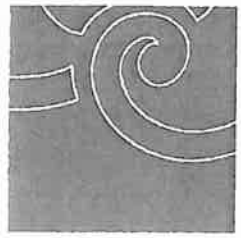

End of year report on nitrogen leaching under lucerne at the Tihoi lysimeter facility, 2011–2012

Landcare Research
Manaaki Whenua

End of year report on nitrogen leaching under lucerne at the Tihoi lysimeter facility, 2011–2012

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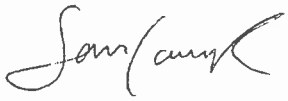
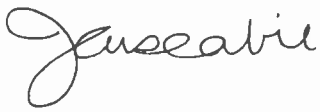
Reviewed by:	*Approved for release by:*
	
Sam Carrick Soil Scientist Landcare Research	Jackie Aislabie Science Team Leader Soils and Landscapes

Landcare Research Contract Report:	LC 945

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Contents

Summary

Project and Client

- Landcare Research has been contracted by Lake Taupo Protection Trust to investigate nitrogen leaching under lucerne near Tihoi on the western side of Lake Taupo.
- The contract runs for 3 years with the project starting in July 2011.
- This report covers installation of a lysimeter array and the planting of lucerne, and presents analytical data for the leachate and herbage collected until February 2012.

Objectives

The objectives of this report are to present:

- the layout/design of the lysimeter facility
- work which has been undertaken at the lysimeter facility
- initial analytical results for the leachate from the lysimeter cores

Methods

- A lysimeter array has been installed that consists of a central underground leachate collection facility surrounded by 12 barrel lysimeters (with 50 cm hanging wicks) each 1 m in diameter by 1.5 m high. Each lysimeter contains intact soil cores of a Pumice Soil.
- Leachate from each lysimeter is collected into 200 L tanks and analyzed for nitrogen, phosphorus and carbon.
- Treatments on the lysimeters are ryegrass/clover, lucerne, lucerne plus biochar.
- Herbage is collected from the lysimeters and analysed for nitrogen and carbon.

Results

- Approximately 370 L of leachate from each lysimeter have been collected and analysed, of which the first approximately 180 L can be considered background levels before treatments were imposed on the lysimeters.
- In general, leachate analyses show low levels of nutrients with total dissolved carbon 3–10 mg/L, NO_x-N <0.005–4.73 mg/L and total phosphorus <0.01–0.68 mg/L.
- Nitrogen in the herbage was in the range of 2 – 3.4%.

Conclusions

- While nitrate levels in the leachate are low it is too early to determine any differences between the treatments as insufficient leachate has been collected.

1 Introduction

Landcare Research has been contracted by Lake Taupo Protection Trust to investigate nitrogen leaching under lucerne near Tihoi on the western side of Lake Taupo. The contract runs for 3 years with the lysimeters being installed in July 2011. This report covers installation of the lysimeter array, planting of lucerne and presents analytical data for the leachate and herbage collected until February 2012.

2 Background

Water in Lake Taupo is deteriorating due to increasing N levels (approx. 1250 tonnes/yr, of which 30–40% come from pastoral farmland). To maintain water quality, Waikato Regional Council has adopted a target of reducing manageable N entering the lake by 20%. Lake Taupo Protection Trust (LTPT) has a fund of approximately $81M (including GST) to reduce manageable N from the Lake Taupo Catchment by 20% over the next 15 years. Much of the reduction is achieved by conversion to forestry, a low N land use.

Alternatively, cut-and-carry lucerne may be an economically viable, low N-loss agricultural option for land use. However, current predictions of N leaching losses for lucerne range between 5 and 26 kg/N/ha/y. Due to this range, farmers cannot participate effectively in the nitrogen trading market, i.e. change farming operations to achieve accurate, quantifiable reductions and hence receive appropriate payments from the Lake Taupo Protection Trust. Nitrogen leaching losses from farming operations are calculated by LTPT using the Overseer® model.

The uncertainty within the wide range in N leaching values under lucerne was highlighted when a potential farm purchaser wanted to step outside more traditional farming practices and develop a farm near Tihoi with multiple land uses including some areas planted in cut-and-carry lucerne. The harvested lucerne was to be exported from the catchment. The wide range in reported N leaching losses under lucerne made it difficult to allocate N leaching loss for the whole-of-farm operation. At that stage there was no module within Overseer® to calculate N leaching losses from a full cut-and-carry lucerne operation.

Approximately 20 km to the south, near Kuratau, there has been a 3-year trial measuring N leaching from cut-and-carry lucerne using suction cup lysimeters installed at 60 cm depth in Pumice Soils (Thorrold & Betteridge 2006). This trial revealed N leaching losses of up to 26 kg/N/ha/y. In this study a large pulse of N was likely moving through the soil as a result of the cultivation associated with the planting of lucerne (S. Ledgard, November 2010, AgResearch, pers. comm.). Furthermore, up to 20 kg N/ha was added to kick-start growth in spring. The aim of this study was to examine the economics of alternative crops rather than minimise N leaching.

Considering the range in N leaching values reported under lucerne combined with the nearby trial values reported by Thorrold and Betteridge (2006), LTPT set the N leaching value for lucerne in the Lake Taupo catchment at 19 kg/N/ha/y, while acknowledging the need for further research. To further investigate N leaching losses from lucerne, Landcare Research received funding from Lake Taupo Protection Trust. The Landcare Research investigation is based on large diameter barrel lysimeters with fibreglass wicks to their bases providing a 50-

cm hanging water column or –5 kPa tension to overcome ponding at the base of the soil core, which could induce anaerobic conditions and consequent N transformations.

3 Objectives

The objectives of this report are to present:

- the layout/design of the lysimeter facility
- work that has been undertaken at the lysimeter facility
- initial analytical results for the leachate from the lysimeter cores

4 Methods

Location and soils

The lysimeter array is located at 521 Hingarae Rd, Tihoi. Grid reference NZTM RF71 E1838720 N5716970 with altitude 500 m a.s.l. Annual rainfall is approximately 1200–1600 mm. Soils are Taupo soils classified as Typic Orthic Pumice Soils (Hewitt 2003), being developed in 70–90 cm airfall Taupo Pumice tephra over older allophanic tephras. Saturated hydraulic conductivity at 1.5 m depth in the older, allophanic tephric material is 20 mm/h. Total porosity of the soil material on site has not yet been determined but judging from data on similar soils is expected to be approximately 70%, giving a pore volume of 723 L in each lysimeter.

Field collection of lysimeters

The lysimeter array consists of a central underground leachate collection facility surrounded by 12 barrel lysimeters each 1 m in diameter by 1.5 m high (Figure 1). The 12 high-density polyethylene (HDPE) barrel lysimeters each contain intact soil cores of a Pumice Soil that were hand carved *in situ* from a dry stock farmed paddock supporting a ryegrass/clover sward on which there had been no N fertilizer input for at least 5 years (Figure 2). A 10-mm internal annulus within each core was filled with petroleum jelly to prevent water preferentially flowing at the soil-casing interface (Figure 3). After the petroleum jelly had set, a taut wire was used to slice through the soil at base of the lysimeter (Figure 4). The lysimeter was then pulled on to a wooden base (Figure 5) and a lifting/rotating frame bolted over the 1.2 tonne core onto the base (Figure 6).

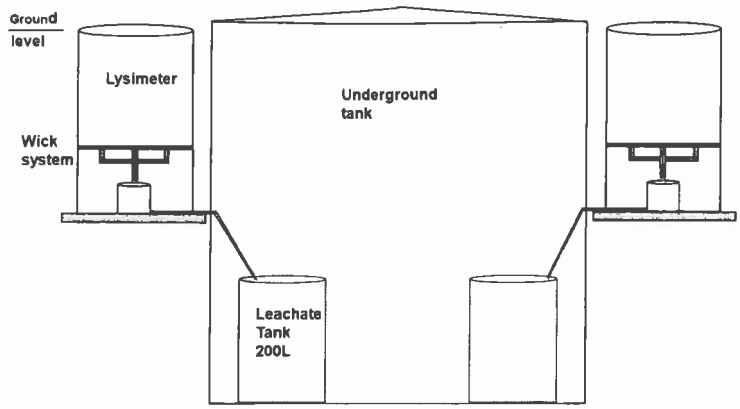

Figure 1. Diagram of lysimeter array. Base of underground tank is 4.1 m below ground level.

Figure 2. Hand-carved lysimeters ready for extraction.

Figure 3. Sealing the edge of the soil with petroleum jelly to prevent edge flow.

Figure 4. Using a wire to slice off the soil at the base of the lysimeter.

Figure 5. Sliding the lysimeter onto the wooden base.

Figure 6. Attatching the lysimeter lifting frame to the wooden base.

Figure 7. Lysimeter base system consisting of HDPE lysimeter base with wicks on the wooden base on concrete manhole riser.

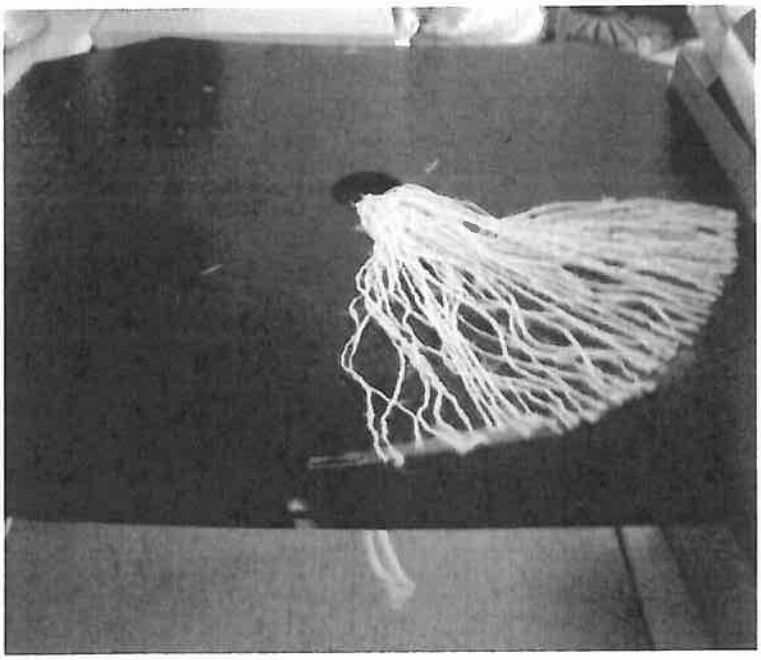

Figure 8. Fibreglass wick is un-braided and laid radially on the lysimeter base.

Figure 9. Rotating the lysimeter before attaching the fibreglass wicks.

Lysimeter base and wick system

The lysimeter barrel bases (Figure 7) were constructed from 10 mm thick × 1100 mm square HDPE. To provide passive suction to the soil core braided fibreglass wicks, 1/2" diameter (Catalogue number 1381, Pepperell Braiding Co., East Pepperell, MA), were hung to 50 cm below the base to provide a tension of –5kPa to the base of the soil core. The fibreglass wicks were loosely encased by 90-mm ID drainpipe socketed to the underside of the HDPE base. On the side of the HDPE base that contacted the soil, the braided fibreglass rope was unravelled so each braid could be laid radially from the central delivery hole to the outside of the core (Figure 8). The number of braids depends on the hydraulic conductivity of the soil and wick characteristics and was calculated following Holder et al. (1991). A circular piece of fibreglass roving cloth (200 g/m^2) was stapled over the wicks using stainless steel staples to prevent disturbance to the wicks during installation.

The HDPE barrel and base with fibreglass wicks sit on a diaphragm-design wooden base atop a 1050-mm ID flange base concrete manhole riser, 900 mm high, which allows the wicks to discharge leachate into a collection funnel connected to a 200-L leachate collection tank.

Field assembly

The lysimeter was lifted, rotated through 180° (Figure 9), where the wooden base was removed and the HDPE base with wicks inserted, before the wooden base was reattached. Finally, the lysimeter was rotated to the correct orientation and lowered onto the concrete manhole riser plumbed to the underground central collection facility. The underground central collection facility was constructed from a 3.8-m diameter 25 000 L concrete water tank with an inverted 15 000 L concrete water tank lowered on top. Holes were drilled in the side of the lower tank to allow entry of the leachate pipes from the lysimeters.

Treatments

On the soils there are three treatments with four replicates. The treatments, all cut-and-carry, are:

1. Lucerne with standard fertiliser
2. Lucerne with standard fertiliser + biochar at a rate of 10 t/ha
3. Ryegrass/clover following the farm fertiliser regime (no fertiliser-N)

Layout

Because of the requirement to match guard crops to the lysimeters crops, the different treatments could not be randomized. The four lysimeters containing ryegrass/clover have been installed in one block with ryegrass/clover as a guard crop, the lysimeters being 60 cm apart. The treatments of the remaining eight lysimeters containing lucerne have been randomized.

Soil analyses, fertiliser, spraying and planting

Following soil analysis (0–15 cm depth) for pH, P, K, Ca, Mg, Na, S, C, N and base saturation the lysimeters containing lucerne received lime at 4 t/ha as well as Kieserite and Calmag at 100 kg/ha as recommended by Genetic Technologies Ltd. The pine sawdust biochar was sourced from Lakeland Steel, Rotorua. While the lysimeters containing ryegrass/clover remained uncultivated, the lysimeters containing lucerne were ripped to 50 cm depth and cultivated to 15 cm to reflect current agricultural practice. Biochar was incorporated to 15 cm depth at the final cultivation.

In spring, lucerne was planted at a depth of 12 mm at a rate of 120 plants per square meter in the eight lysimeters containing lucerne and as a surrounding guard crop to the lysimeters containing lucerne. Before planting the lucerne, a trifluralin-based, pre-emergent spray (Orion Pre-empt) was applied, at label rates, to the final cultivation soil. Weeds in the lucerne over the lysimeters were removed by hand while the lucerne guard crop has received two sprayings with a selective herbicide (Spinnaker) to control weeds (predominantly thistles).

Leachate collection and analyses

Leachate was collected for analysis approximately every month and analysed for total dissolved carbon, dissolved inorganic carbon, dissolved organic carbon, ammonia-N, nitrate-N, reactive phosphorus, total nitrogen and total phosphorous following standard methods (Test No. 314 http://www.landcareresearch.co.nz/services/laboratories/eclab/eclabtest_list.asp).

Analytical results of each lysimeters leachate is quoted in mg/L and can be converted to kg/ha using the leachate volume collected and the surface area of the lysimeter.

Herbage collection and analyses

Ryegrass/clover on the lysimeters is harvested at time intervals based on stock rotation on the surrounding farm. In spring and summer this is approximately every 25 days; it is longer during winter. Lucerne is harvested at 10% flowering, with a final cut in autumn when plant growth is considered to have stopped. Herbage is analyzed for nitrogen and carbon following standard methods (Test No. 204 http://www.landcareresearch.co.nz/services/laboratories/eclab/eclabtest_list.asp).

Weather station

At 9 am each day, air temperature (1.2 m above ground level), 15 cm soil temperature and rainfall over the past 24 hours are logged on a Campbell Scientific CR10X datalogger and telemetered daily to the Landcare Research computer network at Hamilton.

Data location

All information pertaining to the experiment is kept on a Landcare Research Infofile site http://infofile.landcareresearch.co.nz/all/projects/main/00271/Administration/Forms/AllItems.aspx

A diary of on-site work is also kept on the infofile site.

5 Results

We expect the Pumice Soils within the lysimeters to have low bypass flow because the soils are weakly structured with a sandy matrix. They are also ranked as having low microbial bypass flow (McLeod et al. 2008).

We have collected approximately 370 L of leachate from each lysimeter since installation. Approximately 180 L were collected before we imposed treatments and established the background values of nutrients in the leachate. Each lysimeter has a total pore volume of approximately 700 L. Theoretically about half of the pores or voids in the soil have been re-filled with "new" soil water since installation. Since imposing treatments on the lysimeters we have collected approximately 190 L of leachate or <30% of the pore volume of each lysimeter. In matrix flow, soil drainage tends to be dominantly by a piston effect, where water infiltrating downwards into the soil tends to act as a piston and displaces existing soil water at the base of the lysimeter. Due to the uniform matrix flow of water through this soil type, it is likely that post-treatment leachate still largely reflects the background leachate before amendments. Under matrix flow we would expect a theoretical peak in nutrients in the leachate when we have collected one pore volume (approximately 700 L) post treatment.

Results of leachate analyses are shown in Appendix 1. Values for dissolved carbon range from 3 to10 mg/L and total phosphorus from <0.01 to 0.68 mg/L. NO_x-N values in leachate from all the lysimeters ranges from <0.005 to 4.73 mg/L, higher values being present only from lysimeters 6 and 7.

Results of herbage analyses are shown in Appendix 2. For the samples of grass harvested from the four lysimeters containing grass, nitrogen concentration ranged from 2.00% to 3.41%. In the one cut of lucerne nitrogen ranged from 2.14% to 2.55%.

Diary of on-site work

Table 1 Diary of on-site work

Date	Activity
3 July 2011	Empty and clean lysimeter barrels.
24 July	Sample leachate and empty barrels.
5 Sept	Glyphosate sprayed on grass where lucerne to be sown, reset soil temperature probe from 10 cm to 15 cm, install manual rain gauge.
21 Sept	Sample leachate, 57 mm in manual rain gauge, cultivate lucerne lysimeters to 15 cm, added biochar to 4, lime to all. Spoke to International Diffuse Pollution Conference field trip attendees on-site about the lysimeter array and the ongoing research.
4 October	49 mm emptied from manual rain gauge and exhumed #2 lysimeter. Water in concrete riser. Joint to funnel seemed loose. Tightened. Re-installed lysimeter.
6 October	Cultivated topsoil to 75–100 mm and added fertiliser to lucerne lysimeters and guard area. Water in manual rain gauge but did not empty.
20 October	Sprayed with pre-emergent herbicide Trifluralin and sowed lucerne seed 120 plants per square metre = 76 per lysimeter. Seeds 12 mm deep. At office recalibrated Odessy Capacitance Water Level probe. Numbers are 200 mm = 1310 and 1000 mm = 2799.
5 November	Cut pasture on lysimeters and retained in paper bags for N analysis. Re- installed water level probe. Sampled lysimeters for leachate. Avg 66.9 L but 3 dry. Input hoses appear to be leaking so will find a glue to fix them.
12 November	Sealed all input hoses joints with Selleys clear silicone sealer. Could see #6 and #2 dripping. Both barrels empty. Heard them dripping once sealed and could not see any wetness on any of the joints. Removed TCS logger as could not get reply from cell phone. Red light on modem flashing though and green lights showing on boards. Mowed lawns. Some lucerne is visible. Mike says there is enough clover in all the grass/clover lysimeters.
18 November	Richard checked all joints. None leaking. Lysimeters dripping into barrels at 1 drip per 11 sec, so still draining.
14 December	Took herbage cut of 4 grass lysimeters. Mowed lawn in guard area. Sampled leachate about 20 L each drum. Emptied manual rain guage 77.5 mm. Hand weeded lysimeter lucerne. Lucerne guard crop is weedy.
4 January 2012	Gary Harrison planted extra lucerne seedlings in the lysimeters to replace seeds which did not germinate. Now all lysimeters containing lucerne are planted at a rate of 120 plants/m^2.
11 January	Took herbage cut of 4 grass lysimeters. Mowed lawn in guard area. Sampled leachate about 39–55 L each drum. Emptied manual rain guage 213 mm. Lucerne guard crop is about 30 cm high, doing well.
1 February	Leachate sampling with Jim Bockheim (Wisconsin University, USA). Emptied manual rain guage 34 mm.
7 February	Harvested lucerne and trimmed lucerne guard crop.
8 March	Richard harvested grass, mowed grass guard crop, emptied manual rain guage. Not enough leachate to warrant sampling.
1 April	Harvested grass, mowed grass guard crop, emptied manual rain guage. Mike says lucerne will stop growing soon (had a frost already) so made last harvest as well. Mouse hole has been dug in core to at least subsoil depth. Mike will put out bait. Sprayed lucerne guard crops with Spinnaker to control thistles and weeds. Wait one month before trimming guard crop = 1 May approx. Not enough leachate to warrant sampling.

6 Discussion

The large range of the NO_x-N value reflects the high value in two lysimeters. The high values were present in the first sample of leachate, which was obtained before any treatments were imposed upon the soil. Therefore the high NO_x-N value is a background value associated with the previous grazing land use. It is likely the soil for those cores received a "double" urine patch during previous grazings. As the lysimeter cores came from a paddock grazed approximately 2 weeks before the core collection, high NO_x-N values can be expected in the leachate as N pulses move down through the soil.

However, we also expect to see a pulse of N moving through the soil as a result of the cultivation associated with the planting of lucerne. This is not yet evident and may last a number of years (S. Ledgard, November 2010, AgResearch, pers. comm.). As Overseer® measures nitrogen loss at 1.5 m soil depth for lucerne we anticipate the N pulse to still be evident in the leachate at year three of the project.

Ammonia-N values are mostly below detection limits when leachate is sampled at 1.5 m below the ground surface. This is suprising because ammonia-N is deposited by cattle in dung and urine. A probable reason is the conversion of NH_4-N to NO_x-N by nitrifying microbes within the soil column. In this trial stock are excluded from the lysimeters therefore we would expect ammonia-N inputs to be low since installation. It is also possible that while NH_4-N is initially present in the leachate, there is a change in form of nitrogen in the collection tank between collections. Clough et al. (2001) suggest leachate be stored for only 4 days at 4°C to prevent change in N form. We will undertake sequential analysis of the leachate during the coming winter to determine whether there are any changes in the form of nitrogen between samplings. If a freshly collected leachate sample shows an ammonia-N value below detection limits no further analysis will be required.

Total P values in the leachate are very low. P-retention in upper horizons of the pumiceous soil material is approximately 60%. Parent material of the lower subsoil is allophanic soil material (Hewitt 2003), which has very high (>95%) P-retention. Phosphates moving through the soil are likely to be adsorbed onto the allophanic clays.

Further analysis of the data is not yet warranted, as any changes in nutrients leached are unlikely to be present in the leachate because sufficient leachate has not yet been collected.

The relationship between levels of dissolved organic carbon and dissolved inorganic carbon in the leachate is still being investigated.

Nitrogen values for the one cut of lucerne are lower than those shown in the Pioneer® Brand Products Lucerne Manual but pertain to the whole crop rather than the top 150 mm of the crop as in the manual.

7 Conclusions

Twelve barrel lysimeters (1 m diameter × 1.5 m deep) containing an undisturbed Pumice Soil have been installed around an underground facility near Tihoi.

Treatments are undisturbed ryegrass/clover, lucerne with standard fertiliser, lucerne with standard fertiliser and biochar (10 t/ha).

Since imposing treatments on the lysimeters, insufficient leachate has been collected to comment on differences in the leachate quality.

Nitrogen leaching from the all the lysimeters appears to be at low values.

A nitrogen pulse from cultivation could be present in the leachate at least until year three of the project.

8 Recommendations

Changes in N form be undertaken by sequential analysis of leachate samples to ensure the low NH_4-N vaues in the leachate are real and not induced by the longer than optimal storage times.

To extend the trial longer than the currently planned three years Landcare Research and Lake Taupo Protection Trust start work to gain funding from, for example, the Sustainable Farming Fund.

9 Acknowledgements

This project is partially funded by the Lake Taupo Protection Trust. Mike and Sharon Barton have kindly fenced the site, provided a pressurised water supply at the site, sprayed the site for weeds, provided predator control and kept an eye on the site.

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Appendix 1 – Analytical results for leachate

Environmental Chemistry Laboratory
Analytical Report - Water

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Job Number: LJ11009

Customer: Malcom McLeod, Landcare Research Ltd
Private Bag 3127, Hamilton 3240

Date Received: 26th July 2011

Date Reported: 2nd August 2011

Client ID	Sample No.	Total Dissolved Carbon (method 310) mg/L	Dissolved Inorganic Carbon (method 310) mg/L	Dissolved Organic Carbon (method 310) mg/L	Ammonia-N (method 314) mg/L	NO_x-N (method 314) mg/L	Reactive Phosphorus (method 314) mg/L	Total Nitrogen (method 316) mg/L	Total Phosphorus (method 316) mg/L
1 24/07/2011	M11/0280	5	4	<1	<0.004	0.080	0.005	0.05	<0.01
2 24/07/2011	M11/0281	3	3	<1	<0.004	0.087	0.005	0.09	<0.01
3 24/07/2011	M11/0282	4	4	<1	<0.004	0.037	0.005	0.03	<0.01
4 24/07/2011	M11/0283	6	5	<1	<0.004	0.142	0.005	0.15	<0.01
5 24/07/2011	M11/0284	5	5	<1	<0.004	0.157	0.005	0.16	<0.01
6 24/07/2011	M11/0285	5	5	<1	<0.004	4.73	0.005	4.79	<0.01
7 24/07/2011	M11/0286	3	3	<1	0.006	0.270	0.005	0.26	<0.01
8 24/07/2011	M11/0287	5	5	<1	0.004	0.065	0.005	0.06	<0.01
9 24/07/2011	M11/0288	4	4	<1	<0.004	0.125	0.005	0.08	<0.01
10 24/07/2011	M11/0289	6	5	1	<0.004	0.209	0.006	0.21	<0.01
11 24/07/2011	M11/0290	3	3	<1	<0.004	0.047	0.005	<0.02	<0.01
12 24/07/2011	M11/0291	4	4	<1	<0.004	0.040	0.005	0.05	<0.01

LJ Hill

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Analytical Report - Water

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Job Number: LJ11033

Customer: Malcolm McLeod, Landcare Research
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Date Received: 27th September 2011

Date Reported: 4th October 2011

	Client ID	Sample No.	Total Dissolved Carbon (method 310) mg/L	Dissolved Inorganic Carbon (method 310) mg/L	Dissolved Organic Carbon (method 310) mg/L	Ammonia-N (method 314) mg/L	NO_x-N (method 314) mg/L	Reactive Phosphorus (method 314) mg/L	Total Nitrogen (method 316) mg/L	Total Phosphorus (method 316) mg/L
1	21/09/2011	M11/0929	7	7	<1	0.011	0.073	0.005	0.10	<0.01
2	21/09/2011	M11/0930	4	4	<1	0.009	0.091	0.005	0.16	<0.01
3	21/09/2011	M11/0931	4	4	<1	**<0.004**	**<0.005**	0.005	0.06	<0.01
4	21/09/2011	M11/0932	6	6	<1	<0.004	0.116	0.005	0.13	<0.01
5	21/09/2011	M11/0933	6	6	<1	<0.004	0.179	0.004	0.18	<0.01
6	21/09/2011	M11/0934	4	4	<1	0.006	3.340	0.005	2.99	<0.01
7	21/09/2011	M11/0935	6	5	<1	0.046	0.555	0.004	0.62	<0.01
8	21/09/2011	M11/0936	4	4	<1	**<0.004**	0.064	0.004	0.11	<0.01
9	21/09/2011	M11/0937	4	4	<1	0.005	0.113	0.005	0.15	<0.01
10	21/09/2011	M11/0938	7	6	<1	<0.004	0.121	0.005	0.15	<0.01
11	21/09/2011	M11/0939	4	3	<1	0.006	0.037	0.005	0.08	<0.01
12	21/09/2011	M11/0940	6	6	<1	0.005	0.032	0.004	0.09	<0.01
1T	21/09/2011	M11/0941	5	5	<1	0.012	0.061	0.005	0.10	<0.01
2T	21/09/2011	M11/0942	4	3	<1	0.006	0.095	0.005	0.15	<0.01
3T	21/09/2011	M11/0943	3	3	<1	<0.004	<0.005	0.005	0.05	<0.01
4T	21/09/2011	M11/0944	5	5	<1	**<0.004**	0.123	0.004	0.17	<0.01
5T	21/09/2011	M11/0945	5	5	<1	0.007	0.181	0.005	0.25	<0.01
7T	21/09/2011	M11/0946	5	5	<1	0.045	0.559	0.004	0.57	<0.01
9T	21/09/2011	M11/0947	3	3	<1	**<0.004**	0.116	0.005	0.15	<0.01
10T	21/09/2011	M11/0948	4	3	<1	<0.004	0.126	0.004	0.13	<0.01

LJ Hill

Linda Hill, Acting Laboratory Manager

Environmental Chemistry Laboratory
Analytical Report - Water

Landcare Research
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Job Number: LJ11062

Customer: Malcolm McLeod, Landcare Research Ltd
Private Bag 3127, Hamilton 3240

Date Received: 8th November 2011

Date Reported: 24th November 2011

Client ID	Sample No.	Total Dissolved Carbon (method 310) mg/L	Dissolved Inorganic Carbon (method 310) mg/L	Dissolved Organic Carbon (method 310) mg/L	Ammonia-N (method 314) mg/L	NO_x-N (method 314) mg/L	Reactive Phosphorus (method 314) mg/L	Total Nitrogen (method 316) mg/L	Total Phosphorus (method 316) mg/L
5/11/11 1	M11/1950	8	4	4	0.016	0.073	0.006	0.10	<0.01
5/11/11 2	M11/1951	8	5	3	0.021	0.157	0.008	0.33	<0.01
5/11/11 3	M11/1952	7	3	4	0.008	0.009	0.006	0.05	<0.01
5/11/11 4	M11/1953	6	3	2	0.009	0.163	0.006	0.19	<0.01
5/11/11 5	M11/1954	5	2	3	0.009	0.205	0.006	0.28	<0.01
5/11/11 6	M11/1955	7	2	5	0.018	2.29	0.006	2.48	<0.01
5/11/11 7	M11/1956	5	3	2	0.024	0.799	0.006	0.84	<0.01
5/11/11 8	M11/1957	6	2	3	0.006	0.045	0.006	0.10	<0.01
5/11/11 9	M11/1958	6	2	3	0.008	0.151	0.006	0.17	<0.01
5/11/11 10	M11/1959	7	2	4	0.011	0.084	0.006	0.12	<0.01
5/11/11 11	M11/1960	5	2	2	0.016	0.056	0.005	0.10	<0.01
5/11/11 12	M11/1961	6	3	3	0.020	0.028	0.005	0.08	<0.01

LJ Hill

Linda Hill, Acting Laboratory Manager

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Environmental Chemistry Laboratory
Analytical Report - Leachate

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Job Number: LJ11085

Customer: Malcolm McLeod, Landcare Research Ltd
Private Bag 3127, Hamilton 3240

Date Received: 16th December 2011

Date Reported: 20th January 2012

Client ID		Sample No.	Total Dissolved Carbon (method 310) mg/L	Dissolved Inorganic Carbon (method 310) mg/L	Dissolved Organic Carbon (method 310) mg/L	Ammonia-N (method 314) mg/L	NO_3-N (method 314) mg/L	Reactive Phosphorus (method 314) mg/L	Total Nitrogen (method 316) mg/L	Total Phosphorus (method 316) mg/L
14/12/11	1	M11/2497	8	7	<1	0.013	0.075	0.006	0.24	0.11
14/12/11	2	M11/2498	10	9	1	0.016	0.192	0.006	0.22	<0.01
14/12/11	3	M11/2499	6	6	<1	<0.004	0.032	0.006	0.03	<0.01
14/12/11	4	M11/2500	6	6	<1	<0.004	0.237	0.007	0.30	0.03
14/12/11	5	M11/2501	5	5	<1	0.009	0.223	0.006	0.21	<0.01
14/12/11	6	M11/2502	5	5	1	0.024	2.15	0.006	2.35	0.02
14/12/11	7	M11/2503	6	5	<1	0.012	1.44	0.006	1.66	0.02
14/12/11	8	M11/2504	5	5	1	0.021	0.057	0.006	0.06	<0.01
14/12/11	9	M11/2505	6	6	1	<0.004	0.233	0.006	0.38	<0.01
14/12/11	10	M11/2506	6	5	1	<0.004	0.117	0.006	0.12	<0.01
14/12/11	11	M11/2507	4	4	<1	<0.004	0.065	0.006	0.15	0.02
14/12/11	12	M11/2508	4	3	<1	<0.004	<0.005	0.006	0.05	<0.01

LJ Hill

Linda Hill, Acting Laboratory Manager

Environmental Chemistry Laboratory
Analytical Report - Leachate

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Job Number: LJ11099

Customer: Malcolm McLeod, Landcare Research Ltd
Private Bag 3127, Hamilton 3240

Date Received: 13th January 2012

Date Reported: 1st February 2012

Client ID	Sample No.	Total Dissolved Carbon (method 310) mg/L	Dissolved Inorganic Carbon (method 310) mg/L	Dissolved Organic Carbon (method 310) mg/L	Ammonia-N (method 314) mg/L	NO_x-N (method 314) mg/L	Reactive Phosphorus (method 314) mg/L	Total Nitrogen (method 316) mg/L	Total Phosphorus (method 316) mg/L
11/01/12 1	M11/2821	8	5	3	0.010	0.093	0.008	0.16	<0.01
11/01/12 2	M11/2822	7	4	3	<0.004	0.221	0.008	0.31	<0.01
11/01/12 3	M11/2823	6	4	2	<0.004	0.072	0.008	0.06	<0.01
11/01/12 4	M11/2824	7	3	4	<0.004	0.227	0.008	0.26	<0.01
11/01/12 5	M11/2825	7	3	4	<0.004	0.234	0.008	0.24	<0.01
11/01/12 6	M11/2826	8	3	5	0.009	1.97	0.008	1.82	<0.01
11/01/12 7	M11/2827	5	3	2	<0.004	1.69	0.008	1.63	<0.01
11/01/12 8	M11/2828	6	3	4	0.011	0.032	0.007	0.07	<0.01
11/01/12 9	M11/2829	6	3	3	<0.004	0.206	0.008	0.25	<0.01
11/01/12 10	M11/2830	6	3	3	<0.004	0.146	0.009	0.11	<0.01
11/01/12 11	M11/2831	5	3	2	0.005	0.043	0.008	0.09	<0.01
11/01/12 12	M11/2832	6	4	2	<0.004	0.005	0.009	0.05	<0.01

LJ Hill

Linda Hill, Acting Laboratory Manager

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Analytical Report - Leachate

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Job Number: LJ11108

Customer: Malcolm McLeod, Landcare Research Ltd
Private Bag 3127, Hamilton 3240

Date Received: 3rd February 2012

Date Reported: 20th February 2012

Client ID		Sample No.	Total Dissolved Carbon (method 310) mg/L	Dissolved Inorganic Carbon (method 310) mg/L	Dissolved Organic Carbon (method 310) mg/L	Ammonia-N (method 314) mg/L	NO_x-N (method 314) mg/L	Reactive Phosphorus (method 314) mg/L	Total Nitrogen (method 316) mg/L	Total Phosphorus (method 316) mg/L
		Check std								
01/02/12	1	M11/3900	5	2	3	<0.004	0.056	0.004	0.16	<0.01
01/02/12	2	M11/3901	6	6	1	<0.004	0.21	0.004	0.36	<0.01
01/02/12	3	M11/3902	6	5	1	<0.004	0.050	0.004	0.086	<0.01
01/02/12	4	M11/3903	5	4	2	<0.004	0.22	0.004	0.36	0.078
01/02/12	5	M11/3904	6	5	1	<0.004	0.15	0.004	0.32	0.016
01/02/12	6	M11/3905	4	3	1	<0.004	1.61	0.004	1.73	<0.01
01/02/12	7	M11/3906	4	3	2	<0.004	1.98	0.004	2.16	0.059
01/02/12	8	M11/3907	4	2	1	<0.004	<0.005	0.004	0.071	<0.01
01/02/12	9	M11/3908	5	3	2	<0.004	0.14	0.005	0.29	0.68
01/02/12	10	M11/3909	4	3	1	<0.004	0.091	0.004	0.20	0.025
01/02/12	11	M11/3910	3	2	1	<0.004	<0.005	0.004	0.062	0.038
01/02/12	12	M11/3911	4	3	1	0.011	<0.005	0.005	0.095	<0.01

Gareth Salt, Senior Technician & Key Technical Person

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Appendix 2 – Analytical results for herbage

Landcare Research
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Environmental Chemistry Laboratory Analytical Report - Plants

Job Number: LJ11064

Customer: Malcolm McLeod, Landcare Research Ltd
Private Bag 3127, Hamilton 3240

Date Received: 15th November 2011

Date Reported: 25th November 2011

Client ID	Sample No.	Carbon (method 204) (%)	Nitrogen (method 204) (%)
5/11/11 #6	M11/2004	43.6	2.27
5/11/11 #8	M11/2005	44.2	2.42
5/11/11 #11	M11/2006	44.2	2.20
5/11/11 #12	M11/2007	44.2	2.00

LJ Hill

Linda Hill, Acting Laboratory Manager

The laboratory is accredited by International Accreditation New Zealand. The tests reported in this report have been carried out in accordance with its terms of accreditation, except for the tests marked *, which are not accredited. Results apply to the samples received and are expressed on an oven-dry (80°C) basis. This report may not be reproduced, except in full, without the consent of the signatory. Details of method codes are available online at http://www.landcareresearch.co.nz/services/laboratories/eclab/eclabtest_list.asp

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Environmental Chemistry Laboratory Analytical Report - Plants

Job Number: LJ11109
Customer: Malcolm McLeod, Landcare Research Ltd
PO Box 40, Lincoln 7640

Date Received: 7th February 2012
Date Reported: 20th February 2012

Client ID		Sample No.	Carbon (method 204) (%)	Nitrogen (method 204) (%)
#6	14.11.11	M11/3912	44.5	2.81
#8	14.11.11	M11/3913	45.0	2.21
#11	14.11.11	M11/3914	44.5	2.06
#12	14.11.11	M11/3915	44.2	2.37
#6	11.1.12	M11/3916	44.9	3.41
#8	11.1.12	M11/3917	45.7	3.38
#11	11.1.12	M11/3918	45.0	2.81
#12	11.1.12	M11/3919	44.8	3.05

Gareth Salt, Senior Technician & Key Technical Person

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Environmental Chemistry Laboratory Analytical Report - Plants

Job Number: LJ11118

Customer: Malcolm McLeod, Landcare Research Ltd
PO Box 40, Lincoln 7640

Date Received: 20th February 2012

Date Reported: 5th March 2012

Client ID	Sample No.	Carbon (method 204) (%)	Nitrogen (method 204) (%)
Lysimeter 1	M11/4184	44.7	2.29
Lysimeter 2	M11/4185	44.0	2.14
Lysimeter 3	M11/4186	44.0	2.55
Lysimeter 4	M11/4187	43.3	2.53
Lysimeter 5	M11/4188	44.3	2.24
Lysimeter 6	M11/4189	44.6	2.51
Lysimeter 9	M11/4190	44.3	2.54
Lysimeter 10	M11/4191	44.1	2.37

Gareth Salt, Senior Technician & Key Technical Person

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