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ALLIANCE GROUP LTD, LORNEVILLE PLANT WASTEWATER IRRIGATION

ANNUAL MONITORING AND PERFORMANCE REPORT 2014-2015

Prepared for

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Invercargill
New Zealand

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August 2015

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SUMMARY

IRRIGATION AND MONITORING SUMMARY

- Under Environment Southland Consent No 200034, irrigation of treated wastewater occurred on the Alliance Group Ltd Lorneville Farm during the 2014-2015 season for a period of sixty-three days, a longer period than in 2013-2014 (thirty-one irrigation days). This annual irrigation performance report covers the period 1 July 2014 to 30 June 2015.

- Wastewater can be applied to thirty-two paddocks with a combined area of approximately 100 ha using a 'K-Line' irrigation system with a low (2 mm/hour) application rate. The system is well-suited to wastewater irrigation on this Lorneville farm and it continues to be managed well. All of the required irrigation data is fully recorded manually on daily log sheets.

- More irrigation was conducted during the reporting period than in any of the previous irrigation seasons. Thirty of the thirty-two irrigation blocks were used, and on average these received 2.8 irrigations and 143 mm of wastewater. These values compare with corresponding averages for the previous seven irrigation seasons of 1.8 irrigations, and 74 mm of wastewater.

- All daily discharges were again within the permitted maximum volume of 3,000 m^3/day and the average wastewater application per irrigation event (48 mm) remained lower than the permitted maximum (50 mm). The average nitrogen loading to the irrigable area (161 kg N/ha) was higher than in the previous season (103 kg N/ha/yr), but remained much lower than the consent limit of 450 kg N/ha/yr. For all individual irrigations, there was full compliance with the minimum irrigation return time of fifteen days and also with the condition to irrigate only when soil water content is lower than the equivalent of field capacity.

- There were no recorded incidents of ponding or runoff of wastewater, and no irrigation-related complaints were received.

- Wastewater analyses conducted during the irrigation period again showed that it was satisfactory for land application and contained low concentrations of suspended solids, BOD, and total phosphorus. Average concentrations were 43 g/m^3, 9 g/m^3, and 14 g/m^3 respectively. Because more wastewater was applied in 2014-2015, the average amounts of nitrogen (172 kg N/ha mostly in ammoniacal form) and phosphorus (20 kg P/ha) applied to the irrigated blocks were higher than in the previous season (2013-2014; 10 kg P/ha, 103 kg N/ha).

  The average wastewater sodium adsorption ratio (11.2) was again lower than the consent limit of 17, and dissolved oxygen concentrations in the wastewater remained positive (2.4-10.8 g/$m^{3.}$).

- Groundwater monitoring at three bores during the season showed that, as reported for the two previous seasons, some groundwater quality differences at the irrigation bore, compared with the upstream bore, (for chloride, electrical conductivity, and ammonium nitrogen) during the reporting period are likely to be the combined result of both intensive stocking and wastewater irrigation. The effects in 2014-2015, however, were again minor and transient compared with some general upward trends that are occurring upstream. To date, all values of groundwater nitrate-N remain low. The average value recorded for the upstream bore in 2014-2015 was 5.0 g/m^3 whereas for the irrigation bore it was only 1.6 g/m^3.

- Monitoring data for Bateman's drain continues to indicate that while seasonal wastewater irrigation may result in some minor and transient increases in electrical conductivity and in concentrations of total nitrogen and DRP, those effects are no greater than corresponding effects from intensive stocking that occur from time to time. In any particular season, the relative sources of DRP and nitrogen in the drain (from either stocking or irrigation, or both) will be mostly determined by the timing and intensity of high rainfall events.

  For the 2014-2015 season, average concentrations of total nitrogen and DRP in the drain water were 4.4 g/m^3 and 0.022 g/m^3 respectively. The corresponding values in 2013-2014 were 4.8 g/m^3 and 0.224 g/m^3, in 2012-2013 they were 5.4 g/m^3 and 0.02 g/m^3, and in 2011-2012 the values were 4.4 g/m^3 and 0.023 g/m^3.

- Soil chemical monitoring results for 2014-2015 show positive effects of early applications of lime and superphosphate that were recommended in the previous annual report, and also that wastewater irrigation again had no significant adverse effects. All values of the measured chemical parameters remain satisfactory for further wastewater irrigation.

  Soil sodium concentration and soil exchangeable sodium percentage (ESP) have continued slight upward trends since 2010-2011, mostly because of comparatively larger wastewater applications in recent seasons, but values remain low and easily satisfactory for the maintenance of satisfactory soil structure and for further wastewater irrigation. In 2014-2015 average and peak values of ESP were 3.3% and 5.9%, and these were similar to the corresponding values of 3.8% and 5.2% recorded in 2013-2014.

- All individual values of infiltration rate and hydraulic conductivity in 2014-2015 remained sufficient for full surface infiltration and internal A horizon transmission of rainwater and wastewater, however wastewater irrigation in 2014-2015 resulted in some reductions in both, either directly though animal treading mostly during wetter late-season conditions, or indirectly through small ESP-related effects. These occurred mostly in the Waikiwi soil because the Dacre soil is inherently more susceptible to low values of infiltration rate and hydraulic conductivity, thus values at the control site for that latter soil will often be low after wet conditions.

  Mean hydraulic conductivities for the non-irrigated control sites of both soils were higher than those recorded for wastewater sites, whilst all mean values were generally lower than in the previous season. For the control and irrigated sites on Waikiwi soil average conductivities in 2014-2015 were 1.7×10^{-5} m/s and 9.5×10^{-6} m/s respectively, whilst the corresponding values for Dacre soils were

$8.3x10^{-6}$ m/s and $5.7x10^{-6}$ m/s. Nonetheless, whilst lower than in the previous season, all individual hydraulic conductivity values remain satisfactory, as do all values of infiltration rate.

- Annual rainfall during the reporting period (1152 mm) was higher than in the previous season (1083 mm), therefore total drainage from non-irrigated areas was higher. For the 2014-2015, 2013-2014, 2012-2013, 2011-2012, and 2010-2011 seasons, drainage from non-irrigated areas is estimated to have been 390 mm, 335 mm, 314 mm, 483 mm, and 420 mm respectively, thus drainage in 2014-2015 was similar to the average value recorded for the previous four seasons (388 mm). Wastewater applications increased average annual drainage in 2014-2015 to 520 mm, and this value is significantly higher than in 2013-2014 (378 mm). It was also the second highest in the most recent five annual periods when averages for the other 2013-2014, 2012-2013, 2011-2012, and 2010-2011 seasons, were 378 mm, 407 mm, 553 mm, and 460 mm respectively.

  Overall, general hydraulic loadings (irrigation plus rainfall) during the reporting period increased from moderate under non-irrigated conditions to just marginally high under wastewater irrigation. In 2013-2014, they were slightly low to moderate under much less wastewater irrigation in a drier season.

- The 2014-2015 lysimeter data shows that average seasonal leachate nitrate-N concentrations in 2014-2015 for the Waikiwi control, Waikiwi irrigated, Dacre control, and Dacre irrigated areas, were 0.3 g/m^3, 3.7 g/m^3, 0.3 g/m^3, and 1.7 g/m^3 respectively, whilst the corresponding values for the previous season were 0.4 g/m^3, 2.3 g/m^3, 2.5 g/m^3, and 8.1 g/m^3. The average concentration in 2014-2015 for all four wastewater sites (2.7 g/m^3) was low compared with that in 2013-2014 (5.2 g/m^3), consequently the corresponding average value of nitrate-N leached during the reporting period is estimated to have also been lower. At 13.9 kg N/ha, it was approximately one half of that recorded for the previous season (28.2 kg N/ha), but almost the same as the average estimated for the previous eight seasons (13.7 kg N/ha). Currently, therefore, it appears that average annual nitrate-N leaching from wastewater areas on this Lorneville site is approximately 14 kg N/ha in most years.

Effects on the environment

Monitoring data for 2014-2015 has continued to indicate no significant adverse effects on the environment that can be clearly attributed to wastewater irrigation.

Although wastewater again appears to have contributed to some increases in electrical conductivity and increased concentrations of total N and DRP in Bateman's drain, and also to some increases in groundwater electrical conductivity together with chloride and ammonium nitrogen concentrations, these were again minor and transient. The average groundwater nitrate-N concentration recorded at the irrigation bore in 2014-2015 was only 1.6 g/m^3.

Wastewater applications in 2014-2015 also resulted in some reductions in infiltration rate and hydraulic conductivity, either directly though animal treading mostly during wetter late-season conditions, or indirectly through small ESP-related effects, however all values remain satisfactory for full surface infiltration and internal A horizon transmission of rainwater and wastewater.

While irrigation increased overall hydraulic loading (wastewater irrigation plus rainfall) from moderate under non-irrigated conditions to just marginally high under wastewater irrigation, the amount of nitrate-N leached over the 2014-2015 twelve-month period was almost the same as the average estimated for the previous eight seasons (14 kg N/ha).

Recommendations for improvements

Current wastewater irrigation management and recording practices, together with current monitoring procedures, are satisfactory for this wastewater irrigation consent and, based on the 2014-2015 monitoring data, no significant recommendations for improvement are necessary.

1 INTRODUCTION

Under Environment Southland Consent No. 200034, treated wastewater from the Alliance Group Ltd Lorneville meat processing plant can be irrigated onto approximately 103 ha of land adjoining the plant. This report presents the annual performance review of wastewater irrigation, as required under Condition 12 of the resource consent, and covers the period 1 July 2014 to 30 June 2015.

For ease of reference, monitoring requirements set out in the consent are reproduced in the relevant sections of this report.

2 WASTEWATER IRRIGATION AREA AND SYSTEM

The land that is used for wastewater irrigation is located on the south side of Crowe Road, adjacent to the Lorneville Plant. The irrigable area, together with soil types is shown in Figure 2.1. It comprises approximately 103 ha of Waikiwi, Dacre, and Edendale soils, and is divided into 32 irrigation blocks (individual paddocks, Table 2.1) that are irrigated using a 'K-Line' system. The system is designed to apply wastewater to any particular land area at a rate of 2 mm/hr for up to 24 hours.

For the various irrigation blocks, the number of sprinklers that are operational during irrigation varies between 6 and 29 per block. The number per 'string' (an irrigation lateral) varies between 5 and 14. During an irrigation cycle for any particular paddock, individual strings are moved, daily, to different areas within that paddock in order to provide uniform irrigation coverage.

Daily irrigation 'log sheets' are prepared whenever wastewater is being applied. These contain reminders of visual checks for buffer zones, and record any rainfall, spray-drift, runoff, or ponding, during irrigation. Written records of the following irrigation-related data are made:

- date of irrigation
- paddock irrigated
- weather conditions
- daily rainfall
- soil moisture assessment (a subjective assessment)
- total number of operational sprinklers
- total volume of wastewater irrigated
- period of irrigation
- identification of any spray drift or ponding

The area irrigated with wastewater is located within "Zone 1" as described in the consent, and comprises a grass/clover permanent pasture that is grazed by sheep.

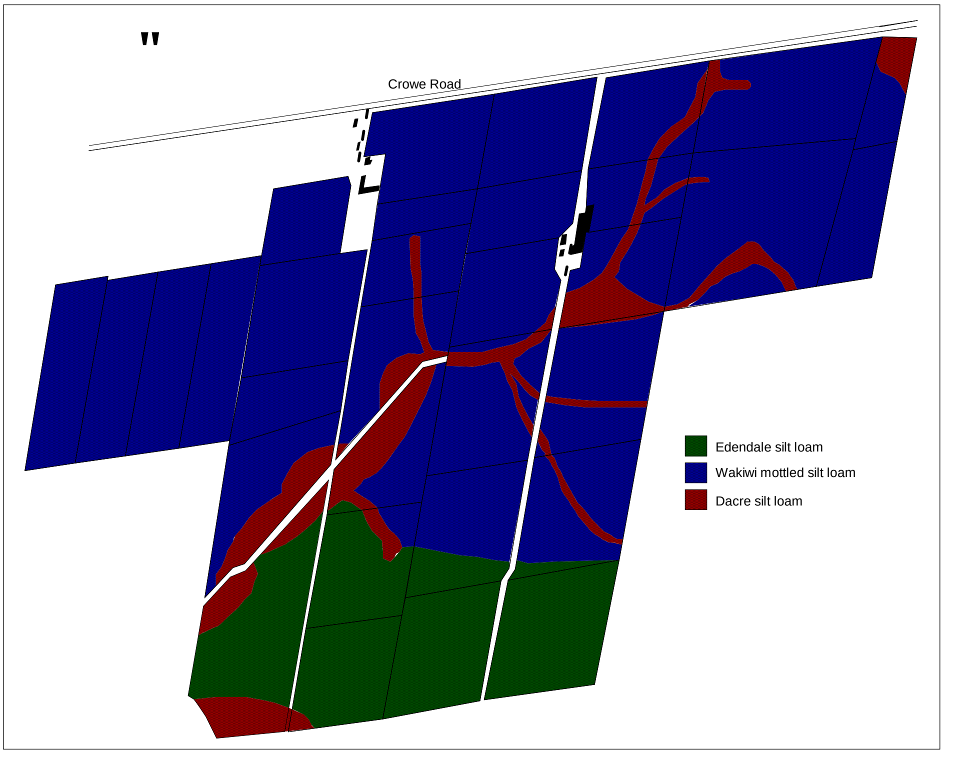


Figure 2.1:
Map of wastewater irrigation areas and soil types.

Table 2.1:
Areas of wastewater irrigation blocks. All blocks are located within "Zone 1".

IRRIGATION BLOCK	AREA (ha)	IRRIGATION BLOCK	AREA (ha)
28	3.0	44	3.0
29	2.8	45	3.0
30	3.1	46	2.1
31	3.0	47	2.0
32	1.9	48	2.9
33	3.8	49	3.0
34	2.0	50	4.1
35	3.7	51	4.2
36	6.1	52	3.9
37	3.1	53	4.0
38	3.3	54	3.7
39	3.1	55	4.2
40	3.0	56	7.5
41	2.0	57	2.2
42	1.1	58	1.4
43	3.2	59	3.1
TOTAL AREA	**102.6**		

3 WASTEWATER IRRIGATION SUMMARY

A summary of irrigation details for 2014-2015, with earlier data, is given in Table 3.1.

Table 3.1:
Irrigation summary, with 2013-2014 data in brackets).

IRRIGATION BLOCK	NUMBER OF IRRIGATIONS (1)	PERIOD OF IRRIGATION	AVERAGE IRRIGATION RETURN PERIOD (1) (days)	AVERAGE % OF BLOCK IRRIGATED (1)	TOTAL WASTEWATER APPLIED (1) (2) (mm)	AVERAGE WASTEWATER APPLIED PER IRRIGATION (1) (3) (mm)	ANNUAL NITROGEN LOADING (1) (kg N/ha)
28	3 (2)	21/1/15-8/3/15	19 (30)	100 (75)	144 (72)	48 (36)	174 (99)
29	3 (2)	21/1/15-9/3/15	19 (30)	100 (68)	144 (65)	48 (33)	174 (89)
30	3 (2)	22/1/15-11/3/15	18 (30)	100 (68)	144 (65)	48 (33)	174 (89)
31	3 (1)	22/1/15-10/3/15	18 (0)	100 (100)	144 (48)	48 (48)	174 (66)
32	3 (2)	21/1/15-10/3/15	21 (23)	100 (90)	144 (86)	48 (43)	174 (118)
33	3 (2)	26/1/15-14/3/15	19 (23)	100 (89)	144 (93)	48 (43)	174 (116)
34	3 (2)	10/2/15-24/3/15	16 (23)	100 (93)	144 (89)	48 (33)	174 (121)
35	3 (2)	29/1/15-21/3/15	20 (23)	100 (100)	144 (96)	48 (48)	174 (132)
36	3 (2)	29/1/15-23/3/15	21 (23)	100 (100)	144 (96)	48 (48)	174 (132)
37	3 (2)	30/1/15-21/3/15	20 (22)	100 (100)	144 (96)	48 (48)	174 (132)
38	3 (2)	9/2/15-25/3/15	17 (22)	97 (93)	140 (89)	47 (44)	169 (121)
39	3 (1)	27/1/15-18/3/15	21 (0)	96 (100)	139 (48)	46 (48)	167 (66)
40	3 (0)	29/1/15-21/3/15	21 (0)	100 (0)	144 (0)	48 (0)	174 (0)
41	3 (0)	22/1/15-13/3/15	22 (0)	100 (0)	144 (0)	48 (0)	174 (0)
42	3 (2)	13/2/15-25/3/15	19 (30)	78 (67)	112 (96)	37 (48)	135 (132)
43	3 (2)	20/1/15-6/3/15	20 (24)	100 (100)	144 (96)	48 (48)	174 (132)
44	3 (1)	21/1/15-7/3/15	20 (0)	100 (100)	144 (48)	48 (48)	174 (66)
45	3 (1)	27/1/15-7/3/15	17 (0)	100 (100)	144 (48)	48 (48)	174 (66)
46	3 (2)	20/1/15-13/3/15	20 (30)	100 (87)	144 (83)	48 (42)	174 (114)
47	0 (0)						
48	3 (1)	20/1/15-8/3/15	20 (0)	100 (100)	144 (48)	48 (48)	174 (66)
49	0 (0)						
50	3 (2)	20/1/15-9/3/15	20 (33)	100 (67)	144 (64)	48 (32)	174 (88)
51	3 (1)	20/1/15-17/3/15	23 (0)	100 (100)	144 (48)	48 (48)	174 (66)
52	3 (2)	26/1/15-15/3/15	20 (28)	100 (100)	144 (96)	48 (48)	174 (132)
53	3 (1)	29/1/15-20/3/15	20 (0)	97 (100)	140 (48)	47 (48)	168 (66)
54	3 (1)	27/1/15-19/3/15	21 (0)	100 (100)	144 (48)	48 (48)	174 (66)
55	3 (2)	20/1/15-10/3/15	20 (20)	100 (100)	144 (96)	48 (48)	174 (132)
56	3 (2)	20/1/15-10/3/15	21 (35)	100 (87)	144 (83)	48 (42)	174 (132)
57	3 (2)	20/1/15-10/3/15	21 (34)	100 (79)	144 (75)	48 (38)	174 (103)
58	3 (2)	20/1/15-11/3/15	21 (34)	100 (90)	144 (86)	48 (43)	174 (118)
59	3 (2)	20/1/15-9/3/15	21 (35)	100 (100)	144 (96)	48 (48)	174 (132)
AVERAGE 2014-2015	**2.8**		**20**	**99%**	**143 mm**	**48 mm**	**172 kg N/ha**
AVERAGE 2013-2014	1.5		28	91%	75 mm	44 mm	103 kg N/ha
AVERAGE 2012-2013	2.6		19	95%	127 mm	45 mm	236 kg/N/ha
AVERAGE 2011-2012	2.2		22	89%	93 mm	43 mm	89 kg N/ha
AVERAGE 2010-2011	1.3		20	63%	40 mm	30 mm	45 kg N/ha
AVERAGE 2008-2009	1			59%	28 mm	28 mm	35 kg N/ha
AVERAGE 2007-2008	3		27	83%	124 mm	40 mm	142 kg N/ha
AVERAGE 2006-2007	1		28	49%	29 mm	26 mm	26 kg N/ha

(1) 2013-2014 season in brackets; (2) Total wastewater application for entire block (irrigated blocks only);
(3) Average wastewater application per irrigation for entire block (irrigated blocks only)

The data in Table 3.1 shows that more wastewater was irrigated during the reporting period than in any other season to date. All except two blocks received wastewater, with an average of 2.8 irrigations per block (3 irrigations per block for those blocks that were irrigated). Two less paddocks were irrigated in the previous season, and in that season an average total of only 75 mm of wastewater was applied to each of the twenty eight paddocks that were irrigated. Previously, the most wastewater applied per block was an average of 127 mm in 2012-2013.

Relevant irrigation-related conditions from Consent No. 200034, together with irrigation parameters recorded for the reporting period, are given below.

CONDITION 2

"This consent authorises the discharge of up to 3,000 m^3/day of treated wastewater,……."

Wastewater irrigation volumes recorded during the period of irrigation (20 January 2015 to 25 March 2015) varied between 89 m^3/day and 2916 m^3/day, a slightly wider range than that recorded in the previous season (680-2851 m^3/day). All daily values remained within the consent limit (3,000 m^3/day).

CONDITION 3

(b) *"irrigation shall not occur when soil matric potential is less than 10 kPa;"*

As in earlier seasons, daily log sheet recordings of approximate soil water content were made on 'irrigation days'. On each of the fifty five irrigation days, soil conditions were recorded as "Dry", "Moist", or "Damp", and based on this data, together with the rainfall data on the sheets, it is considered that wastewater irrigation was in full compliance with this condition during the reporting period.

(c) *"only wastewater with a positive dissolved oxygen concentration, and with a sodium adsorption ratio less than 17, shall be discharged onto land;"*

Recordings show that dissolved oxygen concentrations in the wastewater were positive (2.4-10.8 g/m^3) for each of the days when irrigation occurred. Sodium adsorption ratio (SAR) varied between 9.9 and 12.2, and this maximum value was almost the same as that recorded in the previous season (12.3). It remained well within the consent limit. Full compliance with Condition 3(c) was therefore again achieved.

(d) *"irrigation in Zone 1 shall be as follows:*

(i) the irrigation rate shall average less than 5 mm per hour, and the depth of application shall not exceed 50 mm, to any area in any 24 hour period

(ii) *the return period between applications of treated wastewater to an area of land shall not be less than 15 days*

(iii) *the annual nitrogen loading rate for wastewater and fertilisers on the area available for irrigation shall not exceed 450 kg/hectare."*

As in all previous seasons, individual daily wastewater irrigations were conducted for 24 hours unless stopped because of significant rainfall, and the standard application rate was 2 mm/hr. A maximum of 48 mm of wastewater was therefore applied to any area in any 24-hour period. The average wastewater application per paddock (48 mm for the irrigated paddocks) was slightly higher than that recorded in the previous season (44 mm), and remained within the relevant consent limit (50 mm).

Two additional paddocks received wastewater compared with the previous season, and all of those that were irrigated received three irrigations, compared with 1-2 irrigations in 2012-2013. For all individual blocks, there was full compliance with the minimum irrigation return time of fifteen days, and at twenty days the average return time was again significantly longer than this.

Annual nitrogen loadings for the irrigated blocks in 2014-2015 were within a moderately narrow range of 135-174 kg N/ha. The average value for these was 172 kg N/ha/yr, and for all irrigable blocks it was slightly lower at 161 kg N/ha/yr because two irrigable blocks were not irrigated. These nitrogen applications are significantly higher than in the previous season (average 103 kg N/ha/yr) and are the second highest recorded to date. The highest average loading of 236 kg N/ha/yr occurred in 2012-2013. All nitrogen loadings for the various irrigation blocks in 2014-2015 were again well within the consent limit of 450 kg N/ha/yr for Zone 1 land.

CONDITION 4

(a) *"……….there shall be no surface runoff/overland flow, significant ponding or contamination of surface water resulting from the irrigation of wastewater to pasture…….:*

There were no incidents of surface runoff or ponding reported on the irrigation log sheets. Based on this, there appears to have been full compliance with Condition 4(a).

4 WASTEWATER ANALYSES

Wastewater analyses for the 2014-2015 season are provided in Tables 4.1 and 4.2. The relevant consent condition is reproduced below:

CONDITION 7

"The consent holder shall monitor the discharge by taking representative samples of the wastewater discharge:

(a) *Each week and analysing those samples for:*

- *Suspended solids concentration*
- *BOD_5 concentration*
- *Ammoniacal nitrogen concentration*
- *(nitrate + nitrite) nitrogen concentration*
- *Total phosphorus concentration*
- *Faecal coliform concentrations;*

(b) *each month and analysing those samples for:*

- *the cations calcium, sodium and magnesium and the SAR (sodium adsorption ratio) will be calculated*

Table 4.1:
Summary of wastewater analyses.

DATE	TOTAL SUSPENDED SOLIDS (g/m^3)	BOD (g/m^3)	TOTAL NITROGEN (g/m^3)	AMMONIACAL NITROGEN (g/m^3)	TOTAL OXIDISED NITROGEN (g/m^3)	TOTAL PHOSPHORUS (g/m^3)	FAECAL COLIFORMS (CFU/100 ml)
15-Jan-15	46	9.4	74	76	0.58	7.8	80
23-Jan-15	80	8.0	93	92	0.23	11	160
26-Jan-15	80	12.0	110	96	0.78	12	480
3-Feb-15	53	9.5	110	95	0.98	14	390
11-Feb-15	100	14.0	120	110	0.43	12	1400
19-Feb-15	28	7.0	120	110	1.20	14	120
27-Feb-15	14	6.1	130	120	1.00	16	370
2-Mar-15	23	6.8	140	120	1.00	18	260
10-Mar-15	16	9.6	140	130	0.86	17	350
18-Mar-15	17	8.2	140	130	1.20	17	380
26-Mar-15	18	10.0	150	140	0.35	16	290

Table 4.2:
Summary of wastewater cation analyses and sodium adsorption ratios.

DATE	SODIUM (g/m^3)	CALCIUM (g/m^3)	MAGNESIUM (g/m^3)	SAR[1]
15-Jan-15	290	42	5.2	11.2
23-Jan-15	260	43	5.7	9.9
26-Jan-15	270	43	5.6	10.3
3-Feb-15	280	43	5.6	10.7
11-Feb-15	280	43	5.8	10.6
19-Feb-15	300	44	5.7	11.3
27-Feb-15	300	45	5.5	11.2
2-Mar-15	300	45	5.6	11.2
10-Mar-14	310	43	5.5	11.8
18-Mar-15	330	46	5.6	12.2
26-Mar-15	320	47	5.8	11.7

(1) Sodium adsorption ratio. Calculated using Na, Ca, and Mg data.

Wastewater sampling and analyses occurred approximately weekly (3-8 days) during the period of irrigation, and there were eleven samplings.

Again, most (average 92%) wastewater nitrogen was ammoniacal in form, and during the season the concentration of total nitrogen in the wastewater varied between 74 g/m^3 and 150 g/m^3. The average value for total nitrogen (121 g/m^3), was slightly lower than for the previous season (137 g/m^3), and also lower than in 2012-2013 (186 g/m^3).

Concentrations of suspended solids, BOD, and total phosphorus in the wastewater remained low with average concentrations of 43 g/m^3, 9 g/m^3, and 14 g/m^3 respectively. In the previous season, the corresponding values were 26 g/m^3, 12 g/m^3, and 14 g/m^3. Because more wastewater was applied during the reporting period than in the previous season, the average amount of phosphorus applied to the irrigated blocks (20 kg P/ha) was significantly higher than in that earlier period (10 kg P/ha). Amounts applied to individual blocks in 2014-2015 varied between 16 kg P/ha/yr and 20 kg P/ha/yr, and these are equivalent to the amounts of phosphorus contained in 178-220 kg/ha of Superten fertiliser.

Similarly, the average amount of nitrogen applied in wastewater, while well within the consent limit, was higher in 2014-2015 (172 kg N/ha) than in the previous season (103 kg N/ha). It varied between 135 kg N/ha and 174 kg N/ha and these values are equivalent to the amounts of nitrogen in 294-378 kg urea/ha respectively.

Calculations of wastewater SAR (Table 4.2), show that average SAR was 11.2, a value within the range of averages recorded in other seasons since 2006-2007 (9.4-13.5). All of the individual values in 2014-2015 were again significantly lower than the consent limit of 17, and they remained satisfactory for wastewater irrigation on these soils.

Concentrations of faecal coliforms in the wastewater varied between 80 CFU/100 ml and 1,400 CFU/100 ml. The maximum value recorded was significantly lower than that measured in 2013-2014 (15,000 CFU/100 ml), and the mean (geometric) value was only

295 CFU/100 ml. This value is low, and with land application of wastewater on fine textured soils such as these that do not have a marked bypass flow characteristic, mortality rate of the coliforms is very high and transmission rate through the soil will be very low.

Overall, wastewater that was irrigated during the reporting period was again satisfactory for land application, and agronomically useful amounts of the major nutrients nitrogen and phosphorus were applied.

5 GROUNDWATER MONITORING

Under the current consent, groundwater monitoring is required. Sampling is conducted by Alliance Group Staff. Relevant consent requirements are given below:

CONDITION 8

"The consent holder shall monitor groundwater in two bores on the site, one of which shall be a control site (upstream of the irrigation area), and shall monitor groundwater at the bore (at about map reference NZMS 260 E46:482:173) on the Ridley property:

(a) *by measuring and recording the depth to groundwater at the two on-site monitoring bores (not the Ridley bore) immediately before purging the bores and extracting samples under condition 8(b);*

(b) *by taking representative samples of the groundwater at each site, at monthly intervals, and analysing those samples for the following parameters:*

- Ø *pH*
- Ø *chloride concentration*
- Ø *electrical conductivity*
- Ø *nitrate+nitrite concentration*
- Ø *Ammoniacal nitrogen concentration*
- Ø *Faecal coliform concentrations"*

Results of the 2014-2015 groundwater monitoring are given in Tables 5.1-5.3 and in Figure 5.1. Earlier recordings are included for comparison.

Table 5.1:
Summary of monthly groundwater analyses from the upstream bore (Water Treatment Bore). Measurements made during the reporting period are shown in bold type.

DATE	DEPTH TO GROUND WATER (m)	pH	CHLORIDE (g/m^3)	ELECTRICAL CONDUCTIVITY mS/cm^2	NITRATE NITROGEN (g/m^3)	AMMONIACAL NITROGEN (g/m^3)	FAECAL COLIFORMS (CFU/100 ml)
22/01/2004	5.2	6.8	18	0.135	1.5	0.16	5
12/02/2004	5.0	6.7	18	0.128	0.7	0.019	<1
22/04/2004	3.5	6.8	18	0.132	0.15	<0.010	<1
28/09/2004	2.9	6.2	35	0.36	6.4	<0.010	<1
2/11/2004	3.1	6.1	35	0.29	6.3	0.21	<1
23/11/2004	3.5	6.1	34	0.32	7.0	<0.010	<1
13/12/2004	3.7	6.8	16	0.21	1.4	0.033	30
25/01/2005	3.5	6.8	13	0.17	0.96	<0.010	<1
25/02/2005	5.0	7.0	11	0.20	0.52	<0.010	1
23/03/2005	5.0	6.9	11	0.17	0.12	<0.010	<1
2/05/2005	6.0	6.0	35	0.31	5.7	0.03	<1
19/05/2005	4.5	6.0	31	0.35	5.8	1.5	<1
13/06/2005	3.5	6.0	32	0.33	6.1	0.03	<1
18/07/2005	3.5	6.0	33.95	0.4	5.99	<0.01	<1
23/08/2005	4.6	6.2	33.8	0.33	5.7	<0.01	<1
14/09/2005	4.9	6.3	31.5	0.32	0.09	<0.01	<1
17/10/2005	5.2	6.2	31.5	0.17	5.705	<0.01	<1
22/11/2005	4.9	6.1	37.4	NR	5.694	<0.01	160
8/12/2005	4.8	6.0	44	0.37	5.03	0.02	<1
26/01/2006	4.5	6.9	29	0.29	2.23	0.02	47
22/02/2006	4.7	7.1	33	0.29	0.48	0.038	<1
28/03/2006	4.3	6.6	40	0.29	0.056	0.064	<1
3/05/2006	5.5	6.4	40	0.32	5.1	<0.010	1
17/05/2006	5.0	6.1	34	0.35	5.4	0.017	<1
25/07/2006	4.0	6.1	35	0.38	5.2	0.017	<1
26/09/2006	4.1	6.0	38	0.34	5.2	<0.010	<1
22/11/2006	4.2	6.1	38	0.16	5.2	0.025	<1
11/01/2007	4.3	6.5	36	0.17	4.04	0.01	5
23/02/2007	4.8	6.9	34	0.21	1.4	0.016	<1
26/03/2007	4.6	6.3	18	0.15	1.8	0.017	140
1/05/2007	4.6	6.1	37	0.18	5.1	0.039	<1
30/05/2007	4.7	6.3	37	0.21	4.3	0.016	<1
3/08/2007	3.3	5.6	36	0.23	7.1	0.016	<1
1/10/2007	4.3	6.8	36	0.21	5.4	0.016	<1
6/11/2007	4.2	5.7	34	0.21	5.2	0.060	1
12/12/2007	4.7	7.6	9.87	0.11	1.3	0.011	4
8/01/2008	4.6	5.9	36.2	0.15	6.0	<0.010	<1
4/02/2008	5.3	6.0	32.4	0.19	5.3	0.013	<1
27/03/2008	8.0	6.4	37	0.25	5.4	0.019	<1
29/04/2008	6.0	6.3	38	0.20	5.7	0.010	<1
20/05/2008	5.8	6.0	39	0.22	5.8	<0.010	<1
18/06/2008	8.0	6.4	43	0.25	5.5	<0.010	<1
4/07/2008	8.0	6.1	35.8	0.24	5.7	0.016	<1
14/08/2008	4.6	6.1	40	0.23	6.3	0.016	<1
23/09/2008	4.2	6.6	37.9	0.18	6.2	<0.010	<1
10/10/2008	4.3	6.4	40	0.13	6.5	0.010	<1
25/11/2008	6.0	6.9	36	0.19	6.0	0.011	1
10/12/2008	4.5	6.4	36.4	0.20	6.4	0.031	<1
27/01/2009	4.8	6.0	32	0.17	5.3	0.015	3
10/02/2009	4.9	6.4	34.9	0.16	4.6	0.031	<1
10/03/2009	5.0	6.1	33	0.16	3.7	0.058	3
20/04/2009	5.2	7.0	25.5	0.16	3.6	<0.010	<1
19/05/2009	4.7	7.2	28	0.17	5.3	0.033	3
23/06/2009	4.4	6.2	38	0.30	5.2	<0.010	<1
31/07/2009	4.0	6.4	35.6	0.22	6.1	<0.01	<1
26/08/2009	4.1	6.7	35	0.18	6.18	<0.10	<1
21/09/2009	4.6	6.5	40	0.24	5.9	0.010	<1

Table 5.1: *Continued.*

DATE	DEPTH TO GROUND WATER (m)	pH	CHLORIDE (g/m^3)	ELECTRICAL CONDUCTIVITY mS/cm^2	NITRATE NITROGEN (g/m^3)	AMMONIACAL NITROGEN (g/m^3)	FAECAL COLIFORMS (CFU/100 ml)
13/10/2009	4.4	6.6	7.9	0.13	1.4	0.011	1
17/11/2009	4.6	6.9	10.5	0.11	1.5	<0.010	48
17/12/2009	4.5	6.9	12	0.10	1.2	<0.010	<1
19/01/2010	4.4	6.3	11	0.10	0.95	0.039	<1
3/02/2010	4.4	7.0	12.0	0.10	0.42	<0.010	<1
16/03/2010	4.7	7.5	11	0.10	0.75	0.033	9
13/04/2010	4.8	6.5	33	0.20	4.9	0.015	1
11/05/2010	4.2	6.3	36	0.19	4.0	0.018	<1
24/06/2010	4.5	5.6	35	0.23	5.6	<0.010	1
23/07/2010	4.2	6.1	33	0.22	5.3	<0.010	<1
9/08/2010	4.0	6.0	32	0.20	6.4	<0.010	<1
6/09/2010	3.8	5.9	38	0.19	6.3	<0.010	<1
20/10/2010	3.9	6.0	34	0.21	6.5	<0.010	<1
1/11/2010	3.9	6.0	36	0.21	6.4	<0.010	<1
16/12/2010	4.7	7.0	42	0.27	5.0	0.090	<1
10/01/2011	4.5	5.8	45	0.17	5.0	0.039	<1
8/02/2011	4.3	6.9	20	0.11	2.1	0.014	8
3/03/2011	4.8	6.9	24	0.12	2.0	0.016	1
6/04/2011	4.7	7.3	24	0.17	1.6	<0.010	8
3/05/2011	4.5	7.1	30	0.16	1.0	<0.010	3
8/06/2011	5.0	6.3	79	0.23	6.3	0.044	1
4/07/2011	4.1	6.1	42	0.26	6.7	<0.010	<1
4/08/2011	3.6	6.3	42	0.24	6.9	<0.010	2
8/09/2011	4.2	5.4	45	0.24	7.0	0.013	<1
6/10/2011	3.3	5.5	42	0.23	6.5	0.024	<1
9/11/2011	3.8	6.2	43	0.22	6.5	<0.010	<1
6/12/2011	4.0	6.3	44	0.17	6.4	0.025	<1
9/01/2012	4.7	6.2	40	0.16	5.9	0.028	52
9/02/2012	4.5	6.4	37	0.17	4.6	0.046	31
6/03/2012	5.0	7.2	37	0.16	3.6	<0.010	240
4/04/2012	4.9	7.2	35	0.17	2.0	0.014	33
1/05/2012	4.8	6.5	3	0.18	36.6	<0.010	6
18/06/2012	4.1	6.9	41	0.11	0.7	0.032	<1
2/07/2012	3.8	6.8	40	0.21	0.8	0.052	<1
7/08/2012	4.3	5.9	38	0.33	6.9	<0.005	<1
4/09/2012	4.7	6.3	37	0.32	7.0	0.151	<1
5/10/2012	4.2	6.2	38	0.35	6.3	<0.010	<1
5/11/2012	3.9	6.6	22	0.39	4.1	<0.010	<1
3/12/2012	4.8	6.3	35	0.33	6.8	0.041	<1
8/01/2013	4.9	6.2	38	0.34	6.4	0.262	62
5/02/2013	4.3	6.1	36	0.33	5.6	0.171	410
6/03/2013	4.7	6.0	41	0.38	4.7	0.112	94
4/04/2013	5.2	6.9	27	0.27	3.0	0.090	47
6/05/2013	5.0	6.9	36	0.29	2.3	0.020	<1
5/06/2013	4.3	6.8	40	0.33	2.0	0.390	<1
1/07/2013	4.0	4.0	36	0.33	2.0	<0.01	<1.0
5/08/2013	3.9	3.9	40	0.39	6.4	0.04	<1.0
2/09/2013	4.4	4.4	38	0.38	6.3	<0.01	<1.0
7/10/2013	3.9	3.9	38	0.36	5.9	0.03	<1.0
5/11/2013	3.8	3.8	35	0.36	6.1	0.02	<1.0
2/12/2013	4.9	4.9	36	0.34	5.3	0.02	<1.0
6/01/2014	4.3	4.3	40	0.34	5.3	0.04	<1.0
4/02/2014	4.4	4.4	40	0.31	8.2	0.08	<1.0
4/03/2014	4.7	4.7	32	0.32	1.9	0.13	1.0
1/04/2014	4.9	4.9	39	0.26	1.8	0.11	1.0
6/05/2014	4.8	4.8	28	0.25	1.1	0.01	<1.0
4/06/2014	3.6	3.6	37	0.35	1.1	0.04	<1.0

Table 5.1: *Continued.*

DATE	DEPTH TO GROUND WATER (m)	pH	CHLORIDE (g/m^3)	ELECTRICAL CONDUCTIVITY mS/cm^2	NITRATE NITROGEN (g/m^3)	AMMONIACAL NITROGEN (g/m^3)	FAECAL COLIFORMS (CFU/100 ml)
3/07/2014	**3.8**	**6.0**	**39**	**0.40**	**6.5**	**<0.01**	**<1.0**
3/09/2014	**4.0**	**6.2**	**34**	**0.39**	**5.1**	**0.02**	**<1.0**
17/09/2014	**4.2**	**6.3**	**38**	**0.38**	**6.6**	**0.01**	**<1.0**
7/10/2014	**3.9**	**6.1**	**36**	**0.37**	**3.8**	**0.04**	**<1.0**
7/11/2014	**4.2**	**6.4**	**38**	**0.34**	**12**	**<0.01**	**<1.0**
1/12/2014	**3.9**	**6.5**	**24**	**0.35**	**4.7**	**0.02**	**<1.0**
5/01/2015	**4.2**	**6.4**	**30**	**0.32**	**1.4**	**0.09**	**<1.0**
3/02/2015	**4.1**	**6.4**	**40**	**0.34**	**5.2**	**0.07**	**<1.0**
5/03/2015	**4.5**	**6.4**	**42**	**0.31**	**4.9**	**0.04**	**3.0**
30/03/2015	**4.5**	**6.8**	**41**	**0.32**	**3.8**	**0.08**	**<1.0**
4/05/2015	**4.6**	**7.0**	**24**	**0.29**	**2.8**	**0.03**	**<1.0**
2/06/2015	**4.4**	**6.4**	**39**	**0.30**	**2.2**	**0.05**	**<1.0**
1/07/2015	**3.6**	**6.3**	**37**	**0.39**	**5.6**	**<0.01**	**<1.0**

Table 5.2:
Summary of monthly groundwater analyses from the irrigation bore (Compound Bore). Measurements made during the reporting period are shown in bold type.

DATE	DEPTH TO GROUND WATER (m)	pH	CHLORIDE (g/m^3)	ELECTRICAL CONDUCTIVITY mS/cm	NITRATE NITROGEN (g/m^3)	AMMONIACAL NITROGEN (g/m^3)	FAECAL COLIFORMS (CFU/100 ml)
22/01/2004	3.6	7.1	46	0.247	<0.010	0.076	<1
12/02/2004	4.3	7.2	42	0.255	0.031	0.093	1
22/04/2004	3.5	7.6	36	0.234	0.10	0.53	7
28/09/2004	3.4	7.6	46	0.35	0.036	0.055	1
2/11/2004	3.5	7.7	57	0.30	0.012	0.059	<1
23/11/2004	1.9	7.3	57	0.29	0.11	0.062	15
13/12/2004	3.8	6.9	60	0.41	0.63	0.12	<2
25/01/2005	3.0	8.2	31	0.21	0.13	0.92	4
25/02/2005	4.0	8.8	49	0.44	0.017	1.1	>60
23/03/2005	3.5	8.2	54	0.33	0.017	1.2	27
2/05/2005	4.0	8.1	51	0.30	<0.010	0.94	<1
19/05/2005	3.5	8.2	56	0.36	<0.010	<0.010	<1
13/06/2005	2.5	8.0	58	0.35	0.04	1.1	<1
18/07/2005	2.9	8.3	49.2	0.35	0.18	0.03	<1
23/08/2005	3.5	9.1	51.2	0.31	0.02	<0.01	<1
14/09/2005	5.5	8.3	50.9	0.31	0.04	0.03	<1
17/10/2005	3.8	8.3	53.9	0.15	0.02	<0.01	4
22/11/2005	4.0	8.7	57	NR	0.04	<0.01	<1
8/12/2005	4.0	7.4	66	0.36	0.48	0.11	2
26/01/2006	3.4	7.2	51	0.48	0.05	0.44	38
22/02/2006	3.5	8.6	53	0.34	0.02	0.36	75
28/03/2006	3.5	7.6	58	0.39	0.05	0.62	2
3/05/2006	4.3	8.5	63	0.35	0.01	0.46	8
17/05/2006	3.7	7.3	65	0.42	0.023	0.67	3
25/07/2006	4.3	7.1	42	0.42	0.015	0.52	<1
26/09/2006	3.4	6.1	44	0.29	4.3	0.13	<1

Table 5.2: *Continued.*

DATE	DEPTH TO GROUND WATER (m)	pH	CHLORIDE (g/m^3)	ELECTRICAL CONDUCTIVITY mS/cm	NITRATE NITROGEN (g/m^3)	AMMONIACAL NITROGEN (g/m^3)	FAECAL COLIFORMS (CFU/100 ml)
22/11/2006	3.7	6.1	45	0.22	6.7	0.030	16
11/01/2007	4.1	6.4	68	0.24	6.36	0.14	6
23/02/2007	4.0	6.5	72	0.27	<0.010	0.60	110
26/03/2007	3.8	7.1	58	0.17	0.01	0.41	6
1/05/2007	3.8	7.6	69	0.26	0.029	0.89	12
30/05/2007	3.6	7.7	62	0.26	0.017	0.66	33
3/08/2007	3.3	6.4	57	0.25	0.019	0.19	<1
31/08/2007	3.2	6.6	58	0.24	0.048	0.093	1
1/10/2007	4.2	7.5	62	0.24	6.6	0.035	1
6/11/2007	3.2	7.2	44	0.25	<0.010	0.091	44
12/12/2007	3.8	8.3	55.1	0.22	0.045	0.068	5
8/01/2008	3.9	5.8	60.6	0.23	6.3	0.025	1
4/02/2008	3.9	6.7	48	0.25	2.2	0.50	2
27/03/2008	4.2	8.3	59	0.34	0.016	0.91	21
29/04/2008	5.2	7.4	59	0.26	0.71	1.1	<1
20/05/2008	3.2	7.1	60	0.28	<0.010	0.71	1
18/06/2008	4.2	8.3	60	0.28	<0.010	0.79	<1
4/07/2008	3.8	6.1	57.1	0.29	6.2	0.05	<1
14/08/2008	3.7	6.7	57	0.30	0.66	0.52	<1
23/09/2008	3.2	6.9	66.6	0.29	0.01	5.40	<1
10/10/2008	3.3	7.5	73.3	0.36	0.04	4.20	7
25/11/2008	3.7	6.6	66.2	0.30	0.04	2.70	1
10/12/2008	3.2	7.1	46.6	0.24	0.02	0.12	15
27/01/2009	4.0	6.3	40	0.20	0.06	0.32	1100
10/02/2009	3.8	6.4	53	0.22	0.04	0.43	94
10/03/2009	4.2	6.5	51	0.23	0.04	0.43	9
20/04/2009	4.6	6.9	52.4	0.22	0.04	0.40	<1
19/05/2009	3.7	7.2	46	0.26	0.06	0.32	2
23/06/2009	3.5	6.4	51	0.24	<0.02	0.28	<1
31/07/2009	3.2	6.4	53.3	0.28	3.95	0.028	<1
26/08/2009	4.4	6.8	57	0.24	5.33	<0.10	<1
21/09/2009	4.1	7.4	55.8	0.26	0.031	0.010	<1
13/10/2009	4.5	6.4	49.7	0.30	0.04	0.12	<1
17/11/2009	4.4	6.7	48.3	0.22	0.062	0.073	<1
17/12/2009	4.2	6.2	52	0.23	5.1	<0.010	<1
19/01/2010	4.7	7.2	55.5	0.19	4.7	0.043	<1
3/02/2010	4.1	6.2	56.2	0.21	3.8	<0.010	<1
16/03/2010	4.6	6.0	61.4	0.24	3.4	0.031	2
13/04/2010	4.7	6.8	47.9	0.28	0.030	0.27	4
11/05/2010	4.5	6.4	110	0.23	0.15	0.47	3
24/06/2010	3.5	6.5	53.4	0.29	0.037	0.66	<1
23/07/2010	3.9	7.0	50.7	0.29	3.6	0.062	<1
9/08/2010	3.8	6.2	52.2	0.27	0.31	0.16	<1
6/09/2010	3.7	7.0	48.4	0.24	0.081	0.14	<1
20/10/2010	4.0	6.2	37.6	0.25	5.1	0.010	<1
1/11/2010	3.9	6.4	56.9	0.25	0.077	0.13	10
16/12/2010	3.8	6.9	57.9	0.29	0.13	0.28	1
10/01/2011	4.5	5.9	58	0.20	4.2	0.086	1
8/02/2011	4.2	6.0	63	0.27	0.010	0.17	2
3/03/2011	4.7	6.0	60	0.23	0.32	0.084	3
6/04/2011	3.7	6.2	66	0.27	4.7	0.055	2
3/05/2011	3.5	6.3	88	0.26	5.1	0.17	16
8/06/2011	3.0	7.3	63	0.33	<0.010	0.14	<1
4/07/2011	3.2	7.3	13	0.34	<0.010	0.061	<1
4/08/2011	3.3	7.4	75	0.35	0.038	0.18	<1
8/09/2011	3.7	6.1	60	0.28	5.0	0.038	<1
6/10/2011	3.2	5.6	62	0.28	4.3	0.056	720

Table 5.2: Continued.

DATE	DEPTH TO GROUND WATER (m)	pH	CHLORIDE (g/m³)	ELECTRICAL CONDUCTIVITY mS/cm	NITRATE NITROGEN (g/m³)	AMMONIACAL NITROGEN (g/m³)	FAECAL COLIFORMS (CFU/100 ml)
9/11/2011	4.0	6.4	69	0.24	4.4	0.022	<2
6/12/2011	4.0	6.4	65	0.30	5.3	0.046	<1
9/01/2012	4.1	6.2	50	0.20	3.9	0.113	126
9/02/2012	4.3	6.1	53	0.20	4.2	0.053	5
6/03/2012	4.2	6.2	60	0.22	4.1	0.027	44
4/04/2012	3.5	6.1	61	0.34	2.7	0.047	53
1/05/2012	4.2	5.9	59	0.23	4.7	0.087	11
18/06/2012	3.4	6.3	56	0.16	5.1	0.040	<1
2/07/2012	3.1	5.8	53	0.33	3.5	0.087	<1
7/08/2012	4.1	6.1	90.4	0.40	4.30	0.039	<1
4/09/2012	3.9	6.3	118.0	0.41	3.79	0.066	1
5/10/2012	3.8	6.3	37.1	0.45	4.50	<0.010	<1
5/11/2012	3.9	6.5	50.8	0.45	3.38	0.026	1
3/12/2012	4.0	6.9	55.6	0.51	0.012	0.113	<1
8/01/2013	4.7	5.7	62.7	0.43	5.00	0.036	<1
5/02/2013	3.5	6.9	57.1	0.48	<0.010	0.174	50
6/03/2013	4.3	7.0	59.9	0.50	0.03	0.300	73
4/04/2013	4.9	7.2	55.0	0.37	0.80	4.20	7
6/05/2013	4.1	6.7	67.0	0.41	<0.01	0.38	<1
5/06/2013	3.4	7.0	76.0	0.52	<0.01	0.28	<1
1/07/2013	3.2	7.1	38	0.47	<0.01	0.11	<1.0
5/08/2013	3.8	5.9	63	0.48	3.9	0.02	<1.0
2/09/2013	4.0	5.8	60	0.48	4.6	0.02	<1.0
7/10/2013	4.0	5.9	34	0.46	2.2	0.02	1
5/11/2013	3.0	6.8	62	0.47	0.03	0.13	<1.0
2/12/2013	4.4	6.8	64	0.48	0.03	0.24	1.0
6/01/2014	4.0	5.9	61	0.43	4.1	0.02	<1.0
4/02/2014	3.7	6.6	57	0.45	0.05	0.17	1.0
4/03/2014	3.9	7.0	67	0.49	0.02	0.27	<1.0
1/04/2014	3.8	6.1	56	0.42	2.7	0.05	36
6/05/2014	4.2	6.0	55	0.49	<0.01	0.23	<1.0
4/06/2014	3.1	6.7	61	0.63	0.03	0.16	2.0
3/07/2014	**3.8**	**6.7**	**68**	**0.51**	**0.03**	**0.18**	**14**
3/09/2014	**3.7**	**6.3**	**58**	**0.52**	**<0.01**	**0.12**	**1.0**
17/09/2014	**3.9**	**6.2**	**63**	**0.52**	**4.9**	**0.02**	**<1.0**
7/10/2014	**4.3**	**6.3**	**61**	**0.48**	**4.8**	**<0.01**	**3.0**
7/11/2014	**4.0**	**6.5**	**62**	**0.46**	**0.08**	**0.02**	**1.0**
1/12/2014	**3.9**	**5.8**	**56**	**0.45**	**2.5**	**<0.01**	**<1.0**
5/01/2015	**3.9**	**6.5**	**44**	**0.41**	**3.0**	**0.01**	**<1.0**
3/02/2015	**4.0**	**6.6**	**62**	**0.48**	**3.3**	**0.04**	**<1.0**
5/03/2015	**4.0**	**6.4**	**60**	**0.47**	**0.11**	**0.03**	**<1.0**
30/03/2015	**4.1**	**6.9**	**70**	**0.52**	**0.12**	**0.12**	**<1.0**
4/05/2015	**4.0**	**6.6**	**68**	**0.54**	**0.26**	**0.22**	**<1.0**
2/06/2015	**3.9**	**6.8**	**54**	**0.52**	**0.08**	**0.12**	**2.0**
1/07/2015	**3.2**	**7.2**	**210**	**0.44**	**0.07**	**0.10**	**<1.0**

Table 5.3:
Summary of monthly groundwater analyses from Ridley's Bore.
Measurements made during the reporting period are shown in bold type.

DATE	pH	CHLORIDE (g/m^3)	ELECTRICAL CONDUCTIVITY mS/cm	NITRATE NITROGEN (g/m^3)	AMMONIACAL NITROGEN (g/m^3)	FAECAL COLIFORMS (CFU/100 ml)
22/01/2004	6.1		0.282	8.2	<0.010	<1
12/02/2004	6.0	42	0.284	6.3	<0.010	<1
22/04/2004	6.0	42	0.281	5.3	<0.010	<1
22/01/2004	6.1		0.282	8.2	<0.010	<1
12/02/2004	6.0	42	0.284	6.3	<0.010	<1
22/04/2004	6.0	42	0.281	5.3	<0.010	<1
28/09/2004	6.1	48	0.31	6.7	0.015	<1
2/11/2004	6.1	44	0.32	3.2	<0.010	<1
23/11/2004	6.1	45	0.32	7.4	<0.010	<1
13/12/2004	6.3	50	0.38	0.067	0.016	<1
25/01/2005	6.1	44	0.34	6	0.025	<1
25/02/2005	6.1	44	0.41	6.6	<0.010	<1
23/03/2005	6.0	44	0.35	5.8	<0.010	1
2/05/2005	6.0	44	0.31	5.7	<0.010	<1
19/05/2005	6.1	40	0.4	6.3	<0.010	<1
13/06/2005	6.0	42	0.36	6.1	0.01	<1
21/07/2005	6.1	44.59	0.42	5.880	<0.01	5
23/08/2005	6.1	42.9	0.37	6.41	<0.01	<1
14/09/2005	6.3	40.1	0.37	0.031	<0.01	<1
17/10/2005	6.2	42.96	0.15	6.39	<0.01	<1
22/11/2005	6.1	45.8	NR	6.522	<0.01	<1
8/12/2005	6.1	5	0.30	6.49	0.02	<1
26/01/2006	6.6	42	0.32	6.18	<0.010	<1
22/02/2006	6.5	43	0.45	5.3	<0.010	<1
28/03/2006	6.3	43	0.37	5.2	<0.010	<1
3/05/2006	6.2	45	0.37	4.0	<0.010	<1
17/05/2006	6.0	42	0.38	4.6	0.032	<1
25/07/2006	5.7	58	0.40	4.9	<0.010	<1
26/09/2006	6.1	44	0.37	5.2	<0.010	<1
22/11/2006	6.0	45	0.19	4.7	0.010	1
11/01/2007	6.0	46	0.21	5.9	<0.01	<1
23/02/2007	7.0	45	0.23	4.4	<0.010	1
26/03/2007	6.0	40	0.20	3.7	0.013	<1
1/05/2007	5.8	46	0.22	4.8	0.023	17
30/05/2007	5.9	43	0.24	5.1	<0.010	<1
3/08/2007	5.6	42	0.23	6.6	0.073	<1
31/08/2007	5.5	43	0.20	5.6	0.015	<1
1/10/2007	6.4	42	0.23	5.7	0.010	4
6/11/2007	5.8	43	0.23	5.3	0.020	<1
12/12/2007	6.3	42.4	0.20	5.9	0.024	200
8/01/2008	5.8	43.4	0.18	5.1	<0.010	<1
4/02/2008	6.0	42.7	0.19	4.8	<0.010	1
27/03/2008	6.2	47	0.28	5.3	0.010	<1
29/04/2008	6.4	46	0.22	4.3	<0.010	<1
20/05/2008	6.1	46	0.27	4.3	0.100	<1
18/06/2008	7.1	46	0.23	2.5	0.027	<1
4/07/2008	6.3	43.2	0.25	4.4	0.020	<1
23/09/2008	6.9	42.4	0.24	4.6	<0.010	<1
10/10/2008	6.5	46	0.21	4.7	0.013	<1
25/11/2008	6.6	36	0.22	3.6	0.057	<1
10/12/2008	6.5	41	0.19	4.5	<0.010	1
27/01/2009	6.1	NR	0.20	4.1	<0.010	<1
10/02/2009	6.0	50.6	0.20	4.5	0.015	<1
10/03/2009	6.2	40	0.22	4.4	0.011	<1
20/04/2009	6.4	41	0.21	4.4	<0.010	<1
19/05/2009	6.5	42	0.25	4.2	0.041	<1
23/06/2009	6.5	43	0.24	4.4	<0.010	<1
31/07/2009	6.5	41.8	0.22	3.86	0.171	<1
26/08/2009	6.7	42	0.21	4.22	<0.10	<1
21/09/2009	6.6	50	0.22	4.4	0.019	<1
13/10/2009	6.3	39	0.22	4.31	<0.010	<1
17/11/2009	6.8	35.6	0.23	3.5	0.014	<1

Table 5.3: *Continued.*

DATE	pH	CHLORIDE (g/m^3)	ELECTRICAL CONDUCTIVITY mS/cm	NITRATE NITROGEN (g/m^3)	AMMONIACAL NITROGEN (g/m^3)	FAECAL COLIFORMS (CFU/100 ml)
17/12/2009	6.4	41	0.20	4.2	<0.010	<1
19/01/2010	6.5	41	0.20	4.2	<0.010	<1
3/02/2010	6.4	40.0	0.19	3.4	0.011	<1
16/03/2010	6.2	40	0.20	3.3	0.063	<1
13/04/2010	6.1	41	0.22	4.3	<0.010	<1
11/05/2010	6.2	46	0.21	3.1	0.019	<1
24/06/2010	6.0	38	0.22	3.51	<0.010	<1
23/07/2010	6.7	42	0.24	3.9	<0.010	<1
9/08/2010	6.1	39	0.23	4.4	<0.010	<1
6/09/2010	5.9	22	0.20	4.4	<0.010	<1
20/10/2010	6.2	39	0.22	4.5	<0.010	<1
1/11/2010	6.0	40	0.20	4.3	<0.010	<1
16/12/2010	5.9	52.5	0.20	4.53	0.044	<1
10/01/2011	6.1	50	0.22	4.7	<0.010	<1
8/02/2011	6.2	50	0.19	5.4	<0.010	0
3/03/2011	6.2	51	0.19	4.8	<0.010	<1
6/04/2011	6.5	52	0.24	4.7	<0.010	<1
3/05/2011	6.2	52	0.25	5.3	<0.010	<1
8/06/2011	6.3	52	0.40	5.3	<0.010	<1
4/07/2011	6.2	50	0.26	5.1	<0.010	<1
4/08/2011	6.7	51	0.37	5.4	<0.010	<1
8/09/2011	6.3	49	0.24	5.8	0.012	<1
6/10/2011	5.6	51	0.26	5.2	0.021	<1
9/11/2011	6.7	51	0.22	5.2	<0.010	<1
6/12/2011	6.5	51	0.21	4.2	0.092	<1
9/01/2012	6.3	43	0.18	5.1	0.113	<1
9/02/2012	6.2	46	0.20	5.5	0.023	<1
6/03/2012	6.2	49	0.21	4.9	<0.010	<1
4/04/2012	6.2	46	0.24	2.8	0.028	<1
1/05/2012	6.0	46	0.25	5.1	0.024	<1
18/06/2012	6.3	46	0.12	2.5	<0.010	<1
2/07/2012	6.3	44.1	0.29	4.80	<0.010	<1
7/08/2012	6.1	46.0	0.37	4.86	<0.005	<1
4/09/2012	6.3	45.2	0.35	5.18	0.017	<1
5/10/2012	6.5	32.9	0.38	4.50	<0.010	<1
5/11/2012	6.3	42.8	0.41	4.67	<0.010	<1
3/12/2012	6.4	38.2	0.38	4.31	0.025	<1
8/01/2013	6.3	44.7	0.36	4.95	0.014	<1
5/02/2013	6.4	43.4	0.39	5.12	0.017	<1
6/03/2013	6.3	45.9	0.37	4.47	0.016	<1
4/04/2013	6.2	34.0	0.37	3.50	0.030	<1
6/05/2013	6.2	46.0	0.35	4.60	0.020	<1
5/06/2013	6.4	46.0	0.40	4.50	0.040	<1
1/07/2013	6.4	45	0.39	4.5	<0.01	1.0
5/08/2013	6.1	47	0.40	4.9	0.02	<1.0
2/09/2013	6.0	38	0.40	4.0	<0.01	<1.0
7/10/2013	5.9	27	0.38	2.9	<0.01	<1.0
5/11/2013	5.8	44	0.38	5.1	0.01	<1.0
2/12/2013	6.5	45	0.37	3.8	0.01	5.0
6/01/2014	6.0	44	0.35	4.7	<0.01	<1.0
4/02/2014	6.3	39	0.34	4.3	0.01	<1.0
4/03/2014	5.9	35	0.38	3.9	0.02	<1.0
1/04/2014	6.1	44	0.35	4.8	<0.01	<1.0
6/05/2014	6.3	38	0.38	3.5	0.02	<1.0
4/06/2014	6.2	44	0.41	5.0	0.05	<1.0
3/07/2014	**6.0**	**47**	**0.45**	**4.8**	**<0.01**	**4.0**
3/09/2014	**6.1**	**43**	**0.42**	**4.6**	**<0.01**	**<1.0**
17/09/2014	**6.6**	**45**	**0.38**	**4.8**	**<0.01**	**1.0**
7/10/2014	**No sample collected because of a broken pump**					
7/11/2014	**6.2**	**46**	**0.37**	**4.6**	**<0.01**	**<1.0**
1/12/2014	**6.1**	**45**	**0.38**	**3.2**	**<0.01**	**<1.0**
5/01/2015	**6.6**	**34**	**0.36**	**3.6**	**<0.01**	**<1.0**
3/02/2015	**6.7**	**46**	**0.36**	**3.8**	**0.01**	**<1.0**

Table 5.3: *Continued.*

DATE	pH	CHLORIDE (g/m^3)	ELECTRICAL CONDUCTIVITY mS/cm	NITRATE NITROGEN (g/m^3)	AMMONIACAL NITROGEN (g/m^3)	FAECAL COLIFORMS (CFU/100 ml)
5/03/2015	**6.7**	**66**	**0.35**	**4.5**	**<0.01**	**11**
30/03/2015	**6.6**	**47**	**0.37**	**5.0**	**<0.01**	**<1.0**
4/05/2015	**7.0**	**30**	**0.34**	**5.1**	**0.02**	**<1.0**
2/06/2015	**6.4**	**43**	**0.38**	**3.9**	**0.06**	**<1.0**
1/07/2015	**6.7**	**25**	**0.38**	**4.5**	**<0.01**	**<1.0**

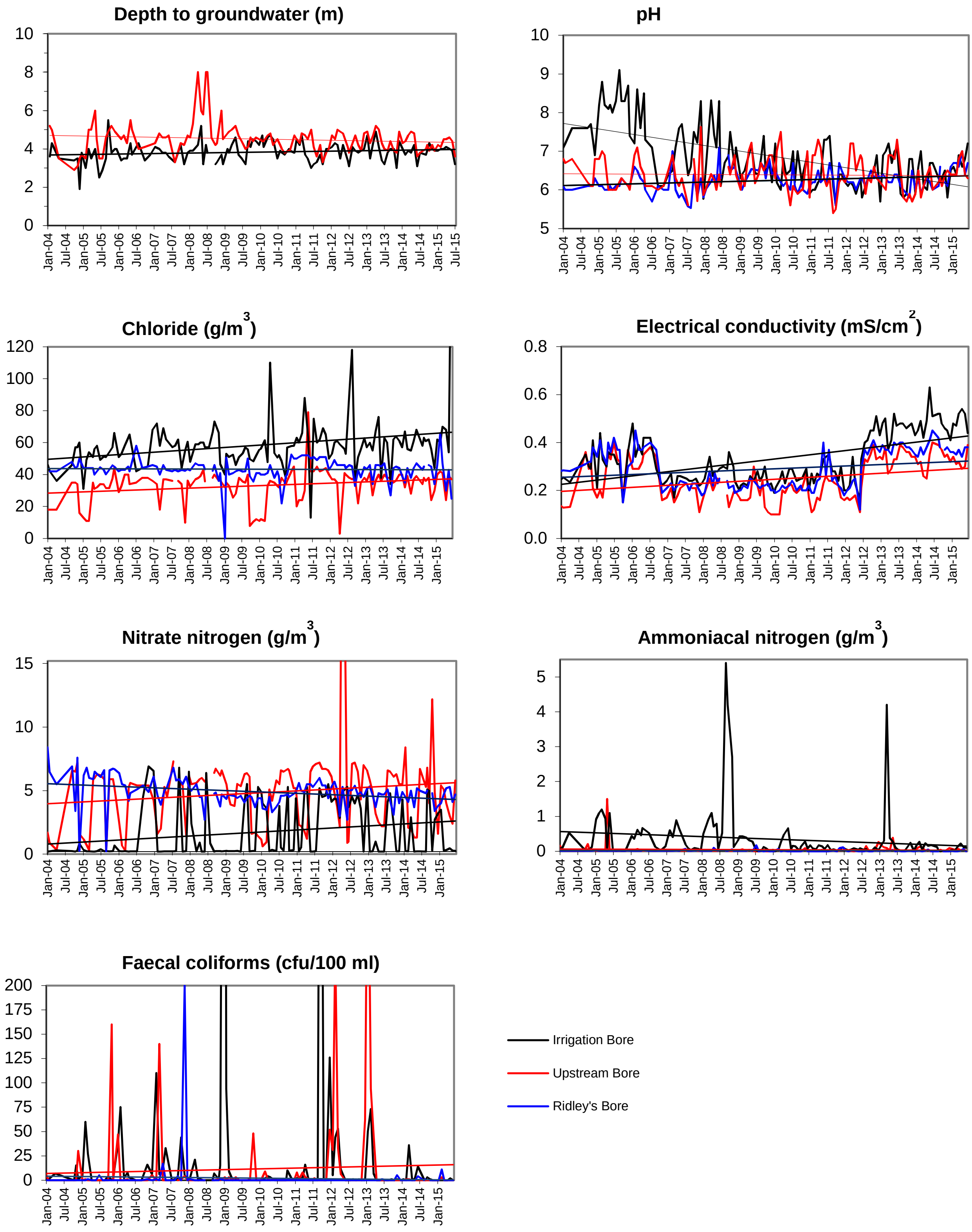


Figure 5.1:
Summaries of monthly groundwater monitoring.

There have now been nine periods of wastewater applications at this site. In the first, in 2004, wastewater was applied for only 20 days and resulted in the average application of just 32 mm of wastewater and 41 kg N/ha. In the second period of wastewater irrigation in 2007, the corresponding values were 45 days, 29 mm, and 26 kg N/ha. During 2007-2008, the amount of wastewater applied was significantly greater, with irrigation for 92 days resulting in an average application of 124 mm of wastewater and 142 kg N/ha, in 2008-2009, the amount of wastewater applied was again very small for 18 days and with an average application of only 9 mm of wastewater and 11 kg N/ha, in 2010-2011 the corresponding values were 21 days, 21 mm, and 24 kg N/ha, in 2011-2012 irrigation occurred over a longer period (50 days) and applied 87 mm of wastewater and 84 kg N/ha, whilst in 2012-2013 irrigation occurred for 58 days, but with a higher average application to the entire irrigable area (119 mm), and with the highest nitrogen loading (222 kg N/ha for the irrigable area) to date. Last season (2013-2014) occurred for a shorter time (31 irrigation days) than in the previous two seasons with averages of only 66 mm of wastewater and 90 kg N/ha being applied to the irrigable area.

Overall, therefore, only approximately 700 kg N/ha was applied in wastewater between 2004 and the end of the 2013-2014 season. This total amount is small in comparison with the consent allowance for annual applications of 450 kg N/ha, and groundwater data collected to 2011-2012 did not show any clear trends in quality that could be attributed solely to wastewater irrigation. During that period, annual wastewater nitrogen application exceeded 100 kg N/ha only once, in 2007-2008 (142 kg N/ha).

For the following 2012-2013 season, when the largest annual amount of nitrogen was applied, some increases in groundwater electrical conductivity and concentrations of chloride and ammonium-N were reported for the irrigation bore and those were attributed to the combined effects of grazing and wastewater irrigation. Similarly, small transient peaks in chloride and ammonium concentrations occurred in 2013-2014 after the application of somewhat less nitrogen than in the season before, and again these were attributed to the combined result of stocking and wastewater irrigation.

During the current reporting period, irrigation occurred for a longer period of time (55 irrigation days) than in the previous season, with averages of 143 mm of wastewater and 172 kg N/ha being applied to the irrigable area. Overall, these application values are lower than in 2012-2013, but higher than in 2013-2014, and overall groundwater trends were similar to those reported for the two earlier seasons.

As in the previous season, nitrate-N concentrations at the two downstream bores remained less than approximately 5 g/m^3 whereas values at the upstream bore were mostly higher (to 6.6 g/m^3). The average value recorded for the upstream bore in 2014-2015 was 5.0 g/m^3 whereas for the irrigation bore it was only 1.6 g/m^3. Values of groundwater pH were similar for all three bores (average 6.4-6.5).

Also as in the two previous seasons, concentrations of chloride were clearly higher under the irrigation area than upstream of that area in 2014-2015, and there was one very high value at the end of the season (210 g/m^3). That latter value cannot be readily explained because it was not accompanied by a significant increase in electrical conductivity. Overall, however, grazing and irrigation operations on the irrigation site together appear to have resulted in small increases in chloride concentrations, although because the values are not significantly higher than those recorded in much earlier seasons, before any appreciable amounts of wastewater irrigation had occurred, it is likely that they are mostly the result of intensive stocking that occurs on the farm from time to time. Overall, the slight upward trend in chloride concentration at the irrigation bore is matched by that at the upstream bore.

Similarly, conductivity is highest under the irrigation area. While increases at that bore are most noticeable since 2012-2013 when irrigation volumes also increased, higher values also occurred at that time in the upstream bore. Nonetheless, the long term graph shows a steeper increasing trend for the irrigation rather than the upstream bore.

For ammonium nitrogen, there was again a minor peak at the irrigation bore after the seasonal period of wastewater irrigation in 2014-2015, but that peak was smaller than in the previous season and the average ammonium concentration for the season (0.08 g/m^3) was lower than in that earlier season (0.12 g/m^3) and it was significantly lower than in 2012-2013 (0.52 g/m^3). It was also lower than in some other periods when only minor amounts of wastewater were applied to the site (e.g. 2007-2008, average ammonium 0.17 g/m^3), thus as reported for earlier seasons, the minor ammonium peaks that have occurred from time to time cannot be attribute to wastewater irrigation alone, but to a combination of both grazing and irrigation.

Mean values of groundwater pH and conductivity, together with mean concentrations of nitrate and ammonium nitrogen, at Ridley's bore were approximately the same as those recorded for the upstream bore, while values of chloride were slightly elevated compared with the upstream bore probably as a result of operations on the wastewater irrigation area. The latter effect was minor, however, and is again attributed to a combination of both intensive grazing and wastewater irrigation.

Overall, therefore, as reported for the two previous seasons, some groundwater quality differences at the irrigation bore, compared with the upstream bore, (for chloride, electrical conductivity, and ammonium nitrogen) during the reporting period are likely to be the combined result of both intensive stocking and wastewater irrigation. The effects in 2014-2015, however, were again minor and transient compared with some general upward trends that are occurring upstream. To date, all values of groundwater nitrate-N remain low.

6 BATEMAN'S DRAIN MONITORING

Monitoring of Bateman's drain is required, and sampling is conducted by Alliance Group Staff. The relevant consent condition is given below:

CONDITION 9

"The consent holder shall monitor the effects of the discharge on Bateman's Drain at the point that it exits the irrigation area……….., by taking representative grab samples of water from the drain, at monthly intervals during the period 1 December to 31 May, and analysing those samples for:

- *electrical conductivity*
- *total nitrogen concentration*
- *dissolved reactive phosphorus concentration"*

Results of the 2014-2015 assessments are given in Table 6.1 and Figure 6.1. Earlier data is included for comparison.

Table 6.1:
Summary of water analyses for Bateman's Drain. Measurements made during the reporting period are shown in bold type.

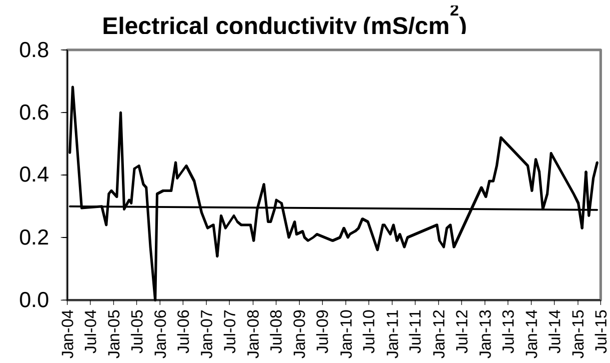
DATE	ELECTRICAL CONDUCTIVITY mS/cm^2	TOTAL NITROGEN (g/m^3)	DISSOLVED REACTIVE PHOSPHORUS (g/m^3)
22/01/2004	0.472	5.9	0.017
12/02/2004	0.681	7.1	0.027
22/04/2004	0.294	4.8	0.010
28/09/2004	0.30	2.9	0.005
2/11/2004	0.24	2.4	0.025
23/11/2004	0.34	3.3	0.018
13/12/2004	0.35	3.5	0.031
25/01/2005	0.33	4.7	0.120
25/02/2005	0.60	5.0	0.090
23/03/2005	0.29	5.0	0.130
2/05/2005	0.32	3.0	0.063
19/05/2005	0.31	3.5	0.014
13/06/2005	0.42	4.2	0.03
18/07/2005	0.43	5.2	<0.01
23/08/2005	0.37	4.6	0.18
14/09/2005	0.36	4.6	<0.01
17/10/2005	0.17	4.1	0.01
22/11/2005	NR	3.8	<0.01
8/12/2005	0.34	3.3	0.01
26/01/2006	0.35	3.9	0.050
22/02/2006	0.35	4.1	0.014
28/03/2006	0.35	3.8	0.013
3/05/2006	0.44	4.5	0.011
17/05/2006	0.39	4.4	0.008
25/07/2006	0.43	4.0	0.010
26/09/2006	0.38	3.3	0.009
22/11/2006	0.28	3.9	0.013

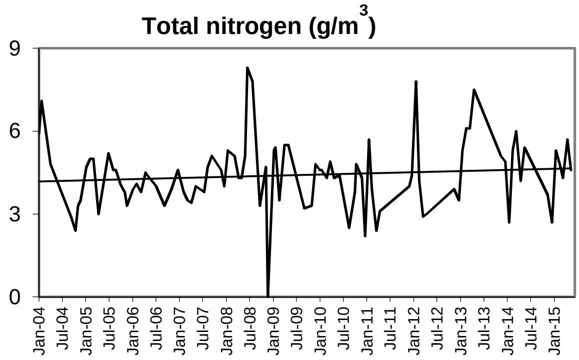
Table 6.1: *Continued.*

DATE	ELECTRICAL CONDUCTIVITY mS/cm	TOTAL NITROGEN (g/m^3)	DISSOLVED REACTIVE PHOSPHORUS (g/m^3)
11/01/2007	0.23	4.6	<0.01
23/02/2007	0.24	3.8	0.008
26/03/2007	0.14	3.5	0.010
1/05/2007	0.27	3.4	0.041
30/05/2007	0.23	4	0.011
3/08/2007	0.27	3.8	0.008
31/08/2007	0.25	4.7	0.007
1/10/2007	0.24	5.1	0.011
12/12/2007	0.24	4.6	0.008
8/01/2008	0.19	4.0	0.140
4/02/2008	0.29	5.3	0.016
27/03/2008	0.37	5.1	0.019
29/04/2008	0.25	4.3	0.019
20/05/2008	0.25	4.3	0.013
18/06/2008	0.29	5.1	0.008
4/07/2008	0.32	8.3	0.010
14/08/2008	0.31	7.8	0.018
10/10/2008	0.20	3.3	<0.005
25/11/2008	0.25	4.7	0.016
10/12/2008	0.21	NR	0.010
27/01/2009	0.22	5.3	0.011
10/02/2009	0.20	5.4	0.028
10/03/2009	0.19	3.5	0.008
20/04/2009	0.20	5.5	0.030
19/05/2009	0.21	5.5	0.069
21/9/2009	0.19	3.2	0.008
17/11/2009	0.20	3.3	0.023
17/12/2009	0.23	4.8	0.009
19/01/2010	0.20	4.6	0.017
3/02/2010	0.21	4.6	0.016
16/03/2010	0.22	4.3	0.013
13/04/2010	0.23	4.9	0.029
11/05/2010	0.26	4.3	0.026
24/06/2010	0.25	4.4	0.011
6/09/2010	0.16	2.5	0.015
20/10/2010	0.24	3.8	0.012
1/11/2010	0.24	4.8	0.008
16/12/2010	0.21	4.3	<0.010
10/01/2011	0.24	2.2	0.092
8/02/2011	0.19	5.7	0.011
3/03/2011	0.21	3.9	0.027
6/04/2011	0.17	2.4	0.025
3/05/2011	0.20	3.1	0.068
20/12/2011	0.24	4.0	0.016
9/01/2012	0.19	4.4	0.009
9/02/2012	0.17	7.8	0.042
6/03/2012	0.23	4.2	0.024
4/04/2012	0.24	2.9	0.035
1/05/2012	0.17	3.0	0.013
3/12/2012	0.36	3.9	0.008
8/01/2013	0.33	3.5	0.015
5/02/2013	0.38	5.3	0.017
7/03/2013	0.38	6.1	0.019
4/04/2013	0.43	6.1	0.046
6/05/2013	0.52	7.5	0.023
2/12/2013	0.43	5.1	<0.005
6/01/2014	0.35	4.9	<0.005
4/02/2014	0.45	2.7	<0.005
4/03/2014	0.41	5.3	0.098
1/04/2014	0.29	6.0	<0.005
6/05/2014	0.34	4.2	0.350
4/06/2014	0.47	5.4	<0.005

Table 6.1: *Continued.*

DATE	ELECTRICAL CONDUCTIVITY mS/cm	TOTAL NITROGEN (g/m^3)	DISSOLVED REACTIVE PHOSPHORUS (g/m^3)
1/12/2014	**0.34**	**3.7**	**0.008**
5/01/2015	**0.31**	**2.7**	**<0.005**
3/02/2015	**0.23**	**5.3**	**0.069**
5/03/2015	**0.41**	**4.8**	**0.021**
30/03/2015	**0.27**	**4.3**	**0.017**
4/05/2015	**0.39**	**5.7**	**0.005**
2/06/2015	**0.44**	**4.6**	**0.014**





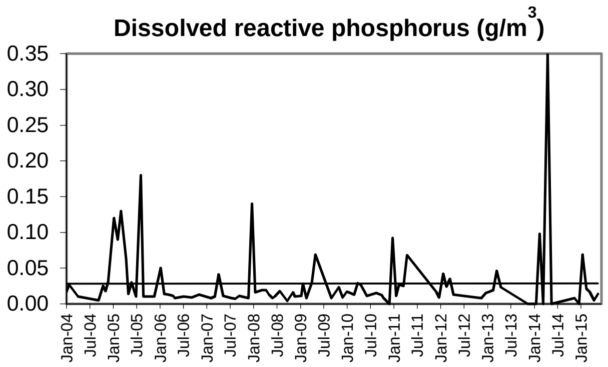


Figure 6.1:
Water analyses for Bateman's Drain.

Earlier data for Bateman's Drain has suggested that wastewater irrigation in 2004 may have increased electrical conductivity, total nitrogen, and dissolved reactive phosphorus (DRP) within the drain because values had increased to the final day of irrigation in that season and then decreased 70 days after the cessation of irrigation. In the 2006-2007 season, similar, but smaller, effects were reported for electrical conductivity and DRP, but these were minor compared with the earlier increases. During 2007-2008, wastewater irrigation again appeared to have had transient effects on electrical conductivity and total nitrogen, but not on DRP concentration, and in 2008-2009 and 2010-2011 there was no clear evidence of any wastewater-related effects on electrical conductivity, total nitrogen, or DRP concentrations.

In 2011-2012, there was again evidence that wastewater irrigation may have resulted in small increases in electrical conductivity and in total nitrogen and DRP concentrations in Bateman's Drain, and in 2012-2013 the drain data showed slight upward shifts of the electrical conductivity and total nitrogen concentration trendlines. In that season, it was reported that further data was required from other seasons with similar or greater wastewater inputs before such changes in drain water quality can be clearly attributed to wastewater irrigation.

In the following season (2013-2014), electrical conductivity remained lower than at the final sampling in 2012-2013, and some peaks in nitrogen and DRP concentrations again occurred. For DRP, the peak value (0.35 g/m^3) was the highest recorded to that time, however the amounts of phosphorus applied in wastewater were small and were less than in the previous season.

Overall, this previous data indicated that seasonal wastewater irrigations appeared to have resulted in some temporary increases in electrical conductivity and concentrations of total nitrogen and DRP in Bateman's Drain, however runoff, seepage, and drainage of animal waste nutrients could also be the major contributor. Last season, land adjacent to the drain was fenced, thus drain data collected from 2014-2015 onward was expected to better reflect any effects of wastewater rather than direct effects of stocking.

For the 2014-2015 season, average concentrations of total nitrogen and DRP in the drain water were 4.4 g/m^3 and 0.022 g/m^3 respectively. The corresponding values in 2013-2014 were 4.8 g/m^3 and 0.224 g/m^3, in 2012-2013 they were 5.4 g/m^3 and 0.02 g/m^3, and in 2011-2012 the values were 4.4 g/m^3 and 0.023 g/m^3. For the earlier 2010-2011 season they were 3.6 g/m^3 and 0.045 g/m^3. For the current reporting period, the amounts of nitrogen and phosphorus applied in wastewater were somewhat lower than in 2012-2013, but they were higher than in the other years, and especially higher than in 2010-2011 when amounts applied in wastewater were very low. Those inputs broadly correspond with drain nitrogen concentrations, but not with values for DRP. For the latter, the drain concentration was higher in an earlier season when only 3-6 kg P/ha was applied in wastewater than in 2014-2015 when an average of 20 kg P/ha was applied. Additionally, the highest value of drain DRP in recent seasons occurred when only 10 kg P/ha was applied during irrigations.

These results suggest that intensive stocking, rather than wastewater irrigation, is the main source of the small DRP peaks each season. Although in recent years those peaks have followed the corresponding seasonal periods of wastewater irrigation, this has not always been the case (e.g. in 2010-2011) and, furthermore, average drain DRP in 2014-2015 was similar to that recorded in 2009-2010 (0.022 versus 0.019 g/m^3) when there was no wastewater irrigation at the site. Additionally, peak values of drain DRP in years when wastewater inputs of phosphorus were highest are no greater than in many other seasons when such inputs were comparatively low. This is also apparent for electrical conductivity.

Overall, therefore, drain data to date continues to indicate that while seasonal wastewater irrigation may result in some minor and transient increases in electrical conductivity and concentrations of total nitrogen and DRP in Bateman's Drain, those effects are no greater than corresponding effects from intensive stocking that occur from time to time. In any particular season, the relative source of DRP and nitrogen in the drain (from either stocking or irrigation, or both) will be mostly determined by the timing and intensity of high rainfall events.

7 SOIL MONITORING

Monitoring of soil is conducted by SoilWork Ltd as required by Condition 10 of the consent.

CONDITION 10

"For the purpose of monitoring the effects of the irrigation of treated wastewater, the consent holder shall:

(a) *carry out sampling of the Waikiwi mottled and Dacre soils, in June each year, at a minimum of four sites for each soil, one of which shall be a non-irrigated control i.e. a site on which no wastewater is irrigated. The remaining monitoring sites shall be irrigated…….The samples are to be analyses for:*

- *infiltration rate (6 replicate locations per site)*
- *hydraulic conductivity (0-20 cm in 5 cm increments)*

(b) *carry out sampling (from the 0-7.5 cm soil depth) of the Waikiwi mottled soil in October, January, April, and July each year at a minimum of four sites, one of which shall be a non-irrigated control i.e. a site on which no wastewater is irrigated. The samples shall be analysed for:*

- *pH*
- *exchangeable calcium*
- *exchangeable magnesium*
- *exchangeable potassium*
- *exchangeable sodium*
- *phosphorus (Olsen P)*

Analysis shall include the calculation of exchangeable sodium percentage (ESP) values for each sampling site.

(c) *Earthworm populations shall be assessed annually at each site.*

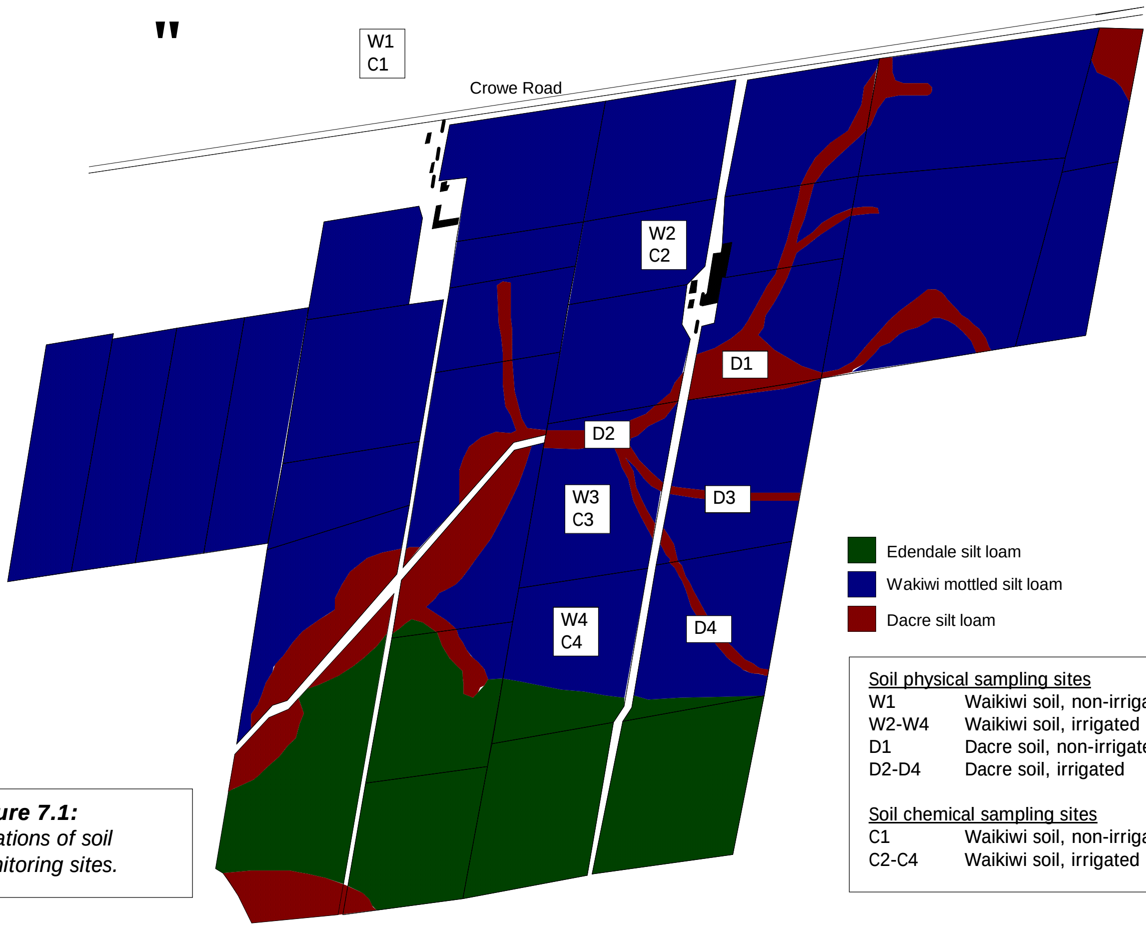
7.1 Sites and sampling

Locations of the sites used for soil chemical and physical analyses are shown in Figure 7.1.

For the 2014-2015 season, soil physical measurements and samplings were made in June 2015. Soil chemical samplings were conducted in October 2014, January 2015, April 2015, and July 2015.

At each of the eight soil physical monitoring sites (W1-W4, D1-D4), six replicate measurements of infiltration rate were made and there were three replicate samplings for hydraulic conductivity. Locations for measurements and samplings were selected at random from within the appropriate area of soil at each site. Areas near fencelines and gateways were excluded.

For the soil chemical sampling, 0-7.5 cm soil cores were sampled at regular distances along diagonal transects across each paddock or sampling area. Approximately 40 soil cores were collected from each site. After mixing, a subsample of sufficient size was withdrawn and used for analyses.



Soil physical sampling sites

W1	Waikiwi soil, non-irrigated
W2-W4	Waikiwi soil, irrigated
D1	Dacre soil, non-irrigated
D2-D4	Dacre soil, irrigated

Soil chemical sampling sites

C1	Waikiwi soil, non-irrigated
C2-C4	Waikiwi soil, irrigated

Figure 7.1: *Locations of soil monitoring sites.*

7.2 SOIL MEASUREMENTS

7.2.1 INFILTRATION RATE

Infiltration rate was measured in situ using the twin ring method. Automatic recordings of water column height in mariotte devices were made with transducers, and a processor coupled to the transducers simultaneously calculated infiltration rate results.

7.2.2 HYDRAULIC CONDUCTIVITY

Hydraulic conductivity was measured on undisturbed soil cores (100 mm diameter x 50 mm depth) collected from the 0-5, 5-10, 10-15, and 15-20 cm soil depths at each sampling location. Measurements were made using constant head permeameters connected to a logging and calculation device. Saturated hydraulic conductivities were measured for each soil core.

7.2.3 SOIL CHEMICAL

Soil chemical determinations were made by RJ Hill Laboratories Ltd, Hamilton.

7.3.4 EARTHWORMS

The assessment of earthworm densities was made in November 2014. Numbers were counted in 6 replicate soil samples of 8,000 cm^3 (to 20 cm depth) from each of the eight soil physical monitoring sites.

7.3 RESULTS

7.3.1 SOIL CHEMICAL

Results of soil chemical tests are given in Table 7.1, together with earlier results for comparison. Average values of soil test parameters are presented for control and wastewater areas for the history of recordings in Figure 7.2.

Table 7.1:
Results of soil chemical analyses for the Waikiwi soil. Analyses conducted during 2014-2015 are shown in bold type.

SITE	DATE	pH	Ca (1)	K (1)	Mg (1)	Na (1)	P (mg ml^{-1})	ESP (%)
Site W1	**Oct 2003**	5.5	5	8	28	10	12	1.9
	Jan 2004	5.4	5	6	24	14	15	2.1
	Apr 2004	5.5	5	7	28	13	15	2.1
	Jul 2004	5.5	4	9	26	12	14	1.8
	Oct 2004	5.5	5	9	27	11	14	1.6
	Jan 2005	5.5	5	8	28	10	14	1.5
	Apr 2005	5.5	5	7	25	13	16	1.9
	Jul 2005	5.6	5	9	29	13	17	1.9
	Oct 2005	5.6	4	9	26	11	19	1.9
	Jun 2006	5.5	5	6	24	11	13	1.8
	Apr 2007	5.5	5	7	24	12	14	1.9
	Jun 2007	5.4	4	6	26	13	15	2.0
	Oct 2007	5.4	5	7	29	13	17	1.8
	Jan 2008	5.5	5	8	29	15	16	2.2
	Apr 2008	5.6	5	8	26	14	15	2.1
	Jul 2008	5.5	4	7	27	11	15	1.8
	Oct 2008	5.4	5	7	27	11	17	1.7
	Jan 2009	5.4	4	7	27	12	16	1.7
	Apr 2009	5.5	5	9	31	15	18	2.3
	Jul 2009	5.4	4	8	26	12	18	1.9
	Oct 2009	5.5	5	7	26	14	16	2.2
	Jan 2010	5.4	4	7	27	12	14	2.1
	Apr 2010	5.4	5	10	31	12	18	2.0
	Jul 2010	5.4	4	9	26	10	18	1.6
	Oct 2010	5.5	5	9	29	12	16	1.7
	Jan 2011	5.4	4	7	25	13	15	1.9
	Apr 2011	5.4	4	6	27	11	16	1.7
	Jul 2011	5.4	4	12	32	13	16	2.0
	Oct 2011	5.5	4	6	27	9	17	1.3
	Jan 2012	5.5	4	5	25	13	11	2.0
	Apr 2012	5.5	4	8	25	10	15	1.4
	Jul 2012	5.6	4	7	25	11	12	1.7
	Oct 2012	5.5	4	8	28	14	16	2.0
	Jan 2013	5.6	4	6	24	11	11	1.7
	Apr 2013	5.5	4	5	22	12	13	1.8
	Jul 2013	5.6	4	6	25	8	10	1.4
	Oct 2013	5.4	4	6	25	9	9	1.3
	Jan 2014	5.3	4	5	25	9	10	1.2
	Apr 2014	5.6	4	4	25	8	11	1.3
	Jul 2014	5.5	4	9	26	12	8	1.8
	Oct 2014	**5.5**	**4**	**8**	**26**	**13**	**14**	**1.8**
	Jan 2015	**5.7**	**4**	**6**	**25**	**10**	**11**	**1.7**
	Apr 2015	**5.6**	**4**	**5**	**27**	**12**	**9**	**1.8**
	Jul 2015	**5.4**	**4**	**8**	**28**	**13**	**13**	**1.9**
Site W2	**Oct 2003**	5.6	6	5	21	12	15	2.0
	Jan 2004	5.5	6	6	21	22	21	3.4
	Apr 2004	5.6	6	6	22	20	15	3.3
	Jul 2004	5.5	6	6	24	18	17	3.0
	Oct 2004	5.5	6	7	24	16	20	2.3
	Jan 2005	5.4	6	6	22	12	16	1.8
	Apr 2005	5.6	6	9	23	13	19	1.9
	Jul 2005	5.6	5	6	23	15	15	2.1
	Oct 2005	5.6	5	6	23	13	19	2.1
	Jun 2006	5.5	5	5	21	12	12	1.8
	Apr 2007	5.6	5	5	18	32	14	5.2
	Jun 2007	5.6	5	8	20	30	18	4.7

Table 7.1: *Continued.*

	DATE	pH	Ca (1)	K (1)	Mg (1)	Na (1)	P (μg ml^{-1})	ESP (%)
Site W2	**Oct 2007**	5.5	5	6	20	16	18	2.5
	Apr 2008	5.7	5	8	20	42	17	6.1
	Jul 2008	5.6	5	11	21	23	18	3.8
	Oct 2008	5.5	5	6	20	20	21	3.3
	Jan 2009	5.5	5	6	21	18	18	2.6
	Apr 2009	5.6	4	5	18	18	16	3.2
	Jul 2009	5.6	5	5	21	19	16	2.9
	Oct 2009	5.4	5	8	22	17	14	2.6
	Jan 2010	5.4	5	5	21	14	16	2.4
	Apr 2010	5.4	5	6	20	16	15	2.5
	Jul 2010	5.5	4	5	19	13	11	1.9
	Oct 2010	5.5	5	5	20	13	15	1.9
	Jan 2011	5.5	4	5	20	14	12	1.4
	Apr 2011	5.5	5	5	21	14	13	2.1
	Jul 2011	5.5	4	7	21	17	13	2.4
	Oct 2011	5.5	5	5	21	8	18	1.3
	Jan 2012	5.6	4	5	18	22	13	3.5
	Apr 2012	5.7	4	4	19	20	13	3.1
	Jul 2012	5.6	4	4	17	24	12	3.8
	Oct 2012	5.6	4	6	20	21	20	3.0
	Jan 2013	5.7	4	4	17	14	11	2.3
	Apr 2013	5.7	4	4	16	29	11	5.1
	Jul 2013	5.8	4	7	17	25	10	3.8
	Oct 2013	5.7	4	5	16	18	9	2.9
	Jan 2014	5.5	4	4	19	19	13	2.8
	Apr 2014	5.7	4	4	15	31	9	5.0
	Jul 2014	5.9	4	4	17	29	9	4.5
	Oct 2014	**5.8**	**9**	**8**	**24**	**28**	**18**	**3.4**
	Jan 2015	**6.1**	**6**	**5**	**20**	**23**	**12**	**3.4**
	Apr 2015	**6.2**	**8**	**12**	**20**	**50**	**19**	**7.7**
	Jul 2015	**6.2**	**8**	**8**	**21**	**28**	**16**	**3.9**
Site W3	**Oct 2003**	5.6	5	6	19	10	26	1.6
	Jan 2004	5.5	5	5	23	23	12	3.6
	Apr 2004	5.7	6	7	25	20	18	3.2
	Jul 2004	5.6	5	6	30	18	21	2.8
	Oct 2004	5.6	8	7	31	14	27	1.8
	Jan 2005	5.6	7	5	24	11	21	1.6
	Apr 2005	5.7	7	4	26	14	23	1.9
	Jul 2005	5.7	6	6	23	14	28	2.0
	Oct 2005	5.6	6	5	22	9	29	1.6
	Jun 2006	5.5	5	5	22	12	18	1.9
	Apr 2007	5.6	4	4	17	32	12	5.7
	Jun 2007	5.5	4	6	17	17	13	2.7
	Oct 2007	5.5	6	7	23	20	13	3.0
	Jan 2008	5.6	5	7	21	20	11	3.2
	Apr 2008	5.6	5	9	18	50	17	7.7
	Jul 2008	5.7	5	10	21	29	18	4.6
	Oct 2008	5.6	5	9	21	25	15	3.9
	Jan 2009	5.5	5	7	23	21	17	3.0
	Apr 2009	5.6	6	5	23	21	13	3.3
	Jul 2009	5.5	5	5	20	17	14	2.7
	Oct 2009	5.6	5	8	23	17	19	2.6
	Jan 2010	5.6	5	6	19	16	17	2.7
	Apr 2010	5.6	4	5	21	17	14	2.9
	Jul 2010	5.6	5	7	24	20	12	2.9
	Oct 2010	5.6	5	4	23	17	14	2.4
	Jan 2011	5.5	4	5	23	17	10	2.6
	Apr 2011	5.4	4	5	20	22	12	3.4
	Jul 2011	5.6	4	5	22	20	14	3.1

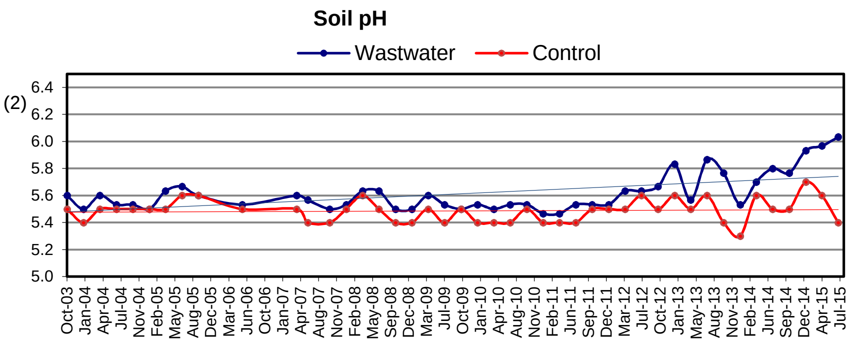
Table 7.1: *Continued.*

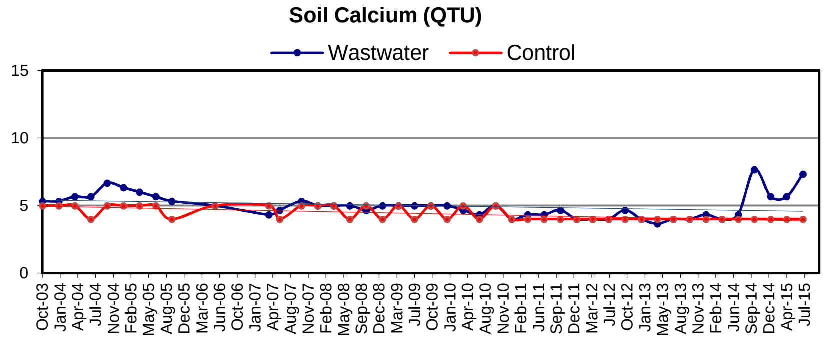
SITE	DATE	pH	Ca (1)	K (1)	Mg (1)	Na (1)	P (mg ml^{-1})	ESP (%)
Site W3	**Oct 2011**	5.6	5	3	20	10	16	1.4
	Jan 2012	5.5	4	4	18	24	9	3.9
	Apr 2012	5.5	4	7	19	33	14	5.2
	Jul 2012	5.7	4	6	18	22	12	3.3
	Oct 2012	5.6	5	5	21	22	17	3.6
	Jan 2013	5.9	4	5	20	17	17	2.8
	Apr 2013	5.6	3	4	13	32	7	5.7
	Jul 2013	6.0	4	4	17	25	11	4.4
	Oct 2013	5.7	4	5	19	19	11	2.7
	Jan 2014	5.6	5	8	21	21	17	3.1
	Apr 2014	5.6	4	7	19	29	14	4.7
	Jul 2014	5.8	4	8	20	22	12	3.4
	Oct 2014	**5.8**	**8**	**13**	**28**	**27**	**22**	**3.5**
	Jan 2015	**5.8**	**5**	**8**	**20**	**21**	**14**	**3.0**
	Apr 2015	**5.8**	**10**	**4**	**16**	**28**	**8**	**4.5**
	Jul 2015	**5.9**	**6**	**8**	**21**	**22**	**16**	**3.3**
Site W4	**Oct 2003**	5.6	5	7	25	12	19	1.9
	Jan 2004	5.5	5	6	19	23	17	3.5
	Apr 2004	5.5	5	9	25	20	14	2.9
	Jul 2004	5.5	6	8	26	20	14	3.0
	Oct 2004	5.5	6	9	30	22	12	3.1
	Jan 2005	5.5	6	5	29	13	11	2.6
	Apr 2005	5.6	5	8	26	17	10	2.8
	Jul 2005	5.7	6	9	27	16	15	2.4
	Oct 2005	5.6	5	6	26	15	11	2.3
	Jun 2006	5.6	5	5	25	14	13	2.2
	Apr 2007	5.6	4	5	24	26	10	4.2
	Jun 2007	5.6	5	12	25	26	18	4.8
	Oct 2007	5.5	5	9	28	24	14	3.2
	Jan 2008	5.5	5	8	23	22	12	3.3
	Apr 2008	5.6	5	7	23	39	11	6.1
	Jul 2008	5.6	5	9	26	33	12	5.0
	Oct 2008	5.4	4	8	24	21	8	3.3
	Jan 2009	5.5	5	7	22	23	12	3.2
	Apr 2009	5.6	5	8	25	23	10	3.4
	Jul 2009	5.5	5	8	26	20	11	3.1
	Oct 2009	5.5	5	7	24	22	9	3.3
	Jan 2010	5.6	5	7	24	18	9	2.9
	Apr 2010	5.5	5	9	24	19	12	2.9
	Jul 2010	5.5	4	6	22	15	8	2.2
	Oct 2010	5.5	5	8	25	18	10	2.5
	Jan 2011	5.4	4	6	25	16	8	2.3
	Apr 2011	5.5	4	6	24	19	12	2.7
	Jul 2011	5.5	5	11	26	23	15	3.0
	Oct 2011	5.5	4	6	22	11	11	1.6
	Jan 2012	5.5	4	5	24	23	8	3.3
	Apr 2012	5.7	4	7	24	31	11	4.8
	Jul 2012	5.6	4	6	22	22	9	3.4
	Oct 2012	5.8	5	9	27	25	16	3.5
	Jan 2013	5.9	4	5	20	17	10	2.8
	Apr 2013	5.4	4	9	18	43	8	6.9
	Jul 2013	5.8	4	10	21	24	10	3.4
	Oct 2013	5.9	4	6	19	20	12	3.2
	Jan 2014	5.5	4	8	22	20	13	2.8
	Apr 2014	5.8	4	6	19	38	9	5.9

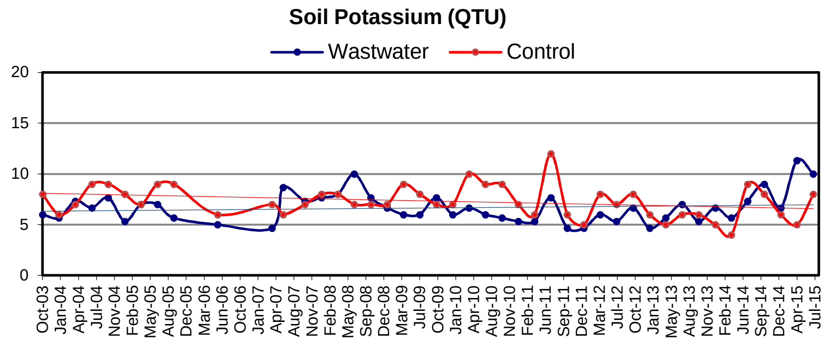
Table 7.1: *Continued.*

SITE	DATE	pH	Ca [1]	K [1]	Mg [1]	Na [1]	P (μg ml^{-1})	ESP (%)
Site W4	**Jul 2014**	5.7	5	10	24	31	9	4.3
	Oct 2014	**5.7**	**6**	**6**	**25**	**24**	**15**	**3.7**
	Jan 2015	**5.9**	**6**	**7**	**21**	**23**	**10**	**3.6**
	Apr 2015	**5.9**	**5**	**12**	**20**	**37**	**13**	**5.6**
	Jul 2015	**6.0**	**8**	**14**	**27**	**32**	**18**	**4.5**

(1) AgResearch Soil Fertility Service Quick Test Units







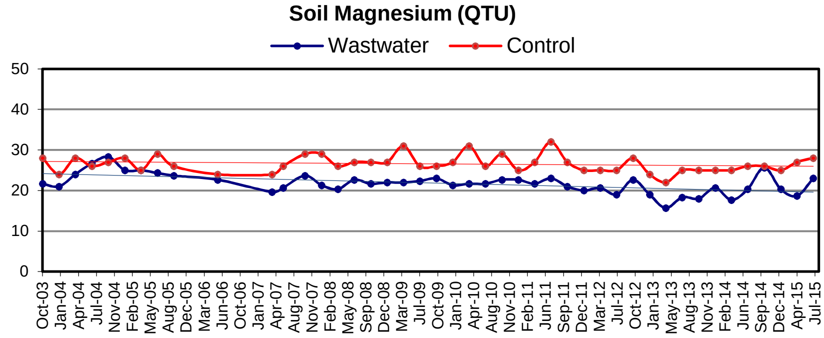
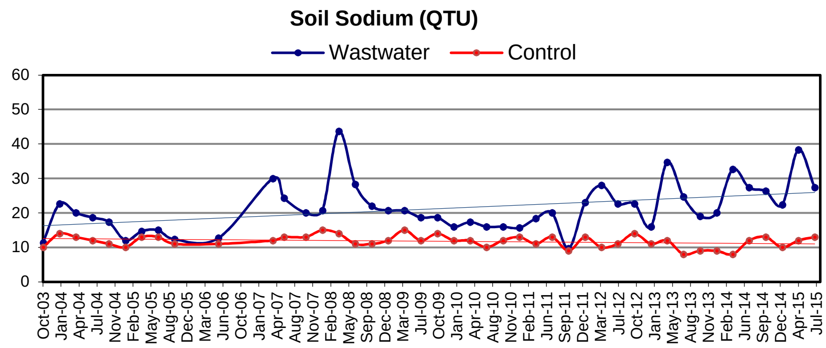
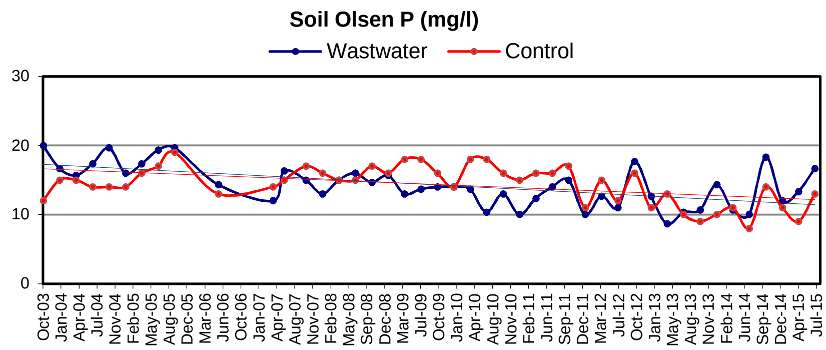


Figure 7.2
Average soil chemical analyses.





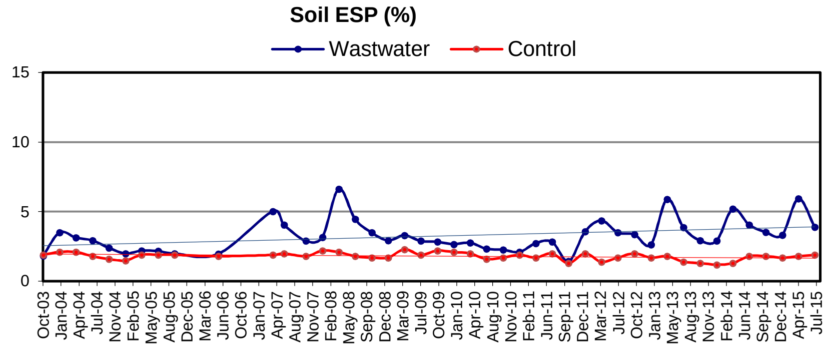


Figure 7.2 (Cont'd)
Average soil chemical analyses.

In the 2014-2015 season, all three soil chemical monitoring sites within the wastewater area again received wastewater, and the same amount was applied to the three (144 mm). The monitoring sites W2, W3, and W4, were typical of the irrigated paddocks on the farm, and they received 174 kg N/ha and 24 kg P/ha in the wastewater.

The soil data in Table 7.1 and the long-term graphs in Figure 7.2 show that, as reported for the previous season, soil pH values were slightly higher under wastewater applications and following a lime application to the wastewater areas early in the 2014-2015 season. Average soil pH at the control site during the reporting period was 5.6 and that for the irrigated sites was 5.9. While and both values are satisfactory for wastewater applications that for the non-irrigated area remains marginally low for optimum pasture production.

Also following the lime application early in the 2014-2015 season, soil calcium concentrations increased from an average value of 4 Quick Test units in 2013-2014 to 7 Quick Test units. Whilst the value at the non-irrigated site that did not receive a lime application remained at an average of 4 Quick Test units, both of these values are satisfactory for pasture production as are current values of magnesium. Soil concentrations of potassium also remain satisfactory, as is to be expected with frequent heavy stocking that occurs here from time to time.

Last season (2013-2014) a small amount of phosphorus (7-13 kg P/ha) was applied in wastewater, and that amount together with animal inputs was sufficient to maintain average soil Olsen P for the irrigated sites at approximately the same value (11 mg/l) as recorded for 2012-2013 (12 mg/l). Those values, however, are deficient for optimum pasture production, thus an application of superphosphate was made at the start of the 2014-2015 season. As a result, and with higher inputs of phosphorus in wastewater during 2014-2015 (24 kg P/ha), the average value of soil Olsen P for the irrigated sites during the reporting period increased to 15 mg/l. At the last sampling in July 2015, however, average Olsen P for the irrigated sites was higher at 17 mg/l, and that for the control area was 13 mg/l. The irrigated value is marginally deficient for optimum pasture production on this farm but is likely to be sufficient if wastewater continues to supply approximately 20-25 kg P/ha as occurred in 2014-2015. For the non-irrigated areas, current soil Olsen P (13 mg/l) remains deficient.

Compared with a long term average value of soil exchangeable sodium percentage (ESP) of approximately 3.5% for the wastewater monitoring sites, wastewater SAR, while lower than the relevant consent requirement, is significantly higher. For the 2013-2014 and 2014-2015 seasons, average values of SAR were 11.7 and 11.1 respectively, and with such values soil ESP would be expected to increases to peak seasonal values of approximately 9-10% if there was full irrigation with wastewater each season. The amounts of wastewater applied, however, are small compared with rainfall (144 mm in 2014-2015 compared with rainfall of 1152 mm), thus the amount of sodium that is applied and is seasonally retained within the soils here is small. As a result, average seasonal soil ESP, as well as average peak ESP, remains low. In the previous season, the average and peak values were 3.8% and 5.2% respectively, whereas in 2014-2015 the corresponding values of ESP were similar at 3.3% and 5.9%. For individual sites, soil ESP during the season remained below 5% in all but two instances. The value recorded for Site 4 in April 2015 was 5.6%, and that for Site 2 at the same time was 7.7%. While that latter value is marginally high for this farm, it was transient, and was the only such value amongst twelve recordings during the season.

Overall, these soil chemical results for 2014-2015 illustrate the positive effects of early applications of lime and superphosphate, but otherwise are generally similar to those for the previous season. Wastewater irrigation again had no significant adverse effects on soil chemical conditions and all values of the measured parameters and of soil ESP remain satisfactory for further wastewater irrigation. Soil sodium concentration and soil ESP have continued slight upward trends since 2010-2011, mostly because of comparatively larger wastewater applications in recent seasons, but values of ESP remain low and easily satisfactory for the maintenance of good soil structure and for further wastewater irrigations.

7.3.2 Soil physical

Results of soil infiltration rate measurements are given in Table 7.2 and Figure 7.3. Hydraulic conductivities are presented in Figures 7.4 and 7.5.

Table 7.2:
Geometric means of infiltration rate measurements.

	Steady state infiltration rate (mm/hr)										
SITE	June 2004	June 2006	June 2007	June 2008	June 2009	June 2010	June 2011	June 2012	June 2013	June 2014	June 2015
W1 (control)	65	61	126	90	86	58	33	72	36	**140**	**104**
W2	68	89	16	9	25	22	23	108	27	**32**	**76**
W3	33	8	23	7	28	32	33	68	13	**28**	**65**
W4	76	37	25	86	72	65	14	36	15	**27**	**54**
D1 (control)	60	7	58	43	8	30	22	119	15	**36**	**29**
D2	48	2	22	65	36	14	47	47	40	**32**	**32**
D3	71	260	22	9	36	108	22	104	40	**31**	**23**
D4	68	93	19	122	65	47	27	50	27	**27**	**19**

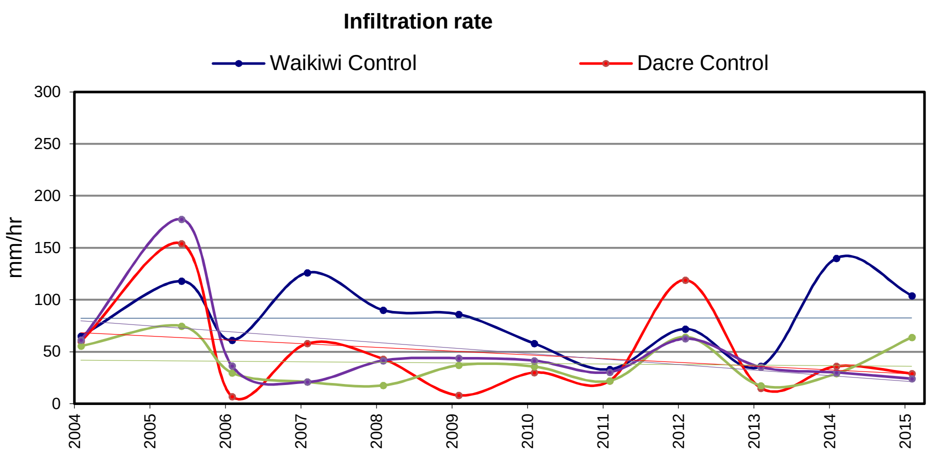


Figure 7.3:
Average (geometric means) infiltration rates.

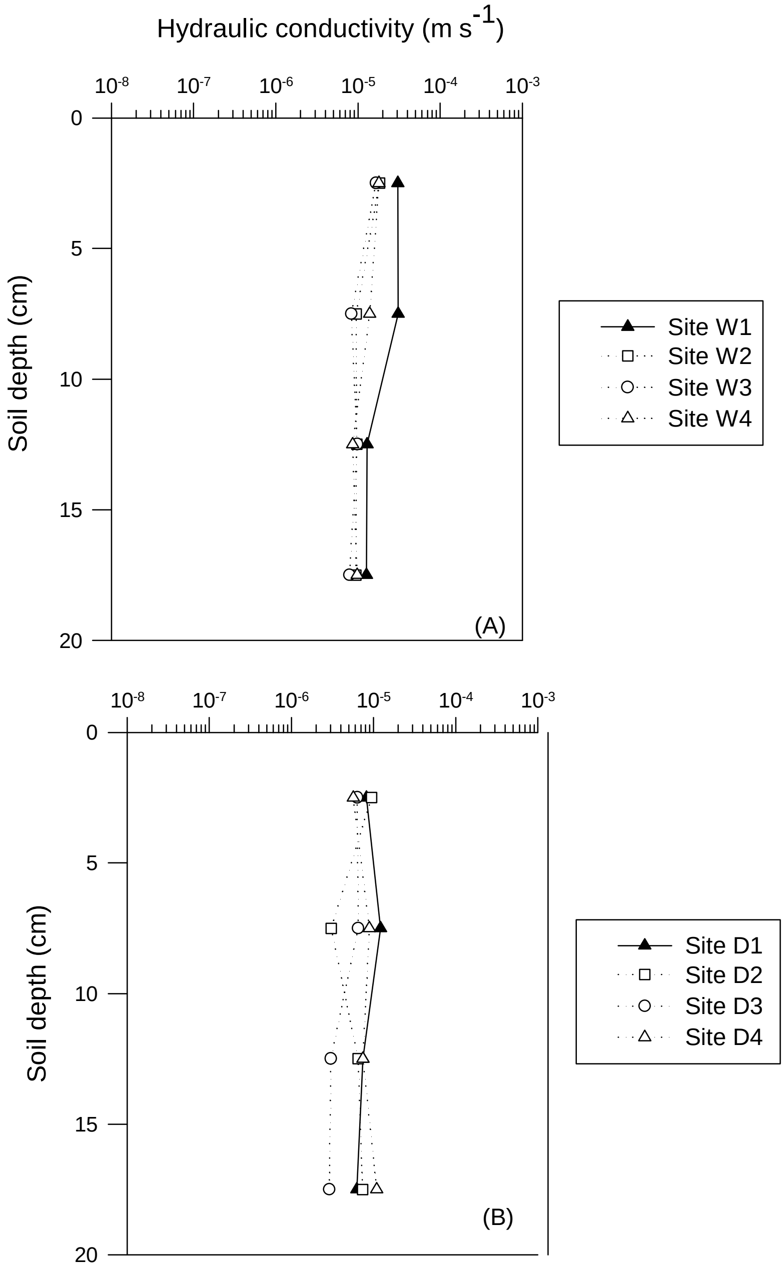


Figure 7.4:
Saturated hydraulic conductivities (geometric means) for the Waikiwi soil sites (A) and Dacre soil sites (B) in June 2015.

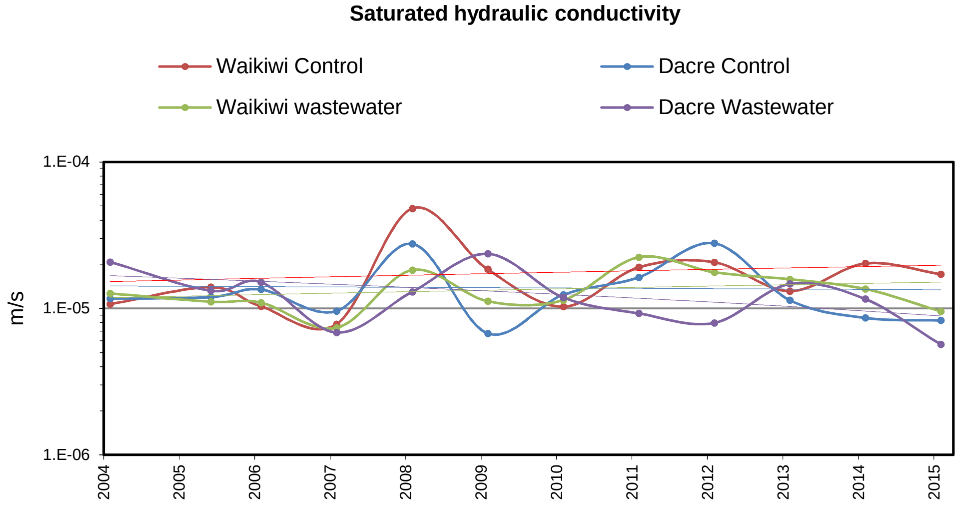


Figure 7.5:
Average saturated hydraulic conductivities (geometric means) for the 5-20 cm soil depth.

Last season, infiltration rates were all within a moderate range except for the Waikiwi control site where the rate was much higher because the soil surface had been protected from recent treading damage by a significant amount of herbage litter. For the current reporting period, infiltration rate at that site was lower whilst values for the wastewater sites on Waikiwi soils were higher, consequently the difference in rates between the control site (104 mm/hr) and the average value for the wastewater sites on that soil (64 mm/hr) was much smaller than in 2013-2014. For the monitoring sites on Dacre soils, average values of infiltration rate in June 2015 were similar to those recorded in the previous June, and they were significantly lower than for the Waikiwi soils.

The most recent measurements followed a period of wet weather, and stock treading on most paddocks during that period appeared to have been reasonably uniform. Clearly, therefore, the higher soil surface bearing strength of the better-drained Waikiwi soil resulted in a more rapid recovery of infiltration rates after that treading. The Dacre soil is poorly drained, stays wetter for longer after rainfall events and irrigations, and therefore has a lower surface bearing strength for longer periods. Consequently, it is more susceptible to low infiltration rates after grazing. Those rates, nonetheless, recover reasonably rapidly at this site through natural soil processes (root and earthworm activities and soil shrink/swell processes) after the cessation of grazing.

The hydraulic conductivity data for 2014-2015 shows that there was a wider difference between mean hydraulic conductivities for the control and wastewater sites compared with the previous season, and also a bigger difference between values for the wastewater areas on Waikiwi and Dacre soils. Mean conductivities in 2014-2015 for the control and irrigated sites on Waikiwi soil were $1.7x10^{-5}$ m/s and $9.5x10^{-6}$ m/s respectively, whilst the corresponding values for Dacre soils were $8.3x10^{-6}$ m/s and $5.7x10^{-6}$ m/s. All of these means are lower than the corresponding means recorded in 2013-2014, and they follow both a wetter season, and also a larger amount of wastewater irrigation.

Clearly, the wetter conditions in 2014-2015, especially in autumn, resulted in increased susceptibility of the soils to compaction during intensive grazing, but the data also reflects the increased susceptibility of poorly drained Dacre soils compared with the well drained Waikiwi soils. Also apparent is an increased susceptibility (compared with 2013-2014) of the soils at the wastewater sites after irrigation that ceased in mid-March just before conditions became wet with significant rainfalls. While this may simply be the result of generally wetter conditions in the irrigated areas then, it may also indicate a small soil ESP-related reduction in soil strength during very wet conditions and thus the soil's ability to withstand compaction by treading and by the transmission of water during that period. Considerably more data, however, is required to assess whether the moderately low values of ESP at this site are sufficient for this.

Nonetheless, while mean hydraulic conductivities for the control sites of both soils were higher than those recorded for the wastewater sites, and mean values were generally lower than in the previous season, all individual hydraulic conductivity values were satisfactory. Conductivities, in general, have mostly remained within a moderate range of satisfactory values since 2004.

Overall, therefore, wastewater irrigation in 2014-2015 resulted in some reductions in infiltration rate and hydraulic conductivity, either directly though animal treading mostly during wet late-season conditions, or indirectly through small ESP-related effects. These occurred mostly in the Waikiwi soils because the Dacre soil is inherently more susceptible to low values of infiltration rate and hydraulic conductivity, thus values at the control site for that soil will often be low after wet conditions. Nonetheless, all individual values of infiltration rate and hydraulic conductivity in 2014-2015 remained sufficient for both full surface infiltration and internal A horizon transmission of rainwater and wastewater.

7.3.3 EARTHWORMS

Average earthworm numbers for each of the monitoring sites on the two soils are shown in Table 7.3.

Table 7.3:
Mean earthworm numbers to 20 cm depth.

	Earthworm densities (number/m^2)			
SITE	**June 2008**	**Average 2008-2012**	**November 2013**	**November 2014**
W1 (control)	379	325	406	**343**
W2	361	396	488	**422**
W3	313	307	537	**481**
W4	338	308	561	**506**
D1 (control)	299	273	327	**231**
D2	364	254	390	**337**
D3	296	301	374	**349**
D4	187	271	399	**295**

Earthworm densities in November 2014 (Table 7.3) were lower than those recorded in the previous season, but were generally higher than for average values between 2008 and 2012. For the Waikiwi control, Waikiwi irrigated, Dacre control, and Dacre irrigated sites average numbers in 2014-2015 were 343/m^2, 470/m^2, 231/m^2, and 327/m^2 respectively, whereas corresponding averages for 2008-2012 were 325/m^2, 337/m^2, 273/m^2, and 275/m^2. Thus, while 2014-2015 numbers are lower than for the previous season, probably because of generally wetter conditions, only for the control Dacre site was the November 2014 value lower than the corresponding long term average. This reflects the greater susceptibility of Dacre soils to waterlogging and anaerobic conditions in wet seasons.

Thus, the 2014-2015 earthworm data continues to show that earthworm populations remain lower in the poorly drained, and therefore less aerobic and colder, Dacre soil than in the Waikiwi soil, and also that numbers remain significantly higher under wastewater applications.

8 WATER BALANCES

Preparation of a soil water balance is required under Condition 10 of the consent:

CONDITION 10

(e) *"A soil water balance shall be prepared annually for the irrigated area and a non-irrigated block comprising Waikiwi mottled soil."*

8.1 METHODOLOGY

The methods used were the same as for previous annual monitoring reports. Soil water conditions were assessed using estimates of the numbers of days when soil water content exceeded the drained upper limit ('field capacity') in the 0-50 cm soil depth. This parameter is a good indicator of overall soil water conditions during the reporting period (1 July 2014 to 30 June 2015). Annual water surplus is used as an indicator of hydraulic loading.

Drainage was calculated using the same SoilWork daily soil water balance model that has been used earlier. It balances water inputs (rainfall and wastewater applications) with storage within the soil, and water losses (evapotranspiration, drainage, runoff). With input of rainfall and potential evapotranspiration data, it estimates actual evapotranspiration using the current soil water content as a basis for adjustments to the potential rate. Actual evapotranspiration and rainfall are used to estimate soil water content. Daily outputs include soil water content, actual evapotranspiration, drainage, and ponding/runoff.

Records from Invercargill, the nearest fully equipped meteorological station for which suitable data was available, were used for rainfall, and for potential evapotranspiration using the 'Penman' equation. Records of wastewater irrigations were supplied by Alliance Group staff.

Soil data used in the model was from measurements made earlier on this farm.

8.2 RESULTS

A summary of results of the water modelling is given in Table 8.1.

Annual rainfall in the 2014-2015 season (1152 mm) was higher than in the previous season (1083 mm), therefore annual drainage in areas that did not receive wastewater was higher. For the 2014-2015, 2013-2014, 2012-2013, 2011-2012, and 2010-2011 seasons, drainage from non-irrigated areas is estimated to have been 390 mm, 335 mm, 314 mm, 483 mm, and 420 mm respectively, thus drainage during the reporting period was similar to the average value recorded for the previous four seasons (388 mm). The number of days when soil water content exceeded field capacity in non-irrigated areas during the reporting period (216 days) was also higher than in the previous season (158 days), however because this increase is moderately large compared with the corresponding increase in drainage, it is clear that the distribution of rainfall was significantly different between the two seasons.

In the previous season, twenty eight of the thirty two irrigable blocks received an average of only 75 mm of wastewater, whereas during the current reporting period two additional paddocks were irrigated, and a much higher average amount of 143 mm of wastewater was applied to the irrigated areas. Thus, significantly more wastewater was applied in 2014-2015 compared with the previous season, and as a result average annual drainage for the wastewater areas in 2014-2015 (520 mm) was significantly greater than in 2013-2014 (378 mm). It was also the second highest in the most recent five periods when averages for the other 2013-2014, 2012-2013, 2011-2012, and 2010-2011 seasons, were 378 mm, 407 mm, 553 mm, and 460 mm respectively.

Similarly, the average number of days when the soil was very wet in the irrigated areas was significantly higher during the reporting period (279 days) than in 2013-2014 (186 days), and it was also significantly higher than the long term average of approximately 210 days. Overall, therefore, under wastewater irrigation during the 2014-2015 season, drainage was the second highest in the most recent five annual periods, whilst the number of days when soil water content exceeded field capacity was also comparatively high.

For the thirty individual irrigation blocks, drainage in 2014-2015 varied between 492 mm and 523 mm. This difference (31 mm) is much smaller than that recorded last season (72 mm), and it reflects a very high degree of irrigation uniformity. In many years such uniformity would result in lower drainage, compared with less uniform irrigation, for the overall site, however in a moderately wet season such as 2014-2105 it would have had only a limited positive result because the amount of additional drainage under wastewater applications was generally similar to the amount of wastewater applied. In 2014-2105, wastewater irrigation (144 mm) increased average annual drainage by 132 mm.

That increase in drainage resulting from irrigation during the reporting period (132 mm) was significantly higher than in the previous season (43 mm) and, similarly, the additional number of days when the soil was wetter than field capacity (63 days) was also much greater than in 2013-2014 (28 days). Approximately one half of those differences is attributed to the additional irrigation applied in 2014-2015 whilst the other half is the result of a higher rainfall minus evapotranspiration water surplus compared with 2013-2014.

Overall, general hydraulic loadings (irrigation plus rainfall) during the reporting period increased from moderate under non-irrigated conditions to just marginally high under wastewater irrigation. In 2013-2014, they were slightly low to moderate under much less wastewater irrigation in a drier season.

Table 8.1: *Summary of annual water balance data for the 2014-2015 season, with 2013-2014 data in brackets.*

IRRIGATION BLOCK	ANNUAL DRAINAGE (mm)	NUMBER OF DAYS ABOVE FIELD CAPACITY
28	509	281
29	509	281
30	511	282
31	511	283
32	502	275
33	515	282
34	523	272
35	520	281
36	522	280
37	522	281
38	519	273
39	509	276
40	520	281
41	509	277
42	492	267
43	501	278
44	504	279
45	514	284
46	510	281
47	390	216
48	504	280
49	390	216
50	504	279
51	509	279
52	515	279
53	515	279
54	516	279
55	504	279
56	504	278
57	509	280
58	504	278
59	503	276
Average Irrigated [1]	**510 (378)**	**279 (186)**
Non-irrigated	**390 (335)**	**216 (158)**

[1] Average includes only the irrigated blocks

9 NITRATE LEACHING

The requirement for estimates of nitrate leaching under the current consent is given below:

CONDITION 10

(d) *"Estimates of nitrate leaching, using the lysimeters described in Condition 14, are to be made monthly to assess nitrate losses. Nitrate-N concentrations are to be measured on leachate samples taken monthly, and estimates are to be made using a daily water balance model for the periods between sampling dates. Nitrate leaching is to be calculated monthly using the nitrate-N concentrations and drainage data and reported within the company's annual report."*

CONDITION 14

"The consent holder shall install lysimeters (six in total) at 1 metre deep in two non-irrigated control paddocks, and four irrigated paddocks, in the Waikiwi mottled or Edendale soils, and Dacre soils prior to exercising this resource consent."

9.1 METHODOLOGY

Lysimeters were installed at six sites in October 2002. Three of the lysimeter sites comprise Waikiwi soils and three comprise Dacre soils. The Waikiwi lysimeter sites (refer to Figure 7.1) are Sites W1 (control), W2 (irrigated), and W4 (irrigated), and the Dacre sites are D1 (control), D2 (irrigated), and D3 (irrigated). Leachate samples are collected monthly.

The lysimeters used are pressure/vacuum soil water samplers which consist of ceramic cups (approximately 5 cm diameter and 6 cm long) attached to lengths of plastic pipe. They contain pressure and vacuum tubes for extracting samples of leachate.

Leachate samples are collected by creating a small suction (dependent on soil water content) within each lysimeter. Leachate travelling through the profile in soil macropores (pores larger than approximately 30 μm) is withdrawn for analysis. Each sample is analysed for nitrate concentration. Nitrate leaching is assessed using the nitrate concentrations in leachate samples together with estimates of drainage for the periods between sampling dates. Drainage is calculated using the daily soil water balance model described in Section 8.

9.2 RESULTS

Nitrate-nitrogen concentrations in leachate sampled from the 100 cm soil depth at the monitoring sites are given in Table 9.1 for the most recent three seasons, and for the full period of recordings in Figure 9.1, and monthly estimates of nitrate-N leached are shown in Table 9.2 and Figure 9.2 for the same periods. Annual estimates of nitrate-N leached for each of the monitoring seasons to date are given in Figure 9.3

Table 9.1:
Mean nitrate-N concentrations (g/m^3) in leachate during the 2014-2015 season (in bold type). Earlier data is included for comparison.

DATE	W1 Waikiwi control	W2 Waikiwi irrigated	W4 Waikiwi irrigated	D1 Dacre control	D2 Dacre irrigated	D3 Dacre irrigated
July 2011	4.7	1.1	0.1	4.1	5.6	0.1
Aug 2011	2.7	3.5	0.1	14.3	2.0	0.1
Sep 2011	2.0	3.3	0.1	10.3	0.7	0.1
Oct 2011	3.0	0.9	0.1	8.9	1.4	0.1
Nov 2011	0.6	2.9	0.1	4.1	0.2	0.1
Dec 2011	0.4	0.6	0.1	3.4	0.2	0.1
Jan 2012	0.3	3.4	0.4	7.9	0.1	0.6
Feb 2012	0.4	3.4	0.1	6.4	0.1	0.6
Mar 2012	0.4	3.5	0.1	4.8	0.2	3.1
Apr 2012	0.4	0.5	0.1	4.0	0.3	3.4
May 2012	0.5	0.1	0.1	3.8	0.9	3.5
June 2012	0.3	0.6	10.8	2.7	3.1	12.2
July 2012	0.4	0.7	4.4	0.1	11.1	7.7
Aug 2012	1.2	2.2	3.2	0.1	3.8	4.0
Sep 2012	1.2	1.5	4.4	0.1	0.4	1.6
Oct 2012	0.9	1.4	3.1	0.1	0.2	1.1
Nov 2012	0.5	0.7	3.7	0.1	0.4	0.5
Dec 2012	0.4	1.0	2.0	0.8	1.1	4.2
Jan 2013	0.8	0.9	0.4	0.1	0.1	3.4
Feb 2013	0.8	0.9	0.2	0.1	0.7	3.7
Mar 2013	0.7	0.9	2.8	0.1	0.2	3.4
Apr 2013	0.8	0.8	2.5	0.1	2.4	3.5
May 2013	0.9	0.8	6.3	0.2	0.2	2.5
June 2013	0.8	2.6	2.9	0.3	2.3	3.6
July 2013	0.7	4.6	4.4	28.7	27.7	13.2
Aug 2013	0.6	3.3	7.1	0.5	29.8	20.2
Sep 2013	0.5	2.9	4.9	0.2	6.1	18.9
Oct 2013	0.3	2.6	2.4	0.1	1.0	6.6
Nov 2013	0.2	1.4	1.3	0.1	0.8	6.4
Dec 2013	0.4	2.1	3.6	0.1	5.2	7.0
Jan 2014	0.3	0.2	0.9	0.1	2.1	15.0
Feb 2014	0.5	0.1	0.4	0.1	0.6	0.1
Mar 2014	0.3	1.7	0.5	0.6	0.1	7.1
Apr 2014	0.3	1.8	0.7	0.1	0.2	1.8
May 2014	0.3	0.6	3.3	0.1	2.8	9.0
June 2014	0.2	0.6	4.9	0.1	3.3	9.0
July 2014	**0.3**	**0.8**	**9.6**	**1.5**	**0.1**	**3.8**
Aug 2014	**0.3**	**0.5**	**11.1**	**0.0**	**0.7**	**2.3**
Sep 2014	**0.4**	**1.0**	**12.3**	**0.1**	**0.2**	**1.7**
Oct 2014	**0.3**	**1.9**	**13.4**	**0.1**	**0.3**	**1.2**
Nov 2014	**0.3**	**1.7**	**7.6**	**0.0**	**0.1**	**0.5**
Dec 2014	**0.4**	**1.4**	**5.6**	**0.1**	**0.1**	**0.2**
Jan 2015	**0.2**	**2.0**	**13.5**	**0.0**	**0.0**	**2.0**
Feb 2015	**0.3**	**1.8**	**0.7**	**0.7**	**0.2**	**1.8**
Mar 2015	**0.3**	**0.3**	**1.6**	**0.0**	**0.4**	**1.3**
Apr 2015	**0.4**	**0.3**	**0.2**	**0.4**	**0.0**	**2.2**
May 2015	**0.3**	**0.5**	**0.6**	**0.1**	**0.0**	**10.0**
June 2015	**0.4**	**0.4**	**0.4**	**0.4**	**0.0**	**11.5**

Table 9.2:
Estimates of mean nitrate-N leached (kg N/ha) during the 2014-2015 season (in bold type). Earlier data is included for comparison.

DATE	W1 Waikiwi control	W2 Waikiwi irrigated	W4 Waikiwi irrigated	D1 Dacre control	D2 Dacre irrigated	D3 Dacre irrigated
July 2011	7.0	1.6	0.1	6.1	8.3	0.1
Aug 2011	1.6	2.1	0.1	8.6	1.2	0.1
Sep 2011	1.4	2.3	0.1	7.2	0.5	0.1
Oct 2011	0.5	0.1	0.0	1.5	0.2	0.0
Nov 2011	0.3	1.4	0.0	2.0	0.1	0.0
Dec 2011	0.0	0.0	0.0	0.0	0.0	0.0
Jan 2012	0.0	0.0	0.0	0.0	0.0	0.0
Feb 2012	0.2	3.1	2.1	0.6	5.9	0.0
Mar 2012	0.0	1.4	0.0	0.0	0.1	1.4
Apr 2012	0.0	0.0	0.0	0.0	0.0	0.0
May 2012	0.1	0.1	0.1	0.8	0.5	1.8
June 2012	0.4	0.7	12.9	3.2	3.7	14.6
July 2012	0.0	0.0	0.2	0.0	0.5	0.4
Aug 2012	0.0	0.1	0.1	0.0	0.1	0.2
Sep 2012	0.6	0.7	2.1	0.0	0.2	0.8
Oct 2012	0.8	1.3	2.9	0.1	0.2	1.0
Nov 2012	0.0	0.1	0.3	0.0	0.0	0.0
Dec 2012	0.0	0.0	0.0	0.0	0.0	0.0
Jan 2013	0.2	0.2	0.1	0.0	0.0	0.7
Feb 2013	0.2	3.1	2.1	0.6	5.9	0.0
Mar 2013	0.0	0.0	0.0	0.0	0.0	0.0
Apr 2013	0.0	0.1	0.9	0.0	1.1	1.7
May 2013	0.4	0.8	6.2	0.1	0.2	2.4
June 2013	0.8	2.5	2.8	0.3	2.2	3.6
July 2013	0.5	3.3	3.1	20.3	19.6	9.3
Aug 2013	0.1	0.8	1.6	0.1	6.9	4.6
Sep 2013	0.3	1.8	3.0	0.1	3.7	11.5
Oct 2013	0.2	1.8	1.7	0.1	0.7	4.5
Nov 2013	0.0	0.1	0.1	0.0	0.1	0.5
Dec 2013	0.0	0.0	0.0	0.0	0.0	0.0
Jan 2014	0.0	0.0	0.0	0.0	0.0	0.0
Feb 2014	0.2	3.1	2.1	0.6	5.9	0.0
Mar 2014	0.0	0.0	0.0	0.0	0.0	0.0
Apr 2014	0.0	0.2	0.1	0.0	0.0	0.0
May 2014	0.2	0.6	3.5	0.1	2.7	8.2
June 2014	0.1	0.3	2.2	0.0	1.4	3.9
July 2014	**0.1**	**0.3**	**3.4**	**0.5**	**0.0**	**1.4**
Aug 2014	**0.3**	**0.5**	**10.6**	**0.0**	**0.7**	**2.2**
Sep 2014	**0.0**	**0.1**	**0.9**	**0.0**	**0.0**	**0.1**
Oct 2014	**0.1**	**0.7**	**5.0**	**0.0**	**0.1**	**0.5**
Nov 2014	**0.2**	**0.9**	**4.1**	**0.0**	**0.1**	**0.3**
Dec 2014	**0.0**	**0.1**	**0.4**	**0.0**	**0.0**	**0.0**
Jan 2015	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Feb 2015	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.1**
Mar 2015	**0.0**	**0.1**	**0.7**	**0.0**	**0.1**	**0.5**
Apr 2015	**0.0**	**0.2**	**0.1**	**0.0**	**0.0**	**1.4**
May 2015	**0.1**	**0.3**	**0.4**	**0.0**	**0.0**	**6.2**
June 2015	**0.4**	**0.4**	**0.5**	**0.5**	**0.0**	**12.0**
Annual 2014-2015	**1.3**	**3.7**	**26.3**	**1.2**	**1.1**	**24.5**
Annual 2013-2014	1.6	11.9	17.4	21.3	40.9	42.7
Annual 2012-2013	3.3	8.8	17.7	1.1	10.5	10.7

Table 9.2:
Continued.

DATE	W1 Waikiwi control	W2 Waikiwi irrigated	W4 Waikiwi irrigated	D1 Dacre control	D2 Dacre irrigated	D3 Dacre irrigated
Annual 2011-2012	11.5	14.2		29.9	19.3	
Annual 2010-2011	2.6	4.9		26.4	7.5	
Annual 2009-2010	1.8	4.9		13.5	5.6	
Annual 2008-2009	3.0	7.0		39.9	38.6	
Annual 2007-2008	0.9	5.5		1.4	19.6	
Annual 2006-2007	1.3	6.4		0.1	6.0	
Annual 2005-2006	0.5	1.4		0.4	1.6	
Annual 2004-2005	1.2	3.9		0.2	2.2	
Annual 2003-2004	0.6	5.9		0.4	2.7	

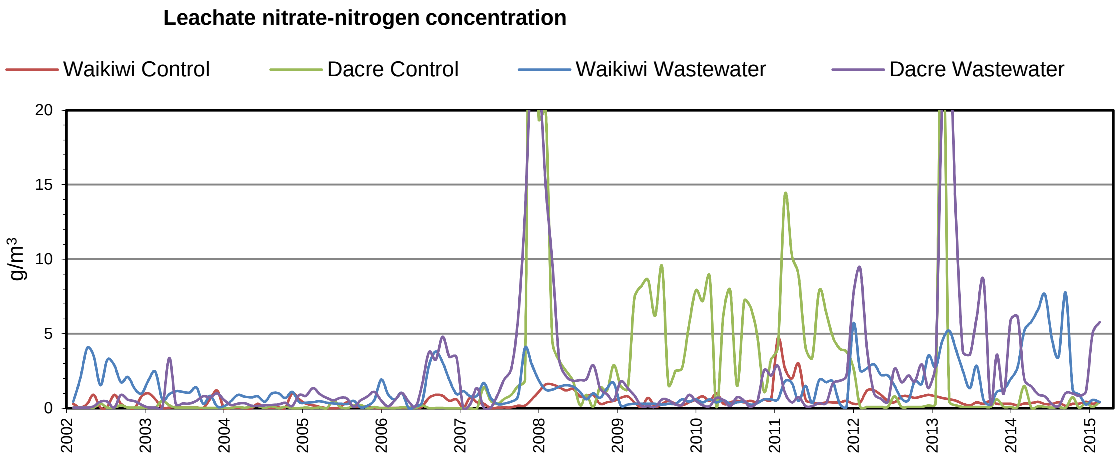


Figure 9.1:
Average nitrate-N concentrations in leachate at each sampling occasion.

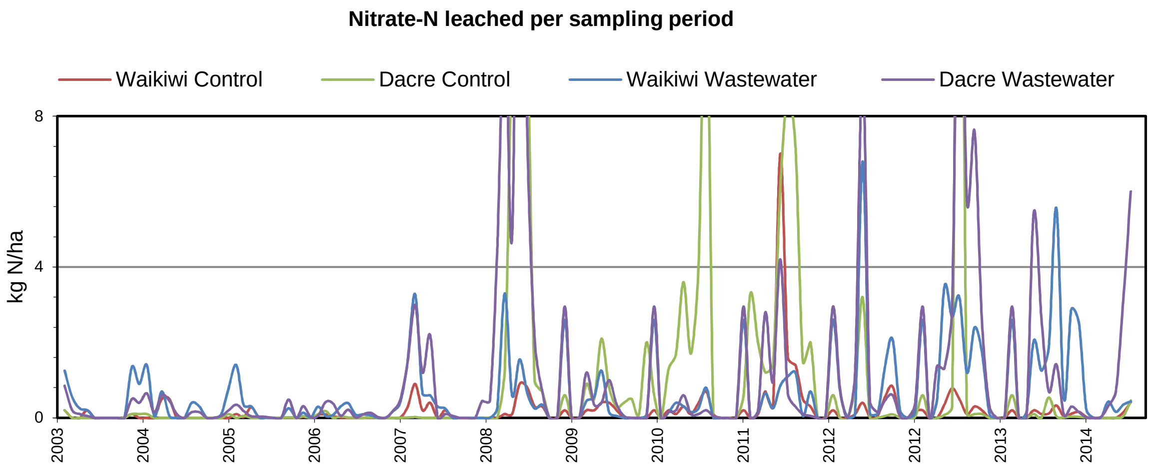


Figure 9.2:
Average nitrate-N leached per monthly sampling period.

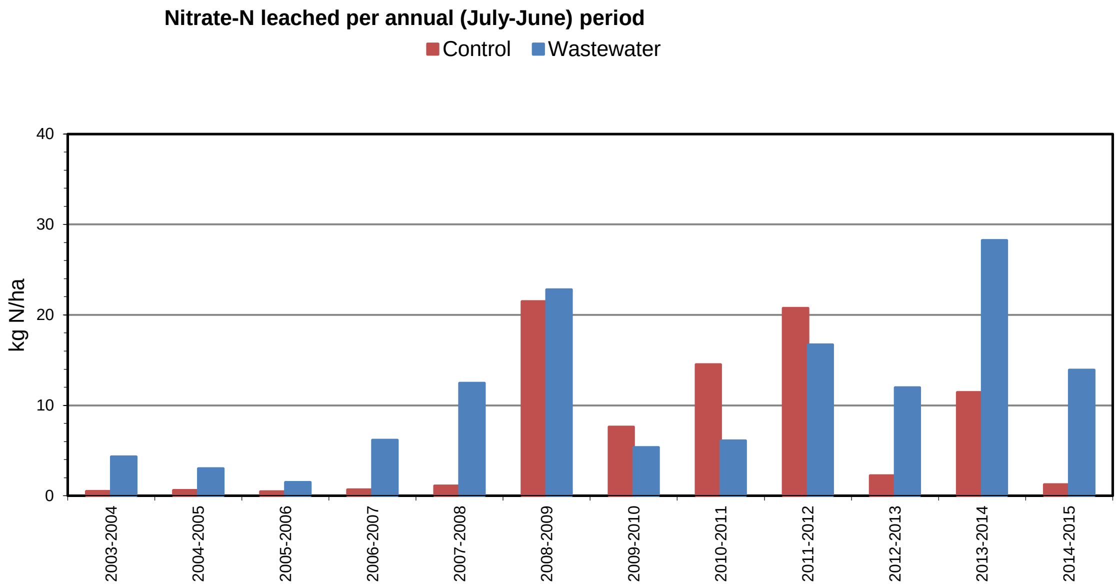


Figure 9.3:
Overall averages of nitrate-N leached per season.

Some of the average nitrate-N concentrations for the 2014-2015 reporting period, mostly from the Dacre soil lysimeter sites, were lower than in the previous season, with the highest average value recorded for those sites being 3.2 g/m^3 compared with 9.5 g/m^3 in 2013-2014. In contrast, average nitrate-N concentration at one of the irrigated Waikiwi soil sites in 2014-2015 (6.4 g/m^3) was higher than the corresponding value in that earlier period (2.9 g/m^3). Overall, average seasonal leachate nitrate-N concentrations in 2014-2015 for the Waikiwi control, Waikiwi irrigated, Dacre control, and Dacre irrigated sites, were 0.3 g/m^3, 3.7 g/m^3, 0.3 g/m^3, and 1.7 g/m^3, whilst the corresponding values for the previous season are 0.4 g/m^3, 2.3 g/m^3, 2.5 g/m^3, and 8.1 g/m^3.

The highest values for the Dacre soils (both control and irrigated) last season were attributed to preferential movement of water and nutrients from surrounding areas of paddocks into lower relict stream channels that contain Dacre soils. During wetter parts of the season these old stream channels are seen to contain significant amounts of surface water. Animal waste is likely to be the main source of nitrogen that has moved by runoff and seepage into these channels because the second highest leachate nitrate-N concentration that season was from a control area. Nonetheless, nitrogen from last season's wastewater irrigations was likely to have contributed to the higher values that were recorded at the Dacre wastewater sites in that period.

While the same processes would have occurred in 2014-2015, but with additional nitrogen contributions from the larger amounts of wastewater applied, amounts of drainage were much higher than in 2013-2014 and this may have resulted in diversion of some of the nitrogen via drains. Alternatively, the lower average nitrate-N concentration for irrigated Dacre sites in 2014-2015 may have been a random result of different times of intensive grazing events in relation to periods of high drainage. Regardless, leachate nitrogen concentrations were lower for the Dacre soils in the current reporting period than in the previous season. Overall, the average concentration in 2014-2015 for all four wastewater sites (2.7 g/m^3) was low compared with that in 2013-2014 (5.2 g/m^3).

With lower average nitrate-N concentrations in leachate from the Dacre soil in 2014-2015 compared with the previous season, average amounts of annual nitrate-N leached for both the Dacre control and Dacre wastewater areas were significantly lower in 2014-2015. During this reporting period, those average amounts were 1.2 kg N/ha and 12.8 kg N/ha, compared with corresponding values of 21.3 kg N/ha and 41.8 kg N/ha for the 2013-2014 season. For the Waikiwi soil sites, average values for control and irrigated areas in 2014-2015, at 1.3 kg N/ha and 15.0 kg N/ha, were much the same as in the previous year.

Compared with longer term average values of nitrate-N leached from the wastewater areas, the 2014-2015 value for Waikiwi soils was higher (15.0 kg N/ha versus 8.8 kg N/ha), while that for the Dacre soils was slightly lower (12.8 kg N/ha versus 18.6 kg N/ha). Averaged for all of the wastewater monitoring sites, the average value of nitrate-N leaching during the reporting period is estimated to have been 13.9 kg N/ha. This value is approximately one half of that recorded for the previous season (28.2 kg N/ha), but almost the same as the average estimated for the previous eight seasons (13.7 kg N/ha).

Currently, therefore, it appears that average annual nitrate-N leaching from wastewater areas at this Lorneville site is approximately 14 kg N/ha in most years.