

FEASIBILITY ASSESSMENT OF INTEGRATED WATER SUPPLY FOR RURAL FARMS AND URBAN RESIDENTS: EVIDENCE FROM NEW ZEALAND

ÉVALUATION DE LA FAISABILITÉ D'UN SYSTÈME INTÉGRÉ D'APPROVISIONNEMENT EN EAU POUR LES EXPLOITATIONS AGRICOLES RURALES ET LES HABITANTS DES ZONES URBAINES : LE CAS DE LA NOUVELLE-ZÉLANDE

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ABSTRACT

The Tutaenui Reservoir, located north of Marton Township in the Rangitikei District Council (RDC), New Zealand, is the primary source of drinking water for the town. Its quality is strongly influenced by rainfall, runoff, and upstream land-use activities. Key water quality issues include higher nutrient concentrations (nitrogen and phosphorus), which affect the taste, colour, and odour and promote algal growth, necessitating comprehensive treatment.

The RDC operates a conventional multi-stage treatment process to produce high-quality drinking water. However, the treated water is also supplied to 35 farms located along the 5 km channel between the Water Treatment Plant (WTP) and the Pressure Reducing Valve (PRV) at 12 Tutaenui Road. This dual-use arrangement places additional pressure on the water supply system, which is already affected by increasing water demand due to population growth and network leakage.

This study aimed to (i) quantify the proportion of treated water used by the 35 farms, and (ii) evaluate system leakage along the water main between the WTP and PRV. Five-minute interval data from two water meters—one at the WTP and another at the PRV—were collected from November 2025 to February 2026.

For farm entry-point meters, readings were collected at the same time on two consecutive days each week over five weeks to estimate daily farm water use and to improve the reliability of the result. Leakage was assessed using the Minimum Night Flow (MNF) technique, based on flows recorded between 00:00AM and 04:00AM. Total daily farm water use was estimated by subtracting leakage losses from the total outflow measured at the WTP.

The results demonstrated a significant variation in farm water use, with a single farm accounting for around 20% of the total farm consumption. In contrast, thirty-one farms collectively represented about 40% of total consumption, while four farms together consumed nearly 60%. Leakage analysis revealed that between the WTP and PRV, leakage accounted for nearly 98% of MNF, with an Infrastructure Leakage Index (ILI) of 9.1, indicating “very poor” performance according to international benchmarks. These findings indicate that supplying treated water to both urban and rural users through a single integrated system is not efficient and sustainable, as a small number of farms consume disproportionately large volumes compared to per capita urban demand.

Keywords: Treated water, rural demand, urban supply, leakage, water management.

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RÉSUMÉ

Le réservoir de Tutaenui, situé au nord de la commune de Marton dans le district de Rangitikei (RDC), en Nouvelle-Zélande, constitue la principale source d'eau potable de la ville. La qualité de cette eau est fortement influencée par les précipitations, le ruissellement et les activités d'occupation des sols en amont. Parmi les principaux problèmes liés à la qualité de l'eau figurent des concentrations élevées en nutriments (azote et phosphore), qui altèrent le goût, la couleur et l'odeur de l'eau et favorisent la prolifération d'algues, rendant ainsi nécessaire un traitement complet.

Le RDC exploite un procédé de traitement conventionnel en plusieurs étapes pour produire une eau potable de haute qualité. Cependant, l'eau traitée est également fournie à 35 exploitations agricoles situées le long du canal de 5 km reliant la station de traitement de l'eau (STE) au réducteur de pression (VRP) situé au 12, Tutaenui Road. Ce double usage exerce une pression supplémentaire sur le réseau d'adduction d'eau, déjà affecté par une demande croissante due à la croissance démographique et aux fuites du réseau.

Cette étude visait à (i) quantifier la proportion d'eau traitée utilisée par les 35 exploitations agricoles, et (ii) évaluer les fuites du réseau le long de la conduite principale entre la STE et le VRP. Des données relevées toutes les cinq minutes à partir de deux compteurs d'eau — l'un situé à la STE et l'autre au VRP — ont été collectées de novembre 2025 à février 2026. Pour les compteurs situés aux points d'entrée des exploitations agricoles, les relevés ont été effectués à la même heure pendant deux jours consécutifs chaque semaine, sur une période de cinq semaines, afin d'estimer la consommation quotidienne d'eau des exploitations et d'améliorer la fiabilité des résultats. Les fuites ont été évaluées à l'aide de la technique du débit nocturne minimal (DNM), sur la base des débits enregistrés entre 00h00 et 04h00. La consommation quotidienne totale d'eau des exploitations agricoles a été estimée en soustrayant les pertes par fuite du débit total mesuré à la station de traitement d'eau.

Les résultats ont mis en évidence une variation significative de la consommation d'eau des exploitations agricoles, une seule exploitation représentant environ 20 % de la consommation totale. En revanche, trente et une exploitations représentaient collectivement environ 40 % de la consommation totale, tandis que quatre exploitations consommaient à elles seules près de 60 %. L'analyse des fuites a révélé qu'entre la station de traitement et le régulateur de pression (VRP), les fuites représentaient près de 98 % du DNM, avec un indice de fuite des infrastructures (IFI) de 9,1, ce qui indique une performance « très médiocre » selon les références internationales. Ces résultats indiquent que l'approvisionnement en eau traitée des usagers urbains et ruraux par un système intégré unique n'est ni efficace ni durable, car un petit nombre d'exploitations agricoles consomment des volumes disproportionnés par rapport à la demande urbaine par habitant.

Mots-clés : Eau traitée; Demande rurale; Approvisionnement urbain; Fuites; Gestion de l'eau.

1 Introduction

Communities worldwide face increasing water supply challenges due to growing demand, climate variability, drought, contamination, and over-reliance on a single water source (Miller, 2006; World Health Organization, 2017; United Nations, 2023;). In response, water reclamation and reuse have emerged as key strategies to address these challenges by resolving water resource constraints and creating new sources of high-quality water. These strategies include the reuse of treated wastewater, agricultural return flows, stormwater, industrial effluents, as well as desalination of seawater and brackish groundwater (Food and Agriculture Organization, 2020; International Water Association, 2018).

Surface water reservoirs remain critical component of drinking water supply systems, particularly in regions dependent on catchment runoff. However, such sources are highly vulnerable to physiochemical and microbiological contamination, necessitating robust treatment prior to consumption (Katsanou and Karapanagioti, 2017; World Health Organization, 2017). Following treatment, the quality of surface water must meet drinking water standards to ensure it is safe and acceptable for use. Key processes in surface

water treatment typically include coagulation (the addition of chemicals to aggregate suspended particles), flocculation (gentle mixing to form larger flocs), sedimentation (settling of solids), gravity sand filtration, Ultraviolet disinfection, and chlorination. Collectively, these processes ensure quality compliance of drinking water to safeguard public health (Katsanou and Karapanagioti, 2017; World Health Organization, 2017).

Integrated water supply systems, in which treated water is distributed across multiple sectors, are generally adopted to optimize the treatment costs supporting the long-term sustainability of water supplies. Globally, treated water is utilised for potable water supply, irrigation, industrial uses, groundwater recharge, and aquifer storage (International Water Association, 2018; Food and Agriculture Organization, 2020).

In some contexts, including New Zealand, this integration extends to supplying treated drinking water to rural farms and also urban users. While access to high-quality water can improve livestock health and productivity (Schütz, 2012), the use of fully treated potable water for agricultural purposes may not always be economically attractive, particularly where lower-quality alternatives are available (Benny, 2022).

The effectiveness of integrated water supply systems depends not only on the adequacy and reliability of source water and the efficiency of treatment processes, but also on how water is allocated among competing users. Supplying treated water to both rural farms and urban residents within a single system can introduce competing demands, potentially reducing the reliability of urban supply during peak demands. Such allocation challenges are central to integrated water resource management, where balancing agricultural and domestic needs are critical for maintaining appropriate equilibrium among all users. In addition, system performance can be significantly constrained by physical losses, particularly leakage in distribution networks. Leakage reduces the effective volume of water available to consumers, increases operational and treatment costs, and undermines overall system efficiency.

The Marton water supply system in New Zealand exemplifies an integrated approach, whereby surface water stored in the Tutaenui Reservoir is treated at the Water Treatment Plant (WTP) located upstream of the town and distributed to both urban consumers and rural farms. This study evaluates the performance of this system by quantifying the proportions of treated water consumed by 35 farms along the 5.5 km transmission main between the WTP and the PRV at 12 Tutaenui Road and assessing leakage between the WTP and the PRV. The findings aim to inform more efficient and sustainable water management strategies for the Rangitikei District Council (RDC) and other regions facing similar challenges.

2 METHODOLOGIES

2.1 Study area

Rangitikei District Council (RDC) supplies treated water to 35 farms located along the water supply main between the Water Treatment Plant (WTP) and the Pressure Reducing Valve (PRV) stationed at 12 Tutaenui Road, Marton (Figure 1). This creates significant water demand pressure on the system, placing considerable strain on the treatment plant, particularly during summer periods. As a result, the system struggles to maintain a required and consistent supply of high-quality treated water for all users during peak demand.

This study focussed on the section of the network supplying the 35 farms, with the objectives of estimating on-farm water use and assessing leakage losses along the water main. In addition, total water use within the Marton Township was estimated to determine the proportion of overall treated water consumption attributable to the farms.

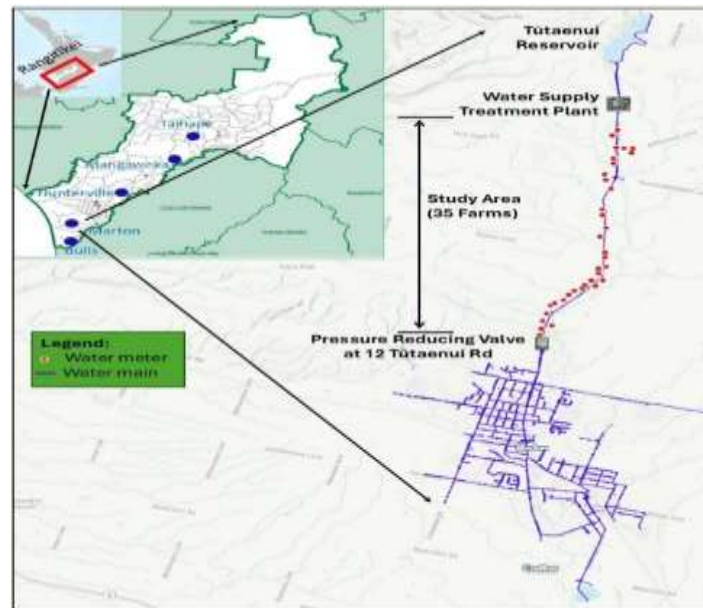


Figure 1. Study area in Marton showing the locations of 35 water meters supplying 35 farms.

2.2 Estimating on-farm water use

Flow monitoring across the network was conducted using automatic water meters installed at the WTP, the PRV, and at 35 water meters located at the supply points to each farm between the WTP and the PRV. Flow rate data at the WTP are available through the SCADA system, with recording intervals of 1, 3, 5, 10, 15, and 30 minutes, as well as 1 hour and 1 day. The automatic water meter at the PRV was configured to record data at any interval from 1 minute to 1 day; for this study, the recording interval was set to 5 minutes. Accordingly, 5-minute interval data from both the WTP and PRV were collected from November 2025 to February 2026.

Water consumption between the WTP and PRV was estimated by subtracting the flow recorded at the PRV from the flow recorded at the WTP. The water meters at the farm points required manual readings, making the collection of short-interval data labour-intensive. Therefore, readings at the farm points were recorded at the same time on two consecutive days each week over five weeks to estimate daily farm water consumption and improve the robustness and confidence of the results.

2.3 Assessing leakage losses

The Minimum Night Flow (MNF) technique was used to estimate leakage in the water main between the WTP and the PRV. This widely used technique is based on the principle that during late-night hours, when legitimate water demand is at its lowest, most of the flow in the system is likely to be lost due to leakage.

The leakage estimation procedure was as follows:

- Step 1: Identify the Night-Time Period of Low Demand. Analysis of the five-minute interval flow data recorded at the WTP and PRV station showed that the minimum flow in this system occurs between 1:00 a.m. and 4:00 a.m.
- Step 2: Measure Minimum Night Flow. From the analysis in Step 1, the lowest flow rate (litres/sec) observed between 1:00 a.m. and 4:00 a.m. was identified as the Minimum Night Flow (MNF).

- Step 3: Correct MNF for Legitimate Night-Time Use. Some night-time flow may be due to authorized uses. In this study, the actual night water use as 1.4 L/s for unmetered residential properties and 1.8 L/s for large water users were taken from works of Lambert, A. & Taylor, R. (2010). This legitimate night-time use was subtracted from the MNF to estimate leakage losses. Finally, leakage was expressed as a percentage of total supply by comparing it with the flow rate at the WTP.

2.4 Estimating water use in Marton Township

The total number of residential connections in Marton was 2,256, of which 204 were unoccupied. Assuming an average household size of 2.5 persons per occupied dwelling, the net population supplied with water was estimated. A per capita water use rate of 250 L/person/day was applied to calculate total daily water consumption for unmetered residential users.

In addition, four large water users in Marton were individually metered, and their daily water use was obtained directly from their metered records. The estimated residential water use was then combined with the metered consumption of the large users to determine the total daily water demand for Marton. This total demand was subsequently compared with the flows measured at the WTP and PRV to estimate Marton's water consumption as a percentage of the supply from the WTP and the PRV.

3 Results and Discussion

3.1 Water treatment process

The Marton Water Treatment Plant draws raw water from the two Marton reservoir. During the dry summer months, when water consumption in town is at its peak, water levels in the reservoir drop, resulting in significant algae blooms. These blooms release geosmin, an earthy-smelling chemical byproduct, causing taste and odor issues in the water. Additionally, routine hydrant and pipe flushing to remove sediment from the network can temporarily cause the water to appear brown. To address these challenges and produce drinking water that complies with New Zealand Drinking Water Standards, the RDC employs a multistage treatment process incorporating both physical and chemical purification methods, as described below.

- *Coagulation.* The coagulation process involves adding chemicals called coagulants, such as aluminium sulphate (alum) or ferric chloride, to raw water to remove fine suspended particles. These particles are usually too small to settle on their own because they carry negative electrical charges that keep them dispersed. When a coagulant is added, it neutralizes these charges, allowing the particles to come together and form larger clumps known as flocs.
- *Clarification / Sedimentation.* The flocculated water then enters a clarification or sedimentation stage where heavier flocs settle out by gravity. This reduces the turbidity and removes a significant portion of suspended solids and organic matter from the water.
- *Filtration.* After clarification, water passes through physical filters — typically through sand media — that further remove residual suspended solids and remaining fine particles that escaped earlier treatment.
- *Ultraviolet (UV) Disinfection.* In recent years, no bacteriological non-compliance events have been recorded. However, achieving protozoal compliance remains more challenging. To address this, filtered water is treated with ultraviolet (UV) light, which destroys protozoa and other pathogens. UV disinfection is a chemical-free method that inactivates microorganisms—including bacteria, viruses, and protozoa—by damaging their DNA, thereby preventing reproduction and infection.

- *Chlorination.* Following UV treatment, a chlorine residual is added to the water to inactivate pathogenic microorganisms. Chlorination also ensures that the water maintains ongoing disinfection effectiveness as it travels through the reticulation network to consumers.
- *Distribution to Network.* Treated water is stored in a reservoir and then supplied to the Marton distribution network where it meets NZ Drinking Water Standards. Regular monitoring and testing confirm water safety even during seasonal quality fluctuations (e.g., taste/odour).

3.2 On-farm Water Usage

3.2.1 Daily On-farm Water Usage

As shown in Figure 2, based on daily data measurements, significant spatial variability was observed in daily farm water usage. Percentile analysis revealed that nearly 59% of the farms used less than 1 m³/day, 21% used between 1 and 2 m³/day, 9% used between 2–4 m³/day, and the remaining 12% used more than 4 m³/day. Notably, a single farm accounted for 20% of the total farm water use. In contrast, thirty-one farms collectively accounted for only about 40% of the total water consumption, while four farms consumed approximately 60% of the total consumption.

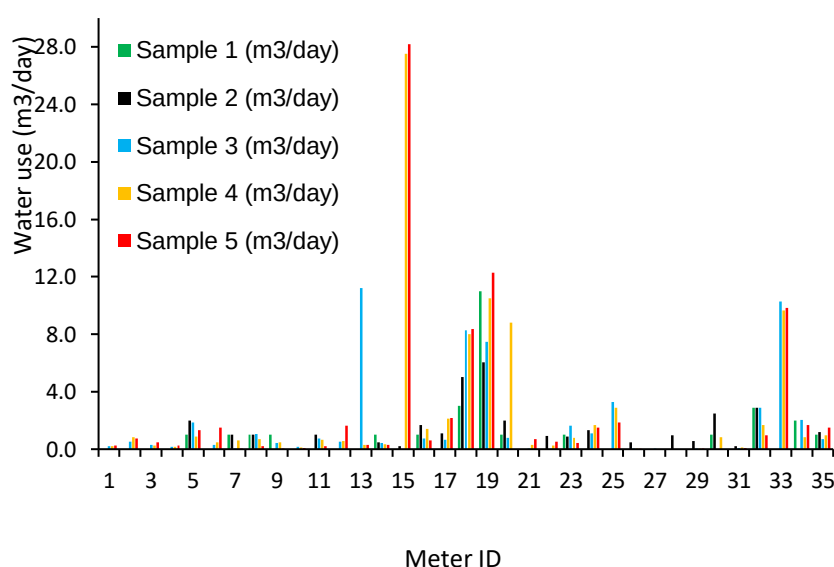


Figure 2. Spatial and Temporal Variability in Farm Water Use Across 35 Water Meters Based on Daily Data

Daily farm water usage also exhibited substantial temporal variability. On certain monitoring days, some farms recorded no water use, whereas on other days the same farms consumed significant volumes. Farms that recorded no water use on some days but high volumes on others may have been filling water storage tanks. However, identifying the specific purpose of water use was beyond the scope of this study, which focused on total water consumption rather than the purpose of use.

Overall, both spatial and temporal variability in daily farm water usage were closely linked to weather conditions, highlighting the influence of environmental factors on water demand. The first and second sampling days experienced light rainfall, resulting in total farm water use far below that of the other three sampling days, which were sunny. Total water use for the five monitoring days was 28.9, 33.5, 57.9, 85.2 and 78.1 m³/day, respectively.

As shown in Table 1, almost 6% of the treated water is used between the WTP and the PRV. Of this amount, approximately 3% is supplied to farms, while about 3% appears to be lost in that section, likely due to leakage. This indicates the need to investigate the location of potential leaks and implement appropriate corrective measures to ensure more efficient water use.

Table 1: Water Use Between the Water Treatment Plant (WTP) and Pressure Reducing Valve (PRV) Based on Daily Data Measurements

Sample number	Sample Collection Date	Farm water use (m3/day)	Water Treatment Plant (WTP) Outflow (m3/day)	Pressure Reducing Valve (PRV) Outflow (m3/day)	Volume of treated water used between WTP and PRV (m3/day)	% of treated water used between WTP and PRV	% of treated water actually used on the farm
Sample 1	15 & 16 Jan 2026	28.9	2,030	1,959	70.9	3%	1%
Sample 2	21 & 22 Jan 2026	33.5	2,070	1,943	126.8	6%	2%
Sample 3	29 & 30 Jan 2026	57.9	2,426	2,304	122.5	5%	2%
Sample 4	11 & 12 March 2026	85.2	2,485	2,282	202.8	8%	3%
Sample 5	19 & 20 March 2026	78.1	2,325	2,123	202.4	9%	3%
Average		56.7	2,267	2,122	145.1	6%	3%

3.2.2 Weekly On-farm Water Usage

As shown in Figure 3, similar to the daily water usage results, significant spatial variability was also observed in weekly farm water usage based on weekly data measurements. Percentile analysis revealed that 59% of the farms used less than 7 m³/week, 15% used between 7 and 14 m³/week, 12% used between 14–21 m³/week, and the remaining 15% used more than 21 m³/week.

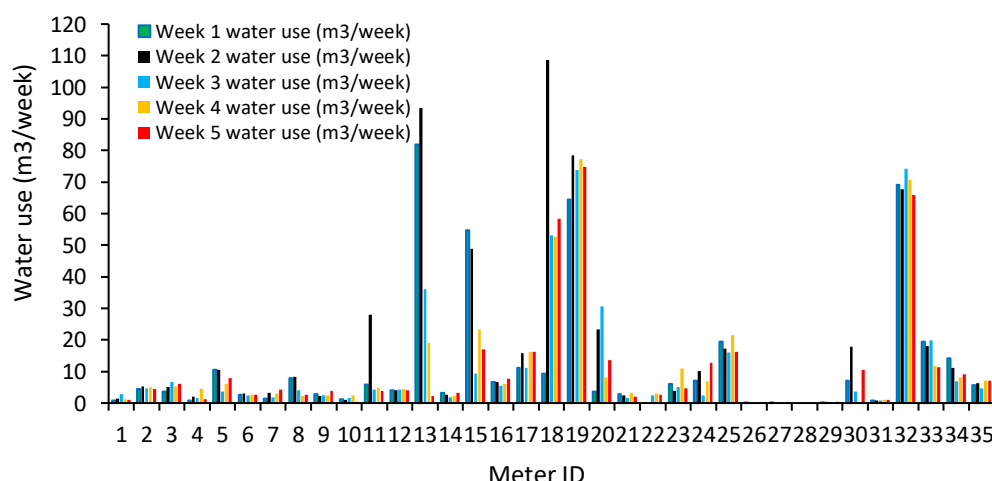


Figure 3. Spatial and Temporal Variability in Farm Water Use Across 33 Water Meters Based on Weekly Data

Notably, a single farm accounted for nearly 20% of the total farm water use. In contrast, thirty farms collectively accounted for only 40% of the total water consumption, while five farms used approximately 60% of the total consumption. Unlike the temporal variability observed in daily water use, weekly farm water use exhibited relatively uniform patterns, suggesting that demand tends to stabilise and balance out over a weekly cycle. As shown in Table 2, almost 14% of the treated water is used between the WTP and the PRV. Of this amount, approximately 3% is supplied to farms, while nearly 11% appears to be lost in that section, likely due to leakage. This suggests the need to investigate potential leakage locations and implement corrective measures to improve water use efficiency.

Table 2: Water Use Between the Water Treatment Plant (WTP) and pressure reducing Valve (PRV) Road Based on Weekly Data Measurements

Sample number	Sample Collection Date	Farm water use (m3/day)	Water Treatment Plant (WTP) Outflow (m3/day)	Pressure Reducing Valve (PRV) Outflow (m3/day)	Volume of treated water used between WTP and PRV (m3/day)	% of treated water used between WTP and PRV	% of treated water actually used on the farm
Sample 1	29 Jan to 5 Feb 2026	433	16,201	13,870	2,330	14.4%	2.7%
Sample 2	5 to 12 Feb 2026	607	17,222	13,733	3,488	20.3%	3.5%
Sample 3	12 to 19 Feb 2026	399	15,696	12,824	2,872	18.3%	2.5%
Sample 4	19 to 26 Feb 2026	393	16,303	14,053	2,250	13.8%	2.4%
Sample 5	12 to 19 March 2026	379	15,894	15,319	574	3.6%	2.4%
Average		442	16,263	13,960	2,303	14.2%	2.7%

Table 3 indicates that daily data measurements are more appropriate for analysing the spatial and temporal variability of farm water use. However, if the objective is to obtain a more balanced estimate of overall water usage, data collected on a weekly basis are more suitable. Therefore, the estimate that 14% of treated water is used between the WTP and the PRV, based on weekly data measurements, represent a more realistic figure than the 6% estimated from daily data measurements. Both measurement approaches indicate only 3% of the treated water used by the farm, indicating significant water loss between the WTP and the PRV, suggesting the presence of considerable leakage in this section of the system.

In the context of the 35 farms studied, the primary concern is not the total volume of water use but the variability in consumption across farms. A small proportion of farms accounts for disproportionately high-water use, indicating a skewed distribution of demand. This finding highlights a targeted opportunity to engage with a limited number of high-usage farms to identify and implement measures that improve water-use efficiency.

Table 3: Comparison of Average Water Use Based on Daily and Weekly Data Measurements

Data Measurement Period	Farm water use (m3/day)	Water Treatment Plant (WTP) Outflow (m3/day)	Pressure Reducing Valve (PRV) Outflow (m3/day)	Volume of treated water used between WTP and PRV (m3/day)	% of treated water used between WTP and PRV	% of treated water actually used on the farm
Average Daily Figures from Daily Data	56	2,267	2,122	145	6%	3%
Average Weekly Figures from Daily Data	397	15,873	14,857	1,015	6%	3%
Average Weekly Figures from Weekly Data	442	16,263	13,960	2,303	14%	3%
Average Daily Figures from Weekly Data	63	2,323	1,994	329	14%	3%

3.3 Identification of High Water-Use Farms

Based on daily water measurements, 31 farms each accounted for less than 4% of total water use, while the remaining four farms (farm meter ID 15, 18, 19 and 33) each consumed more than 10%. Similarly, weekly measurements show that 30 farms each accounted for less than 4% of total water use, whereas the remaining five farms (farm meter ID 13, 15, 18, 19 and 32) each consumed more than 7%. On this basis, six farms (farm meter ID 13, 15, 18, 19, 32 and 33) have been identified as high water users, as illustrated in Figure 4.



Figure 4. Six high water using farms, based on daily and weekly measurements

3.4 Leakage Estimation

An Excel-based model was developed to estimate leakage rates over a four-month period (November 2025 to February 2026). Leakage was quantified using the MNF approach, based on measurements obtained at the PRV and at the WTP. The methodology and results are presented below.

3.4.1 Leakage Estimation Based on MNF measured at the PRV Site

Table 4 presents the estimated Net Night Leakage Rate (NLR) derived from MNF measurements at the PRV. The MNF at the PRV was 9.9 L/s. Other input parameters were obtained from Rangitikei District Council (RDC) internal records and relevant guidelines published by Water New Zealand. After accounting for legitimate night-time consumption—including unmetered residential use and large water users—the NLR was estimated at 6.9 L/s. This indicates that approximately 70% of the measured MNF was attributed to leakage.

Table 4: Net Night Leakage Rate based on MNF measured at PRV site

Parameters	Values	Units		
Number of service connection (house) in Marton (Nc)	2,052	L/s	m3/hr	Litres/conn/ hour
Number of Large Water Users	4.0			
Length of water mains (Lm) in km)	5.5			

Average length measured from the main to the customer meter (lp) in km	0.2			
Average Night Pressure (P) in metres (kPa/10)	60.0			
Minimum Night Flow (MNF)	9.9	35.5	17.30	
Actual Night Water Use by unmetered residential properties (ANWUbyURP)	1.1	4.1	2.00	
Actual Night Water Use by Large Water User's (ANWUbyLWU)	1.8	6.51	1,626	
Net Night Leakage Rate (NLR) = MNF -ANWU-ANWUbyLWU	6.9	24.9	12.1	

The NLR was subsequently converted to a daily leakage rate using a night-to-day factor of 22.8. As shown in Table 5, the estimated daily leakage was 567 m³/day, equivalent to 276 L/connection/day.

Table 5: Net Daily Leakage Rate estimated based on MNF measured at Tutaenui PRV site

Parameters	m3/hour	Hour/day	m3/day	Litres/conn/ day
Night Leakage Rate	24.9			
Night Day Factor		22.8		
Daily leakage			567	276

The Infrastructure Leakage Index (ILI) was calculated to evaluate system performance. The ILI is defined as the ratio of actual losses to unavoidable losses. As presented in Table 6, the ILI for the study area was estimated at 5.7.

Table 6: Calculation of infrastructure leakage index (ILI)

Parameters	L/s	m3/hr	Litres/conn/ hour
Night leakage rate	6.9	24.9	12.10
The Unavoidable Real Losses (URL)	1.2	4.4	2.12
Infrastructure leakage index (ILI)	5.7	5.7	5.7

Comparison of the calculated ILI value with international performance benchmarks (Table 7) indicates that the system falls within the “poor leakage” category. This suggests that significant improvements are required, including enhanced leakage detection, pressure management, and network maintenance.

Table 7: International Leakage Performance Categories (World Bank Institute (2005))

ILI range	Calculated	Remarks
Less than 2		Further loss reduction may be uneconomic
2 to < 4		Potential for improvements; consider pressure management, and network maintenance
4 to < 8	5.7	Poor leakage, intensify leakage reduction efforts
8 or more		Very inefficient use of resources; leakage reduction programs imperative and high priority

3.4.2 Leakage Estimation Based on MNF measured at the WTP and PRV

In this approach, the MNF measured at the PRV was subtracted from the MNF recorded at the WTP, resulting in a residual MNF of 0.82 L/s for the pipeline section between the WTP and the PRV site. The subsequent analysis followed the same methodology described in Section 3.4.1. The NLR estimated for this section was 0.8 L/s. This indicates that approximately 98% of the measured MNF in this section was attributed to leakage. The ILI for this pipeline segment was calculated as 9.1. When compared with international leakage performance benchmarks, this value falls within the “very poor” category (ILI ≥ 8). This classification indicates a highly inefficient use of water resources and highlights the urgent need for

targeted leakage reduction measures, including active leak detection, pressure management, and infrastructure renewal.

3.4.3 Summary of Leakage Estimates

Table 8 summarizes the MNF, NLR, leakage as a percentage of MNF, and ILI for the four monitoring months. The results are presented separately for the section between the WTP and the PRV, and for the network downstream of the PRV station. As shown, the section between the WTP and PRV exhibits significantly higher leakage compared to the downstream network. This segment demonstrates extremely inefficient water use, with NLR accounting for approximately 98% of the MNF and ILI values consistently above 9. These findings indicate that immediate intervention is required to reduce losses in this section.

Table 8: Summary of MNF, Net Night Leakage, and Infrastructure Leakage Index (ILI) for four monitoring months

Description	Based on the MNF at WTP and PRV (WTP - PRV)				Based on the MNF at PRV			
	Nov-25	Dec-25	Jan-26	Feb-26	Nov-25	Dec-25	Jan-26	Feb-26
Minimum Night Flow (MNF) (L/s)	0.8	1.0	1.0	0.9	9.9	10.4	10.6	9.9
Net Night Leakage Rate (NLR) (L/s)	0.8	1.0	1.0	0.9	6.9	7.4	7.7	7.0
Net Night Leakage Rate (NLR) (Litres/connection/ day)	1,775	2,134	2,154	1,979	290	311	321	294
Leakage as percentage of MNF flow (%)	98%	98%	98%	98%	70%	72%	72%	70%
Infrastructure leakage index (ILI)	9.1	10.9	11.0	10.1	5.7	6.1	6.3	5.8

4 CONCLUSIONS

This study provides a comprehensive assessment of water supply, farm water use, and system leakage within the Marton water supply distribution network. Analysis of the existing surface water treatment process revealed recurring taste, odour, and colour issues, primarily driven by seasonal algal blooms associated with nutrient enrichment. On-farm water use exhibited substantial spatial and temporal variability, with a small subset of farms consuming disproportionate shares of total water. Daily measurements indicated that approximately 6% of treated water supplied between the WTP and the PRV is delivered to farms, of which only about 3% is directly consumed on-farm. Weekly measurements suggested an even higher loss of approximately 14%, indicating significant leakage within this section.

Leakage analysis using the MNF approach revealed critical inefficiencies in the distribution network. Downstream of the PRV, leakage accounted for approximately 70% of MNF, with an ILI of 5.7, classifying the system as having “poor” leakage performance. Between the WTP and PRV, leakage was more severe, representing nearly 98% of MNF and yielding an ILI of 9.1, indicating “very poor” performance according to international benchmarks. These findings highlight the urgent need for targeted leakage management strategies, including active leak detection, pressure management, and pipeline renewal.

Overall, the study demonstrates that the Marton water supply system faces concurrent challenges related to source water quality, distribution network inefficiencies, and variable on-farm demand. Effective water management will require a combination of infrastructure upgrades, optimisation of treatment processes, and comprehensive leakage reduction programmes.

5 WAYS FORWARD

Among the 35 meters analysed, several were associated with farms where water use was likely dominated by livestock drinking, cleaning, and disinfection activities rather than feed production. Although this aspect was beyond the scope of the present study, further investigation into the distribution of on-farm water use would be valuable, particularly to quantify the proportions allocated to animal drinking and cleaning operations. In New Zealand pasture-based dairy systems, these technical water uses are generally lower than those reported for stall-fed systems. For example, regional guidelines for the Marton area recommend an allowance of 45 L cow⁻¹ day⁻¹ for drinking water (Bennett, 2022), compared with average consumptions of 91.1 and 54.4 L cow⁻¹ day⁻¹ reported for automatic milking and herringbone systems, respectively, in North-East Germany (Krauß et al., 2016). Similarly, cleaning water demand in New Zealand systems has been estimated at approximately 30 L cow⁻¹ day⁻¹ (Bowler & Longhurst, 2020), which is comparable to values reported in Germany. These findings suggest that technical water use within farm infrastructure contributes relatively little to total dairy water demand compared with feed production, which may have a water footprint of approximately 170 L cow⁻¹ day⁻¹.

Water availability and quality are both important determinants of dairy productivity, although water quantity appears to exert the stronger influence. Daros et al. (2019) reported that herds with unrestricted access to drinking water produced, on average, 1.7 L more milk cow⁻¹ day⁻¹ than herds with restricted access, while Holstein herds produced 2.8 L more milk cow⁻¹ day⁻¹ than non-Holstein herds ($p < 0.01$). These findings highlight the importance of adequate water supply and herd characteristics in influencing production outcomes. Further research examining the relationship between farm water use, management practices, and productivity would therefore be beneficial.

References

- Benadie, A. 2021. Asset Management Plan - 3 Waters – 2021-2031. Rangitikei District Council. Available from: [Asset-Management-Plan_Three-Waters-2021-31.pdf](#)
- Bennett, L. 2022. Stock Drinking Water Requirements. Horizons Regional Council, Aqualinc Report. Aqualinc Research Ltd. Available from: freshwater.horizons.govt.nz/?a=3439
- Benny T. 2022. Cows prefer bore water over town supply. Available from: [Cows prefer bore water over town supply | LIC](#)
- Bowler, L., & Longhurst, B. 2020. Using green water for yard washing: case study of a manawatu dairy farm. Available from: [Paper_Bowler_2020.pdf](#)
- Daros, R. R., Bran, J. A., Hötzel, M. J., & von Keyserlingk, M. A. 2019. Readily available water access is associated with greater milk production in grazing dairy herds. *Animals*, 9(2), 48.
- Food and Agriculture Organization. 2020. Water reuse in agriculture: Practices and guidelines.
- International Water Association. 2018. Water reuse and water loss management guidelines.
- KC, B., Benadie, A., Schultz, B., Prasad, K., and Pandey, VP. 2025. Spatio-temporal variability in inflow and infiltration into sewer networks under different soils. 4th World Irrigation Forum (WIF4), 7-13 September 2025, Kuala Lumpur, Malaysia.
- Katsanou, K., & Karapanagioti, H. K. 2017. Surface water and groundwater sources for drinking water. In *Applications of advanced oxidation processes (AOPs) in drinking water treatment* (pp. 1-19). Cham: Springer International Publishing.
- Krauß, M., Drastig, K., Prochnow, A., Rose-Meierhöfer, S., & Kraatz, S. 2016. Drinking and cleaning water use in a dairy cow barn. *Water*, 8(7), 302.
- Lambert, A. & Taylor, R. 2010. Water Loss Guidelines. Prepared for: Water New Zealand. Available from: [WATER LOSS GUIDELINES](#)
- Miller, G. W. 2006. Integrated concepts in water reuse: managing global water needs. *Desalination*, 187(1-3), 65-75.
- Rangitikei District Council (RDC). 2021. Rangitikei District Council – Asset Management Plan - 3 Waters – 2021-2031. Available from: [Asset-Management-Plan_Three-Waters-2021-31.pdf](#)
- Schütz, K. 2012. Effects of providing clean water on the health and productivity of cattle. Report for NRC, 400, 346.
- United Nations. 2023. World Water Development Report.
- World Bank Institute (2005): NRW Training Module 6: Performance Indicators
- World Health Organization. 2017. Guidelines for Drinking-water Quality.