TAUPO DISTRICT LAND TREATMENT SCHEME - REVISITED

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ABSTRACT

The surface waters of the Taupo district are of high quality and are sensitive to inputs of nitrogen. To reduce the amount of nitrogen discharged to surface water, the Taupo District Council (TDC) has employed a land treatment scheme (LTS), where treated municipal wastewater is irrigated onto ryegrass pasture. To limit the possibility of nitrogen pollution, consent conditions for the scheme govern the amount of effluent that TDC may irrigate.

An expansion of the LTS in late 2008 (referred to as the View Road LTS) was established to accommodate projected Taupo population increases and the potential for future connection of two additional satellite communities, Acacia Bay and Waitahanui. In addition, the original LTS scheme at Rakaunui Road had reached nutrient loading operating capacity and has since further reduced in operating capacity as a result of the Eastern Taupo Arterial Bypass which bisects the site.

The combined LTS (View Road and Rakaunui Road) has been in operation for over five years now and has the potential to irrigate up to 15,000 m^3/d of treated wastewater effluent across almost 500 hectares of farmland. The cut and carry haylage crop is bailed and sold to dry stock farmers as part of this sustainable reuse initiative and helps to fund the scheme which now represents the largest municipal wastewater irrigation scheme in New Zealand.

We explore here a number of the successes and operating challenges that have faced TDC over the past five years. An update on the nitrogen loading rate trials, that were implemented as part of the scheme to quantify the nitrate leaching rates from the proposed scheme, are also presented.

KEYWORDS

Land treatment, nitrogen load, nitrogen leaching, cut and carry, wastewater disposal.

1 INTRODUCTION

Over the past decade, the quality of New Zealand's fresh water has become the subject of high public concern and vigorous debate. The consequence of nutrient (nitrogen and phosphorus) pollution in waterways has become a particular focus with the Government embarking on a programme of reforms in the management of fresh water with one key milestone being the development of the 2014 National Policy Statement (NPS) for Freshwater Management. The NPS requires that the *'overall quality of fresh water'* in all regions of the country be maintained or improved. Nutrient runoff as a result of intensive farming across all rural areas is causing significant eutrophication of waterways resulting from a substantial increase from nutrients released into the ecosystem presenting a challenge for regulators to determine what are appropriate nitrogen loading or nitrogen leaching rates for the disposal of wastewaters to land.

The urban area of Taupo lies within the catchment of Lake Taupo. Lake Taupo is an oligotrophic lake with a very high water quality. Phytoplankton growth is limited by nitrogen from July to December and by phosphorous between January and June (Coffey 2000). The lake is a national treasure and there is legitimate concern regarding the impact of controllable nutrients into the lake, in particular point sources of nitrogen that are manageable. As such, strict regulations governing the use of the nutrients in the Lake Taupo catchment have been developed. The 2020 Taupo nui-a-tia Action Plan for example, is a non-statutory long-term action plan for Lake Taupo, developed in consultation with Ministry for the Environment, Department of Conservation, Department of Internal Affairs, Waikato Regional Council (the regulator), TDC the Tuwharetoa

Maori Trust Board along with the Lakes and Waterways Action Group. This plan aims to '*Reduce manageable nitrogen input into the lake by at least 20 percent through the work of the Protecting Lake Taupo Strategy and through a variation to the Waikato Regional Plan including a new regime for controlling diffuse run-off of nutrients from all land and higher standards for wastewater disposal'.*

Since the mid 1980's TDC has progressively implemented nutrient removal wastewater schemes, servicing communities around the lake, some via high rate treatment systems for nutrient removal (e.g. Sequencing Batch Reactor (SBR), Membrane Bioreactor (MBR)) and some using land treatment systems (LTS) for nutrient uptake. In 1995 TDC implemented a new land treatment scheme (referred to herein as Rakaunui Road LTS) located outside of the Lake Taupo catchment, to treat and dispose of secondary treated municipal wastewater from the Taupo Wastewater Treatment Plant (WwTP) to land in a cut and carry farming operation (Power and Wheeler, 2007). Prior to this time, the treated effluent from the Taupo WwTP was discharged directly into the Waikato River. Moving from direct disposal into water to application onto land was seen as a big improvement both culturally and environmentally. The treated wastewater is irrigated to pasture where nutrients are stripped from the effluent by plant uptake and biological soil mechanisms, with excess nitrogen leaching to groundwater or volatising to the atmosphere. The plant bound nutrients are removed from the system during harvest when grass is cut, baled and taken off site. Reduction of nutrient inputs into the upper Waikato River system and elimination of public health risk to users of the river upstream of the Huka Falls was seen as a significant step forward.

In late 2008 an expansion of the existing Taupo LTS was commissioned at a new site located outside of the Lake Taupo catchment (referred to herein as View Road LTS) to service the projected Taupo population increases and potential for future connection of two additional satellite communities. In addition, the Rakaunui Road LTS had reached operating capacity with land lost to the Eastern Taupo Arterial Bypass roading project which dissects the LTS site and nutrient loading often not meeting consent condition limits (Waikato Regional Council, 2008), thus necessitating the development of the new View Rd LTS site.

A key concern to Waikato Regional Council at the time of consenting the scheme was the nitrogen application rate. An excessive N application rate could cause unacceptable contamination of groundwater, with eventual leaching to surface water such as the Waikato River, Pueto Stream and Lake Rotokawa. In the Taupo area a typical dairy farm leaches approximately 52 kgN/ha/yr, a moderately intense beef farm leaches about 20-28 kgN/ha/yr and a moderately intense sheep farm leaches about 15 – 18kg N/ha/yr (EW, 2008). Such landuse activities were 'permitted', however the level of effect was not considered to be minor by Waikato Regional Council, and as such a variation to the Waikato Regional Plan (Variation 5 – Lake Taupo Catchment) was undertaken. The regional plan now triggers the requirement for consent, within the Taupo Catchment if a particular landuse results in leaching rates exceeding 8 kgN/ha/yr, whilst outside the Taupo Catchment the following loading application rates apply as a permitted activity:

Table 1: Nitrogen Loading Rates for Various Land Users (Waikato Regional Plan,

Land Use Type	**Max. N Loading Rate (kg N/ha of spayed land/year)**
Grazed pasture	150
Cut and carry grass (hay, silage)	600
Pinus radiate	150
Eucalyptus (coppice)	250
Maize silage	200

View Rd was historically operated by Landcorp as a dry stock farm prior to becoming a LTS. Waikato Regional Council determined as part of the consent that the maximum acceptable nitrogen load rate from the LTS would initially be 550 kgN/ha/yr based on previous research and outputs from OVERSEER. The consent however contained a mechanism to increase the Nitrogen load limit through the trialing of loading rates up to 650 kgN/ha/yr on part of the site over a five year period, and to monitor soil nitrogen concentrations and nitrogen leaching. If the trials proved that on average the leaching rates did not exceed 30 kgN/ha/yr (considered by Waikato Regional Council to be a sustainable leaching rate) then the nitrogen load could be reset.

The View Road LTS has been in operation now for over 5 years under contract with Waterforce. There have been a number of regulatory and technical successes and challenges facing the implementation and ongoing operation of the View Road LTS in comparison with the original Rakaunui Rd LTS. These successes and challenges are considered here. A summary of key findings of the extensive nitrogen loading and leaching trial that was undertaken as part of the consent to optimise nitrogen uptake by the ryegrass cultivar is also presented.

2 SCHEME DESCRIPTION

Wastewater reticulated from the Taupo catchment is treated at the Taupo WwTP to a secondary treatment level, using trickling filtration and clarification. No tertiary treatment is provided. The effluent quality being received by the LTS is comprised of the following constituents:

Table 2: Taupo WwTP Effluent Quality (2012-2013)

12 month average	BOD_5	TSS	TN	NO_3-N	NH_4-N	TP	pH	*E.coli*	*Enterococci*
	g/m^3							MPN/100mL	
	30	34	49	3.4	38	6.0	7.5	4,495,738	291,508

From the plant, treated effluent is conveyed via a 4.6km rising main to the original LTS at Rakaunui Rd and a portion of the flow is on-pumped a further 4.5km to the new View Road LTS (refer to Figures 1 and 2 below for a scheme layout and conveyance system schematic).

The Rakaunui Road LTS comprises 103.2 ha of irrigable land operated as a number of separate harvesting blocks with effluent irrigation undertaken using pop-up sprinklers. The View Road LTS comprises 351 ha of land, however, only stage one of the site is currently operational (119.1 ha of irrigable land). The irrigation at View Road LTS is undertaken using centre pivot irrigators. Once fully developed the combined scheme would have the potential to irrigate up to 15,000 m^3/d of treated wastewater across almost 500 hectares of farmland. This scheme now represents the largest municipal wastewater land treatment scheme in New Zealand.

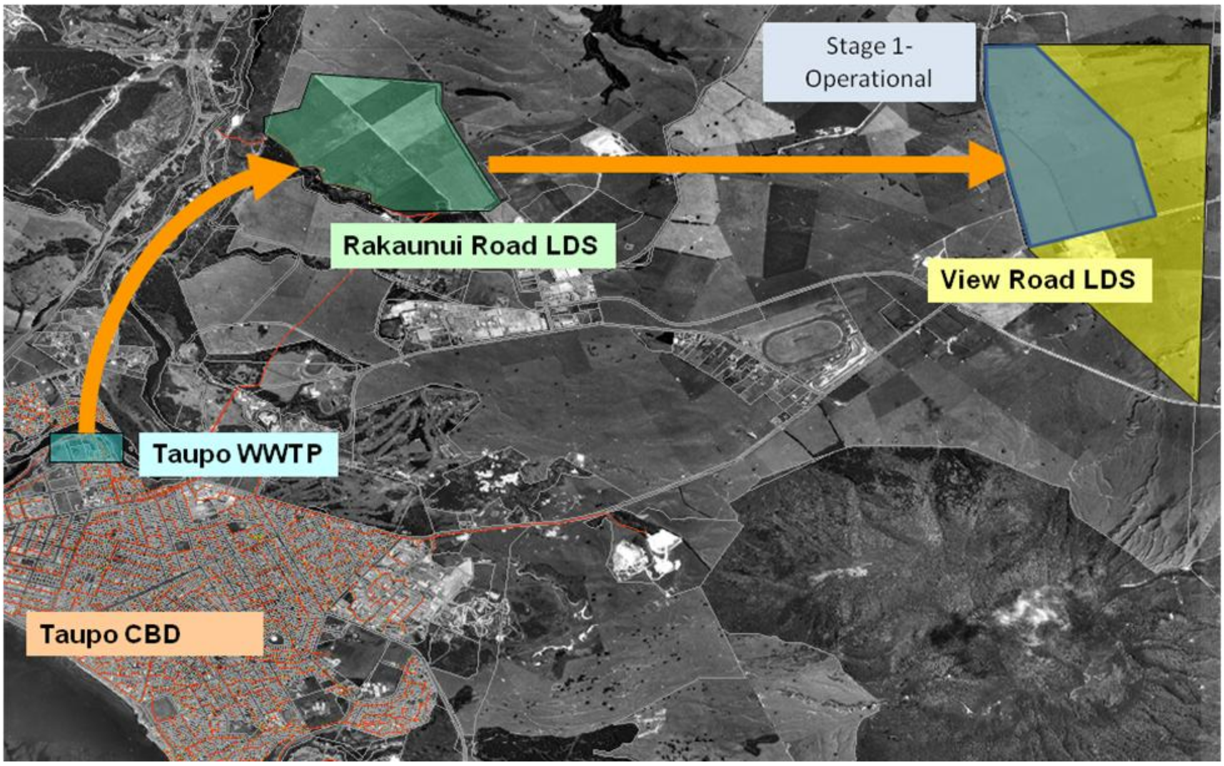

Figure 1: Application of wastewater from the Taupo catchment

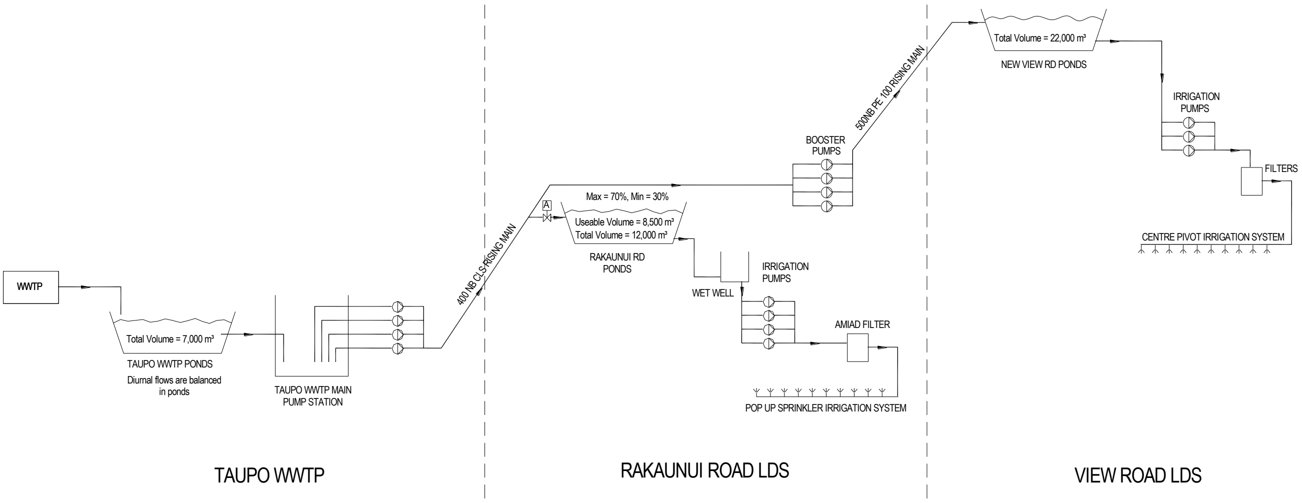

Figure 2: Schematic of Taupo effluent conveyance system post commissioning of View Rd LTS

Both schemes are operated as rotational cropping "cut and carry" systems of perennial ryegrass. The View Road LTS was cultivated (ploughed), then fertilised and sown in September 2008 with ryegrass (cultivar 'Impact'). Lime was applied at 200 kg/ha and Super Ten at 18 kg P/ha. The ryegrass crop uptakes a significant portion of nitrogen from the wastewater applied and is harvested between 4 to 6 times annually, therefore, serving as a renewable resource, a method of nitrogen removal, and a source of income in the form of a haylage crop. The View Road irrigation area is divided into 7 blocks (1 to 7) to manage the harvesting regime, which are currently irrigated to by 8 centre pivots (A to H).

The topography of the View Road site ranges from near level through undulating and rolling to some smaller areas with hilly and restricted steep land. There are deep dry gullies originating from the north and north-eastern part of the site that fall in the direction of Lake Rotokawa. Prior to development of the LTS the site was characterised by some localised depressions and humps created by natural geomorphology and artificial sheep shelters. Stage one of the LTS was commissioned on 24th December 2008 and is operated on the flatter sections of the site. Some earthworks were undertaken to level out localised depressions and humps to facilitate harvesting.

The View Road LTS is characterised by pumice soils, with four major soil types being identified, Atiamuri, Whenuaroa, Tauhara and Waipahihi soil series. These soils are well, to moderately well drained soils and have developed from Taupo formation either as air fall tephra deposits or as reworked alluvial material.

Two significant surface water features are located near the site: the Waikato River and Lake Rotokawa. Lake Rotokawa is approximately 1 km northeast of the north-eastern corner of the site. This Lake has a significant input of hot geothermal water and sub-surface steam. While most geothermal water of deep origin is alkaline-chloride composition, the discharges at Rotokawa are acid-sulphate, due to the oxidation of hydrogen sulphide gas in the ascending water to sulphuric acid. The lake has a pH of 2 and a temperature several degrees higher than nearby freshwater lakes. The Waikato River is located approximately 3km north of the northern boundary of the site. Careful consideration was given to the potential environmental effects (i.e. leaching of nitrogen into ground water within the Waikato River and Lake Rotokawa catchments) for both of these significant surface water bodies as part of the overall proposal and design of the View Road LTS.

3 OPERATIONAL SUCCESSES

3.1 MAINTENANCE AND LABOUR

One of the most significant successes achieved through the implementation of the centre pivot scheme compared with the original pop-up sprinkler system has been the significant reduction in maintenance time and cost, and consequently reduced labour requirements.

While pop-up sprinklers have been effective for surface effluent application, they have a high incidence of mechanical failure and hence a high maintenance cost associated with them. The most common fault is for pop-up sprinklers to break off at their point of connection to the irrigation main or for the sprinkler barrel to split due to fatigue caused by the repetitive reactive force at the joint when the sprinkler pops up into position. . This mode of failure requires urgent maintenance to be undertaken to avoid ponding of effluent and if unattended to can result in point loading of nutrients and potential breakthrough to groundwater.

Pop-up sprinkler failure also commonly results from the sprinkler head becoming tangled in long grass as the head rotates, causing the internal plastic gears to jam. Too much pressure in the system can result in sprinkler heads popping off, and nozzle clogging may result from biofilm build-up in the sprinkler mechanism. Automatic valves can fuse up and/or the spring inside the valve can fail resulting in weeping of effluent out the side of the pop-ups where a pop-up has not fully retracted. This results in wetted areas around the sprinkler head.

The above types of failure can lead to a third of all sprinkler heads at Rakaunui Rd LTS requiring replacement each year. In terms of labour, Rakaunui Road LTS requires up to one full time equivalent employee to cycle the farm on a daily basis to maintain sprinklers and valves. In comparison, Waterforce who currently hold the maintenance contract for View Road LTS, undertake weekly visual inspections, quarterly more invasive inspections, a biannual inspection of each pivot tower, span (wheel to wheel) and drive unit, and a full annual service. TDC undertake one visit per month only, unless a specific alert is received through SCADA from the site. Most of the operation of View Road is undertaken remotely, and through a proactive maintenance programme, the overall scheme operational and maintenance issues are minimal.

Sprinkler heads on the View Road centre-pivots generally have a very low failure rate (approximately 0.01% (Waterforce *pers comm*, 2014). For the past four years, Komet sprinkler nozzles have been trialed. View Road LTS was selected for this trial, due to its size and the type of water being irrigated (i.e. treated wastewater provides greater challenges than potable water due to its organic constituents). The nozzle has a grooved deflector plate that wobbles, such that when water flows through the sprinkler in its central axis, the deflector oscillates around this central axis diverting precise amounts of water radially into the air for effective droplet dispersion. The intention of these nozzles is to mimic rainfall and provide even distribution of the effluent. The nozzles can stop rotating due to biofilm or sediment build-up under the deflector plate, however as noted earlier the failure rate of these nozzles is very low. Whilst, other nozzles may be limited in operational hours, the Komet nozzles being trialed are capable of operating for 24 hours a day and therefore are more conducive to wastewater scheme operations. Corrosion of the orifice over time can lead to an increase in the application rate and loses in scheme efficiency through higher pumping rates, therefore, it is recommended by equipment manufacturers, that nozzles are changed every 10,000 – 20,000 hours. This can be determined through monitoring water meter flows and/or rain gauge testing to measure the actual hydraulic application rate per pivot pass.

Rakaunui Road LTS is also susceptible to lightning strikes due to the extensive network of electrical infrastructure in the ground to control the pop-ups. This has caused major damage to electrical componentry which resulted in significant replacement costs in 2013. Lightning strikes do not appear to be an issue with the View Road LTS site. A power surge during a storm event did result in a number of fuses blowing in the control building, however, this resulted in little disturbance to the overall operation of the site and was relatively easy to repair.

The harvesting methods used between schemes are fairly similar, and the large open areas provided by both these irrigation methods are conducive to ease of harvesting and are favourable to harvesting contractors as opposed to other irrigation methods. However, feedback from operational personnel is that pop-up sprinklers are far more susceptible to damage from harvesting machines and can result in up to three days of sprinkler repair following harvesting. Comparatively no real maintenance following harvesting at View Road is required.

TDC have not yet had to re-cultivate the View Road site or undertake any under-sowing over the first five years of operation. The original pasture is in relatively good condition, although TDC are likely to re-cultivate in the next year or two. Re-cultivation is a maintenance issue for both schemes, although, re-cultivation at View Road will be much easier than at Rakaunui Road due to the large open areas without in-ground infrastructure to avoid. TDC engages pastoral specialists to assess crop health based on yields and annual pasture monitoring and to provide TDC advice on under-sowing and/or re-cultivation requirements.

As presented above, there are significant practical benefits for centre-pivot irrigation over other irrigation methods when applying treated municipal wastewater to land; particularly if a cut and carry type operation is being sought. The ultimate end land use and site constraints will always dictate the type of irrigation method, and some end land uses may demand other irrigation methods, thus consideration of the irrigation technology would be on a case by case basis.

3.2 CONSENT COMPLIANCE

Full consent compliance has been achieved for the View Road LTS (Taupo District Council, 2013b). Key consent conditions include:

Effluent discharge volumes.

The scheme has been run at approximately one third of its total capacity and therefore has not exceeded the consented limit of 15,000m^3/d since operations commenced.

Hydraulic application rates.

The consent limits the hydraulic loading rates to 5mm/hr, 15mm/d and 45mm/week. The centre pivots have been set to a particular speed and fitted with specific sprinkler nozzles to meet the hourly requirements in a single pass, and with irrigation limited to up to three passes per day, meet the daily limit. Flow meters are located on each pivot, and at the initial phase of the commissioning, rain gauges were used to measure the actual hydraulic application rate per pivot pass to calibrate the speed and pumping rates to each pivot. The average daily application rate for all 8 pivots in the last year of monitoring was 2mm/d and 14.5mm/week with no exceedences in any of the hydraulic loading rates.

- Groundwater monitoring.

An analysis comparing groundwater quality prior to the commencement of the scheme and the average concentration of monitoring parameters collected to date has been made. Based on this comparison, there does not appear to be any apparent trend in groundwater levels. There is no significant trend in Total Organic Nitrogen (TON) concentrations with one of the highest measurements occurring in a control bore. There has been an increase in Dissolved Reactive Phosphorus (DRP) concentrations in five of the monitoring bores including the control bores, however chloride and conductivity data does not provide any evidence to suggest impact of wastewater discharges on groundwater quality.

There has been no evidence of microbial contamination with exception to one bore (376) which also coincided with an elevated chloride result indicating a possible impact to groundwater at this point. To better manage and prevent chlorides being leached through the soil and into groundwater, an alternative mineral fertiliser (organic potash), which is produced without chlorides, is now being applied. Further groundwater monitoring will determine whether this change in operational practice will result in a reduction in chloride levels.

Nitrate and *E.coli* monitoring of offsite wells monitored for health purposes provide no indication of potential contamination of groundwater from the LTS.

Soil and Pasture Monitoring.

This monitoring has been undertaken annually by AgResearch since 2009 with a baseline report undertaken in 2007. Soil bulk density, hydraulic conductivity (saturated and unsaturated), soil moisture and soil nutrients are measured along set transects.

The 2012-2013 analysis (Lucci and Power, 2013) indicated suitable soil infiltration rates and bulk densities with soils capable of supporting the current application rates (up to 15mm/d) without ponding occurring. This was partly attributed to the dry summer conditions preceding the measurements, with soil drying out, shrinking and cracking to create more large pores. There has been high variability between years with no detectable trend evident. A slight decline in bulk density measurements over the past 5 monitoring periods, indicates good management overall, and that the use of machinery to harvest the pasture has not caused any appreciable soil compaction.

Over the term of operation, AgResearch has identified a decrease in unsaturated soil conductivity in some areas on the View Road site, although variation between years has been high, and therefore it is difficult to determine the significance of any trends. A reduction in unsaturated hydraulic conductivity means that fewer small pores are transporting water, and the soil's efficacy to trap nutrients is also reduced. A reduction in the unsaturated hydraulic conductivity of the soil can be due to the clogging of fine pores due to physical processes (e.g. dispersion), biological growth, prolonged wet conditions resulting in poorly aerated soils and/or soil damage from repeated use of heavy vehicles, particularly when the soil is wet. If soil physical damage does occur then infiltration rates may be reduced resulting in ponding and runoff occurring. To prevent future ponding issues, operators have instigated a hogging (aerating) programme.

Some effects of irrigation on soil nutrient status has become apparent with time (since 2009). Soil pH has increased under irrigated soils, while soil potassium, sulphur and Olsen Phosphorus status have decreased to concentrations less than optimum for production. Application of fertilisers to correct soil fertility levels and to optimize production and uptake of nitrogen is therefore being undertaken upon recommendation from AgResearch.

Soil sodium and magnesium have both increased under irrigation, although concentrations are not yet at levels of concern that could lead to soil dispersion and reduction of hydraulic conductivity and infiltration rates. Concentrations of soil nitrogen (TKN) and organic carbon have also increased. Continued monitoring of these parameters is to be undertaken.

Odour monitoring.

There have been no complaints received regarding the operation of the View Road LTS since operations commenced.

Stormwater runoff monitoring.

The irrigation area is regularly inspected by operations personnel during and following significant rainfall events to assess for any potential ponding or runoff. No significant rainfall events have resulted in overland flow or stormwater runoff beyond the site boundary.

Harvest Summary and Pasture Nutrient Uptake.

Although not specifically required by resource consent, analysis of crop yield at the time of harvesting enables calculation of a nitrogen budget and to assess site overall performance. A total of 7730 bales of ensilage was produced from View Road LTS during the most recent monitoring period. Grass samples are collected from all seven blocks on the day of each harvest and analysed for dry matter, nitrogen and phosphorus to determine pasture production and nutrient uptake. A summary of pasture production and nutrient uptake over the last 3 monitoring years is provided in the Table 2. For the latest monitoring period all blocks were harvested 4 times with exception to Block 7 which was harvested 5 times.

Table 3: Pasture Production and Nutrient Uptake at View Road LTS

Date	%DM	Yield (kg/DM/ha)	%N (kg/ha)	N Uptake (%)	%P (kg/DM/ha)	P Uptake (kg/ha)
2010-2011	18.9	2996	3.0	88	0.4	11.7
2011-2012	20.8	3367	2.8	89	0.39	12.9
2012-2013	22.8	3543	2.6	90	0.41	14.6

Nutrient Distribution Rates

Effluent nitrogen concentrations and individual pivot application volumes are used to calculate the nutrient distribution rates across the scheme. The average load of nitrogen for the total irrigation area during the 2012-2013 monitoring period was 362kg/ha/yr, well within the consented limit of 550kgN/ha/yr. Over the years of operation the average nitrogen loading rate has ranged from 305 – 435 kgN/ha/yr again well within the consented limit. Nitrogen loading rates for each pivot are also calculated and compliance has been achieved for all blocks since irrigation commenced with exception to pivot H during 2012-2013 year which exceeded the nitrogen application by only 14kg (Taupo District Council, 2013a).

3.3 ENVIRONMENTAL IMPROVEMENTS

In addition to determining the nutrient distribution rates, AgResearch (Lucci, 2013) have prepared a nitrogen budget using climate data, effluent volumes, nitrogen concentrations, bale numbers and silage analytical data and the OVERSEER® model to perform the budget calculations.

A total of 366 kg N/ha/y was calculated to have been applied to the View Road Site during 2012-2013 (this is similar to the average loading rate calculated by TDC). The nitrogen content of the harvested ensilage was calculated to be 321 kg N/ha/y, a difference of 45 kg N/ha/y, or equivalent to 88% of applied effluent-N. When compared with previous years, the amount of N applied is lower than that applied in previous years and below the amounts typically applied at Rakaunui Road prior to the commissioning of the View road site.

The %Nitrogen in the bales was lower compared with previous years, leading to less Nitrogen removed in spite of a greater number of bales harvested. The amount of N leached from the View Road site was estimated to be less than 20 kg N/ha/y, with a nitrate-nitrogen concentration in drainage of less than 2 ppm, well below the National maximum for drinking water standards of 11.3 ppm (Ministry of Health, 2008).

Table 4: Annual N Budget for View Road since 2009

Year	Bales harvested	Bales harvested /ha	% DM	t DM /ha/y	%N	Effluent kgN/ha	kgN/ha removed	Effluent applied (mm/week)	Estimated N loss kgN/ha/yr
2009/10	7878	66	45.6	21.9	2.17	400	393	18.2	< 20
2010/11	6908	58	39.6	13.8	2.37	388	327	16.5	< 30
2012/13	7730	65	40.6	16.1	2.02	366	321	14.4	< 20

When compared with Rakaunui Rd, the View Rd nitrogen leaching rates are significantly less, (i.e.Rakaunui Rd nitrogen leaching estimated to be 60kgN/ha/yr with a nitrate-nitrogen concentration in drainage of 4mg/L).

Feedback from TDC operational personnel is that pasture growth at View Road is notably more even than at Rakaunui Road, indicating that a more even application of wastewater is achieved by the centre-pivots. It is also therefore likely that leaching rates are also more evenly distributed thus minimising the potential for localised contamination of groundwater.

Finally, groundwater monitoring data indicates that since the commencement of the View Road LTS a plateauing effect on groundwater quality degradation is now being recognised at Rakaunui Road LTS, thus overall the combined scheme is likely to be having reduced environmental effects.

4 OPERATIONAL CHALLENGES

4.1 MAINTENANCE

Following scheme commissioning, rutting where the wheels from the centre pivots pass became an issue. The wheel rutting leads to uneven ground resulting in the locking of the wheels which could have led to gear box failure within individual drive units due to stresses on the spans. The uneven ground also caused problems for harvesting equipment. To overcome this problem, TDC built a bespoke rutt hopper that lays aggregate into the wheel track. As the centre-pivot rotates, the aggregate is compacted with time enabling it to compact flush with the ground allowing the harvesters to operate more effectively.

Photograph 1: Rut Filler Trailer specifically designed by TDC

Photograph 2: Wheel Tracks

A general decline in ryegrass coverage following commencement of the scheme was observed, with ryegrass coverage reported to be only 50% and declining during the 2011-2012 reporting period. The ryegrass was balding and clumping in places creating exposed un-vegetated spaces. The concern was that other grass species that were proliferating were lower yielding and less effective at removing Nitrogen and Phosphorus from the soil.

A population of grass grub was discovered at the View Road LTS, and was determined to be the likely cause for the decline in ryegrass coverage and other site management issues. Molyhawkes (southern black-backed gull) from a nearby landfill were also abundant at the site around this time, and were found to be uprooting clumps of ryegrass to feed on the grass grubs. During harvesting, the hay rake when gathering grass into windrows, was also pulling up clumps of grass as a result of the grass grubs weakening the root structure.Advice sought from pasture specialists was that the grass grubs primarily grow on the roots of ryegrass. A weed spraying programme was initiated in conjunction with soil conditioning.

Previously TDC had used a myriad of fertilisers and soil conditioners such as potash. It was found that the potash used contained high concentrations of chloride which was potentially having an effect on the natural soil microbial populations. An organic potash is now used and avoidance of sprays where possible that may have impact on the worm population. As a result the grass grub population has declined and the remaining ryegrass is regenerating at a rate faster than the native grasses. Site operators will continue to monitor this ryegrass re-establishment and if necessary will under-sow in the new season. Spraying will continue to prevent proliferation of grass grub in future.

The View Road site is fairly exposed to high wind, and although this has not been an issue to date, it is a potential issue that needs active management. If the pivots are perpendicular to the wind direction, a harmonic resonance occurs along the pivot resulting in the pivot rocking, with the potential for the pivot to turn and twist. TDC ensure that when high winds are forecast that all pivots are parked parallel to the wind direction to avoid the risk of this occuring.

4.2 EQUIPMENT

During the first year of operation there was a problem with the centre pivot tyres rupturing often. This was found to be due to the wheel rim galvanizing (beading), which had been designed for tubeless tyres rubbing on the tube causing rupturing. All tyres had to be replaced in that first year.

A compressor on each of the centre-pivot units enables the opening and closing of the pneumatic valves that regulate effluent flow to each pivot span and in particular for View Road, controls those zones in close proximity to Broadlands and View Roads where end guns and/or sections of the span are required to stop irrigation to maintain appropriate buffer distances to the property boundary. These compressors are 110V, rather than 240V. A number of these compressors have failed, and due to difficulty in sourcing new parts from the United States, have resulted in the faulted pivots being offline for extended periods. TDC are therefore in the process of investigating changing this equipment to 240V to enable local sourcing of replacements.

Each pivot is set-up with a GPS north position to enable the operators to know exactly where on SCADA the pivots are in their rotation in the irrigation blocks. Operations personnel have observed the designated north position drifting, which at times, results in under irrigation of blocks due to losing a section of the irrigation wedge with time. This is an issue that is currently being investigated.

Infrequently, the drive unit on a centre-pivot span can fail. If the remainder of the pivot drives were to continue to operate with a drive unit failed this would result in pivot misalignment and mechanical damage. To avoid this, each drive unit A frame is fitted with a set of micro-switches configured to stop the pivot entirely in event of pivot mis-alignment. This system also notifies an alarm to SCADA to alert the operators that an issue has arisen.

5 NITROGEN AND PASTURE HARVESTING TRIALS

5.1 NITROGEN TRIAL

Resource consent 116596 authorises the discharge of treated effluent onto pasture at View Road. Condition 5 requires that TDC manage the disposal area to '*ensure that the renovation of contaminants and uptake of nutrients from the wastewater is maximized and the extent of nutrient, and in particular nitrogen, leaching to groundwater, is minimised'*.

As noted earlier, a limit of 550 kgN/ha/year is applied across the View Road site. The computer model OVERSEER® was used by Waikato Regional Council to estimate the nitrogen leaching losses and consent conditions were based on these estimates. The resource consent did also authorise a trial to be undertaken on up to 15% of the site, between the years of 2008 - 2013, where up to 650 kgN/ha/yr could be applied. The trial aim was to quantify the actual amount of nitrogen leached from the soil to meet consent conditions and determine whether a higher loading rate could be applied.

In 2009, the nitrogen trial was set up in collaboration with the University of Waikato to assess nitrogen losses, nitrogen yields and estimated impact on the groundwater and surface water. The trial was facilitated by University Masters students Glen Treweek (2011) and Erin Telfer (2013).

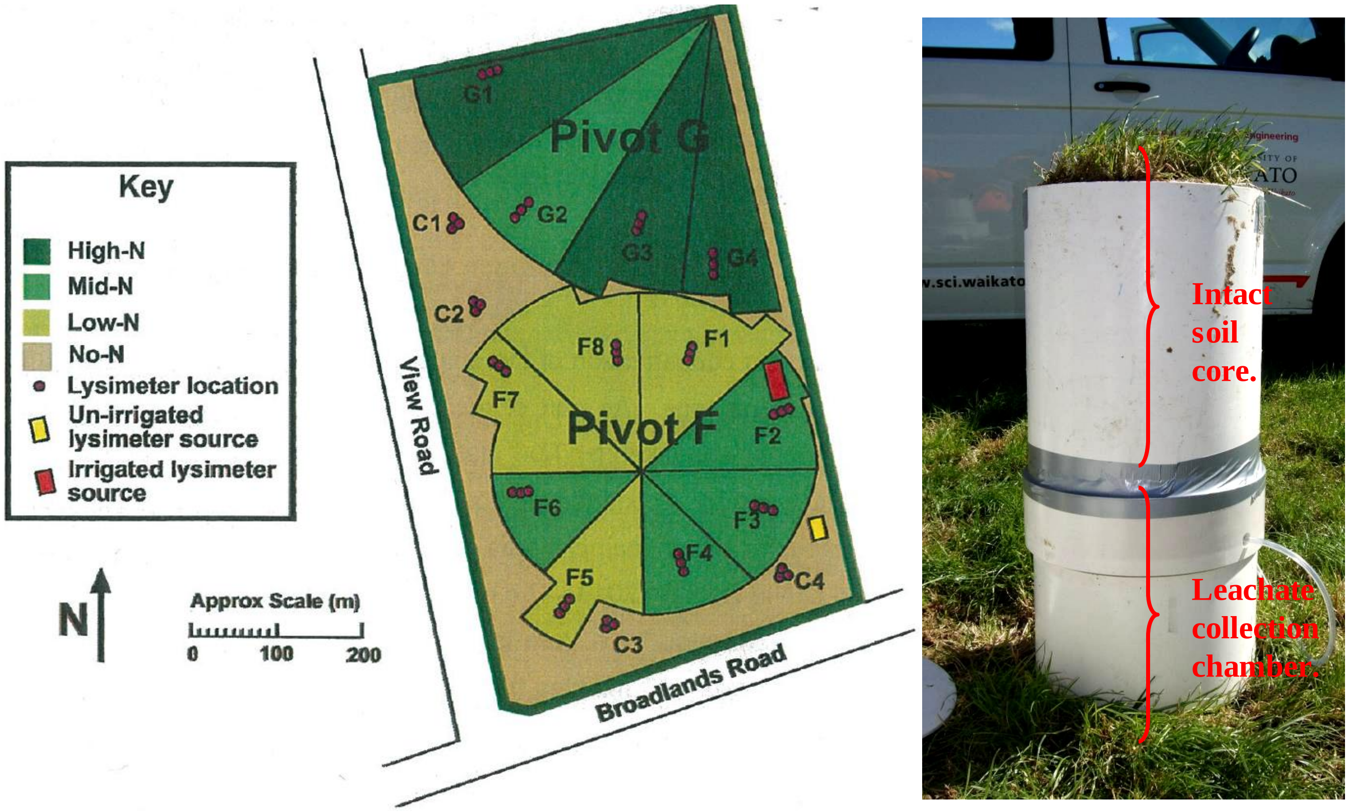

Figure 3: Overview of study layout and Lysimeter ready for installation, (sourced from Treweek, 2011)

The nitrogen trial consisted of forty eight (48) intact soil monolith lysimeters (300 mm diameter x 400 mm depth) installed beneath two centre pivot irrigators (pivot F and half of Pivot G). Effluent was applied to the trial area of 29 hectares with the intention that three different application rates would be applied (450 kgN/ha/yr, 550 kgN/ha/yr and 650 kgN/ha/yr) and no application made to the selected control (non-irrigation) areas. The application rate was varied by adjusting the speed at which the irrigators moved across the site, applying more or less effluent per unit area as required (refer to Figure 3 above).

Lysimeter leachate was collected monthly and analysed for nitrogen species during the periods December 2009 to December 2010 (Treweek, 2011) and September 2011 to September 2012 (Telfer, 2013). Grass was harvested from each lysimeter and analysed for percentage dry matter and nitrogen. Rainfall data was measured from an onsite weather station, wastewater application volumes and nitrogen concentrations were measured using TDC flow meter and water quality analysis data.

Following the initial trial in 2010, it was concluded that:

- nitrogen leaching losses from the LTS were not believed to have reached a steady state after two years of operation and therefore uncertainty remained regarding future leaching losses;

- the targeted application rates of 450, 550 and 650 kgN/ha/yr were not reached (i.e. 280 to 520 kgN/ha/yr application rates were achieved), therefore uncertainty remained over confirming the most appropriate nitrogen loading rate.

- Despite the target rates not being achieved, valuable findings from the initial trial were:

    - Effluent irrigation significantly increased pasture growth and nitrogen leaching compared to the un-irrigated treatments although there was no significant difference between application rates.

    - The pasture of high-nitrogen treatments had a significantly higher nitrogen concentration than the low-nitrogen treatments and consequently removed greater nitrogen per ha (390 kgN/ha for high-N application compared to 310 kgN/ha removed from mid-N and low-N treatments).

- Of the nitrogen that was irrigated, on average, 84% was removed in the pasture, 5% was leached, and 11% remained un-accounted presumably stored in the soil or converted to nitrogen gasses. The control sites leached 5 $\pm$ 3 kgN/ha, low-N treatment leached 15 $\pm$ 1 kgN/ha, mid-N treatment leached 17 $\pm$ 1 kgN/ha and high-N treatment leached 26 $\pm$ 1 kgN/ha.

- The nitrogen concentrations in the leachate from irrigated treatments did not correlate with the volume of water drained, or the amount of nitrogen applied or removed by pasture. Leachate comprised on average 53% nitrate-nitrogen and 45% organic nitrogen while the leachate of un-irrigated treatments comprised on average 26% nitrate-nitrogen and 72% organic nitrogen. Ammoniacal nitrogen accounted for approximately 2% of the nitrogen leached.

- Nitrate-nitrogen leaching was greatest following rain events during summer and autumn with mean concentration of nitrate leached from irrigated treatments of 1.3gN/m^3 well below the Ministry of Health guidelines (2008).

Conclusions from the second part of the trial completed in 2012 were based on a more comprehensive data set and the LTS had at that stage been in operation for almost three years.

- Again the desired application rates could not be achieved with application rates ranging between 286 to 567kgN/ha/year (refer to Figure 4).

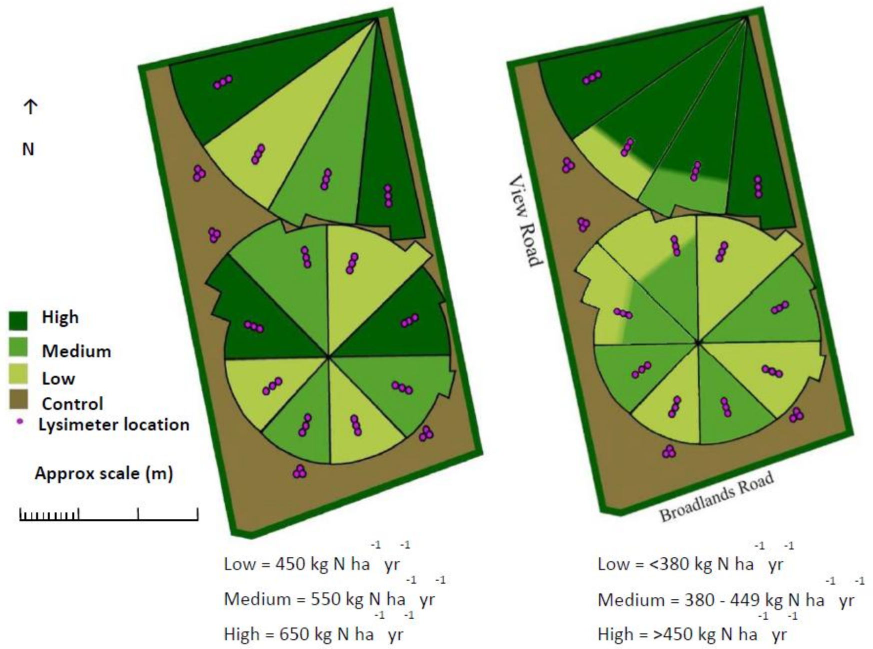

Figure 4: Summary of target and measured nitrogen application rates (TDC, 2013a)

- It was confirmed that pasture growth was significantly greater under irrigation than no-irrigation treatments, however no significant difference in pasture dry matter or nitrogen uptake was determined between the different application rates. Therefore under the current irrigation regime, the higher application rates do not lead to significant increases in nitrogen removal by pasture.

- Nitrogen leaching losses were found to be similar to that observed in the original trial with increasing leaching rates as loading rates are increased (control sites leached 2.8 $\pm$ 0.6 kgN/ha, low-N treatment leached 12.7 $\pm$ 4.2 kgN/ha, mid-N treatment leached 16 $\pm$ 7.2 kgN/ha and high-N treatment leached 28.6 $\pm$ 10.1 kgN/ha).

- In addition, nitrogen uptake, leaching and unrecovered percentages for the different irrigation treatments were also found to be similar to that observed in the original trial, with percentage uptake by pasture decreasing and unrecovered nitrogen increasing with increasing nitrogen application.

- The leaching rates measured therefore provided some evidence that applying wastewater at an application rate greater than 550 kgN/ha/yr would likely result in leaching of nitrogen in excess of 30 kgN/ha/yr (as prescribed by the consent).

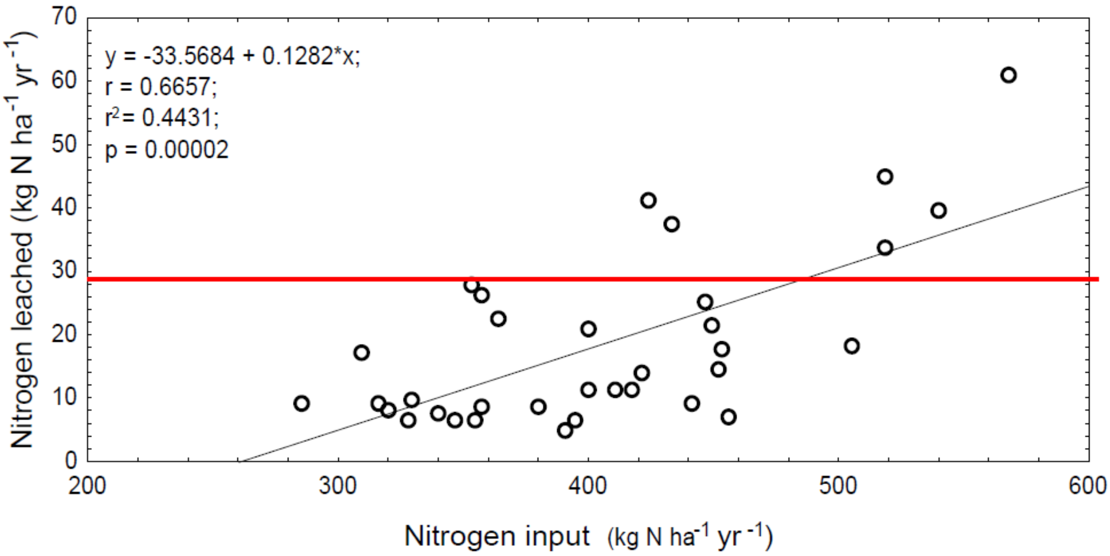

Figure 5: Relation between nitrogen leaching losses and nitrogen input (TDC, 2013a)

In summary, the current irrigation application rates are not resulting in losses of nitrogen to leaching in excess of 30 kgN/ha/yr. At an application rate of 550 kgN/ha/yr, approximately 6% or 33 kgN/ha/yr is anticipated to be lost to leaching. As a result TDC will not be seeking a change to the current resource consent limit of 550 kgN/ha/yr as the current limit is likely to prevent adverse environmental effects from wastewater discharges. Estimated nitrogen leaching losses under the current irrigation regime based on data collected during the nitrogen trial appear to align well with the annual nitrogen budgets undertaken by AgResearch (Table 4). Therefore, the annual OVERSEER ® nitrogen budget will continue to be undertaken as a conservative tool in monitoring the LTS performance and nitrogen uptake and removals.

Table 5: Estimated Nitrogen Leaching Losses Under Current Operation Compared with Calculated Overseer ® Nitrogen Leaching Values

Year	N Loading Rate kgN/ha/yr	Estimated N Leaching (kgN/ha/yr)	Nitrogen Budget Calculated N Leaching (kgN/ha/yr)
2009/10	381	12	< 20
2010/11	435	20	< 30
2012/13	362	12	< 20

5.2 PASTURE HARVESTING TRIAL

The aim of the pasture harvesting frequency trial was to quantify dry matter production and nitrogen removal by pasture harvested under two different frequencies. A study area was set up at the View Road LTS and divided into 12 sections containing 1m by 1m blocks to be harvested every 5 or 10 weeks from January 2012 to November 2012. At harvesting time the pasture was removed and analysed for dry matter and total nitrogen count.

Mean pasture yields, mean nitrogen concentration in the pasture, and nitrogen removal were greater under the more frequent harvesting regime. On average 96% of the nitrogen applied was removed under the 5 week regime compared to 73% when harvested after 10 weeks. Therefore this trial has shown that in terms of nitrogen removal there is overall environmental benefits in increasing the harvesting frequency.

Due to complexities around harvesting operations at the site (for example, necessary stand down periods for pathogen reduction, weather dependence, block rotations to ensure compliance with consent application rate limits, grass length requirements), TDC do not intend to increase harvesting frequency. If, however in future, an increase in nitrogen loading rates needs revisiting, then an increased harvesting frequency may be one solution in mitigating environmental effects and ensuring sustainable leaching rates are maintained.

6 CONCLUSIONS

Although there has been some relatively minor operational challenges with the centre-pivot scheme, overall, the pivots are much easier to operate and maintain when compared to the original pop-up sprinkler system. Overall the View Road LTS has been considered a successful scheme both in terms of operation as well as environmental impact.

Based on the nitrogen trials undertaken at View Road, TDC will not be seeking an increase to the consented loading rate or any alterations in harvesting frequency. However if in future an increase in nitrogen loading rates needs revisiting, then an increased harvesting frequency may be one solution in mitigating environmental effects and ensuring sustainable leaching rates are maintained.

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