Government of Niue

NIUE NATIONAL FRAMEWORK FOR IMPROVING WATER USE EFFICIENCY AND COST RECOVERY STRATEGY

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1 Executive Summary

Niue's water supply infrastructure is aging and requires extensive replacement of key components such as water pumps, reservoir tanks and main lines. Currently some villages are facing water supply shortages due to collapsed water bores. One of the longstanding challenges for Niue has been the lack of a clear picture about Niue's water demand and water supply on the Island. This is due to a lack of metering primarily at the household level. While data loggers have been installed on water pumps and tanks, there are no consistent data collection and data analysis procedures in place.

This report has attempted to clarify Niue's water supply and water demand figures based on data provided by Niue Water Supply. In addition the primary cost component of producing this water supply was determined using electricity data for water pumps provided by Niue Power Corporation. This data was analysed using a reproducible framework with statistical tools, and the results were uploaded onto an online dashboard for review. Finally, budget projections for Niue Water Supply were used to supplement the findings from the data.

1.1 Water Supply

Water pump volume data was received from Niue Water Supply for 15 bore and tank locations from May 2019 to April 2021. This data is summarized in Table 1, and in Figures 2 and 3. The total volume of water pumped over the entire available period was 549,126m^3 or approximately 549.1 million liters[1]. The total for 2020 which is the most complete year is 290,556m^3 (approx. 290.5 million liters), the total for 2019 which has missing data for the first quarter is 175,332m^3 (approx. 175.3 million liters), and for 2021 which has data for only the first quarter is 82,238m^3 (approx. 82.3 million liters). The top 5 pumps by volume over the entire period are Paliati Green Tank (13.07 percent), Tamakautoga (12.15 percent), Tapeu (12.15 percent), Liku (8.51 percent) and Avatele (8.39 percent).

Electricity consumption data for all 19 submersible and pressure water pumps was received from the Niue Power Corporation[2]. This is summarized in Table 2, Table 3 and in Figure 4, Figure 5, Figure 6 and Figure 7. The time period for this data was from 2016 to 2020, however data for 2017 was not available. The total water pump electricity usage over the available period is 1,014,608kWh (1,014 MWh). The average annual water pump electricity usage for Niue is approximately 253,187 kWh (253.2 mWh).

According to the Niue Power Annual Report for July to June 20121 Niue Power produces 341.25 MWh on average per month at a cost of $0.50 per kWh (Kulatea 2021). This means that on average the NPC produces approximately 4,095 MWh per year, and that water pumps consume approximately 6.2 percent of this total. The last row in Table 2 shows the estimated total cost of pumping water annually for Niue, which on average is $126,594 over the 2016 to 2020 time period. Table 3 outlines the annual billings using NPC's tiered tariff schedule for each water pump as well as the total for all water pumps. The average over all pumps over the 2016 to 2017 period is approximately $169,939, which means that the average billed yearly cost from NPC is $62,504 or 37 percent higher than the average estimated cost of pumping water calculated from kWh units used.

One consideration when examining efficiency standards on the supply side are water pumps. Niue uses two common models of submersible Grundfos pumps, SP8A-15 and SP8A-18 which are capable of handling flows up to 470 m3/h (Siohane and Chapman 2009). According to the Asset Management Plan 2015 (Holland and Zeelie 2016) these were installed between 1980 and 2009, and with estimated working lives of 8 years are overdue for replacement. Table 4 shows average pump efficiency figures which is calculated as Volume/kWh. The average efficiency figures ranged form about 0.98 - 1.26 m^3/kWh in Liku, Avatele and Vaiea to about 8.28 and

[1] 1m^3 = 1,000 liters

[2] Insert contact person received from and date

9.41 for m^3/kWh for Tamakautoga and Hakupu respectively. This is a considerable spread and warrants further exploration into the cost of replacement submersible pumps.

1.2 Water Demand

Determining water demand in Niue has proven very difficult in the past due to the lack of metering of end users, and this remains true today. Although a few households and end users were metered in 2019 to 2021, this data is not sufficient to clearly articulate total water demand estimates for Niue at the household or end user level. However, some insights into these individual water users can be drawn. From March 2019 to February 2021, 12 end users were metered. Three government properties were metered (Niue Foou Hospital, Niue Hospital and Scenic Matavai), 3 business properties (Fualahi NLB, Swanson Supermarket, and Homofiti Units), and 6 residential households in Tamakautoga. Table 5 shows the annual total water usage, Figure 8 shows the monthly trends, and Figure 9 shows the available quarter hourly data. The Niue Government properties had the highest water consumption. Of the 3, Scenic Matavai was the highest water user, followed by Niue High school and Niue Foou Hospital. Of the 3 business properties, Homofiti units had the highest consumption followed by Swanson and NLB. The highest annual consumption for the Tamakautoga Households was 585m^3. Quarter hourly data was logged for a few days in June and October 2019 and is shown in Figure 9 for Monday June 17 2019, which had data for all users except Scenic Matavai. The data for households appears normal as volume drops to zero intermittently. However, the volume for Niue High School and Niue Foou remained consistent over the majority of the 24 hour period implying that water was being used 24 hours a day.

Another way to gain insight into Niue's water demand is to calculate Niue's water demand as total water withdrawal per person, and compare this figure to previous estimates as well as other countries as benchmarks. Total water withdrawal per person is calculated by dividing total water supplied from the borehole for all uses, by the population who access and use that water supply. Given that Niue does not have significant industrial or agricultural uses for water, this figure should provide a close estimate for general water demand on the island. The estimated total water withdrawal per person per year for Niue is approximately 187.6 m^3 (187,577 liters) per person per year, or 514 liters per person per day.[3]

This estimate is significantly higher than the most recent estimate of 200 liters per person per day or 73 m^3 (73,000 liters) per person per year in 2011 (Buncle 2012), or the prior estimate of 350 liters per person per day or 127.75 m^3 (127,750 liters) per person per year in 2006 (SOPAC 2007). This clearly illustrates the problems arising from the lack of consistent data and reproducible methods employed in calculating water demand estimates. One reason the estimate calculated here could be higher is that we are calculating for total water withdrawal from the borehole, rather than total water use or demand at the household or end user level. Without significant water leakage in the reticulation system these two figures should be similar, however this is not the case with significant losses. It is unclear whether these past estimates took potential losses into account. Another reason could be that we have been provided with more data than that for previous estimates. Our estimate is calculated from a whole year worth of data in 2020, which could differ from estimates calculated from a few months worth of data. Finally, one possibility is that there is an error in the data or methods employed here. While this is always a possibility, we would like to note that the methodology utilized for this report is based on reproducible standards. Ultimately, without clear articulation of methodology and data used from any previous estimates it is difficult to fully ascertain the reason for these differences. When comparing to other countries, it is useful to note that the estimate for Niue calculated here is below the average for annual water withdrawal for Oceania which is estimated

[3] It is important to note that this number is potentially an underestimate, particularly if some water bores are not being metered or if the water pumped from the bores is not captured due to leakage from bore to meter

to be a little over 500 m^3 (500,000 liters) per person per year or 1,369 liters per person per year.

1.3 Water Use Efficiency Plan

Water use efficiency plans are usually focused on imposing measures to reduce water loss and water consumption. However, this requires robust measurement of both water supply and water consumption, which is an issue for Niue. Given this, the following recommendations place focus initially on the supply side as these will have the highest impact in the near term, with the demand side water use efficiency policies being introduced more aggressively in the longer term once a clearer picture of Niue's water supply and demand is known.

1.3.1 Supply Side

Recommendation 1. Installation of water meters at all boreholes, and major water mains diversion points.

Recommendation 1 is intended to improve the measurement of water supply throughout the main reticulation system in order to detect major water leaks is a timely manner. Currently there is not much information on how much water is pumped from the borehole into storage, and from storage to the water mains in each village. Although any major leaks can usually be observed, there may be minor leaks that go undetected for long periods of time.

Recommendation 2. Installation of water meters at all end user that connect to the water supply mains.

Recommendation 2 is intended to improve the measurement of water supply to each end user whether they are households, businesses or other entities. The benefits are 1) it will be easier to detect major leaks at the end user level and 2) it enables the option of imposing a water tariff structure.

Recommendation 3. Develop and implement a formal data collection system to read meter data on a monthly basis.

Recommendation 3 involves implementing a data collection system that is similar to the meter reading that is carried out for the electricity system. It is important that this is consistent and timely in order to derive the maximum benefits from the installation of the water meters.

Recommendation 4. Develop and implement a data analysis framework to enable timely and consistent information to be compiled from water and power meter data.

Recommendation 4 is intended to ensure that the data collected is turned into actionable information in a timely manner. Such a system need not be complicated, however it is preferable to minimize human intervention as much as possible.

Taken together Recommendations 1 - 4 will provide a much clearer picture of water supply and water demand for Niue. This will enable more timely response to water leaks, water demand and supply and enable improved policy responses.

Recommendation 5. Re-evaluate the cost of utilizing solar to power water pumps.

One issue with the current water pump set-up has been the fluctuations in the power supply which appear to have damaged the electronic feedback systems that manage village reservoir levels. Smaller stand-alone solar units would reduce the need to transfer power over the national grid compared to larger solar array farms, and also reduce the need to manage loads on the grid due to a variable nature of solar power.

Recommendation 6. Survey all households to determine rainwater harvesting utilization.

Although government initiatives in the past subsidized the purchase and installation of rainwater harvesting equipment, it is not clear to what degree these have been utilized on Niue. Not only can rainwater harvesting offset the demand for water supplied through the national water supply grid, it also provides an important backup source of water for households in case of water supply interruptions.

Recommendation 7. Re-evaluate the health and size of the water lens.

The last comprehensive study on the water lens was completed in 2005 (Mosely and Carpenter 2005) and since then some estimates have been based on rainfall data (SOPAC 2007). Taking into consideration climate change and the risk to Niue of extended droughts, commissioning a comprehensive review of Niue's water lens should be a priority in the near future.

Recommendation 8. Evaluate all current submersible pumps to determine if it is necessary to replace inefficient units.

Table 4 shows that there is a significant variation in the volume of water pumped per kWh of electricity consumed. If the inefficient units are old and have been earmarked for replacement, it may be pertinent for this process to be prioritized.

1.3.2 Demand Side

Recommendation 9. Adopt a water efficiency standard which is required to be met for all new installations.

Recommendation 10. Adopt a water efficiency standard which required to be met for all previously connected users.

Recommendations 9 and 10 refer to the adoption of a water efficiency standard which is a key component of any water efficiency plan. One general issue is that if there are costs associated with the implementation of these measures, these are generally passed onto the consumer. In addition, such a policy would usually take time to implement as it may require enforcement. In order to reliably evaluate the effect of these standards on the water demand in Niue, a robust water metering system needs to be in place prior to the introduction of water efficiency standards.

1.4 Cost Recovery Plan

The cost recovery plan depends on which recommendations are to be adopted in the Water use Efficiency Plan. Assuming that the meter installations are the only recommendations accepted, the baseline or business as usual (BAU) case will be continuation of the current situation where only some of the bores and tanks are metered. The treatment case will be installation of water meters.

For the 2020/2021 financial year, the total voted budget for the water supply division was $433,000 NZD[4]. Approximately $228,000 or 52 percent was allocated to personnel, and $147,000

[4] Niue Water Supply 2020/2021 Budget Proposal Summary

or 34 percent to Other, which includes the electricity charges which total $130,000 or 30 percent of the total budget.

The following cost recovery outline has 2 levels.

- Level 1 intends to recoup the cost of installation of water meters to all water bores and mains diversion points, as well as all water users connected to the national water supply grid.
- Level 2 intends to recoup the costs in Level 1, as well as the cost of provision of electricity

Recommendation 11. Introduce a one time fixed fee for connecting any end users to the water supply system.

Recommendation 12. Introduce a low fixed monthly fee for remaining connected to the water supply system.

Recommendation 11 is intended to provide a modest offset to water meter installation, while Recommendation 12 is intended to discourage end users from maintaining a connection to the water mains supply unnecessarily. This will reduce the opportunity for any leaks that develop to impact the water supply system. Taken together they can provide a way to offset the cost of water meters.

The cost for individual water bore meters has been estimated to be about $800, and for 18 boreholes on Niue (Holland and Zeelie 2016) this is expected to cost at a minimum $14,400. Adding another 18 water meters for water main diversion points brings the total to $28,800. As of 2016 there were 797 connections to Niue's water supply grid (Holland and Zeelie 2016), and with the cost for individual end user meters at about $400, the total cost to meter all users is estimated to cost $318,000 in total. In total to meter all bores and end user it will cost $347,600, which are summarised in Table 6.

If this cost is spread out over 7 years, it will cost approximately $5.20 per month per end user connection. This cost could be passed on to consumers as a fixed monthly rate for being connected to the water supply system. A $5 dollar fixed monthly fee will generate $3,985 per month or $47,820 a year. As outlined in Table 7, over a period of 10 years $5, $6 or $7 will be sufficient to cover the cost of all water meters.

Recommendation 13. Adopt a per unit tariff structure for the provision and use of water.

This recommendation is intended to generate enough revenues to offset the electricity cost of water supply, which is to essentially introduce a per unit charge for water supply equivalent to the per unit cost for power generation. As it currently stands it costs about $0.50 NZD to produce a kWh of electricity (Kulatea 2021).

1.4.1 Flat Rate Tariff

The first option is a flat rate for all users, providing a one-to-one cost recovery option which simple and straightforward to understand. Using the demand figures for 2020, the total water pumped from the water bores was 290,557m^3 (290 million liters) using 161,328 kWh of electricity for a total cost of $80,664. Table 8 shows the revenue for a fixed rate per unit of water used. At a rate of $0.25/m^3, $72,639 of revenue is expected, at $0.30/m^3 $87,167 of revenue is expected and at $0.35/m^3 a revenue of $101,694 is expected.

In order fully recover the water supply division budget allocation of $433,000 for 2020, the flat per unit tariff rate would have to be increased to at least $1.50 as outlined in Table 9.

1.4.2 Increasing Block Tariff

The second option is a tiered structure based on water usage, like the current tariff structure used for power. These types of tariff structures are usually intended to reduce usage, so users are charged higher brackets for higher levels of water use. The disadvantage for this type of structure is that setting the brackets and charge amounts can be complicated.

Following the IBT structure by Ambroz 2011 of allowing the first 14.6m^3 (14,600 liters) per person per year free of use as minimal water required for basic health and hygiene, this implies that 23,272m^3 (23.272 million liters) is not charged based on Niue's most recent population estimate of 1,594[5]. This leaves approximately 267,285m^3 (267.285 million liters) or approximately 92 percent of the total water supply to recover the cost of pumping water. Table 10 shows the revenue for an IBT tariff rate per unit of water used, with the first 14.6m^3 (14,600 liters) per person per year free. At a rate of \$0.30/m^3, \$80,185 of revenue is expected, at \$0.35/m^3 \$93,594 of revenue is expected and at \$0.40/m^3 a revenue of \$106,914 is expected.

In order fully recover the budget allocation for the year 2020 for the water supply division of \$433,000, the IBT tariff rate would have to be increased to at least \$1.60 as outlined in Table 11.

[5] Source: SPC Statistics for Development Division - sdd.spc.int/nu

2 Introduction

Development of Niue's water supply infrastructure goes back to the 1950's with the drilling of water bores pumped by wind mills, which replaced village rainwater water catchment systems installed in the 1940's as the main source of potable water.[6] In the 1960's piping was installed from the water bores to village water reservoirs, which was extended to taps for village households in the 1980's. In the early 1990's, new bores fitted with electrical centrifugal pumps were drilled for each village, with piping to new steel reservoir tanks installed. In the late 1990's there were extensive improvements carried out under the Pacific Technical Assistance Mechanism (PACTAM) and other AusAID funded projects. Extensions to the piping network have been added incrementally with new developments or replaced on a needs basis, however the majority of the original piping is still being used today.

Available records show that Niue's population peaked in the early 1970's at around 5,000 residents, which has since declined to it's current figure of around 1,600 residents today (GON Census 1997, 2011). The Asset Management Plan conducted in 2015 (Holland and Zeelie 2016) found that the current water supply infrastructure appears to have sufficient capacity to continue servicing the current population, however their findings were contingent on the immediate replacement of key components. The report also notes that the majority of Niue's water supply assets are past their useful working lives and recommended a plan to schedule replacement. The recommendation to replace Niue's ageing water infrastructure has been reiterated by other assessments over the years (SOPAC 2007, Siohane and Chapman 2009). The Niue government plans to increase the capacity to service tourism on the island which is expected to impact water demand.

According to the Asset Management Plan 2015 (Holland and Zeelie 2016), there are 18 water bores, 22 reservoir storage tanks, and 11 pressure booster pumps servicing the 13 villages on Niue. Alofi has 6 bores while all other villages have 1 each. There are 797 connections supplying 467 households, businesses and industrial or agricultural premises. These are all connected through an estimated 113 kilometers of pipes including mains and service lines. Altogether these assets are valued at approximately $2.4 million, about half of which are mains and around 30 percent are the water reservoirs. Figure 1 shows the location of water bores and water tanks on Niue.

Approximately 98 percent of households on Niue are connected to the water supply system, which is sourced from a groundwater lens (SPREP 2019). This in turn is recharged by rainfall on the island through the porous limestone atoll rock. Past assessments indicated that the total withdrawal from the water lens for water supply is less than 2 percent of the available capacity (SOPAC 2007, Mosely and Carpenter 2005).

Water quality tests conducted in the past found Niue's water safe to drink (Hasan and Hetutu 2010). However, key threats to the available quantity and quality of water drawn from the water lens include extreme water events such as droughts, and surface contaminants filtering down with rainfall (Siohane and Chapman 2009). To mitigate these concerns a Drinking Water Safety Plan was introduced in 2009 to provide a framework to help address some of the risks to Niue's drinking water supply (Siohane and Chapman 2009; Talagi 2011). In addition, rainwater catchment systems were provided to all households on Niue through the PACC project (Buncle 2012). The Niue State of Environment Report states that 60 percent of households have fully functional water tanks and identified the need to increase this number (SPREP 2019). However, the current level of of rainwater utilization for general everyday use is unclear.

At present there are several areas on the island that are facing low pressure as well intermittent service interruptions, and some villages are facing major service disruptions. Hikutavake village has been experiencing water disruptions and depends on water carted from Alofi and Tamakautoga using fire trucks. Similarly, Namukulu village currently depends entirely on carted

[6] Refer to Appendix A for images.

water since it's water bore collapsed and had to be decommissioned. One issue that has impacted Niue's water pump systems is the intermittent and variable nature of Niue's power supply. Submersible pumps in some villages depend on an automated feedback system in order to turn on or off, and these were reported to have been damaged by fluctuations in the power grid. This has led to some of the water pumps having to be manually turned on or off.

The most recent water demand estimate for Niue was 200 liters per person per day or 73 m^3 (73,000 liters)[7] per person per year in 2011 (Buncle 2012). This had declined from an estimated demand of 350 liters per person per day or 127.75 m^3 (127,750 liters) per person per year in 2006 (SOPAC 2007), after a comprehensive leak repair program through the PACTAM project. Mosely and Carpenter 2005 estimated water demand to be as much as 500 to 1000 liters per person per day or 182.5 m^3 - 365 m^3 (182,500 liters - 365,000 liters) per person per year. Overall, Niue does not have comprehensive water supply and demand figures due to the lack of consistent and reliable metering of Niue's water bores or households. Currently there are some houses in Alofi and Tamakautoga which have had meters installed but it is unclear whether there is a meter reading program in place.

All of Niue's water-bore and pressure pumps are currently run on the main electricity grid which is powered primarily by diesel fuels. In the past Niue had one water bore submersible pump in Makefu village powered by solar panels on a trial basis (SOPAC 2007). This pump had been decommissioned by 2009 after the solar PV system failed as there was lack of technical capacity for maintenance (Siohane and Chapman 2009). An assessment on supplying some or all of Niue's water pumps from solar power in 2011 found it cost prohibitive at that time relative to grid supplied power (Ambroz 2011). The total annual estimated costs of water pumping and reticulation amounted to $246,000 (2008/2009), of which $85,000 is the cost of electricity for pumping alone.

More recently the total expenditure of the Water Supply team in the 2014 to 2015 financial year was $426,811, while the financial year 2015/16 expenses were budgeted at $514,000 (Holland and Zeelie 2016). For the 2020/2021 financial year, the total voted budget for the water supply division was $433,000 NZD[8]. The Niue Infrastructure Plan 2016 outlined its intention to introduce cost recovery schemes. Proposals for a water cost recovery scheme had been introduced in previous national plans. However this proved to be a politically sensitive topic as there was anecdotal references to community resistance (Ambroz 2011). In addition, cost recovery schemes also required installation of water meters. In 2007, the total cost of installing water meters for all customers was estimated to be $53,268 at a cost of $92 per meter (Wide Bay Water Corporation 2007).

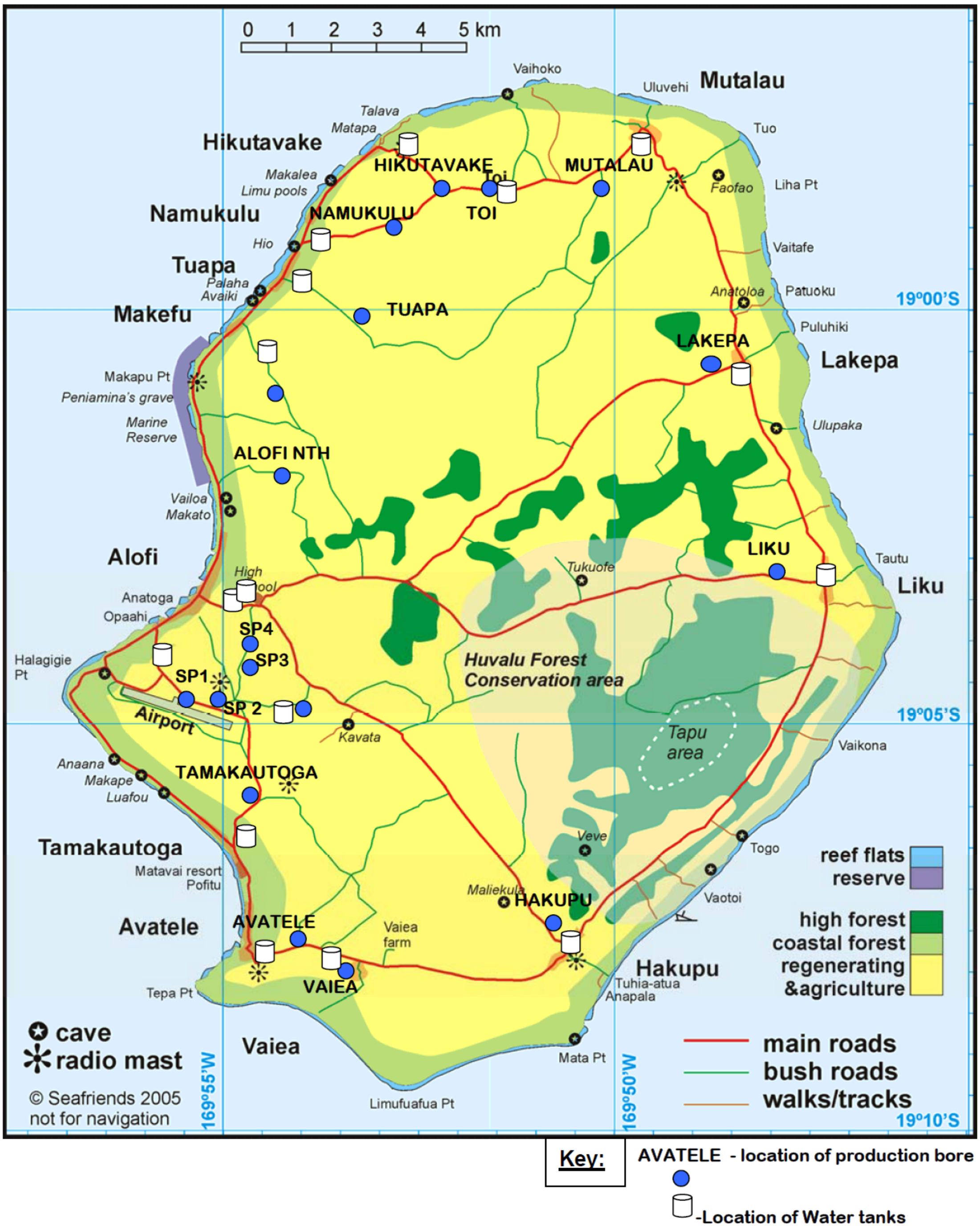
Ambroz 2011 estimated that a full cost recovery for annual provision of water to Niue using a flat per unit tariff would be achieved at $\$0.85/m^3$ ($0.85/1000 liters), with the average household paying $397 per year. Increasing this to $\$0.87/m^3$ ($0.87/1000 liters) would recover the cost of installation of all water meters after 10 years, at a cost of $404 per year for the average household. Ambroz 2011 also proposed an alternative option utilizing increasing block tariffs (IBTs), where the first $14.6m^3$ (14,600 liters) per person per year would be provided free of charge[9] and any additional use would be charged at $\$0.95/m^3$ ($0.95/1000 liters). This IBT was estimated to have been sufficient to provide full cost recovery annually.

[7] $1\ m^3 = 1{,}000$ liters

[8] Niue Water Supply 2020/2021 Budget Proposal Summary

[9] The rationale behind the first $14.6m^3$ (14,600 liters) being free is that it corresponds to a minimum of 40 liters per person per day for basic health and hygiene (Taylor, Gabbrielli, and Holmberg 2008)

Figure 1: Location of water bores and water tanks on Niue.



3 Methodology

The key components of the consultation are the Water Use Efficiency Plan and the Cost Recovery Policy. These two components are closely related and depend on the availability of reliable borehole volume data, borehole electricity use data, and household water use data. In turn these are all dependent on whether sufficient surveillance and metering equipment have been installed on the relevant mechanisms for each of the measures, and whether these measurements have been recorded on a consistent basis.

To assess Niue's need for a Water Use Efficiency Plan, available household water use data was examined to investigate if there were losses at the household level due to leakage, and whether residential use in Niue is in line with international standards. It was then determined whether water efficiency standards at the household level are appropriate as a policy recommendation, or intermediary recommendations such as the installation and maintenance of meters is more appropriate.

Examination of borehole volume data to estimate total water withdrawal and water supplied to the national water grid was also conducted. It was investigated whether there was a discrepancy with the household use data that would indicate losses in the water main supply lines. A list of recommendations and policy options were then provided based on the findings.

For the cost recovery policy, the cost of producing water was estimated by analyzing borehole electricity usage, or the primary cost of water production. Secondary costs such as labor and equipment maintenance were also included.

3.1 Data Collection and Consultations

Electricity consumption data was received from the Niue Power Corporation. The time period for this data was from 2016 to 2020, and included monthly usage and costs charged per pump. Data was not available for 2017. Water meter data was received from Niue Water Supply. The time period for this data was available from March 2019 to April 2021.

All of the data was cleaned and processed for analysis using the R statistical package (R Core Team 2021), following guidelines for reproducible results. Power data was extracted directly from the excel files provided, and data for each month was read only from the corresponding month tab. Water data was extracted directly from the provided data logger files. There were several discrepancies between the different formats from the water meter logger output. The CSV files had the most comprehensive data, however the .txt files had some data that was not captured in the CSV files and vice versa. In addition there were discrepancies between the logger monthly summary and the calculated monthly summary from daily data. Daily log data was used instead of monthly log data to reduce the impact of any errors from the log data. Volume for each day was calculated by subtracting the current day from previous day. This resulted in some extreme negative values presumably due to the logger being reset or changed out. These negative values were either replaced with zero or ignored depending on their magnitude.

The resulting cleaned and processed data was entered into the data visualization program Microsoft PowerBI to develop an interactive online dashboard available here. The graphs were downloaded for use in this report.

In person consultations were conducted between August to October 2021, and a community consultation was conducted on November 29, 2021.

4 Water Supply Costs

4.1 Water Supply

The cost of provision of water services can be classified into two general cost components.

1. Fixed Costs
2. Variable Costs

Fixed costs consist of any expenses paid that are independent of production or business activity. These are also known as sunk costs. A general rule of thumb is that costs are fixed if they are paid even when production is at zero. For the provision of water utility services, fixed costs are primarily capital investments for infrastructure such as water storage tanks, water mains systems, and pumps. The cost of fixed assets can be spread over the expected working life of the asset, also known as depreciation, to assess viability of investment. Other time frames can also be considered, for example the lifetime of a project. Although these costs can be significant up front for major infrastructure investments, these generally have long working lives and when depreciated over these long periods the costs can be considered moderate. We will consider fixed costs to be zero unless there are major capital upgrades that will be impacted by policy recommendations.

Variable costs consist of any expenses that vary with production or business activity. For the provision of water services, these are primarily related to the cost of pumping water. Maintenance expenses are also usually considered variable costs as maintenance requirements generally increase with production.

In order to provide context to the cost of producing water, we first outline the water supply volume data provided by Niue Water Supply, then examine power data provided by Niue Power Corporation.

4.1.1 Water Pump Volume

Water pump volume data was received from Niue Water Supply for 15 bore and tank locations from May 2019 to April 2021. This data is summarized in Table 1, and in Figures 2 and 3. Data for Makefu is not available since the bore and tank are not operating and water is instead pumped from Tuapa. Similarly data for Namukulu and Hikutavake were not provided as their bores are both decommissioned. The majority of the metered data is complete for 2020.

The total volume of water pumped over the entire available period was approximately 549,126 m^3 (or approximately 549.1 million liters[10]). The total volume of water pumped in 2020, which is the year with the most complete data, was approximately 290,557 m^3 (or approximately 290.5 million liters); for 2019, which has missing data for the first quarter, was approximately 175,332 m^3 (or approximately 175.3 million liters); and for 2021, which has data for only the first quarter, was approximately 82,328 m^3 (or approximately 82.3 million liters). The average volume of water pumped per month for 2020 was approximately 24,213 m^3 (or approximately 24.2 million liters), and is shown in the last row of Table 1. The water supply appeared to fall from May then increased again from July until the end of the year into January of the next year. This corresponds to the winter months in Niue and the generally accepted tourist season prior to the COVID19 pandemic.

Figure 2 shows a breakdown of the percentage of volume of water pumped by each pump and tank compared to the total volume of water pump over the available period. The top 5 pumps over the entire period are Paliati Green Tank (17.14 percent), Tamakautoga (14.27 percent), Tapeu (13.26 percent), Liku (9.29 percent) and Avatele (8.73 percent). Figure 3 shows the Monthly Volume by Pump, which shows several spikes in the data. Those spikes are likely

[10] $1m^3$ = 1,000 liters

caused by missed meter readings, which causes the next available reading to be an accumulation of the missing months. The readings for all the meters in the month of October 2020 aside from Tapeu were affected by missing data in the previous 4 months; and the readings for 2 meters in the month of August 2019 were missing readings from the previous month.

Table 1: Annual water supply volume (m^3) total for PWD pumps, 2019 - 2021.

METER	2019[11]	2020	2021
Avatele	18,533	26,971	0
Hakupu	19,609	22,879	,2975
Lakepa	10,768	14,204	3,640
Liku	18,450	25,906	5,514
Malekau	1,235	1,096	199
Mutalau	11,792	16,368	5,625
Paliati Green tank	14,488	65,586	12,997
Paliati Yellow tank	-	3,887	5,270
Tamakautoga	23,310	37,445	17,610
Tapeu	21,124	38,257	12,872
Toi	2,815	7,217	,1821
Tuapa	21,540	12,912	9,800
Vaiea	10,260	14,959	4,129
Vaipapahi	1,408	2,870	786
Total	**175,332**	**290,557**	**83,238**
Monthly Average	19,481	24,213	27,746
NOTE: 2019 data available from March - December. 2021 data available only from January - April.			

Figure 2: Summary of Niue Water Supply water pump total annual volume from May 2019 to April 2021. (See here for more)

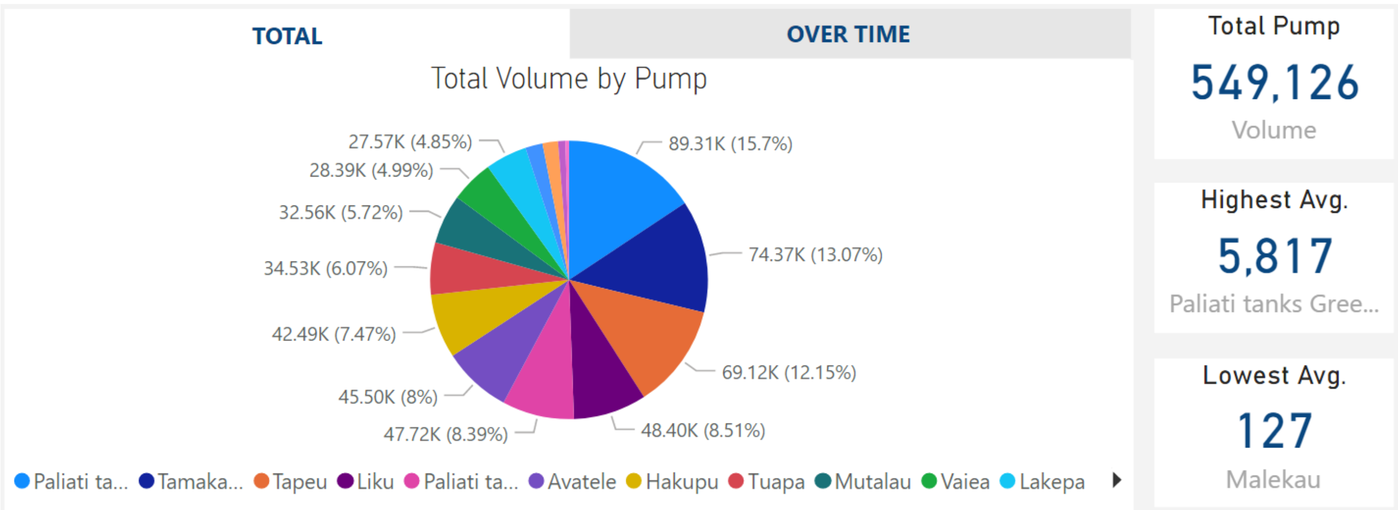
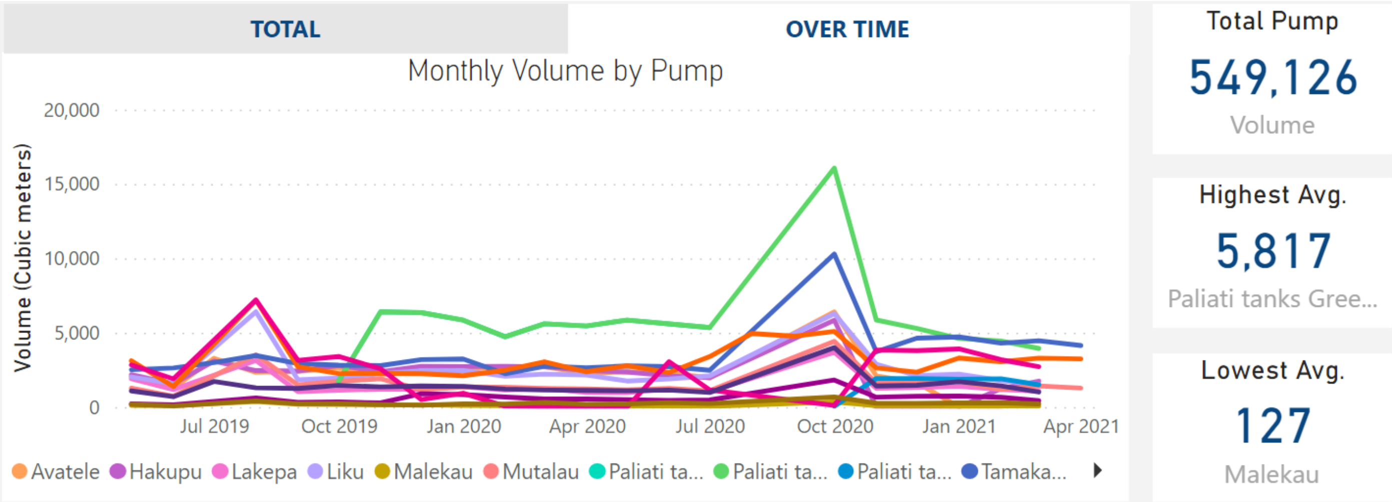


Figure 3: Summary of Niue Water Supply water pump monthly volume from May 2019 to April 2021. (See here for more)



4.1.2 Water Pump Electricity Usage

Electricity consumption data for all 19 submersible and pressure water pumps was received from Niue Power Corporation. This data is summarized in Table 2, Table 3 and in Figure 4, Figure 5, Figure 6 and Figure 7. The power data was subset for the account number 256.4621.000 to get the list of water pumps. The time period for this data was from 2016 to 2020, however data for 2017 was not available. The data was collected at monthly intervals corresponding to when the meters were read, and included detailed usage and billing amounts. The total water pump electricity usage over the available period was approximately 1,014,608 kWh (or approximately 1,014 MWh). The average annual water pump electricity usage over the available period for Niue was approximately 253,187 kWh (or approximatley 253.2 MWh).

Figure 4: Summary of Niue Power Corporation water pump electricity total use from 2016 to 2020. (See here for more)

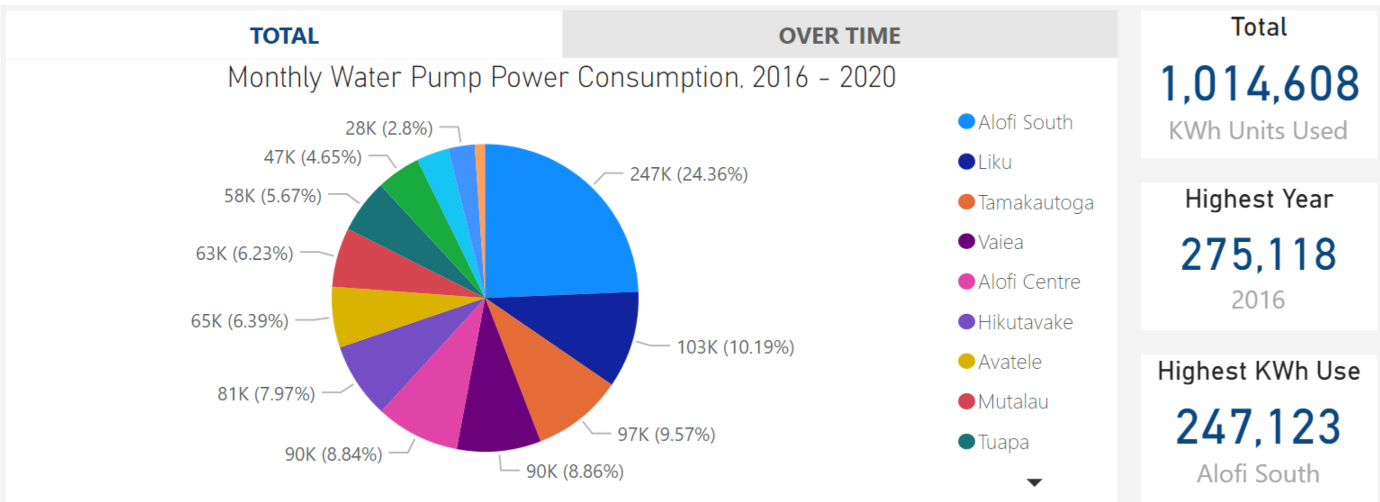


Figure 5: Summary of Niue Power Corporation water pump electricity usage over time. (See here for more)

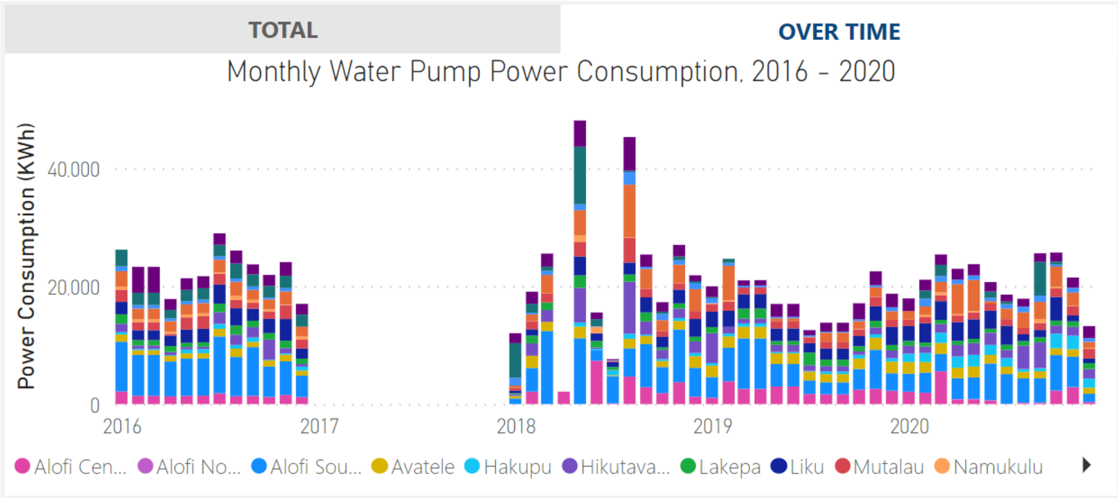


Figure 6: Summary of Niue Power Corporation water pump electricity billings. (See here for more)

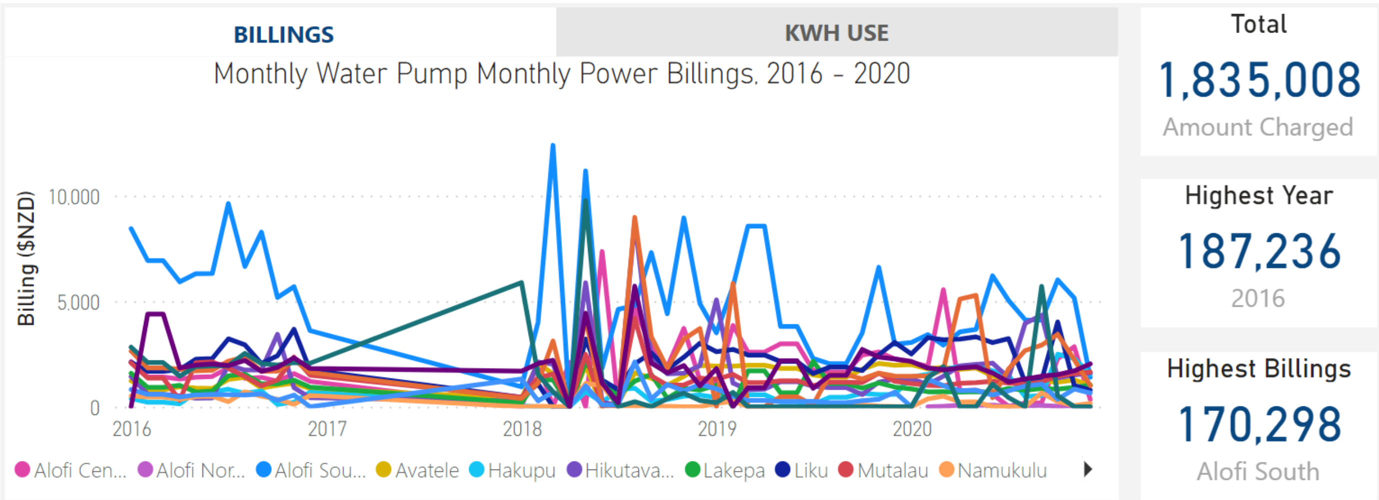
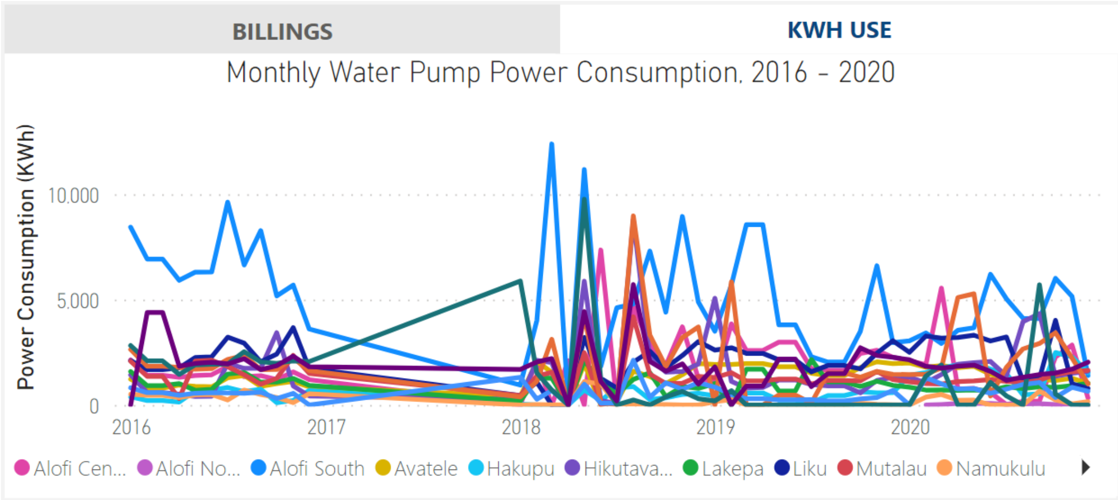


Figure 7: Summary of Niue Power Corporation water pump electricity consumption kWh. (See here for more)



According to the Niue Power Corporation (NPC) Annual Report for July to June 2021, Niue Power Corporation produces approximately 341.25 MWh on average per month at a cost of $0.50 per kWh (Kulatea 2021). This means that on average the NPC produces approximately 4,095 MWh per year, and that water pumps consume approximately 6.2 percent of this total.

While the billing data could be used to represent the cost of pumping water, this may not be completely representative of the actual financial cost of pumping water in Niue since the NPC has a tiered tariff structure charging a higher rate for higher consumption brackets. Nonetheless, this billings charged data shown in Figure 6 provides useful context and represents the cost of pumping water that is passed back to the Niue Government. A more accurate estimation of this cost figure would be to determine the financial cost of producing one unit of electricity, and multiplying this figure by the amount of power used by the water pumps.

The last row in Table 2 shows the estimated total cost of pumping water annually for Niue, which on average is approximately $126,594 over the 2016 to 2020 time period. Table 3 outlines the annual billings using NPC's tiered tariff schedule for each water pump as well as the total for all water pumps. The average over all pumps over the 2016 to 2020 period is approximately $169,939, which means that the average billed yearly cost from NPC is approximately $62,504 or 37 percent higher than the average estimated cost of pumping water calculated from kWh units used.

Table 2: PWD Submersible and pressure pump annual electricity usage (kWh) from 2016 - 2020.

Pump Description	**Location**	**Meter**	**2016**	**2018**	**2019**	**2020**
PWD Submersible pump No.6- Tusekolo	Alofi Centre	GAC. 039Y	17,664	26,057	28,407	17,532
Water Supply-Fou Bore Pump No.7	Alofi North	GAN.001Z	-	-	-	490
PWD-Tapeu P.Pump	Alofi South	GAS. 111	11,760	12,847	7,928	6,299
PWD Submersible pump No.1	Alofi South	GAS. 150	20,887	9,032	82	100
PWD Submersible pump No.2	Alofi South	GAS. 180	20,422	30,196	30,145	30,375
PWD Submersible pump No.3	Alofi South	GAS. 190	0	-	-	-
PWD Submersible pump No.4	Alofi South	GAS. 193	26,769	13,218	15,209	11,854
PWD-Submersible pump	Avatele	GAV. 110	12,085	13,540	21,514	17,734
Water Pump 2	Hikutavake	GHK. 042B	2,303	10,879	5,084	8,249
Water Pump	Hikutavake	GHK. 044	5,323	7,944	7,207	5,375
DAFF-Pressure pump	Namukulu	GHK. 047	3,260	6,419	3,569	10,353
Water Pump 3	Hikutavake	GHK. 047A	3,279	1,479	-	-
PWD-Submersible pump	Hakupu	GHP. 036Z	5,569	3,897	5,348	6,055
PWD-Pressure pump	Hakupu	GHP. 040A	0	408	0	13,067
PWD-Pressure pump	Liku	GLK. 024A	20,832	11,033	5,554	12,457
PWD-Submersible pump	Liku	GLK. 089	6,957	7,507	21,506	-
PWD-Pressure pump	Lakepa	GLP. 034A	4,501	4,641	5,595	3,796
PWD-Submersible pump	Lakepa	GLP. 077	8,753	6,626	7,441	5,860
PWD-Submersible Pump	Mutalau	GMT. 001A	14,553	12,170	12,199	11,732
PWD-Pressure pump	Mutalau	GMT. 016	4,114	2,917	2,659	2,872
Namukulu-Submersible pump	Namukulu	GNM. 001Z	5,231	2,295	539	2,464
Tamakautoga Submersible pump	Tamakautoga	GTM. 175	23,260	30,026	14,294	29,500
PWD-Pressure pump	Toi	GTO. 017A	6,194	8,801	4,415	9,036
PWD-Submersible pump	Tuapa	GTP. 026Z	24,953	20,655	-	11,020
PWD-Submersible pump	Vaiea	GVA. 001B	26,449	23,999	19,163	20,258
TOTAL KWh Units			**275,118**	**266,586**	**217,858**	**161,328**
Total Cost at 0.50 per Unit			$137,559	$133,293	$108,929	$80,664
Total Cost at 0.60 per Unit			$165,070	$159,951	$130,714	$96,797
Total Cost at 0.70 per Unit			$192,582	$186,610	$152,500	$112,929
NOTE: PWD Submersible pump No.5 in Kaimiti is not included as it has been inactive for a long time						

Table 3: PWD Submersible and pressure pump annual electricity billing ($NZD) from 2016 - 2020.

Pump Description	Location	Meter	2016	2018	2019	2020
PWD Submersible pump No.6- Tusekolo	Alofi Centre	GAC. 039Y	12,065	18,078	19,585	12,032
Water Supply-Fou Bore Pump No. 7	Alofi North	GAN.001Z	-	-	-	410
PWD-Tapeu P.Pump	Alofi South	GAS. 111	7,932	8,770	5,290	4,169
PWD Submersible pump No.1	Alofi South	GAS. 150	14,321	6,416	221	230
PWD Submersible pump No.2	Alofi South	GAS. 180	13,995	20,943	20,802	20,972
PWD Submersible pump No.3	Alofi South	GAS. 190	180	-	-	-
PWD Submersible pump No.4	Alofi South	GAS. 193	18,450	9,046	10,503	8,058
PWD-Submersible pump	Avatele	GAV. 110	8,160	9,270	14,760	12,114
Water Pump 2	Hikutavake	GHK. 042B	1,572	7,472	3,283	5,524
Water Pump	Hikutavake	GHK. 044	3,430	5,383	4,785	3,491
DAFF-Pressure pump	Namukulu	GHK. 047	2,213	4,362	2,482	7,037
Water Pump 3	Hikutavake	GHK. 047A	2,370	1,099	-	-
PWD-Submersible pump	Hakupu	GHP. 036Z	3,658	2,603	3,476	3,938
PWD-Pressure pump	Hakupu	GHP. 040A	180	400	180	8,900
PWD-Pressure pump	Liku	GLK. 024A	14,282	7,557	3,764	8,420
PWD-Submersible pump	Liku	GLK. 089	4,570	5,107	14,754	-
PWD-Pressure pump	Lakepa	GLP. 034A	2,866	3,062	3,664	2,392
PWD-Submersible pump	Lakepa	GLP. 077	5,827	4,439	5,024	3,802
PWD-Submersible Pump	Mutalau	GMT. 001A	9,927	8,323	8,239	7,912
PWD-Pressure pump	Mutalau	GMT. 016	2,631	1,938	1,659	1,795
Namukulu-Submersible pump	Namukulu	GNM. 001Z	3,387	1,670	471	1,646
Tamakautoga Submersible pump	Tamakautoga	GTM. 175	15,982	20,812	9,848	20,350
PWD-Pressure pump	Toi	GTO. 017A	4,076	5,948	2,829	6,065
PWD-Submersible pump	Tuapa	GTP. 026Z	17,167	14,284	-	7,652
PWD-Submersible pump	Vaiea	GVA. 001B	17,994	16,385	13,035	13,592
Total Annual Billing			**187,235**	**183,367**	**148,654**	**160,501**
NOTE: PWD Submersible pump No.5 in Kaimiti is not included as it has been inactive for a long time						

Water Pump Efficiency
One consideration when examining efficiency standards on the supply side are water pumps. Niue uses two models of submersible Grundfos pumps, SP8A-15 and SP8A-18, which are capable of handling flows up to 470 m^3/h (Siohane and Chapman 2009). According to the Asset Management Plan 2015 (Holland and Zeelie 2016), these were installed between 1980 and 2009, and with estimated working lives of 8 years are overdue for replacement.

Although there are a number of different factors affecting efficiency, including appropriate sizing and age, we can use a simple calculation of water volume divided by electricity units to get an approximate idea of the figures for Niue.

$$Water\ Pump\ Efficiency\ = \frac{Water\ volume\ supplied}{Power\ consumed}$$

While the data is limited to two months for 8 of the water pumps, some insights can still be drawn from these numbers. Table 4 shows average pump efficiency figures which is calculated as Volume/kWh.

The average efficiency figures ranged form about 0.98 - 1.26 m^3/kWh in Liku, Avatele and Vaiea to about 8.28 and 9.41 for m^3/kWh for Tamakautoga and Hakupu, respectively. This is a considerable spread and warrants further exploration into comparison of the cost of a replacement submersible pump and the cost of retaining the use of the current low efficiency pumps. We note that Tuapa did not have power usage data available, and the power usage number for Lakepa appears to be very low, which may be an error.

Table 4: PWD Submersible pump average efficiency, m^3/KWh for select months in 2019.

Village	**Meter**	**Water Volume**	**Units Used**	**m^3 per KWh**
Avatele	GAV. 110	2,056.54	1,818	1.26
Hakupu	GHP. 036Z	2,178.52	235	9.41
Liku	GLK. 089	2,020.75	1,841	0.98
Lakepa	GLP. 077	1,900.83	12	124.34
Tamakautoga	GTM. 175	2,513.39	473	8.28
Tuapa	GTP. 026Z	2,836.79	0	-
Vaiea	GVA. 001B	1,087.61	1,106	1.26

4.2 Water Demand

Determining water demand in Niue has proven very difficult in the past due to the lack of metering of end users, and this remains true today. Although a few households and end users were metered from 2019 to 2021, this data is not sufficient to clearly articulate total water demand estimates for Niue at the household or end user level. However, some insights into these individual water users can be drawn.

From March 2019 to February 2021, 12 end users, 3 government properties (Niue Foou Hospital, Niue Hospital and Scenic Matavai), 3 business properties (Fualahi NLB, Swanson Supermarket, and Homofiti Units), and 6 residential households in Tamakautoga were metered. Table 5 shows the annual total water usage, Figure 8 shows the monthly trends, and Figure 9 shows the available quarter hourly data. Only Niue High School, Niue Foou Hospital and Scenic Matavai were metered over the entire period, however all users were metered to some extent in 2019. There are spikes present in the data which reflect the accumulation of missed meter reading months, which is especially evident in the last quarter of 2020.

The Niue Government properties had the highest water consumption. Of the three government properties, Scenic Matavai was the highest water user, followed by Niue High School and Niue Foou Hospital. Of the three business properties, Homofiti units had the highest consumption followed by Swanson and NLB. The highest annual consumption for the Tamakautoga Households was approximately 585 m^3.

Quarter hourly data was logged for a few days in June and October 2019, as shown in Figure 9 for Monday June 17 2019, which had data for all users except Scenic Matavai. The data for households appears normal as volume dropped to zero intermittently. However, the volume for Niue High School and Niue Foou Hospital remained consistent over the majority of the 24 hour period implying that water was being used 24 hours a day.

Total Water Withdrawal per Person

Another way to gain insight into Niue's water demand is to calculate Niue's water demand as total water withdrawal per person, and compare this figure to previous estimates and other countries as benchmarks.

Total water withdrawal per person was calculated by dividing the total water supplied from each borehole and water tank for all uses, by the population who accessed and used that water supply. Given that Niue does not have significant industrial or agricultural uses for water, this figure should provide a close estimate for general water demand on the island. In addition, due to the lack of extensive metering at the household level, this would likely have been the same method to estimate water demand employed in the past.

$$Total\ water\ withdrawal\ per\ Person = \frac{Total\ water\ supplied}{Population}$$

Taking the total annual volume of water for 2020, which was approximately 290,557 m^3 (outlined in Section 4.1.1), as the total water supplied and the most recent population figure of 1,549[12], the calculations for Niue are as follows:

$$Total\ water\ withdrawal\ per\ Person\ per\ Year = \frac{290,557}{1,549} = 187.6\,m^3$$

The estimated total water withdrawal per person per year for Niue was approximately 187.6 m^3 (or approximately 187,577 liters), or 514 liters per person per day.[13]

Our estimate here is approximately 157 percent higher than the most recent past estimate of 200 liters per person per day or 73 m^3 (73,000 liters) per person per year in 2011 (Buncle 2012),

[12] Source: SPC Statistics for Development Division - sdd.spc.int/nu

[13] It is important to note that this number is potentially an underestimate, particularly if some water bores are not being metered or if the water pumped from the bores is not captured due to leakage from bore to meter

or approximately 47 percent higher than the previous estimate of 350 liters per person per day or 127.75 m^3 (127,750 liters) per person per year in 2006 (SOPAC 2007). This clearly illustrates the problems arising from the lack of consistent data and reproducible methods employed in calculating water demand estimates.

One reason the estimate calculated here could be higher is that we are calculating for total water withdrawal from the borehole or tank, rather than total water use or demand at the household or end user level. Without significant water leakage in the reticulation system these two figures should be similar, however this is not the case with significant losses. It is unclear whether these past estimates took potential losses into account. Another reason could be that we have been provided with more data than that for previous estimates. Our estimate is calculated from a whole year worth of data in 2020, which could differ from estimates calculated from a few months worth of data.

Finally, another possibility is that there may be an error in the data or methods employed here. While this is always a possibility, we would like to note that the methodology utilized for this report is based on reproducible standards. This means that the data and the computer code written for the statistical package R used to clean and process the data, can be reviewed and vetted over time. A significant amount of time was dedicated to extracting and cleaning the water data from the data logger files, which would have been much more difficult and susceptible to human error without the use of statistical software. In addition, this data has been uploaded to a data dashboard and is available for review by the public.

Ultimately, without clear articulation of methodology and data used from any previous estimates it is difficult to fully ascertain the reason for these differences.

When comparing to other countries, it is useful to note that the estimate for Niue calculated here is below the average annual water withdrawal for Oceania which is estimated to be a little over 500 m^3 (500,000 liters) per person per year or 1,369 liters per person per year. (FAO 2020).[14] Given that Niue does not have large agricultural or industrial uses for water, this appears to be a reasonable comparison.

Table 5: Annual water volume (m^3) total for end users, 2019 - 2020.

METER	**2019**	**2020**	**2021**
Fualahi Area NLB	54		-
Fualahi Area Swansons Supermarket	126	-	-
Homofiti Units	1,022	467	-
Niue Foou Hospital	1,559	1,699	425
Niue High School	2,851	5,882	722
Scenic Matavai	3,272	10,228	3,049
Tamakautoga households Christopher Lagiono	23	29	-
Tamakautoga households Etu Ikihele	423	101	-
Tamakautoga households Eu Funaki	158	27	-
Tamakautoga households Kela Vilisoni	585	56	-
Tamakautoga households Lapo Ikihele	271	51	-
Tamakautoga households Vakaheketaha	78	29	-

[14] See also ourworldindata.org/water-use-stress

Figure 8: Summary of daily water volume (m^3) users that were metered in 2019. (See here for more)

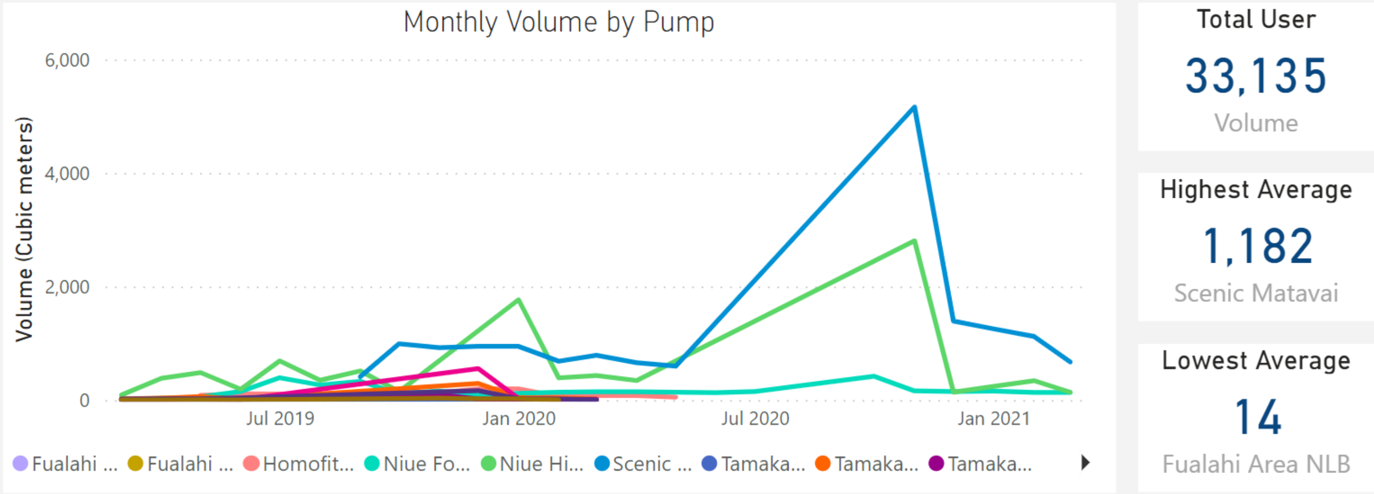
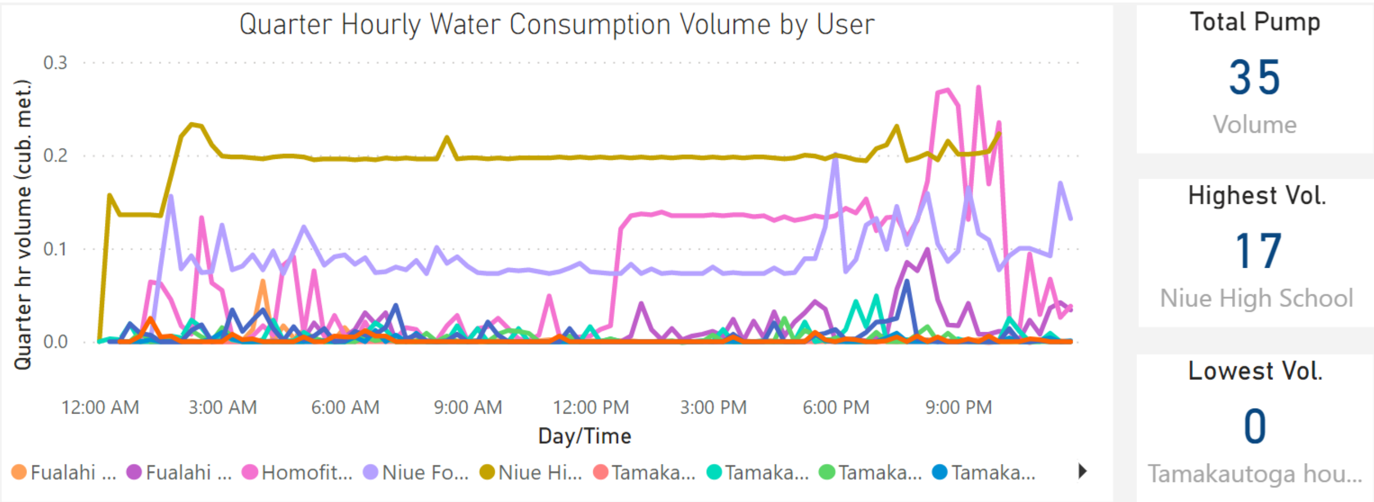


Figure 9: Summary of quarter hourly user water volume (m^3) for June 17 2019. (See here for more)



5 Water Use Efficiency Plan

Water use efficiency plans are usually focused on imposing measures to reduce water loss and water consumption. However, this requires robust measurement of both water supply and water consumption, which is currently an issue for Niue. Given this, the following recommendations place focus on the supply side as these will have the highest impact in the near term, with the demand side water use efficiency policies being introduced more aggressively in the long term once a clearer picture of Niue's water supply and demand is known.

5.1 Supply Side

Recommendation 1. Installation of water meters at all boreholes, and major water main diversion points.

Recommendation 1 is intended to improve the measurement of water supply throughout the main reticulation system in order to detect major water leaks is critical. Currently there is not much information on how much water is pumped from the borehole into storage, and from storage to the water mains in each village. Although any major leaks can usually be observed, there may be minor leaks that go undetected for long periods of time. These leaks could introduce bacteria, viruses or pathogens into the water supply [provide citation], but they also could be causing the loss of a significant amount of water. Given the very high gross water demand calculated for Niue, this is a high priority.

The cost for individual water bore meters has been estimated to be about $800 (Holland and Zeelie 2016). For 18 boreholes on Niue this is expected to cost at a minimum $14,400. Adding another 18 water meters for water main diversion points brings the total to $28,800. This cost for 32 borehole meters is about 22 percent of the cost of pumping water in Niue which is estimated to be on average $126,594 over the 2016 to 2020 time period. If there are significant leaks detected from the installation of these meters, the costs for these borehole pumps could be offset by savings in water pumping costs within a few years.

Finally, given Niue's plan to replace it's entire water supply system, understanding where to prioritize the order of replacements based on water demand and leakage could be beneficial, since a major infrastructure upgrade could take a significant amount of time to fully execute.

Recommendation 2. Installation of water meters at all end users that connect to the water supply mains.

Recommendation 2 is intended to improve the measurement of water supply to each end user whether they are households, businesses or other entities. The benefits are 1) it will be easier to detect major leaks at the end user level and 2) it enables the option of imposing a water tariff structure. The cost for individual meters has been estimated to be about $400 (Holland and Zeelie 2016). For 467 households on Niue this is estimated to cost $186,800 in total. If this cost is spread out over 6 years, it will cost roughly $5.50 per month. This cost could be passed on to the consumers in the form of a flat monthly rate for being connected to the water supply system.

One option for meters is the use of a pre-paid system such as those currently used for power. Given that these units would likely cost more and possibly require a constant power source, these may be less cost effective. In addition, if the prepaid meter was to run out unexpectedly, the consequences of a water shut-off could be higher for homeowners and businesses relative to a power cutoff.

Recommendation 3. Develop and implement a formal data collection system to read meter data on a monthly basis.

Recommendation 3 involves implementing a data collection system that is similar to the meter reading that is carried out for the electricity system. It is important that this is consistent and timely in order to derive the maximum benefits from the installation of the water meters. One immediate option is to have the electricity and water meter reading conducted together, and should be part of a wider organizational plan to ensure viability in the long term.

Recommendation 4. Develop and implement a data analysis framework to enable timely and consistent information to be compiled from water and power meter data.

Recommendation 4 is intended to ensure that the data collected is converted into actionable information in a timely manner. Such a system need not be complicated, however it is preferable to minimize human intervention as much as possible. However, the costs and maintenance of such a fully automated system would likely be high and unsustainable in the long term unless comprehensive measures are taken. In reality, a system in the middle ground is likely to be the best option. For example, a tablet or phone could be used to take a photo of the meter, and would only require the phone or tablet first to be verified, and all the necessary data is extracted automatically. In this case the photo will be kept for verification checks.

Taken together, Recommendation 1, Recommendation 2, Recommendation 3 and Recommendation 4 will provide a much clearer picture of water supply and water demand for Niue. This will enable more timely responses to water leaks, water demand and supply and enable improved policy responses.

Recommendation 5. Re-evaluate the cost of utilizing solar to power water pumps.

One reported issue with the current water pump set-up has been the fluctuations in the power supply which appear to have damaged the electronic feedback systems that manage village reservoir levels. This has caused some villages to resort to manually switching the water pumps on and off. This approach appears to be unreliable and there have been reports of water reservoirs overflowing in some instances, and not filling up to sufficient levels in others.

Since the last evaluation in 2011 (Ambroz 2011) the cost of solar power components has fallen significantly, while the level of technology particularly in regard to battery storage has improved. Stand alone units with battery banks to store power could be a viable solution, especially if the power demands are not significant as in the case of smaller pumps. These units are able to supply power consistently which is crucial for sensitive electronic pressure monitoring systems, and if sized correctly for the demand of the pumps could be a cost effective solution in the long run.

Smaller stand-alone solar units would reduce the need to transfer power over the national grid compared to larger solar array farms, and also reduce the need to manage loads on the grid due to the variable nature of solar power. In the case of power failures on the main grid, these would not be affected. Finally the connection to the power grid could be maintained as a means of back-up in case there are adverse weather events with insufficient sunlight to provide enough power. However, safeguards need to be put in place to prevent damage from power surges.

Recommendation 6. Survey all households to determine rainwater harvesting utilization.

Although government initiatives in the past subsidized the purchase and installation of rainwater harvesting equipment, it does not appear clear to what degree these have been utilized on Niue. Not only can rainwater harvesting offset the demand for water supplied through the national water supply grid, it also provides an important backup source of water for households in case of water supply interruptions. Clarifying the state of rainwater harvesting utilization on Niue will provide information to evaluate whether it can be a viable option in the future to significantly reduce dependence on Niue's water grid. The survey can be conducted at the same time when the Health Village inspections (Kitekite Kaina) are carried out.

Recommendation 7. Re-evaluate the health and size of the water lens.

The last comprehensive study on the water lens was completed in 2005 (Mosely and Carpenter 2005) and since then some estimates have been based on rainfall data (SOPAC 2007). Taking into consideration climate change and the risk to Niue of extended droughts, commissioning a comprehensive review of Niue's water lens should be a priority in the near future. There has been some interest in commercializing Niue's water through a bottled water franchise. If this is to be become a serious consideration, then this recommendation is especially important to make sure that this will not compromise Niue's water lens capacity to supply its current and future residents.

Recommendation 8. Evaluate all current submersible and pressure pumps to determine if it is necessary to replace inefficient units.

Table 4 showed that there is a significant variation in the volume of water pumped per kWh of electricity consumed. If the inefficient units are old and have been earmarked for replacement, it may be pertinent for this process to be prioritized.

5.2 Demand Side

Recommendation 9. Adopt a water efficiency standard which is required to be met for all new installations.

Recommendation 10. Adopt a water efficiency standard which required to be met for all previously connected users.

The adoption of a water efficiency standard is a key component of any water efficiency plan. One general issue is that if there are costs associated with the implementation of these measures, these are usually passed onto the consumer. Given that these standards usually require the replacement of faucets and other fittings to lower flow or more efficient equipment, this is a likely outcome. In addition, such a policy would usually take time to implement as it may require enforcement. This would mean that plumbers, hardware supplies and anyone else involved in construction and installation need to be informed and trained. In terms of impact in the near term, given the leakage reduction projects in the past, any decrease in water demand may not have a significant impact unless water leakage from the main reticulation system are reduced to a minimum.

In order to reliably evaluate the effect of these standards on the water demand in Niue, a robust water metering system needs to be in place prior to the introduction of water efficiency standards.

6 Cost Recovery Plan

The cost recovery plan depends on which recommendations are to be adopted in the Water Use Efficiency Plan in Section 5.

Assuming that the meter installations are the only recommendations accepted, the baseline or business as usual (BAU) case will be continuation of the current situation where only some of the bores and tanks are metered. The treatment case will be installation of water meters.

For the 2020/2021 financial year, the total voted budget for the water supply division was $433,000 NZD[15]. Approximately $228,000 or 52 percent was allocated to personnel, and $147,000 or 34 percent to Other, which includes the electricity charges which total $130,000 or 30 percent of the total budget. This is in line with the estimated cost for power used by water pumps outlined in Table 2. The following cost recovery outline has 2 levels.

- Level 1 intends to recoup the cost of installation of water meters to all water bores and water main diversion points, as well as all water users connected to the national water supply grid.
- Level 2 intends to recoup the costs in Level 1, as well as the cost of provision of electricity

Level 1 pertains directly to the recommendations outlined in the Water Use Efficiency Plan outlined in Section 5, while Level 2 takes steps towards recovering the primary variable cost of water supply provision.

Recommendation 11. Introduce a one time fixed fee for connecting any end users to the water supply system.

Recommendation 12. Introduce a low fixed monthly fee for remaining users currently connected to the water supply system.

Recommendation 11 and Recommendation 12 are both intended to offset the cost of meter installation and maintenance. Recommendation 11 is intended to provide a modest offset to water meter installation, while Recommendation 12 is intended to discourage end users from maintaining a connection to the water mains supply unnecessarily. This will reduce the opportunity for any leaks that develop to impact the water supply system. Taken together they can provide a way to offset the cost of water meters.

As mentioned in Recommendation 2, the cost for individual water bore and water main diversion point meters has been estimated to be about $800, and for 18 boreholes on Niue (Holland and Zeelie 2016) this is expected to cost at a minimum $14,400. Adding another 18 water meters for water main diversion points brings the total to $28,800. As of 2016 there were 797 connections to Niue's water supply grid, with 467 being occppied houses and 330 businesses and industrial and agricultural premises (Holland and Zeelie 2016). The cost for individual end user meters has been estimated to be about $400, and for 797 connections on Niue this is estimated to cost $318,000 in total. In total to meter all bores and end user it will cost $347,600. These costs are summarised in Table 6 .

If this cost is spread out over 7 years, it will cost approximately $5.20 per month per end user connection. This cost could be passed on to the consumers as the fixed monthly rate for being connected to the water supply system. As outlined in Table 7, a $5 dollar fixed monthly fee will generate $3,985 per month or $47,820 a year. A $6 dollar fixed monthly fee will generate $4,782 per month or $57,384 a year. A $7 dollar fixed monthly fee will generate $5,579 per month or $66,948 a year. Over a period of 10 years, any of these amounts will be sufficient to cover the cost of all water meters.

[15] Niue Water Supply 2020/2021 Budget Proposal Summary

Table 6: Estimated water meter installation cost.

	Number	Meter Cost ($)	Total ($)
End User Connections	797	400	318,800
Bores and Diversion points	36	800	28,800
Total			347,600

Table 7: Estimated schedule of returns for a monthly fixed fee.

Fixed Fee ($)	Monthly ($)	Yearly ($)	3 years ($)	5 years ($)	7 years ($)	10 years ($)
5	3,985	47,820	143,460	239,100	334,740	478,200
6	4,782	57,384	172,152	286,920	401,688	573,840
7	5,579	66,948	200,844	334,740	468,636	669,480

Recommendation 13. Adopt a per unit tariff structure for the provision and use of water.

This recommendation is intended to generate enough revenues to offset the electricity cost of water supply, which is to essentially introduce a per unit charge for water supply equivalent to the per unit cost for power generation. As it currently stands it costs about $0.50 NZD to produce a kWh of electricity (Kulatea 2021).

The first option is a flat rate for all users. The advantage of this option is that it is a one-to-one cost recovery option which is simple and straightforward to understand and could help in receiving acceptance. Using the demand figures for 2020, the total water pumped from the water bores was 290,557 m^3 (290 million liters) using 161,328 kWh of electricity for a total cost of $80,664. Table 8 shows the revenue for a fixed rate per unit of water used. At a rate of $0.25/$m^3$ $72,639 of revenue is expected; at $0.30/$m^3$ $87,167 of revenue is expected; and at $0.35/$m^3$ a revenue of $101,694 is expected. The break even point is at approximately $0.28/$m^3$.

Table 8: Estimated flat rate per m^3 (1000 liters) water tariff revenues at $0.25/$m^3$, $0.30/$m^3$ and $0.35/$m^3$.

Annual Volume m^3	Revenue at $0.25 ($)	Revenue at $0.30 ($)	Revenue at $0.35 ($)
290,557	72,639.25	87,167.1	101,694.95

In order fully recover the budget allocation for the year 2020 for the water supply division of $433,000 the flat per unit tariff rate would have to be increased to at least $1.50 as outlined in Table 9.

Table 9: Estimated flat rate per m^3 (1000 liters) water tariff revenues at $0.45/$m^3$, $0.50/$m^3$ and $0.60/$m^3$.

Annual Volume m^3	Revenue at $0.45 ($)	Revenue at $0.50 ($)	Revenue at $0.60 ($)
290,557	421,307.65	43,5835.5	464,891.2

The second option is a tiered structure based on water usage, like the current tariff structure used for power. These types of tariff structures are usually intended to reduce usage, so users are charged higher brackets for higher levels of water use. The disadvantage for this type of structure is that setting the brackets and charge amounts can be complicated.

Following the IBT structure by Ambroz 2011 of allowing the first 14.6 m^3 (14,600 liters) per person per year free of use as minimal water required for basic health and hygiene, this implies that 23,272 m^3 (23.272 million liters) would not be charged based on Niue's most recent population estimate of 1,594[16]. This leaves approximately 267,285 m^3 (267.285 million liters) or approximately 92 percent of the total water supply to recover the cost of pumping water.

Table 10 shows the revenue for an IBT tariff rate per unit of water used, with the first 14.6 m^3 (14,600 liters) per person per year free. At a rate of \$0.30/m^3 \$80,185 of revenue is expected, at \$0.35/m^3 \$93,594 of revenue is expected and at \$0.40/m^3 a revenue of \$106,914 is expected. The break even point for recovering water pumping costs alone is at approximately \$0.30/m^3.

Table 10: Estimated revenues for ITB rate per m^3 (1000 liters) water volume, with the first 14.6m^3 (14,600 liters) per person per year free, at \$0.30/m^3, \$0.35/m^3, and \$0.40/m^3.

Annual Vol. m^3	**ITB Vol. m^3**	**Revenue at \$0.30 (\$)**	**Revenue at \$0.35 (\$)**	**Revenue at \$0.40 (\$)**
290,557	267,284.6	80,185.38	93,549.61	106,913.84

In order fully recover the budget allocation for the year 2020 for the water supply division of \$433,000 the IBT tariff rate would have to be increased to at least \$1.60 as outlined in Table 11.

Table 11: Estimated revenues for ITB rate per m^3 (1000 liters) water volume, with the first 14.6m^3 (14,600 liters) per person per year free, at \$1.50/m^3, \$1.60/m^3, and \$1.70/m^3.

Annual Vol. m^3	**ITB Vol. m^3**	**Revenue at \$1.50 (\$)**	**Revenue at \$1.60 (\$)**	**Revenue at \$1.70 (\$)**
23,272.4	26,7284.6	400,926.9	427,655.36	454,383.82

A third option is categorizing users based on the primary usage of the water, and charging different prices accordingly. For example, connections which the primary use is for businesses such as tourist accommodations could be charged a higher rate relative to households. The same could be applied to high water use installations such as pools or spas. The disadvantage for this option is again complexity involved in setting categories and charge amounts. This would require wider and more in depth consultations with all stakeholders involved. For this reason we do not provide schedule options or revenue calculations for this option.

[16]Source: SPC Statistics for Development Division - sdd.spc.int/nu

7 Conclusion

Niue's water supply infrastructure is aging and requires extensive replacement of key components such as water pumps, reservoir tanks and main lines. Currently some villages are facing water supply shortages due to collapsed water bores. One of the longstanding challenges for Niue has been the unclear picture about Niue's water demand and water supply. This is due to a lack of metering, primarily at the household level. While data loggers have been installed on water pumps and tanks, there does not appear to be consistent data collection and data analysis procedures in place.

This report has attempted to clarify Niue's water supply and water demand figures based on data provided by Niue Water Supply. The primary cost component of producing this water supply were determined using electricity data for water pumps provided by Niue Power Corporation. This data was analysed using a reproducible framework with statistical tools, and the results were uploaded onto an online dashboard for review. Finally, budget projections for Niue Water Supply were used to supplement the findings from the data.

Overall the data provided was sufficient to improve Niue's water supply figures. However there is insufficient data to clearly articulate Niue's water demand at the household level. An aggregate figure for water demand was found using total water pumped at the water bore or resevoir, however this figure was higher than previous estimates. Cost figures were generally in line with budget estimates.

Several recommendations were provided for the Water efficiency Plan which place focus initially on the supply side as these will have the highest impact in the near term. Priority is placed on a framework for robust measurement of both water supply and water consumption. Once a clearer picture of Niue's water supply and demand is know, water use efficiency policies can be introduced more aggressively in the longer term with the adoption of water use efficiency standards focused on imposing measures to reduce water loss and water consumption.

The cost recovery plan provides options for cost recovery of meter installations only, and cost recovery of meter installations and cost of water supply. The cost of water meter installation can be offset or completely recovered within 7 - 10 years with a modest flat rate monthly fee of \$5 or \$6. To recover the cost of electricity for water supply, a flat per unit tariff of around \$0.30 per m^3 is sufficient. An option using Increasing Block Tariff would provide the first $14.6m^3$ (14,600 liters) per person per year free of use as minimal water required for basic health and hygiene. This will leave around 92 percent of the total water supply to be charged a tariff, and at a cost of around \$0.35 per m^3 this would be sufficient to recover the cost of electricity for water supply.

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Appendices

A Assets

Figure 10: Concrete tank with old shelter at Liku (communal tank) before the windmills.

Figure 11: The Southern Cross diesel pump at Tumau, Alofi.

Picture credit: Johliah Mautofiga Talagi

Figure 12: Green tank with pressure pump shed on the side in Liku.

Figure 13: Twin new tanks at Tapeu servicing Alofi South.

Figure 14: Twin green and yellow Paliati tanks servicing Alofi North.

Figure 15: Water pump with transformer and black box Tusekolo, Alofi. Servicing Alofi north and Paliati area.

Figure 16: Water pump powered with solar panels at Fonuakula, Alofi.