

Effluent management or nutrient management: A case study of improving dairy shed effluent disposal

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ABSTRACT

The change from farm 'dairy effluent disposal' to 'effluent nutrient management' at the Telford Polytechnic dairy demonstration farm has been an active process to maximise the whole farm benefits of farm dairy effluent. Within the programme of improvement the following processes were followed: the soil chemical, physical and drainage profiles were established; pastures and soils on the farm that could benefit from FDE application were identified; the irrigation system was measured to understand how much water and nutrients were being applied; nutrient and water budgets were used to optimise farm dairy effluent use; and a new system of farm dairy effluent application was developed to capture maximum production and environmental benefits. These analyses enabled the farm dairy effluent disposal system to be expanded onto a total of 79 of the 170 effective ha of the farm with a balance between high and low intensity application methods. This approach allows for the maximisation of the use of farm dairy effluent as both a fertiliser and irrigation source, estimated to add approximately 1 t DM/ha to 25% of the farm, as well as saving approximately \$8,500/annum in fertiliser spending.

Keywords: farm dairy effluent; nutrient management; irrigation; whole farm system.

INTRODUCTION

Farm dairy effluent (FDE) application is an important part of managing the environmental footprint of a dairy farm (Longhurst *et al.*, 2000). There is often a trade off between the disposal of the effluent and the capital requirements, land area and labour requirements of the process. In addition, effluent management is a heavily regulated activity that has gained high awareness both within the dairy industry and in the general public (MfE, 1997; Vant, 2001).

Nutrient management is a critical component of dairy farming. Nutrients from FDE can provide a significant proportion of the potential fertiliser resource required (Houlbrooke *et al.*, 2004). The land application of FDE maximises the nutrient value of animal excreta deposited when dairy cattle are off pastures and increases pasture production (Roach *et al.*, 2001). Unlike fertiliser, most dairy operations are unable to accurately track and manage nutrient applications made via FDE as the depth of FDE applied is not typically recorded and the concentration of nutrients contained in the effluent usually unknown.

In recent years the technology and knowledge around effluent storage and application has increased markedly. Best practice dairy farmers now enjoy the added peace of mind of having reliable collection and storage systems and benefit from the increased production from effective effluent nutrient application. In contrast, poorly designed and operated dairy units suffer from a high risk to

compliance breaches and poor efficiency and profitability of nutrient use.

This paper documents the process of change from effluent disposal to nutrient management in the context of improving the sustainability of effluent management systems. The study used a range of measurements and tools to optimise the dairy farm effluent system at the Telford dairy farm between 2007 and 2010.

MATERIALS AND METHODS

Since 2007/08 DairyNZ has supported the Telford Polytechnic dairy unit as a Demonstration Farm to identify and demonstrate local issues in the Dairy Industry. Effluent nutrient management has been a core part of this project.

Effluent management and nutrient management were considered as part of a wider analysis of the strengths and weaknesses of the whole farm system to devise a plan for improvements in all three factors. Within the programme of improvement the following processes were followed:

1. Evaluate the soil chemical, physical and drainage profiles
2. Identify pastures and soils on the farm that could benefit from FDE application
3. Measure the irrigation system to understand how much water and nutrients were being applied
4. Use nutrient and water budgets to optimise (as per current best practice) FDE use

- Develop a new system of FDE application to finally capture maximum production and environmental benefits.

The Telford dairy unit comprises a total area of 175 ha, 170ha effective. Approximately 525 cows are farmed on the milking platform at a stocking rate of 3.1 cows/ha. Cows are dried off on approximately May 15th and come back to the farm in calving groups from Mid July onwards with extensive use of calving pads and feed pads from early August. The lactation length is approximately 268 days with an average production of between 360 and 375 kg MS/cow.

Understanding the soil attributes is an important part of developing effective FDE disposal systems. An investigation of the soil types was done by an FDE agricultural engineering consultant to help determine the type of FDE delivery system that would best suit the different soil types on the farm. A soil nutrient survey was also conducted and formed the basis for a nutrient budget for the farm (using the software OVERSEER™).

The actual impacts of the original FDE delivery system were measured and documented. The original FDE disposal at the Telford dairy unit applied FDE to land using a Plucks twin boom rotating travelling irrigator. The machine is typical of the majority of irrigators used to apply FDE in New Zealand. An evaluation of the application rate, application depth and application uniformity of the Telford irrigator was made in the 2007/2008 season for both its fastest and slowest speed setting.

These evaluations led to the installation of a K-Line irrigation system on a part of the farm that had previously received no FDE, and had a different soil type than the original area that had been used.

The loading rate of nutrients applied as FDE is determined by application depth and nutrient concentration. The Telford travelling irrigator and K-Line irrigation system were both assessed to determine application depth given factors such as run time (K-Line system) and travel speed, number of passes and the number of nozzles operating (travelling irrigator). During the course of the 2008/2009 milking season, seven effluent pond samples were collected and sent to a commercial laboratory for analysis of N, P, K, S, Ca, Mg & Na. Furthermore, samples from under the irrigator were collected and analysed for 20 of the FDE applications.

Understanding the capacity of the system and comparing this with the weather and soil moisture conditions is critical to managing both the storage and delivery of FDE in an environmentally appropriate manner. Weather data from the Balclutha electronic weather station for the last five milking seasons was downloaded from the NIWA Climate Information website. A simple set of rules

was put in place to make decisions about (a) applying effluent, and to generate a soil water balance for a single hectare to determine the amount of water that could be applied, (b) year to year variations, (c) how applications could be made safely, and (d) the start and end points of the irrigation season.

The rules applied were:

- Effluent was not applied in the rain
- Effluent was not applied if there was to be more than 2 mm rain the following day (estimated to be wide-spread showers in the weather report).
- Effluent was only applied when the water deficit (as estimated by NIWA) left a buffer of 10 mm after effluent application. This then translates into a 20 mm deficit for the Travelling irrigator and a 13.1 mm deficit for the K-Line system.

The minimum application depth was used on any one day. This was 10 mm for the Traveler and 3.1 mm for the K-Line.

RESULTS

The farm is almost equally divided into two major soil groups. The Tokomairiro deep silt loam is classified as a Fragic Pallic soil with a slow permeability resulting in imperfect drainage as indicated by its perch gley conditions. Artificial drainage in the form of mole and tile drainage are in place. The Puerua silt loam is classified as a Recent gley soil. This soil has moderate permeability but very poor natural drainage due to the high water table. Drainage is supplemented by open drains at 50 m spacings. Mean annual rainfall is 750 mm/annum.

The original effluent disposal system was sited on the Puerua soils due to their relatively greater permeability. This avoided ponding or runoff due to the high application rate of the traveling irrigator. Ponding and runoff are considered key indicators of system performance and environmental compliance (ORC, 2001).

The travelling irrigator has a mean application depth of 10 mm with an application peak of 16 mm (Figure 1) when set at its fastest speed. The mean application depth is increased to 25 mm with application peaks in excess of 40 mm (Figure 1) when set at the slowest speed. The estimated soil water deficit under the testing conditions prior to FDE irrigation was 18 mm. Considerable surface ponding was observed when the irrigator was set at its slowest speed as a result of the application depth being in excess of the soil moisture deficit. The static application rate from the travelling irrigator was measured as 70 mm/h. This indicated that the travelling irrigator had to move as fast as possible to maintain a small application depth to match soil permeability and avoid ponding and runoff.

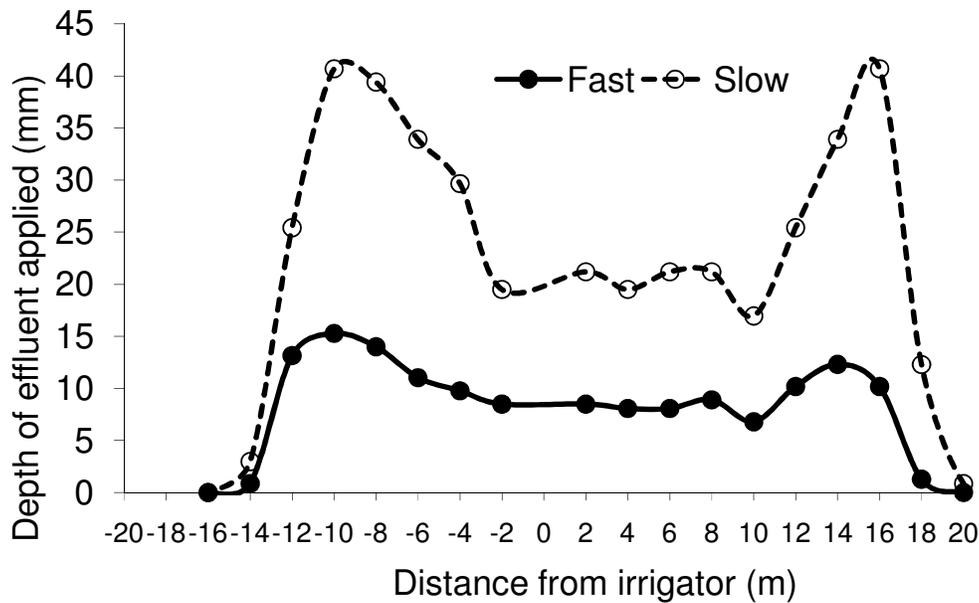


FIGURE 1: Spread pattern and depth from one pass for the Telford irrigators fastest and slowest travel speed.

Soil test results indicated that the Puerua soils that had been traditionally receiving regular FDE application had average soil quick test potassium values of 24, well above the recommended range. The Tokomairiro soils have an average soil quick test potassium value of 4, which is below the recommended range for dairy farming. OVERSEER™ nutrient budgeting indicated that even with the use of 40 ha for FDE disposal, the quick test potassium values would still increase at the rate of 1 unit per annum without further management interventions such as removal of silage to be fed elsewhere.

Individual paddock grazing records (including pre and post grazing herbage mass, number of cows grazing and number of grazing events per annum) were examined to determine the relative pasture production and utilization over the whole farm (Figure 2). The data indicated a difference of approximately 1t/ha in median productivity of the two soil types and identified paddocks that were performing poorly relative to the average of the soil types. This information was integrated with the soil type data and the potential improvement that may be made due to changing nutrient inputs and adding irrigation water to determine the best site to extend the effluent disposal system on to.

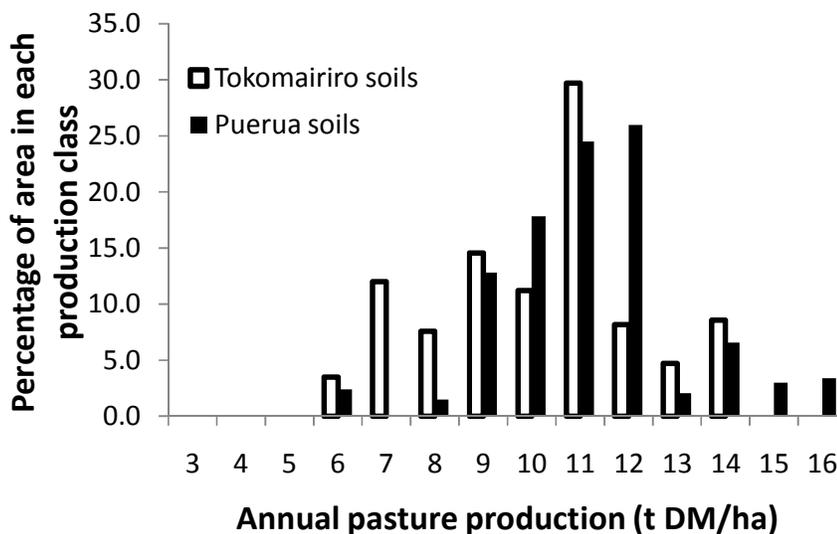


FIGURE 2: The distribution of pasture production on the two soil types of the Telford Dairy farm.

An area of the Tokomairiro silt loam soil was chosen as suitable for both productivity and logistic reasons and was coupled to a low application rate system, the K-Line, to match the slow permeability of the soil, minimising the chance of runoff or leaching to drainage water in the artificial drainage systems.

Both the Travelling irrigator and the K-Line systems were re-evaluated to determine the final rates of application and application depths that were being achieved. The K-Line system delivered on average 3.1 mm/hr. While one pass from the travelling irrigator delivered a mean depth of 10 mm at the fastest travel speed, the blocking of one nozzle of the travelling irrigator resulted in a reduction of application depth to 8.5 mm/pass.

A comparison of FDE nutrient concentration from samples collected direct from the pond with those applied to paddocks (Table 1) presents an average nutrient loading per hectare in 2008/09. Average application depth was 18 mm/ha.

Assuming a fertiliser value of \$1.51/kg N, \$4.35/kg P, \$2.05/kg K and \$0.95/kg S the NPKS value of nutrients applied equated to **\$212.5/ha** (\$41.28 N/ha, \$30.58 P/ha, \$137.6 K/ha, \$3 S/ha).

There would also be additional benefits from the applied Ca, Mg and Na.

The current ponds are approximately 57 x 32 x 2.5m and 32 x 30 x 5m respectively, making a total of 9,360m³. Effluent is collected from the dairy shed, feed pad, standoff pad and races connected to an underpass. This generates significantly more FDE than standard dairy sheds. Results from the 2009/2010 season (Table 2) indicate that a total of nearly 20,000 m³ were applied to 45 ha. In this season an average of 77 kg N, 165 kg K and 18 kg P were applied and using the previous value of nutrients were worth \$116.27, \$338.25 and \$78.30/ha or \$532.82/ha

On average during the milking season there is a 70mm soil moisture deficit (below 50% available soil moisture), but the rules that were used allowed more than that to be applied. The range of the amount able to be applied was marginally higher on the K-Line system being 153 mm/ha, or 1530 m³, and 142 mm/ha for the Traveller. When seasons were wetter then the K-Line had a larger margin of application rate over the Traveller, but here was little or no difference when the season was dry (Table 3).

TABLE 1: Average nutrient concentration of farm dairy effluent (FDE) collected from the irrigator and from the pond and loading for a single paddock receiving FDE.

	Nutrient analysis of Farm Dairy Effluent						
	N	P	K	S	Ca	Mg	Na
Pond conc. (mg/L)	169	49	375	18	87	47	147
Applied conc. (mg/L)	174	41	371	17	81	43	165
Applied load (kg/ha)	27	7	67	3	15	8	30
Load of FDE (kg/mm)	1.5	0.4	3.7	0.2	0.8	0.4	1.7

TABLE 2: Effluent application of the Telford dairy farm in 2009/2010 for the two soil types.

Soil type	Amount applied per ha					Total effluent applied m ³	Application times Number per season
	Area (ha)	Water (mm)	N (kg)	K (kg)	P (kg)		
Puerua	18	59	103	220	24	10,800	7.0
Tokomairiro	27	34	59	127	14	9,180	8.5
Total (or Average)	45	44	77	165	18	19,800	

TABLE 3: Potential irrigation outcomes using K-Line or a Travelling irrigator following the application of the effluent irrigation rules to historical data on the Telford Dairy farm.

		Year				
		2004/05	2005/06	2006/07	2007/08	2008/09
Potential amount applied (mm/ha)	Traveller	110	140	150	180	130
	K-Line	130	140	158	183	155
Start date	Traveller	7-Nov	16-Sep	6-Oct	19-Sep	20-Oct
	K-Line	14-Oct	11-Sep	5-Oct	14-Sep	14-Oct
Finish date	Traveller	26-Feb	28-Mar	5-Apr	17-Apr	2-Apr
	K-Line	19-Apr	1-Apr	5-Apr	16-Apr	24-Apr
Potential drainage events within 5 days	Traveller	2	3	2	3	3
	K-Line	2	3	5	4	5
Potential drainage event next day	Traveller	0	0	0	0	0
	K-Line	0	0	0	0	0

Starting date was slightly earlier for the K-Line system as the deficit needed before application was lower. However, in most years this was only by a matter of 5 or 6 days. Generally irrigation could not start before mid-October, though this ranged from mid-September to early-November. Again the K-Line was able to start earlier in a wet year.

The finishing date was very similar for both systems as rainfall takes over at low evapotranspiration rates and fills the soil with water by mid April.

The rules worked well with no runoff within 2 days of any irrigation event. Runoff within 5 days occurred on average 3 times for the Traveller and 4 times with the K-Line. This was due to the K-Line deficit being much closer to 10 mm more often, as the Traveller had to reach 20 mm, rather than 13.1 mm before application.

DISCUSSION

Over the course of the Telford Dairy demonstration farm project there have been several reviews and analyses related to farm dairy effluent use including; soil structure and drainage, farm dairy effluent management, effluent nutrient analysis, and water budgeting for effluent application.

Soil and pasture analysis provided data to re-assess the use of the effluent disposal system as a nutrient and water application system. This has enabled the opportunity to improve pasture production and reduce fertiliser inputs over a greater and more appropriate area of the farm. This analysis has also ensured that the significant potassium loading in the effluent is spread over areas of the

farm that are currently low in potassium, maximising its effects as a fertiliser and minimising any potential animal health impacts at calving.

Effluent nutrients have provided a valuable nutrient resource; however, most dairy operations do not usually determine their input or value. During the 2008/09 milking season the average application load per paddock at the Telford dairy farm contained 27 kg N/ha, 7 kg P/ha and 67 kg K/ha. The average dollar value of effluent applied was \$212/ha. Given the cost of regular nutrient analysis, it would not seem cost effective to collect paddock specific FDE samples on a typical dairy operation. However, considering the similarity of nutrient content between mean pond concentration and mean applied concentration, it would appear that periodic sampling of FDE storage facilities would be sufficient to help track nutrient loading rates. Sufficient samples would need to be taken to allow for large potential variance between spot samples, say once per month during the lactation season. A pond sampling programme could provide additional support for farm nutrient budgeting and help guide fertiliser management practices. However, care would need to be taken if effluent nutrient concentrations varied with dilution due to differences in rainfall and washdown volumes of water added.

The recent implementation of a twin sludge bed system may result in a difference between the nutrient concentrations of the effluent applied and the pond given that the solids are filtered out and applied separately. Because of the separation of solids from the liquid sludge, this solid material should be tested before land application occurs to ensure suitable application rates are achieved.

The current areas available for FDE application are 38 and 41 ha for the K-Line and travelling irrigator, respectively. This provides ample area to apply all of the FDE available within each season, while being able to shift from area to area between seasons to minimise potassium build-up. Rates applied in the 2009/10 season indicated that potassium applications were still high and justify the large area dedicated to the FDE disposal system.

The two irrigation methods are quite compatible as K-Line provides the opportunity to start earlier, especially in a wet year (e.g. 2004/05), and occasionally to finish a little later in a wet year under the rules imposed. Research has also shown that K-Line can be used to apply 1 mm at a time in closely monitored situations and thus deliver effluent to soils at near field capacity with very minor impacts, but this approach was not modelled here. The smaller the amount applied then the earlier the start and the later the finish date will be with K-Line. The travelling irrigator provides the opportunity to apply relatively high volumes when the conditions are right.

As an aid to irrigation both effluent application methods may provide some benefits. In the 2009/10 season an average of 44 mm was applied to 27 ha of the Pallic soils. At a response rate of 20 kg/mm of applied water (Martin *et al.*, 2006) then the extra production would be 880 kg DM/ha and could provide some extra feed during a traditionally low production period on these soils (Figure 2). Further increases of pasture production may be expected from the additional nutrients in the applied FDE.

As well as physical changes to the effluent application system, the monitoring and review has instigated a range of changes to Telford's Dairy Effluent Management. These included:

1. A new staff induction to increase knowledge and awareness of effluent management
2. Effluent management guidelines for staff
3. Re-design of the effluent system including Twin Sludge beds and K-Line (low rate) application
4. Improved staff training and skills
5. Improved recording systems for effluent application and monitoring
6. New strategies for effluent nutrient management at Telford.

It is important to note that the data presented here is specific to the way FDE is collected and stored for the Telford dairy farm. Each farm and each change to a farm will require some further data collection before a full understanding of the FDE system can be gained. Many benefits can be captured, both through an improvement in environmental outcomes and through whole farm productivity and profitability.

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REFERENCES

- Houlbrooke, D.J.; Horne, D.J.; Hedley, M.J.; Hanly, J.A. 2004: A review of literature on the land treatment of farm-dairy effluent in New Zealand and its impact on water quality. *New Zealand journal of agricultural science* **47**: 499-511.
- Longhurst, R.D.; Roberts, A.H.C.; O'Connor, M.B. 2000: Farm dairy effluent: a review of published data on chemical and physical characteristics in New Zealand. *New Zealand journal of agricultural science* **43**: 7-14.
- Martin, R.J.; Thomas, S.M.; Stevens, D.R.; Zyskowski, R.F.; Moot, D.J.; Fraser, T.J. 2006: Improving water use efficiency on irrigated dairy farms in Canterbury. *Proceedings of the New Zealand Grassland Association* **68**: 155-160.
- MfE. 1997: Reducing the impacts of agricultural runoff on water quality: a discussion of policy approaches, Wellington, NZ, Ministry for the Environment. P 44.
- ORC. 2001: Environmental considerations for dairy farming in Otago, <http://www.orc.govt.nz/portal.asp?categoryid=167>. P 22.
- Roach, C.G.; Longhurst, R.D.; Ledgard, S.F. 2001: Land application of farm dairy effluent for sustainable dairy farming. *Proceedings of the New Zealand Grassland Association* **63**: 53-57.
- Vant, W.N. 2001: New challenges for the management of plant nutrients and pathogens in the Waikato river, New Zealand. *Water science and technology* **43**: 137-144.