

# System Loss Management Plan

## Niue Island

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**Every Drop Counts!**

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## Executive Summary

A review of Niue Island water systems shows that in the 2006-2007 year:

- 274 mega litres were supplied into the system;
- There were 579 water supply connections and 51.4 kilometres of mains;
- System losses were as follows –
  - Current Annual Real Losses – estimated at 92 mega litres
  - Unavoidable Annual Real Losses of 15 ML
  - Apparent Losses – 0ML (water lost through metering errors, data management errors or unauthorised consumption. As water is not metered or charged for, there is unlikely to be any theft and consequently no Apparent Losses).

If unavoidable annual real losses (15 ML) are deducted from the real losses (92 ML) this leaves 77 ML per annum of potential savings without pressure management.

In order to ensure that the leakage issues are monitored and further data collected, Niue Island has installed flow metering on all of the existing reservoirs. This will allow continuous monitoring and detailed analysis of network performance.

Recommendations in this draft System Leakage Management Plan include:

- Establish District Metered Areas centred on each individual village. This will allow continued monitoring of overall flow volumes and minimum night flows.
- Implement a program of active leakage detection targeting the following areas:
  - Tuapa Village
  - Tapeu-Alofi South
  - Paliati-Alofi North

Once this work is completed water savings and minimum night flows can be assessed and further action planned on the basis of a re-evaluation of water losses in each of the DMAs.

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## Introduction

This System Loss Management Plan was prepared by Wide Bay Water Corporation in response to a request from the Pacific Islands Applied Geoscience Commission to evaluate the water losses from the Niue Island water system and prepare an appropriate System Loss Management Plan. The evaluation was to include an assessment of financial savings that could be achieved by implementing a suitable System Loss Management Plan.

Experience internationally and in Australia shows that often it is more cost-effective for water authorities to reduce water losses rather than supplement supply by development of infrastructure such as new reservoirs, pipelines or treatment plants.

Pressure Management and Active Leakage Control are proven methodologies which, separately or in combination, are used to reduce water losses from leakage and bursts in water reticulation networks.

## Scope of Work

Wide Bay Water was engaged to undertake a technical and economic assessment of the water savings and financial benefits to be gained by reducing water losses using proven water loss management principles. The information gained from the evaluation determined the basis of this System Loss Management Plan SLMP.

The SLMP will provide for the application of the principles of water loss management based on Active Leakage Control, including sectorisation, network monitoring and leak detection programs, to the Niue Island water system.

The assessment process for this study has been undertaken using the concepts and techniques recommended by the International Water Association Water Loss Task Force.

Documentation and data collection included investigation and analysis of leakage and system pressure using various existing software packages.

## Definition of Terms

- *System Input Volume* (SIV) is the volume of water supplied into a water supply system, usually measured on an annual basis. <sup>1</sup>
- *Current Annual Real Losses* (CARL) are defined as physical water losses from the water supply system up to the point of the customer meters. The annual volume

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<sup>1</sup> Manual 1- Managing and Reducing Losses from Water Distribution Systems, Environmental Protection Agency  
Wide Bay Water Corporation 2005.

lost through all types of leaks and bursts depends on burst frequency, flow rates, and average duration of leaks. <sup>2</sup>

- *Unavoidable Annual Real losses* (UARL) – The section of Real Water Losses which consists of small background leakage that cannot be discovered through currently available leakage detection techniques. <sup>3</sup>
- *Apparent Losses* consist of “losses” due to inaccuracies in flow meters and customer meters, water theft, data transfer errors and data management errors. <sup>4</sup>
- *Authorised Consumption* is that proportion of the water supply, metered or unmetered, which is consumed with the knowledge and consent of the water service provider. <sup>5</sup>

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<sup>2</sup> Manual 1- Managing and Reducing Losses from Water Distribution Systems, Environmental Protection Agency Wide Bay Water Corporation 2005.

<sup>3</sup> Manual 1- Managing and Reducing Losses from Water Distribution Systems, Environmental Protection Agency Wide Bay Water Corporation 2005.

<sup>4</sup> Manual 1- Managing and Reducing Losses from Water Distribution Systems, Environmental Protection Agency Wide Bay Water Corporation 2005.

<sup>5</sup> Manual 1- Managing and Reducing Losses from Water Distribution Systems, Environmental Protection Agency Wide Bay Water Corporation 2005.

## **Evaluation of the Niue reticulation System**

The objective of the evaluation of the Niue water systems was to collect information to demonstrate the economic and environmental benefits of both leakage control and the division of the distribution network into sectors where leakage levels are easier to monitor.

The actions necessary to achieve this objective were:

- Undertake a water balance;
- Estimate the volume of water losses attributable to leakage;
- Make recommendations for the sectorisation of the water supply network;
- Highlight the economic benefits of reducing water losses;
- Recommend appropriate strategies to achieve reduced water losses;

## **Benefits of Water Loss Management**

There are significant benefits for water supply utilities undertaking water loss reduction and management programs.

These benefits include:

- Short term financial benefits associated with the costs of delivering water and include power costs and savings in the costs of repairing burst mains.
- Long term benefits relate to reducing whole-of-life asset costs as a result of a reduction in pipe failures which will extend asset life.
- Indirect financial benefits also occur with more efficient use of existing water supplies. In particular, reduced water losses help to ensure that existing water supplies can meet future increases in demand. This can defer construction of new water infrastructure such as mains.
- A degree of drought security will be provided. In the event of droughts, supply can be maintained for longer periods as a result of the lower per capita water consumption.
- Increased knowledge of the distribution system enables staff to become more familiar with the operating and maintenance issues, including the location of mains and valves. This knowledge assists utilities to respond more quickly to emergencies such as mains breaks and provides an early indication of any increases in water losses from leakage.
- Customer service will improve as most leaks can be repaired on a planned basis rather than developing into major breaks which disrupt service.



## Evaluation of the Niue Reticulation System

### Data Collection

The following data was provided by Andre Siohane and refers to the period 30 June 2006 to 1 July 2007:

**Table 1. Data Collection Form**

	Data Title	Data	Data Source
1*	Total Length of mains (km)	51.2	Service Provider Total_Pipe_length_fo_each_Village.xls
2*	Number of service connections	579	Service Provider Households_numbers_and_areas_services.xls
3*	Average operating Pressure (KPa)	30.4	Wide Bay Water estimation From average data in each villages communicated by the Service Provider
4*	System input (KL)	274,000	Wide Bay Water estimation using 2 months collected data from meters installed after each tank by WBW and associating to a 12 month average value
5	Water exported (KL)	0	Service Provider
6	Metered residential (KL)	0	No flow meters installed
7&8*	Unmetered residential (KL) & Unmetered non-residential (KL)	180	Wide Bay Water estimation based on 1,805 inhabitants and a consumption of 273 L/per/d given by the service provider
9	Marginal cost of water – production (\$/KL)	0	No water treatment
10*	Selling price of water (\$/KL)	0.71	There is no tariff applied, all is absorbed by Niue Island Government Wide Bay Water Estimation based on the Annual cost and production
11	Annual cost of running the water supply system (\$)	206,503	Budget Review August 2006 2006-2007 Total Budget

Rows indicated with an asterisk \* are essential, but an attempt to complete all fields should be made indicating estimated data in the data source column where required.

The water system input value (KL) is quite accurate as its estimation comes from metered data. As consumption is not recorded using flow meters at each connection, the figure given for residential & non-residential water use is an estimate.



## Water Balance Niue Island Water Systems

Table 2. Water Balance

WATER INPUT FROM OWN SOURCES	WATER EXPORTED		OTHER BILLED AUTHORISED CONSUMPTION		
	0	l/conn/day			
1297 l/conn/day			0 l/connection/day		metered
			180 l/connection/day		unmetered
WATER IMPORTED	WATER SUPPLIED		UNBILLED AUTHORISED CONSUMPTION		
	1297	l/conn/day	6 l/connection/day		metered and unmetered
0 l/conn/day			APPARENT LOSSES		
			0 l/connection/day		Unauthorised Consumption
			0 l/connection/day		Retail metering errors
			REAL LOSSES (System Leakage, Water Leakage)		
			437 l/connection/day		Leakage and overflows at storage reservoirs, and leakage on mains and service connection up to meter
			92 Megalitres/year		
			312% Confidence limits		

<b>Water input (Own Sources)</b>	The volume of water input to a system from the Water Service Provider's own sources
<b>Water Imported</b>	The volume of bulk water transfers into a system across operational boundaries
<b>Water Exported</b>	The volume of bulk water transfers out of a system across operational boundaries
<b>Water Supplied</b>	Calculated as Water input from Own Sources + Water Imported - Water Exported
<b>Authorised Consumption</b>	<p>The volume of water consumed by registered customers, the Water Service Provider and others who are implicitly or explicitly authorised to do so, for residential, commercial and industrial purposes.</p> <p><b>Note:</b> Authorised consumption may be billed or unbilled, metered or unmetered. It include items such as fire fighting and training, flushing of mains and sewers, street cleaning, watering of municipal gardens, public fountains, building water, etc.</p> <p><b>Useful Tip:</b> When allocating components of consumption within a water balance, consider the answers to the following 3 questions in this order - <b>Is it Authorised? Is it Billed? Is it metered?</b></p>
<b>Non Revenue Water</b>	The volume of water entering the system that does not produce revenue for the Water Service Provider. It consists of Unbilled Authorised Consumption, Apparent Losses and Real Losses
<b>Unauthorised Consumption</b>	Illegal consumption (theft)
<b>Customer Metering Errors</b>	<p>Systematic errors in customer meter data used in the water balance</p> <p><b>Note:</b> Customer metering errors include not only systematic under-registration or over-registration of meters (due to type, age and throughput) but also systematic errors in the data handling of meter readings (including methods of dealing with stopped meters, allowances for poor quality water etc)</p>
<b>Apparent Losses</b>	Calculated as the sum of Unauthorised Consumption and Customer Metering Errors
<b>REAL LOSSES:</b>	Physical water losses from the pressurised system, up to the point of measurement of consumption. The volume lost through all types of leaks, bursts and overflows depends on frequencies, flow rates, and average duration of individual leaks, bursts and overflows
<b>Water Leakage, System Leakage in Act &amp; Guidelines</b>	<b>Note:</b> Although physical losses after the point of customer metering or assumed consumption are excluded from the assessment of Real Losses, this does not necessarily mean that they are not significant or worthy of attention for demand management purposes

## Water Consumption Calculations

### Consumption per connection per day

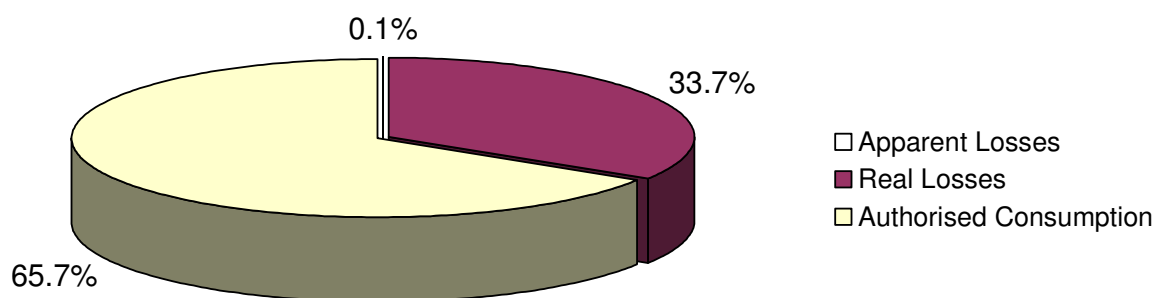
Consumption per connection is calculated by dividing the total volume of water delivered into the system by the number of connections:

274 ML/year divided by 579 connections = 473 KL/connection/year

This equates to a water supplied figure of 1297 litres/connection/day. The figures used for authorised consumption are an estimate, provided by the service provider, based on 1,805 inhabitants and a per capita consumption of 273 litres per day.

### Water Losses

The figure below shows the basic components of Niue Island water system expressed as a percentage of total water supplied:



**Figure 1.** *Components of Water Supplied.*

### **Apparent Losses**

Apparent losses are unauthorized consumption (theft), inaccuracies in customer meters and errors in meter data transfers. As water is not metered or charged for, there is unlikely to be any theft and consequently no Apparent Losses.

## Infrastructure Leakage Index

The recommended International Water Association (IWA) detailed performance indicator for real losses is the infrastructure leakage index (ILI). This is the ratio of the current annual real losses divided by unavoidable annual real losses (UARL).

The IWA formula for UARL takes into account the system specific factors of density of service connections (per km of main), average operating pressures and location point of metering (or consumption) relative to the edge of the street. It is a non-dimensional performance indicator of the current overall management of the infrastructure for leakage purposes.

$$\text{UARL (L/d)} = (18 \times \text{Lm} + 0.8 \times \text{N}) \times \text{P}$$

Lm: Length of mains (in km)

N: Number of Service Connections, main to meter

P: Average system pressure in meters

The more the ILI exceeds 1.0, the greater is the opportunity for further management of real losses. This is accomplished through infrastructure management, intensive water demand practices such as district metering, active leakage control and improved speed and quality of repairs.

An ILI of 1.0 would show that the losses within the infrastructure match the best possible result for the condition of the network.

Any ILI below 1.0 must be questioned as it would show that the system is operating better than the best achievable result.

The average density of connections is 11.3 per kilometre of main with an average operating pressure of 30.4 kPa. The average operating pressure has been estimated using average value for each village and is believed to be a sensible reflection of system pressures if it has been measured on site.

The infrastructure leakage index for the supply area was as follows:

The UARL (calculated using the IWA formula) is 15 ML or 73 litres/connection/day

The ILI is calculated by dividing the Current Annual Real Losses (CARL) by the Unavoidable Annual Real Losses (UARL)

CARL (92 ML) divided by UARL (15 ML)

ILI = 6.1

## The Financial Value of Water Losses

The value of water losses can be calculated at the cost of production or at the retail cost to the consumer. In Niue there is no charge for domestic consumption. Financial savings resulting from reduced water losses will therefore be found in reduced production and supply cost. Electricity is the single biggest cost that is directly linked to the volume of water produced. Other significant costs are fixed and therefore not responsive to variations in the volume of water produced.

The following Table shows an assessment based on savings in electricity costs gained by reducing water losses.

**Table 3.** *Financial Saving from Reduced Electricity Usage.*

Financial Savings From Reduced Electricity Use	
Annual Water Supply (ML)	274
Annual Electricity Budget	\$66,000
Annual Electricity Cost per ML Supplied	\$240.88
Potential Annual Savings From Active Leakage Control (ML)*	46
<b>Potential Annual Financial Savings</b>	<b>\$11,080.29</b>

\* Based on detecting and preventing 50% of current real losses.

## General Principles of Sectorisation

### Establishment of District Metered Areas – Sectorisation

There are huge variations in the size and value of the operations of water utilities worldwide, from rural communities supplying a few hundred consumers from a local source, to vast metropolitan utilities with thousands of connections supplied from a complex mixture of water resources.

Assessment of leakage and economic levels of leakage requires that the overall losses (from source to consumer) in large water supply systems be calculated separately for different groupings of infrastructure, each of which has its own characteristics (see below). The major sub-divisions are between:

- Raw water losses (between abstraction and treatment)
- Losses in transmission from treatment (production) to storage reservoirs
- Losses on distribution system served by reservoirs/pumping stations

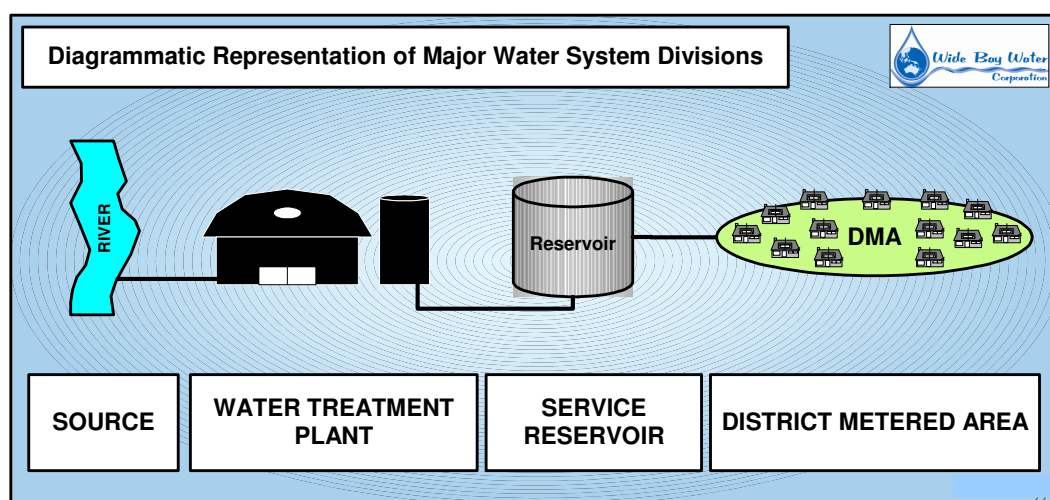


Figure 2. Diagram of Major Water System Components.

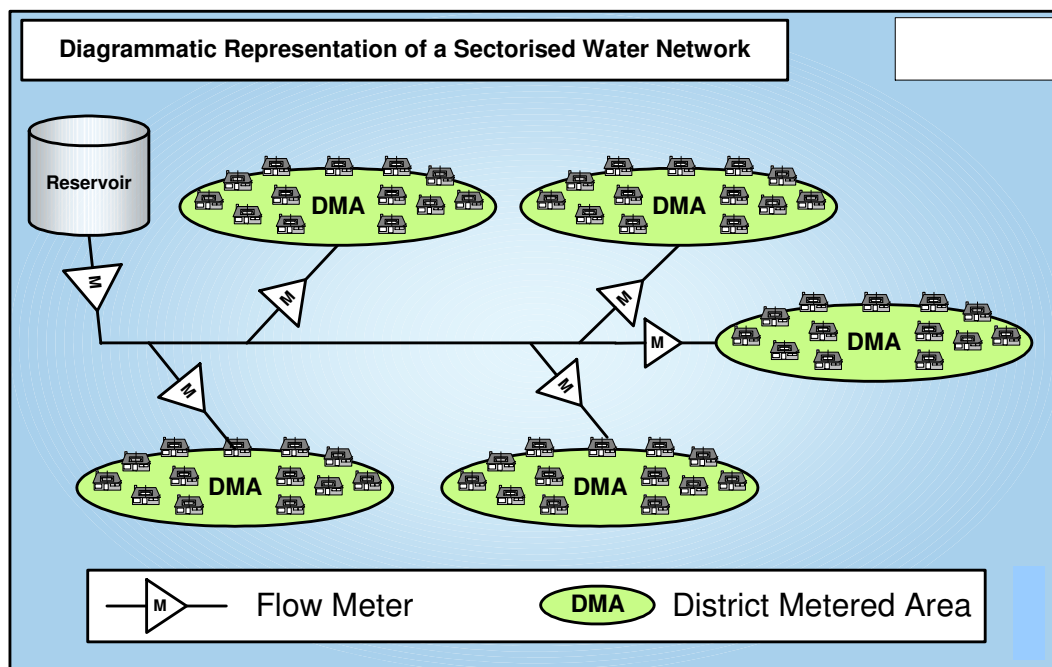
In small water supply systems without water treatment plants, such as Niue Island, overall losses are calculated for different groupings of infrastructure between the storage tank and the customers. Losses occur on the distribution system served by reservoirs/pumping stations.

The input and output from each of these groupings of infrastructure should always be continuously monitored with reliable metering. The input is monitored by meters installed after the distribution reservoir and the output should also be monitored through the

customer's meters. Separate regular water balances calculations should be carried out to allow trends in real losses to be monitored in each sub-division.

By installing meters on the distribution system, Niue Island representatives will be able to identify and target problem areas rather than looking for water losses through the entire network. Water balances and audits can be then carried out on an individual basis rather than on a total system basis.

To enable continuous monitoring of leakage, it is recommended that Niue Island utilise its existing boosted zones by installing flow meters and logging technology. Review of the gravity-fed Alofi zone should also be carried out to identify the possibility of further sectorisation.



**Figure 3.** *Diagram of Sectorised Water System.*

By sectorising its water supply system, Niue Island can identify those areas with the greatest losses and initiate active leakage control where most appropriate.

Real losses in these zones consist of three components:

- Leakage on distribution mains
- Leakage on connections
- Leakage and overflows on private pipes



Selecting an appropriate size for such districts is a trade-off between cost of establishing and maintaining the district and the size of the unreported leaks that can be identified from inflow measurements.

As districts size increases, so does the difficulty in discerning difference between the flow rate of a new unreported leak and a slight increase in consumption. In a district metered area of 5000 connections it would be difficult to be sure that increases in night flow of around 10 KL/hr was a leak and not simply a variation in night consumption.

However, as the Niue distribution systems consist of 16 separate small districts, all with small numbers of service connections, the interpretation of night flow data becomes much less complex than for larger DMAs, as (with suitably accurate district metering) it should be possible to identify the presence of any leakage anywhere downstream of the meter on a night to night basis.

### **Water Quality**

Water quality is always an issue when closing down valves permanently as this leads to the creation of dead ends. However if managed properly problems from dead ends can be minimized. From experience in other parts of the world a number of simple procedures have been used to remove these problems:

1. Installation of washouts/hydrants at each boundary valve to allow flushing as required.
2. Valve security – Indiscriminate opening of boundary valves can also lead to water quality problems due to the sudden change in flow velocity. This should be managed so that these events are minimized. Education of field staff and valve tagging are the most effective way to achieve this outcome.
3. If a boundary is to be opened, it is best practice to open a fire hydrant or washout prior to the valve being open; this will ensure that any dirty water from one zone is flushed out and not transferred to the adjacent zone.

If these simple procedures are followed then water quality should not be an issue.

### **Planned District Metered Areas**

A District Metered Area or Sector is a defined area of a water system where the flow into the area is limited to one or two feeder pipes which are metered. Thus the total volume of water flowing into a DMA is constantly measured.

On this basis each of the reservoirs on Niue and the areas they service would form an individual DMA. The simplest DMA model would be based on a single flow meter at the outlet point of each reservoir (all outlets from water storage points in Niue have been fitted with flow meters). This would provide data on flow volumes and flow rates used to

determine minimum night flows which in turn would indicate those DMA,s with highest water losses.

The Table below includes 16 villages which may form the basis of individual DMAs. Estimated leakage, calculated on minimum night flow data, is included for those villages for which data was supplied.

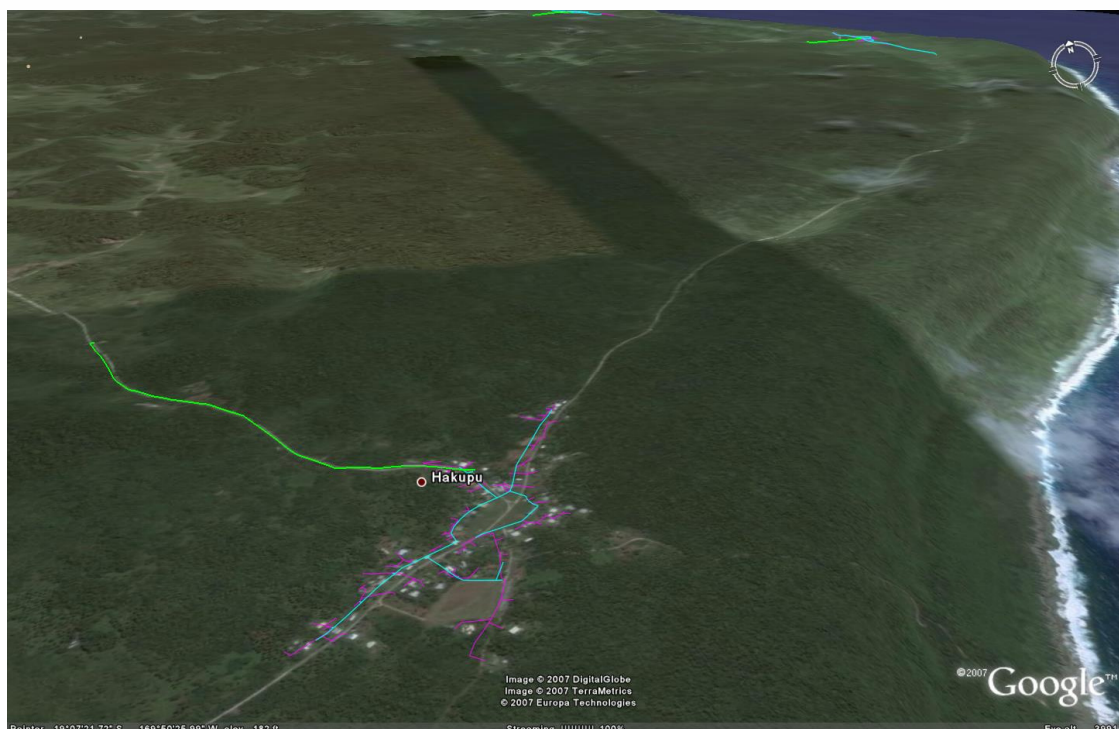
**Table 4. Proposed DMAs and Estimated Water Losses**

<b>Village(DMA)</b>	<b>Estimated Losses (litres/klm water main/day)</b>
Tuapa Village	24771.5
Tapeu-Alofi South	17443.4
Paliati-Alofi North	16541.0
Tapeu-Airport	10196.4
Avatele	9808.8
Tamakautoga Village	9221.8
Mutalau Village	7962.4
Hakupu Village	4392.7
Toi Village	4191.4
Lakepa Village	3363.4
Liku Village	3304.9
Vaiea-Talamaitoga	1431.6
Hikutavake Village	No Data
Fualahi/Kaimiti/Toa	No Data
Makefu	No Data
Nmaukulu	No Data

The above table is also a priority list for investigation and/or intervention with active leak detection.

It must be noted that these initial designs are not final, as with most sectorisation programs from desktop study to field implementation initial designs are subject to change due to variable factors such as:

- Anomalies in asset capture and physical situation on the ground
- Niue Island Water Supply input and changes
- Unknowns – closed and buried valves
- Sensitive areas



**Figure 4.** Example DMA based on one reservoir - one village. (Courtesy Google Earth)

### Customer Metering

It is always preferable to have individual households are metered as this will allow cross-referencing with the DMA flowmeters to provide more accurate estimates of leakage within each DMA. However, as DMA's in Niue are so small it should be possible to identify leakage volumes with a high degree of accuracy without the need for individual customer metering.

If Niue decides to go ahead with individual customer metering, the estimated cost would average around NZ\$ 92.00 per meter.

Total cost of installing meters on all 579 individual water connections would be NZ\$53,000, as shown in the following Table.

**Table 5.** Estimated Customer Meter Installation Costs

Estimated Costs of Installing Individual Customer Meters (NZ\$)	
Materials	\$44
Labour	\$50
Cost per Meter	\$92.00
<b>Total Cost to Install 579 Meters</b>	<b>\$53,268.00</b>

It should be noted that these are equivalent to current Wide Bay Water costs and may differ considerably in Niue (freight costs may be higher but labour costs may be lower???)



***Every Drop Counts!***

This extra cost would only be justified in the event customers were charged by consumption.

**Table 6. Niue's Water Balance**

	<b>WATER EXPORTED</b>	
	0	l/conn/day
<b>WATER INPUT FROM OWN SOURCES</b> 1297 l/conn/day	<b>OTHER BILLED AUTHORISED CONSUMPTION</b>	
	0	l/connection/day metered
	180	l/connection/day unmetered
<b>WATER IMPORTED</b> 0 l/conn/day	<b>UNBILLED AUTHORISED CONSUMPTION</b>	
	6	l/connection/day metered and unmetered
	<b>APPARENT LOSSES</b>	
	1	l/connection/day Unauthorised Consumption
	0	l/connection/day Retail metering errors
	<b>REAL LOSSES (System Leakage, Water Leakage)</b>	
	437	l/connection/day
	92	Megalitres/year
	312%	Confidence limits
	Leakage and overflows at storage reservoirs, and leakage on mains and service connection up to meter	

Financial Savings From Reduced Electricity Use	
Annual Water Supply (ML)	274
Annual Electricity Budget	\$66,000
Annual Electricity Cost per ML Supplied	\$240.88
Potential Annual Savings From Active Leakage Control (ML)*	46
<b>Potential Annual Financial Savings</b>	<b>\$11,080.29</b>

\* Based on detecting and preventing 50% of current real losses.

## Recommendations

It is recommended that the Niue System Leakage Management Plan be based on the following actions:

- Establish District Metered Areas centred on each of the supply reservoirs which feed individual villages. This will allow continued monitoring of overall flow volumes and minimum night flows.
- Implement a program of investigation and active leakage detection targeting the following areas:
  - Tuapa Village
  - Tapeu-Alofi South
  - Paliati-Alofi North

Once this work is completed water savings and minimum night flows can be assessed and further action planned on the basis of a re-evaluation of water losses in each of the DMAs.

## Appendix A – SLMP Work Book Calculations

### Water Loss Calculations

Table 8. Leakage Assessment Sheet

WATER BALANCE TO ASSESS SYSTEM WATER LEAKAGE FOR				Niue	
Start and Finish Dates of Water Balance >		01/07/2006	01/07/2007	365	days
Service conns =	579	Mains km =	51.2	Connections/km =	11.3
Average pressure =	30.4	metres	System is pressurised	100%	of period
Component of Water Balance			Volume in Megalitres	litres/ conn/day	95% Confidence limits +/- %
Water input to this system from WSP's own sources			274	1297	100.0%
Water Imported to this system from other WSP's			0	0	0.0%
Water Exported from this system			0	0	0.0%
Water Supplied to this system			274	1297	100.0%
Authorised consumption		Billed Retail metered	0	0	1.0%
		Billed unmetered	180	852	50.0%
NRW: Non Revenue Water			94	445	306.8%
Authorised unbilled consumption	0.50%	of Water Supplied	1	6	0.0%
Unauthorised Consumption	0.10%	of Water Supplied	0	1	0.0%
Retail Meter under-registration	2.00%	of Billed Metered	0	0	0.0%
Apparent Losses			0	1	
Current System Leakage (water leakage)			92	437	312.3%
Unavoidable Annual Real Losses UARL			15	73	
Infrastructure Leakage Index ILI =			6.01	WBI Band C	

### Leakage Reduction Estimates

Using advanced leak detection technology, it is expected that an intensive Active Leakage Control program could reduce real losses by 50%\* over a 12 month period. This would result in a saving of 40 to 46 megalitres of water per annum.

- Note: based on wide experience in Australian water reticulation systems.



## Appendix B - Niue District Metered Areas

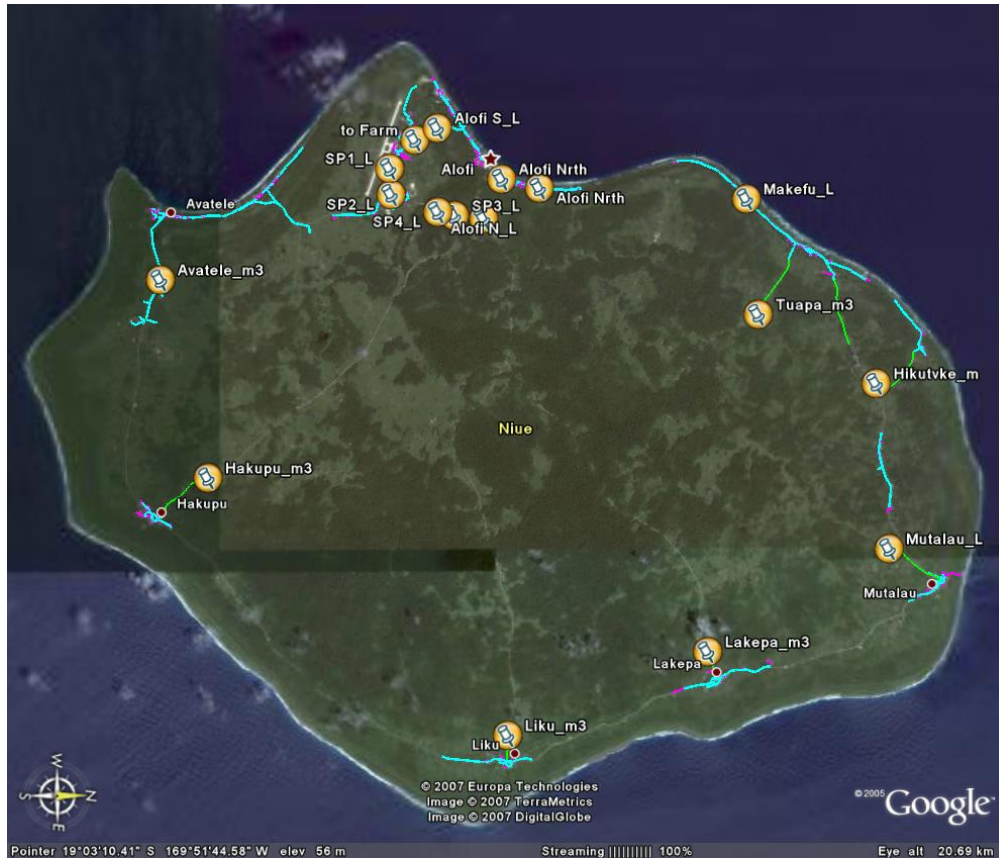


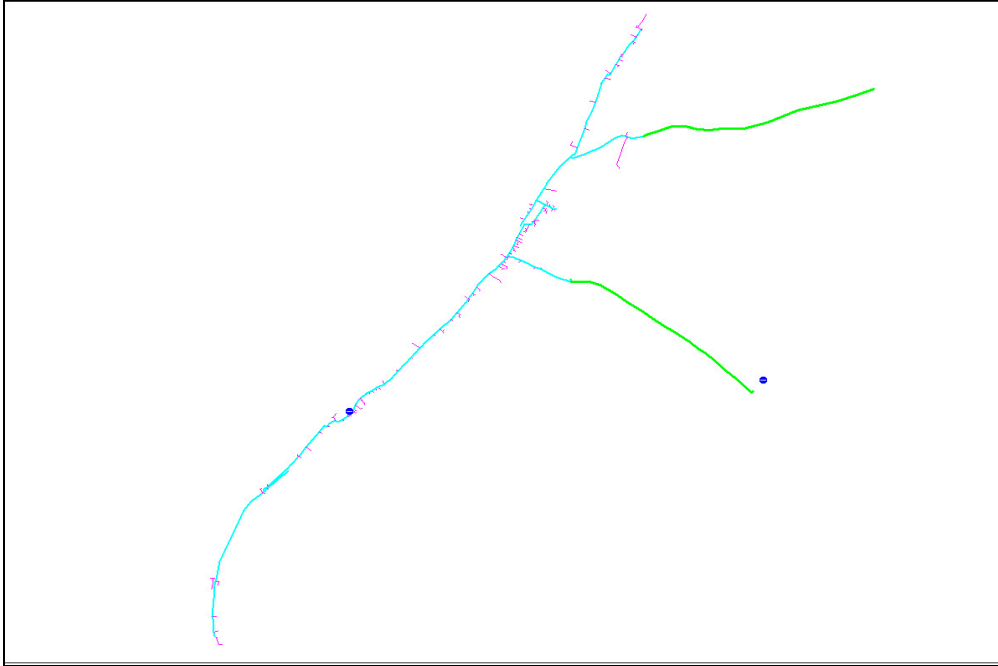
Figure 5. Niue Island and Proposed DMAs (Courtesy Google Earth)

### Data Issues

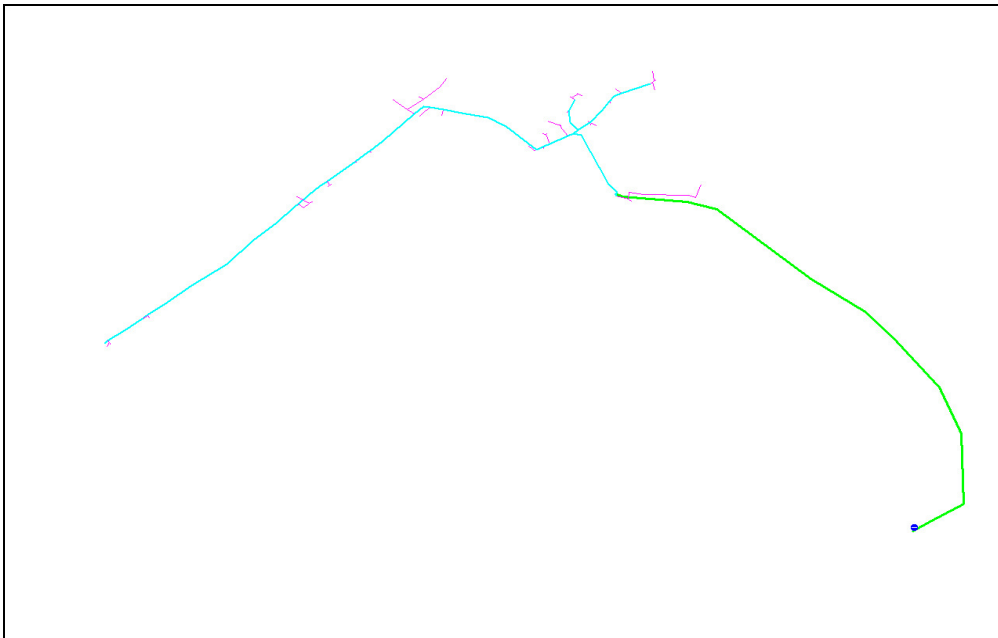
The following maps were produced from GIS data supplied. There are only 14 DMAs represented on the Maps below. If there are 16 planned DMAs then it must be assumed that either GIS data was not supplied for these missing villages or they constitute part of other DMAs but were not individually named in the GIS data

**Alofi North and Alofi South District Metered Areas (Incomplete Data or Missing DMAs??)**

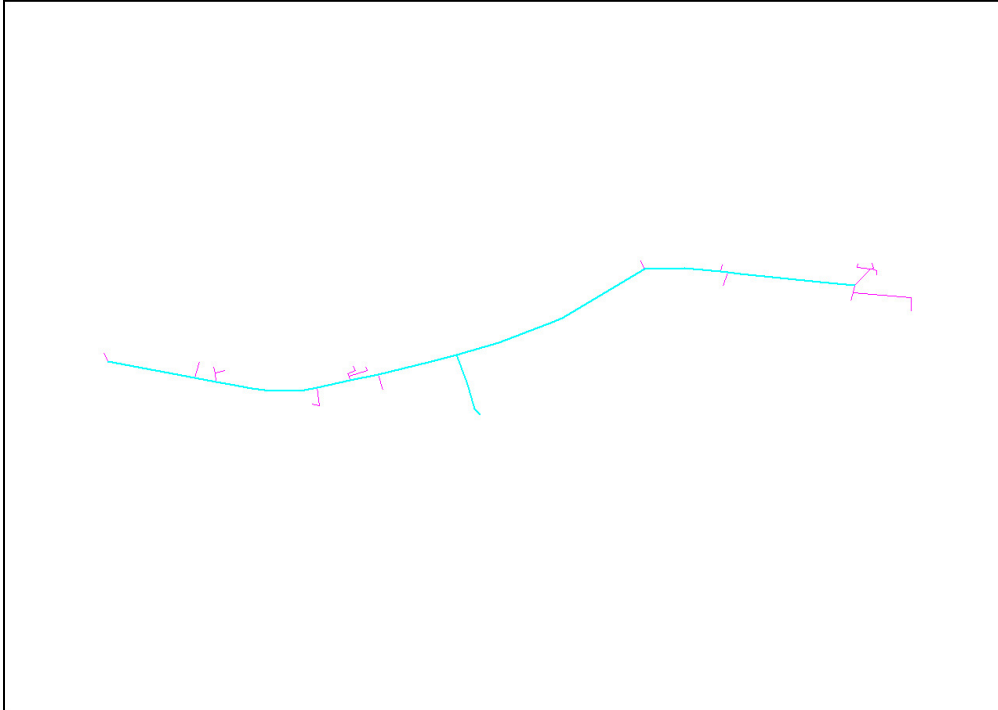
**Tuapa, Makefu and Namukulu District Metered Areas**



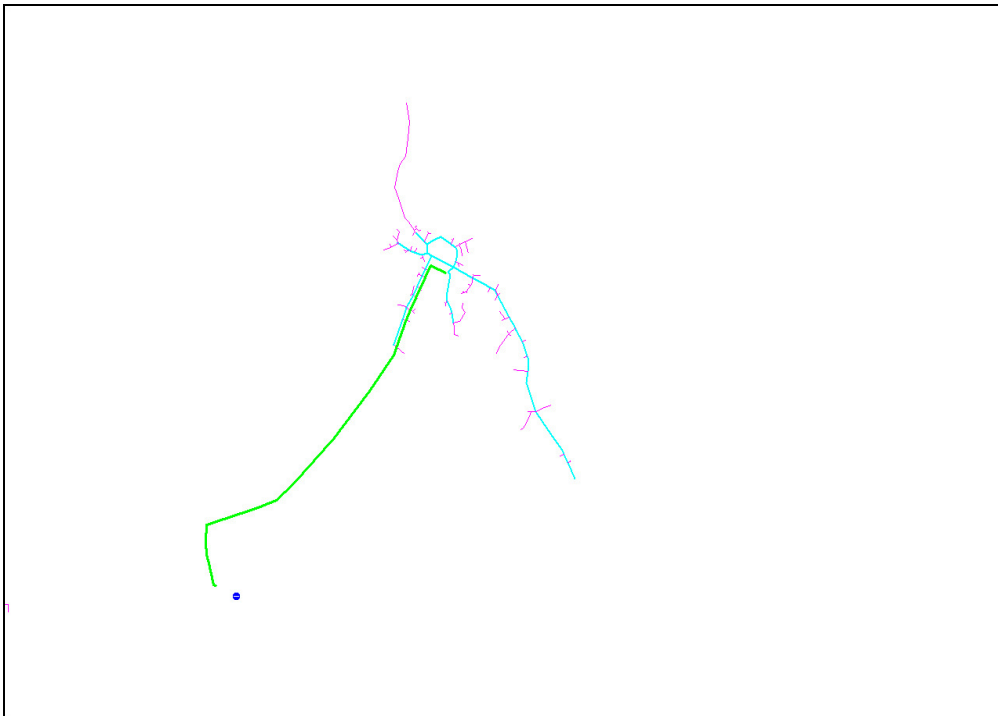
**Hikutavake District Metered Area**



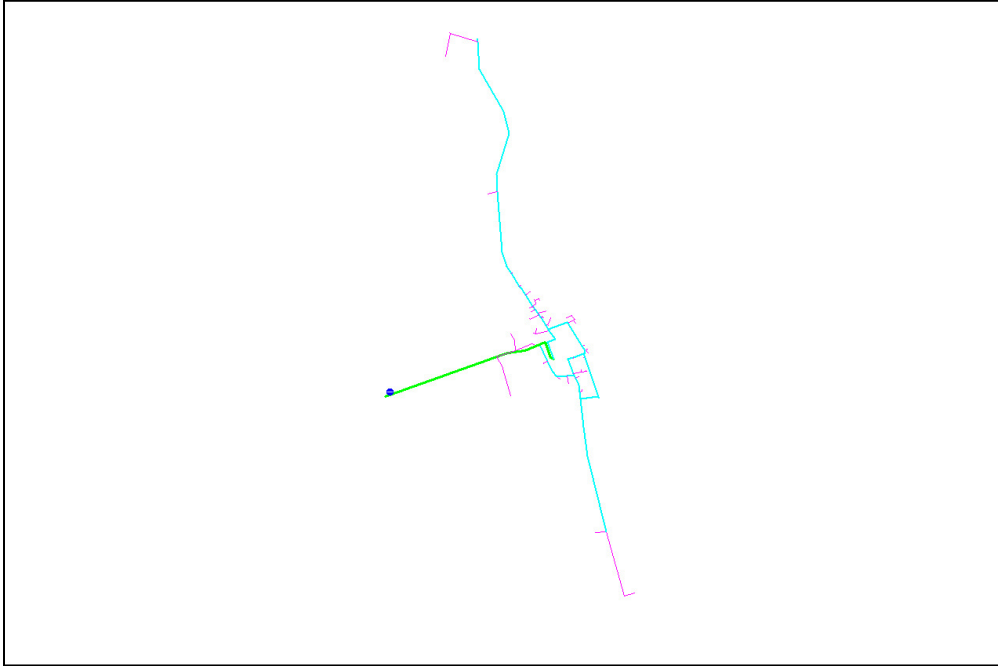
Toi District Metered Area



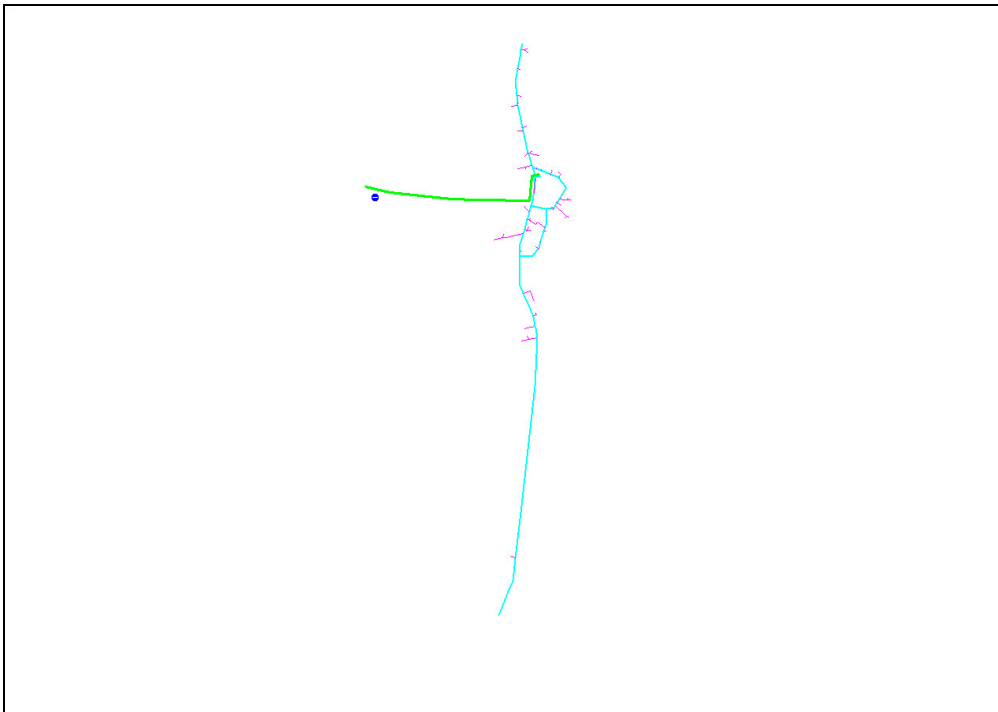
Mutalau District Metered Area



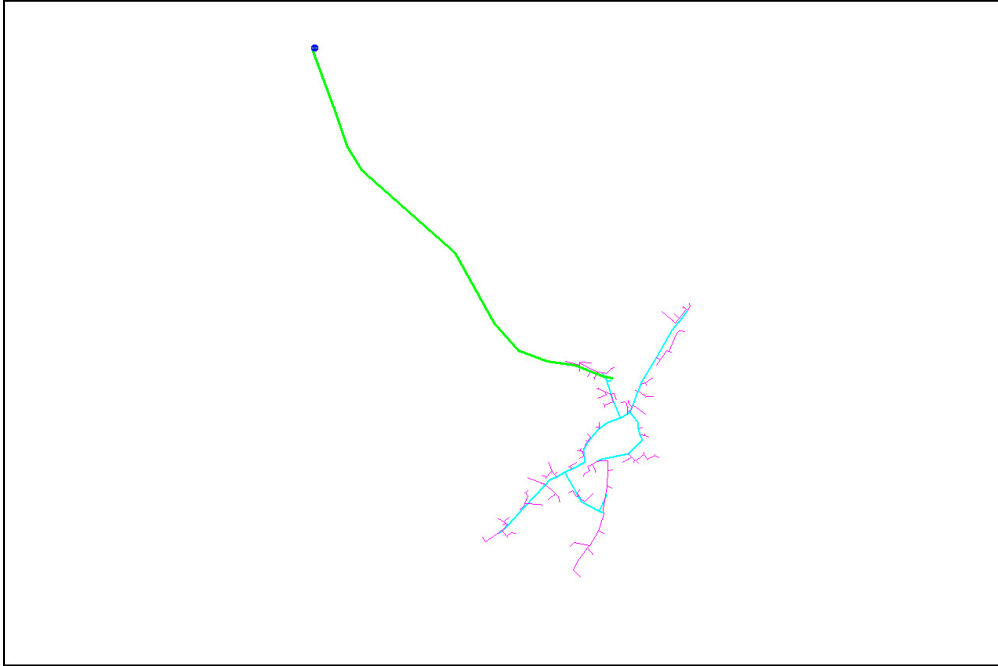
**Lakepa District Metered Area**



**Liku District Metered Area**



Hakupu District Metered Area



Tamakauton, Avatele and Valea District Metered Areas

