SECRETARIAT OF THE PACIFIC REGIONAL ENVIRONMENT PROGRAM (SPREP) AND COMMONWEALTH SECRETARIAT

Niue Pacific Adaptation to Climate Change (PACC) Water Sector Demonstration Project

A Cost Benefit Analysis

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Contents

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Executive Summary

Climate variability and climate change presents a number of risks to the Niue water sector. The most significant climate risks threatening residential water supply specifically appears to relate to cyclone and extreme rainfall hazards (GWP 2008). When cyclone and extreme rainfall events occur, the potential impacts are:

- Water-borne disease and illness. This occurs through surface contaminants entering the groundwater lens and (cracked) pipes, which in turn degrades the quality of the groundwater supply.
- Interruptions to public water delivery services and associated losses. When cyclones occur, the electricity and public water supply systems are shut down as a precautionary measure interrupting public water supply.

As part of the Pacific Adaptation to Climate Change (PACC) project, a demonstration project will be implemented to help reduce these risks. The proposed option for this demonstration project is household rainwater tanks (5KL and/or 10KL HDPE tanks).

A Cost-Benefit Analysis (CBA) was undertaken to assess whether household rainwater tanks represent a worthwhile option to be implemented under PACC, and to also assess potential constraints to realising project benefits and provide recommendations on how to overcome these constraints.

Overall findings

The results of the CBA indicate household rainwater tanks may be a worthwhile demonstration project to be implemented under the PACC providing certain complementary measures are implemented and only if certain design options are adopted.

NPVs calculated for a 5KL storage capacity rainwater tank located in upper-terrace areas of Niue were shown to be small - ranging from NZ$62 to NZ$213 per tank, depending on the future groundwater contamination scenario. However, these results were not robust to sensitivity tests about households use of rainwater tanks - if households do not properly care for rainwater tanks and related infrastructure as was the experience in Niue in the 1970s and 1980s then the NPV is reduced to around -NZ$2,107 per tank. This sensitivity result highlights the importance of addressing barriers to behaviour change for project success for which complementary measures will be needed. Given the small size of net community benefits generated from the project option, the analysis also suggests a conservative approach to demonstration (i.e. small scale) is warranted.

Net Present Values (NPVs) for 10KL storage capacity tanks were shown to be negative for all of the groundwater contamination scenarios modelled. 10KL tanks are therefore assessed to be not worthwhile for the PACC demonstration project.

NPVs for all tank storage capacity options (i.e. 5KL and 10KL) in lower-terrace areas of Niue were shown to be significantly negative for all of the groundwater contamination scenarios modelled - primarily because public water supply to these areas are pressure-fed and so household rainwater tanks would not generate reduced water supply interruption benefits. Lower-terrace areas of Niue are therefore not assessed to be a worthwhile demonstration site(s) for household rainwater tanks under the PACC demonstration project.

Overcoming constraints - complementary measures

As state above, the analysis indicates that overcoming constraints to behaviour change is very important for project success. Part of this will be awareness and education to support demonstration. Another part is making sure households face the correct (economic) incentives to bring about this behaviour change.

Awareness raising and education

Community consultations indicate that a lack of information about how to properly maintain rainwater tanks and a lack of confidence in the durability and safety of the plastic tanks (pers comms, Haden Talagi, see also Ambroz (2009) and Talagi (2011)) is a constraint to the uptake and use of rainwater tanks in Niue.

Demonstration is one way to address these information problems but it is likely that complementary awareness-raising and education is also required.

Awareness raising and education measures could draw/build on work already done as part of the Training on Harvesting Rainwater Guidelines produced by SOPAC.

Water tariff system

Another project barrier, and perhaps the most significant barrier, is a lack of rates/tariffs currently charged for providing public water supply services in Niue. A lack of charging for public water supply services discourages households from properly caring for and maintain tanks, and to optimally manage water use - why would households spend time and money maintaining rainwater tanks when they can get public groundwater supply services for free that are only marginally lower in terms of quality and reliability? In the same way, a lack of charging for public (ground)water supply services also discourages households from (privately) purchasing and installing rainwater tanks.

A very worthwhile measure/reform to be progressed as part of PACC and/or PACC+ appears to be a water tariff system, including roll-out of household meters. This is consistent with the Niue National Strategic Plan: 2009-2013, which includes introduction of a water tariff system by 2013 as one of its targets. Water tariff reforms will also generate broader community benefits in terms of water supply efficiency, (financial) sustainability of public water supply services, and reducing community vulnerability to water supply shocks.

Potential unintended effects

Experience from the renewable energy sector in the Pacific, including Niue, is that broad-scale provision of renewable energy by Government/donor (at highly subsidised rates or for free) can depress the development of local markets (PIGGAREP project brief 2008, PIGGAREP project document 2008).

The PACC project should be careful not to let this happen in the Niue rainwater tank market - which currently comprises of at least one private supplier of rainwater tanks in Niue who reportedly provides tanks at prices and quality comparable to the New Zealand rainwater tank market.

To avoid any unintended effects on the Niue rainwater tank market, PACC provision of rainwater tanks should be limited to demonstration (i.e. small scale).

Introduction

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As part of the Pacific Adaptation to Climate Change (PACC) project, a demonstration project will be implemented to help reduce these risks. The proposed option for this demonstration project is household rainwater tanks (5KL and/or 10KL HDPE tanks).

The objective of this report is to assess whether household rainwater tanks represent a worthwhile option to be implemented under PACC. A secondary objective is to assess potential constraints to realising project benefits and provide recommendations on how to overcome these constraints. The intention of the report is to help inform decision-making by the Niue Government about the PACC demonstration project, alongside other advice provided by Niue Government officials and Development Partners.

The rest of this report is organised as follows:

1. Background
2. Problem Statement
3. Objective
4. Options
5. Methodology
6. Data
7. Results
8. Findings and Recommendations

Background

PACC

The Pacific Adaptation to Climate Change (PACC) project is a US$13 million, 5-year UNDP/GEF project which began implementation in February 2009. It covers 13 Pacific Island Countries (PICs) and aims to reduce community's climate change and disaster risks in the water, food security (agriculture), and coastal sectors.

The PACC project design comprises of 3 main components. These are (i) 'mainstreaming' of climate change risk into relevant government processes, policies and strategies; (ii) piloting and/or demonstration of practical adaptation measures; and (iii) communication of climate change risk and lessons learned. More information on the PACC project design can be found at http://www.sprep.org/pacc-home.

In 2006, a team of experts[1] conducted in-country consultations with Niue Government to determine, among other things, priorities for PACC activities in Niue. The result of these consultations was an agreement to focus on water as the thematic sector for PACC Niue. A copy of the Niue PACC Report of In-Country Consultations (2006) can be found at http://www.adaptationlearning.net/sites/default/files/PACC%20Niue%20%20Project%20Details.pdf.

In 2009, the Niue PACC project commenced implementation with project management responsibilities set up in the Department of Environment.

Community information

Niue is the least-populated of the African, Caribbean and Pacific (ACP) countries, with a resident population of 1460 people as at 2011 (Table 1.1, Census Book of Tables 2011). Population in Niue has decreased markedly over last couple of decades, down from a peak of 5,194 in 1966. This has mostly been emigration to New Zealand where Niueans have citizenship rights and economic opportunities are better.

Most of this population (approx 77 per cent), as well as the commercial centre and tourism accommodation, is located along the west-side of the island near the capital Alofi. The remaining 23 per cent are spread across villages on the eastern side and the upper terrace of the island. These main villages here are Toi (23 residents, 9 households), Mutalau (90 residents, 31 households), Lakepa (51 residents, 21 households), Liku (70 residents, 22 households), and Hakupu (127 residents, 39 households). As at May 2012, villages on the eastern side and upper terrace areas of Niue are the pilot sites for the PACC project. Any up-scaling of project options as part of PACC+ will also look at the west-side of the island.

Niueans do not suffer from poverty, due in part to the existence of a government welfare scheme and the subsistence living that Niueans practice. Niue has a high level of education, sanitation and public health services; and has already managed to achieve most of the Millennium Development Goals way before 2015. According to the Human Development Index (HDI), Niue is ranked third in the Pacific region after Palau and the Cook Islands.

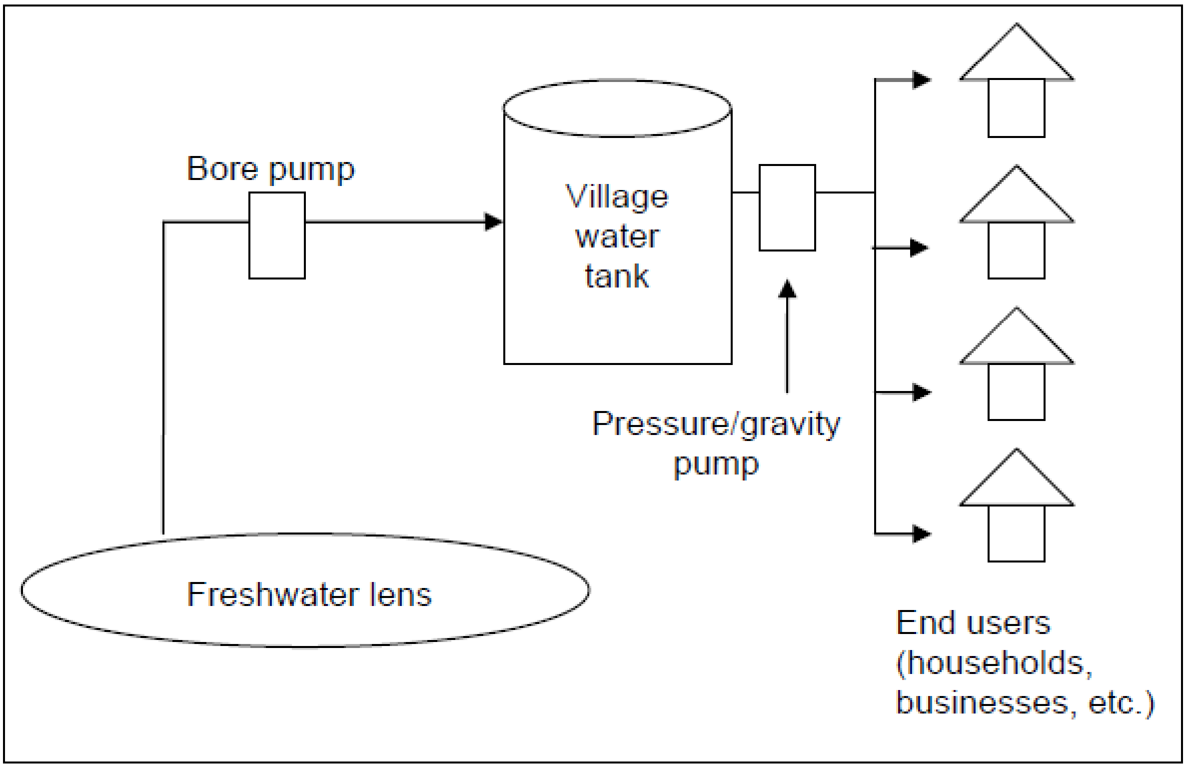
[1] This team comprised a Chief Technical Adviser, UNDP Programme Officer and a GEF Expert Consultant.

Water Sector

Niue is the world's largest and highest single coral atoll, with a land area 259 km^2. Water supply on Niue relies almost entirely on its large and thick (35 metres) groundwater lens. The sustainable yield from this lens is estimated to be approximately 39.7 Million m3/yr[2] and water in this lens is currently of very good quality (GWP, 2008). Being a raised coral atoll, Niue has no surface water.

The Public Works Division (PWD) is responsible for providing public water services to municipal areas of Niue. The public groundwater supply system comprises of 4 main infrastructure components: (i) bore pumps to extract water from the lens, (ii) village water tanks/reservoirs; (iii) pressure pumps to power distribution; and (iii) piping. There is no treatment of water before supply to users (WHO Pacific 2008). Figure 1 provides a graphical illustration of a groundwater system for a Niue village.

Figure 1. Typical groundwater pumping system in Niue



Source: Ambroz (2009)

A key feature of the Niue groundwater reticulation system is that distribution of water from the village water tank to end users is gravity fed for villages located in lower terrace areas of Niue (reservoir tanks can be situated on adjacent upper-terrace sites that are higher up) and pressure pumped for villages located in upper terrace areas (where a gravity fed system is not feasible). Pressure (and bore) pumps are powered by the Niue electricity system.

The Niue Water Works Division (WWD), housed in the Public Works Department (PWD), last estimated abstraction from the groundwater lens was at 274ML in 2006 (pers comms Clinton

[2] This was based on (i) a recharge rate of 662 mm/yr which, over the 200km area of the lens, equates to 132.5 Million m3/yr of lens recharge (Mosely and Carpenter, 2005); and (ii) an estimated useable yield of 30% of this recharge amount (Falkland, 2003).

Chapman 2012, Wide Bay Water/SOPAC 2007, and Talagi 2011) which is well within estimates of the sustainable yield. Approximately 62 ML (22.6 per cent) is lost to leakages of which 13 ML (4.7 per cent) is considered unavoidable (Chelsea Giles-Hansen, Water Demand Management Programme Officer/Water Engineer, personal comm., Aug 2010, see also Talagi (2011)). Of the remaining 212 ML, 80 per cent (169.6 ML) was estimated to be allocated to the residential sector, 15 per cent (31.8 ML) to the industrial sector, and 5 per cent (10.6 ML) to the agriculture sector. 100 per cent of households are connected to the public groundwater reticulation system. No rates/tariffs are charged for providing water services.[3]

In addition to groundwater, a small amount of water is also sourced from household rainwater tanks (3 households out of 477) as well as imported bottled water (approx 9,400 litres per year[4]). Prior to installation of the groundwater reticulation system in the 1970's, community and household rainwater tanks (which were typically concrete construction) were in fact the primary source of water. Since the groundwater system has been in place however, rainwater tanks have been neglected. Reasons for this neglect include:

- the lack of charging for reticulated groundwater supply. This reduces incentives to maintain and use rainwater tanks as maintaining rainwater tanks costs money and time whereas water from groundwater supply services does not cost the household anything; and
- the perceived health risks of using rainwater tank water. Rainwater harvesting was discouraged in the 1980's due to concerns about mosquito-borne illnesses (O'Keefe 2007) and to a lesser extent, concerns about the use of corrugated asbestos roofing (pers comms Clinton Chapman, July 2012).

For community rainwater tanks, the inconvenience of collecting water relative to the reticulated supply system was also a major factor (pers comms Haden Talagi, Niue PACC Co-ordinator).

Estimates for household water consumption vary significantly. The most recent estimates are from a sample of 25 household water meters in the Alofi region which have been monitored over the last 6 months. These sample reading indicate an average household consumption rate of 200 litres per capita per day (pers comms Clinton Chapman, July 2012)[5]. Other estimates for household water consumption are 350 litres per capita per day[6] (SOPAC IWRM Diagnostic Report, 2007) and 500 to 1,000 litres per capita per day[7] (Mosley and Carpenter, 2005).

A further 100 household water meters are planned to be installed over the next 6 months which will provide a more accurate estimate of average household water consumption. In general, a minimum

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[3] The exception is where a house is located well away from the main public pipe line, in which case the owner is required to meet the reticulation costs only.

[4] Talagi (2011)

[5] If extrapolated for the entire population for a full year, this suggests an annual total usage of 106.58 ML (1460 people x 200 litres per day x 365 days = 106,580,000) . This quantity is far below (best) estimates of supply of 169.8ML (after accounting for leakage) as estimated in 2006.

[6] 1460 people x 350 litres per day x 365 days = 186,515,000

[7] 1460 people x 500 litres per day x 365 days = 266,450,000; 1460 people x 1000 litres per day x 365 days = 532,900,000

of 20 - 40 litres of water per capita per day are needed to maintain basic hygiene and health (Taylor et al. 2008).

Detailed information on the uses of water at the household level is not available at this stage. It is known however that 93 per cent of households have flush toilets and 75 per cent have washing machines (Census Book of Tables, 2011). Household water is not used for subsistence gardening plots, which are typically located inland from village areas (pers comms, Haden Talagi).

Problem Statement

Nature and extent of problem

As outlined in the Niue PACC Report of In-Country Consultations (2006), climate change presents a number of risks to the Niue water sector. The most significant risks appear to relate to cyclone and extreme rainfall hazards which increase the likelihood that surficial contaminants enter the lens and (cracked) pipes and degrade the quality of the groundwater supply, as well as cause short-term interruptions to public water supply services.

Projections for cyclone and extreme rainfall hazards and their potential impacts on water quality and reliability are separately discussed below.

It is also worth mentioning here that the Niue residential water sector is not considered to be vulnerable to drought (GWP, 2008)[8]. The food production sector however can be adversely impacted by (soil) drought conditions, though this has not been the focus of the Niue PACC pilot project.

Climate projections

Projections are for extreme rainfall to increase (by 13%) in Niue by the year 2055, as indicated by the Pacific Climate Change Science Program (PCCSP - see http://www.pacificclimatefutures.net). This is based on an average of projections generated from the range of Global Climate Models (GCMs) available using the IPCC A1B medium emissions scenario. The increase in extreme rainfall is caused by the projected increase in intensity of the South Pacific Convergence Zone (SPCZ) which lies over Niue during the wet season, and causes increased precipitation. A less likely, but potentially high impact climate future is for extreme rainfall days to increase by as much as 20% by 2055, as predicted by the GFDL-CM2.1 global climate model.

The PCCSP report projects a reduction in cyclone frequency and intensity from its historical average of 15 tropical cyclones per decade. However, these projections are highly uncertain as the GCMs do

[8] Prior to 2008, there had been significant uncertainty about the discharge rate of the groundwater aquifer which in turn affects the effective storage of the aquifer and hence vulnerability of household water supply to drought. Specifically, this uncertainty related to whether the structural make up of the aquifer is dominated by the karst system (1-2 per cent porosity) or rock mass (20 per cent porosity). In 2008, GWP took measurements of aquifer draw-down during dry periods. Based on these measurements, the discharge properties of the aquifer were assessed to behave most like a rock mass dominated system. This assessment is also consistent with historical observations that there has been no incidents of water shortage from the groundwater lens during the lifetime of the groundwater supply system including during numerous severe drought events (i.e. longer than 6 months). WWD advise this is their current understanding of the storage capacity of the lens.

not have fine enough resolution to allow country-level predictions of cyclone hazards. The PCCSP report relies on larger scale parameters inferred from GCMs. Refer to *Climate Change in the Pacific: Scientific Assessment and New Research* (Volume 1, Section 4.8) http://www.cawcr.gov.au/projects/PCCSP/Jan2012/PCCSP_Report_Vol1_WEB_120202.pdf for more information on this approach.

Water quality

The groundwater lens is considered to be highly vulnerable to surficial land use activities due to the permeable nature of the coral structure (IWRM Diagnostic, SOPAC, 2007). When cyclone and extreme rainfall events occur, there is an increased chance that surficial contaminants will enter the groundwater lens and (cracked) pipes and degrade water quality. This in turn can cause water-related disease and sickness and also interrupts supply.

Current and future risks of groundwater contamination are not well understood - partly because water quality data has not been consistently and regularly collected in an island wide manner. To date, there have only been a few minor groundwater quality incidents reported (Carpenter and Mosely, 2003) and nothing has happened which has resulted in recorded water-related disease or sickness, or long-term interruptions to groundwater supply services. In the future, contamination risks are broadly expected to increase if land use activities increase (such as the resumption of more extensive taro exporting) and groundwater supply infrastructure - notably pipes - continues to deteriorate (Niue Drinking Water Safety Plan, 2009 – Andre Siohane, Clinton Chapman).

The Drinking Water Safety Plan (2009) and the IWRM Diagnostic Report (2007) identifies cracks in the pipes (and to a lesser extent reservoir tanks) as the highest risk of groundwater supply contamination. Since 2009, repair of household water leaks and replacement of reticulation pipeworks has happened in some of the villages in Niue (Alofi, Makefu, Tuapa, Namukulu, Hikutavake, Toi, Liku, and Hakupu) as part of WWD water demand management program and the Integrated Water Resources Management (IWRM) project. Only a very small part of the existing mains pipework have been replaced. Funding to complete this work, as indentified under the Governments Infrastructure Plan, has not been secured and so these risks are still considered to be high in some areas.

Land-based pollution is the other significant risks to groundwater quality (Drinking Water Safety Plan (2009) and IWRM Diagnostic Report (2007)). The three major stakeholders (PWD, Department of Health, and Department of Environment) identify sewage as the pollution type which presents the highest risk to the groundwater lens (Talagi, 2011). If more extensive export of taro resumes, contamination from fertilisers and herbicides is also considered a high risk (Talagi, 2011).

Key threats are summarised in Table 1.

Table 1. Sources of key threats to groundwater quality

Source		Hazard	Priority[3]
Leakages in reticulation system		Microbial contamination	High
Effluent Discharge	Waste Water (Septic tank overflows)	Microbial contamination	High
	Piggeries	Microbial contamination	Medium
Potential increase in fertiliser use		Increased level of nitrates	Medium
Potential increase in Herbicide		Chemical contamination	High

Source: Talagi (2011)

Water supply reliability

As outlined in the Background section, reticulation of groundwater supply to households located in upper terrace areas must be pumped using pressure pumps. When cyclone warnings are issued, these pumps (and other components of the groundwater supply system) are shut-down as a precautionary measure resulting in short-term water supply interruptions to these areas.

The average duration of cyclone-related interruptions is approximately 4 days (pers comms, Clinton Chapman, July 2012). During this time affected households must collect water rationed directly from the village tank/reservoir, which is an inconvenience.

Historically, the average number of short-term interruptions associated with cyclone warnings and events is 1.5 times per year (PCCSP, 2011).

Non-climate change causes of water quality and reliability problems

In addition to climate hazards, there are several non-climate change factors contributing to water quality and supply reliability problems in Niue. The key factors identified are inadequate regulation of land-use pollution (pollution externalities), and inadequate pricing of public groundwater supply services. Each of these factors are discussed further below.

Inadequate regulation of land-use pollution (pollution externalities)

There are a number of land-use activities which present pollution risks to groundwater supply (SOPAC 2007, Talagi 2011). Some of these land-use activities are not adequately regulated/controlled. These are:

- Sewage discharge - The Department of Environment is responsible for emptying the septic tanks and according to the Department, a lot of septic tanks have not been constructed in accordance with the standards required of the Niue Building Code and on many occasions encounter tanks without cement floors and without proper absorbtion trenches for secondary treatment (Sauni Togatule, Director of Environment, Clinton Chapman, personal comm., Apr 2010).Use of agrichemicals - The Department of Agriculture, Forestry and Fisheries (DAFF) currently does not have mechanisms in place to monitor imports and usage of fertilisers, but they do believe that due to the high cost very little is being imported (Brandon Pasisi, Director, personal comm., Apr 2010).

- Piggery effluent discharge – There are a number of piggeries around the island from which effluent is discharged overland without retention or treatment (pers comms, Clinton Chapman, July 2012).

- Illegal dumping of household waste – Although there is a regular collection round of household rubbish, there is still dumping of waste outside of the village boundaries, primarily on roadsides and on family land plots (pers comms, Clinton Chapman, July 2012).

In 2008, the SOPAC Integrated Water Resource Management (IWRM) project introduced a number of pilot measures to strengthen controls of some of the abovementioned land use activities - mostly sewage and waste oil collection. However, these measures are limited to the Alofi area. Land use activities in non-Alofi areas are still not adequately controlled.

Inadequate pricing for public groundwater supply services

As mentioned above, the Public Works Division (PWD) do not currently charge for providing public groundwater supply services. The absence of price means that government does not earn revenue from the sale of water from which it could fund catchment management and infrastructure maintenance, needed to help ensure the quality of groundwater supply services remains high (and improve reliability).

A lack of pricing also means that households have no incentive to constrain their consumption to levels that are sustainable, affordable or efficient - resulting in (unjustified) higher water supply costs and potentially diverting resources away from catchment management and infrastructure maintenance to ensure high water quality and improve reliability.

Further, as mentioned above, a lack of pricing for public groundwater services can discourage households from privately augmenting water supply to improve water quality and reliability - such as through installation of household rainwater tanks. Why would households pay the entire amount/cost (which is substantial) for alternative water supply services when they can get public groundwater supply services that are only marginally lower in terms of quality and reliability (or at least appear to be) for free? This matter is discussed in more detail in the Findings section.

Objective(s)

The high level objective of the Niue PACC project is to increase the resilience of the Niue water sector to the adverse impacts of climate change (PACC Report of In-Country Consultations: Niue, 2006. p.10).

Based on the problem analysis outlined above, this objective can be further defined as *to reduce risks to the quality and reliability of Niue household water supply from cyclone and extreme rainfall hazards.*

It should be noted that the (further defined) project objective does not cover other causes of the water quality and reliability problem - specifically inadequate regulation of land-activity-related pollution and inadequate pricing for public groundwater supply services. As discussed in the Findings section, these causes of the problem will need to be addressed if the project options are to effectively and efficiently improve water supply quality and reliability in Niue.

Options

As part of the In-Country consultation undertaken in 2006 it was agreed the PACC would focus on supply-side infrastructure measures (PACC Report of In-Country Consultations: Niue, 2006. p.16). Since inception, activities undertaken for the pilot component of the Niue PACC have focussed exclusively on household rainwater tanks (for household water supply, not agriculture). Household rainwater tanks are intended to provide both back-up supply in the event of groundwater contamination and short-term groundwater supply interruptions, as well as day-to-day household water supply (primarily for drinking). A Technical Design study has been undertaken (Chapman, 2012) which identifies HDPE plastic tanks of 5KL or 10KL capacity as most suitable.

Some previous assessments have been undertaken of household rainwater tanks in Niue. Ambroz (2009) found household rainwater tanks to be a more expensive means of delivering water supply services to households relative to the existing groundwater supply system - though, as per the terms of reference for the study, this analysis did not consider benefits associated with potential improvements in water quality or reliability from household rainwater tanks). Of note, household rainwater tanks were not identified as a priority measure in the Niue Drinking Water Safety Plan (2009) or in the Integrated Water Resource Management (IWRM) project design document (2007).

For comparison, this study also considers repair and/or replacement of leaking (groundwater reticulation) pipes as another supply-side option (note, this option is distinct from leakages within the household). Repair/replacement of system pipeworks is part of the Niue Drinking Water Safety Plan (2009) and the IWRM pilot project, and is intended to, among other things, reduce risks of contamination directly entering pipes. Part funding for this option(s) has already been allocated and remaining amounts are expected to be secured from other sources (Pers comms Sauni Tongatule, July 2012).

Previous assessments have been undertaken of repair/replacement of leaking system pipeworks by Talagi (2011), who assessed this measure as part of a group of priority measures to improve/maintain the quality of groundwater supply. This study found that, collectively, these measures generate net cost savings for delivering groundwater supply services as well as health benefits. This study did not assess system pipeworks as a stand-alone option.

Methodology

The methodology used for assessing the Niue PACC pilot project was a standard cost-benefit framework.

Cost-benefit analysis is a technique that evaluates the benefits and costs of a project from the perspective of society (as opposed to a single individual). It involves:

- measuring the gains and losses to the community of an action, using money as the measuring rod for those gains and losses; and
- aggregating the monetary valuations of the gains and losses, discounting them over time, and expressing them as net community gains or losses (Pearce 1983).

Projects which are assessed as generating a net community gain are considered to be worthwhile.

With and without analysis

To assess household rainwater tanks using the cost-benefit framework it is necessary to firstly define the without-project scenario. This provides the 'baseline' from which costs and benefits of the (with) project option can be measured. The intent is to identify only the impacts that are clearly associated with the project, and not include as impacts any changes (in the economy) that would have occurred even without the project (Brouwer and Pearce, 2005).

The with-project and without-project scenarios for the PACC pilot demonstration project are summarised in Table 2.

Table 2. With and Without project analysis

Without project	Household rainwater tank	Repair/replace leaking groundwater pipes
Household water supply continues to be supplied exclusively from groundwater reticulation system and some imported bottled water Ongoing threat of groundwater supply contamination, potential for water borne disease Water supply interruptions due to tropical cyclones, mains breakages, other power outages, and scheduled water maintenance	Costs	
	Capital costs (household rainwater tank, installation, standpad, guttering and facias, first flush device, and downpipes) Maintenance costs	Capital costs (piping,fittings, machinery hire, fill, labour) Maintenance costs
	Benefits	
	Improved water supply quality (reduced potential for water borne disease) Improved water supply reliability (reduced time spent collecting water from village tanks during tropical cyclones, other power outages, and scheduled water maintenance) Reduced use of water pumped from lens, leading to lower pump costs to government/PWD over time Potential, reduced import bottled water.	Improved water supply quality (reduced potential for water borne disease) Reduced use of water pumped from lens, leading to lower pump costs to government/PWD over time Potential, reduced import bottled water.

A further description of each of the benefit categories identified in the above table is provided at Appendix A. As described in this Appendix, due to data limitations, current and future risks of groundwater supply contamination are not well understood and so accurate forecasts of related health impacts are not possible - at least not without doing further in-depth studies.

Nonetheless, to get a basic understanding of the potential health impacts from groundwater supply contamination and the benefits of reducing these impacts, indicative scenarios are used/developed. These are based on scenarios developed by Talagi (2011) in his assessment of groundwater infrastructure upgrades and water quality monitoring activities (to improve public water supply quality/safety) in Niue. Also, two additional without-project scenarios are developed for this analysis to account for the high uncertainty of future contamination risks, especially relating to climate hazards.

Valuing Costs and Benefits

In CBA, the value of a cost or benefit is typically measured in terms of "willingness-to-pay" (Boardman et al, 2006). Where markets exist and work well, willingness-to-pay can be determined from the market. Where markets do not exist however or are 'distorted', willingness-to-pay can be much more difficult to measure. This is the case for water benefits in Niue.

One approach to estimating households willingness to pay for improvements in water (quantity, quality and/or reliability) where there is no market price information is through stated-preference survey techniques. However, such a study would require several months to complete and this time is not available to the PACC project. Also, the cost of these stated-preference surveys is high (>NZ$20,000) and, given the small size of the Niue PACC pilot project, the value of this information is not considered to be worth the expense. For these reasons, stated-preferences techniques were not used in the analysis.

A more practical but possibly less precise approach to estimating willingness to pay for water supply improvements is to estimate damages and loss avoided. This approach was used in the analysis and is described further below for each of the benefit categories:

Improved water supply quality (reduced potential for water borne disease)

Where the introduction of water tanks and repair of pipes leads to increased water quality, medical costs and lost income associated with water-related health problems would be reduced.

As described in the with and without analysis at Appendix A, improved water quality from household rainwater tanks and repair/replacement of leaking pipes is expected to reduce incidence of mild and serious water-related sickness and associated medical costs and lost income by 50 per cent and 61 per cent respectively relative to projected levels without any intervention.

The value of medical costs avoided are estimated by multiplying the number of consultations and overnight hospital stays avoided by the estimate unit costs of NZ$150 per consultation and NZ$500 per overnight hospital stay as estimated by the Niue Health Department (2010).

The value of lost income avoided is estimated by multiplying the number of sickness days avoided by the average wage rate of NZ$80 per day (Household Income and Expenditure Survey (2002), Talagi (2011)).

Improved water supply reliability (reduced time spent collecting water from village tanks during tropical cyclones, other power outages, and scheduled water maintenance)

Where the introduction of water tanks leads to increased reliability in water supply, time would be saved by householders as they would not need to collect water during water supply interruptions.

Nor would they need to purchase storage containers. Also, time would be saved by PWD staff as they are no longer required manage rationing of water at village reservoirs.

The expected period of time saved from avoided interruptions is described in the with and without analysis at Appendix A. The value of this time saved is calculated by multiplying the number hours saved by the average wage rate of NZ$15 per hour (Household Income and Expenditure Survey (2002), Talagi (2011)).

Storage container purchase costs avoided are approximated at NZ$15 per household per year based on market survey.

Reduced use of water pumped from lens, leading to lower pump costs to government/PWD over time

Where the introduction of water tanks and repair of leaking pipes leads to reduced groundwater supply (more specifically for leaking pipes), pumping costs of providing groundwater supply services would be reduced.

The quantity of groundwater expected to be offset from rainwater tanks cannot be empirically estimated with the information available (there is no water price information or detailed water consumption data). Assumptions are thus used to estimate the quantity of groundwater expected to be offset. For this analysis, it is assumed that water produced from tanks will fully offset groundwater supply and leakage reduction will reduce the equivalent quantity of water abstracted from the lens. This assumption is discussed further below.

The quantity of water produced from rainwater tanks is taken from estimates made in the Technical Design document (Chapman, 2012). These water yields are based on estimated failure rate of providing 100 litres per day per person using historical rainfall data and utilisation of full catchment areas for various house types (i.e. modern, hurricane extended, hurricane).

The quantity of water saved from leakage reduction is calculated using estimates of the proportion of total avoidable leakage that is attributable to leaking pipes (24.5 ML[9]) and then multiplying this by the estimated achievable leakage reduction rate of 90 per cent (pers comms, Clinton Chapman, July 2012).

The value of offset groundwater supply is estimated by multiplying the quantity of offset water by the variable cost of providing groundwater supply services. Variable costs are taken to be electricity costs of pumping plus the carbon costs associated with this electricity generation. No infrastructure costs will be offset as there is little scope to down-size infrastructure and still provide groundwater supply services (with the possible exception of village storage tanks/reservoirs).

Electricity costs of pumping are estimated by dividing the total electricity cost for water pumping excluding fuel tax budgeted for 2011 of NZ$121,764 (10-11 Budget for Water Works Division) by the total quantity of water pumped in 2006 of 274 ML (WBWC/SOPAC 2007, Niue Water Benchmarking document, Chapman, Talagi (2011))

[9] The total avoidable leakage estimated in 2006 was 49 ML (Chelsea Giles-Hansen, Water Demand Management Programme Officer/Water Engineer, personal comm., Aug 2010, see also Talagi (2011)). The percentage of this leakage that is attributable to leaking pipes is approximately 50 per cent (Pers comms, Chapman, June 2009, see also Ambroz (2009)).

Carbon costs are estimated at NZ$54/ML[10] and are taken from Ambroz (2009).

Potential, reduced import bottled water.

Where the introduction of water tanks and repair of leaking pipes leads to reduced imports of bottled water, costs of purchasing imported bottled water would be reduced.

The expected reduction of imports of bottled water resulting from the introduction of household rainwater tanks and repair of leaking pipes is described in the with and without analysis at Appendix A. The value of this expected reduction in bottled water imports calculated by multiplying the quantity of bottles reduced by the market price for that water of NZ$2/litre bottle (Talagi, 2011).

Key assumptions

There are a number of important data gaps, particularly as they relate to groundwater contamination risks and subsequent impacts on community health. Also forecasts about the future are inherently uncertain. As such, numerous assumptions were required in the analysis. In addition to the assumptions outlined in the contamination scenarios at Appendix A, the key assumptions used in the analysis are outlined in Appendix B.

Weak assumptions - i.e. assumptions for which there is little confidence and which are potentially contentious - are listed below:

i. Households will properly maintain and care for household rainwater tanks and related infrastructure such that tanks will last the full 20 year expected useful life (Chapman, 2012); water yields estimated in Chapman (2012) are realised; and water is of safe drinking quality.
ii. Households will optimally manage consumption of water such that household rainwater tanks will fully offset water supply from groundwater system and reduce imports of bottled water to 50 per cent of current levels; and households will preferentially consume water from rainwater tanks for drinking such that water-related health incidences are reduced by 50 per cent.
iii. Opportunity cost of time is NZ$15/hour and NZ$80[11] per day (Niue Household Income and Expenditure Survey (2002), see also Talagi (2011)).

The first two assumptions are based on the ideal implementation scenario whereby complementary measures are also undertaken to address other causes of the problem not covered in these project options - i.e. strengthening of land-use regulations to reduce groundwater pollution and pricing reforms to provide the correct incentives for water management and use. This is discussed further in the Findings section.

These assumptions are also based on the understanding that there is currently no unmet demand for the quantity of water except during interruptions and so households do not treat water from tanks as additional water. This is considered likely because there is currently no water pricing, no water restrictions, and no water scarcity in Niue.

[10] This was calculated by estimating the peak-electricity avoided from reduced water pumping of 57 ML, estimating the emissions offset (109 tonnes) and using a carbon price of €12.25/ton.
[11] Average Household Income 32487 (Niue HIES 2002) adjusted for 27.33 percent inflation from 2002 to 2008 (Niue Statistics 2010) divided by the average of two household earners (Niue HIES 2002).

Data

Data was collected from a range of primary and secondary sources.

Data used and sources of this data are summarised in Appendix C.

Project costs are summarised in Table 3 below.

Table 3. Costs for Household Rainwater Tank and Repair/Replacement of leakage pipes

Household rainwater tanks	Price of tank (NZ$2,500/5KL tank, NZ$3,200/10KL tank)[12] Installation costs (NZ$1,299/5KL tank, NZ$1,586/10KL tank) Gutters and facias (NZ$1,400/modern house, NZ$1,036/hurricane extended and hurricane house First flush device and downpipes (NZ$158/house) Maintenance cost (NZ$60/house/year)	Chapman (2012) Technical Design Document
Repair/replacement of repairing leaking pipes	Capital costs of pipe work program (NZ$586,000). This is a lower-bound estimate.	Pers comms, Clinton Chapman (July, 2012) - based on 2010 Asset Valuation.

Results

Net Present Value and Benefit:Cost Ratio

Cost-benefit analysis aggregates the monetary valuations of the gains (benefits) and losses (costs) over time. This can be expressed as an absolute number - known as the Net Present Value (NPV) - or as a ratio of (present value) benefits to (present value) of costs. A positive Net Present Value or a B:C ratio that exceeds 1 indicates the project is expected to generate a net benefit for society.

This is the decision criteria adopted in this study. If the project option shows a positive NPV or B:C ratio greater than 1, then the project is considered worthwhile (and vice versa) and should considered for implementation. B:C ratios are useful for comparing and prioritising project options of different size/scale when there are budget constraints - as is the case with the Niue PACC pilot project.

Table 4 below summarises the NPVs and B:C ratios calculated for each of the project options under each of the future groundwater contamination scenarios. Note that NPVs and B:C ratios calculated for rainwater tanks are done for a single household/tank for both a household located in the upper-terrace area and in the lower-terrace area. The reason for assessing rainwater tanks individually is because the scale of this project option has not yet been determined. The reason for separately assessing household rainwater tanks in upper-terrace and lower-terrace areas is because lower-

[12] Note, the cost for rainwater tanks and appurtenances by Chapman 2010 is an estimate only. See Chapman (2012) for more information on how these estimates were determined/calculated.

terrace areas currently do not suffer water-supply reliability problems (and so tanks would not generate material reliability benefits in these areas) whereas upper-terrace areas do (and so tanks would generate material reliability benefits in these areas).

Table 4. NPV and B:C results by option and future groundwater contamination scenario

	Talagi contamination scenario		Low contamination future		High contamination future	
	NPV ($)	B:C Ratio	NPV ($)	B:C Ratio	NPV ($)	B:C Ratio
5 KL Tank - upper terrace areas						
Modern House	139	1.02	62	1.01	213	1.04
Hurricane Extended	424	1.07	348	1.06	499	1.09
Hurricane	305	1.05	228	1.04	379	1.07
5 KL Tank - lower terrace areas						
Modern House	-4,624	0.24	-4,701	0.22	-4,550	0.25
Hurricane Extended	-4,339	0.22	-4,415	0.23	-4,264	0.25
Hurricane	-4,458	0.22	-4,535	0.21	-4,384	0.23
10 KL Tank - upper terrace areas						
Modern House	-750	0.89	-827	0.88	-676	0.90
Hurricane Extended	-430	0.94	-507	0.92	-356	0.95
Hurricane	-531	0.92	-608	0.91	-457	0.93
10 KL Tank - lower terrace areas						
Modern House	-5,513	0.21	-5,590	0.20	-5,439	0.22
Hurricane Extended	-5,193	0.22	-5,270	0.21	-5,119	0.23
Hurricane	-5,294	0.20	-5,371	0.19	-5,220	0.22
Repair/replace leaking system pipe works						
All service areas	-32,970	0.94	-113,381	0.80	68,674	1.12

Appendices D and E provide a further breakdown of cost and benefit value estimations over time for select options.

A copy of the excel worksheet developed for this analysis is also available at the SPREP PACC website, http://www.sprep.org/Table/Pacific-Adaptation-to-Climate-Change/Reports/.

Sensitivity Analysis

As outlined in the key assumptions section, there are significant information gaps and uncertainties about the future - which has required the use of assumptions. This section tests how sensitive the results are to changes in some of the key assumptions. This is done in order to assess the robustness of the results and hence the confidence we can place in them for informing decision-making.

The assumptions tested are those 'weak' assumptions outlined above in body of the report. These are:

(i) *Households will properly maintain and care for rainwater tanks*. A valid alternative to this assumption is that households do not properly maintain and care for rainwater tanks, especially if complementary measures are not undertaken to address other causes of the problem not covered in these project options - e.g. pricing reforms to provide the correct incentives for water management and use. This was modelled as a reduction in the expected useful life of rainwater tanks from 20 years to 10 years.

(ii) *Households will optimally manage consumption of water.* A valid alternative to this assumption is that households do not optimally manage water consumption, especially if other awareness/education activities are not undertaken to address information problems and no measures are undertaken to address other causes of the problem - e.g. pricing reforms to provide the correct incentives for water management and use. This was modelled as a reduction in the effectiveness of tanks in mitigating health incidences from 50 per cent to 25 per cent.

(iii) *Opportunity cost of time is NZ$15/hour*. A valid alternative view is that persons collecting water during interruptions have a lower opportunity cost of time compared to the average wage rate because they are more likely to be unemployed. This was modelled as a reduction in the opportunity cost of time from NZ$15/hour to NZ$7.50/hour.

Sensitivities are conducted using the Talagi contamination scenario and the 5 KL tank option on a modern house located in an upper-terrace area. Results of these sensitivities are summarised in Table 5 below.

Table 5. Summary of sensitivity analysis results for 5KL rainwater tank on a modern house located in an upper-terrace are under the Talagi contamination future scenario.

Assumptions	Primary results		Sensitivity test results	
	NPV ($)	B:C ratio	NPV ($)	B:C ratio
Expected useful life (years)	139	1.02	-2,107	0.63
Effectiveness of rainwater tanks in mitigating health incidences (% reduction in incidences)	139	1.02	62	1.01
Opportunity cost of time ($/hour)	139	1.02	-2,126	0.65

Findings and Recommendations

General findings

Limited data was an issue for this analysis, particularly water quality information[13] and water market data.[14] Further data collection however would be very time consuming (and costly) and this time is not available to the PACC.

[13]This data is needed to accurately model the biophysical relationship between cyclone, extreme rainfall, and other relevant hazards and groundwater contamination as well as between groundwater contamination and

Despite these data issues, the analysis is considered to be sufficiently accurate for the purposes of PACC decision-making. It also provides very useful insights to help improve project design and implementation. Results should nonetheless be interpreted with caution.

Overall, the results of the analysis indicate that household rainwater tanks may be a worthwhile project providing certain conditions are satisfied. These conditions are (i) adoption of certain technical design specifications, (ii) tanks are allocated to households in select areas only, and (iii) complementary measures are implemented to help ensure project benefits are realised. Each of these conditions/matters are discussed below.

The results also indicate that the merits of household rainwater tanks (under the same conditions mentioned above) are broadly similar to the option of repairing/replacing leaking system pipe works (i.e. both options have B:C ratios close to 1 - see Table 5). This gives some assurance that, in terms of supply-side options, household rainwater tanks represent a satisfactory option for the PACC.

However, given the B:C ratios are close to 1 for both options and less than 1 for some scenarios, the analysis also perhaps suggests that supply-side measures should not have been the focus of the Niue PACC pilot project. Demand-side measures are likely to be a more effective and efficient way to reduce vulnerabilities in the water sector, especially given water consumption rates in Niue are less policy effort has been allocated to this area over the last couple of decades. This finding is also consistent with the findings of the Niue Scoping Mission Report for the Water Demand Management Program (Kleppen, 2006).

Technical design specifications

The results suggest that rainwater tanks with a 5 KL storage capacity are the only storage capacity specifications of those recommended in the Technical Design Report (Chapman, 2012) that are potentially worthwhile for implementation in Niue (i.e. may generate a small net community benefit). Table 4 shows that NPV's are positive for 5KL tanks for all contamination scenarios in upper-terrace areas, albeit small.

10KL tanks on the other hand are not shown to generate a net benefit under any of the scenarios or sensitivities modelled**.** This can be mostly explained by the higher capital cost of purchasing and installing larger tanks with little additional gains in terms of avoided health impacts or avoided water supply interruptions. **It is therefore recommended that 10KL tanks are not implemented as part of the Niue PACC demonstration project (Recommendation 1).**

Note, the positive NPV result for 5KL tanks is not robust to changes in weak assumptions (see Sensitivity Analysis, Table 5) and is discussed shortly.

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community health outcomes. This necessitated the use of contamination scenarios to approximate these biophysical relationships.

[14]This data is needed to estimate willingness to pay information for water supply service improvements (quality, quantity, and reliability). This necessitated somewhat crude estimation of damages and loss avoided as a proxy measure. Consideration should be given to a Stated-Preferences Valuation Study for water quality, quantity, and reliability. This could be done co-operatively with other Pacific Island Countries as part of a regional study.

Community areas to be allocated tanks

The results indicate that it is only worthwhile to implement (5KL) rainwater tanks in upper-terrace areas - not in lower-terrace areas (see Table 4). This is because avoided water supply interruptions generated from rainwater tanks make up a large proportion of total project benefits and these are not generated in lower-terrace areas (because they are pressure-fed and not impacted by cuts to electricity etc). **It is therefore recommended that, if household rainwater tanks are to be implemented as part of the PACC, they should only be done so in upper-terrace areas, not lower-terrace areas (Recommendation 2).**

Complementary measures

As indicated above, the results for 5KL tanks in upper-terrace areas are very sensitive to changes in assumptions. Of particular note, Table 5 shows that 5KL tanks in upper-terrace area will generate a large net cost if the tank only lasts for 10 years rather than 20 years - as would be expected if households do not properly maintain and care for rainwater tanks.

Underpinning this assumption is the scenario where complementary measures are not implemented to address other causes of the water quality and reliability problem that are not covered by household rainwater tanks (e.g. inappropriate/incorrect pricing of public water services, and inadequate regulation of pollution). This result highlights the importance of implementing complementary measures to help ensure project benefits are realised.

Key complementary measures identified include water tariff reforms (to provide the correct incentives for water management and use); strengthened/expanded land-use pollution controls (to reduce contamination risks); and awareness and education (to address information failures constraining the uptake and use of rainwater tanks). Each of these measures/reforms are briefly discussed below.

Water tariff system

Water pricing reforms are part of the Niue National Strategic Plan (2009-2013), which includes a target to introduce a water tariff system by 2013.

A benefit of water pricing reforms not explicitly mentioned earlier is that it will likely reduce the quantity of water used by households. In this way, pricing reduces households dependency/reliance on large quantities of water and hence vulnerability to any events which disrupt supply of quality water including from climate hazards.

A water tariff system could be progressed as part of PACC and/or PACC+, including roll-out of a metering program.

It is recommended that a water tariff system is progressed as part of PACC and/or PACC+ (Recommendation 3).

Land pollution reduction measures

The groundwater lens is the primary and most important source of water for Niue, and will continue to be into the future. Rainwater tanks by themselves are not enough to meet the full needs and wants of Niueans. In this way, protecting the quality of the groundwater lens is important for maximising community benefits generated from rainwater tanks.

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).

For these reasons, it is important that this water source is protected. The IWRM project is piloting such measures in the Alofi region.

If there are excess/available funds under PACC, it is recommended that IWRM measures to control land-based pollution should be properly evaluated and, if shown to generate a net community benefit, considered for implementation as part of PACC + (Recommendation 4).

Awareness raising and education

As identified from community consultations, information failures are a barrier constraining the uptake and use of rainwater tanks and were a key reason why household rainwater tanks were neglected during the 70s and 80s.

Demonstration is one way to address these information problems but it is likely that complementary education and awareness raising is also required to realise benefits from rainwater tanks. This would include information on amongst other things, how to maintain tanks, what practices should be followed to ensure water is of good quality, what applications the water is best used for (i.e. drinking and hygiene), and how to effectively manage consumption of tank water so it is there when you need it.

It is therefore recommended that awareness raising and education measures be implemented to help address information failures affecting the use of household rainwater tanks (Recommendation 5). This measure should draw/build on work already done as part of the Training on Harvesting Rainwater Guidelines produced by SOPAC.

Potential unintended effects

There is currently at least one private supplier of rainwater tanks in Niue who reportedly provides tanks at prices and quality comparable to the New Zealand rainwater tank market. PACC/Niue Government intervention in the Niue water tank market should be careful not to adversely impact on the further development of this (local) market. To this end, selection of instrument for PACC intervention in the water tank market and the scale of this intervention is important.

Government intervention in markets is generally only justifiable if it is addressing a barrier which is seen to be distorting the function of that market - or a case can be made on equity grounds. If the instrument does not directly address/target a significant barrier, the potential implications are that it will make it harder for private suppliers of household water tanks operate in Niue - potentially stifling economic development.

For example, Government intervention through large subsidies may make it unprofitable for competing private suppliers to profitably sell tanks. Government provision (through large subsidisation) may also create the expectation (in non-pilot area communities of Niue) that Government will also provide water tanks to these areas, and so these other households will not be willing to purchase tanks from local suppliers/businesses (thereby depressing the development of local markets). If additional funding is not forthcoming, then these sites will not get tanks and/or there will be no local supplier available to affordably provide these tanks.

Such unintended effects (sometimes also termed 'perverse effects') from inappropriate donor interventions are commonplace in the Pacific region. A sector which has experienced many such perverse effects and which shares many similarities to the water sector is the electricity sector - specifically renewable energy. Indeed, the Pacific Island Greenhouse Gas Abatement through Renewable Energy (PIGGAREP) project has been set up specifically to address constraints to the provision of renewable energy by the private sector, including donor-created constraints related to free provision of renewable energy technologies or against very small nominal charges. See PIGGAREP project documentation for further discussion on this matter - http://www.sprep.org/Pacific-Islands-Greenhouse-Gas-Abatement-through-Renewable-Energy-Project/piggarep-documents.

Another implication of inappropriate Government intervention, but perhaps less important in this context, is that PACC/Government intervention may result in wastage or inefficient use of resources relative to provision of these services by the private sector/'free-market'.[15]

Barriers to the Niue rainwater tank market

Barriers identified as constraining the Niue rainwater tank market include (i) information failures, (ii) incorrect/inappropriate pricing (set by Niue Government) for public groundwater supply services, and (iii) split incentives. Each of these barriers and the appropriate intervention to address them are discussed in turn:

Information failures

A key barrier identified as part of community consultations is a lack of information about how to properly maintain rainwater tanks and a lack of confidence in the durability/safety of the plastic tanks (pers comms, Haden Talagi, see also Ambroz (2009) and Talagi (2011)). These type of barriers are known as 'information failures'. The appropriate intervention mechanism(s) for this type of barrier is demonstration and awareness raising/education.

The aim is to address information failures constraining the uptake of rainwater tanks by households, for which purpose a small number of tanks would appear to be sufficient. Small scale demonstration is therefore recommended for the PACC (Recommendation 6). Small scale intervention also seems appropriate given that net benefits generated from household rainwater tanks are expected to be small and maybe negative.

Incorrect/inappropriate pricing of groundwater supply services

As mentioned above, lack of pricing for groundwater supply services acts as a disincentive for households to privately augment water supply. Where households are not required to pay anything for groundwater supply services, there is little incentive for them to pay the entire amount/cost for alternative services that are only marginally better in terms of quality and reliability. The appropriate intervention here is to remove the public groundwater supply subsidy or part thereof. This is in line with Recommendation 3.

[15] For example, if full subsidisation of tanks is selected, some households will receive rainwater tanks under the PACC who don't really need or value improved water supply from these tanks and, if required to pay for tanks, would not do so. Similarly, households who receive tanks from PACC may in fact prefer a bigger or smaller tank or some other feature different to the PACC-provided tank.

Split incentives

'Split incentives' in this case refers to the different incentives to investment in household rainwater tanks faced by persons renting a house (i.e. tennants) and owners of a house who are not occupying that house (i.e. landlords). Tennants will not install a tank because they will likely only stay in the house for a few years and cannot easily take the tank with them when they leave, and so will not receive the full benefits of their investment over the entire useful life of the tank. Similarly, there is little motivation for landlords to install a rainwater tank as they will be unlikely to attract sufficiently higher rents for the house as a result of the tank, especially if public water supply services are provided for free. In this circumstance, and provided tanks do in fact generate a net community benefit, regulations such as through building codes may be an appropriate intervention.

In Niue, the proportion of households which are rented is less than 9 per cent (41 out of 477 households) and most of these households are in Alofi (30 households) - which is not in the primary pilot area of the PACC project (Table 6.6, 2011 Census Book of Tables). As such, split incentives does not appear to be a significant barrier in Niue. Regardless, the IWRM Project is in the process of reviewing the 1990 Niue Building Code.

Equity considerations

Equity reasons can sometimes be a justification for Government intervention in private adaptation measures such as household rainwater tanks, particularly in developing countries. This is where there is not a formal tax-welfare systems in place (i.e. the purpose built mechanism to achieve equity objectives) or this system is inadequate. In this situation, means-tested subsidies are the appropriate intervention mechanism. However, in Niue there appears to be a well-functioning tax-welfare system[16] and, as such, subsidies for household rainwater tanks is not appropriate. Equity objectives are more efficiently achieved through the purpose-built system tax-welfare system (and avoid potential unintended effects).

Summary of Recommendations

1. Technical design specifications for rainwater tanks adopted for the PACC focus on 5KL storage capacity tanks, not 10KL storage capacity tanks.
2. Demonstration sites for household rainwater tanks under the PACC should be in upper-terrace areas, not lower-terrace areas.
3. A water tariff system be progressed as part of PACC and/or PACC+, including roll-out of a metering program.
4. IWRM pilot measures to control land-based pollution be considered for implementation as part of PACC + (Recommendation 4).
5. Awareness raising and education measures be implemented to help address information failures affecting the use of household rainwater tanks.
6. Demonstration of household rainwater tanks be small-scale.

[16] the Human Development Index (HDI) ranking of number 3 in the Pacific region is one indicator of this.

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APPENDIX A: WITH AND WITHOUT ANALYSIS

A summary of the with-project and without-project scenarios are provided at Table 2 of main document. A further description of each of the benefit categories identified in this table are provided below:

Improved water supply quality (reduced potential for water borne disease)

As outlined in the Problem section, current and future risks of groundwater supply contamination are not well understood. In turn, accurate forecasts of water-related health impacts from these contamination risks are not possible - at least not without doing further in-depth studies.

Nonetheless, to get a basic understanding of the potential health impacts from groundwater supply contamination and the benefits of reducing these impacts, indicative scenarios are developed. These are based on scenarios developed by Talagi (2011) in his assessment of groundwater infrastructure upgrades and water quality monitoring activities (to improve public water supply quality/safety) in Niue. This scenario is summarised as follows:

- As a result of microbial and other lens contamination, there will be an outbreak of water-borne disease in five years, which will recur every two years, with an average of 6 cases of residents falling sick per outbreak and requiring hospitalization.
- There will be two mild occurrences per month (24 per year) of water-borne illness requiring consultation with a doctor and medication, which will occur yearly, and increase by two cases every year.
- Cases requiring hospitalization will be assumed to require a week off work, and every consultation case will require two days off work.

In light of the high uncertainty of future contamination risks, especially relating to climate hazards, two additional without-project scenarios are developed for this analysis:

- *Low contamination future.* This scenario describes a future where frequency and intensity of cyclone and extreme rainfall hazards are lower than the Talagi scenario. It also describes a scenario where land use activities do not materially increase from what it is now (i.e. extensive taro exporting does not resume). Under this scenario, the probability of an outbreak of water-borne disease is reduced to once every 4 years. Also, the incidence of mild health cases is 50% lower than the 'Talagi contamination scenario'. That is, start at 12 cases of mild water-borne illness per year and increase by 1 per year.
- *High contamination future.* This scenario describes a future where frequency and intensity of cyclone and extreme rainfall hazards are higher than the Talagi scenario. As described in the Problem section of this report, this is less likely but nonetheless very possible. This future also describes a future where land use activities increase significantly over time. Under this scenario, the probability of an outbreak of water-borne disease increases over time - starting at once every 2 years in 2018, increasing to once every 1 1/2 year in 2023, increasing again to once every year in 2027 and so forth. Also, the incidence of mild health cases is 50% higher than the Talagi contamination scenario (that is, start at 36 and increase by 3 per year).

With the household rainwater tank project, supply of good quality water from household rainwater tanks is expected to reduce incidence of mild and serious water-related sickness (relative to the without project scenario) by 50 per cent. This is based on the expectation that households will preferentially consume (good quality) water from rainwater tanks for drinking such that exposure to contaminated water is reduced by 50 per cent.

With the repair/replacement of leaking pipes project, groundwater supply contamination risks will be reduced such that the incidence of mild and serious water-related sickness (relative to the without project scenario) will be reduced by 61%. This is crudely based on the cost-share of system pipework costs[17] relative to total costs of priority measures in Drinking Water Safety Plan[18] and the assumption made in Talagi (2011) that priority DWSP measures will reduce water-related health costs by 100% relative to the without project scenario.

Improved water supply reliability (reduced time spent collecting water from village tanks during tropical cyclones, other power outages, and scheduled water maintenance)

As outlined in the problem section, when groundwater supply interruptions occur due to cyclones (which happens 1.5 times per year on average and lasts for 4 days), households located on the upper-terrace areas of Niue must currently collect water rationed directly from the village tank/reservoir. This takes them approximately 1.5 hours to do each day and also requires them to purchase storage containers. Moreover, rationing of water from the village reservoir must be managed by a PWD employee.

The same also applies for groundwater supply interruptions caused by power outages and scheduled water infrastructure maintenance. The frequency of power outage interruptions is approximately 6 times per year and last for 6 hours (pers comms, Director Power Authority, 30 May 2012). The frequency of water infrastructure (regular) maintenance in each village is once per year and lasts for 2 days (pers comms, Clinton Chapman, May 2012).

With the household rainwater tanks project, the above-mentioned interruption does not occur as households can draw on water from rainwater tanks during this time. So, with household rainwater tanks, time spent by upper-terrace households collecting water is saved. Also these households avoid having to spend money on storage containers and a PWD staff member is not required to manage rationing of water from the village reservoir.

With the repair/replacement of leaking pipes project, these interruptions still occur and so no time is saved collecting and managing water or money saved on storage containers.

Reduced use of water pumped from lens, leading to lower pump costs to government/PWD over time

Under the without project scenario, the quantity of groundwater supplied to households is expected to remain at 2006 levels. Without the PACC project, it is expected that recurrent and capital budgets will be insufficient to fully-fund groundwater infrastructure up-grades described in the DWSP and the Niue Infrastructure Plan (2009). Consequently water losses from leakage will increase by 4 per cent per annum from current levels of 62 ML per year (pers comms, Clinton Chapman). Under the without project scenario, purchases of imported bottled water are also expected to increase by

[17] This cost is NZ$586,000 and is a lower-bound estimate provided by Clinton Chapman (pers comms, July 2012) and is based on an Asset Valuation undertaken in 2010.

[18] Total costs of priority measures in Drinking Water Safety Plan are NZ$960,950. Pipe work costs as a share of total costs is 0. 61 (586,000/960,950=0.61).

approximately 3 per cent per annum in line with current trends (Statistics 2010, see also Talagi 2011).

With household rainwater tanks, water supply from household rainwater tanks is expected to 'displace' groundwater supply and some imported bottled water. The extent to which this occurs cannot be accurately predicted. As outlined by Ambroz (2011), this will depend on, among other things, whether households view rainwater tanks as an additional or a supplementary source of water and whether households properly maintain tanks. To the extent that groundwater supply is displaced by water from household rainwater tanks, variable costs of groundwater supply - which are primarily pumping costs (i.e. electricity costs of bore and pressure pumps) - will be offset. Included in the calculation of pumping costs is carbon costs, as electricity is generated using greenhouse intensive fossil-fuel. Note, there is little scope to down-size groundwater supply infrastructure and still provide groundwater supply services, with the possible exception of village storage tanks/reservoirs. As such, offset groundwater supply will not materially reduce groundwater infrastructure costs. Purchase of imported bottled water is expected to reduce to approximately half of current levels in line with the expectation that water from rainwater tanks will be high quality and thus a good substitute for imported bottled water.

With repair/replacement of leakage pipes, this option is expected to reduce the amount of water lost during distribution by roughly 45 per cent[19].

Potential, reduced import bottled water.

Repair of leaking pipes is also expected to increased consumer confidence in the quality of groundwater supply and so is expected to reduce the amount of imported bottled water purchased.

The extent to which purchases of imported bottled water is expected to be reduced is 30.5 per cent. Similar to water-borne disease, this is crudely based on the cost-share of pipe work and reticulation and improvement investigation costs relative to total costs of priority measures in Drinking Water Safety Plan[20] and the assumption made in Talagi (2011) that priority DWSP measures will reduce purchase of imported bottled water by 50% relative to current levels.

[19] This is based on detecting and preventing 90 per cent of current real losses from the piping network (source: WBWC 2007), which itself is estimated to make up 50 per cent of total losses (pers comms Clinton Chapman WWD June 2009)

[20] Pipe work is NZ$586,000 (pers comms, Clinton Chapman, July 2012). Total costs of priority measures in Drinking Water Safety Plan are NZ$960,950. Pipe work costs as a share of total costs is 0.61.

APPENDIX B: KEY ASSUMPTIONS

There are a number of important data gaps. Also forecasts about the future are inherently uncertain. As such, numerous assumptions were required in the analysis. The key assumptions are outlined in Appendix B. Weak assumptions (i.e. assumptions that there is little confidence in and which are potentially contentious) are listed below:

i. Projected rainfall for the next 15 years, including intra-annual (seasonal) and inter-annual variability will be the same as historical monthly data collected at Hannan Airport for the period January 1954 to July 2007. This is broadly in line with projections reported in the PCCSP (2011), that indicate any (climate) changes in total annual rainfall in the short-term (before 2030) are likely to be modest.

ii. Expected useful life of a household rainwater tank is 20 years (Chapman, 2012).

iii. Houses require installation of gutters and facias.

iv. Household rainwater tanks are cyclone-proof. As outlined in Chapman (2012), this requires household tanks to be properly situated and for tanks to be tied-down during cyclone events among other things.

v. Households will properly maintain household rainwater tanks and related infrastructure such that useful life of tanks and water yields estimated in Chapman (2012) are realised, water is of safe drinking quality, and water is optimally managed.

vi. Households will optimally manage consumption of water such that household rainwater tanks will fully offset water supply from groundwater system and reduce imports of bottled water to 50 per cent of current levels; and households will preferentially consume water from rainwater tanks for drinking such that water-related health incidences are reduced by 50 per cent.

   Moreover, because water yields from 5KL rainwater tanks and 10KL rainwater tanks are both sufficient to meet demand for drinking and basic hygiene uses, the extent to which household rainwater tanks reduce incidence of water-related sickness is assumed to be the same across rainwater tank size options.

vii. Repair/replacement of leaking pipes will improve the quality of groundwater supply services such that the incidence of water-related sickness will be reduced by 61 per cent relative to the without project scenario.

viii. Opportunity cost of time is NZ$15 per hour and NZ$80[21] per day (Niue Household Income and Expenditure Survey (2002), see also Talagi (2011)).

ix. Current quantities of groundwater supply is at 2006 levels as estimated by WBWC (2007).

[21] Average Household Income 32487 (Niue HIES 2002) adjusted for 27.33 percent inflation from 2002 to 2008 (Niue Statistics 2010) divided by the average of two household earners (Niue HIES 2002)

x. Purchases of imported bottled water will increase by 3 per cent per annum without the household rainwater tank or leakage reduction projects in line with current trends and expected degradation of groundwater supply quality.

xi. Groundwater service capacity will remain at current levels. This reflects preliminary analysis undertaken as part of this study and supported by the PWD team that household water tanks by themselves are not enough to supply household water in Niue at service standards considered by the PWD to be acceptable.[22] It also reflects the fact there is little scope to down-size infrastructure and still provide groundwater supply services, with the possible exception of village storage tanks/reservoirs.

xii. Per-unit groundwater pumping costs increase by 4% per annum (real) without the piping project. This reflects the situation that recurrent and capital budgets will be insufficient to fund groundwater infrastructure up-grades and funding from external sources cannot be secured.

xiii. real discount rate is 4 per cent.

[22] Analysis undertaken as part of technical work by Chapman (2012) indicates that a 10KL tank situated next to a modern house will generate a water yield of around 100 litres/day/capita at a failure rate of 10.64 per cent. This water yield is significantly below current supply levels and is not considered by the PWD division to be acceptable to the Niue community in the short-term.

APPENDIX C: DATA SOURCES, BY TYPE

	Data type	Data Source
Community	Total resident population (1460) Total number of households (477) Average number of households in upper-terrace villages (25) Average number of persons per household (3.06)	Census Book of Tables 2011
	Wage rate (NZ$15/hour, NZ$80/day)	Household Income and Expenditure Survey (2002), Talagi (2011)
Costs of household rainwater tanks	Expected useful life of tank (20 years) Price of tank (NZ$2,500/5KL tank, NZ$3,200/10KL tank) Installation costs (NZ$1,299/5KL tank, NZ$1,586/10KL tank) Gutters and facias (NZ$1,400/modern house, NZ$1,036/hurricane extended and hurricane house First flush device and downpipes (NZ$158/house) Maintenance cost (NZ$60/house/year)	Chapman (2012) Technical Design Document
Costs of repairing leaking pipes	Expected useful life of pipes (30 years)	Water Fixed Asset Register (2010)
	Capital costs of pipe work program (NZ$51,000) Reticulation improvement investigation (NZ$280,000).	Talagi (2011)
Avoided health costs	Scenarios for groundwater contamination and subsequent incidence of water-related sickness	Talagi (2011) PCCSP (2011)
	Cost of medical consultation (NZ$150/consultation) Cost of overnight stay at hospital (NZ$500/night)	Consultations with the Health Department, see Talagi (2011)
	Proportion of health incidences avoided with rainwater tanks (50%)	Judgement by author[23]
	Proportion of health incidences avoided with repair/replacement of leaking pipes (34%[24])	Talagi (2011)
Avoided interruption costs	Frequency of cyclone event or warning (1.5 times per year)	Pacific Climate Change Science Program (2011)
	Average duration of cyclone related interruptions (4 days)	Pers comms, Clinton Chapman (May-July, 2012)

[23] This is based on the expectation that households will preferentially consume (good quality) water from rainwater tanks for drinking such that exposure to contaminated water is reduced by 50 per cent.

[24] This is crudely based on the cost-share of pipe work and reticulation and improvement investigation costs relative to total costs of priority measures in Drinking Water Safety Plan[24] and the assumption made in Talagi (2011) that priority DWSP measures will reduce water-related health costs by 100% relative to the without project scenario.

	Frequency of power failure related interruption (6 interruptions per year) Duration of typical power failure related interruption (6 hours per interruption)	Pers comms, Director Power Authority
	Frequency of scheduled water infrastructure related interruptions (1 per year per village) Duration of typical water infrastructure related interruption (2.5 days per interruption)	Pers comms, Clinton Chapman (May-July, 2012)
	Time spent collecting water during interruptions (1.5 hours per household per interruption day)	Pers comms, Clinton Chapman (May-July, 2012)
	Time spent by PWD staff managing rationing of water from village reservoir tanks (0.5/interruption day)	Pers comms, Clinton Chapman (May-July, 2012)
	Annualised cost of storage containers (NZ$15/household/year)	Market survey
	Proportion of interruptions avoided with household rainwater tanks (100%)	Pers comms, Clinton Chapman (May-July, 2012)
Avoided groundwater pumping costs	Total quantity of groundwater supply (274 ML/year)	WBWC/SOPAC 2007, Niue Water Benchmarking document, Talagi (2011)
	Total electricity pumping costs, excluding fuel tax (NZ$121,764 for 2011)	10-11 Budget for Water Works Division
	Carbon costs (NZ$54/ML)[25]	Ambroz (2011)
	Total quantity of unavoidable water losses (49 ML)	Chelsea Giles-Hansen, Water Demand Management Programme Officer/Water Engineer, personal comm., Aug 2010, see also Talagi (2011)
	Proportion of avoidable water losses attributable to leaking domestic pipework (50 per cent)	Pers comms, Clinton Chapman (May-July, 2012)
	Water yields from rainwater tanks (93,397 litres/year/5KL tank/modern house, 86,303 litres/year/5KL tank/hurricane extended house, 72,953 litres/year/5KL tank/hurricane house,100,100 litres/year/10KL tank/modern house, 96,872 litres/year/10KL tank/hurricane	Chapman (2012) Technical Design Document

[25] This was calculated by estimating the peak-electricity avoided from reduced water pumping of 57 ML, estimating the emissions offset (109 tonnes) and using a carbon price of €12.25/ton.

	extended house, and 85,577 litres/year/10KL tank/hurricane house)[26]	
	Water savings from repair/replacement of leaking pipes (90 per cent of avoidable water losses attributable to leaking domestic pipework)	Pers comms, Clinton Chapman (May-July, 2012)
Avoided purchase of imported bottled water	Total quantity of bottled water imported estimated in 2012 (15,600 litres) Rate of increase without projects (3%)	Statistics Niue 2010, see also Talagi (2011)
	Price of imported bottled water (NZ$2/litre)	Talagi (2011)
	Total quantity of bottled water imported estimated in 2013 with rainwater tank project (7,800 litres - 50% of estimated current levels) Rate of increase without projects, with rainwater tank project (0%)	Estimate made by author
	Reduction in quantity of bottled water imported with repair/replacement of leaking pipes project (31%[27] lower than without project levels)	Talagi (2011)

[26] These yields are based on estimated failure rate of providing 100 litres per day per person using historical rainfall data and utilisation of full catchment areas for various house types (i.e. modern, hurricane extended, hurricane). The failure rate for a 5 KL tank is 16.4 %, 22.5% and 34.7% for a modern, hurricane extended, and hurricane house type respectively. The failure rate for a 10 KL tank is 10.4%, 13.29%, and 23.4% for a modern, hurricane extended, and hurricane house type respectively.

[27] this is crudely based on the cost-share of pipe work and reticulation and improvement investigation costs relative to total costs of priority measures in Drinking Water Safety Plan and the assumption made in Talagi (2011) that priority DWSP measures will reduce purchase of imported bottled water by 50% relative to current levels.

APPENDIX D: Economic Analysis worksheet, 5 KL tank, Modern House, Upper-terrace area, Talagi (2011) contamination scenario.

year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
ECONOMIC ANALYSIS																					
<u>Costs</u>																					
tank		2500																			
installation		1299																			
guttering and facias		1400																			
first flush device and downpipes		158																			
maintenance		60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
disposal																					200
Total Costs (annual, undiscounted)		5417	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	260
Total Costs (aggregate, discounted)	$6,057.66																				
<u>Benefits</u>																					
avoided water-related health costs																					
overnight hospital stay		0	0	0	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
medical consultation		0	0	0	0	0	6	6	6	6	7	7	7	8	8	8	9	9	9	10	10
lost income		0	0	0	0	0	6	6	6	7	7	7	8	8	8	9	9	9	10	10	10
total avoided water-related health costs (annual, undiscounted)		0	0	0	0	0	13	13	14	15	15	16	17	17	18	19	19	20	20	21	22
total avoided water-related health costs (aggregate, discounted)	$153.25																				
avoided short-term water supply interruption costs																					
cyclone-related water interruptions		163	155	155	155	155	155	155	155	155	155	155	155	155	155	155	155	155	155	155	155
power outages interruptions		135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135
scheduled water infrastructure maintenance interruptions		60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
total avoided short-term water supply interruption costs (annual, undiscounted)		358	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350
total avoided short-term water supply interruption costs (aggregate, discounted)	$4,763.07																				
avoided groundwater and bottled water supply costs																					
groundwater pumping costs inclusive of carbon costs		48	45	47	49	50	53	55	57	59	61	64	66	69	72	75	78	81	84	87	91
bottled water costs		21	22	23	25	26	27	29	30	32	33	35	36	38	40	42	44	45	47	49	51
total avoided groundwater and bottled water supply costs (annual, undiscounted)		69	67	70	73	76	80	83	87	91	95	99	103	107	112	116	121	126	131	137	142
total avoided groundwater and bottled water supply costs (aggregated, discounted)	$1,280.18																				
Total Benefits (aggregate, discounted)	$6,196.51																				
NPV	**$139**																				
Benefit:Cost Ratio	**1.02**																				

APPENDIX E: Economic Analysis worksheet, Repair/replacement of leaking system pipe works, Talagi (2011) contamination scenario.

ECONOMIC ANALYSIS																		
Costs																		
capital cost of pipe replacement		586000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Costs (annual, undiscounted)		586000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Costs (aggregate, discounted)	$563,461.54																	
Benefits																		
avoided water-related health costs																		
overnight hospital stay		0	0	0	0	0	915	915	915	915	915	915	915	915	915	915	915	915
medical consultation		0	0	0	0	0	3203	3386	3569	3752	3935	4118	4301	4484	4667	4850	5033	5216
lost income		0	0	0	0	0	3270	3465	3660	3855	4050	4246	4441	4636	4831	5026	5222	5417
total avoided water-related health costs (annual, undiscounted)		0	0	0	0	0	7387	7765	8144	8522	8900	9278	9656	10035	10413	10791	11169	11547
total avoided water-related health costs (aggregate, discounted)	$162,840.53																	
avoided groundwater and bottled water supply costs																		
groundwater pumping costs inclusive of carbon costs		10992	10992	10992	10992	10992	10992	10992	10992	10992	10992	10992	10992	10992	10992	10992	10992	10992
bottled water costs		5902	6079	6262	6450	6643	6842	7048	7259	7477	7701	7932	8170	8415	8668	8928	9196	9471
total avoided groundwater and bottled water supply costs (annual, undiscounted)		16895	17072	17254	17442	17635	17835	18040	18251	18469	18693	18924	19162	19407	19660	19920	20188	20464
total avoided groundwater and bottled water supply costs (aggregated, discounted)	$367,644.78																	
Total Benefits (aggregate, discounted)	$530,485.31																	
NPV	-$32,976																	
Benefit:Cost Ratio	0.94																	

capital cost of pipe replacement	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Costs (annual, undiscounted)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
overnight hospital stay	915	915	915	915	915	915	915	915	915	915	915	915	915	915	915	915	915
medical consultation	5399	5582	5765	5948	6131	6314	6497	6680	6863	7046	7229	7412	7595	7778	7961	8144	8327
lost income	5612	5807	6002	6198	6393	6588	6783	6978	7174	7369	7564	7759	7954	8150	8345	8540	8735
total avoided water-related health costs (annual, undiscounted)	11926	12304	12682	13060	13438	13817	14195	14573	14951	15329	15708	16086	16464	16842	17220	17599	17977
groundwater pumping costs inclusive of carbon costs	10992	10992	10992	10992	10992	10992	10992	10992	10992	10992	10992	10992	10992	10992	10992	10992	10992
bottled water costs	9756	10048	10350	10660	10980	11309	11649	11998	12358	12729	13111	13504	13909	14326	14756	15199	15655
total avoided groundwater and bottled water supply costs (annual, undiscounted)	20748	21040	21342	21652	21972	22302	22641	22990	23350	23721	24103	24496	24901	25319	25748	26191	26647