Does the quality of drinking water (bore vs. town supply) influence water intake, milk production and animal preferences by dairy cattle?

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REPORT FOR OUR LAND AND WATER (OLW)

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Contents

1. Executive Summary

- Water intake and feed intake are closely related in cattle, thus conditions that restrict water intake are likely to influence production.

- Cattle are sensitive to water contamination, for example with manure, however, there is little evidence of how cows perceive bore water that sometimes contain high concentrations of natural contaminants, such as iron and manganese.

- There is anecdotal evidence from New Zealand that changing drinking water from unfiltered to filtered bore water increase production, however, this has not been demonstrated scientifically.

- The aim of this study was to investigate if providing water of high quality (town supply) compared with unfiltered bore water, high in iron and manganese, will increase water intake and milk production in dairy cattle. A further aim was to investigate animal preferences for these water sources.

- Four groups of cows (50 cows/group) managed on pasture were offered either town supply water or unfiltered bore water for two weeks, before changing the water treatment for another two weeks in a cross-over design. During this period, group water intake and individual milk production was measured daily (n=4 groups/treatment).

- A small preference study on a subset of animals was undertaken after the four weeks initial trial period. Two groups of cows (n=2, 20 cows/group) were offered both water sources simultaneously for three days during which group water intake was recorded.

- Drinking water treatment did not influence water intake or milk production ($P \geq 0.641$), however, cows preferred to drink the unfiltered bore water compared to town supply in the preference study (descriptive data). It is likely that previous experience of cows to drink the unfiltered bore water influenced the results as this was the main source of drinking water on the farm. It is also possible that animal perceptions of palatability differed between the two water sources. The town supply was chlorinated, and it is possible that cows found this taste or smell aversive compared to the bore water to which they were accustomed.

- Future research could investigate long-term effects of providing drinking water high in iron and manganese on cow health and welfare. Future studies could further investigate water intake and animal preferences for unfiltered, filtered bore water and town supply of cows with previous experience of different water sources.

2. Background

Drinking water is the primary source of water for most cattle, however, depending on its source, water can sometimes contain various solutes and suspended particulate matter that can influence its appearance, smell, taste, and physical and chemical properties. Water consumption is positively associated with feed intake in both beef (Brew et al. 2011) and dairy (Stockdale & King 1983) cattle. Factors which limit the desire of cattle to drink water, in particular its quality and palatability, have the potential to not only reduce welfare, but limit growth and production. The most studied influences on the quality and palatability of water include concentrations of dissolved minerals, microbial contamination, particularly from fecal matter, and temperature. Willms et al. (2002) suggested that high salt content of water can influence its consumption level, and thus also feed intake and growth rates of beef cattle. Similarly, Grout et al. (2006) demonstrated that when water contains high levels of sulphates, particularly magnesium sulphate, palatability and quality is decreased and beef cattle will decrease their water consumption, even to the point of indication of dehydration. Similar observations are made when considering fecal contamination of water. Both beef and dairy cattle will, when given a choice of clean water, avoid water that is contaminated with manure (0.05 mg/g water, Willms et al. 2002, Schütz et al. 2019). In the study by Willms et al. (2002), when testing the impact of only consuming contaminated water, the authors observed that water consumption was reduced at manure concentrations above 2.5 mg/g water, followed by a reduction in feed consumption at concentrations greater than 5 mg/g water. Lardner et al. (2005) demonstrated similar results in a study when they tested different ways of treating contaminated water for beef cattle. In that study, as well as that by Willms et al. (2002), growth rates were linked to improvements in the palatability and quality of the water, as results cattle drank more and consumed more solid feed. Water intake by dairy cattle was reduced when the water was contaminated with 1 mg manure/g water, however, this was not reflected in milk production (Schütz et al. 2021).

To date there has been no published work showing the relationship between drinking water from a bore, with natural contaminants such as iron and manganese, and milk production in New Zealand. Anecdotal evidence from a farm in Northland showed a significant increase in milk production (up to 10%) from changing the water supply, however, this has not been demonstrated scientifically. High iron in drinking water may reduce the palatability (acceptability) and therefore amount and rate of water intake. Also, a dark slime formation in plumbing and waterers formed by iron-loving bacteria may affect water intake and even the rate and volume of water flow through pipes (Beede 2008). Deleterious consequences of excess free iron include abundant and excessive amounts of reactive oxygen species (e.g., peroxides) that cause oxidative stress. Oxidative stress damages cell membrane structure, functions, and perturbs otherwise normal biochemical reactions. Consequences of iron toxicity and heightened oxidative stress that are magnified in transition and fresh cows include compromised immune function, increased fresh cow mastitis and metritis, greater incidence of retained fetal membranes as well as diarrhea, sub-normal feed intake, decreased growth, and impaired milk yield (Beede 2008). Another concern about iron that it can interfere with the absorption of copper and zinc (which is routinely given to dairy cattle as prevention of facial eczema). There is little information about the effects of manganese, this micromineral element is often considered along with iron when addressing water quality. In general, a concentration greater than 0.05 ppm is thought to affect water intake because of the off-taste it imparts (Beede 2008).

Therefore, the aim of this project was to investigate if the provision of town supply water would improve milk yield of cows compared to when the drinking water was unfiltered bore water that contained high levels of iron and manganese. We also aimed to establish a preference for water source when the cows were provided with a free choice of both water sources.

It was predicted that cows with drinking water from town supply would produce more milk than cows provided with unfiltered bore water due to differences in the quality and palatability of the water. It was further predicted that when given a free choice, cows would prefer to drink town supply water over bore water.

3. Material and methods

3.1 Main study

The main study was undertaken at the DairyNZ Lye Farm, Hamilton, New Zealand (37˚76'S 175˚37'E) during March and April 2021 (Southern Hemisphere autumn). All procedures involving animals in this study were approved by the Ruakura Animal Ethics Committee under the New Zealand Animal Welfare Act 1999. Two hundred lactating, pregnant and non-pregnant (51 cows were empty) Friesian and Friesian-cross dairy cows were divided into two replicates of 100 cows, each replicate was further divided into two treatment groups, each consisting of 50 cows. Groups were randomised based on age, days in milk, and pregnancy status. The cows were habituated into their groups and were transitioned to once-a-day milking regime for period of 3-7 days before measurements began. During habituation, cows had access to unfiltered bore water as this is what cows normally have access to on the research farm. Thus, cows were used to drinking the unfiltered bore water.

3.2 Preference study

After the main study was completed two groups of cows (20 cows/group randomly selected from the main study, 10 from each original group) were managed as in the main study (below), however, with access to the two water sources simultaneously for three days. Water intake on group level was recorded in the morning using the same set up and methodology as in the main study (below).

3.3 Paddock set up

Each replicate of cows was grazed for each 24-hour period in a one hectare paddock, which had been divided in half with electric fencing to accommodate two groups (one of each treatment). Cows were offered approximately 14 kg DM feed/day (they ate approximately 12kg DM/day overall). The pasture available was supplemented with either pasture silage or maize silage to reach this requirement. Cows were milked at approximately 06:00 h and during this time the water treatments were set up in their fresh paddock and supplements fed along the fence line. Pasture and maize silage made up 50-75% of the cows' intake.

3.4 Water treatments and design

Each group had access to one of the two water treatments (two groups/treatment) for 14 days before changing treatment for another 14 days. The design was therefore a cross-over design (n=4 groups, 50 cows/group).

There were two treatments: 1. Town supply, which is routinely treated with chlorine at source, and 2. Unfiltered bore water, which originated from a deep bore on the farm (Table 1). The bore water had particular high levels of iron, manganese but also magnesium, compared to town supply (Table 1). Cows had free access to drinking water at all times while at pasture. Each treatment group's water was supplied from five 1000 L Industrial Bulk Containers (IBC, recycled, 15 previously carried sugar syrup, 5 from Ross pumps after carrying product used in developing water bores) which were secured to existing farm tractor trailers. The containers were connected using 50 mm alkathene pipe and fittings to form one pipe to the trough, before the trough the pipe was reduced to a 25 mm diameter pipe a water meter was connected into the pipeline and water was then delivered into a commercially available 500 L trough which had a protected ballcock. The treatment water on each trailer was replenished each morning during milking and then taken to the new paddock and reconnected to the trough. An electric fence placed around the trough so that no cow could gain access to drink until the trough was filled and the meter reading had become stable, a reading from the water meter was then taken and the fence removed. The water troughs were unprotected from the weather.

3.5 Water intake

Water intake was measured daily at group level, volume consumed being measured through Zenner RNK-RP-N water meters (MICO TeRapa, Hamilton). The meter was read after the cows left the paddock for milking. Water samples were collected once during the trial period for water quality analysis and sent to Hill laboratories for water quality analyses. The water analyses for the two water sources are provided in Table 1. The full analysis including summary of methods is provided in Appendix 1. Images of the two water sources are provided in Figure 1.

Figure 1. The two water treatments used in the experiment (unfiltered bore water to the left and town supply to the right).

Sample Type: Aqueous					
Sample Name:		Lye Farm - Bore Water 29-Apr-2021 4:30 pm	Lye Farm - Town Water 29-Apr-2021 4:30 pm	Guideline Value	Maximum Acceptable Values (MAV)
Lab Number:		2598405.1	2598405.2		
Routine Water + E.coli profile Kit					
Escherichia coli	MPN / 100mL	< 1	< 1	-	< 1
Routine Water Profile					
Turbidity	NTU	73	0.17	< 2.5	-
pH	pH Units	6.8	7.4	7.0 - 8.5	-
Total Alkalinity	g/m³ as $CaCO_3$	157	41	-	-
Free Carbon Dioxide	g/m³ at 25°C	53	2.9	-	-
Total Hardness	g/m³ as $CaCO_3$	91	46	< 200	-
Electrical Conductivity (EC)	mS/m	31.2	19.3	-	-
Electrical Conductivity (EC)	µS/cm	312	193	-	-
Approx Total Dissolved Salts	g/m³	210	129	< 1000	-
Total Arsenic	g/m³	0.0045	0.0020	-	0.01
Total Boron	g/m³	0.022	0.25	-	1.4
Total Calcium	g/m³	13.7	13.5	-	-
Total Copper	g/m³	< 0.00053	< 0.00053	< 1	2
Total Iron	g/m³	13.9	< 0.021	< 0.2	-
Total Lead	g/m³	< 0.00011	< 0.00011	-	0.01
Total Magnesium	g/m³	13.8	3.0	-	-
Total Manganese	g/m³	1.42	0.00061	< 0.04 (Staining) < 0.10 (Taste)	0.4
Total Potassium	g/m³	3.5	3.2	-	-
Total Sodium	g/m³	39	19.5	< 200	-
Total Zinc	g/m³	0.050	0.0011	< 1.5	-
Chloride	g/m³	8.3	16.7	< 250	-
Nitrate-N	g/m³	0.06	0.29	-	11.3
Sulphate	g/m³	< 0.5	20	< 250	-

Note: The Guideline Values and Maximum Acceptable Values (MAV) are taken from the publication 'Drinking-water Standards for New Zealand 2005 (Revised 2018)', Ministry of Health. Copies of this publication are available from https://www.health.govt.nz/publication/drinking-water-standards-new-zealand-2005-revised-2018

Table 1. Water quality analyses of the two sources of drinking water (bore water and town water).

3.6 Pasture management and measures

Each day, the paddocks were plated pre and post grazing to determine the amount of feed available and quantity of supplement required, as well as feed eaten. Daily pasture samples were also taken to determine the dry matter (DM) content of the pasture and the estimated amount of water obtained from pasture (on group level). The DM content of the pasture was on average 20.1% (range: 13.4 to 29.6%).

Silage samples (pasture silage and maize silage) were obtained twice weekly for dry matter content and NIR analyses. The DM content of the silage was on average 32.6% (range: 19.6 to 41.3%) and 26.1% (range: 18.0 to 32.8%) for maize and pasture silage, respectively.

The nutritional composition of the pasture and silage are provided in Table 2.

Table 2. Mean (± SEM) nutrient composition (% DM, unless otherwise stated) of feeds offered throughout the experiment.

	Pasture	*Pasture silage*	*Maize silage*
CP	20.2 (0.6)	17.0 (0.5)	7.0 (0.4)
ADF	24.2 (0.5)	35.8 (0.6)	28.6 (0.8)
NDF (% NDF)	45.0 (0.6)	50.8 (1.7)	47.0 (2.2)
Fat	3.8 (0.1)	3.0 (0.1)	3.7 (0.1)
SSS	10.3 (0.3)	3.3 (0.3)	28.4 (1.7)
Ash	10.2 (0.2)	9.1 (0.4)	4.4 (0.2)
ME (MJ/kd DM)	11.0 (0.1)	11.2 (0.2)	10.3 (0.1)
OMD	76.5 (0.6)		
Fresh DM	20.1 (0.9)	26.1 (1.1)	32.6 (1.5)
Dig	-	70.1 (1.1)	-
pH	-	4.1 (0.1)	3.8 (0.03)
NH4N (mg/100g DM)	-	237.2 (4.6)	108.0 (9.8)

3.7 Milk production

Cows were milked through a 30-bail rotary platform and using a GEA milking plant (Hamilton, New Zealand). Milk production for each cow was recorded daily and milk composition was analysed at the start and end of each treatment period.

3.8 Environmental conditions

Air temperature (°C), and rainfall (mm) were recorded at 10 minute intervals using two portable weather station (Fan-Aspirated Vantage Pro2™ Plus Stations, model 6163, Davis Instruments Hayward, California, USA). The weather stations were located in an unsheltered and non-shaded area in the proximity of the paddocks being used for this study.

3.9 Statistical analyses

A linear mixed model was used to investigate the fixed effect of body condition, liveweight, pregnancy status, days in milk, age group, and water treatment (bore/town supply) on milk production (kg milk per cow per day). The random effects were cow nested within group, date, and a group by day random intercept. Period was used as a fixed effect. Body condition, liveweight and days in milk were centered by deducting each value by their respective mean.

A linear mixed model weas used to investigate the fixed effects of water treatment, average daily temperature and daily rainfall on water intake per cow. Rainfall was categorised into three categories (0-9, 10-19, 20+ mm/day). The random effects were the date, and the group. Period was used as a fixed effect.

Milk protein and fat for the two treatments are presented descriptively. Water intake during the preference study is also presented descriptively.

4. Results and Discussion

Water intake was not influenced by the drinking water source (P=0.641, Figure 2) or air temperature (P=0.940), however, rainfall and period did influence water intake (P<0.001). Cows consumed on average 33.1 L/cow/day (SE: 3.93 L, town water) and 33.5 L/cow/day (SE: 3.93 L, bore water). Not surprisingly, the rainfall decreased water intake, likely due to water intake through the feed being greater. Cows consumed on average 11.7 L of water/day through their feed (calculated from estimated average intakes and the DM content of the feeds). It has previously been shown that 26.4 mm of rainfall on one day decreased free water intake by pastured dairy cattle by 62% (Morris et al. 2010). It is also likely that the water intake was underestimated on rainy days since the troughs had no roof and thus rain would fall into the trough. Overall, cows consumed less water during the second period of the experiment and we are unsure of the reasons for this, but greater rainfall during this period may have contributed to feeds containing more water and therefore less free water intake.

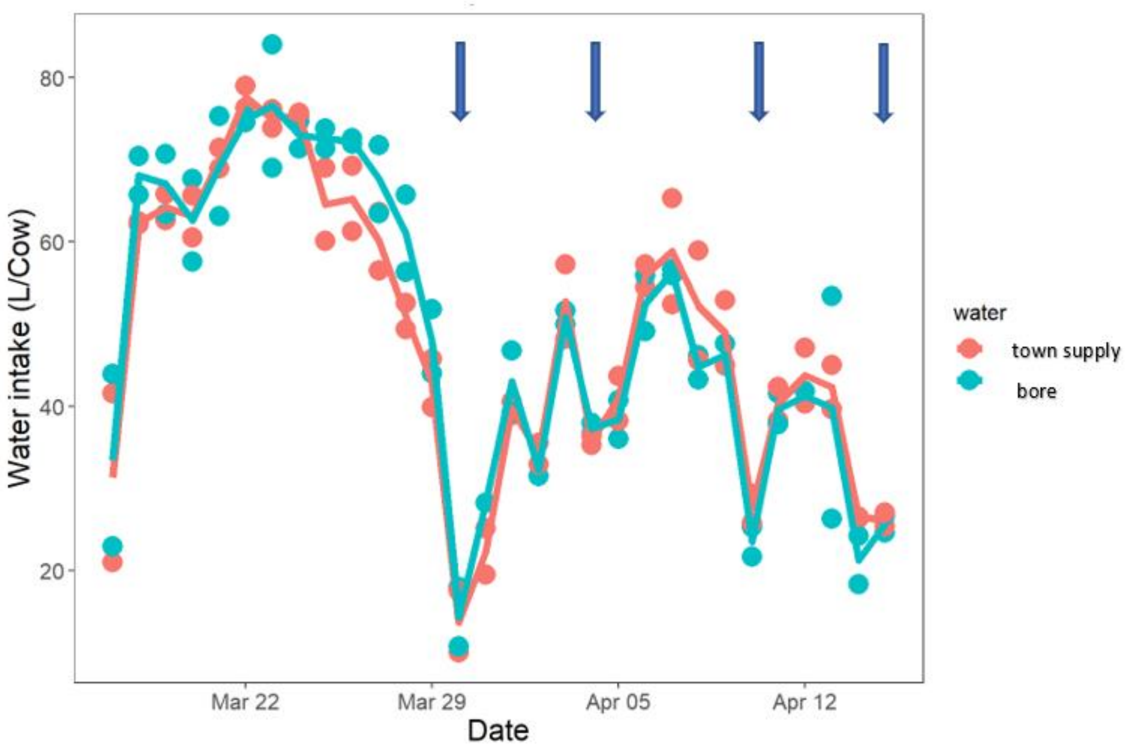

Figure 2. Daily water intake (L/cow) of dairy cattle provided either with drinking water from town supply or unfiltered bore water (n=4 groups/treatment in a cross-over design, 50 cows/group) throughout the experiment. Days with rainfall are indicated by the blue arrows.

Milk production was not influenced by the water source provided to the cows (P=0.699, Figure 3). The milk production was influenced by liveweight, body condition, days in milk, age, pregnancy status and period (P<0.05) but as treatment groups were balanced on these variables and the main aim of this study was to investigate the effects of drinking water quality on milk production these results are not further discussed. Cows produced on average 8.9 L (SE: 0.20 L, town water) and 8.8 L (SE: 0.20 L, bore water) of milk per cow and day.

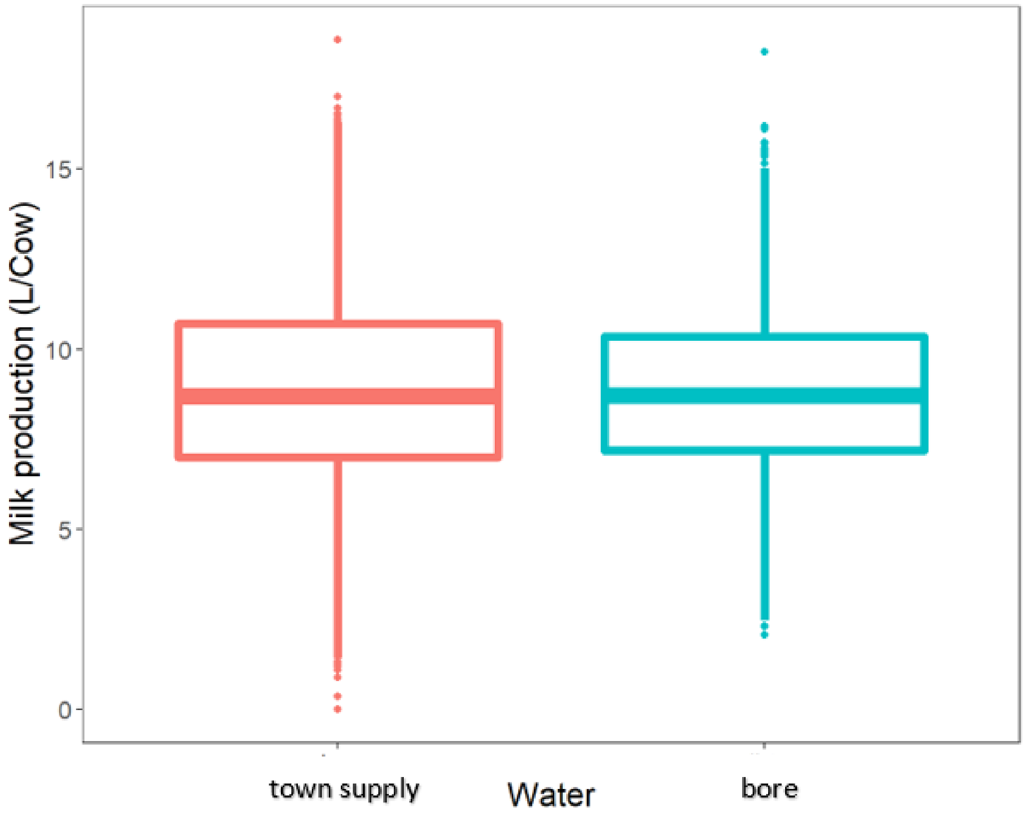

Figure 3. Effect of drinking water source (town supply vs. unfiltered bore water) on milk production of dairy cattle (n=4 groups/treatment, 50 cows/group) over a two-week period in a cross-over design.

Milk fat and protein for the treatment groups and the two periods are descriptively presented in Figure 4. There were no differences in milk solids between the two treatment groups.

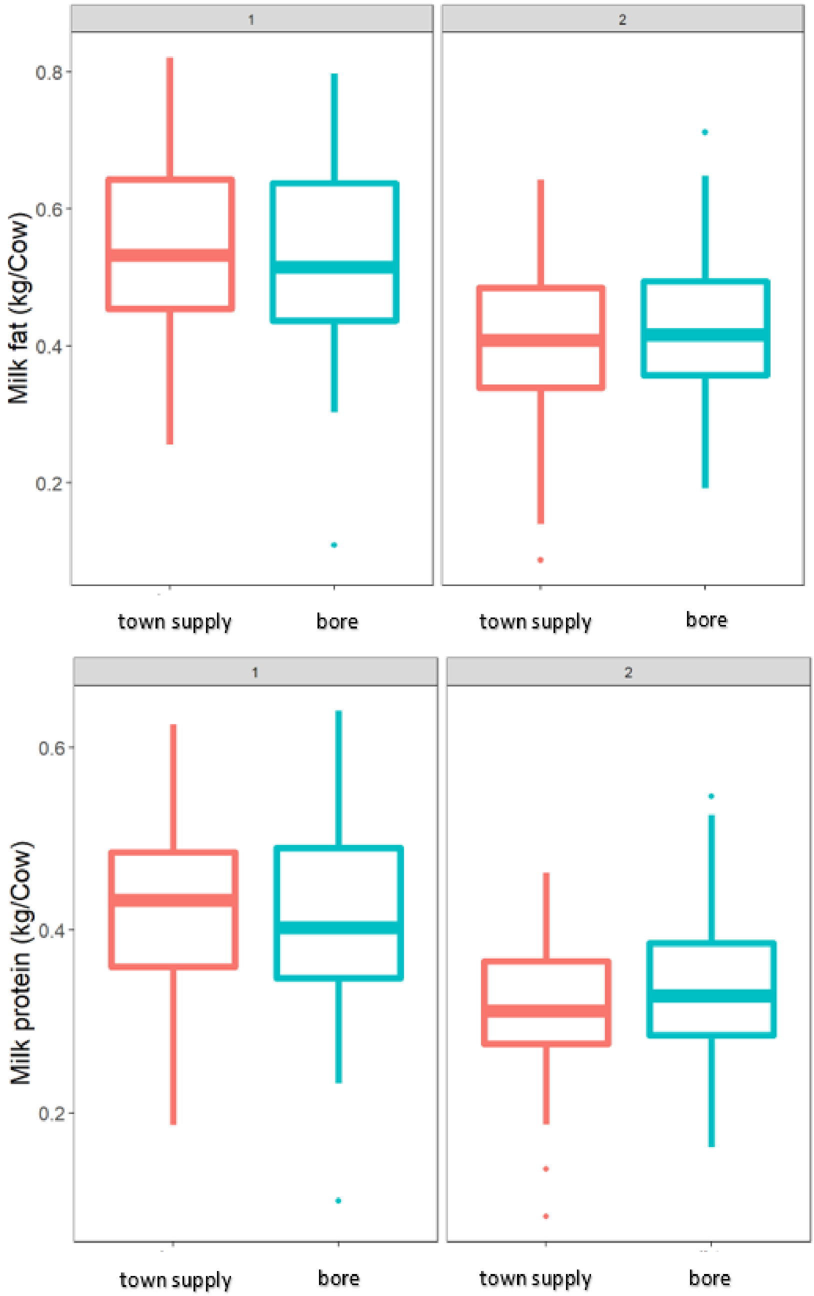

Figure 4. Milk fat and protein of dairy cattle (n=4 groups/treatment, 50 cows/group) provided with different drinking water sources (town supply vs. unfiltered bore water) on milk production of dairy cattle during two periods (1 and 2) in a cross-over design.

After the main study was completed the preference for the two water sources were investigated on a subset of randomly selected animals for three days. During these days two groups of cows had free access to both water sources (town supply and bore water) and the water intake from both sources was recorded. The results are provided descriptively in Figure 5 and indicate that the cows preferred to drink the bore water over the town supply.

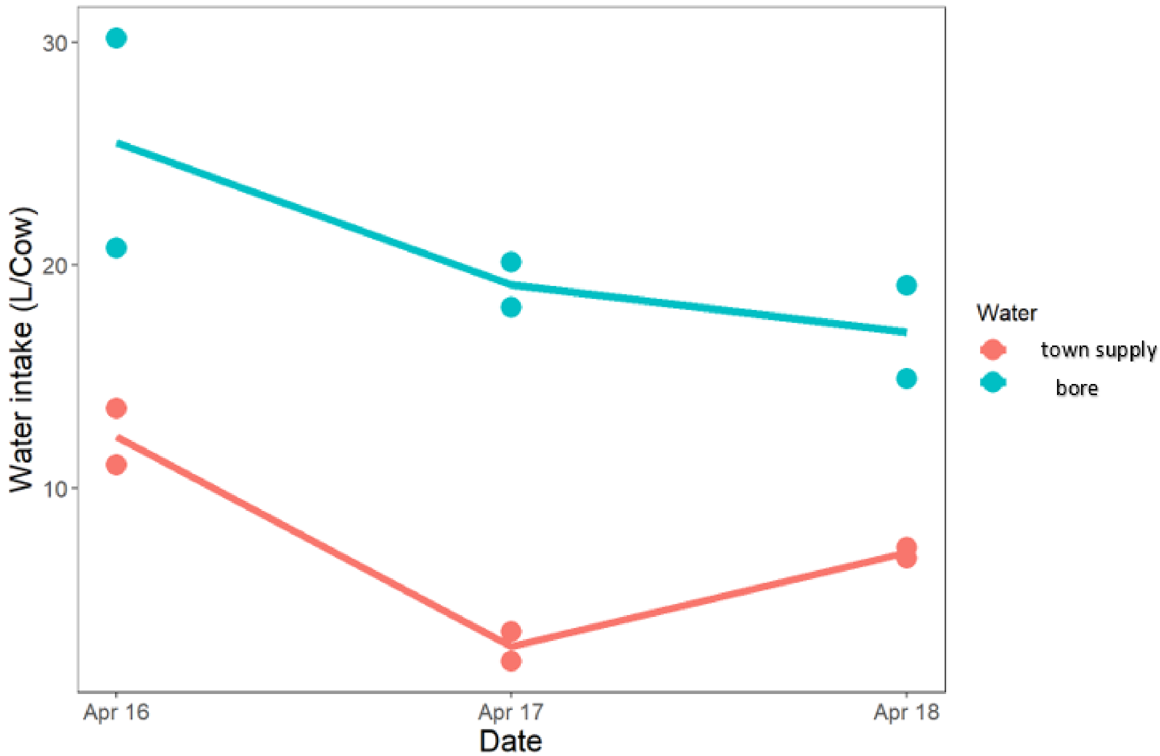

Figure 5. Preference for drinking water source (town supply vs. unfiltered bore water) by lactating dairy cattle (n=2 groups, 20 cows/group) over three days.

There are at least two possible explanation for these findings. Firstly, the cows in the study were used to drinking the unfiltered bore water as this was the main source of drinking water on the farm. Other studies have shown that previous exposure or experience to a particular resource, such as lying substrate, influence animal preferences (e.g. Tucker et al. 2003). Future studies should control for previous experience of cows. It is also however possible that the cows found the taste or smell of the town water to be more aversive than the bore water, perhaps due to the presence of chlorine in town water.

The definition of water quality typically encompasses physiochemical factors (e.g., turbidity, taste, smell), micro- and macromineral elements, organic matter, and microbial contaminants, as well as potential risk from anthropogenic pollutants and contaminants. Most measures of water quality in the present study were within the recommended levels for what is considered safe for humans and livestock (Table 1), except for high concentrations of iron and manganese in the unfiltered bore water. Unexpectedly, cows seemed to prefer the bore water over town supply. The iron levels at the study farm were much higher than what has previously been found on the North Island (13.9 mg/L vs. 0.32 mg/L water, Abacus Biotech 2005), and is much higher than what has been previously been recommended being safe for humans and livestock (0.2 mg/L water, Beede 2012). The levels of manganese on the study farm were also higher (1.42 mg/L) than what is deemed safe for humans and livestock (0.05 mg/L water, Beede 2012). Cows did not seem to mind drinking the bore water high in iron and manganese and in fact showed a preference to drink this water. Considering the well-known negative effects of high iron levels on dairy cattle health (compromised immune function, increased fresh cow mastitis and metritis, greater incidence of retained fetal membranes as well as diarrhea, sub-normal feed intake, decreased growth, and impaired milk yield), studies investigating the long-term effects on the health and productivity of cows drinking water high in iron are warranted. This study highlights the fact that water quality and water palatability do not necessary go hand in hand and what is palatable to humans is not necessarily palatable to cows. It is well established that cows can detect very small concentrations of contaminants in their drinking water. For example, dairy cows are extremely sensitive to manure contamination in their drinking water. In a previous study, it was demonstrated that cows can detect as little as 0.005% manure contamination in their drinking water (0.05 mg/g of water), which was the lowest level tested (Schütz et al. 2019). Indeed, when cows could choose between two water sources they showed a clear preference to drink clean water; 75 and 99% of the water intake was from this water source when the other option was water contaminated with 0.05 mg or 1.0 mg fresh manure/g water, respectively (Schütz et al. 2019). A similar preference was demonstrated by yearling steers that had a free choice between drinking three types of water containing 0, 0.05, or 0.25 mg fresh manure/g water; 75% of the daily intake came from the clean water source, and only 6.2% from the water contaminated with 0.25 mg/g water (Willms et al. 2002). It is unclear at this stage whether the preference to drink the unfiltered bore water over town supply is due to previous experience and/or palatability of the drinking water. We encourage future studies to investigate water intake and animal preference for town supply and unfiltered and filtered bore water using cows that are used to different water sources.

5. Conclusions and recommendations

Dairy cattle accustomed to drinking unfiltered bore water containing high levels of iron and manganese consumed similar amounts of this water compared to cows that were provided with town water. All cows were previously used to drinking the unfiltered bore water as this was the source of drinking water on the farm. Milk production was not influenced by water treatment. When given a free choice of both water sources, the cows preferred to drink the unfiltered bore water over the town supply. Previous experience to only one source of drinking water (the unfiltered bore water) and/or differences in animal perceptions regarding the palatability of the drinking water is likely to have influenced the results. Future studies are encouraged to investigate water intake and animal preferences for unfiltered and filtered bore water, and chlorinated town supply by cows that have had previous experience of different water sources.

6. Acknowledgements

This study was funded by Our Land and Water (contract reference: RPF 2) and a collaboration between Livestock Improvement Corporation (LIC), DairyNZ, and AgResearch Ltd. We are very grateful to DairyNZ Lye and Scott farm staff Stu Morgan, Bruce Sugar, Ben Fisher, Matt MacDonald, Johannes Nagel and Olivia Jordan for their assistance during the trial.

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8. Appendix 1. Water analyses and methods

Hill Laboratories
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Certificate of Analysis

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DWAPv1

Client:	FarmWise LIC	**Lab No:**	2598405
Contact:	Edward Hardie	**Date Received:**	29-Apr-2021
	C/- FarmWise LIC	**Date Reported:**	07-May-2021
	Private Bag 3016	**Quote No:**	
	Hamilton 3240	**Order No:**	4500381844
		Client Reference:	LIC - Farmwise
		Submitted By:	Edward Hardie

Sample Type: Aqueous

Sample Name: / Lab Number:	Units	Lye Farm - Bore Water 29-Apr-2021 4:30 pm / 2598405.1	Lye Farm - Town Water 29-Apr-2021 4:30 pm / 2598405.2	Guideline Value	Maximum Acceptable Values (MAV)
Routine Water + E.coli profile Kit					
Escherichia coli	MPN / 100mL	< 1	< 1	-	< 1
Routine Water Profile					
Turbidity	NTU	73	0.17	< 2.5	-
pH	pH Units	6.8	7.4	7.0 - 8.5	-
Total Alkalinity	g/m³ as $CaCO_3$	157	41	-	-
Free Carbon Dioxide	g/m³ at 25°C	53	2.9	-	-
Total Hardness	g/m³ as $CaCO_3$	91	46	< 200	-
Electrical Conductivity (EC)	mS/m	31.2	19.3	-	-
Electrical Conductivity (EC)	µS/cm	312	193	-	-
Approx Total Dissolved Salts	g/m³	210	129	< 1000	-
Total Arsenic	g/m³	0.0045	0.0020	-	0.01
Total Boron	g/m³	0.022	0.25	-	1.4
Total Calcium	g/m³	13.7	13.5	-	-
Total Copper	g/m³	< 0.00053	< 0.00053	< 1	2
Total Iron	g/m³	13.9	< 0.021	< 0.2	-
Total Lead	g/m³	< 0.00011	< 0.00011	-	0.01
Total Magnesium	g/m³	13.8	3.0	-	-
Total Manganese	g/m³	1.42	0.00061	< 0.04 (Staining) < 0.10 (Taste)	0.4
Total Potassium	g/m³	3.5	3.2	-	-
Total Sodium	g/m³	39	19.5	< 200	-
Total Zinc	g/m³	0.050	0.0011	< 1.5	-
Chloride	g/m³	8.3	16.7	< 250	-
Nitrate-N	g/m³	0.06	0.29	-	11.3
Sulphate	g/m³	< 0.5	20	< 250	-

Note: The Guideline Values and Maximum Acceptable Values (MAV) are taken from the publication 'Drinking-water Standards for New Zealand 2005 (Revised 2018)', Ministry of Health. Copies of this publication are available from https://www.health.govt.nz/publication/drinking-water-standards-new-zealand-2005-revised-2018

The Maximum Acceptable Values (MAVs) have been defined by the Ministry of Health for parameters of health significance and should not be exceeded. The Guideline Values are the limits for aesthetic determinands that, if exceeded, may render the water unattractive to consumers.

Note that the units g/m³ are the same as mg/L and ppm.

This Laboratory is accredited by International Accreditation New Zealand (IANZ), which represents New Zealand in the International Laboratory Accreditation Cooperation (ILAC). Through the ILAC Mutual Recognition Arrangement (ILAC-MRA) this accreditation is internationally recognised.
The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked * or any comments and interpretations, which are not accredited.

Routine Water Assessment for Sample No 2598405.1 - Lye Farm - Bore Water

pH/Alkalinity and Corrosiveness Assessment
The pH of a water sample is a measure of its acidity or basicity. Waters with a low pH can be corrosive and those with a high pH can promote scale formation in pipes and hot water cylinders.
The guideline level for pH in drinking water is 7.0-8.5. Below this range the water will be corrosive and may cause problems with disinfection if such treatment is used.

The alkalinity of a water is a measure of its acid neutralising capacity and is usually related to the concentration of carbonate, bicarbonate and hydroxide. Low alkalinities (25 g/m³) promote corrosion and high alkalinities can cause problems with scale formation in metal pipes and tanks.

With the pH and alkalinity levels found, this water could be corrosive towards metal piping and fixtures.
The high alkalinity of this water may cause an increase in the pH in the root zones of plants which are irrigated using this water.

Hardness/Total Dissolved Salts Assessment
The water contains a low amount of dissolved solids and would be regarded as being slightly hard.

Nitrate Assessment
Nitrate-nitrogen at elevated levels is considered undesirable in natural waters as this element can cause a health disorder called methaemaglobinaemia. Very young infants (less than six months old) are especially vulnerable. The Drinking-water Standards for New Zealand 2005 (Revised 2018) suggests a maximum permissible level of 11.3 g/m³ as Nitrate-nitrogen (50 g/m³ as Nitrate).

Nitrate-nitrogen was detected in this water but at such a low level to not be of concern.

Boron Assessment
Boron may be present in natural waters and if present at high concentrations can be toxic to plants.
Boron was found at a low level in this water but would not give any cause for concern.

Metals Assessment
Iron and manganese are two problem elements that commonly occur in natural waters. These elements may cause unsightly stains and produce a brown/black precipitate. Iron is not toxic but manganese, at concentrations above 0.5 g/m³, may adversely affect health. At concentrations below this it may cause stains on clothing and sanitary ware.

Iron was found in this water at a very high level.
Manganese was found in this water at a high level.
Treatment to remove iron and/or manganese will be required.

Bacteriological Tests
The NZ Drinking Water Standards state that there should be no Escherichia coli (E coli) in water used for human consumption. The presence of these organisms would indicate that other pathogens of faecal origin may be present. Results obtained for Total Coliforms are only significant if the sample has not also been tested for E coli.

Escherichia coli was not detected in this sample.

Final Assessment
The parameters Turbidity, pH, Total Iron and Total Manganese did NOT meet the guidelines laid down in the publication 'Drinking-water Standards for New Zealand 2005 (Revised 2018)' published by the Ministry of Health for water which is suitable for drinking purposes.

Routine Water Assessment for Sample No 2598405.2 - Lye Farm - Town Water

pH/Alkalinity and Corrosiveness Assessment
The pH of a water sample is a measure of its acidity or basicity. Waters with a low pH can be corrosive and those with a high pH can promote scale formation in pipes and hot water cylinders.
The guideline level for pH in drinking water is 7.0-8.5. Below this range the water will be corrosive and may cause problems with disinfection if such treatment is used.

The alkalinity of a water is a measure of its acid neutralising capacity and is usually related to the concentration of carbonate, bicarbonate and hydroxide. Low alkalinities (25 g/m³) promote corrosion and high alkalinities can cause problems with scale formation in metal pipes and tanks.

The pH of this water is within the NZ Drinking Water Guidelines, the ideal range being 7.0 to 8.0.
With the pH and alkalinity levels found, it is unlikely this water will be corrosive towards metal piping and fixtures.

Hardness/Total Dissolved Salts Assessment
The water contains a low amount of dissolved solids and would be regarded as being soft.

Nitrate Assessment
Nitrate-nitrogen at elevated levels is considered undesirable in natural waters as this element can cause a health disorder called methaemaglobinaemia. Very young infants (less than six months old) are especially vulnerable. The Drinking-water Standards for New Zealand 2005 (Revised 2018) suggests a maximum permissible level of 11.3 g/m³ as Nitrate-nitrogen (50 g/m³ as Nitrate).

Nitrate-nitrogen was detected in this water but at such a low level to not be of concern.

Boron Assessment
Boron may be present in natural waters and if present at high concentrations can be toxic to plants.
Boron was found at a low level in this water but would not give any cause for concern.

Metals Assessment
Iron and manganese are two problem elements that commonly occur in natural waters. These elements may cause unsightly stains and produce a brown/black precipitate. Iron is not toxic but manganese, at concentrations above 0.5 g/m³, may adversely affect health. At concentrations below this it may cause stains on clothing and sanitary ware.

Iron was not detected in the water
Manganese was found in this water at a low level.
Treatment to remove iron and/or manganese should not be necessary.

Bacteriological Tests
The NZ Drinking Water Standards state that there should be no Escherichia coli (E coli) in water used for human consumption. The presence of these organisms would indicate that other pathogens of faecal origin may be present. Results obtained for Total Coliforms are only significant if the sample has not also been tested for E coli.

Escherichia coli was not detected in this sample.

Final Assessment
All parameters tested for meet the guidelines laid down in the publication 'Drinking-water Standards for New Zealand 2005 (Revised 2018)' published by the Ministry of Health for water which is suitable for drinking purposes.

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request.
Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Routine Water Profile		-	1-2
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-2
Total Digestion	Nitric acid digestion. APHA 3030 E (modified) 23rd ed. 2017.	-	1-2
Turbidity	Analysis by Turbidity meter. APHA 2130 B 23rd ed. 2017 (modified).	0.05 NTU	1-2
pH	pH meter. APHA 4500-H+ B 23rd ed. 2017. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field. Samples and Standards are analysed at an equivalent laboratory temperature (typically 18 to 22 °C). Temperature compensation is used.	0.1 pH Units	1-2
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (modified for Alkalinity <20) 23rd ed. 2017.	1.0 g/m³ as $CaCO_3$	1-2
Free Carbon Dioxide	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D 23rd ed. 2017.	1.0 g/m³ at 25°C	1-2
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 23rd ed. 2017.	1.0 g/m³ as $CaCO_3$	1-2
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 23rd ed. 2017.	0.1 mS/m	1-2
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 23rd ed. 2017.	1 µS/cm	1-2
Approx Total Dissolved Salts	Calculation: from Electrical Conductivity.	2 g/m³	1-2
Total Arsenic	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.0011 g/m³	1-2
Total Boron	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.0053 g/m³	1-2
Total Calcium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.053 g/m³	1-2
Total Copper	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.00053 g/m³	1-2
Total Iron	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.021 g/m³	1-2
Total Lead	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.00011 g/m³	1-2
Total Magnesium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.021 g/m³	1-2
Total Manganese	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.00053 g/m³	1-2
Total Potassium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.053 g/m³	1-2
Total Sodium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.021 g/m³	1-2
Total Zinc	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.0011 g/m³	1-2
Chloride	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23rd ed. 2017.	0.5 g/m³	1-2
Nitrate-N	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23rd ed. 2017.	0.05 g/m³	1-2
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23rd ed. 2017.	0.5 g/m³	1-2
Escherichia coli	MPN count using Colilert (Incubated at 35°C for 24 hours) and 97 wells. APHA 9223 B 23rd ed. 2017.	1 MPN / 100mL	1
Escherichia coli	MPN count using Colilert (Incubated at 35°C for 24 hours) and 51 wells. APHA 9223 B 23rd ed. 2017.	1 MPN / 100mL	2

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Testing was completed between 30-Apr-2021 and 07-May-2021. For completion dates of individual analyses please contact the laboratory.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

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Ara Heron BSc (Tech)
Client Services Manager - Environmental