WAIPA DISTRICT METER AREA DESIGN

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ABSTRACT

Waipa District Council (WDC) began its water demand management planning journey in 2010 when it prepared its first water conservation and demand management plan to serve as a road map for the future. This developed a better understanding of historical water demand and presented a high-level evaluation of each scheme's most relevant future water demand management measures. One of the WDC 2021 activity management plans is non-revenue water (NRW) reduction to reduce both real water losses (physical leakages) and apparent water losses (commercial losses), with a greater priority for reduction of real water losses by improving network assets management, active leakage control, speed and quality of leak repairs, and pressure management to increase water supply capacity.

In this project, the District Meter Area (DMA) network zoning approach, as a demand and leakage management initiative, is adapted to align with WDC strategic objectives and ensure a solution that will support current needs and adapt to future requirements. The paper introduces the DMA zoning approach, reviews the existing Waipa water supply network, outlines the development of the DMA concepts plans and the smart networks.

The hydraulic analysis was performed in the existing water supply network model for each DMA to verify each DMA's functionality in terms of the minimum level of service and the fire flow. The hydrants in each DMA ware tested for fire flow in terms of minimum residual pressure to supply the firefighting water (FW2) flow requirements.

Concept plans are developed to split the existing water supply zones into manageable DMAs. Waipa District's water supply system is divided into ten main areas based on district water balance areas used for the model build and calibration project. There are district zones already metred and provided a starting point for this project to refine and develop 20 new smaller DMAs. High-level cost estimation with an implementation plan was conducted as well.

KEYWORDS

Water Supply, District Meter Area, Hydraulic Modelling, Asset Management, Leakage Management, Smart Networks

PRESENTER PROFILE

Haiming Li is a Water Resources Engineer at WSP. He joined the Hamilton team in 2020 after completing his master's degree in Civil Engineering. During his first year, he has gained valuable project experience in asset management, water supply modelling and stormwater management, He is passionate about managing water resources effectively and sustainably for future generations.

1 INTRODUCTION

WDC is in the Waikato region of New Zealand in the North Island and contains the urban hubs of Te Awamutu/Kihikihi, Cambridge/Karapiro, Ohaupo and Pirongia, located to the south of Hamilton. The district is also an important economic development area, according to published statistics, in Year 2003, the permanent population of the district was about 58,000, and is forecasted to rise to approximately 185,000 by 2050.

Figure 1 shows the location of the townships within the Waipa District boundary including the growth areas. This project concentrates on the main towns that have interconnected water supply networks.

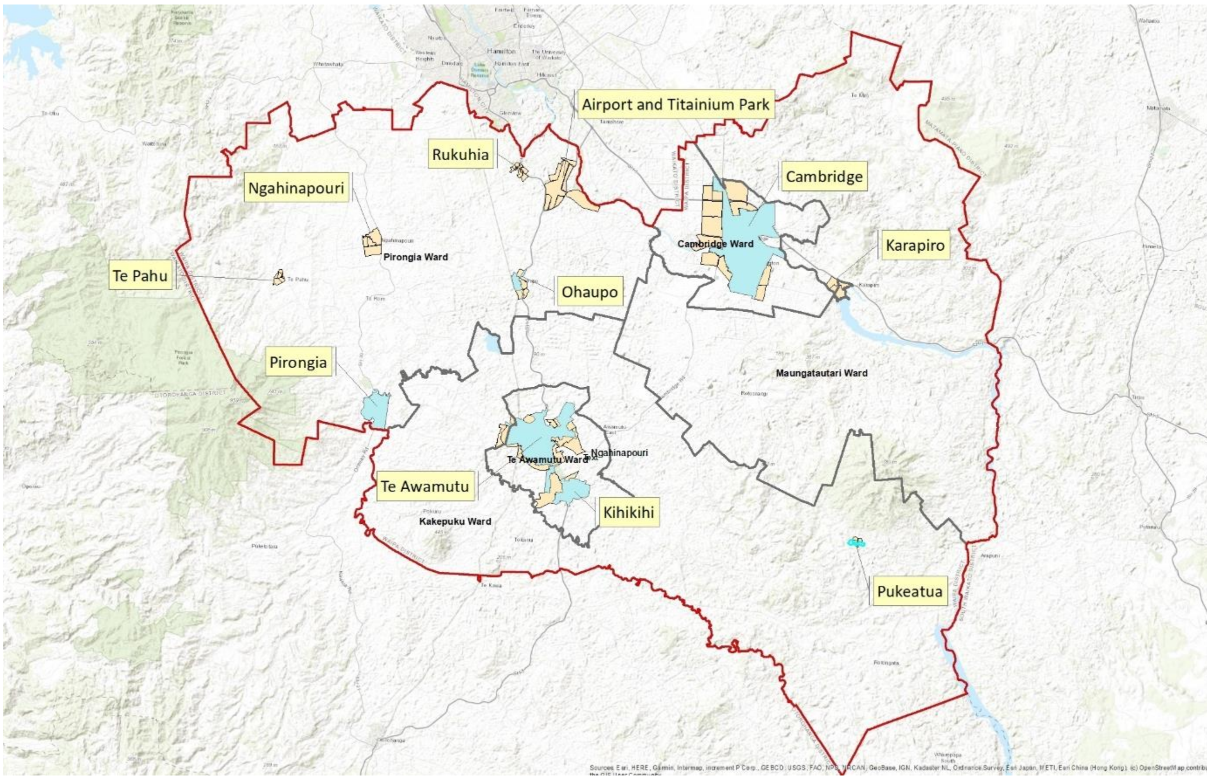


Figure 1: Waipa District Townships

The hydraulic model was rebuilt and calibrated in October 2019 and could be broken down into the ten zones (*Figure 2*) to develop unique demand profiles for these zones based on field flow measurements.

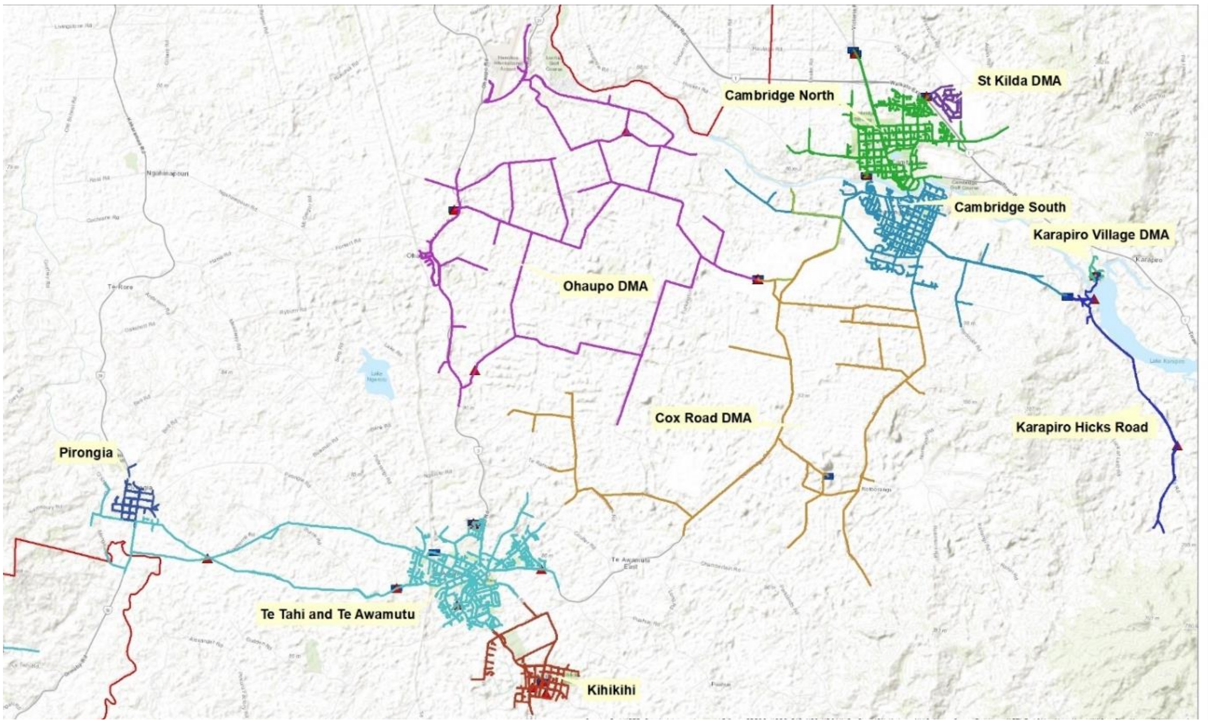


Figure 2: Waipa District Water Supply Zones

The main objective of this phase comprises the following:

- Network Zoning and Restructuring to establish water supply zones and district metered areas (DMAs), to monitor and control network flow, pressure and NRW.

The subsequent phases will seek to reduce both real water losses (physical leakages) and apparent water losses (commercial losses), with a greater priority for reduction of real water losses by improving network assets management, active leakage control, speed and quality of leak repairs, and pressure management, to increase water supply capacity.

2 DISTRICT METER AREA APPROACH

WDC proposes to establish district metered areas (DMAs) within the network zones. Water first flows into a network zone through bulk water meter, from where the water then flows to each DMA. Each DMA would be isolated within each network zone by installing valves or utilising existing valves at the boundaries of the DMA. Water would flow into the DMA from one location or cascading DMAs, and meters would be installed to measure the flow into the DMA.

The technique of leakage monitoring requires the installation of flowmeters at strategic points throughout the distribution system, where each meter records the flows into a discrete area or multiple-feed areas with a defined and permanent boundary DMA.

It therefore follows that a leakage monitoring system will comprise several districts where flow is measured by permanently installed flowmeters. In some cases, the flowmeter incorporates a pressure-reducing valve.

Depending on the characteristics of the network, a DMA will be:

- supplied via single or multiple feeds
- a discrete area (i.e. with no flow into adjacent DMAs)
- an area which cascades into an adjacent DMA.

Several factors should be considered when designing a DMA, such as:

- the required economic level of leakage
- size (geographical area and the number of properties)
- variation in ground level
- water quality considerations.

DMAs in dense urban areas, e.g. inner cities, may be larger than 3000 properties, because of the housing density. In the rural areas, it is also difficult to lay downsizing guidelines, as rural DMAs may consist of a single village, or may encompass a cluster of villages (a small number of properties in a large geographical area).

If a DMA is larger than 5,000 properties, it becomes difficult to discriminate small bursts (e.g. service pipe bursts) from night flow data, and it takes longer to locate. However, large DMAs can be divided into two or more smaller DMAs by temporarily closing the valves so that each sub-area is fed in turn through the DMA meter for leak detection activities. In this case, any extra valves required should be considered at the DMA design stage.

In practice, DMAs fall into three categories:

- small: <1,000 properties
- medium: 1,000-3,000 properties
- large: 3,000-5,000 properties.

The project team have agreed with WDC at the start-up workshop that sizing of DMAs is determined by the hydraulic conditions, rather than number of properties.

2.1 NETWORK ZONING AND RESTRUCTURING

2.1.1 ESTABLISHMENT OF NETWORK ZONES

This phase of the project proposes to divide the network into several large water supply zones, so that inflows to each zone can be measured, and zone water balances can be calculated to quantify NRW for each zone. Each zone would be isolated by installing valves at the boundaries of the zone, while installing water meters to measure flows between zones.

The Waipa base 2021 Base model has been used for this assessment. The base 2021 hydraulic model includes all 2021 committed projects as defined in the 2020 3 Water Master Plan (Scrimgeour et al., 2020).

The current hydraulic model has been divided into ten discrete zones that have been identified as closed discrete zones where flow measurement exists to quantify demand as shown below in *Figure 3*.

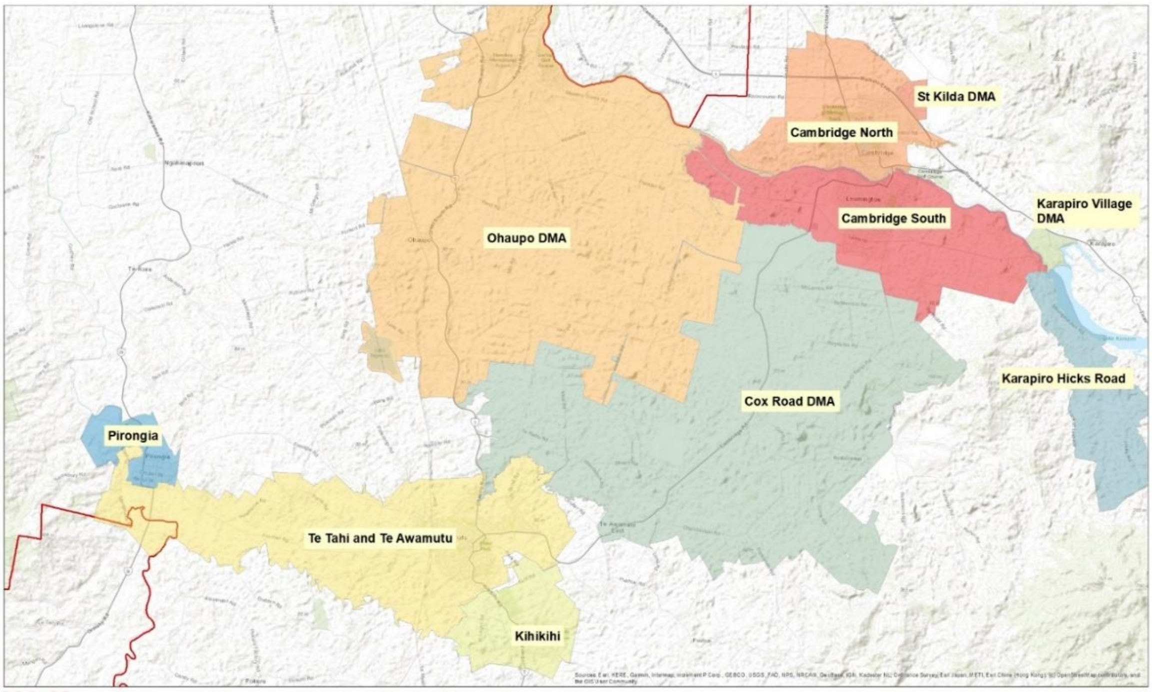


Figure 3 : Waipa Model Network Zones

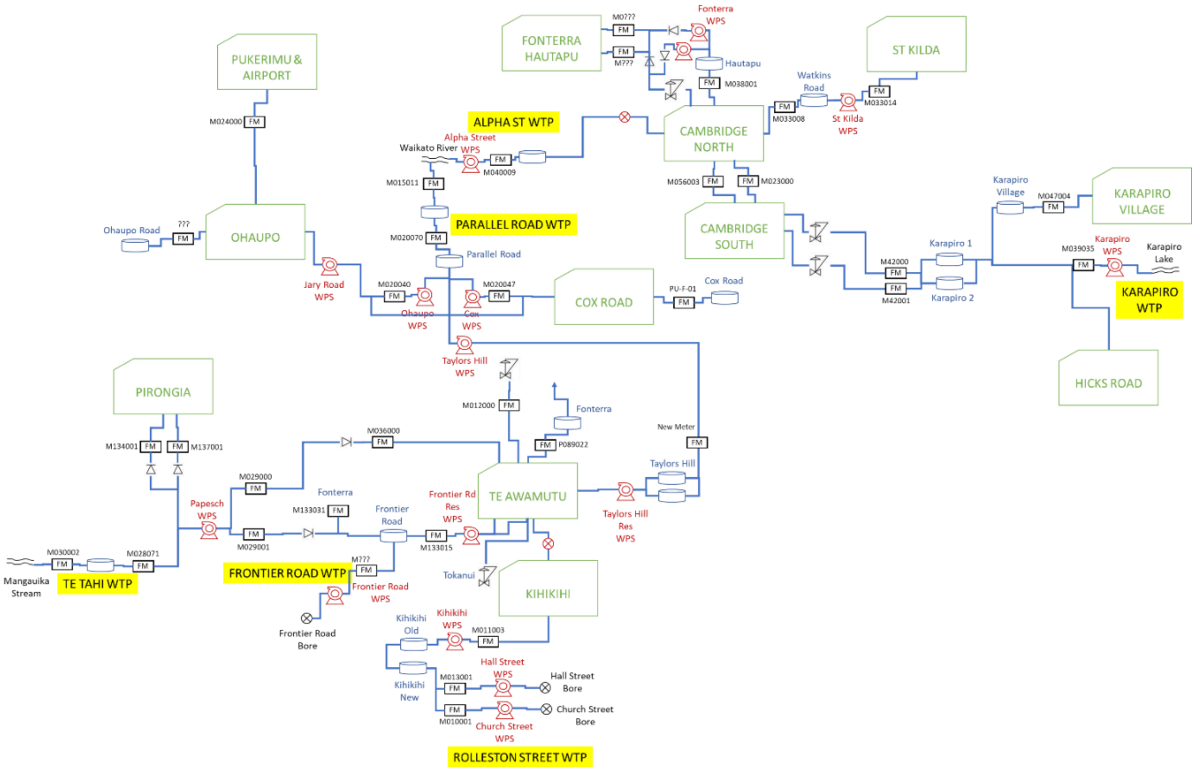


Figure 4 : Waipa Network Zone Schematic

These demand zones where used as the Network Zones and a Network Zone schematic was developed as illustrated in *Figure 4* to assist with the development of a Network Zone water balance. This approach with the use of the hydraulic models to design, establish the models and test the DMAs for levels of service and fire flow requirements.

3 NETWORK ZONING

3.1 MODELLING REVIEW

The Model Build and Calibration Study in conjunction with the 3 Waters Master Plan Study recommended the design of a Metering system to better report and monitor water balances as detailed in the previous sections. The project team recommend the design of a three tier Metering system, Grades 1 to 3 as summarised below.

3.1.1 INSTALLATION OF GRADE 1 AND GRADE 2 METERING WORKS

Grade 1 and Grade 2 Metering Works would apply electromagnetic flow meter technology, comprising electromagnetic flow meters, pressure sensors and data loggers. Electromagnetic flow meters should have minimum: graphical display with touch keypad, two individual pulse outputs (including net flow volume), internal or external battery pack, integrated data logger with selectable log interval, power management with selectable battery alarm level, real time clock and date, and self-check feature with automated data back-up. Pressure sensor and data logging technology can either be integrated with the metering equipment or installed separately.

3.1.2 INSTALLATION OF GRADE 1 AND GRADE 2 METERING WORKS

Grade 3 Metering Works would apply permanent, multi-point ultrasonic flow metering technology, with data logging capability. Transducers would be installed as insertion type with direct water contact for existing mains, where the sensors would be installed under pressure.

3.2 NETWORK METERING SYSTEM

3.2.1 GENERAL

WDC has a layered water supply structure. WDC currently meters the output from each of its sources. The seven sources (present and future) distribute water to all but a very few customers. The water transmission pipelines convey treated water from each of the Water Treatment Plants (WTPs) directly to customers and to respective service reservoirs.

Figure 4 shows the current network schematic arrangement for water supply and *Figure 5* illustrates the water balance at Zone level. WDC have the district wide area divided into three clusters as follows:

- Cluster 1: Cambridge
- Cluster 2: Pukerimu
- Cluster 3: Te Awamutu

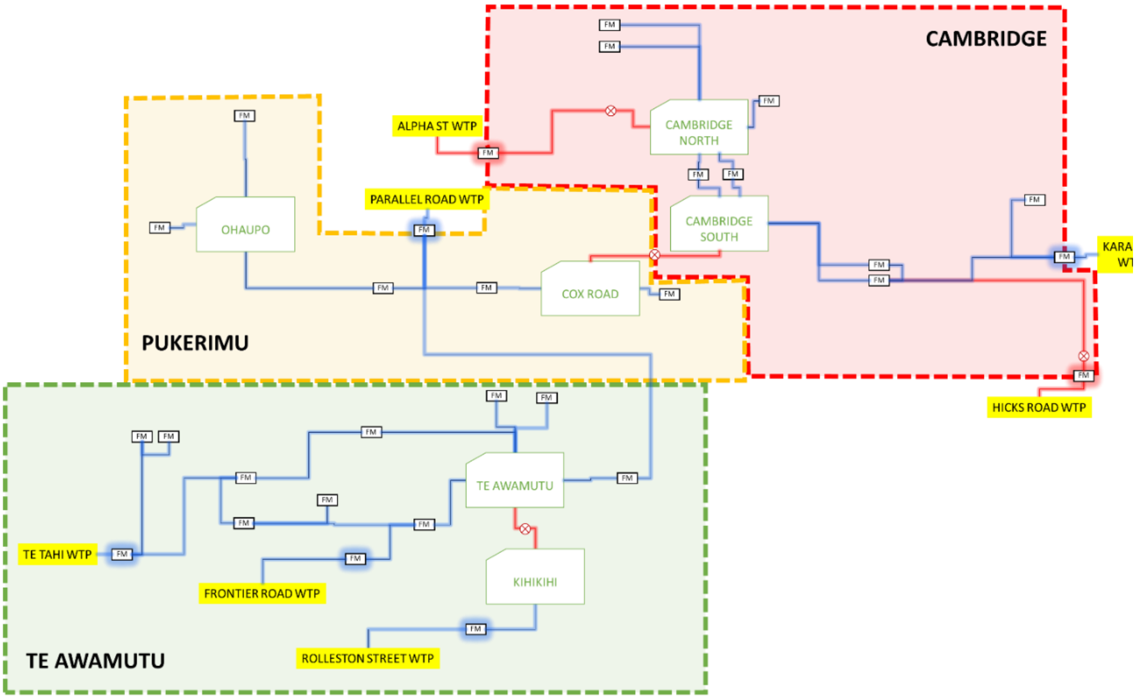


Figure 5 : Zoned Meter Schematic

There are currently gaps in the meter network that make it impossible to completely measure the volume of water supplied to each of the zones. The existing bulk meters are mostly operational, are equipped with data loggers and represent a very useful source of information and a potential NRW measurement facility for the Project.

The existing bulk meter system is incomplete and cannot measure the total water quantity supplied to the water zones. This lack of meters prevents the accurate assessment of NRW for each DMA. It also seems that there are some existing meters that do not provide any logical sense for flow monitoring. At present, there are six water treatment plant bulk meters (including bore sources) and some 18 secondary meters / sub-meters.

To ensure all the water supplied to the DMAs are fully measured WDC must install sufficient monitors and react to NRW along the transmission and distribution mains. The two-hierarchy approach will allow WDC to monitor transmission loses and as denoted by equation (1) below

$$NRW_{Transmission\ mains} = \sum(WTP\ Meters) - \sum(Bulk\ Meters) - \sum(Demand) \quad (1)$$

Similarly, DMA loses denoted by equation (2) below.

$$NRW_{DMA} = \sum(DMA\ Meters) - \sum(Demand) \quad (2)$$

However, to meet the objectives a full coverage of metering is required.

3.2.2 EXISTING BULK METERS

Figure 4 shows a schematic of the Waipa District meter locations with the known Telemetry Tag number for the respective Meters. The system input to the WDC water supply network is managed and operated by the WTPs, where the flows and volumes of the treated water pumped into the water transmission network from the existing water treatment plants are measured.

Through the existing bulk water meters, the WTPs control the amount of treated water flow pumped into the WDC water supply network or to storage reservoirs.

At present, the bulk meter systems of the WTPs are adequate to control the input water flow to the transmission pipeline network. However, as a future consideration it is recommended that all the meters are of the same make to avoid any discrepancies in accuracy range from different manufacturers.

4 DISTRICT METER AREAS

Distribution networks have a hierarchical structure, with transmission mains branching into multiple trunk mains, trunk distribution mains and street mains.

The large pipes usually carry large flows and have few customer connections, while the street distribution mains have comparatively small flows with many customer connections. Ideally, DMAs should be fed directly from trunk distribution mains with as few customer connections upstream of the DMA meters as possible.

This arrangement:

1. Facilitates the use of single-feed DMAs, which are the easiest to track;
2. Avoids the need for large capacity meters, which are expensive and less sensitive to the low flows that may need to be measured during step tests (progressive isolation of sub-sections of the DMA to identify which ones change the night flow the most);
3. Is usually a better hydraulic solution than supplying from one or more neighbouring DMAs;
4. Eliminates the increase in the margin of error in measured supply when outflows must be subtracted from inflows.

The Waipa District Zones are fed from a network of trunk mains running mostly from West to East and East to West to North. These intersect and branch to form a connected grid between the different sources.

There are three such water supply zone clusters in Waipa District, as shown in *Figure 6*. These three clusters have been examined in the Waipa District Council, Waipa District Water Management Plan. These three clusters have been used as the basis to create smaller DMAs.

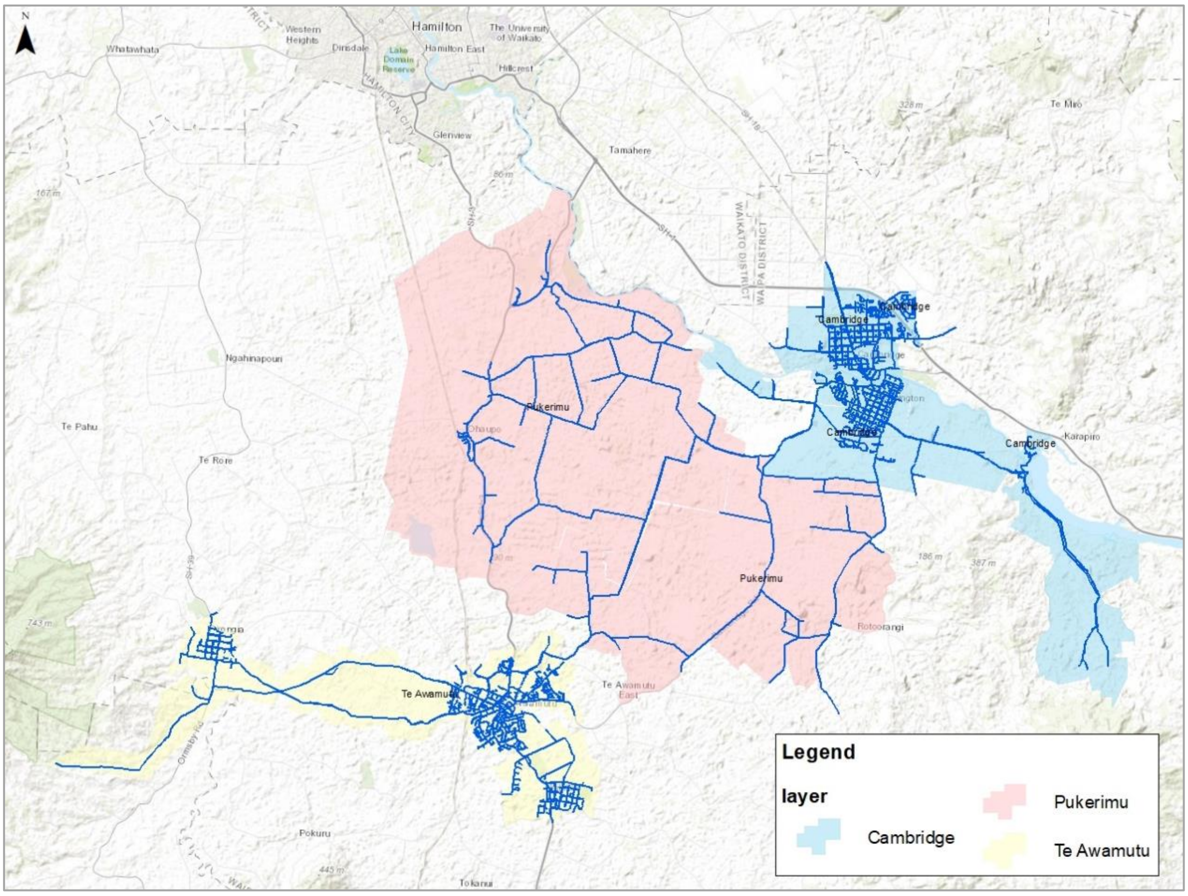


Figure 6 : The Three DMA Clusters in Waipa District

4.1 DMA DEVELOPMENT

The three DMA clusters have been split into ten clusters based on discrete water balance measurements during the model build and calibration project. These ten zones have been used as a starting point to refine and develop new smaller DMAs. The ten DMA zones are shown in *Figure 7.*

The project team have used the hydraulic models to assess current flow paths and system pressures with the network. They have also incorporated growth, and all known committed projects to assess and model new DMAs.

The ten DMA zones have now been further divided into 20 DMAs (*Figure 8*) based on the locations of existing meters and control valves within the network, whilst maintaining levels of service and determining locations for critical points (CP) within each DMA.

The list of patients on home haemodialysis requiring prior notification of planned water cuts has been provided by WDC. The addressed have been geo-coded and a GIS layer created.

The proposed 20 DMAs are presented in *Table 1*.

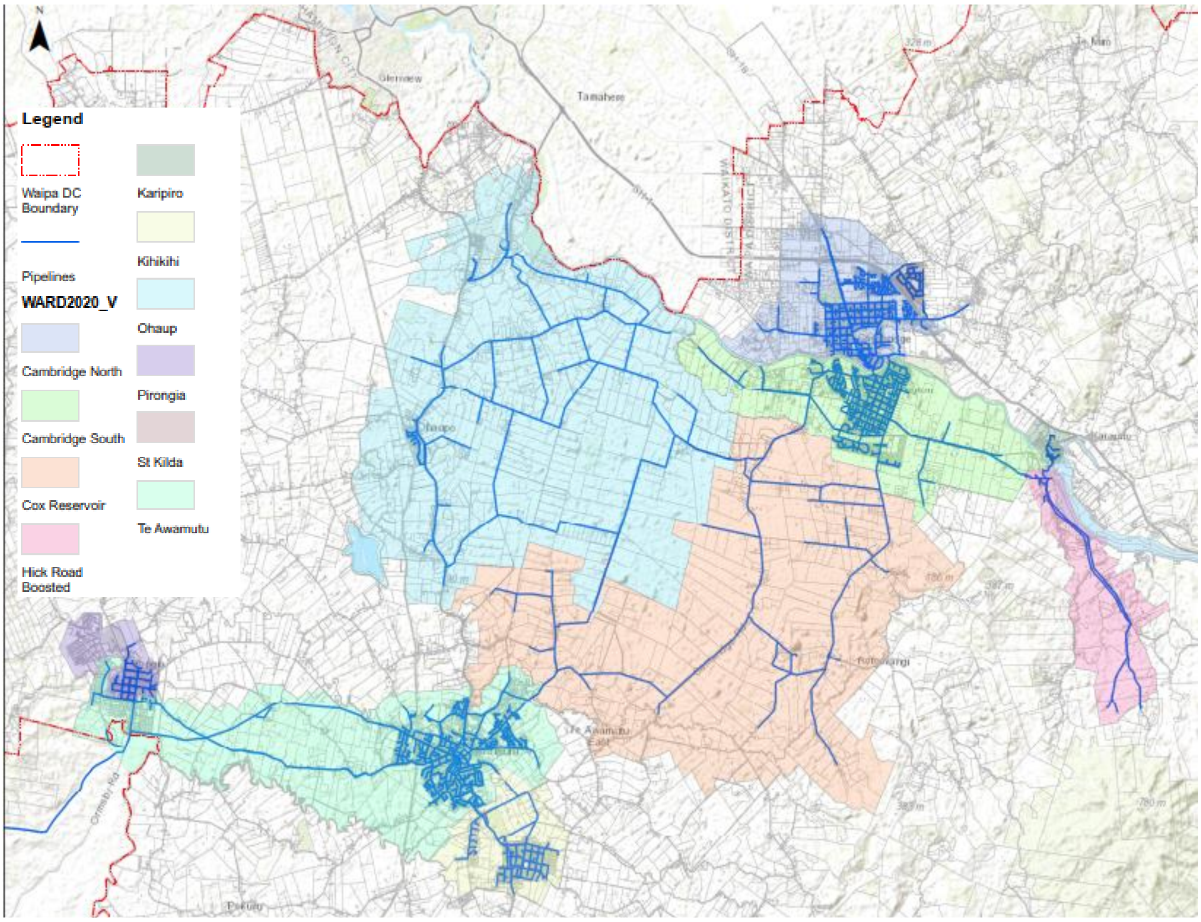


Figure 7 : The 10 DMAs within Three Clusters in Waipa District

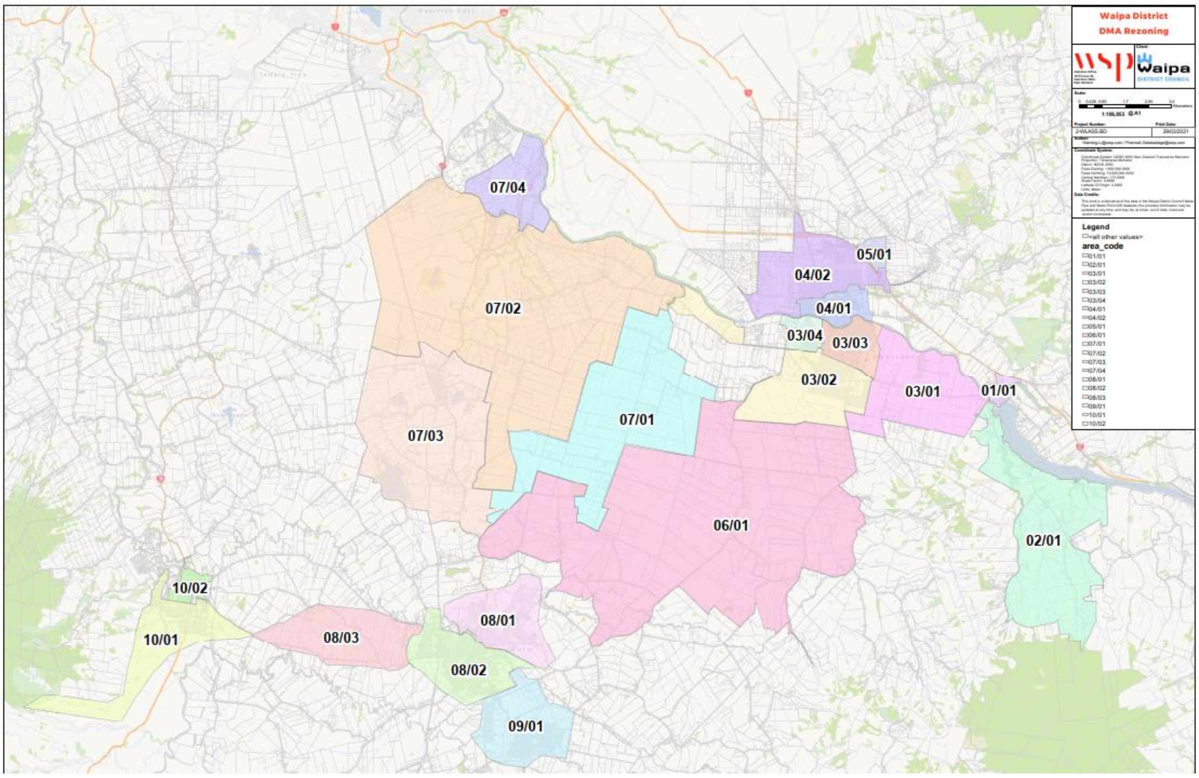


Figure 8 : The 20 New DMAs in Waipa District

Table 1 : Proposed DMA Details

ITEM	DMA NO.	DMA NAME
1	01/01	Karapiro Village
2	02/01	Hicks Road
3	03/01	Cambridge South Trunk Main
4	03/02	Cambridge South 3
5	03/03	Cambridge South 1
6	03/04	Cambridge South 2
7	04/01	Cambridge North 1
8	04/02	Cambridge North 2
9	05/01	St Kilda
10	06/01	Cox Road
11	07/01	Ohaupo 1
12	07/02	Ohaupo 2
13	07/03	Ohaupo 3
14	07/04	Ohaupo 4
15	08/01	Te Awamutu 1
16	08/02	Te Awamutu 2
17	08/03	Te Awamutu 3
18	09/01	Kihikihi
19	10/01	Te Tahi Trunk Main
20	10/02	Pirongia

Most of the cost of establishing DMAs is in the preparation of their boundaries. The most cost-effective set of DMAs will be obtained by respecting the hydraulic boundaries around and within the DMA clusters. DMAs are at least partially surrounded by other DMAs, so their boundaries are not exclusive to a single DMA but are usually shared with others. The subdivision of each cluster into DMAs is described in the following Section.

4.2 DMA HYDRAULIC ANALYSIS

The hydraulic analysis is performed to review and verify the functionality of the proposed DMAs. The approach is to isolate individual DMA by closing boundary valves while leaving the main inflow/outflow pipe open and then see whether each DMA can provide the minimum Level of Service (20.0 m head pressure) to the allocated customer points.

The minimum night flows indicated as the required demand flows for each DMA are also calculated based on the model run results. Both peak day demand and average day demand are utilised and allowed in the hydraulic analysis to provide a holistic review of the design DMAs.

Table 2 below summarises the characteristics of the proposed new DMAs. We have included existing pipe length as a supplementary measure, but this should be treated with caution as some areas have relatively few piped streets at present.

Table 2 : DMA Characteristic Summary

Current DMA	NO. OF New DMAS	BOUNDARY VALVE SUMMARY		NO. OF PROPERTIES / DMA	PIPE LENGTH / DMA (M)
		EXISTING	NEW		
Karapiro Village	1	0	0	103	3,027
Hicks Road	1	3	0	121	26,731
Cambridge South	4	17	1	870	26,818
Cambridge North	2	8	3	1,892	56,363
St Kilda	1	0	0	295	12,177
Cox Road	1	2	1	239	55,096
Ohaupo	4	0	0	173	20,699
Te Awamutu	3	0	0	1,738	48,300
Kihikihi	1	1	0	1,172	41,320
Pirongia	2	0	0	261	16,700
Total:	**20**	**31**	**5**	**6,864**	**307,231**

4.2.1 FIRE FLOW

The fire flow testing was carried out to confirm the suitability of hydrants in each DMA, to meet the required fire flow requirements.

For a hydrant to pass the fire flow test, the requirement tabulated *in Table 3* must be satisfied. In addition, the hydrants in each DMA must maintain a minimum residual pressure of 10m at maximum fire flows FW2 for residential areas (12.5 L/s).

Table 3 : Fire Flow Requirement

CODE	DESCRIPTION	REQUIREMENTS
		MIN. (L/S)
FW2	Residential	12.5

As a part of the concept design, the closed boundary valves were opened in each DMA and the fire hydrants were re-tested to assess if the fire flows can be provided. Where opening boundary valves cannot satisfy fire flow requirements, these DMAs will require upgrading the pipe sizes to improve the fire flow.

This aspect of work was not continued, because all Fire Flow assessments and improvements were identified in the 2020 3 Waters Mater Plan and WDC are addressing these in a separate commission to resolve them.

4.3 COST ESTIMATION

An estimate of budgets for the setup of the new DMAs, the proposed new flow meters and boundary valves has been carried out with estimates acquired from the suppliers based on the diameters of the flow meters and valves and discussions with WDC regarding contingencies to use.

For the cost estimates, the team have used unit costs based on diameter size for valves and meters as follows:

- Valves, Gate valves
- Meters, Electromagnetic Flow Meters.

The estimates will be further refined during the next stage of this project. The DMAs with high implementation costs will be investigated further for set up as potential Virtual DMAs to reduce costs (further investigated and discussed in the following section).

5 CONCEPT DESIGN FOR SMART NETWORKS

5.1 INTRODUCTION TO VIRTUAL DMAS

Digital solutions are transforming leak detection by offering utilities new ways to identify and help prevent leaks through advanced technologies. Instead of creating a physical hydraulic control, a vDMA maintains more flexibility.

In contrast to a traditional DMA, the monitored area of a vDMA has no strict hydraulic boundary and doesn't require actual boundary valve closing and pipe isolation, eliminating any hydraulic performance or water quality issues. Field costs are lowered as crews aren't required to work the midnight hours, also eliminating safety risks with crews having to manually open or close valves.

The concept of a vDMA is to continuously measure the flow rate and pressure at several points and compare the metered data with known or historical reference values. In addition to the metered flow data also pressure data can be used. Compared to a DMA these monitored areas have no strict hydraulic boundary.

When measuring the minimum night flow, a comparison with former metered data allows the system to identify the occurrence of new leaks. In theory, every leak will lead to a specific change in flow or pressure, but the localization of a leak will depend on the accuracy of the water meter.

A schematic of the process for vDMAs is shown below in *Figure 9.* With strategic positioning of flow meters and/or pressure loggers in the network, Virtual DMAs are established between these meters.

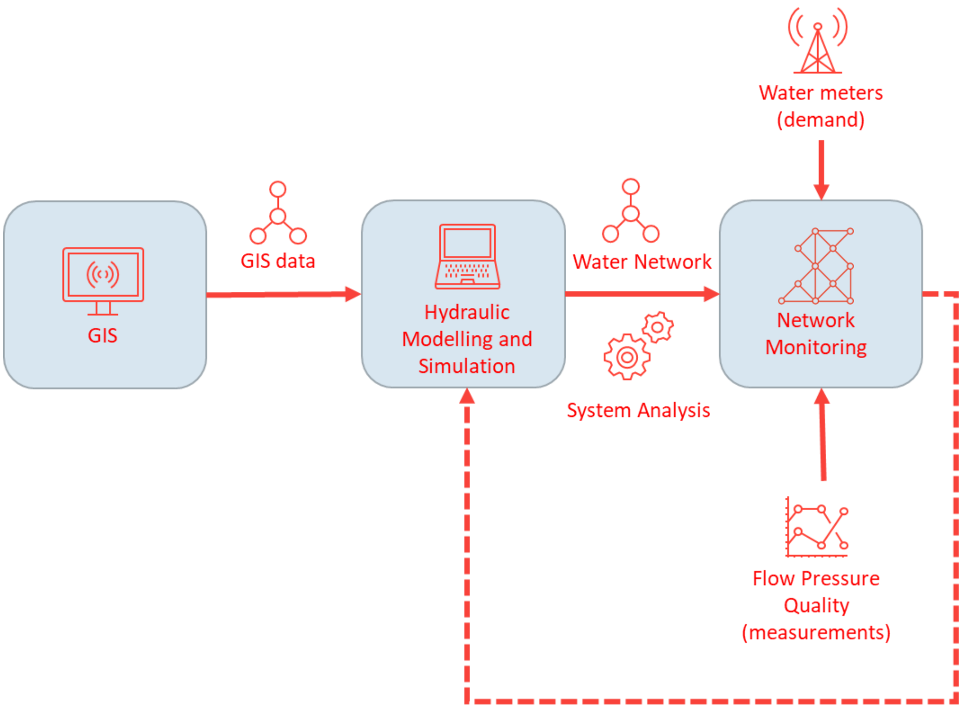


Figure 9 : Process for vDMA Demand and Leakage Management

5.2 CALCULATION OF BASELINE OF VIRTUAL DMAS

WDC intend to use buried flow meters with AOT SCADA technology. WDC will need to set up a baseline to calculate the baseline leakage in the new DMAs. Leak detection in vDMAs is a combination of network monitoring and model-based analysis.

The basic methodology of monitoring a vDMA is to continuously measure the flow rate at several points and compare the metered data with reference values. In addition to the metered flow data also pressure data can be used. Compared to a DMA these monitored areas have no strict hydraulic boundary.

When measuring the minimum night flow, a comparison with former metered data allows the system to identify the occurrence of new leaks. In theory, every leak will lead to a specific change in flow or pressure, but the localization of a leak will depend on the accuracy of the water meter.

If the system is not divided into district metered areas the meters must be positioned at hydraulically relevant points (pipes) over the distribution system to meter significant changes in the flow velocity or pressure. If these significant changes are stable for more than two or three days (nights), this change is highly likely to be based on a leakage and not the influence of customer habits. This change in flow velocity or pressure is measured by the installed meters and is relative to their hydraulic position (closeness) to the leak as shown in the figure above.

The idea is the same as a physical DMA. Flow is measured into and out of a vDMA. The vDMA total demand (what goes in minus what goes out) can be monitored accurately.

Subtracting the authorised consumption (residential and commercial demands) from the total demand will leave the non-revenue water. With this baseline set for each vDMA, monthly checks can be carried out and if there is a change, leakage teams can be deployed to find and fix leakages.

The Cambridge water balance components for 2018-19 is shown in *Figure 10* below as an example.

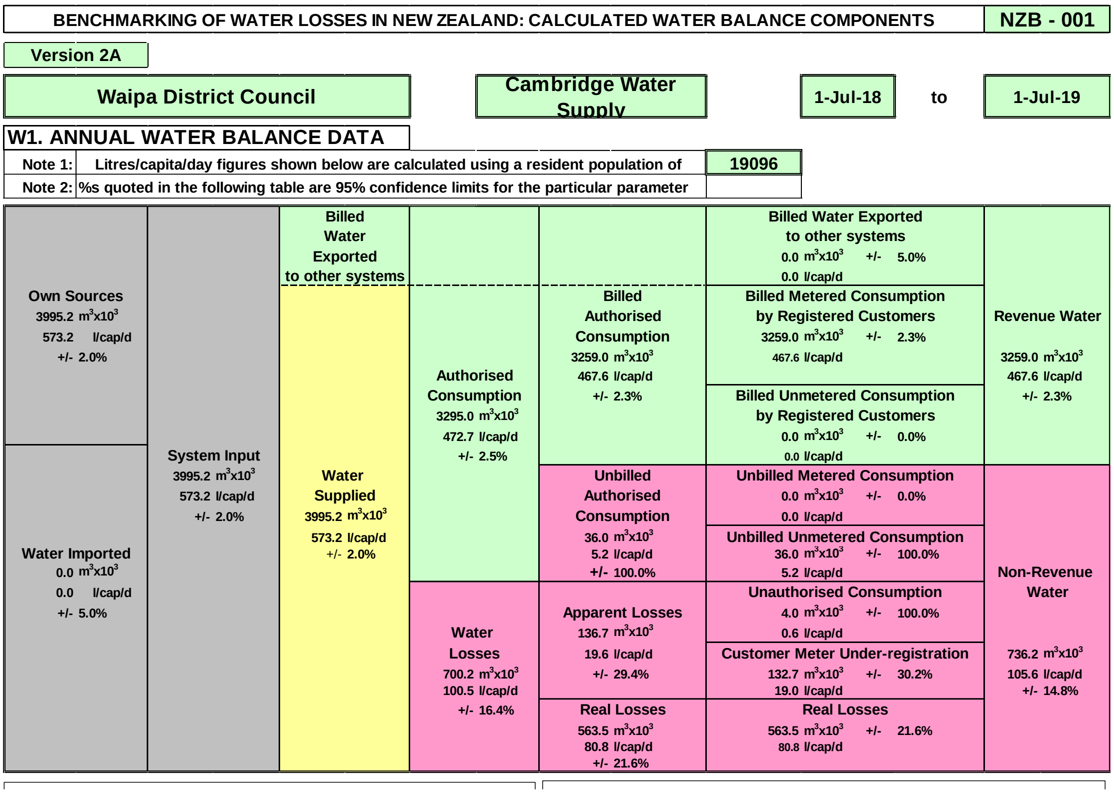
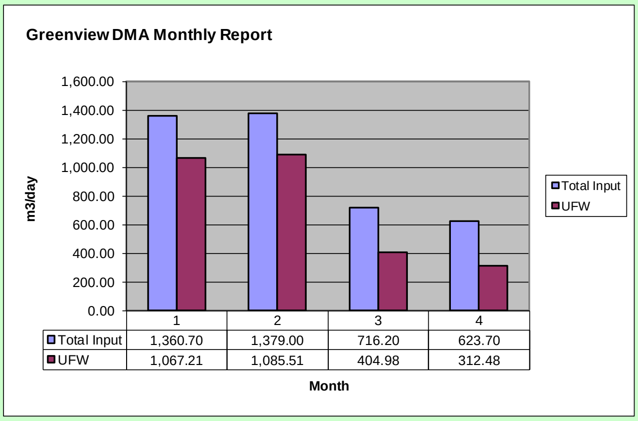


Figure 10 : vDMA Demand and Leakage Calculation Using the Water Balance Spreadsheet

Meters are normally read at regular periods, weekly or monthly, and the results analysed to determine any areas in which significant increases in supply have occurred. If no legitimate reason can be found for the increase in flow, the inspection teams sound all stopcocks, hydrants, valves and other fittings searching for the characteristic noise of leaking water.

Once set up a simple dashboard like that shown below can be set up using WDC Water Outlook to monito and reduce leakage to an acceptable limit.

Greenview DMA								Report: Jan - April 2008		
Survey Date	Total number of domestic meters	Measured Accounted for water m3/day	Total Input M3/day	Balance unaccounted for	Legitimate Night time use @ 1.7 litres/hr/prop	% UFW	MNF m3/hour	Cost of lost water @ 0.90RM/day	Annual Cost of water lost	Comments
30/01/2008	271	293.49	1,360.70	1,067.21	0.46	78.43%	44.00	RM960.49	RM350,578.49	
28/02/2008	271	293.49	1,379.00	1,085.51	0.46	78.72%	45.60	RM976.96	RM356,590.04	9 x leaks repaired this month
22/03/2008	271	311.224	716.20	404.98	0.46	56.55%	27.60	RM364.48	RM133,034.62	
25/04/2008	271	311.224	623.70	312.48	0.46	50.10%	13.85	RM281.23	RM102,648.37	



DMA data		
Meter type		6" Woltex
Number of domestic properties		271
Meters not registering		13
Successful PZT	Yes/No	Yes : March 2008
Logged ?	Yes/No	Yes : Pressure & Flow

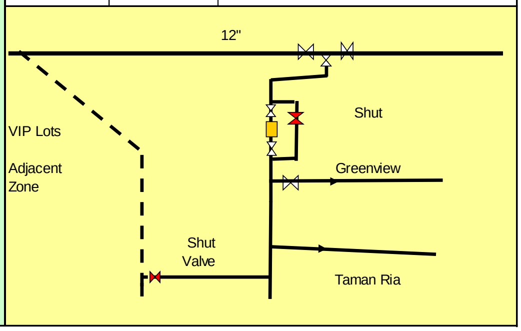


Figure 11 : Example of vDMA and DMA Monitoring Dashboard

5.3 POSSIBLE TARGET VDMAS

The project team have identified four possible candidates for vDMAs. *Table 4* below lists the details of the proposed vDMA candidates.

Table 4 : Summary of vDMA Candidates

DMA Name	DMA No.	NO. NEW BOUNDARY VALVES	NO. NEW METERS
Cambridge South 1	03/03	0	3
Cambridge North 1	04/02	3	1
Te Awamutu 1	08/01	0	5
Te Awamutu 2	08/02	0	3

The costs associated with the new boundary valves and meters for the new DMAs can be further reduced by introducing virtual metering. This means rather than installing permanent Electro Magnetic meters, using probe meters that can be fitted to logging equipment to measure and record flows and pressures. A cost benefit analysis will be carried out as part of stage 2 of this project.

6 CONCLUSIONS

The objective of the project is to demonstrate a clear alignment with WDC strategic objectives, and the process ensures a solution that will support current needs and adapt to future requirements.

The project team have reviewed current data, utilised the current hydraulic models to assess network performance, regarding WDC renewals strategy, Master Planning/AMPs, leakage reporting, and recent bulk meter strategy.

The DMA design concept criteria has been workshopped at the commencement of the project and used to design DMAs, by using the existing boundaries used for the high-level water balance and the second level of water balance used for the hydraulic models, as illustrated in *Figure 6* and *Figure 7*, respectively.

There are three water supply clusters within Waipa District including Cambridge, Pukerimu and Te Awamutu. The water supply system of Waipa District is divided in to ten main water supply zones based on discrete water balance measurements during the model build and calibration project. These ten DMAs are used as a starting point to refine and develop 20 new smaller DMAs.

The project team have assessed use of DMAs vs Virtual DMAs at those DMAs that show a large cost for implementation. There are four DMAs as detailed in Section 5.2, these will be taken into the next stage of Stage 2 Project of Proof of Concept and DMA Rollout to consider cost benefits to WDC.

Hydraulic analysis was carried out for each DMA with the new boundary valves installed, and existing boundary valves closed to isolate the DMAs. New DMA meters were installed where required to simulate the expected inflows/outflows of each DMA.

A hydraulic analysis was performed for each DMA to verify the functionality of each DMA in terms of the minimum level of service (20.0m head pressure). The hydrants in each DMA ware tested for fire flow in terms of minimum residual pressure to supply FW2 fire flow requirements. There are several DMAs where opening boundary valve to meet fire flow is not enough. These DMAs will require upgrading the pipe sizes to meet fire flow these will be assessed in the next stage of the project.

Based on the assessment and concept design completed, WDC can implement DMAs to further measure and manage the water supply and monitor and reduce leakage in the network. The next stage of this project is recommended to be approved so that the concept design can be taken to detailed design and proved on site. In parallel software and hardware recommended to monitor and report can be developed.

DMA implementation Plan – Staging of Capital projects, operational requirements, budgets, and roadmap for DMA rollout will be further developed and refined from the outcome of Phase 2 of this project.

ACKNOWLEDGEMENTS

The authors would like to acknowledge Martin Mould and Kelsi Green from Waipa District Council for the project opportunity. This project would not complete without their continuous support.

Haiming Li and Pramodi Galabadage would like to express their gratitude to Jivir Viyakesparan and Dorcas Adjei-Sasu for their guidance and technical support in completing this project.

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