The Effects of Water Quality on Cattle Weight Gain

Results of Study Years 1999 – 2003

A collaborative study conducted by Agriculture and Agri-Food Canada and the Western Beef Development Centre

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1.0 Introduction

1.1 Background

Dugouts are a common means of storing water for range cattle. Variability in the quality of dugout water raises questions about the possible impacts on animal health and productivity. Surface water dugouts can be expected to have natural microbiological contamination (bacteria, parasites, viruses) as well as other impurities which could affect animal health and weight gain. Dugouts that are fed by groundwater may contain mineral salt concentrations at levels that could compromise animal health. Through exposure to surface runoff, all dugouts become sinks for nutrients. Nutrient enrichment may lead to proliferation of algal populations which may produce toxins (e.g. liver toxins or neuro-toxins from cyanobacteria, blue green algae). Direct access of livestock to dugout water may allow for the spread of pathogens from one animal to the whole herd. It is also known that cattle are sensitive to taste and odour in water supplies and may limit their intake of less palatable water, possibly leading to reduced weight gain. All of these potential water quality problems can be classified under a category of potential problems associated with particulate organic and inorganic matter.

It is therefore probable that particulate organic and inorganic matter may make water unsafe for animal consumption, difficult to utilize for water distribution (e.g. clogging watering bowls and nipples), and may also impart an undesirable taste and odour. Presently there is no substantiated evidence that coagulated or aerated water can cause significant improvements in livestock weight gain. Interest in improving water quality for animals is significant. This project will evaluate the significance of improving water quality for animal consumption using inexpensive treatments. If production or health benefits are identified, significant economic benefit will be realised by the livestock industry.

Coagulation has been used for more than a century to improve water quality, primarily as a means of reducing particulate matter. Coagulation will also result in reduction of bacteria, parasite and virus concentrations. Coagulation does not disinfect water, but reductions in particulate matter will allow for more effective disinfection when required. Coagulation can also reduce dissolved matter. Reductions of dissolved organic carbon are beneficial by creating better tasting water and allowing more effective disinfection.

This project also improves knowledge about remote watering and aeration systems and their relationship to cattle weight gain. Pumping water to a trough and aerating the water are two forms of water treatments that are simple, practical and inexpensive.

Pumping water to a trough eliminates contamination of the water from cattle entering the water source and introducing faeces and urine to the water. Introduction of manure to the water has been found by Willms (Unpublished) to depress feed consumption. Introduction of faeces contaminated with parasites to the drinking water is expected to spread the parasites to other animals and could affect animal health. Direct entry by livestock also shortens the useful life of dugouts. Increased erosion and sedimentation, degradation of wildlife habitat and reduction of plant cover are a few of the negative results of direct livestock watering.

Aeration of the water is known to improve palatability. Concentration of iron, manganese, hydrogen sulphide and ammonia are reduced, and the dugout ecosystem is improved with greater prevalence of zooplankton.

For the growing season of 2003 the addition of a ground water source was added for comparison to the four surface water treatments. This expansion is of considerable interest to producers affected by drought that are considering wells in the Hatfield Aquifer and other aquifers with marginal water quality. The Hatfield aquifer is known for its high sulphate and generally poor quality water and producers are concerned about the impact this water would have on livestock. Some researchers suggest that the groundwater with salts will be the water of choice for cattle and short term consumption will cause insignificant health impacts. The addition of this treatment addresses a recognized client concern, confirm or disprove the researchers' suggestion, and contribute to the Department's drought mitigation strategy.

Differences in animal weight gain in response to different water supplies have been previously documented (Willms et al., 1996); (Holechek et al., 1989). This study will investigate the effect of dugout aeration, restricted cattle access to dugouts, and coagulation treatment (including disinfection) of source water from an aged dugout and compare to well water on cattle weight gains.

This report includes results for five years of study. The only significant variations from the first year protocol was the addition of a cow/calf trial for the years 2000 - 2002, to run at the same time as the steer trial and the addition of a deep well treatment in 2003.

1.2 Objectives:

(1) To evaluate the benefits of remote watering, aeration and coagulation/chlorination of livestock drinking water.
(2) To evaluate effect of high sulphate well water on livestock performance and weight gains.
(3) To identify causal factors affecting livestock water intake.

1.3 Study Partners

The research was conducted at the Termuende Research Farm managed by Western Beef Development Centre. The project was jointly undertaken by Western Beef Development Centre (WBDC), Prairie Farm Rehabilitation Administration (PFRA) and Research Branch (Agriculture and Agri-Food Canada). Funding was provided by the Canada-Saskatchewan Agri-Food Innovation Fund, PFRA, Matching Investment Initiative, Ducks Unlimited, and the Rural Water Development Program.

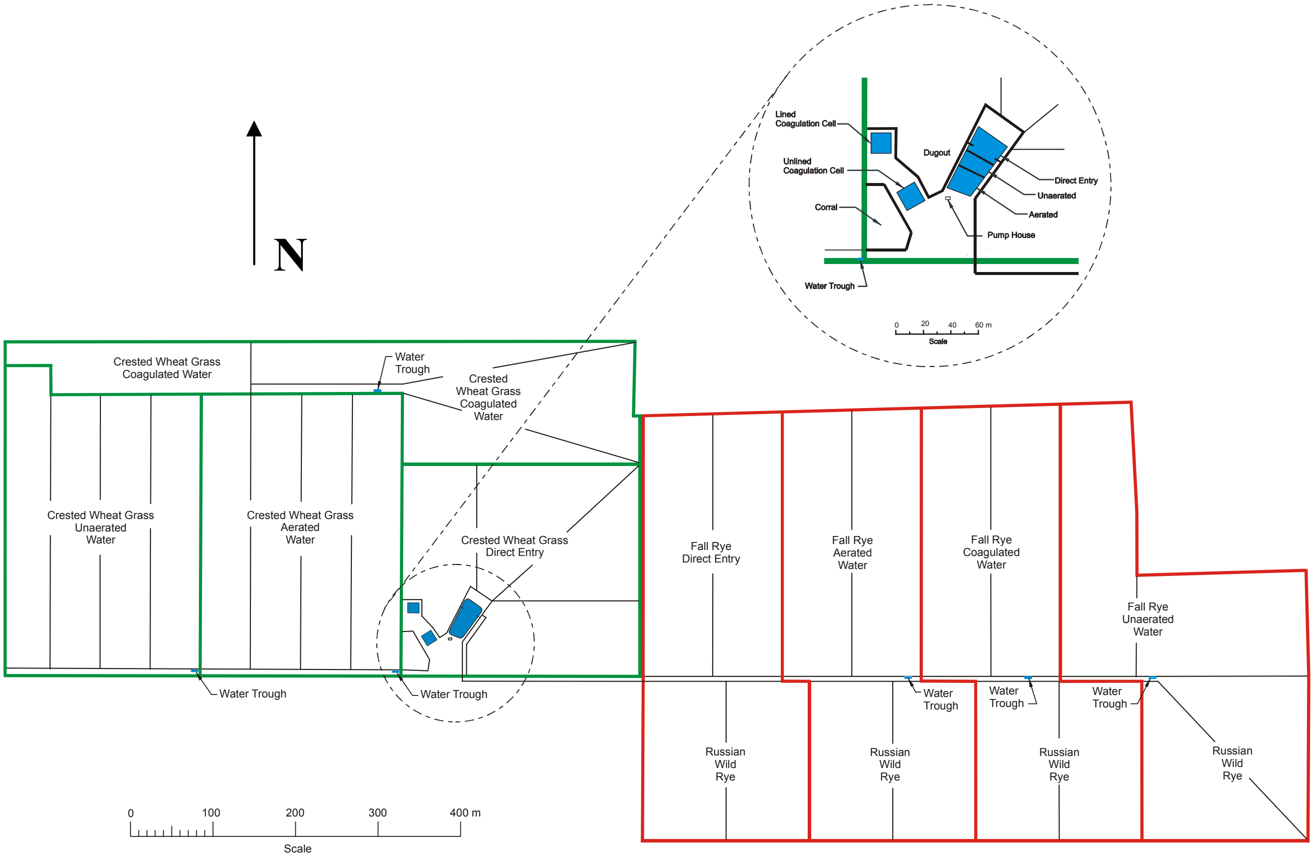
2.0 Materials and Methods

2.1 Site Layout

A 30 hectare pasture fenced into 16 paddocks of predominantly crested wheatgrass and alfalfa was used for the steers. A 90 hectare pasture of 8 paddocks of fall rye and 8 paddocks of Russian wild rye was fenced for the cow/calf pairs (Figure 1(a)). The size of the paddocks ranged from 1.72 to 2.5 hectares. Four paddocks were grazed per treatment in a rotational system in order to maximize quality and productivity of the forage. The treatment types included:

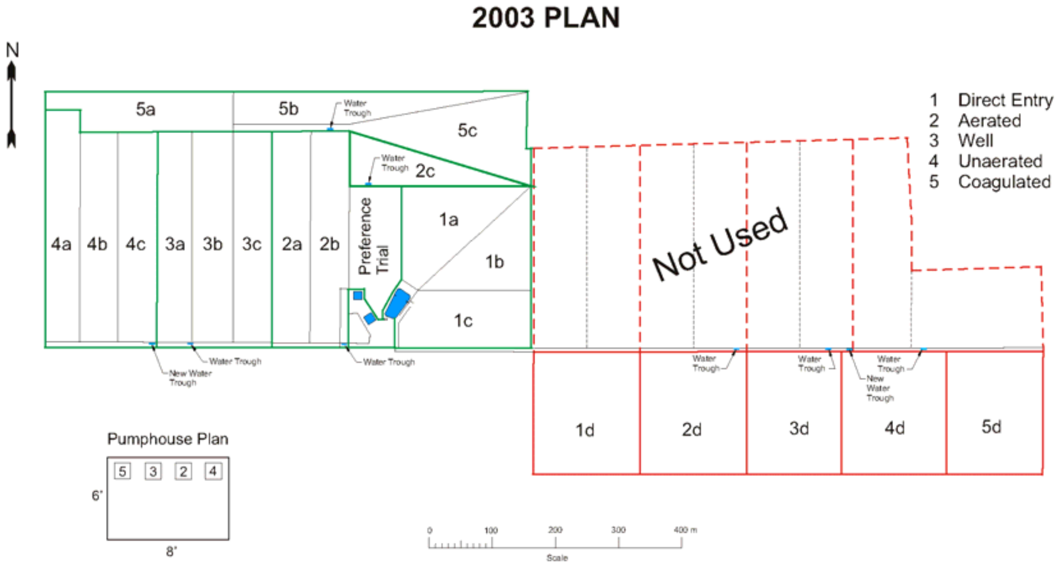
- direct accessed dugout
- unaerated water in a trough
- aerated water in a trough
- coagulated and chlorinated water in a trough

Figure 1(a): Site Plan (1999-2002)



In 2003 the study design changed in that there were no cow/calf pairs but an additional water well treatment using steers was added. The change resulted in the fall rye paddocks no longer being used in the study, and the steers using both the Crested Wheatgrass/Alfalfa paddocks and the Russian Wildrye (Figure 1(b)).

Figure 1(b): Site Plan (2003)



Site Plan 2003

The dugout was partitioned into three cells with two sheets of 30 mil polyethylene cut to adhere to the profile of the dugout. The polyethylene curtain was fabricated with an edge pocket to allow containment of weighting chain. The top of the curtain was fastened with a cable and end anchors. Monitoring of the oxygen concentration of the aerated and unaerated adjacent cells indicated that the curtain was an effective seal. In 1999, the dugout water levels were more than adequate, however, for the following 3 years supplemental water was needed. Prior to installing the curtains in dry years, the dugout was pumped full from a surface slough in order to ensure a supply of water for the full grazing season.

A coagulation cell (lined with polyethylene) stored water that had been pumped from the dugout and coagulated.

The various types of water all originated from the same source water. Each treatment had a separate group of steers and cow/calf pairs. The cow/calf pairs and steers receiving the same water treatment were grazed and watered separately as well. One dugout cell was left for direct access (water$_{direct}$) by one group of cattle. The middle dugout cell had untreated water pumped ($water_{pumped}$) to a trough for the second group of steers and cow/calf pairs. The third dugout cell was continuously aerated ($water_{aerated}$) using a compressor and diffusion system; the water was then pumped to a trough for the third group of cattle. The second and third group of cattle were prevented from accessing water at the dugout shore.

The fourth group of livestock were provided with the highest quality of water. Dugout water was used to fill a constructed cell known as a lined coagulation cell ($water_{coag}$) . The water was then treated by batch treatment of coagulation using liquid aluminum sulphate. Continuous treatment using chlorination was provided by adding chlorine immediately downstream of the pump with a goal to achieve a residual free chlorine concentration of 0.5 to 1.0 mg/L. The treated water was pumped to a trough to the fourth group of steers and cow/calf pairs. Cattle were prevented from accessing water at the coagulation cell.

In the fall of 2002, a deep well was drilled to a depth of 314 feet into the Hatfield Aquifer. Water from this well was pumped to a trough for a fifth treatment of steers.

2.2 Parameters Monitored

The project monitored:
- animal weight on a monthly basis
- parasites in faecal samples at the beginning and end of the study
- water consumption and water quality
- climatic conditions including rainfall, wind and air temperature
- water temperatures
- forage production, consumption and quality
- cattle behaviour

2.2.1 Cattle

Forty-four (44) yearlings were sorted into similar weight groups. Steers from each group were randomly assigned to each treatment. Each treatment included 11 steers. Each yearling was tagged to allow individual identification. In 2003 a fifth group of steers was added for the well treatment to bring the total to fifty-five (55).

In the years 2000 - 2002 forty (40) first calf heifers with calves were sorted into similar weight groups and assigned to each treatment. Each treatment included 10 cow/calf pairs, which were tagged to allow for individual identification.

(a) Methods

Trials were conducted with steers and cow-calf pairs in 2 separate experiments over 5 and 3 years, respectively. The duration of the trials with steers, over 5 years, varied from 74 to 117 days while those of the cow-calf pairs, over 3 years, varied from 61 to 90 days.

The starting date of the trials varied from 23 May to 15 July and was dictated by water and forage conditions and the breeding program of the cows.

(b) Activity

The orientation of the paddocks in the Cow-Calf Experiment made it difficult to observe the animals from a single vantage point. Therefore observations on animal activity were made only in the steer experiment. All observations were made for a 1 wk period near the end of July or early August, in each of 3 years (1999-2001), by timing and recording the herd activity in 30 minute increments from dawn to dusk.

(c) Weight gain

Body weights of steers, cow and calves were obtained in the morning on two consecutive days at the beginning and end of the experiment and at 30 d intervals during the trial periods each year. However, for subsequent analyses each trial period was divided into 2 sub-periods defined by early and late summer. The dates represented by each was approximately from early June to late July or early August and the final sub-period terminating from the end of August to late September.

(d) Pathogens

The role of pathogens and parasites in influencing cattle weight gain and the effect of water treatment on infectivity were examined by the presence of Trichostrongyle, Eimeria spp., Giardia spp., Cryptosporidium spp., and Nematodirus spp. in fecal samples taken rectally from each animal. Samples were collected prior to animal turnout on pasture and again at the end of the summer. All fecal samples were refrigerated prior to being submitted to Prairie Diagnostic Services, Western College of Veterinary Medicine, University of Saskatchewan, Saskatoon, Saskatchewan, for analysis of Trichostrongyle, Eimeria, Nematodirus, Giardia and Cryptosporidium oocysts. The qualitative fecal flotation technique was used for the identification of Trichostronglye, Nematodirus and Eimeria oocysts. Detection of Giardia cysts and Cryptosporidium oocysts was determined using the immunofluorescent antibody test (Cyst-a-Glo, Waterborne Inc, New Orleans, LA).

2.2.2 Scientific Equipment on Site

The equipment for pumping, aerating, data logging, energy storage and triggering pumps was housed in a 2 metre by 2.6 metre wooden structure. Six 60 watt solar panels provided energy for operation of the pumps, aeration system, data logger, sensors and cellular phone.

A Campbell Scientific CR10X data logger was used to record various parameters including pump operation, aerator operation, wind speed, rainfall, air temperature and dissolved oxygen. The logger was connected to a cell phone to allow remote monitoring and downloading of data.

Water consumption was monitored with flow meters tested to be accurate to within 0.5 percent. Water consumption for the direct entry treatment could not be monitored. Trough water level was maintained by using a float system with a pressure valve. The change in line pressure following valve operation triggered a pressure switch at the pump that turned the pump on and off as required. Year 2002 was the first year using the pressure to control pump operation. In the past, a telephone cable was used to relay signals back to the pumps.

2.2.3 Water Quality Monitoring

Water samples were collected every two weeks. Water analysis included a standard suite of chemical, physical and biological parameters. Samples were drawn directly from the three troughs supplying the steers and the direct entry cell, and were sent to the Saskatchewan Research Council laboratory for analysis. In addition, readings taken at various depths in the coagulation cell and at each of the dugout cells included temperature, dissolved oxygen, conductivity, and pH. In 2000 and 2001, algae identification samples were taken five times between June 15th and September 15th, and four times between July 3rd and September 10th in 2003. In 1999 algae was sampled only once in August. Gas chromatography - mass spectrometry (GC-MS) samples were taken mid June, July and August in 1999, 2000 and 2001. In 2002, GC-MS sampling was discontinued, as the scans did not identify useful trends.

2.2.4 Equipment Monitoring

WBDC staff visited the research site daily to monitor trough levels, aeration operation, chlorine levels, animal health & behaviour, and algae concentration. Weekly tasks included monitoring dugout and coagulation cell water levels, and pump filter maintenance.

2.2.5 Meteorological Monitoring

A Texas tipping bucket rainfall sensor was used for rainfall monitoring. The wind sensor was a Dicor manometer placed 3.6 metres above the ground. The temperature sensor was a thermistor style temperature probe protected with a radiation shield.

2.2.6 Water Temperature Monitoring

Water temperature monitoring in the trough and the direct entry dugout was implemented on August 4, 1999 using Stow Away Tidbit temperature loggers. This water temperature data was not accessible from the CR10X logger and an optical reader was used to download the data.

2.2.7 Forage Management

(a) Steer paddocks

Paddocks received liquid fertilizer coulter applied in mid-May, at a rate of 60 lb actual N/acre. Fertilizer was applied based on soil test results. Starting between May 23 and July 15, depending on growing conditions, four groups of 11 steers rotationally grazed crested wheatgrass (*Agropyron cristatum*)/smooth bromegrass (*Bromus inermis)/*alfalfa (*Medicago sativa)* paddocks for between 74 and 117 days. One animal in the Coagulated Water Group died from a lightning strike in mid-July, 2002.

(b) Cow-calf paddocks

Fifty-four acres of Prima fall rye was seeded in mid-May in 2000-2002 at a rate of 2.0 bushels per acre. Partner® was applied to seeded paddocks prior to fall rye seedling emergence. In 2000 and 2001 all paddocks were fertilized at 60 kg/ha. In 2002 fertility levels for the fall rye paddocks were sufficient from past applications of beef manure. Russian wild rye paddocks were not fertilized in 2002. Starting between May 23 and July 15, four groups of ten cow-calf pairs rotationally grazed the Russian wild rye (*Psathyrostachys juncea)*. The cow-calf pairs were on both pasture types for a total study period ranging from 61 to 90 days.

Forage production was monitored in all paddocks by clipping five $0.25 m^2$ samples in each paddock when animals were introduced and removed. Forage quality samples were submitted for analysis from both steer and cow-calf paddocks.

2.3 Statistical Analysis

The effects of water treatment ($\text{Water}_{\text{direct}}$, $\text{Water}_{\text{pumped}}$, $\text{Water}_{\text{coagulated}}$, and $\text{Water}_{\text{aerated}}$) on animal weight gains (total summer period and early and late summer sub-periods), animal activity, and infection by parasite were analyzed as a randomized complete block design with 4 water treatments and years as replicates (blocks). Infection rate by parasites was determined individually for Trichostrongyle, Eimeria, Giardia/Cryptosporidium, or Nematodirus spp. as the change of infection (+ or -) among animals in each water treatment. All analyses were evaluated using mixed effects ANOVA (SAS 1999) with year being a random variable and the main effects (year, water treatment) were tested by their interaction (error df ≤ 9). The small degrees of freedom severely reduced the ability to identify differences; therefore, a probability of $P<0.10$ was selected as significant. Treatment means were compared using single degree of freedom contrasts (Steel et al. 1997). With the addition of the well water in 2003, it was analyzed separately in comparison to the dugout treatments for 2003 only.

A second analysis was performed to determine the effects of parasites on animal weight gain. For these analyses, the design ignored the water treatments and allocated all animals into one of two groups depending on the presence or absence of infection by Trichostrongyle, Eimeria, Giardia, Cryptosporidium, or Nematodirus species. Animals that tested positive only once in a trial were considered positive for the test. The data was then analyzed as a randomized complete block with year as the replicate. Since the number of animals representing each group was often highly unbalanced, their means were weighted by the number of animals in each group.

3.0 Results and Discussion

3.1 Forage Production and Quality

(a) Steers

In 1999 paddock forage production was more than adequate for grazing yearlings (Table 1(a)). However, in 2000 and 2001, forage production of all paddocks was significantly affected by lack of precipitation. In 2001, pastures received only 5 to 6 inches of rainfall between May 1 and August 31, 2001. Forage yield averaging 1530 lb/ac in May was not a limiting factor for steers grazing these pastures at this time (Table 1). However, by July 25, pasture productivity dropped to 440 lb/ac, severely limiting animal performance. Forage quality (Table 2) was similar in 1999 and 2000 across paddocks with an expected decline in nutrient levels as the grazing season progressed and plants matured. This decrease in quality, including energy and crude protein, is one contributing factor in lower average daily gains (lb/day) later in the grazing season (NRC 1996). In 2001 however, quality was higher in August than in June due to timely rains occurring in July allowing for good vegetative growth in all paddocks.

Lack of winter moisture and low spring rainfall in 2002 caused a delay of forage production. Forage production on all paddocks improved late in the summer due to above average precipitation. Pastures received over 15 inches of rainfall between June 15 and September 6, 2002. Forage yield averaging 840 lb/ac in July was not a limiting factor for steers grazing these pastures at this time (Table 1). However, by July 21, pasture productivity had increased to 1000 lb/ac, allowing adequate animal performance. Forage quality (Table 2) was similar among paddocks with an expected decline in nutrient levels as the grazing season progressed and plants matured. However, with the late season precipitation a decrease in quality was not observed, and energy and crude protein in the forage were equivalent if not better than earlier in the season.

In 2003, forage production on all paddocks was adequate early summer (May-June) (Table 1) due to average precipitation. However lack of significant rainfall late summer reduced both yield and pasture quality. Pastures received only 7.46 inches of rainfall May 1 to September 30, 2003, with only 2.76 inches falling in July and August.

Forage yields on the Russian wild ryegrass paddocks averaged 3217 lb/ac in May (Table 1). However, by July 4, pasture production had decreased to 970 lb/ac on those pastures. At this time, steers were rotated onto the crested wheatgrass paddocks beginning July 7 until the end of the study period. Forage yields on the crested wheatgrass pastures ranged from 2268 to 902 lb/acre from early July until September, respectively (Table 1).

Forage quality was similar among paddocks in late May with an expected decline in nutrient levels as the grazing season progressed and plants matured (Table 2). However, by late summer pasture quality had decreased significantly which was reflected in reduced animal performance during this time. Crude protein in the Russian wild ryegrass pastures was 16% during late May which was more than adequate for growing steers. However, by early September crude protein was only 6% in the crested wheatgrass paddocks. Energy declined similar to protein content with levels of 64% total digestible nutrients (TDN) early summer falling to 56% TDN late summer.

Table 1a. Forage dry matter yield of crested wheatgrass paddocks.

	Pasture 1A	Pasture 2A	Pasture 3A	Pasture 4A
1999				
May 31	2208	1906	2483	3410
June 17	3205	1938	4194	2188
July 7	3070	2738	2637	2727
July 29	3532	5144	3960	4622
August 20	**2784**	**3232**	**3216**	**3226**
September 7	3496	2916	2761	2803
September 23	1799	2069	2310	2318
2000				
May 23	2198	2814	2283	2091
June 24	2622	2662	2628	2797
July 15	3001	3275	3141	3484
August 3	2046	2644	2083	2418
August 23	1893	2009	2118	2413
2001				
May 23	1161	1433	1831	1696
June 14	947	1531	1130	1128
July 4	309	1170	747	830
July 25	372	360	677	353
August 14	858	1056	1147	645
2002				
July 2	820	790	875	830
July 21	919	862	997	1112
July 27 OUT	777	657	845	763
August 13	916	913	940	795
August 20 OUT	523	603	639	854
September 9	1137	1095	1145	1255

Table 1b. Forage dry matter yield of steer paddocks 2003 (lb/acre).

	Pasture 1[z]	Pasture 2	Pasture 3	Pasture 4	Pasture 5	AVERAGE
RWR[y]						
May 30	2659	3129	3534	3847	2914	**3217**
July 4	1076	760	1032	907	1074	**970**
CWG[x]						
July 7	2251	2012	2056	2966	2052	**2268**
July 23	1335	1164	1624	1250	1411	**1357**
Aug 5	1008	1392	1780	1250	1272	**1340**
Aug 13	653	834	1039	1098	889	**902**
Sept 5	1121	1429	1318	1243	864	**1195**

[z] Pasture 1=Direct access steers; Pasture 2=Aerated water steers; Pasture 3=Well water steers; Pasture 4=Pumped water steers; Pasture 5= Coagulated water steers

[y] RWR=Russian wild ryegrass

[x] CWG=crested wheatgrass

Table 2a. Forage quality (DM) of crested wheatgrass paddocks.

	CP*	TDN	ADF	Ca	P	Mg	K	Na	Nitrate
1999									
June 5									
Pasture 1A	11.9	63.0	33.4	-	-	-	-	-	-
Pasture 2A	11.3	60.1	36.1	-	-	-	-	-	-
Pasture 3A	10.2	59.0	37.1	-	-	-	-	-	-
Pasture 4A	11.5	61.0	35.2	-	-	-	-	-	-
September 7									
Pasture 1A	4.0	54.2	41.6	-	-	-	-	-	-
Pasture 2A	5.2	54.8	41.1	-	-	-	-	-	-
Pasture 3A	3.6	55.0	40.8	-	-	-	-	-	-
Pasture 4A	5.1	53.5	42.3	-	-	-	-	-	-
2000									
May 23									
Pasture 1A	11.28	55.64	40.24	0.30	0.11	0.12	1.10	0.00	0.05
Pasture 2A	12.04	57.90	38.13	0.29	0.16	0.13	1.44	0.00	0.04
Pasture 3A	10.38	56.36	39.57	0.47	0.14	0.15	1.17	0.01	NIL
Pasture 4A	10.44	54.49	41.32	0.29	0.10	0.10	1.01	0.00	0.07
August 3									
Pasture 1A	7.23	53.99	41.79	0.35	0.08	0.17	0.73	0.01	NIL
Pasture 2A	8.15	54.16	41.63	0.32	0.11	0.13	1.21	0.00	NIL
Pasture 3A	8.34	54.90	40.94	0.36	0.08	0.17	1.04	0.01	NIL
Pasture 4A	7.61	53.50	42.25	0.32	0.05	0.12	0.74	0.02	NIL
2001									
June 11									
Pasture 1A	11.65	60.13	36.04	0.38	0.09	0.13	1.24	0.02	NIL
Pasture 2A	12.68	58.12	37.92	0.37	0.12	0.15	1.44	0.02	NIL
Pasture 3A	11.05	57.99	38.05	0.44	0.08	0.18	1.05	0.02	NIL
Pasture 4A	13.32	57.41	38.59	0.34	0.11	0.13	1.31	0.04	NIL
August 9									
Pasture 1A	26.72	72.19	24.76	0.38	0.16	0.14	2.82	0.02	NIL
Pasture 2A	17.72	66.75	29.84	0.49	0.30	0.15	3.40	0.02	NIL
Pasture 3A	22.76	68.27	28.43	0.37	0.29	0.16	4.17	0.02	0.13
Pasture 4A	21.04	64.30	32.14	0.37	0.16	0.13	2.52	0.04	0.15
2002									
July 2									
Pasture 1A	16.23	64.87	31.61	0.40	0.28	0.17	2.89	0.05	NIL
Pasture 2A	17.03	65.32	31.19	0.44	0.31	0.18	2.83	0.05	NIL
Pasture 3A	15.48	64.17	32.26	0.44	0.32	0.24	2.29	0.03	NIL
Pasture 4A	14.56	64.90	31.58	0.38	0.25	0.15	1.96	0.05	NIL
July 16									
Pasture 1A	14.72	64.48	31.97	0.38	0.13	0.23	1.69	0.05	NIL
Pasture 2A	16.55	63.94	32.47	0.32	0.19	0.15	2.63	0.02	0.21
Pasture 3A	18.87	67.87	28.80	0.41	0.17	0.18	2.51	0.05	0.18
Pasture 4A	14.22	63.96	32.46	0.39	0.19	0.15	1.75	0.05	0.12
Sept 9									
Pasture 1A	9.5	56.57	39.40	0.24	0.08	0.14	0.85	0.02	NIL
Pasture 2A	15.6	62.95	33.40	0.44	0.10	0.12	1.24	0.03	NIL
Pasture 3A	17.3	61.76	34.50	0.46	0.19	0.16	2.37	0.01	NIL
Pasture 4A	13.3	64.18	32.30	0.41	0.25	0.14	2.96	0.01	0.55

[z]CP=crude protein; TDN=total digestible nutrients; ADF=acid detergent fiber; Ca=calcium; P=phosphorous; Mg=magnesium; K=potassium; Na=sodium

Table 2b. Forage quality (DM) of steer paddocks 2003 (%).

	Pasture 1[z]	Pasture 2	Pasture 3	Pasture 4	Pasture 5	AVERAGE
RWR[y]						
May 30						
CP[x]	13.3	18.7	17.0	16.7	14.4	**16.0**
TDN	64.9	65.8	62.8	64.4	61.8	**63.9**
ADF	31.5	30.8	33.6	32.1	34.5	**32.5**
Ca	0.19	0.30	0.20	0.31	0.25	**0.25**
P	0.22	0.30	0.28	0.22	0.27	**0.26**
CWG[w]						
September 5						
CP	4.6	6.3	5.5	6.1	6.8	**5.9**
TDN	53.4	56.7	58.7	57.0	55.9	**56.3**
ADF	42.4	39.3	37.4	39.0	38.5	**39.3**
Ca	0.27	0.18	0.21	0.19	0.20	**0.21**
P	0.08	0.05	0.03	0.05	0.06	**0.05**

[z] Pasture 1=Direct access steers; Pasture 2=Aerated water steers; Pasture 3=Well water steers; Pasture 4=Pumped water steers; Pasture 5= Coagulated water steers

[y] RWR=Russian wild ryegrass

[x] CP=crude protein; TDN=total digestible nutrients; ADF=acid detergent fiber; Ca=calcium; P=phosphorous

[w] CWG=crested wheatgrass

(b) Cow-Calf Pairs

Cow-calf pairs began grazing Russian wild rye paddocks early June in both 2000 and 2001. Forage production (Table 3) did become a limiting factor by mid-June (due to a relatively dry spring in both years) and grass-alfalfa hay was fed for a ten-day period. In 2001, regrowth in previously grazed Russian wild rye paddocks was not sufficient by July to allow cows to re-graze these paddocks until the fall rye paddocks had adequate forage growth. Fall rye paddocks were grazed late June (2000) and early August (2001).

During a four-week period in both 2000 and 2001, cow-calf pairs consumed three different types of forage. These variances in feed type as well as forage availability may have been contributing factors in water consumption and animal performance results. Because feeds themselves contain some water, not all water must be provided by water consumption. Actively growing forages, such as the fall rye, are usually very high in moisture while hays are low in moisture. This variance in feed types is another variable affecting water consumption (NRC 1996). Animal performance may have been directly affected by the quantity of forage available. Forage availability has been shown to affect feed intake (NRC 1996) with intake maximized when forage availability is approximately 2250 kg dry matter/ha (NRC 1987). Forage availability for cow-calf pairs was below this critical level for both grazed species across all treatments throughout the season.

In 2002, cow-calf pairs began grazing Russian wild rye paddocks on July 15. Forage production (Table 3) was very reasonable given the early drought conditions experienced at the farm. Regrowth in previously grazed Russian wild rye paddocks was adequate by August to allow cows to re-graze these paddocks until the fall rye paddocks had adequate forage growth. Fall rye paddocks were grazed beginning July 30, 2002.

During July and August, cow-calf pairs consumed two different types of forage. Feed type as well as forage availability early may have been contributing factors in cow performance data (See Section 3.7.1). Animal performance may have been directly affected by the quantity of forage available. Forage availability has been shown to affect feed intake (NRC 1996) with intake maximized when forage availability is approximately 2250 kg dry matter/ha (NRC 1987). Forage availability for cow-calf pairs was below this level for both grazed species across all treatments throughout the season.

Forage quality (Table 4) was very good in the Russian wild rye (RWR) paddocks at various times throughout the grazing season with nutrient levels more than adequate for lactating beef cows (NRC 1996).

Table 3. Forage yield (DM) of Russian wild rye and fall rye paddocks.

	Pasture 1A	**Pasture 2A**	**Pasture 3A**	**Pasture 4A**
2000	**Direct**	**Pumped**	**Aerated**	**Coagulated**
RUSSIAN WILD RYE				
June 1	1350	1352	1499	1478
June 24	1070	1123	1116	1292
August 25	1406	1570	2433	1756
FALL RYE				
June 30	1636	1507	1491	1672
July 28	1246	1260	998	1147
2001				
RUSSIAN WILD RYE				
June 5	1124	1238	1325	1366
June 16	1772	1128	1259	2200
FALL RYE				
August 3	850	1891	904	1039
August 15	837	1057	614	858
2002				
RUSSIAN WILD RYE				
July 15	1468	1633	1880	1828
July 22	1057	895	1255	1234
August 15	1040	1637	1324	1139
FALL RYE				
July 30	1234	990	1120	1212
August 7	670	895	855	922
August 30	964	1088	1126	1206
September 9	1717	1990	1344	1755

Table 4. Forage quality (DM) of Russian wild rye and fall rye paddocks.

	CP*	TDN	ADF	Ca	P	Mg	K	Na	Nitrate
2000									
May 31 (RWR)									
Pasture 1A	16.54	64.27	32.17	0.41	0.21	0.15	2.08	0.00	NIL
Pasture 2A	18.26	67.88	28.79	0.41	0.28	0.17	2.58	0.00	0.04
Pasture 3A	21.01	71.26	25.63	0.38	0.27	0.20	2.85	0.00	NIL
Pasture 4A	19.81	70.69	26.17	0.33	0.25	0.22	2.62	0.00	NIL
July 27 (Fall Rye)									
Pasture 1A	25.88	72.12	24.82	0.45	0.45	0.32	4.98	0.02	0.26
Pasture 2A	29.02	72.01	24.93	0.38	0.49	0.26	5.37	0.00	1.43
Pasture 3A	26.38	72.64	24.33	0.48	0.48	0.30	5.42	0.04	0.36
Pasture 4A	30.97	73.11	23.90	0.40	0.44	0.26	5.77	0.02	1.30
Aug 21 (RWR)									
Pasture 1A	14.28	62.27	34.04	0.47	0.19	0.25	2.59	<0.01	NIL
Pasture 2A	16.30	62.72	33.62	0.40	0.19	0.25	2.81	0.02	0.09
Pasture 3A	14.28	61.77	34.51	0.42	0.17	0.31	2.50	0.01	NIL
Pasture 4A	14.54	62.24	34.07	0.44	0.15	0.33	2.78	0.05	NIL
2001									
June 4 (RWR)									
Pasture 1A	17.60	62.47	33.85	0.42	0.24	0.20	2.22	0.02	NIL
Pasture 2A	19.90	66.99	29.63	0.46	0.25	0.20	3.04	<.005	NIL
Pasture 3A	19.66	63.93	32.49	0.47	0.25	0.21	2.71	0.02	0.07
Pasture 4A	25.80	69.70	27.08	0.54	0.23	0.21	2.72	0.01	0.12
Aug 3 (Fall Rye)									
Pasture 1A	31.23	74.37	22.72	0.47	0.68	0.26	5.66	0.01	0.23
Pasture 2A	33.90	73.63	23.41	0.53	0.65	0.24	5.58	0.01	2.36
Pasture 3A	33.65	74.81	22.31	0.48	0.74	0.23	5.83	0.02	0.28
Pasture 4A	35.65	73.47	23.56	0.54	0.64	0.22	5.95	0.02	2.01
2002									
Russian wild rye									
July 15									
Pasture 1A	14.87	61.08	35.16	0.46	0.16	0.20	2.15	0.05	NIL
Pasture 2A	-	-	-	-	-	-	-	-	-
Pasture 3A	14.28	63.06	33.30	0.32	0.21	0.23	3.09	0.01	NIL
Pasture 4A	13.90	58.85	37.24	0.40	0.17	0.16	2.28	0.01	NIL
Aug 15									
Pasture 1A	25.2	66.17	30.4	0.31	0.33	0.20	3.20	0.01	0.15
Pasture 2A	22.9	63.76	32.6	0.30	0.26	0.18	2.86	0.01	0.37
Pasture 3A	18.1	63.10	33.3	0.30	0.31	0.22	2.39	0.01	NIL
Pasture 4A	-	-	-	-	-	-	-	-	-
Fall rye									
July 30									
Pasture 1A	25.80	69.23	27.53	0.46	0.54	0.23	6.05	0.05	0.78
Pasture 2A	30.88	74.20	22.88	0.53	0.54	0.27	5.83	0.05	1.00
Pasture 3A	33.92	75.90	21.29	0.49	0.59	0.30	6.83	0.04	2.17
Pasture 4A									
Aug 30									
Pasture 1A	30.2	72.22	24.7	0.47	0.57	0.25	5.08	0.01	0.44
Pasture 2A	30.3	69.72	27.1	0.38	0.63	0.27	5.47	0.01	1.13
Pasture 3A	28.3	67.41	29.2	0.35	0.49	0.18	4.77	0.02	1.26
Pasture 4A	21.1	68.81	27.9	0.41	0.58	0.24	4.23	0.01	NIL

[z]CP=crude protein; TDN=total digestible nutrients; ADF=acid detergent fiber; Ca=calcium; P=phosphorous; Mg=magnesium; K=potassium; Na=sodium

3.2 Precipitation and Air Temperature

The Western Beef Development Center area received an average snowfall over the 2002-03 winter period, followed by an average rainfall during April (118% of normal) and May (97% of normal) of 2003. The June to August rainfall varied from 55% to 70% of normal while precipitation during September was slightly above normal (106%). The air temperature for the April - August of 2003 was above normal however, was below normal for September. The air temperature varied from 3.1 ^{o}C above normal during August to 0.3 ^{o}C below normal during September. The air temperature was 1.4 ^{o}C, 1.2 ^{o}C, 0.6 ^{o}C and 0.5 ^{o}C above normal for April, May, June and July, respectively.

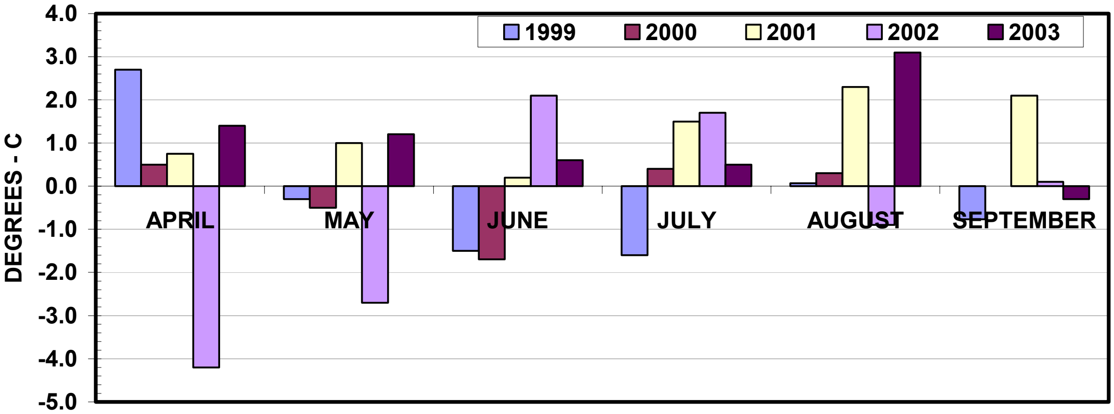


FIGURE 2 : AIR TEMPERATURE VARIATION FROM NORMAL

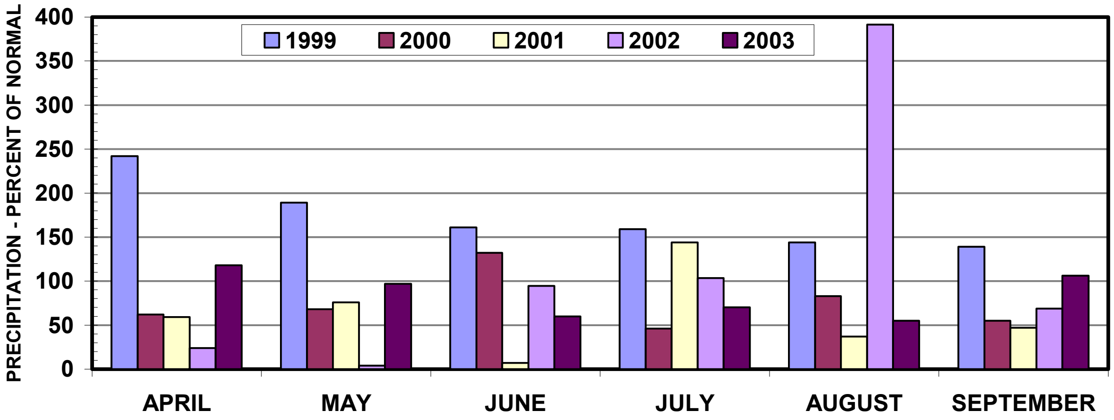


FIGURE 3 : PRECIPITATION - PERCENT OF NORMAL

The total rainfall for the April - September period was below normal for 2003, 2001 and 2000, above normal for 2002 and near normal for 1999. However, these total period rainfalls can be miss-representative of the forage moisture growing conditions, especially early in the growing season. For example, 2002 had the driest April - July period of the five year period (1999-2003) however, rains in August increased the period totals to above normal. Whereas, 1999 and 2003 had near normal rainfall during the spring period (April to early June), and then for 2003 the amount of rainfall decreased to below normal by the end of September and for 1999 the rainfall continued at a near normal rate to the end of September. The spring and early summer (April to mid July) period for 2001 was dry and there was no significant rainfall until mid July and then little rainfall in August to September. The rainfall for 2000 was similar to 2001 during the April to June period and then rainfall during the early part of June increased the rainfall total to near normal until mid-July, and then the rainfall totals tracked slightly below normal until the end of September.

The mean monthly air temperature for the April-September, 1999-2003 period, varied from 3.1 ^{o}C above normal during August of 2003 to 4.2 ^{o}C below normal during April of 2002. The warmest year was 2001 with an overall mean temperature of 1.6 ^{o}C above normal and 2002 was the coolest year with a mean temperature of 0.8 ^{o}C below normal. The air temperature for the period April to September for 1999 varied from 1.6 ^{o}C below normal to 2.7 ^{o}C above normal. The temperature in 2000 varied from 1.7 ^{o}C below normal to 0.5 ^{o}C above normal and for 2001, it varied from 0.2 ^{o}C to 2.3 ^{o}C above normal. The greatest mean monthly temperature variation occurred in 2002; 4.2 ^{o}C below normal to 2.1 ^{o}C above normal. The temperature in 2003 varied from 0.3 ^{o}C below normal to 3.1 ^{o}C above normal.

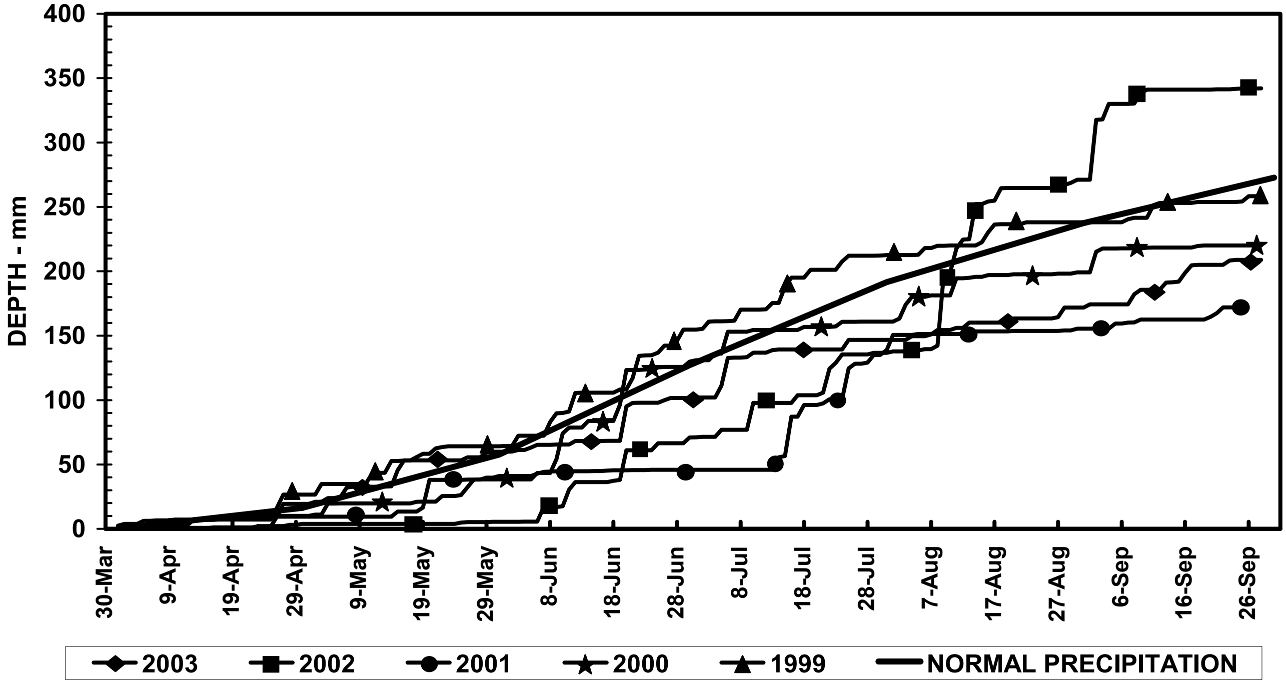


Figure 4: Accumulated Daily Precipitation

3.3 Water Chemistry

Inorganic ions and nutrient concentrations were below the recommended limits for livestock for the surface water in all five years of the study (Task Force on Water Quality Guidelines, 1997). The well water, introduced in 2003, exceeded the recommended limits for sulphate of 1000 mg/L by about 50%. Over the course of the study, the biological guideline (1000 *E. coli* counts/100 mL) was exceeded only in the direct entry cell. See Table 5 for a summary of selected constituents for 1999 to 2003.

The average values found in Table 5 provide a summary of the water quality and show the improvement in water quality with better dugout management practices and treatment. The combination of faeces and disturbed sediment in the direct entry cell contributed to high levels of *E. coli*, turbidity, ammonia, odour and dissolved organic carbon (DOC). Restricting cattle access (pumped cell) significantly reduced these parameters. It also reduced the concentration of iron, manganese, chlorophyll *a* and phosphorus. The sensitivity of cattle to these various constituents is not known, but the constituents are known to impart foul taste and odour to water. The well water was high in sulphates and ammonia, as compared to the four other water types. It also contained low levels of phosphorous and as expected, chlorophyll a.

The improvement of water quality with aeration was not apparent 2003. The 2003 results showed small variance in constituents between aerated and unaerated water. A slight decrease in iron and ammonia was seen with the aerated water. The marginal improvement in water quality from aeration in 2003 may be related to inadequate aeration. The oxygen demand was higher than normal in 2003 and oxygen levels in the water were less than desirable for a month in the middle of the study. Aeration has been shown to reduce iron, manganese, phosphorus and chlorophyll *a* in ponded water by maintaining an aerobic condition on the pond bottom. A reduced E. coli count in the aerated cell is common, and may be the result of increased water circulation and exposure of bacteria to the sun’s UV rays.

The improvement of water quality with coagulation was extensive. All parameters shown in Table 5 were significantly reduced with the exception of sulphates. Aluminum sulphate coagulation adds some sulphates to the water and therefore the sulphate concentration was expected to increase.

The average values in Table 5 provide a good summary for each year, however, examination of the bi-weekly data for 2003 shows additional trends. Figures 5 and 6 show the relationship of iron and turbidity levels for the various treatments. Cattle entering the cell (direct access) contributed to considerable sediment resuspension and the addition of nutrients to the water. The iron and turbidity measurements fluctuated according to the time lapse between cattle drinking and sampling.

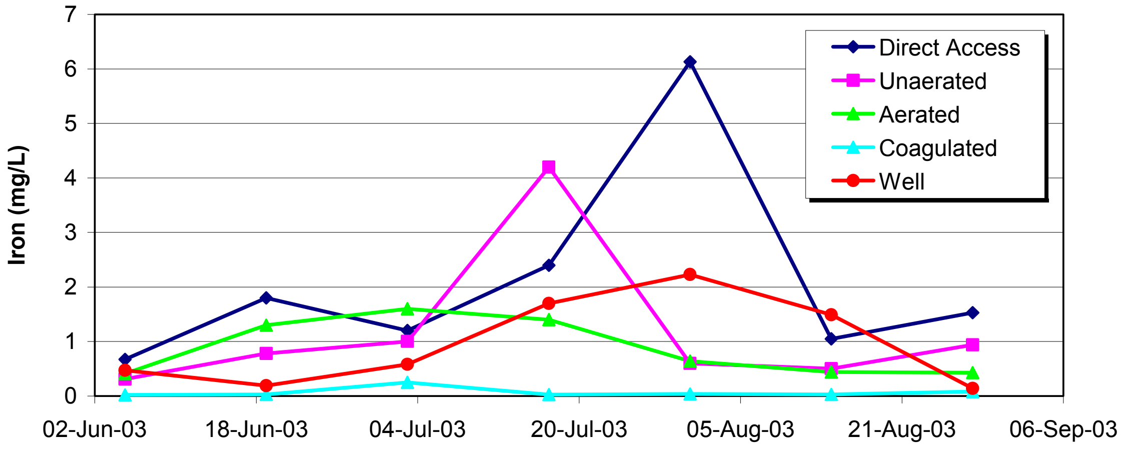


Figure 5: Iron in Various Water Types – Year 2003

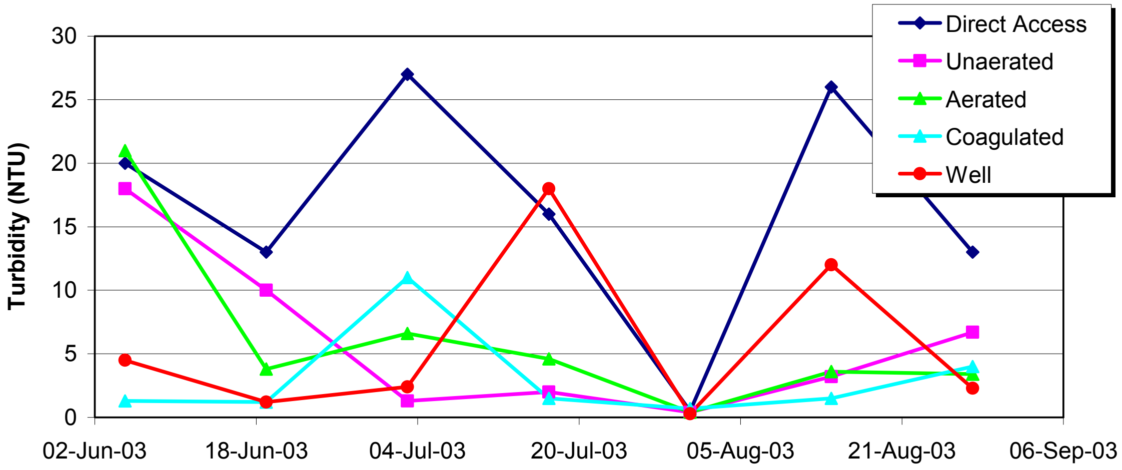


Figure 6: Turbidity in Various Water Types – Year 2003

Table 5 - Average Concentration of selected constituents in water offered to cattle

Water Quality	E coli (ct/100mL)	Fe (mg/L)	Mn (mg/L)	Chlor a (ug/L)	Sulphate (mg/L)	DOC (mg/L)	Dissolved P (mg/L)	Colour (APHA)	Turbidity NTU	Ammonia (mg/L)	Total P (mg/L)	Odour (TON)	D.O. (top)	D.O. (bottom)
1999														
Direct Access	3504	1.55	0.13	82	2	19.2	0.14	48	7.42	N/A	0.25	N/A	8.6	5.1
Unaerated	572	1.64	0.21	58	2	16.8	*	48	5.75	N/A	*	N/A	9.8	4.8
Aerated	28	1.27	0.23	63	2	17.0	*	46	6.15	N/A	*	N/A	8.3	7.4
Coagulated	27	0.03	0.06	1	90	8.4	*	6	1.73	N/A	*	N/A	8.6	9.0
2000														
Direct Access	6594	5.38	0.56	404	4	28.0	0.25	89	43.0	1.66	0.95	70	5.7	1.2
Unaerated	193	1.98	0.28	174	3	25.0	0.25	55	9.0	0.38	0.64	65	7.8	1.6
Aerated	79	1.32	0.24	128	14	24.3	0.25	53	9.8	0.30	0.64	27	7.7	7.2
Coagulated	67	0.10	0.09	10	106	11.1	0.04	14	2.7	0.24	0.06	2	8.3	8.2
2001														
Direct Access	5950	2.09	0.44	28	333	39.0	0.33	62	48.5	4.07	0.45	5	3.9	3.1
Unaerated	97	0.13	0.20	41	403	37.3	0.25	46	3.4	1.06	0.38	3	6.0	2.4
Aerated	13	0.13	0.20	41	413	37.0	0.27	45	3.6	0.48	0.39	3	7.0	6.9
Coagulated	10	0.02	0.03	5	385	13.5	0.03	6	1.5	0.23	0.06	1	7.5	6.7
2002														
Direct Access	5976	2.01	0.44	74	81	28.5	0.28	45	122.3	1.30	1.02	73	4.7	1.9
Unaerated	728	0.21	0.20	49	83	25.2	0.24	38	64.4	0.96	0.81	87	10.8	1.7
Aerated	949	0.25	0.31	82	82	25.6	0.28	40	62.4	0.90	0.77	85	7.7	5.5
Coagulated	7	0.03	0.03	6	236	11.2	0.01	5	3.0	0.11	0.03	0	9.7	9.3
2003														
Direct Access	706	2.11	0.41	109	6	23.9	0.36	53	16.5	0.71	0.75	20	5.4	0.6
Unaerated	8	1.19	0.26	22	6	20.0	0.45	48	5.9	0.77	0.63	16	4.3	0.7
Aerated	2	0.89	0.37	22	6	21.4	0.48	50	6.2	0.65	0.65	16	4.4	2.7
Coagulated	3	0.07	0.09	8	135	10.1	0.03	7	3.0	0.18	0.06	0	9.2	8.2
Well	1	0.97	0.24	2	1450	7.7	0.03	8	5.8	2.40	0.06	2	N/A	N/A
5 Year Average														
Direct Access	**4546**	**2.63**	**0.40**	**139**	**85**	**27.7**	**0.27**	**59**	**48**	**1.93**	**0.68**	**42**	**5.7**	**2.4**
Unaerated	**319**	**1.03**	**0.23**	**69**	**99**	**24.9**	**0.30**	**47**	**18**	**0.79**	**0.62**	**43**	**7.7**	**2.2**
Aerated	**214**	**0.77**	**0.27**	**67**	**103**	**25.1**	**0.32**	**47**	**18**	**0.58**	**0.61**	**33**	**7.0**	**5.9**
Coagulated	**23**	**0.05**	**0.06**	**6**	**190**	**10.9**	**0.03**	**8**	**2**	**0.19**	**0.05**	**1**	**8.6**	**8.3**
Guideline	1000	N/A	N/A	N/A	1000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

* Phosphorus values were very high in the troughs and data was deleted. It is speculated that contamination with fertilizer occurred.
Samples on June 25 and September 22 indicated directly from the coagulated cell showed dissolved phosphorus was only 0.01 and 0.02 mg/L respectivelyl

In 1999, the direct entry cell was deep and turbidity levels were not influenced to the same degree by the cattle. However, anaerobic conditions at the bottom of the cell in the late summer caused the iron to resuspend. In 2003, anaerobic conditions also caused the iron concentrations to slightly increase at the end of the trial in both the unaerated and direct access cells.

In general, the organic and inorganic constituents in 2003 were improved as treatment progressed from direct entry to coagulated water.

3.4 Biological Constituents (*E. coli*)

The biological constituents are more difficult to interpret for ruminants because they are capable of buffering the effects of microbial pathogens. *E. coli* counts *(E. coli* count indicates the presence of faeces) in 2003, shown in Figure 7, are similar to results from previous years. As in other years, the direct entry cell exhibits much higher counts than the other cells.

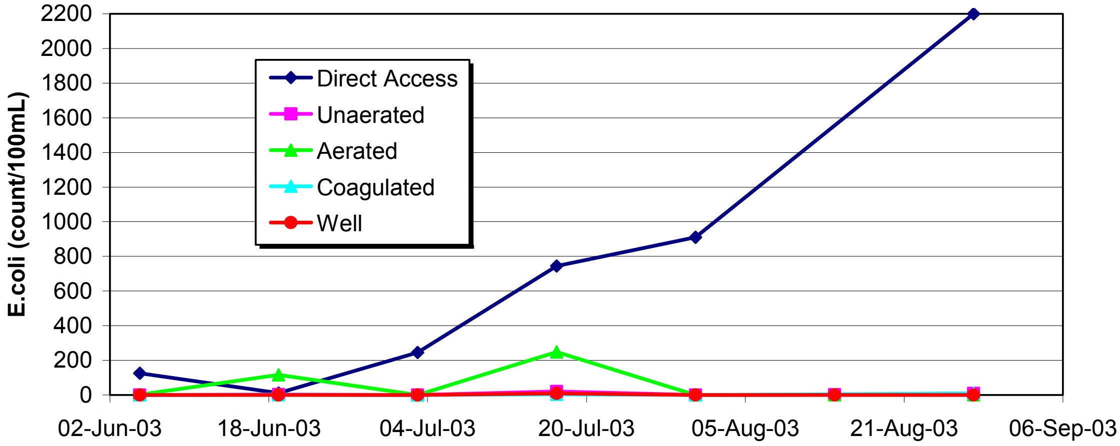


Figure 7: E-coli in Various Water Types – Year 2003

The last sample in the direct entry cell exceeded the Australian guideline for livestock of 1000 counts per 100 ml. This guideline is based on faecal coliforms, of which *E. coli* is one type (Task Force on Water Quality Guidelines, 1997). Young calves have been shown to contact scours when drinking water containing coliform bacteria of more than 1 count per 100 mL.

A water sample was taken bi-weekly from each of the cells to identify the algae type, and determine the presence or absence of algae toxins. Table 6 identifies the predominant species of algae and associated characteristics for the years 1999 to 2003. It shows that in 1999 and 2001, the algae would probably have had minor impact on water quality compared to 2000. In 2000, the predominant algae species was *Anabeana*, known to produce taste, odour and toxins and the chlorophyll *a* concentration was also the highest over the five years of the project.

Oscillatoria was the predominant algae species in 2002 and 2003 (with the exception of the coagulated cell in 2003) in all types of water. *Oscillatoria* is known to impart taste and odour to the water, but is not usually associated with toxins. The blooms occurred in August and July, and were most pronounced in the direct entry cell.

Aphanothece was the predominant algae species in the coagulated cell in 2003.

In general, the E. coli and algae population decreased with increased level of treatment.

Table 6: Comparison of Algae.

Year	Treatment	Chlor *a* (mg/L)	Cyanobacteria (%)	Predominant Species	Comments
1999	Direct Access	82	95	Chrococcus	Chrococcus not known to produce toxins nor odours
1999	Unaerated	58	75	Chrococcus	
1999	Aerated	63	100	Chrococcus	
1999	Coagulated	1	95	Microsystis	May produce liver toxin
2000	Direct Access	404	35	Anabaena	May produce neurotoxin
2000	Unaerated	174	90	Anabaena	May produce neurotoxin
2000	Aerated	128	60	Anabaena	May produce neurotoxin
2000	Coagulated	10	10	Green	Cyanobacteria was Oscillatoria
2001	Direct Access	28	90	Aphanizomenon	Aphanizomenon known to produce taste and odours
2001	Unaerated	41	60	Aphanizomenon	
2001	Aerated	41	90	Aphanizomenon	
2001	Coagulated	5	100	Lyngbya	Lyngbya - no known taste or odours
2002	Direct Access	147	35	Oscillatoria/Plankothrix	taste and odours
2002	Unaerated	81	45	Oscillatoria	taste and odours
2002	Aerated	79	20	Oscillatoria/Plankothrix	taste and odours
2002	Coagulated	6	90	Oscillatoria/Pseudoanabaena	taste and odours
2003	Direct Access	109	38	Oscillatoria	taste and odours
2003	Unaerated	25	17	Oscillatoria	taste and odours
2003	Aerated	26	73	Oscillatoria	taste and odours
2003	Coagulated	8	100	Aphanothece	

3.5 Taste and Odour

Results from five years of water consumption monitoring suggest that cattle can distinguish between different types of water and exhibit preferences for high quality, good tasting water. For humans, some major compounds causing taste and odour problems in surface water include: geosmin, MIB, hydrogen sulphide, ammonia, chlorine, iron, manganese, etc. Geosmin and MIB are compounds released by cyanobacteria (blue-green algae). Geosmin imparts an earthy odour and MIB imparts a musty taste to the water. Hydrogen sulphide is associated with the anaerobic decomposition of organic matter and gives off a gas with a rotten egg smell. Ammonia is a pungent gas that forms under anaerobic conditions in the presence of nitrogen. Iron and manganese can change the colour of water and impart a metallic-like taste.

The odour of the water, based on human sense of smell, was also tested every two weeks (Figure 8). The water was heated to 65°C and diluted with distilled water until the odour disappeared to 50% of the panel. The dilution factor required to eliminate the odour is referred to as the threshold odour number (TON). Although cattle have a different sense of smell than humans, the TON is still a useful measure. Odour was not tested in 1999. In 2000, 2001, 2002 and 2003 the coagulated water, with about 50% of the organics removed, consistently had the lowest TON, usually between 1 and 3. The direct entry water, with the exception of 2002 and 2003, had the highest odour.

In 2003, a peak in odour for the direct, aerated and unaerated cells was seen on July 3rd. Chlorophyll *a* also decreased significantly on this date, exhibiting an algae kill (Figure 9). When algae die they may release odour, which may be the reason as to why the three water types peaked in odour on this date.

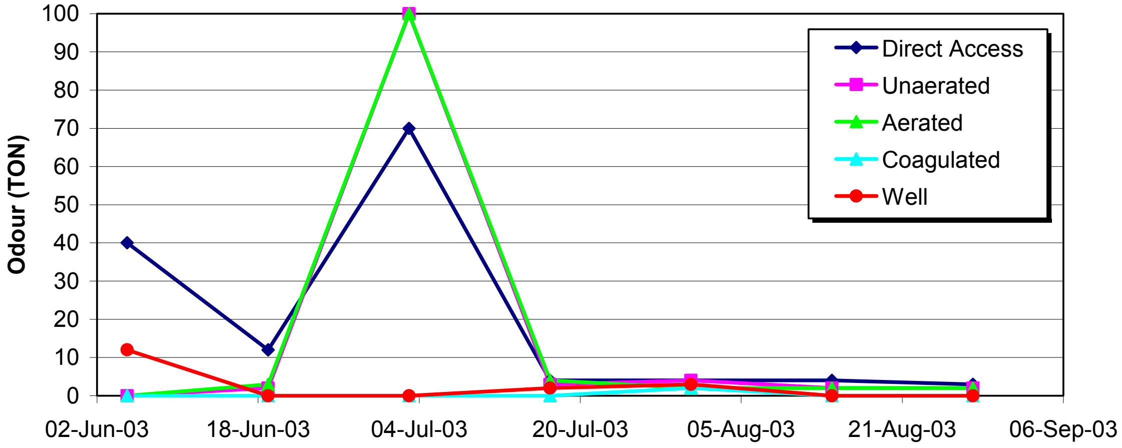


Figure 8: Odour in Various Water Types – Year 2003

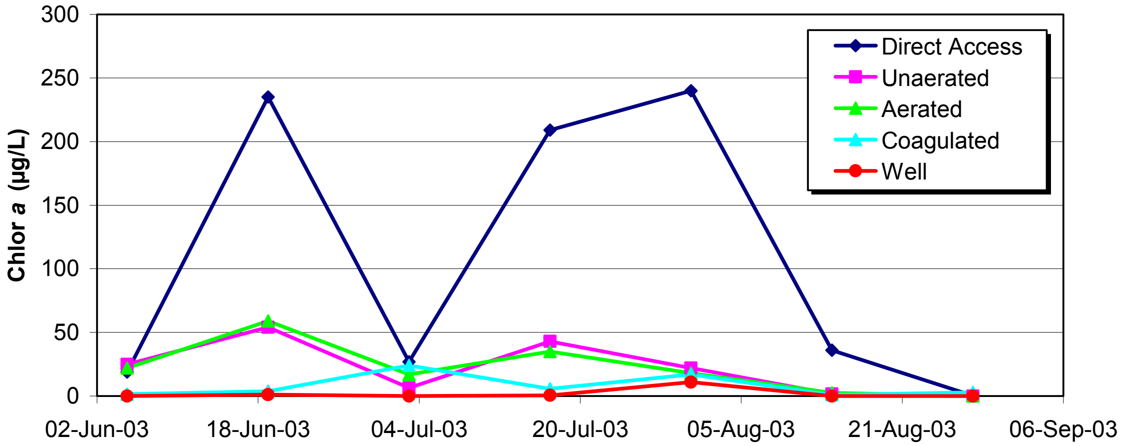


Figure 9: Cholorphyll *a* in Various Water Types – Year 2003

With anaerobic conditions present in the direct entry and unaerated cells, one would expect significant production of ammonia. Analysis for ammonia showed increasing ammonia concentrations as water quality deteriorated (Figure 10). The ammonia concentration in the coagulated cell remained low throughout the summer, demonstrating the benefit of coagulation and aeration. The aerated cell showed ammonia production in July and August, indicating inadequate aeration for the oxygen demand. Ammonia in the well water remained fairly consistent throughout the summer months. It would be of interest to determine if cattle are sensitive to the pungent odour of ammonia, and if so, what concentration is acceptable.

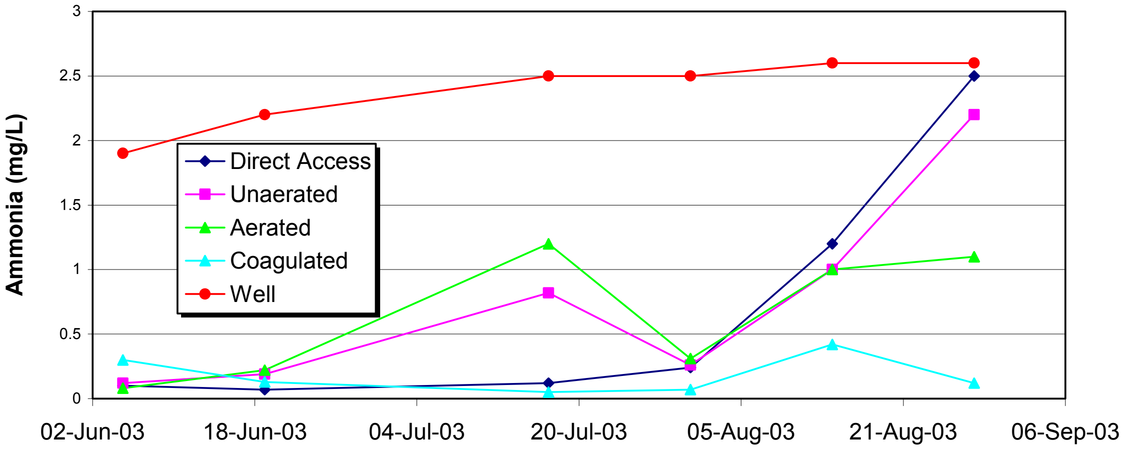


Figure 10: Ammonia in Various Water Types – Year 2003

Chlorine imparts taste and odour that most people experience in swimming pools. In the first year, high chlorine doses were applied to the coagulated water in an attempt to maintain chlorine residuals in the trough. This was difficult as the sunlight and open air quickly dissipated the chlorine. In 2000, 2001, 2002 and 2003 chlorine was injected at a dose sufficient to maintain free chlorine in the distribution line for a minimum of 20 minutes. This is similar to recommendations for drinking water for humans to ensure a three log removal of bacteria. As the chlorine entered the trough it was diluted and dissipated. This is probably a rational approach to achieve reasonable disinfection while minimizing chlorine odour at the trough.

One would expect that if taste and odour affected consumption, it would have been noticed in 2000. Water consumption did not vary significantly during the peak of cyanobacteria in 2000 and associated rises in odour.

In general, the odour improved with increased treatment and was most noticeable in 2000. Preference trials to determine the sensitivity of cattle to chlorine, ammonia and possibly other parameters such as odour and algae levels would be helpful.

3.7 Water Consumption and Weight Gains

3.7.1 Dugout Treatments

Water treatment affected steer performance significantly ($P < 0.10$) over the entire trial period, and there was a tendency for improved weight gain with $\text{Water}_{\text{aerated}}$ and $\text{Water}_{\text{coagulated}}$ compared to $\text{Water}_{\text{direct}}$, and the treatment ranking was $\text{Water}_{\text{direct}} < \text{Water}_{\text{pumped}} < \text{Water}_{\text{coagulated}} < \text{Water}_{\text{aerated}}$ (Table 13). Also, water treatment affected ($P < 0.10$) weight gains by steers in early summer but not ($P > 0.10$) in late summer (Table 13). Observation over individual years indicates an interaction with water treatment where the response in 1999 and 2002 deviated markedly from 2000 when the aerated treatment produced the smallest gains. The inability to detect significant ($P < 0.10$) differences is at least partly the result of a relatively small degree of freedom for error and, apparently, the loss of treatment effectiveness or an improvement in the palatability of untreated water ($\text{Water}_{\text{direct}}$). The departure in the trend of weight gain among treatments in 2000, and to a lesser extent in 2001, compared to the other three years (1999, 2002, 2003; Table 3) may be related, through an unrecognized mechanism, to the drought conditions. For example, water quality would be expected to be altered through aeration and mixing in 2000 and 2001 when it was pumped to the test dugout from other sources. However, this effect is not discernable in standard qualitative analyses (Table 5). $\text{Water}_{\text{aerated}}$ had no effect ($P > 0.10$) on the weight gains of cows and calves while pumping without treatment ($\text{Water}_{\text{pumped}}$) appeared to be the most effective (Table 7). $\text{Water}_{\text{pumped}}$ and $\text{Water}_{\text{aerated}}$ tended to produce greater ($P < 0.10$) weight gains in calves than $\text{Water}_{\text{direct}}$ in the first period but this difference had disappeared by the second period (Table 7). Calf sex had no effect on the weight gains of cows ($P > 0.10$) but male calves produced greater ($P < 0.10$) weight gains than female calves (Table 7). However, the effect of calf sex was consistent ($P < 0.10$) among treatment with male calves gaining more ($P < 0.10$) weight when drinking $\text{Water}_{\text{pumped}}$ and $\text{Water}_{\text{coagulated}}$ than $\text{Water}_{\text{direct}}$, while female calves gained less weight ($P < 0.10$) drinking $\text{Water}_{\text{coagulated}}$ than $\text{Water}_{\text{direct}}$ (Table 7).

Water treatment had no effect ($P > 0.10$) on infection by Trichostrongyle, *Eimeria*, *Giardia*/*Cryptosporidium*, or *Nematodirus* spp. for either steers, cows or calves (Tables 8 and 9). This is in contrast to Olson et al. (1995) who demonstrated that infected lambs had a reduced rate of gain without a reduction in intake, suggesting a malabsorptive disease. Holechek et al. (1989) also concluded that depressed weight gains of cattle drinking from fecal contaminated water was the result of reduced water intake leading to reduced forage intake.

Steers on the $\text{Water}_{\text{direct}}$ treatment spent less ($P < 0.10$) time grazing and more ($P < 0.10$) time resting than animals drinking from $\text{Water}_{\text{pumped}}$, $\text{Water}_{\text{coagulated}}$, or $\text{Water}_{\text{aerated}}$ (Table 10). Drinking frequency was similar ($P > 0.10$) among treatments but steers drinking (actual time spent ingesting water) from $\text{Water}_{\text{pumped}}$ spent less time than those on $\text{Water}_{\text{direct}}$, $\text{Water}_{\text{coagulated}}$, or $\text{Water}_{\text{aerated}}$ (Table 11). This was reflected in the tendency of less water consumed from $\text{Water}_{\text{pumped}}$ than from $\text{Water}_{\text{coagulated}}$ or $\text{Water}_{\text{aerated}}$ (Table 11). It is unclear why $\text{Water}_{\text{direct}}$ illicited a longer drinking response than the treated water ($P > 0.10$) or $\text{Water}_{\text{pumped}}$ ($P < 0.10$). However, this observation is supported by Willms et al. (2002) and suggests that animals may reduce their rate of intake due to palatability factors. The ratio of the quantity of water consumed per unit weight of gain increased from the first to the second half of the grazing trial (Table 12) presumably as the forage became senescent and average air temperatures increased. However, the water treatments had no effect ($P > 0.10$) on that ratio (Table 12).

Table 7. Effect of water treatment and calf-sex on the weight gain of cows and calves on pasture over 3 years (n=10, number of cows with calves per year).

	Period 1[†]	Period 2	Season	Period 1	Period 2	Season
	Cows			Calves		
Source of Variation	-------------------------------	--(Probability)--	-----------------------------			
Treatment	0.188[‡]	0.404	0.095	0.178	0.488	0.545
Sex	0.115	0.600	0.250	0.055	0.224	0.095
Sex x Treatment	0.877	0.624	0.880	0.027	0.774	0.040
	-------------------------------	--(ADG[§], kg d^{-1})--	----------------------------			
Direct	0.15^{a}	0.58^{a}	0.33^{a}	1.15^{a}	1.26^{a}	1.18^{a}
Pumped	0.30^{ab}	0.78^{a}	0.47^{b}	1.22^{b}	1.30^{a}	1.22^{a}
Coagulated	0.39^{b}	0.41^{a}	0.41^{ab}	1.21^{ab}	1.26^{a}	1.20^{a}
Aerated	0.19^{ab}	0.50^{a}	0.30^{a}	1.23^{b}	1.17^{a}	1.18^{a}
SEM[¶]	0.26	0.34	0.27	0.12	0.12	0.03
	Cows with male calves			**Males calves**		
Direct	0.14^{a}	0.51^{a}	0.29^{a}	1.15^{a}	1.28^{a}	1.19^{a}
Pumped	0.24^{a}	0.82^{a}	0.45^{b}	1.28^{b}	1.36^{a}	1.27^{b}
Coagulated	0.31^{a}	0.41^{a}	0.37^{ab}	1.34^{b}	1.31^{a}	1.30^{b}
Aerated	0.10^{a}	0.63^{a}	0.30^{a}	1.34^{b}	1.22^{a}	1.24^{ab}
	Cows with female calves			**Female calves**		
Direct	0.17^{a}	0.64^{a}	0.37^{ab}	1.15^{ab}	1.25^{a}	1.18^{b}
Pumped	0.36^{ab}	0.74^{a}	0.49^{b}	1.16^{ab}	1.24^{a}	1.16^{ab}
Coagulated	0.46^{b}	0.40^{a}	0.44^{ab}	1.08^{a}	1.21^{a}	1.10^{a}
Aerated	0.27^{ab}	0.36^{a}	0.30^{a}	1.17^{b}	1.12^{a}	1.12^{ab}
SEM	0.27	0.36	0.27	0.12	0.13	0.03

[†] Period 1=1 June to 31 July; Period 2=1 August to 30 September.

[‡] Within columns of a subset, means having the same superscript letter do not differ significantly (*P* > 0.10).

[§] ADG=average daily gain.

[¶] Standard error of the mean.

Table 8. Effect of water treatment on the infection[†] of steers, on pasture, by parasites over five years (n=11, number of animals per treatment per year).

Treatment	Trichostrongyle	*Eimeria*	*Giardia/Crypto*	*Nematodirus*
	---------------------------------	(Δ Infectivity)	---------------------------------	
Direct	$-0.25^{‡a}$	-0.09^{a}	0.02^{ab}	0.22^{a}
Pumped	0.04^{b}	-0.23^{a}	-0.00^{ab}	0.13^{a}
Coagulated	-0.19^{ab}	-0.01^{a}	-0.05^{a}	0.23^{a}
Aerated	-0.15^{ab}	-0.15^{a}	0.05^{b}	0.22^{a}
SEM[§]	0.24	0.21	0.10	0.27

Source of Variation	---------------------------------	(Probability)	---------------------------------	
Year	0.01	<0.01	0.41	0.15
Treatment	0.31	0.17	0.19	0.93

[†] Infection as a result of water treatment is determined by the change in animals that are infected (based on the presence or absence of the parasites) and determined as: infection at the beginning of the trial minus infection at the end of the trial. Consequently, negative values indicate increased infection.

[‡] Within a column, means having the same superscript letter do not differ significantly ($P > 0.10$).

[§] Standard error of the mean.

Table 9. Effect of water treatment on the infection[†] of cows and their calves, on pasture, by parasites over 3 years (n=10, number of animals per treatment per year).

Treatment	Trichostrongyle	*Eimeria*	*Giardia/Crypto*	*Nematodirus*
Cows	------------------------------------(Δ Infectivity)	------------------------------------		
Direct	$0.10^{‡a}$	0.17^{ab}	-0.03^{a}	-0.00^{a}
Pumped	-0.13^{a}	0.13^{ab}	0.03^{a}	-0.00^{a}
Coagulated	0.16^{a}	0.10^{a}	0.03^{a}	-0.03^{a}
Aerated	0.26^{a}	0.33^{b}	0.03^{a}	0.00^{a}
SEM[§]	0.13	0.08	0.07	0.02
Source of Variation	------------------------------------(Probability)	------------------------------------		
Year	0.51	0.74	0.94	0.42
Treatment	0.42	0.25	0.87	0.45
Calves	------------------------------------(Δ Infectivity)	------------------------------------		
Direct	-0.47^{a}	-0.17^{a}	0.17^{a}	-0.27^{a}
Pumped	-0.53^{a}	0.04^{a}	0.21^{a}	-0.14^{a}
Coagulated	-0.53^{a}	-0.20^{a}	0.27^{a}	-0.10^{a}
Aerated	-0.47^{a}	-0.10^{a}	0.13^{a}	0.00^{a}
SEM	0.10	0.11	0.07	0.13
Source of Variation	------------------------------------(Probability)	------------------------------------		
Year	0.01	0.23	0.17	0.19
Treatment	0.92	0.46	0.56	0.32

[†] Infection as a result of water treatment is determined by the change in animals that are infected (based on the presence or absence of the parasites) and determined as: infection at the beginning of the trial minus infection at the end of the trial. Consequently, negative values indicate increased infection.

[‡] Within a column, means having the same superscript letter do not differ significantly ($P > 0.10$).

[§] Standard error of the mean.

Table 10. Effects of water treatment on the daily activity of steers on summer pasture over 3 years (n=5, number of days that animals were observed per year).

Treatment	Activity			
	Grazing	Loafing	Resting	Drinking[†]
	----------------------(30 min intervals)----------------------			
Direct	14.6[‡]^{a}	1.9^{a}	12.1^{b}	1.4^{a}
Pumped	16.4^{ab}	2.2^{a}	10.0^{a}	1.3^{a}
Coagulated	16.2^{ab}	2.2^{a}	10.3^{ab}	1.3^{a}
Aerated	16.5^{b}	2.3^{a}	9.6^{a}	1.5^{a}
SEM[§]	0.7	0.5	0.7	0.2
Source of variation	--------------------------(Probability)--------------------------			
Year	0.17	0.16	0.08	0.01
Treatment	0.26	0.94	0.19	0.74

[†] In this context, drinking is defined as the time spent near water when ingesting water was the primary pursuit.

[‡] Within a column, means having the same superscript letter do not differ significantly ($P > 0.10$).

[§] Standard error of the mean.

Table 11. The effect of water treatment on the daily drinking behavior of steers defined by the frequency and time spent ingesting water on pasture over three years (n=5, number of days that animals were observed per year).

Treatment	Frequency	Time·Freq^{-1}	Total
	----(no.)----	-----------(Seconds)----------	
Direct	3.0$^{\dagger a}$	48^{b}	152^{b}
Pumped	3.0^{a}	34^{a}	106^{a}
Coagulated	2.8^{a}	48^{b}	144^{b}
Aerated	2.9^{a}	44^{b}	133^{b}
SEM‡	0.2	2	11
Source of variation	-------------------(Probability)-------------------		
Year	<0.01	<0.01	<0.01
Treatment	0.68	<0.01	0.05

†Within a column, means having the same superscript letter are not different ($P > 0.10$).

‡Standard error of the mean.

Table 12. The effect of water treatment on average daily water consumption per animal and the ratio of average daily gain to the average daily water consumption of steers during two grazing periods over five years.

Treatment	**Period 1**	**Period 2**	**Total**	**Period 1**	**Period 2**	**Total**
	------Consumption (L d^{-1})-----			**-----------------Ratio----------------**		
Pumped	**40[†]^{a}**	**34^{a}**	**37^{a}**	**31^{a}**	**59^{a}**	**38^{a}**
Coagulated	**42^{a}**	**38^{b}**	**39^{a}**	**30^{a}**	**66^{a}**	**39^{a}**
Aerated	**43^{a}**	**38^{b}**	**40^{a}**	**31^{a}**	**63^{a}**	**38^{a}**
SEM[‡]	**1.7**	**1.4**	**1.1**	**1.4**	**5.2**	**1.2**
	----------------------------------Probability----------------------------------					
Source of variation						
Year	**<0.01**	**<0.01**	**0.01**	**<0.01**	**0.11**	**<0.01**
Treatment	**0.60**	**0.13**	**0.21**	**0.84**	**0.66**	**0.96**

[†]Within a column, means having the same superscript letter are not different (*P* > 0.10).
[‡]Standard error of the mean.

Table 13. Effect of water treatment on weight gains of steers on pasture over 5 years (n=11, number of steers per year).

Treatment	Period[†]			Year				
	1	2	All	1999	2000	2001	2002	2003
	---(ADG[‡], kg·d^{-1})--------------------------------------							
Direct	1.18[§]^{a}	0.50^{a}	0.97^{b}	0.88	1.17	0.94	0.80	1.05
Pumped (P)	1.21^{ab}	0.54^{a}	1.00^{ab}	0.94	1.14	0.88	0.92	1.15
Coagulated (P)	1.33^{b}	0.54^{a}	1.05^{a}	1.06	1.15	0.95	0.92	1.17
Aerated (P)	1.30^{b}	0.53^{a}	1.06^{a}	1.05	1.08	0.99	1.02	1.12
SEM[¶]	0.04	0.03	0.01					
Source of Variation	------------(Probability)----------							
Treatment	0.002	0.77	0.02					

[†] Period 1=1 June to 31 July; Period 2=1 August to 30 September.

[‡] ADG=average daily gain.

[§] Within a column, means having the same superscript letter do not differ significantly (*P* > 0.10).

[¶] Standard error of the mean.

3.7.2 Well Water

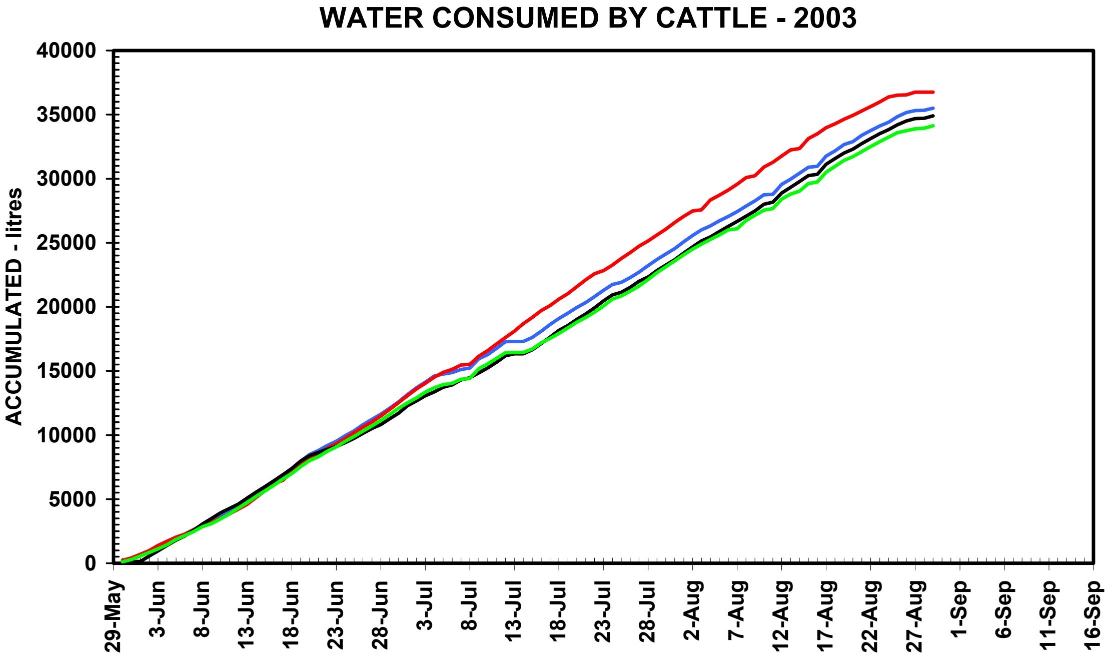
The well water treatment was only added for 2003, and with only one year of data is compared separately with the 2003 data for the dugout treatments. The well water treatment consistently had the steers with the highest weight gains throughout the year (Table 14). The quality parameters of the well water were similar to the highest quality dugout treatments, aerated and coagulated. The only difference being significantly elevated levels of sulphate and ammonia in the well water. Water intake for the well water was lower than aerated and pumped, but higher than coagulated during 2003 (Figure 11). There is no apparent water quality or consumption evidence to support the reason of the higher weight gains produced by the well water at this time. This is the first year of the well water treatment, and research on weight gains in natural environments is variable, thus another year of data will be required prior to drawing any conclusions.

Table 14. Effect of 5 water treatments on steer performance (ADG, kg/day) on pasture in 2003
(n = 11, number of steers per year)

[†] Period 1=30 May to 0 July; Period 2=31 July to 30 August.
[‡]ADG=average daily gain.

Treatment	Period		
	1	2	Season
Direct Access	1.67	-0.20	1.05
Pumped	1.58	0.28	1.15
Coagulated	1.66	0.18	1.17
Aerated	1.67	0.06	1.12
Well	1.74	0.16	1.21

Figure 11



4.0 Summary

Water consumption showed consistent trends in 1999 and 2000, with consumption highest for coagulated water. In 2001 and 2002 the results were inconsistent. In 1999, the variation in seasonal weight gain closely matched the variation in seasonal water consumption.

It is speculated that the drought in 2000 and 2001 affected the study. The quantity and quality of forage was lower than in 1999 and 2002. The water quality was also lower in 2000 and 2001, but the improvement in water quality with treatment was generally more extensive than in 1999 and 2002.

Water treatment affected ($P<0.10$) weight gains by steers in the early summer but not ($P>0.10$) in late summer. There were significant effects of 0.08 and 0.09 kg day for the aerated and coagulated treatments respectively versus direct entry. There was a trend for improved weight gain with a ranking of direct access < pumped < coagulated < aerated. Water consumption was higher for coagulated and aerated treatments than the pumped treatment. The quantity of water consumed per unit of weight gain increased as the season progressed, presumably, as the forage became senescent and average air temperature increases. Steers drinking direct access water spent less time grazing and more time resting than the steers in the other treatments. Drinking frequency was similar among treatments ($P>0.10$), but steers spent more actual time ingesting water in the direct access, coagulated, and aerated treatments than the pumped. This may be linked to the fact that animals may reduce their intake due to palatability factors.

The variable animal weight response to water treatment is open to speculation and further investigation. It seems reasonable to assume that in 2000 and 2001, the reduced forage quality and quantity from drought may have been a limiting nutrient and obscured any benefit of improved water quality. There is no doubt that live weight gain is the end result of a treatment response produced by animal behavior, physiological reaction and, possibly, livestock management. There is a trend developing with the steers showing an increase in weight gains with an increase in water quality

Inexpensive treatments of dugouts can reduce levels of taste, odour, and animal health related constituents. Water quality impacts both water intake and weight gains. The aerated treatment demonstrated a significant increase in water intake and weight gains. Thus aeration can be an economical method to improve water quality, livestock production, and dugout longevity.

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