost of CO_2 emissions (NZ$)	NZ$3 085
*Total annual cost** (NZ$)*	NZ$228 759

* Discounted at a rate of 10% per year

** Undiscounted

Table 26: Comparison of financial and economic marginal costs of supply: fossil fuels.

	Unit cost (NZ$/KL)
Financial	0.46
Economic	0.64

The unit economic cost of supply using fossil fuels is NZ$0.18 greater than the unit financial cost of supply (Table 26). This difference captures the true value of fuel, free of market distortions such as taxes, as well as the cost of carbon emissions, represented by the world price of carbon. It should also be noted that some of the benefits of reducing CO_2 emissions accrue to countries other than Niue – carbon emissions are a global concern. For this reason, it is likely that the cost of carbon used is an imperfect measure of the true cost of carbon.

E.1.2 Solar energy

With solar energy, there are some savings associated with a reduction in carbon emissions. The yearly cost associated with maintaining the infrastructure remains the same as in the previous case, as the bore pumps, pressure pumps and village tanks would continue to be used (Table 28). Instead, the major difference in costs can be attributed to: the initial investment costs associated with purchasing the solar panels and installing them, a reduction in fossil fuel pumping costs, a reduction in carbon emissions and a reduction in lube oil use (Table 27).

Table 27: Incremental benefit analysis of switching to solar energy. Source: McGill (2004).

	Baseline	**Alternative**	**Increment (Alternative-Baseline)**
Global Environmental Benefits	Fossil fuel usage at 107.8 litres/hr during midday peak	Fossil fuel usage of 93.3 litres/hr During midday peak	Fossil fuel savings of 14.5 litres/hr during the day time peak
	CO_2 emissions of 3498 G/hr	CO_2 emissions of 302 G/hr	Saving of CO_2 emissions of 3196 G/hr
	CO_2 emissions of 302.7 kG/hr	CO_2 emissions of 245.5 kG/hr	Saving of CO_2 of 57.2 kG/hr
	No exploitation of solar power	Up to 140 kW of solar power available for exploitation	Up to 140 kW of solar power generated
Domestic Benefits	High diesel maintenance costs, oil change 140 litres/month	Zero diesel maintenance oil changes on peak sets	Saving of 140 litres of lube oil per month
	Dual set Exhaust particulates of 674.3 G/hr	Exhaust particulates of 15.3 G/hr	Less exhaust pollution of 659 G/hr
	Water available only when electricity available	Water continues to be pumped during the day	Water availability no longer dependent on electricity supply

Solar energy is expected to replace 16 per cent of fossil fuel pumping, which amounts to 57 ML of water pumped via solar energy and 299 ML pumped via traditional fossil fuel energy (Table 28). In terms of costs, this means that NZ$58 484 is paid every year to NPC for pumping costs and NZ$2 502 worth of CO_2 emissions are generated (Table 28). This amounts to a total annual economic cost of NZ$217 036 in supplying water using this mixed system. After ten years, the total cost of supply would be over NZ$2.5 million (discounted at a rate of 10 per cent) (Table 28).

Table 28: Economic costs of water supply using solar pumping over ten years.*

Year	**1**	**2**	**…5**	**…10**
Total population	2 125	2 125	2 125	2 125
Total supply: groundwater pumping (litres)	299 199 582	299 199 582	299 199 582	299 199 582
Total supply: renewable energy pumps	56 990 397	56 990 397	56 990 397	56 990 397
Cost of water pumping (NZ$)	8 484	58 484	58 484	58 484
Operational costs (NZ$)	156 050	156 050	156 050	156 050
Cost of CO_2 emissions (NZ$)	2 502	2 502	2 502	2 502
Installation cost (NZ$)	973 473	0	0	0
*Total annual cost** (NZ$)*	1 190 509	217 036	217 036	217 036
Net present value of total costs, after ten years (NZ$)*	2 524 102			
Net present value of total costs, after ten years (NZ$) – Without installation costs*	1 550 629			

* Discounted at a rate of 10% per year
** Undiscounted

The unit economic cost is calculated using a weighted sum of the unit economic cost of fossil fuel-based water pumping and the marginal economic cost of solar pumping. This is NZ$0.61/KL (Table 29).

Table 29: Comparison of financial and economic marginal costs of supply: solar pumping.

	Unit cost (NZ$/ML)
Financial	0.46
Economic	0.61

The unit economic cost of supply using only fossil fuels is NZ$ 0.64, while the unit economic cost of supply using mixed system with solar pumping is NZ$ 0.61 (Table 29). This is a saving of NZ$0.03 on every ML of water supplied. As the price of fossil fuels rise, it is likely that this saving will increase and solar energy will become increasingly cost effective (Purohit 2007).

E.1.3 Rainwater tanks

The National Integrated Strategic Plan for Niue 2009-2013 targets a 20 per cent increase in rainwater harvesting by 2013. In such a case, the current infrastructure of groundwater pumping would be maintained to accommodate the remaining 80 per cent of fossil fuel-based pumping. This indicates that the annual infrastructure maintenance costs would be the same as in the status quo case: NZ$156 050 (Table 30).

There would be a slight reduction in CO_2 emissions as compared to a completely fossil fuel-based groundwater pumping system: from NZ$3 085 per year to NZ$2 468 (Table 30). The total annual economic costs of water supply under the hybrid system would be NZ$214 217 (Table 30). Over ten years, this would amount to a total discounted economic cost of over NZ$2.8 million (Table 30).

Table 30: Economic costs of water supply using rainwater harvesting over ten years.*

Year	**1**	**2**	**…5**	**…10**
Total population	2 125	2 125	2 125	2 125
Total supply: groundwater pumping (litres)	284 951 982	284 951 982	284 951 982	284 951 982
Total supply: rainwater harvesting	71 237 996	71 237 996	71 237 996	71 237 996
Cost of water pumping (NZ$)	5 699	55 699	55 699	55 699
Other infrastructure cost (NZ$)	156 050	156 050	156 050	156 050
Cost of CO_2 emissions (NZ$)	2 468	2 468	2 468	2 468
Installation cost (NZ$)	1 295 368	0	0	0
*Total annual cost** (NZ$)*	1 509 585	214 217	214 217	214 217
Net present value of total costs, after ten years (NZ$)*	2 825 857			
Net present value of total costs, after ten years (NZ$) – Without installation costs*	1 530 489			

* Discounted at a rate of 10% per year
** Undiscounted

The per unit economic cost of supply is a weighted sum of the unit cost of supply using fossil fuel-based groundwater pumping and the marginal cost of supply using rainwater tanks. This is NZ$0.57/KL (Table 31).

Table 31: Comparison of financial and economic costs of supply: rainwater tanks.

	Marginal cost (NZ$/KL)
Financial	0.43
Economic	0.57

When 20 per cent of water supply is from rainwater harvesting, the remaining 80 per cent relies on the current groundwater pumping infrastructure. This infrastructure necessarily leads to a higher unit cost, both financial and economic (Table 31). In this case, the economic cost of supply is NZ$0.14/KL higher than the financial cost of supply due to the carbon emitted during groundwater pumping.

E.2 Least-cost analysis

Analysis of the *total economic cost* of supply over ten years indicates that the current infrastructure would be the least-cost option. This finding reflects the medium-term effects of the initial investment costs. That is, there is no infrastructure investment required for the use of fossil fuels for water pumping, making it cheaper to establish, whereas any combined rainwater/fossil fuel-based system or combined solar/fossil fuel-based system would require substantial infrastructure investment to establish in the first year. This would lead to higher costs when summing over ten years, and therefore maintaining the current infrastructure would be the least-cost option, (Table 32).

Table 32: Total economic cost of supply for ten years (discounted), by technology.

Technology	**Total cost of supply for ten years* (NZ$)**	**Total cost of supply for ten years* (NZ$) – With funding**
Fossil fuel-based groundwater pumping	*1 634 383*	634 383
Solar energy-based groundwater pumping	2 524 102	1 550 629
Rainwater harvesting	2 825 857	*1 530 489*

* Discounted at a rate of 10%

By comparison, incorporating economic factors into the calculation of per unit cost indicates that hybrid systems are cheaper. Rainwater harvesting supplementing pumping is economically the cheaper *per unit* option, particularly as environmental benefits of reduced carbon emissions are generated (Table 33).

Table 33: Per unit economic cost of supply, by technology.

Technology	**Cost per ML (NZ$)**	**Rank**
Fossil fuel-based groundwater pumping	0.64	3
Solar energy-based groundwater pumping mixed with fuel pumping	0.61	2
Rainwater harvesting mixed with fuel pumping	0.57	1

Examining the annual cost of supply likewise demonstrates that hybrid of rainwater harvesting system and fuel pumping is the least-cost option (Table 34). The second least-cost is solar pumping. Fossil fuel-based groundwater pumping has the highest economic cost of supply (Table 34).

Table 34: Annual economic cost of supply, by technology.

Technology	**Annual cost of supply (NZ$)**	**Rank**
Fossil fuel-based groundwater pumping	228 759	3
Solar energy-based groundwater pumping	217 036	2
Rainwater harvesting	*214 217*	*1*

An interesting feature of the economic analysis is the cost of CO_2 emissions that would be generated under the different water supply options. Renewable energy can affect the peak hour carbon emissions, when the NPC would normally use two generators running at low load in order to satisfy demand. The use of two generators is an inefficient solution for energy supply. Renewable energy would thus allow the NPC to use only one generator for energy production (Rupeni Mario, Adviser Energy, personal communication, 16 March 2009). In comparing peak hour CO_2 emissions, substituting some fossil fuels for renewable energies could already lead to substantial carbon savings – from 21 tonnes per year (or NZ$ 583) to the entire load of 22 tonnes (or NZ$ 617) if rainwater harvesting was adopted (Table 35).

Table 35: Carbon emissions under each scenario.

Technology	**Peak hour CO_2 emissions (tonnes)**	**Peak hour CO_2 emissions (NZ$)**	**Rank**
Fossil fuel-based groundwater pumping	109	3 085	3
Solar energy-based groundwater pumping	88	2 502	2
Rainwater harvesting	87	2 468	1

Nevertheless, since a functioning rainwater harvesting infrastructure is not already established on Niue, it would take many years of operational and carbon savings to cover the cost of establishing the new infrastructure for this, so the current fossil fuel-based technology remains the least cost overall for the present.

F POLICY ISSUES

Niue presently operates a 100 per cent fossil fuel-driven pump system for water supply. The infrastructure for this technology is in place and operating. Financial and economic analysis therefore indicates that it would be cheaper to maintain the status quo fossil fuel-based system as any new water supply system would incur new establishment costs which would be expensive. On the other hand, per unit of water supplied analysis also indicates that financial and economic operating costs are actually lower for both a combined solar/fossil fuel pump system and a combined rainwater/fossil fuel pump system. That said, the expense to Niue of potentially establishing the new infrastructure required for both these options would be expected to eradicate any supply cost savings for many years.

By comparison, if external aid could be found by Niue to fund the establishment of rainwater harvesting, the benefits of water tanks supplementing existing groundwater pumping would be likely to outweigh the costs.

Having said this, establishing a new supply system for Niue would require further examination. In particular, a new rainwater harvesting/fossil fuel system would mean a substantial change for Niue and would require work to ensure social acceptability. For example, in the reestablishment of a rainwater harvesting system, community concerns regarding mosquito-borne illnesses and the quality of the “first flush” technology used will need to be addressed in the new rainwater tank design (O’Keefe 2007). New legislation has also been developed to require private maintenance of the new rainwater harvesting system (O’Keefe 2007). Furthermore, it has been proposed that rainwater tanks and associated plumbing will be required on all new or altered buildings under the National Building Code (O’Keefe 2007).

Effective management of rainwater tanks by households and communities would be also critical to ensure that any potential economic benefits are realised. Regular cleaning will prevent build up of debris and leaves, and will hence ensure that the rainwater quality is high. If tanks are instead left to decay and poor maintenance, economic costs will be generated. Such costs, which result from the possibility of poor maintenance, were not included in the analysis. It is possible that the Government of Niue would need to hold regular awareness training courses for the community on the proper operation and maintenance of rainwater tanks. Given that the cost of such training courses would be comparatively low and variable (i.e. it would fluctuate with the perceived need to hold such course), the economic analysis excluded these costs.

An example of an effective community awareness campaign was the Pacific Technical Assistance Program (PACTAF). This project, which began in 1997, targeted water demand management on Niue and its community awareness approach proved effective (Green 1999). There was no water demand management on Niue before the PACTAF project (Kleppen 2006) but water consumption was halved through its household leak detection programme (Dawe 2000). This amounted to savings of NZ$500 000 per annum in annual power costs (Davis 2005). Prior to the PACTAF project implementation, Niue had experienced water shortages (SOPAC 2007d).

At present, the extent to which households might incorporate rainwater tanks into their typical water consumption cannot be predicted. There is, for example, the possibility that additional household expenses would be required for the proper maintenance of the tanks. For example, if the tanks suffer any damage, the household would be required to pay for repairs. Furthermore, typically, rainwater tanks are perceived as a back-up option for when groundwater pumping fails. Households may hence only use the rainwater in times of failed groundwater pumping, or for any “extra” uses (e.g. gardening, car washing). In such a case, water demand would increase as households begin to view rainwater tanks as an additional – rather than supplementary – source of water. It is important, then, that any future consideration of rainwater harvesting would include, among other things, awareness programmes to promote rainwater tanks as a replacement of 20 per cent of the typical daily water supply.

F.1 Sustainable financing

Currently, water is free for all consumers on Niue. The historical perception of water has been that it is a natural right removed from the economic sphere and is “God-given”. Recently, however, there has been a move towards redefining water as both a natural resource and an economic good. Unsurprisingly, water charges are a politically charged issue which is unpopular among the general community (Green 1999).

That said, water charges remain an integral part of water demand management, and past work has demonstrated that water demand management is necessary (Kleppen 2007). Due to this need for improved demand management, the concept of water charges is supported among government stakeholders (O’Keefe 2007). It is therefore important to examine the feasibility of water charges and the types of water charges available for use in Niue.

Recent trends among policymaking are that the most effective management of water should balance both its economic role – that is, as an input into various activities, from industrial production to human capital (via maintaining human health) – and as a basic human right. Valuing water’s contribution to the economy and putting a price on it has influenced the development of different tariff schemes throughout the world in recent years. Ideally, charging for water will achieve various objectives: it will influence user behaviour towards more efficient water consumption, ensure cost recovery and provide an approach to support disadvantaged groups (Taylor et al. 2008). According to Taylor et al. (2008), water charges are based on economic, rather than financial, costs as they are meant to capture environmental externalities as well.

F.2 Cost recovery

Given that the current fossil fuel-based technology presently offers the lowest costs for water supply, initial consideration of water charges for Niue under this system is presented below.

F.2.1 Per unit tariffs

The most typical economic instruments used to manage water demand and, where possible, recover supply costs are a flat tax on water use, a subsidy to acquire more water efficient equipment (e.g. rainwater tanks) and a per unit charge. General economic theory indicates that a per-unit charge will have a strong effect on regulating water consumption. Yet, for this option, meters are required. At present, no households are metered on Niue, though there are meters on the village tanks (Dawe 2000). The cost of installing individual meters on all Niue households has been estimated at NZ$ 53 268 (Table 36).

Table 36: Estimated costs of installing individual customer meters.

Item	NZ$
Materials	4
Labour	50
Cost per Meter	92
Total Cost to Install 579 Meters	53 268

Source: WBWC 2007

According to the 2008-2009 proposed budget for the Water Works Division, approximately NZ$4 000 is spent annually to maintain reticulation of the general water supply. This includes repairing broken water mains, household leaks and plumbing fittings. Given that the PWD’s water staff currently operate house-calls for leak repair, it is likely that the cost of checking household meters will not be substantially elevated as water staff can incorporate meter checking into their routine of pipe repair. If it was assumed that the approximate cost of checking all household meters is the same as the approximate cost of addressing all household leakages (e.g. broken sinks, faulty plumbing), then the total yearly cost of checking all household meters is NZ$ 1 000.

F.2.2 Partial cost recovery

If a unit water charge is set at the WBWC (2007) estimated selling price of water – NZ$0.71/KL – the average household would pay NZ$333 per year, and total annual revenues, based on total demand for household, agricultural and industrial use, would be NZ$192 743 (Table 37). This would amount to a net loss of NZ$90 284 in the first year for the PWD, as meters are installed on all households, and a loss of NZ$37 016 per year once the meters are installed (Table 37).

Based on GDP per capita estimates, which are NZ$10 048 per year per person, a payment of NZ$333 is less than 1 per cent of annual per capita income.

Table 37: Potential net revenues from a per unit charge.

Year	**1**	**2**	**…10…**	**…25…**
Cost of supplying water (fossil fuel) NZ$	228 759	228 759	228 759	228 759
Cost of installing meters NZ$	53 268	0	0	0
Cost of checking meters NZ$	1 000	1 000	1 000	1 000
Total cost NZ$	283 027	229 759	229 759	229 759
Total revenues NZ$	192 743	192 743	192 743	192 743
Net revenues NZ$	- 90 284	- 37 016	- 37 016	- 37 016

F.2.3 Full cost recovery

The level of tariff necessary to ensure full cost recovery each year would be NZ$0.85/KL. At this price, the Water Works Division would break even every year. The average annual household expenditure on water would be NZ$397. In order to absorb the cost of installing meters after ten years, a tariff of NZ$0.87/KL would need to be charged. This would lead to a small net revenue every year which, after ten years, would sum to the cost of installing the meters. At this rate, households would pay a small increase in their annual water expenditure: NZ$404. This corresponds to 1 per cent of per capita annual GDP.

F.2.4 Increasing block tariffs (IBTs)

Community resistance to the introduction of cost recovery-based per unit water tariffs is likely. Given that water tariffs would be new to Niue, a community awareness campaign may be in order to prepare local attitudes. In terms of addressing the perception of water as a basic human right, increasing block tariffs (IBTs) may be considered as an option.

IBTs are an attempt to capture both the economic and social aspects of water. That is, water can be perceived of as both a basic human right as well as an economic good and input into production. These contrasting views inform water policy in that water tariffs, while an attempt to capture the positive economic externalities of water use as well as its scarcity, must likewise ensure that a basic level of water is available for all consumers. IBTs are set in such a way that the first “block” of water usage is free, as that block corresponds to fulfilling health and sanitation needs. The next blocks are instead priced at increasing rates. In this way, everyone is guaranteed a certain amount of water, but heavy users must pay an increasing per unit charge. An enabling water management system is defined as one which effectively promotes equity, efficiency and sustainability for water management (Taylor et al. 2008). IBTs can provide a useful method of ensuring equity and efficiency.

IBTs could be applied to the Niuean context by considering minimum requirements compared to total demand. The minimum daily water requirement for basic health and hygiene is listed as forty litres per capita per day (Taylor et al. 2008). This translates to 14 600 litres per capita per year. (Note that the delineation of a minimum daily supply may be subject to community consultation on Niue, and hence may differ slightly from the Taylor et al. (2008) suggestion.) At present, annual per capita water demand is 127 750 litres. It is expected that an IBT system would provide the first 14 600 litres per year free, followed by the remaining 113 150 litres being charged at the NZ$0.71/KL rate. At this rate, the typical household annual expenditure on water would be NZ$295 (Table 40). Total annual revenues would then be NZ$170 715, which leads to net losses of NZ$59 044 (Table 38).

Table 38: Potential net revenues from increasing block tariffs (IBTs).

Year	**1**	**2**	**…10…**	**…25…**
Free water (ML)	31	31	31	31
IBT water (ML)	240	240	240	240
Cost of supplying water (fossil fuel) NZ$	228 759	228 759	228 759	228 759
Cost of installing meters NZ$	53 268	0	0	0
Cost of checking meters NZ$	1 000	1 000	1 000	1 000
Total cost NZ$	283 027	229 759	229 759	229 759
Total revenues NZ$	170 715	170 715	170 715	170 715
Net revenues NZ$	- 112 312	- 59 044	- 59 044	- 59 044

A full cost recovery IBT would instead be NZ$0.95/KL. At this tariff rate, households would pay NZ$397 per year and the WWD would just break even.

F.2.5 The role of leakage detection

It is expected that a leakage reduction programme would be able to reduce leakages by 50 per cent (WBWC 2007). If this is the case, the potential savings would amount to NZ$11 080 per year (Table 39). These savings would come in the form of avoided pumping from boreholes or laying new mains pipe-work to support increasing water demand (Government of Niue 2008). Under the Water Demand Management (WDM) Programme implemented through SOPAC, the Water Works Division worked to reduce water losses using a variety of WDM techniques including metering, sectorisation and leakage detection. As this programme continued and capacity built within the Water Works Division, it is expected that, over time, leakages will be reduced, resulting in these savings being achieved. Since water and leak fixing are both provided free of charge to Niuean consumers, there is theoretically no incentive to maintain household pipes privately. For this reason, the Water Works Division would need to dedicate some of its budget every year for house-to-house leak inspection (Government of Niue 2008). Yet addressing leakages would have some immediate benefits for the community.

Table 39: Financial savings from reduced electricity use.

Annual Electricity Cost per ML Supplied	NZ$240.88
Potential Annual Savings From Active Leakage Control (ML)*	46
Potential Annual Financial Savings	NZ$11 080.29

* Based on detecting and preventing 50% of current real losses. Source: WBWC 2007

Addressing leakages reduces the annual cost of supply as less water would need to be pumped to reach the consumer. These cost savings have a direct effect on the cost recovery water tariff needed. If leakages are addressed, a full cost recovery per unit charge would fall from NZ$0.85/KL to NZ$0.81/KL, and a full cost recovery IBT would fall from NZ$0.95/KL to NZ$0.91/KL. Hence, leakages provide a low-cost option for improving water supply efficiency.

Both of these tariff structures would require an annual household expenditure of NZ$378.

F.3 Cost and welfare analysis under different tariff schemes

There are several options available to policymakers (Table 40).

Table 40: Cost recovery options: key.

Option	**Description**
Option 1	A per unit charge of NZ$0.71/KL
Option 2	A per unit charge of NZ$0.85/KL
Option 3	An increasing block tariff charge of NZ$0.71/KL
Option 4	An increasing block tariff charge of NZ$0.95/KL
Option 5	A per unit charge of NZ$0.81/KL, as well as a leakage reduction programme
Option 6	An increasing block tariff charge of NZ$0.91/KL, as well as a leakage reduction programme

If the aim of the cost-recovery scheme is to minimise costs borne by the household, *Option 3* may be the most preferable (Table 41). Under this scenario, households would be expected to each pay only NZ$295 per year for water, and the Water Works Division generates a revenue of NZ$ 170 715 (Table 41).

If the aim is complete cost recovery, there are several tariff options available, depending on whether the government addresses leakages or not. Options *5* and *6* both achieve cost recovery, with households paying NZ$ 378 per year (Table 41).

All cost-recovery calculations have been made under the current water supply system (fossil fuel-based groundwater pumping).

Table 41: Summary table of cost-recovery options.

Water tariff option	**Household expenditure on water per year (NZ$)**	**Percent of annual GDP per capital**	**WWD net revenues per year (NZ$)**
Option 1	333	0.9%	-37 016
Option 2	397	1.1%	0
Option 3	295	0.8%	-59 044
Option 4	397	1.1%	0
Option 5	378	1%	0
Option 6	378	1%	0

F.4 Challenges

F.4.1 Public perception of water

There are several challenges to water tariffs in Niue. First, while government stakeholders have expressed support for the idea, it is likely that there will be some community resistance. That said, community awareness and education can begin to change general opinion so that users are aware that water is a limited, vulnerable resource which must be subject to sustainable consumption and management in order to remain available into the long-term future. At present, it is believed that water's economic value is not well appreciated by end users (SOPAC 2007d).

Some methods of building community support for cost-recovery options are through the involvement of community leaders – for example, church leaders and community groups. Also, clearly telling users where their tariffs go and demonstrating the costs involved in delivering water services will raise community awareness regarding the issue.

F.4.2 Potential vandalism

There might be a problem of vandalism on the meters. That is, there is a perverse incentive by householders to tamper with meters and lower the usage levels recorded. In order to ensure that this does not happen, it is likely that the WWD will require extra expenditures in order to monitor and enforce accurate metering. At present, the level of meter tampering is unknown, and therefore the potential enforcement cost has not been included in the analyses.

F.4.3 Welfare effects under IBTs

There are several criticisms associated with IBTs. The first is that sometimes the minimum daily requirement may be set so high that few users pay so that, while equity is achieved, efficient water usage suffers (Foster 2005).

Another criticism is that IBTs punish heavy water users by charging them a per unit tariff, yet those heavy users may not necessarily be inefficient. For example, it has been found that each additional household member contributes approximately the same amount of water demand (Dahan and Nisan 2007). Since larger households are sometimes relatively poorer, they will be the heavier users yet without the capacity to pay higher water tariffs (Dahan and Nisan 2007).

Balancing equity with efficiency is therefore a somewhat complex problem. The minimum daily requirement must not be set so high as to include all consumption, but neither must it be set so low that subsistence needs are not covered. Similarly, it must be examined whether larger Niuean households are also the poorer households – if this is the case, then IBTs may have inadvertent negative welfare effects.

One solution is to conduct a poverty and water consumption analysis, which estimates the link between the former and the latter. A suitably welfare-oriented and sustainable cost-recovery tariff structure could be determined from the results of such a study.

F.4.4 Technological change

Water tariffs have been calculated under a system of fossil fuel-based groundwater pumping. If alternative water supply sources are implemented – such as solar pumping or rainwater harvesting – the cost-recovery tariffs and challenges faced will most likely change. For example, it is unlikely that householders will have an incentive to pay a per unit water tariff on rainwater tanks. Likewise, it is difficult to measure water consumption using rainwater tanks.

It has been argued that cost sharing leads to a sense of local ownership in new technologies (Argaw et al. 2003). Hence while per unit cost recovery may not be achieved with rainwater tanks, for example, community resources could be used in the initial instalment costs. A method of ensuring an organic transition to alternative sources of water supply, while pursuing cost-recovery aims, is to apply per unit tariffs to water consumed under the current, fossil fuel-based system, and to provide leasing arrangement or other market-based financial options for investing in renewable technologies such as rainwater tanks (Argaw et al. 2003).

F.4.5 Flat rates

Another possibility for cost recovery would be to present households with an option: they can either purchase reticulated water from groundwater pumping at a fixed rate, or purchase a meter which records their per unit charge. The fixed rate and per unit charges could be set at levels which ensure that, after a certain number of years, the meters "pay for themselves" – that is, households will have saved enough via metered and managed water consumption to cover the original cost of the meter.

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ANNEX 1 TERMS OF REFERENCE

Background

Water is a basic human right and essential for the social and economic development of countries. The Government of Niue is currently targeting the sustainable development of its water resources with the assistance of a number of regional and international initiatives. These include several SOPAC executed initiatives such as:

- Global Environment Facility (GEF) funded Integrated Water Resource Management project;
- EU funded Integrated Water Resource Management National Planning Programme;
- NZ Aid funded Water Demand Management project;
- NZ Aid funded Water Quality Monitoring Capacity Building Programme; and
- UNESCO supported development of a groundwater resources assessment and monitoring programme, including review of current legislation relating to the management of freshwater and pollution on Niue.

A key issue for Niue is the efficient supply of water on the island. There are two issues:

- First, the limestone nature of the island means that no surface water exists and that the country is reliant upon the existence of groundwater resources which must be pumped to the surface for supply. While supplies are good, pumping the water to the surface and for distribution is expensive, such that pumping costs currently account for over half of the budget of the government's Water Supply Division (O'Keefe 2007). With rising fuel costs in the Pacific, the costs of continued supply of water is increasingly expensive in Niue.
- Second, the sustainability of supply services is dependent on access to funds. The Government does not operate cost recovery for water supplies (water is supplied free of charge – Kleppen 2007) and adequate funding is needed for infrastructure maintenance, refurbishment and replacement if future supply failure is to be avoided (O'Keefe 2007). The absence of any charging system means that water use may not be efficient and this could threaten safe supply in the future. Recent investigations suggest that, if water demand is not managed, demand may climb high enough to cause water shortages as was seen in the period prior to 1997 (Kleppen, 2007, p.5). Kleppen notes that some form of charging for water (say, for connections) might help to manage water demand by conveying the message to the community that water delivery has a value and thereby encourage more efficient use. Currently, there is widespread support on the island for the concept of fees and charges for water use (O'Keefe 2007) but no policy development on how to extend or revise the current system, or advocate for its change.

The Government of Niue is understandably concerned about these efficiency and sustainability issues. It has therefore approached SOPAC, under its EDF9 *Reducing Vulnerabilities* project and EU Integrated Water Resource Management National Planning Programme to provide economic advice to implement recommendations from the water demand project, as well as inform the value of water and its management more generally.

Objectives

To conduct an economic analysis of providing efficient and sustainable water supply across all Niue consumers, considering the following options:

- current water supply system (pumping of water from the lens using fossil fuel);
- pumping from the water lens using renewable energy;
- provision and use of water tanks.

Outputs

- Assessment of the cost of options to supply water to consumers in Niue;
- An economic assessment of cost recovery options for water supply on Niue;
- Recommendations to underpin the sustainable development of water resources on Niue.

These outputs will take the form of two written documents (see 'Reports Required' below):

- Technical report for consideration by national, regional and international stakeholders; and
- Draft media release (contained as an annex to the technical report).

Tasks to be performed

- Identify least cost options for the supply and distribution of water across the island:
  - assess the costs of provision (market and, if relevant non market) of the alternative options;
  - assess the benefits of provision (where appropriate) and the sustainability of provision (reliable access to inputs etc.) of alternative options;
  - comment on any distributional impacts of supply options across the community;
  - comment on the robustness of the assessments made (assumptions underpinning assessments);
  - in light of the above, identify the most efficient water supply option for Niue households, government and businesses;
  - Identify and assess economic cost recovery policy issues for the ongoing funding of the supply of water services. Identification and assessment should include consideration of: who should pay, options for cost sharing, social acceptability; possible payment mechanisms for further consideration (tariffs, meters, level of charges etc. Analysis of cost recovery issues should be made on the basis of: (i) the identified least cost approach; and (ii) the current approach, if this is not least cost;
- Identify any constraints to achieving optimal water supply (social unacceptability of option, reliability of supply, necessary institutional arrangements etc.) and identify potential ways to overcome these constraints to maximise benefits;
- Identify any relevant key issues to support education, awareness or advocacy in implementing possible policies;
- Note key policy implications for the appropriateness of the concept, including any wider public interest concerns, policy implications and governance issues needed to support implementation;
- Document activities conducted and findings in two drafts report to SOPAC and other relevant stakeholders, and incorporate comments into a final report, as relevant; and
- Present findings to relevant SOPAC staff, key Government of Niue stakeholders and other stakeholders, as relevant.

Reports required

Technical report

This report is to be written to be comprehensible to:

- Medium to highly educated decision makers on Niue who have a good background understanding in the water situation but who may have no understanding of resource economics; and
- Highly educated international stakeholders such as donors who may have an understanding of resource economics but have little or no understanding of water and environmental situation on Niue.

Accordingly, the technical report will be written in plain English and will:

- be a stand alone report that includes an explanation of the water issue on Niue, the SOPAC EDF9 *Reducing Vulnerabilities* project and EU Integrated Water Resource Management National Planning Programme and the role this analysis has in them;
- contain an easy to follow Executive Summary providing a general overview of activities, findings and recommendations as relevant. This summary should be written to double as a brief to Cabinet and other decision makers in Niue.
- describe the methodologies used to conduct the analysis, explaining why the method (s) used was most appropriate and the relevant concepts used;
- detail the work and analysis conducted, sources of information used for analysis (including summaries of consultations conducted as part of the evaluation) and assumptions used;
- provide quantitative estimates of the economic and financial values generated and, where appropriate, comment on the robustness of the assumptions and the estimates generated. Where quantitative estimates are not possible or appropriate for the benefit cost analysis, the consultant will provide appropriate qualitative information;
- provide recommendations for any further action such as research or activities to create an appropriate enabling environment to address gaps in information;
- include a draft media release for consideration by SOPAC and other stakeholders to support responsible release of the work; and
- provide other relevant findings or recommendations as appropriate.

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