An investigation of the incorporation of a standoff facility with the grazing of fodder beet in a Canterbury dairy wintering system

A dissertation
submitted in partial fulfilment
of the requirements for the Degree of
Bachelor of Agricultural Science (Honours)

at
Lincoln University
by
N. M. Brown

Lincoln University
2014

Abstract of a dissertation submitted in partial fulfilment of the requirements for the Degree of Bachelor of Agricultural Science (Honours).

An investigation of the incorporation of a standoff facility with the grazing of fodder beet in a Canterbury dairy wintering system

by

Nikki Brown

Dairy farmers are under scrutiny for the negative effect their farming operations have on the environment, particularly in regard to nitrate leaching. The National Policy Statement for Freshwater has directed regional councils to set limits for nutrient losses by 2030. Of particular interest are the traditional fodder crop wintering systems which have a higher density of urine patches at times of greater drainage. Since plant demand is low, high levels of nitrate leaching result. Current proposed alternative strategies, such as shed housing can have a large initial cost, with impacts on the financial viability of the business.

This project investigated the environmental and economic effects of a fodder beet/standoff pad wintering system as an alternative to the current Lincoln University Dairy Farm (LUDF) forage crop wintering system, where all crop/supplement are fed in paddock. These systems were modelled using partial budgets for the winter period and analysis in Overseer® version 6.1.3 to quantify the economic and environmental effects.

In the models, 400 cows were either grazed 24 hours per day on the crop with silage, or an alternative system which restricted grazed fodder beet for six hours per day for the 61 day period, with silage fed on a pad that collects all effluent. In both case the cows were allocated 8 kg DM per cow of fodder beet. For the paddock option, they were allocated 6 kg DM of silage and on the pad 4.8 kg DM of silage (due to better utilisation).

This analysis concluded that the proposed system cost $41.07 per cow per week, which was 82.3% more expensive than the historical system at $22.53 per cow per week. The proposed system’s levels of nitrogen lost to water were 56.9% lower than the historical system, with losses of 28 kg N/ha for the proposed system and 65 kg N/ha for the current system.

These results conclude that a fodder beet/standoff pad system provides a viable means of reducing nitrate leaching in a wintering system in Canterbury; however, the cost of this is significantly higher than a traditional paddock based system. A calculation estimated that the use of a structure to reduce leached nitrogen was $171 per kg of leached nitrogen mitigated.

Acknowledgements

I cannot believe this dissertation is done! It's unlikely I would have even started without the help and support of so many people which I am incredibly grateful for.

Firstly a huge thank you must go to Marv Pangborn. I cannot thank you enough for all your time you have put into this dissertation. I think you know as much as I do that there is no way that this dissertation would have been started, let alone finished, without you. I am so lucky to have had such a knowledgeable and supportive supervisor. Your industry knowledge and the many hours you spent going through my work, which probably made little sense at times, has been really appreciated. Thank you so much.

Thanks must also go to Ian Domigan, especially for your expertise with designing this system, and to Guy Trafford and Keith Woodford, for your feedback and support.

Many people from the industry also helped to form this dissertation. Your time and expertise was truly valued. Thanks to Ron Pellow, Dawn Dalley, Matt Cullen and Rangi Holland. Thanks must also go to Miranda Hunter for your knowledge of the industry and help battling with Overseer® was awesome and hugely appreciated.

The financial support from DairyNZ, the Mataura Licensing Trust and the Community Trust of Southland has been invaluable and I'll always be grateful. Special thanks to Bill Barwood and Susan Stokes from DairyNZ for the mentoring and additional support that they have provided me throughout my time at Lincoln University.

My interest in agriculture has been inevitable ever since my parents dragged me along to the cowshed and the farm before I could walk. So thanks to my parents, Roger and Jenny, for your enthusiasm about whatever big ideas I have. Thanks must also go to my sisters, Renee, Kate, Alice and Rebecca.

To my fellow fourth years, we're finally done! Special mention Matt, Marc, Kate, Angus and Nick, I think we all helped each other to not go insane. To my flatmates, Olivia, Crawf, Aled, Angus and Gemma, thanks for putting up with me and my hopeless, cooking me dinner and listening to my predicaments. Tara, Bentley, Bev, Rachael and Tessa have also been a special part of this fourth year. All the best, I look forward to hearing of all your successes and fun.

Table of Contents

List of Tables

List of Figures

Chapter 1:
Introduction

There is increasing pressure upon New Zealand dairy farmers to make their farming practices more environmentally sustainable (Clark, Caradus, Monaghan, Sharp, and Thorrold, 2007). This is especially true in regard to the declining water quality of New Zealand's lakes and rivers which has been partially attributed to the process of nitrate leaching from dairy farming operations. Improving water quality through decreasing nitrate leaching is important not only for human and aquatic health (McLaren and Cameron, 1996) but also to maintain the 'clean and green' image on which our export market relies (Baskaran, Cullen, and Colombo, 2009). Because of this, the National Policy Statement for Freshwater has directed regional councils to set limits for nutrient losses by 2030 (Ministry for the Environment, 2014). A particular problem is with amplified levels of nitrate leaching occurring in winter due to high drainage and low plant demand (Dalley, Verkerk, Geddes, Irwin, and Garnett, 2012).

Winter is a critical part of the dairy farm system in which many key activities occur that impact on the following milking season, such as gaining body condition (Cottier, 2000; Dalley, 2013). The animal welfare of the animals is also an issue that needs to be considered and is becoming of increasing concern to the public (Dalley *et al.*, 2012). A farm's wintering system forms a large part of the farm working expenses (Cottier, 2000), therefore it impacts upon a farm's level of profitability. In the South Island of New Zealand, cows are typically wintered off farm on forage crops. These systems have particularly high levels of nitrate leaching because of the high stocking rate resulting in a high density urine patches, which contain levels of nitrogen far in excess of demand (Dalley, 2011; Monaghan, Beare, and Boyes, 2009). Despite alternative systems, such as a standoff pad or wintering barn, having lower levels of nitrate leaching, they have a high initial cost which may impact negatively on the profitability of the farming business (Journeaux, 2013).

This quantitative study will look at the value of incorporating a standoff pad into a fodder beet wintering system in Canterbury as a lower cost alternative to a shed system for lowering nitrogen losses. Nitrogen losses will be focused on in the study as nitrates have been identified as the greatest risk to groundwater in Canterbury (Ministry for the Environment, 2009). Fodder beet has been chosen due to its ability to produce high levels of high quality dry matter (DM) at a reasonable cost (Agricom, 2012). The cows will spend a proportion of their day grazing the fodder beet and then be moved onto the standoff pad where they will be fed silage. The effluent will be collected and exported at times of year which are not as prone to leaching, from September-December. This system will be evaluated from an environmental and financial perspective, using scenario modelling in Overseer® version 6.1.3 and Microsoft® Office Excel respectively. It is anticipated that through the timelier and even spread application of effluent, nitrogen losses can be reduced while still maintaining productivity and profitability.

The dissertation will be organised into five chapters as outlined below.

Chapter 1: Introduction

Introduces and briefly describes the topic and background, providing an overview of the research.

Chapter 2: Literature Review

A review of literature relating to dairy wintering systems in New Zealand. This helps to draw conclusions about existing research and potential areas for future research.

Chapter 3: Research Methods

Outlines the research methods used for modelling and data analysis and details why these methods were selected. This chapter also proposes the research questions.

Chapter 4: Systems model

The systems for the current and proposed systems are detailed and the associated assumptions are listed.

Chapter 5: Financial analysis

This chapter provides the financial analysis for the current and proposed systems.

Chapter 6: Environmental analysis

The results of the environmental analysis of the systems are presented.

Chapter 7: Discussion and conclusions

The levels of nitrate leaching and profitability between the two systems are compared, followed by a discussion on the relevance and implications of the results. This chapter summarises key findings, presents a number of alternatives to the assumptions and provides concluding statements for the dissertation.

Chapter 2:
Literature Review

2.1 Introduction

The purpose of this literature review is to evaluate dairy wintering systems in New Zealand, particularly in regard to the nitrate leaching levels and economic benefits of the systems. Other benefits and disadvantages of the present systems are also discussed. The literature review will identify gaps in knowledge and subsequent areas of potential research.

The majority of literature came from journals or conference proceedings which have been peer-reviewed, making the findings of the trials reliable. The results discussed mainly came from trials within New Zealand thus it is directly relevant to New Zealand systems. However, most data comes from the southern regions of New Zealand, due to very few trials being carried out in other regions.

2.2 Environmental concerns

2.2.1 Nitrate leaching

A urine patch from a dairy cow has an nitrogen loading rate of up to 1,000 kg N/ha (Di and Cameron, 2002). This is far in excess of what a plant can assimilate and as a result nitrogen accumulates in the soil profile and can be leached when there is sufficient moisture (Christensen, Hanly, Hedley, and Horne, 2010; Dalley, 2011; Di and Cameron, 2002; McLaren and Cameron, 1996). Dung patches also contain nitrogen, however this does not contribute as significantly to nitrate leaching because the nitrogen is organically bound and is therefore released more slowly (de Klein and Ledgard, 2001).

The nitrate (NO_3^-) form of soil nitrogen has a negative charge so is relatively mobile, unlike other forms of soil nitrogen. Due to the negative charge, when it is in excess of plant demand it is repelled by cation exchange sites and accumulates in the soil profile. In times of drainage, when field capacity is exceeded, the accumulated nitrate is readily drained through the soil profile and can enter waterways. This process is called nitrate leaching (McLaren and Cameron, 1996).

Studies indicate that the majority of nitrogen losses to water from a winter forage crop grazing system occur through nitrate leaching (Dalley *et al.*, 2012; Monaghan, 2012). Due to the higher rainfall and lower plant growth rates, nitrogen losses through nitrate leaching is greater during the winter (Dalley, 2013; Dalley *et al.*, 2012; Di and Cameron, 2002; McFarlane, 2013; McLaren and Cameron, 1996; Monaghan, 2012).

2.2.2 Water quality

Approximately 39% of monitored lakes and rivers in New Zealand have nitrate levels above the natural background levels, with a number having levels exceeding 11.3 mg/L, the level deemed safe for drinking by the New Zealand Ministry of Health (Baskaran *et al.*, 2009). Methaemoglobinaemia (blue baby syndrome), cancer and eutrophication, which can lead to the eventual depletion of aquatic life, have been linked to high nitrate levels in waterways (McLaren and Cameron, 1996).

An increase in nitrate levels in underground and drinking water supplies can be caused by nitrate leaching and run-off soil nitrogen (McLaren and Cameron, 1996). A 2008 Environment Waikato report states that "monitoring shows that important aspects of soil and water quality are deteriorating across intensively farmed areas of the region" (Environment Waikato, 2008). Modelling studies have indicated that if current dairy management systems continue, high levels of nitrate leaching will continue and subsequently a further deterioration of water quality will be observed (Di and Cameron, 2002). This is likely to have negative impacts on human and aquatic health. It will also impact on the 'clean and green' image that is pivotal to much of the demand for New Zealand's export products, therefore consequences of this image being tarnished could be drastic to the New Zealand economy (Baskaran *et al.*, 2009).

2.3 Farm systems

Prior to the 1960's, there was minimal active collaboration between technical agricultural scientists, agricultural economists and anthropologists/rural sociologists, with each area being analysed as a separate component. However, when the reductionist approach began to fail in terms of developing technologies, a farm system approach evolved and scientists began to work together (Norman, 2002).

A farm system is described by McConnell and Dillon (1997) as "an assemblage of components which are united by some form of interaction and interdependence... to achieve specified agricultural objectives." Because of the interactions and interdependence of the various components, altering one component affects the ability of the agricultural system to be able to achieve its overall objectives. On a dairy farm, key components include pasture production, animal health and welfare, weather, nutrient losses, season, staff management, feed and cash flow. These components, along with many others, interact to achieve objectives such as productivity, profitability and sustainability. The whole farm system approach is crucial for evaluating new technologies or strategies, such as proposed in this research. Although one component may be affected positively, the impact on the whole farm system may be negative, resulting in the overall objectives not being achieved. A wintering system is a key component of a farm system which can have significant impacts on the farm system as a whole. Therefore, the whole farm system approach is important when analysing the viability of a wintering system in order to evaluate its value to the farming business.

2.4 Wintering systems

Dairy wintering describes the management approach of feeding dairy cows between drying off in late May until calving for the following season in August (Monaghan, 2012). A successful wintering system is a component of the farm system that is crucial to the overall success of the whole dairy farm system

(Cottier, 2000; Pinxterhuis, Dalley, Tarbotton, Hunter, and Geddes, 2014). With calving usually commencing in August, a healthy environment for the growing foetus over winter must be maintained (Cottier, 2000). Body condition score (BCS) is correlated to optimising milk production, reproduction, animal health and welfare (Kay, 2014), thus a common goal of farmers is for cows to gain half a BCS during the wintering period, with many cows being dried off at a BCS of 4.5 and a target of a BCS of 5 going into calving (Judson and Edwards, 2008). If a wintering system fails to support these activities, it may have significant negative impacts on the farming business as a whole, in terms of animal health and welfare, production and profitability.

The traditional New Zealand wintering systems are based on a low cost approach in order to maximise profitability. In the North Island, in regions such as Northland, Waikato and Taranaki, adequate pasture growth is maintained through the winter. This allows the majority of cows to be wintered on pasture and fed supplements (Dalley, 2014). In the South Island, in areas such as Southland and Canterbury, adequate pasture growth cannot be maintained due to low temperatures (Dalley, 2014) therefore the majority of dairy farms winter cows on summer sown forage crops (Tarbotton, Bell, Mitchelmore, and Wilson, 2012). Many cows are wintered off the milking platform at a substantial cost that equates to 20-25% of the annual farm working expenses in Southland (Cottier, 2000). In recent years, there has also been increasing scrutiny from the public surrounding not only environmental sustainability but also animal welfare issues associated with New Zealand's wintering systems (Dalley, 2014; Kay, 2014).

2.5 Forage crop wintering systems

Winter forage crops offer larger quantities of feed on a relatively small area (Monaghan *et al.*, 2009). The crop is break fed, using temporary electric fencing to split the paddock of forage crop into daily allocations. There is no large initial capital cost of this system, aligning well with the traditional low-cost approach to dairying in New Zealand (DairyNZ, 2010). Currently, two of the most popular options of forage crops in Canterbury include kale and fodder beet.

2.5.1 Kale

Kale is a popular winter forage crop in Canterbury, and other regions of the South Island. Its energy value is relatively high at 10.5-11.5 MJME/kg DM (Matthew, Nelson, Ferguson, and Xie, 2011). Unlike other forage crop options, its nutritive value does not decline as greatly throughout the winter season (Judson and Edwards, 2008). It provides high levels of protein and calcium, but the high Ca/P ratio can cause milk fever at calving (DairyNZ, 2010). Costs of establishment for a kale crop (10-12 t DM/ha) is $800-1,200/ha (Agricom, 2012).

2.5.2 Fodder beet

The popularity of fodder beet has increased over the past few years. Fodder beet has a high energy value, with an average of 14.5 MJME/kg DM in the bulb and 10.7 MJME/kg DM in the leaf (Matthew *et al.*, 2011). The average yield for a fodder beet crop is 18-22 t DM/ha, with average costs of establishment of $1,800-2,000/ha. Despite the higher costs of production of fodder beet, the higher production and energy value results in an economic advantage over kale. Fodder beet is also described as having very good tolerance to insects and disease, while kale has a moderate insect toleration (Agricom, 2012). While it has a very high energy value, there is risk of rumen acidosis, so care must be taken to transition cows onto this feed, introducing it into the diet gradually. Transition periods are usually between 10-14 days (DairyNZ, 2010).

2.6 Wintering barn

A wintering barn is a structure which allows cows to be fully fed and housed indoors over the winter months (Journeaux, 2013), with feed being cut-and-carried or supplements bought in. Effluent can be collected and stored. While these structures are commonplace in European countries (de Klein and Ledgard, 2001), they are presently not popular in New Zealand, with only 7% of Southland farmers using them as a wintering system alone and 6% incorporating them into cropping systems (Tarbotton *et al.*, 2012).

2.7 Standoff pad

A standoff pad wintering system involves cows being removed from paddocks after a specified grazing time to a pad with supplement (Christensen *et al.*, 2010). The surface of the pad can vary with surfaces of concrete, bark chip and rubber reported (Dalley, 2014). Like wintering barn systems, standoff pads are more common in European countries (de Klein and Ledgard, 2001). It is the least common wintering system in Southland, with only 3% of dairy farms wintering solely on a standoff pad (Tarbotton *et al.*, 2012). Most pads do not control the drainage of effluent (Monaghan, 2012).

2.8 Revenue

2.8.1 Structure cost

Wintering barns are relatively expensive compared with other wintering options, Journeaux (2013) estimates the cost of erecting a wintering barn between $1,800-2,000/cow. However, constructors have suggested that recently constructed sheds and associated effluent system have cost $4,000/cow (B. Miller, personal communication, 18 September, 2014). Standoff pads are cheaper to erect compared to wintering barns (Monaghan, 2012). A covered, deep litter standoff, with drainage and effluent capture, costs approximately $1,200- $1,500/cow (Journeaux, 2013). Lowering the initial capital cost results in interest repayments on borrowings being reduced therefore, unlike the wintering barns, the pressure to intensify the farm system is not so great.

2.8.2 Expenses

In the southern regions of New Zealand, Beukes, Gregorini, Romera, and Dalley (2011) conducted a theoretical study regarding the cost of four different wintering systems; forage crop (on a support block with additional silage), pasture (on a support block with additional silage), standoff pad (on the milking platform and fed silage) and a wintering barn (on the milking platform and fed silage). It was concluded that a farm system with a forage crop wintering system has the lowest level of expenses on a $/kg of milk solid (MS) basis. Forage crops are closely followed by a pasture based system and considerably cheaper than systems incorporating standoff pads or housing (see Table 1).

Table 1: Average annual expenses of farm systems with different wintering strategies on a $/kg MS basis over 35 independently simulated climate years. Source: Beukes *et al.* (2011)

System	Forage Crop	Pasture	Standoff pad	Housed
Cost ($/kg MS)	3.83	3.85	4.01	4.11

2.8.3 Financial returns

Despite having higher expenses, the work of Beukes *et al.* (2011) concluded that wintering barns had higher levels of operating profit per ha than forage crop, all pasture and stand-off pad systems (see Table 2). Operating profit is calculated as revenue less expenses, with non-cash adjustments for runoff, wages of management, feed inventory, livestock values and depreciation. However, it must be acknowledged that this work did not include capital cost which is likely to have impacted on the annual expenses (shown on Table 1) and the operating profit (shown on Table 2).

Table 2: Operating profit of dairy farms in Southland with different wintering systems. Source: Beukes *et al.* (2011)

System	Wintering barn	Forage crop	Pasture	Stand-off pad
Operating profit ($/ha)	743	599	681	613

The works of Journeaux (2013) undertook a similar study which summarised the financial returns of building and wintering cows in a housed structure on farm compared to the current system of wintering cows off farm. However, in this study capital cost was included. This study was based in the Manawatu district of New Zealand and used comprehensive whole farm system financial analysis. It was reported that at an 8% discount rate, the net present value (NPV) of the investment was -$770,000, indicating a poor investment. When Journeaux (2013) intensified the operation, through increasing cow numbers and cow production, the analysis resulted in a NPV of $160,000 at an 8% discount rate, implying that it would be a good financial investment. The findings of Journeaux (2013) appear to differ from the findings of Beukes *et al.* (2011) as a housing system needed to be intensified before it became a worthy financial investment. This is likely to be a result of Journeaux (2013) including capital cost in the analysis whereas Beukes *et al.* (2011) did not and implies that including capital cost of a wintering barn can impact the viability of the investment.

2.9 Nitrate leaching

The high stocking rate of a forage type system results in high density of urine patches when plant growth and uptake of nutrients is low and rainfall and drainage is high (Monaghan, 2012). This ultimately leads to a disproportionate amount of nitrate leaching from the area where the cows are wintered (Dalley, 2011; Monaghan, 2012; Monaghan *et al.*, 2007). In research conducted by Monaghan *et al.* (2007) in the Waikakahi catchment, South Canterbury, it was reported that nitrogen losses from dairy wintering on forage crops are high, relative to the area that they occupy and other land uses (see Figure 1).

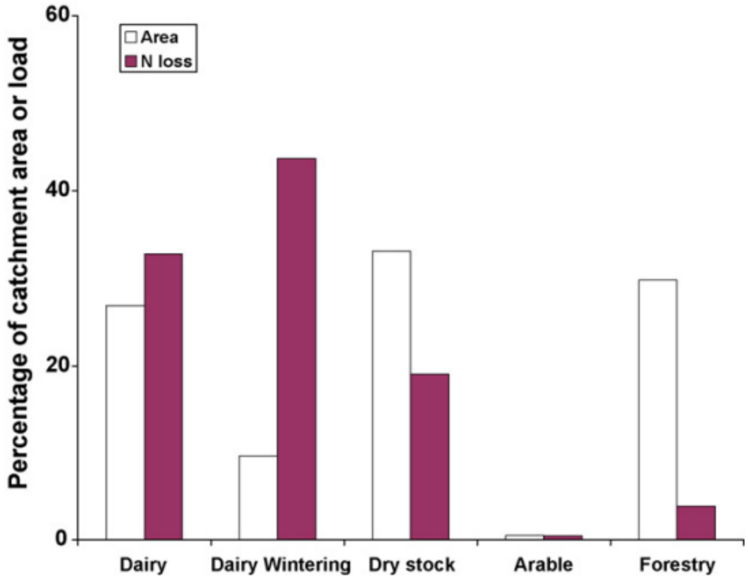

Figure 1: Relative area occupied and predicted contribution to stream N load of the different Modelled land uses within the Waikakahi catchment. Source: Monaghan *et al.* (2007)

This was supported by de Klein, Smith, and Monaghan (2006) who reported nitrogen losses in Southland were four to five times greater on forage crops, relative to nitrogen losses measured under pasture systems. It was estimated that the area used for wintering constituted 15% of the total farming operation area, yet 44% of nitrogen losses were attributed to the winter forage grazing area. This disproportionate amount of nitrate leaching from winter forage crop systems could contribute to a decline in water quality in New Zealand.

Forage crop selection also impacts upon nitrate leaching levels. Using feeds that have lower nitrogen concentrations reduces dietary nitrogen concentration (SIDDC, 2013). Fodder beet has a crude protein (CP) content of 8.9% in the bulb (Matthew *et al.*, 2011) while kale has a CP content of 13.7% (Westwood and Mulcock, 2012). Nitrate leaching levels also varies between fodder beet and kale, relative to their CP content, with leaching levels estimated of 55-60 kg N/ha and 75-85 kg N/ha respectively (SIDDC, 2013). Recent research indicates that urinary nitrogen content when animals are grazing fodder beet is lower than previously reported (K. Cameron, personal communication, 14 October, 2014). When this information becomes included in software that models nitrate leaching, it is likely that projected nitrate leaching levels will decrease from fodder beet.

In a wintering barn system where the effluent is collected, rather than the nitrogen being heavily condensed in one area as is the case of urine patches, the effluent can be spread at times and rates which match plant demand (Christensen *et al.*, 2010). Usually this period is between late spring and early autumn as plant demand is relatively high and drainage is relatively low, therefore reducing the risk of leaching. It was reported by Journeaux (2013) that in a wintering barn system, nitrate leaching levels can be reduced by a third, relative to pasture systems, through the collection of effluent and application at appropriate times. While in the work of de Klein and Ledgard (2001) cows were housed all year round, effluent was dealt with in a similar manner and nitrate leaching was reduced by 55-65%.

As wintering barn structures have a significant capital cost, high financial returns are required in order to meet debt repayments. It was suggested by Journeaux (2013) that while this is possible in years with a high milk payout, debt repayments may not be able to be met when the milk payout is lower. A realistic means of ensuring debt repayments can be achieved every year is through intensification by increasing cow numbers or extending lactation. When the operation was increased to a level that minimised the risk of debt repayments not being met, it resulted in a greater leaching loss on a whole farm basis than prior to building the structure. This was due to more cows on the same area (Journeaux, 2013).

The sealing of standoff pads or feed lots is essential in determining the effectiveness of these structures mitigating nitrogen losses. It was concluded by Monaghan (2012) through modelling studies that if 15% of the excretal nitrogen deposited onto a standoff pad escaped, it would result in an overall loss greater than the projected figure for nitrogen losses in a grazed winter forage crop system. These findings demonstrate that effective design and management of standoff pad structures are pivotal to their success in minimising nitrate leaching.

Using standoff pads alongside forage crop is another wintering system that could be used to mitigate nitrate leaching. This is not common with only 6% of Southland farms using this as their wintering system (Tarbotton *et al.*, 2012). In the Manawatu region of New Zealand, Christensen *et al.* (2010) found that by reducing the time cows spent on pasture by 50%, nitrate leaching levels were reduced by 41%. This was a full year experiment, so not specific to the winter period. However, it was reported that the levels of nitrate leaching during the winter period were lower when cows were on a standoff pad for a proportion of the day compared to when cows were grazed completely on crop. This aligns with the work of de Klein and Ledgard (2001) that reports if grazing time is reduced on pasture during winter, nitrogen losses are reduced by 35-50%. However, both trials involved grazing pasture therefore it is currently inconclusive as to whether similar reduction in losses would be observed should cows be grazed on crop and further research needs to be undertaken in this area.

2.10 Pasture production

In a wintering barn or standoff pad wintering system where effluent is collected, the more even and timely application of the effluent also has positive effects on pasture production. Increased pasture production is also a result of the nutrients being returned to the paddock, opposed to on the laneways or at the shed during the milking season (Kemp, 1999). Pasture production increases of 0.5-2.0t/DM (Macdonald, 2014) and 3-8% increases have been reported (de Klein, Monaghan, Ledgard, and Shepherd, 2010). This would have positive effects on the whole farming operation as fertiliser costs could be reduced and more pasture would be available for cows. A study was conducted in Southland by DairyNZ (2014) where cows were on a structure for 24 hours per day during the winter period, with effluent collected. The value of nutrients in the effluent was calculated to be $45/cow.

During times of high rainfall, pasture and soil can be damaged by stock treading, resulting in pugging (Clark *et al.*, 2007). Pasture and soil damage is high in pasture and forage crop wintering systems due to a high stocking rate when soils are saturated. However, because forage crops can produce a large amount of feed in a relatively small area, this can isolate damage to soil to only a few paddocks of the milking platform, reducing the total amount of damage on farm relative to a pasture system (Monaghan *et al.*, 2009). Pugging can result in decreased pasture production for up to 29 weeks after the damage occurs, with an initial reduction of approximately 51% (Drewry, Cameron, and Buchan, 2008). Nitrogen fixation can also decrease by 60-80% in moderate to severe cases of damage (Clark *et al.*, 2007). Utilisation may be affected as well, with a 20-40% reduction noted when soils have been pugged or compacted (Journeaux, 2013). These factors have negative implications on feed supply for the remainder of the season.

2.11 Feed allocation

Overestimating the quantity and utilisation of feed is common in forage crop systems and often results in insufficient feeding and consequently poor performance (Dalley, 2014). It was reported by Judson and Edwards (2008) that two-thirds of cows winter grazed on kale in Canterbury were being fed 1 kg DM/day below their target intake, with some cows being underfed by up to 8 kg DM/day. Utilisation can be lower than what is estimated by the farmer due to increased trampling making kale unpalatable or inedible (Judson and Edwards, 2008). Underfeeding would have large consequences on the success of the wintering system with it being very likely cows would not maintain and/or put on sufficient body condition. The effects of this would flow on to the following season as BCS is correlated to optimising milk production, reproduction, health and welfare (Kay, 2014).

2.12 BCS and affect on milk production

As a wintering barn system allows for high control of feeding, BCS can be regulated (Beukes *et al.*, 2011; Journeaux, 2013). It was reported by Beukes *et al.* (2011) that using a wintering barn system had the potential to increase the lactation period by 37 days, relative to the baseline of 254 days, thus further increasing operating profit by $250/ha. This figure was generated without incorporating the premium paid for winter milk, which would also increase the operating profit as well as the Return On Assets (ROA) and Return On Equity (ROE). While the work of Journeaux (2013) supports extending lactation, it was not extended by the same extent, with 70% of the herd milking for 21 days longer. However, Journeaux (2013) attributes an additional 7.5 kg MS to each cow over the whole system to the increase in body condition. In the work of Journeaux (2013), a 2% increase in conception rate was also factored in, due to the increase in BCS. This decreases the replacement rate from 20% to 18%.

2.13 Animal welfare

2.13.1 Lying time in structures

It was reported by Dalley *et al.* (2012) that wintering barns are often perceived by the public as causing animal welfare issues due to less space per cow relative to a pasture based system. Cows have a preference to lie for around eight hours a day (Dalley *et al.*, 2012). Not being able to lie would contravene the animal welfare code of conduct which states animals need to be able to express normal behaviour (Botreau, Veissier, Butterworth, Bracke, and Keeling, 2007). When lying time is inadequate, it results in physiological stress and behavioural signs of frustration (Dalley *et al.*, 2012). Increased standing time is also positively correlated with lameness (Cook and Nordlund, 2009) which is not only an animal welfare issue but will have financial implications on the business, through treatment and possible loss of production. It was reported by Dalley *et al.* (2012) that as area per cow increased in grazed off systems, lying time increased (see Table 3).

Table 3: Area per cow, lying behaviour and time of cows on monitored dairy farms with structures in Southland during winter (average of 2011 and 2012). Source: Dalley *et al.* (2012)

Wintering system	Lying surface type	Area per cow (m^2/cow)	Average lying time (h/cow/day) (Mean±SD)	Less than 8h lying (% cows)
Herd Home™	Slatted concrete	3.7	8.0±2.2	63
Loose house barn	Sawdust	5.2	8.5±1.6	37
Free stall barn	Rubber matting	8.0	9.7±2.0	10
Wintering pad	Bark chips	12.0	11.2±1.2	0

When cows in the trial were grazed on forage crops and pasture, the average lying time in all cases exceeded eight hours, with the greatest lying time being recorded for the cows grazed on pasture (11.5±0.5hours).

2.13.2 Influence of surface material on lying time

It was reported by Dalley (2014) that cows on standoff pads have longer lying periods relative to other wintering systems which incorporate infrastructure (see Table 3). However, Webster (2014) reported that cow lying time varies between standoff pads with different surfaces. In this trial, an area of 4.9 m^2 was allocated to each cow with four different pad surfaces evaluated: bare concrete, woodchips, concrete covered with 12 mm rubber matting and concrete covered with 24 mm rubber matting. Cows on the woodchips had the longest lying periods (10.8 hours), whereas cows on the concrete had the shortest lying time at 2.8 hours. The standoff pads with rubber matting supported lying times of 6 hours and 7.3 hours from the 12 mm and 24 mm rubber matting respectively. As mentioned earlier, cows have a preference to lie for around eight hours a day (Dalley *et al.*, 2012). This implies that the surface of the standoff pad is closely linked with the level of animal welfare.

2.14 Labour implications

A different skill set is required for wintering barn systems, with particular skills surrounding animal welfare and health (Beukes *et al.*, 2011; Journeaux, 2013). Many New Zealand dairy workers may not be proficient in these areas and as a result farmers may either have to employ additional staff, or 'up skill' current employees (Journeaux, 2013). In an intensive system which produces 500 kg MS/cow, Journeaux (2013) estimates additional labour costs at $25,000/year (0.5FTE on a $50,000 salary). This would obviously impact upon the profitability of the whole farm system.

2.15 Restricted grazing time

The most recent and specific study about standing cows off forage crops was carried out by Jenkinson, Edwards, and Bryant (2014) at the Ashley Dene research farm, Lincoln. This study recorded grazing behaviour, dry matter intake and urination patterns of dairy cows grazing kale or fodder beet in winter. Cows grazed the crops for six hours and then were stood off the crop. The pregnant, dry Friesian x Jersey cows were fed diets composed of differing levels of crop and supplement. These diets also resulted in the cows having different levels of nitrogen intake. The late sown kale (LK) diet had the highest nitrogen intake, followed by the early sown kale (EK) diet and fodder beet (FB). The cows consumed the majority of the crop within six hours of allocation, with the highest proportion of intake relative to the available feed, being on the fodder beet diet. This information is shown on Table 4.

Table 4: Diets in trial by Jenkinson *et al.* (2014) at Ashley Dene, Lincoln

Treatment	Diet composition	Nitrogen intake (g N/cow/day)	Intake of crop within six hours (%)
EK	14 kg DM kale, 3 kg DM barley straw	281	82
LK	11 kg DM kale, 5 kg green-chop oat silage	296	76
FB	8 kg DM fodder beet, 6 kg DM baleage	228	90

This will have implications in terms of nitrate leaching as higher levels of nitrogen in the diet will result in excess nitrogen in the urine which will be vulnerable to leaching. The cows consumed 82%, 76% and 90% of their crop allocation (11.5, 8.4 and 7.2 kg DM/cow) on the EK, LK and FB diets respectively within the six hours.

Urinary and faecal events and their corresponding nitrogen concentrations were also recorded in the study. EK diet recorded the least urination events, but the urine nitrogen concentration was the highest out of the three diets (see Table 5).

Table 5: Urination patterns of dairy cows grazing early sown kale, late sown kale or fodder beet diets in winter during six hour period. Source: Jenkinson *et al,* (2014)

Crop	Early sown kale (EK)	Late sown kale (LK)	Fodder beet (FB)
Total urination events	2.0	3.1	2.9
Urine N concentration (g/L)	2.44	2.01	2.23
Total faecal events	1.7	1.5	2.9
Faecal N concentration (% DM)	2.19	2.01	2.09

The level of urination and faecal events are important factors to consider when evaluating the environmental impact of a system. Nitrogen in faeces is less readily leached than nitrogen in urine as it is organically bound and therefore does not impact nitrogen losses as greatly (de Klein and Ledgard, 2001). To determine what urination and faecal events mean in terms of nitrate leaching, a weighted average formula is used which considers the area of the paddock with and without urine patches. If more urination and faecal events occur, the greater weighting this is given, resulting in higher nitrate leaching levels being projected.

While this research did not incorporate a standoff pad, the results indicate that standing cows off the paddock is a viable option to reduce nitrogen losses due to the reported urination and faecal event frequency and the proportion of feed intake within six hours of allocation.

2.16 Literature review conclusions

Nitrate leaching is a major problem in New Zealand agriculture, particularly in the dairy and dairy support sectors. Nitrate leaching is a contributor to the decline in water quality in New Zealand, having negative effects on human and aquatic health and potentially the marketing of New Zealand's exports. High levels of nitrate leaching have been reported during the winter period due to high rainfall and low plant demand. This is amplified in the more southern regions of New Zealand, due to the cooler temperatures and high drainage. As a result, the environmental impacts of wintering systems are under scrutiny.

New Zealand wintering systems vary from region to region. However, most research concerning wintering systems has been conducted in the southern regions of New Zealand. Due to the different climatic nature across the country, further research in other regions would be beneficial as current research may be skewed by regional anomalies.

Forage crop systems are common in the South Island and provide a relatively cheap, high energy source of feed in a relatively small area. This allows soil damage from stock treading in wet periods to be isolated to only a few paddocks. However, the high stocking rate results in a disproportionate amount of nitrate leaching in a small area. Underfeeding can be common in forage crop systems due to overestimating quantity and utilisation.

Wintering barns are a relatively new and uncommon system in New Zealand. However, these structures require a significant capital cost initially and when this is included in the financial analysis, intensification of the farming operation was required to provide financial returns. The intensification may result in increased nitrate leaching. The ability to feed supplements in the sheds can lead to the lactation period being extended, increasing returns. With effluent collected and spread at appropriate times, nitrate leaching is reduced. Due to the cows being off pasture for the entirety of the winter period, soil damage can be avoided. Lying duration was also lower when cows were wintered in barns compared with other wintering structures; this implies that there were lower standards of animal welfare when these systems were implemented.

Standoff pads are also a relatively uncommon wintering option in the South Island of New Zealand. The initial costs of standoff pads are lower than a wintering barn, although similar benefits can be derived in terms of avoiding damage to pastures and reducing leaching losses. The surface material influences lying behaviour of cows, with cows lying for shorter periods on concrete surfaces and longer on bark chip surfaces. The sealing of the standoff pad is crucial to its success in mitigating nitrate losses, with escaped excreta from the standoff pad resulting in nitrogen losses greater than losses from forage crop systems. It was reported that cows consumed the majority of the feed allocation on kale or fodder beet crops within six hours, with few urination or faecal events occurring. This indicates that if the cows were stood off after this grazing period on a contained facility, the standoff could prove a worthy means of mitigating nitrate leaching. Standing cows off crop on a fully contained pad facility is a wintering system which has not been fully investigated from either a financial or environmental perspective.

Chapter 3: Research Methods

3.1 Introduction

As discussed in the literature review a number of wintering systems exist; however, it appears there is a gap in the knowledge of the economic and environmental effects of a fodder beet/standoff pad system. Therefore, this study will model a change of the Lincoln University Dairy Farm (LUDF) wintering system. In the proposed system, cows will be wintered on a fodder beet crop but spend a proportion of the day on a standoff pad with effluent to be collected. Fodder beet was chosen due to lower costs of production per kg DM and its lower nitrogen content which results in lower levels of nitrate leaching (Jenkinson *et al.*, 2014). This quantitative study requires scenario modelling of a proposed system to determine profitability and environmental modelling to determine the sustainability of the system. Input data will be derived from industry information and historical details about the LUDF wintering system.

3.2 Research questions

Research of wintering systems in New Zealand has largely been concentrated in the southern regions of New Zealand; however, this research will concentrate on Canterbury. The Canterbury region has 1,046 dairy farms and is home to 826,325 cows (17.3%) of the New Zealand's dairy cows, with an average herd size of 790 cows. Production in Canterbury is higher than most other regions in New Zealand with average production of 388 kg MS/cow or 1,345 kg MS/ha (DairyNZ, 2013b). The average stocking rate in Canterbury is also higher than in other regions of New Zealand, with an average stocking rate of 3.48 cows/ha (DairyNZ, 2013b). Much of Canterbury is noted for containing porous soil types.

The research project involves answering the following research questions about the proposed wintering system:

- What are the levels of nitrate leaching from the proposed system versus the historical system?
- What are the financial implications of the adoption of the proposed system versus the historical system?

3.3 Research Approach

Quantitative research is the most suitable method to answer the questions posed in this study. Quantitative research falls into the category of empirical or statistical studies and essentially reduces data to numbers (Newman, 1998). An advantage of quantitative research is that the numbers can be graphed, ranked or compared more accurately with other studies (McLeod, 2008). The numbers associated with this study will compare levels of nitrate leaching and financial performance of the proposed system versus the historical wintering method. The modelling techniques will be conducted in Overseer® version 6.1.3 and Microsoft® Office Excel respectively.

3.4 The system

Details about the system design will come from a focus group, an engineer and industry experts, as well as relevant literature. This will include the structure design, grazing duration of fodder beet and feed allocation. Currently the cows from LUDF are wintered at Ashley Dene, the Lincoln University sheep research farm. Some of the cows are wintered on fodder beet following a typical forage crop wintering system, with the cows being break fed fodder beet and remaining in the paddock for 24 hours a day. In the proposed system the cows will be grazed on fodder beet for six hours. Fodder beet was chosen due to its ability to produce the highest level of DM per ha on a small area and its lower nitrogen content. The cows will then be moved onto a standoff pad where the balance of their feed requirement will be met from grass silage. Effluent from the standoff pad will be collected and distributed at times of low leaching risk during the year (September- December).

3.5 Environmental analysis

3.5.1 Overseer®

The environmental analysis will be conducted in Overseer® version 6.1.3. Overseer® is a computer modelling tool which was originally developed as a decision support tool for making economic fertiliser recommendations but has since been developed to estimate nutrient losses. The nutrient flows are calculated using input data about the property and the system. The input information includes details such as soil type, climate and distance from the coast and fertiliser applications. The nutrient flows produced include nutrient run off, leaching and greenhouse gas emissions. This model has a relatively high margin of error at +/- 30% (Overseer, 2013). Despite its limitations, it is currently the accepted modelling tool on the market and is used by regional councils to evaluate a farm's level of nitrate leaching. In this study, the important number from Overseer® will refer to the level of nitrate leaching as a property's 'nitrogen loss to water' (below the root zone but above the water table). This number is most important to this study because in Canterbury the greatest risk to groundwater is nitrates (Ministry for the Environment, 2009). However, it is acknowledged that within other catchments in New Zealand, other contaminants will pose greater risks to groundwater, such as *Escherichia coli* and phosphorus.

3.5.2 Input data

The property input data will be based upon information about the Ashley Dene and LUDF properties. As demonstration/research farms, information about the properties is readily accessible. Ashley Dene consists of 355 ha (effective), comprised of silt loam soils. There are a variety of sheep breeds on the property, predominantly of the Coopworth breed, with 3,544 stock units in total. It has an average temperature of 12.1°C and a mean annual rainfall of 633 mm. The LUDF consists of 161.1 ha (effective) and runs 650 cows, producing 475 kg MS/cow (R. Pellow, personal communication, 22 August, 2014). The soils range from Paparua and Templeton soils, which are well-drained, to Temuka and Wakanui soils, which are less perfectly drained. The average annual temperature is 12.1°C, with a mean annual rainfall of 666 mm. The pasture mix comprises ryegrass, white clover and timothy, with 340 kg N applied annually (SIDDC, 2014b).

This information will contribute to the input data in order to produce a scenario report. The nutrient losses in the report, in particular nitrogen lost to water, will be compared to leaching levels from the current wintering system.

3.6 Financial analysis

Financial analysis will be undertaken in Microsoft® Office Excel. A partial farm budget will be prepared to account for the costs associated directly with the historical and proposed wintering system.

The standoff pad design will be priced by a commercial entity familiar with structures. Debt servicing costs of the structure will be based upon current bank interest rates. Other costs and savings associated with implementing this structure will be based on information in academic publications and industry sources, as well as historical data from the LUDF.

From the budget, the key outcomes to be analysed will be the cost of wintering per cow for each of the systems and the effect of the incorporation of a wintering pad on the farms cost of production per ha. A further analysis will calculate the cost of nitrate leaching mitigation. This number will be calculated as the total difference in costs divided by the total difference in number of kg of nitrogen mitigated.

3.7 Hypothesis

The hypothesis for this study is:
"while a standoff pad with the grazing of fodder beet will increase the costs of a Canterbury dairy wintering system, it will be a viable means of reducing nitrogen leached."

Chapter 4:
System Model

4.1 Introduction

Chapter 3 discussed the methods of how this study will take place. This chapter will detail the current and proposed systems and the associated assumptions. The development of this system was informed by the Southern Wintering project, as detailed in the literature review in Chapter 2.

4.2 LUDF

In 2001, the South Island Dairying Development Centre (SIDDC) was established in order to promote continual gains in efficiency and productivity while encouraging innovation. This is an industry funded partnership consisting of seven dairy sector organisations: Lincoln University, DairyNZ, Ravensdown, Livestock Improvement Corporation (LIC), Plant and Food Research, AgResearch and the South Island Dairy Event (SIDE). SIDDC manages the LUDF which was launched in 2001 (SIDDC, 2014a).

LUDF's main objective is to "develop and demonstrate world-best practice in dairy farm systems and transfer them to South Island dairy farms. The farm also tests and develops practical applications of new technologies to help maximise the use of pastoral production systems, while achieving a commercial return, protecting the environment, and considering the industry's 4% productivity gain target" (SIDDC, 2014b).

The property is 160.1 ha (effective), with a 15.2 ha runoff (East block) adjacent. The average annual temperature at the property is 12.1°C, with average temperatures during May-August ranging between 5.6 and 8.6°C. The property is summer dry, with a mean annual rainfall of 633 mm (SIDDC, 2014b).

LUDF's strategic objective (2011-2015) that is relevant to this project is to:
"Increase productivity, without increasing the farm's total environmental footprint" (SIDDC, 2014b)

The consideration for the environment is further explained in their additional objectives:

- "To consider the farms full environmental footprint, land requirement, resource use and efficiency in system decision making and reporting
- To use the best environmental monitoring and irrigation management systems in the development and implementation of practices, that achieve sustainable growth in profit from productivity and protection of the wider environment.

- To ensure optimal use of all nutrients on farm, including effluent, fertiliser, nutrients imported from supplements and atmospheric nitrogen; through storage where necessary, distribution according to plant needs and retention in the root zone" (SIDDC, 2014b)

4.3 Ashley Dene

The Ashley Dene property is the Lincoln University sheep research farm and is located near Springston (43°65' S, 172°32' E. 39 m above sea level). The majority of the LUDF's milking cows are wintered on the Ashley Dene property. The property is dominated by Lismore silt loam soils (Landcare Research, 2014). This is a well-drained soil with very low water-logging vulnerability (Environment Canterbury, 2014) which is advantageous for wintering dairy cows as soil damage is reduced. However, it is classified as having 'very high' nitrate leaching vulnerability and 'medium' phosphorus leaching vulnerability (Environment Canterbury, 2014).

4.4 Historical wintering system

In 2014, the average BCS of the cows going to Ashley Dene to graze the fodder beet was 4.0, with an average weight of 501 kg. The first group of cows grazed the fodder beet in late May (R. Pellow, personal communication, 22 August, 2014). The cows were predominantly Friesian x Jersey breed and had produced 475 kg MS/cow (SIDDC, 2014b). The fodder beet system at Ashley Dene had the paddock split into daily allocations of fodder beet using temporary electric fencing, allocated at 8 kg DM/day/cow. This was supplemented with grass silage at 6 kg DM/day/cow. The silage was fed onto the paddock using a tractor and feed out wagon. The cows remained in the fodder beet paddocks for the entirety of June and July (61 days). The first group of cows went back to the LUDF property in late July, dependent on their calving date, with a minimum BCS of 5 (5.5 for first and second time calvers). The other cows returned to LUDF in relation to their calving dates by early August (R. Pellow, personal communication, 22 August, 2014).

4.5 Proposed system

This study will build on the findings of Jenkinson *et al.* (2014) that were described in the literature review in Chapter 2. As this study was conducted at the same site of the proposed system, this data will provide the basis for some of the input data concerning the system. The fodder beet crop was sown in October and yielded 19.2t DM/ha. The Jenkinson *et al.* (2014) study found that cows consumed 90% of fodder beet, when allocated at 8 kg DM/day and fed with 6 kg DM/day of grass silage, within six hours of allocation. From this information, it will be assumed that cows can consume close to 100% of the fodder beet allowance when it is allocated on its own within six hours. The silage will be fed on the standoff pad when the cows are stood off the paddock. The materials used on the structure will be stones and straw as these materials will allow the deposited faeces and urine to drain through and be captured.

4.6 Proposed structure

4.6.1 Standoff pad shape and size

The proposed standoff structure is an uncovered standoff pad with an effluent system to be built at Ashley Dene on the existing wintering area. The standoff pad was designed with assistance from an engineer at Lincoln University. The standoff pad was able to be uncovered due to the low rainfall in the Canterbury region. After analysing many options, the major consideration for the standoff pad shape and design was ensuring animal welfare guidelines were adhered to. For 400 cows, the area of the standoff pad was required to be 3,200 m^2 (8 m^2 /cow), with feeding space of 420 m (0.8 m/cow at the troughs). To ensure that this was met, areas and perimeters of various shapes were analysed to see which could meet the guidelines most efficiently. For designs with a circular shape, the circumference was also calculated three metres inside the shape to ensure that there was sufficient room for the cows' pregnant bodies at an angle. Table 6 details the shapes considered for the pad.

Table 6: Standoff pad shape

Shape	Perimeter	Area	Advantages	Disadvantages
Square (86 m x 86 m)	344 m (800 mm /cow)	7396 m^2 (18.5 m^2/cow)	ᵒ Straight line (easy) feeding out ᵒ Easy construction ᵒ A lot of space/cow	ᵒ 36 m^2 wasted in corners ᵒ Wasted space in the middle ᵒ Long distance for effluent to travel ᵒ Inefficient perimeter: area ratio
Rectangle (56 m x 116 m)	344 m (800 mm/cow)	6496 m^2 (16.24 m^2/cow)	ᵒ Less wasted space in the middle compared to square shape ᵒ Straight line (easy) feeding out ᵒ Easy construction	ᵒ 36 m^2 wasted in corners Inefficient perimeter: area ratio
Rectangle (26 m x 146 m)	344 m (800 mm/cow) ᵒ	3796 m^2 (9.49 m^2/cow)	ᵒ Same as above, but more efficient in terms of perimeter: area ratio	ᵒ 36 m^2 wasted in corners
Circle (radius 54 m)	339.3 m (848 mm/cow, three metres in 800 mm/cow)	9160.9 m^2 (22.9 m^2/cow)	ᵒ High area per cow- good animal welfare ᵒ Only one feeding out motion-saves time	ᵒ Feeding out and cleaning more difficult ᵒ Wasted space in the middle ᵒ Railing more complicated ᵒ More wasted space in the middle ᵒ Long effluent distance
2 x rectangle (26 m x 66 m)	368 m (800 mm/cow)	3432 m^2 (8.58 m^2/cow)	ᵒ Could prioritise feeding with different conditioned cows on each pad ᵒ Easy construction ᵒ Less wasted space than other options ᵒ Straight line (easy) feeding out ᵒ Shorter distance for effluent to travel ᵒ High efficiency of perimeter: area ratio compared with other shapes investigated	ᵒ 76 m^2 wasted space
Oval (100 m long, radius= 22 m)	On side= 800 mm/cow In ends= 921 mm/cow head, 796 mm/cow 3 metres in	5920.5 m^2 (14.8 m^2/cow)	ᵒ No space wasted with corners ᵒ Distance for effluent not that great	ᵒ Feeding and cleaning out more difficult ᵒ Possible difficult construction
Oval (138 m long, radius= 10 m)	On side= 800 mm/cow In ends= 1142 mm/cow head, 800 mm/cow 3 metres in	3074 m^2 (7.7 m^2/cow)	ᵒ No space wasted with corners ᵒ Distance for effluent not that great	ᵒ Not enough space/cow (animal welfare) ᵒ Feeding and cleaning out more difficult ᵒ Possible difficult construction
Oval (123 m long, radius= 15 m)	On side= 800 mm/cow In ends= 992 mm/cow head, 802 mm/cow 3 metres in	4396 m^2 (11 m^2/ cow)	ᵒ No space wasted with corners ᵒ Distance for effluent not as great	ᵒ Feeding and cleaning out more difficult ᵒ Possible difficult construction

As the two rectangle shapes were found to be the most efficient in terms of meeting both the area and feeding space animal welfare guidelines, this shape was chosen for further design. In order for ease of moving cows on and off the standoff pad, it was decided to have double gates at the end of each pad which also allowed for cleaning from either end. This resulted in removing troughs at the end of the pad, so the length of the pad was extended to 80 m to allow more trough space along the side. This led to a reduction in wasted space in the corners and also improved the efficiency of the perimeter area ratio.

The solid manure will be scraped to a concrete collection area at the end of the pad. A weeping wall, designed to remove solids from effluent, will allow the liquid effluent to be separated and flow to the effluent pond. The liquid effluent that is deposited onto the straw will also drain to the pond. A schematic representation of the structure's design can be found in Figure 2.

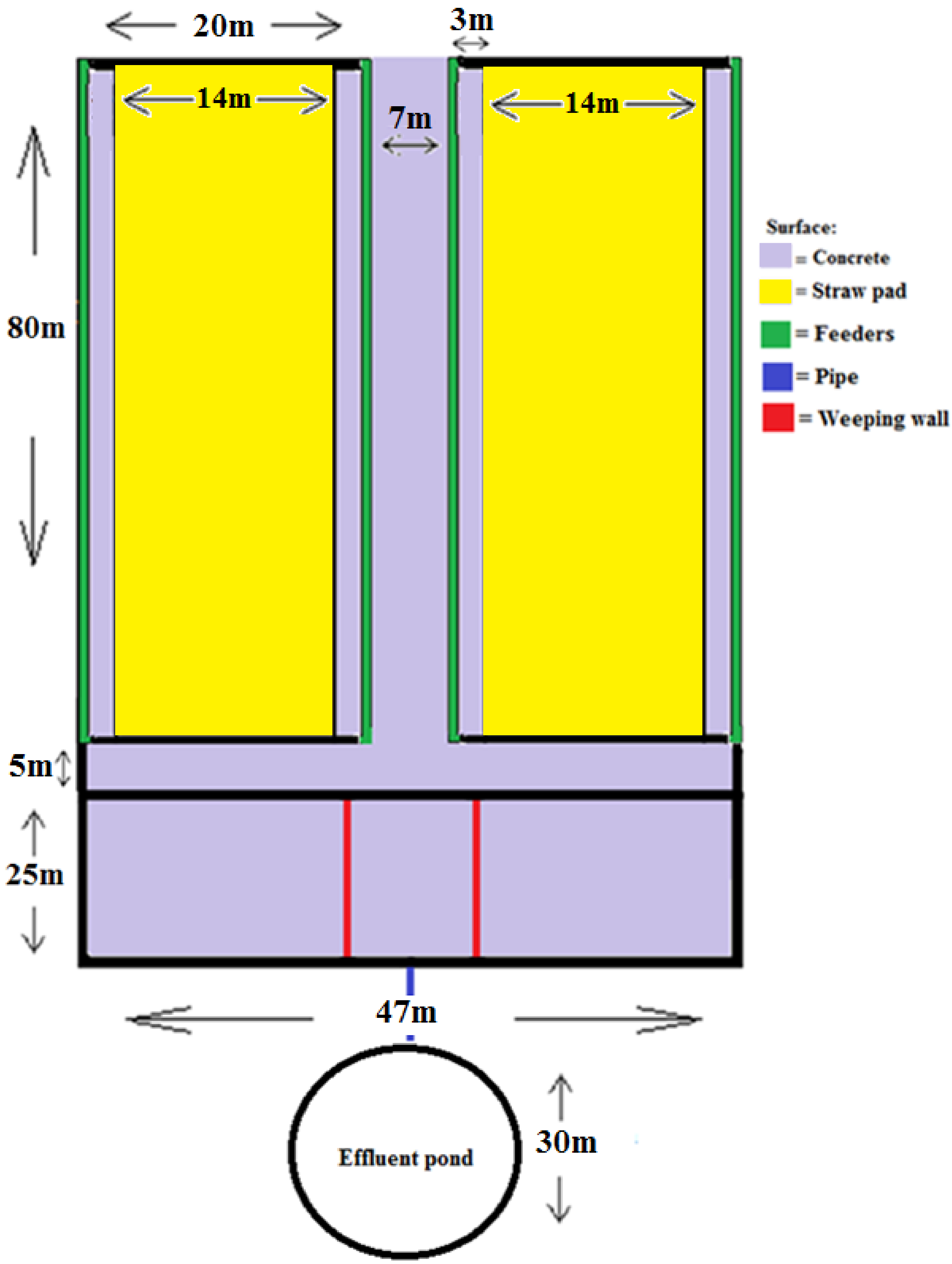

Figure 2: Shape of standoff pad

4.6.2 Standoff pad construction

The standoff pad will consist of a variety of products including a plastic sheet, bentonite, stones and straw. Earthworks will be the first step in the construction process. Two pits will be excavated, with dimensions of 80 m x 20 m x 0.775 m (see Figure 2) in order to form a tub for the products.

First, a plastic sheet of suitable grade for an effluent system will be placed on the soil to ensure that the effluent could not escape, even if the bentonite did split or crack. This is important as escaped excreta from a standoff pad can result in nitrate leaching levels higher than a forage crop system (Monaghan, 2012). Next bentonite will be laid to seal the standoff pad. It will be laid at a depth of 0.075 m. Despite bentonite being more expensive per unit compared with concrete, $53,962 can be saved due to a less labour costs required for laying, as shown on Table 7. Bentonite is also self-sealing (I. Domigan, personal communication, 6 June, 2014) which is important to mitigate losses as much as possible, especially in a region that has had several recent earthquakes.

Table 7: Total cost of using concrete and bentonite on standoff pad

Total area required (m^3)	Laid concrete	Laid bentonite
336	$ 95,962	$ 42,000

The laying of stones to facilitate drainage will be next in the construction process. The stones, approximately 15 mm each in diameter, will be laid on top of the bentonite at 0.4 m deep. Lastly, straw will be placed on top of the stones for cows to lie and loaf on. The straw would be applied at a thickness of 0.3 m. In order to reduce straw building up around the feeding troughs, an area 3 m in width and 0.15 m in depth, will be concreted in front of the troughs. This area would not be covered in straw. Fresh straw will be added to the stones as required. Effluent from the feeding area will be scraped to a holding area to be stored.

The feeding modules will be made out of concrete. The modules will also act as a fence around the feeding sides (B.Miller, personal communication February 2014).

4.7 Proposed system's operating regime

4.7.1 Wintering system

The cows would arrive on the property in late May once they have been dried off. The transition period from the pasture diet that the cows have been fed during the milking season to the winter diet is important as acidosis is a potential issue due to the high water soluble carbohydrate content and low fibre of fodder beet. It is recommended by Clutha Vets (2012) to have a 14 day transition period where the fodder beet is introduced slowly and cows cannot gorge. This consists of feeding 2 kg DM per cow per day, while supplementing the rest of their energy requirements with silage. The fodder beet allowance will increase by 1 kg DM every second day with the silage allowance being decreased accordingly. The cows would return to the LUDF property at the end of July, for a total of 61 days on the system.

4.7.2 Daily system overview

The cows will be moved onto the fodder beet in the morning and remain in the paddock for six hours. The paddock will be split into breaks of daily feed using temporary electric fencing. The breaks will allow for 8 kg DM per cow per day of fodder beet (3,200 kg DM/day total).

During the grazing period, straw as necessary for cow comfort will be added to the standoff pad. The straw will be moved onto the standoff pad using a front end loader and the cows will spread the straw through their movements (M. Hunter, personal communication, 6 October, 2014). Grass silage will be put into the troughs along the side of the structure using a feed out wagon. This will be allocated at 6 kg DM/day (2,400 kg DM/day total). If necessary, the troughs will be cleared using a shovel before the new silage is placed into the troughs.

After the six hour grazing period, the cows will be moved off the fodder beet by staff and onto the standoff pad where they will consume the allocated grass silage and remain for the rest of the day.

All urine and faeces deposited during the 18 hour period the cows are on the standoff pad will be collected. The liquids that drain through the straw/stones and the liquids collected from the concrete storage pad will be stored in the effluent pond and eventually spread over a 30 ha area at Ashley Dene. The solids will also be spread at Ashley Dene on the same 30 ha as the liquid effluent. After the winter period in August, the straw will be removed from the standoff pad and composted for later spreading. This will be carried out at a low leaching risk time of year when rainfall is low and plant growth and uptake is high (September-December).

Chapter 5:
Financial analysis

.

5.1 Introduction

The purpose of this analysis is to prepare a budgeting analysis to determine how the systems compare financially. Using the information described in Chapter 4, assumptions will be made regarding the cost of implementing the system. Partial budgets will be used in order to evaluate the total cost of wintering as well as the cost per cow per week and the income in the farm's cost of production per kg MS in the respective systems. This information will be used to calculate the cost of per kg of nitrate leaching mitigation in Chapter 6 after the environmental analysis has been conducted.

5.2 Fodder beet costs

In the historical system, 8 kg DM per cow per day would be fed to the 400 cows over a 61 day period, resulting in a total annual demand of 195,200 kg DM of fodder beet. The feed requirements and daily allocation of fodder beet of the proposed system was determined from the work of Jenkinson *et al.* (2014) and are detailed in Table 8. This feed requirement considers the cows' maintenance, pregnancy and BCS gain requirements through the winter period. The fodder beet will be allocated at the same rate in both systems. It is anticipated that the fodder beet would yield 19.2 t/ha (Jenkinson *et al.*, 2014), which results in 10.17 ha of fodder beet being required in order to meet the total feed demand. As the same area and production is being assumed for both systems, it will also be assumed that the same costs are associated with fodder beet in both systems.

Table 8: Fodder beet requirements

Winter period (days)	61
Cows	400
Fodder beet yield (kg DM/ha)	19,200
Fodder beet in 6 hours (kg DM)	8.0
Silage (kg DM/day)	6.0
Fodder beet total (kg DM)	195,200
ha required	10.17
Total silage (kg DM) for the historical system	146,400

The cost of growing fodder beet is made up of the establishment, fertiliser and weed control costs, as shown in Table 9. It will be assumed that the fodder beet will be sown using conventional cultivation techniques and fertiliser and weed control practices as advised in the 'Fodder beet growing and grazing guide' (Speciality Seeds, 2014). A fine and fertile seed bed for fodder beet establishment is necessary. In November of the year prior to the fodder beet grazing, the paddock will be cultivated through use of a plough, maxitill (x3) and Cambridge roller. The fodder beet seed will be sown using precision drilling at a rate of 4 kg/ha. At establishment, Cropzeal 16 and salt will be applied. Urea will be applied in the three months following establishment. Weed control of fodder beet is very important in growing a successful fodder beet crop. In this system weeds will be controlled using Roundup Transorb before establishment, Norton applied twice pre-emergence, Lorsban and Betanal Forte post crop establishment (Speciality Seeds, 2014).

Table 9: Costs of fodder beet establishment

Establishment					
Ploughing					
	10.17 ha	@	$138.00 /ha	**$1,403.00**	
Maxitill (x3)					
	10.17 ha	@	$45.00 /ha	**$1,372.50**	
Cambridge roll					
	10.17 ha	@	$30.00 /ha	**$305.00**	
Precision drilling					
	10.17 ha	@	$135.00 /ha	**$1,372.50**	
Seed					
	40.67 kgs	@	$30.00 /kg	**$1,220.00**	
					$5,673
Fertiliser					
Cropzeal 16					
	175 kg/ha	@	$0.87 /kg	**$1,546.10**	
Agricultural salt					
	125 kg/ha	@	$0.40 /kg	**$504.52**	
Urea 1st application					
	90 kg/ha	@	$1.00 /kg	**$915.00**	
Urea 2nd application					
	90 kg/ha	@	$1.00 /kg	**$915.00**	
Urea 3rd application					
	90 kg/ha	@	$1.00 /kg	**$915.00**	
Fertiliser spreading first application					
	10.17 ha	@	$17.00 /ha	**$172.83**	
Fertiliser spreading second application					
	10.17 ha	@	$17.00 /ha	**$172.83**	
Fertiliser spreading third application					
	10.17 ha	@	$17.00 /ha	**$172.83**	
					$5,314
Weed control					
Roundup Transorb					
	3.20 L/ha	@	$11.22 /L	**$364.94**	
Lorsban					
	0.40 kg/ha	@	$125.00 /g	**$508.33**	
Norton pre emergence					
	2.00 L/ha	@	$49.04 /L	**$997.15**	
Norton pre emergence					
	2.00 L/ha	@	$49.04 /L	**$997.15**	
Betanal Forte					
	3.00 L/ha	@	$140.00 /L	**$4,270.00**	
					$7,138
TOTAL ESTIMATE					**$18,125**

5.3 Annual costs of historical wintering system

The historic wintering system requires no infrastructure but the total cost of the system is made up of the annual costs of fodder beet establishment, silage, machinery and labour. As land costs will be the same in both systems, it is not included in the annual costs. However, it is acknowledged that this cost does exist and would add to the cost of wintering within a farm system.

5.3.1 Silage costs of historical system

The historical system feeds 146.4 t DM of silage annually in order to provide 6 kg DM per cow per day. At a purchase price of $0.35/kg DM (R. Pellow, personal communication, 22 August, 2014), this results in a total annual cost of $51,240.

5.3.2 Machinery costs of historical system

The historical system requires a feed out wagon and a tractor to be operated in order to feed out silage onto the paddock. The feed out wagon required would be 6.3 m^3 and cost $45,000, with a useful life of 2,000 hours. The tractor required would be 100 hp and cost $100,000, with a useful life of 6,000 hours. A machinery costing spreadsheet is shown on Table 10. This spreadsheet accounts for overhead and variable costs and predicts that the feed out wagon will be $29.03 per hour and the tractor running costs will be $44.67 per hour, for a total of $73.70 per hour.

Table 10: Cost per hour of tractor and feed out wagon operation

MACHINE:	**FEED OUT WAGON**		**OVERHEAD COSTS**		
			Opportunity Cost on Avg. Value		$15,400.00
Purchase Price		$45,000.00	Depreciation		$35,000.00
Salvage Value		$10,000.00	Insurance		$3,150.00
Useful Life in Hours		2000 hrs	Registration		$0.00
Kilowatts		0	**TOTAL OVERHEADS**		**$53,550.00**
Opportunity Cost		8.00%			
Annual Use in Hours		300 hrs	**VARIABLE COSTS**		
Life in Years		7.00 Yrs	Repairs & Maintenance		$4,500.00
Depreciation Rate		15.00%	Fuel	0.26 kw/Hr	$0.00
Marginal Tax Rate		0.00%	Lubrication		$0.00
Registration per annum		-	Labour		$0.00
Insurance @	1.00% pa	$ 450.00	**TOTAL VARIABLE COSTS**		**$4,500.00**
R & M as %age of Cost		10.0%	**TOTAL COST**		**$58,050.00**
Cost of Fuel per Litre		0	**COST PER HOUR**		**$29.03**
MACHINE:	**TRACTOR**		**OVERHEAD COSTS**		
			Opportunity Cost on Avg. Value		$54,000.00
Purchase Price		$100,000.00	Depreciation		$65,000.00
Salvage Value		$35,000.00	Insurance		$10,000.00
Useful Life in Hours		6000 hrs	Registration		$1,000.00
Kilowatts		74	**TOTAL OVERHEADS**		**$130,000.00**
Opportunity Cost		8.00%			
Annual Use in Hours		750 hrs	**VARIABLE COSTS**		
Life in Years		10.00 Yrs	Repairs & Maintenance		$10,000.00
Depreciation Rate		15.00%	Fuel	0.20 /kwHr	$124,320.00
Marginal Tax Rate		0.00%	Lubrication		$3,729.60
Registration per annum		$ 100.00	Labour		$0.00
Insurance @	1.00% pa	$ 1,000.00	**TOTAL VARIABLE COSTS**		**$138,049.60**
R & M as percentage of Cost		10.0%	**TOTAL COST**		**$268,049.60**
Cost of Fuel per Litre		$ 1.40	**COST PER HOUR**		**$44.67**
TOTAL COST TO RUN BOTH MACHINES PER HOUR					**$73.70**

After consultation with Canterbury dairy farmers (M. Pangborn, personal communication, 14 October, 2014), it was determined that loading of the feed out wagon and feeding it onto the paddock would take 1.5 hours each day. This results in a total annual machinery cost of $6,744 as shown on Table 11.

Table 11: Historical system annual machinery costs

Hours/day	1.5
Total hours	91.5
Total cost	$6,744

5.3.3 Labour costs

The historical system requires a labour unit to load up and feed the silage and move the breaks. After consultation with Canterbury dairy farmers (M. Pangborn, personal communication, 14 October, 2014), it was determined that the loading of the feed out wagon and feeding the silage onto the paddock would take 1.5 hours each day and moving breaks and the cows would take half an hour each day, resulting in a daily labour requirement of two hours and an annual labour requirement of 122 hours. At $20 per hour, this results in a labour cost of $2,440.

5.4 Proposed system infrastructure

The proposed system will require infrastructure for operation. There will be capital costs incurred by the farming business which will require annual debt servicing. It was assumed in this project, after consultation with bankers, that interest rates over a long term loan will be 7% (J. Clayton, personal communication, 3 September, 2014). The depreciation rates for the pad and pond will be assumed at 5% (L. Dick, personal communication, 3 September, 2014).

5.4.1 Standoff pad

The standoff pad as described previously in Chapter 4 will be the most significant capital cost, as detailed in Table 12. The costs of the items and labour were supplied by engineer I. Domigan (personal communication, 6 June, 2014). This results in a total cost of $229,406, which is a cost of $574/cow.

Table 12: Standoff pad costs (materials and labour inclusive)

Plastic	2240	m^2	@	$1.50	per m^2	$3,360
Bentonite	336	m^3	@	$125.00	per m^3	$42,000
Rocks	896	m^3	@	$8.00	per m^3	$7,168
Concrete feeding area	144	m^3	@	$285.60	per m^3	$41,126
Concrete strip between pads	84	m^3	@	$285.60	per m^3	$23,990
Concrete at end of pad	176.25	m^3	@	$285.60	per m^3	$50,337
Feeding modules	100		@	$500.00	per each	$50,000
Stock water system 2 troughs			@	$450.00	per each	$900
Connecting to current water system						$2,000
Gates	8		@	$100.00	per each	- $800
Contingency	@	5%		of total cost		$11,084
TOTAL COST						**$229,406**
ANNUAL INTEREST SERVICING @ 7%						**$16,058**
DEPRECIATION @ 5%						**$11,470**

5.4.2 Effluent pond

The effluent pond will be another capital cost incurred when developing this system. As indicated in Figure 3, the facility will need to hold 4,337 m^3 which is specific to the mean rainfall over a 30 year period. The size was determined by utilising the Dairy Effluent Storage Calculator (DESC) designed by Massey University and Horizons Regional Council. The DESC combines long-term climatic data, supplied by NIWA and Plant and Food Research, and farm details, such as climate, soil risk factor and rainfall catchment area, to produce the effluent storage volume required (DairyNZ, 2013a).

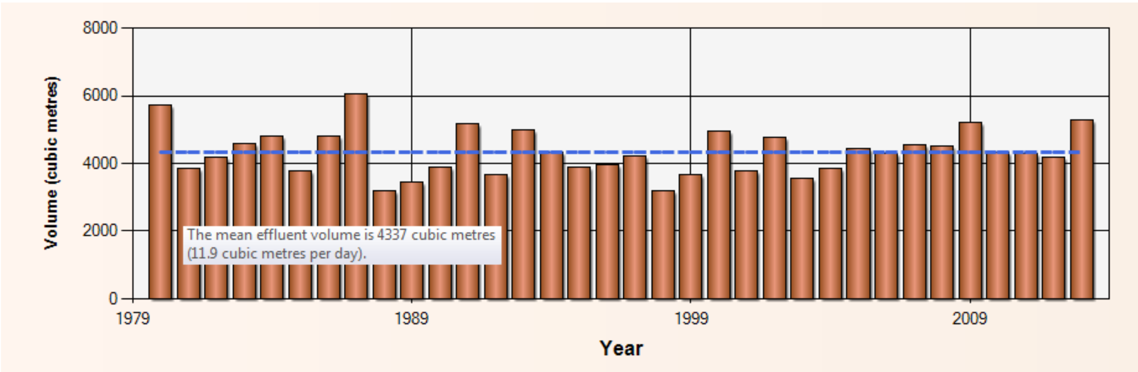

Figure 3: Effluent pond size estimation

This calculation was review by a sustainability officer from Fonterra (M. Cullen, personal communication, 27 July, 2014). The initial effluent pond design was reviewed by commercial agricultural engineering firm (M. Lotter, personal communication, 4 August, 2014) and this informant provided estimated prices as shown in Table 13. This results in a total cost of $62,000, which is a cost of $155/cow.

Table 13: Effluent system costs (materials and labour inclusive)

750m^3 envirosaucer	$	47,000
Application, engineering, designs, certification, testing etc for statutory consents	$	5,000
Excavations and ground works for saucer	$	10,000
TOTAL COST	**$**	**62,000**
ANNUAL INTEREST SERVICING @ 7%	**$**	**4,340**
DEPRECIATION @ 5%	**$**	**3,100**

5.5 Proposed system annual costs

Along with the debt servicing on the capital items, the proposed system will incur a number of annual costs as detailed below in the following tables.

5.5.1 Machinery costs

The proposed system will require a tractor and feed out wagon of the same specifications as the historical system in order to feed out silage onto the standoff pad. The hourly cost of operating the machines will be the same as the historical system and is detailed in Table 10. After consultation with Canterbury dairy farmers (M. Pangborn, personal communication, 14 October, 2014), it was determined that the loading of the feed out wagon and feeding the silage onto the standoff pad would take one hour each day for the proposed system. The total annual cost is detailed in

Table 14.

Table 14: Annual machinery costs

Hours/day	1
Total hours	61
Total cost	$4,496

5.5.2 Silage

The silage requirements will be based upon the work of Jenkinson *et al.* (2014). In this study it was reported that cows were fed 6 kg DM per cow per day when fed on crop. It will be assumed after consultation with farmers who have used a similar system, that the utilisation of this was 80% (M. Pangborn, personal communication, 14 October, 2014). As the silage is fed on a standoff pad in the proposed system, it will be assumed the utilisation is higher and closer to 100%. This results in feeding the cows 4.8 kg DM per cow per day, resulting in 117.1 t DM of silage required annually, in order to achieve the same energy intake as reported in the work of Jenkinson *et al.* (2014). At a purchase price of $0.35/kg DM, this results in a total annual cost of $40,992.

5.5.3 Straw

Straw will be applied to the standoff pad as required. It was assumed that 200 bales, measuring 0.9 m x 1.2 m x 2.1 m, will be required annually (P. Davey, personal communication, 9 October, 2014). Each bale will be assumed to cost $45. This will result in a total annual cost of $9,000.

5.5.4 Straw removal

The straw will be removed from the standoff pad at the end of each winter period. Due to the continual trampling from the cows and the cows eating some of the straw, there will be a lower volume of straw than what was applied. After consulting with a farmer who has a similar system, it was assumed that the total volume of straw for removal at the end of the winter would be 230 m^3 (P. Davey, personal communication, 9 October, 2014). The cost of removal and spreading will be assumed at $6 m^3 which will result in a total annual cost of $1,500.

5.5.5 Effluent transportation

The mean annual effluent volume will be 4,337 m^3 as shown on Figure 3. Cost of removing and spreading the effluent will be assumed to cost $6/$m^3$ (M. Lovett, personal communication, 22 September, 2014). This will result in a total annual cost of $26,022.

5.5.6 Standoff pad repairs and maintenance

It is assumed that repairs and maintenance of the standoff pad will be $5,000 per year (I. Domigan, personal communication, 6 June, 2014).

5.5.7 Labour costs

A labour unit will be required to load and feed the silage from the feed out wagon, move the breaks and move the cows on and off the standoff pad. After consultation with Canterbury dairy farmers (M. Pangborn, personal communication, 14 October, 2014), it was determined that loading the feed out wagon and feeding it onto the standoff pad would take one hour each day and moving the breaks and the cows to and from the standoff pad would take 1.5 hours each day, resulting in a daily labour requirement of two and a half hours and an annual labour requirement of 152.5 hours. At $20 per hour, this results in a labour cost of $3,050.

5.6 Total annual costs

The proposed system is 82.3 % more expensive than the historical system as shown on Table 15, with costs per cow per week being $41.07 for the standoff and $22.53 for the historical system. There is a difference between the two systems of $64,605 annually or $18.54 per cow per week. In terms of the cost per kg MS, the proposed system is $0.34/kg MS more expensive, when production per cow is assumed to be 475 kg MS in both systems.

Table 15: Total annual costs

	Historical system		Proposed system	
Feed pad @ 7% interest on capital cost			$	16,058
Effluent storage @ 7% interest on capital cost			$	4,340
Feed pad depreciation @ 5%			$	11,470
Effluent storage depreciation @ 5%			$	3,100
Fodder beet	$	18,125	$	18,125
Tractor and feedwagon running costs	$	6,744	$	4,496
Silage	$	51,240	$	40,992
Straw			$	9,000
Straw removal and spreading			$	1,500
Effluent spreading			$	26,022
Feed pad repairs and maintenance			$	5,000
Labour	$	2,440	$	3,050
TOTAL ANNUAL COST	**$**	**78,548**	**$**	**143,153**
COST PER COW PER WEEK	**$**	**22.53**	**$**	**41.07**
COST PER KG MS	**$**	**0.41**	**$**	**0.75**

Chapter 6:
Environmental analysis

6.1 Introduction

The purpose of this chapter is to perform an analysis using Overseer® version 6.1.3 to determine how the systems compare environmentally. This computer modelling tool produces nutrient flows from input data concerning details about a property. While Overseer® was originally developed as a decision support tool for making economic fertiliser recommendations, it has since been developed to estimate nutrient losses. It is currently the accepted tool which regional councils are using to monitor farms' leaching levels.

The input information concerning the dairy pastoral block was obtained from the LUDF management (R. Pellow, personal communication, 22 August, 2014) and was consistent across the current and proposed scenario. Input data concerning the dairy system can be found in the Appendices (A.1 & A.2).

6.2 Adaptations to model

Overseer® operates within certain guidelines to project the nutrient flows from a system. When a system falls outside of these guidelines, Overseer® cannot project the nutrient flows. In order to generate results for this study, adaptations had to be made to the input model. A summary of these adaptations follow.

When the proposed wintering system was modelled, Overseer® version 6.1.3 guidelines suggested that the amount of fodder beet and silage fed in the works of Jenkinson *et al.* (2014) could not be fed. In order to receive a prediction of nitrogen lost to water, the feed input would have had to be reduced from 8 kg DM to 5.2 kg DM of fodder beet and from 6 kg DM to 3.9 kg DM of silage. As the work of Jenkinson *et al.* (2014) suggested that a higher feeding level of 8 kg DM and 6 kg DM of fodder beet and silage respectively was possible, this would not accurately reflect the system.

It is proposed that this occurred due to the utilisation assumptions that exist within Overseer® version 6.1.3, with utilisation on a standoff pad assumed to be substantially higher than when fed on a crop paddock. However, feeding at this rate would have resulted in inconsistent assumptions between the two systems which could negatively impact upon the accuracy of results and would not allow for a relative comparison. After consultation with Overseer® experts, it was suggested that 1) the wintering systems be incorporated into a whole dairy scenario (rather than a separate block) and 2) the silage be fed on the paddock, with the cows still being stood off for 18 hours per day. With these adaptations, Overseer® version 6.1.3 was able to calculate nutrient flows from the system. However, the comparisons will be made between the block report components of the models, opposed to the scenario reports, as the scenario reports would include nutrient flows from the pastoral block on the dairy farm. This will ensure that nutrient flows are associated with only the wintering system, despite being part of a dairy farm scenario.

Another problem that Overseer® version 6.1.3 developers identified was that the available water capacity (AWC) values differ between industry standard S-map factsheets[1] and the AWC values produced in the scenario reports of the programme. As AWC is an important driver of drainage, it is therefore also an important driver of nitrate leaching so inaccuracies may negatively impact upon the reliability of the results. The developers of Overseer® version 6.1.3 admit this error exists and anticipate that this error will be resolved by April 2015; however, as this dissertation has a deadline of November 2014, the soil profile was altered in consultation with industry professionals in order to make the results as accurate as possible. This change was kept consistent across both the current and the proposed system to allow for an even comparison.

6.3 Historical system

6.3.1 Overseer® input information

This system is based on the historical wintering system of the LUDF cows. Cows are wintered at the Ashley Dene property on fodder beet, supplemented with silage, for a total of 61 days. This system was detailed in Chapter 4. A full report of Overseer® inputs can be found for the historical wintering system in the Appendices (A.1).

[1] S-maps factsheets have been developed by Landcare Research and contain quantitative and comprehensive information about key properties of a soil. Using a suite of models, these properties are interpreted to classify soils regarding environmental risk (Landcare Research, 2014).

Table 16 summarises the critical assumptions included in the Overseer® model for the historical system. A full report of Overseer® inputs can be found for the historical wintering system in the Appendices (A.1).

Table 16: Summary of Overseer® information for historical wintering system

Location	Christchurch
Blocks	Pastoral: 116.0 ha, Crop: 10.17 ha, Total area: 132.0
Supplements imported	146t DM average quality purchased silage on crop
Cows:	Numbers: June: 400, July: 400. F x J Cross breed, Median calving date: 14 August, Maximum weight: 501 kg
Production	Milk solids: 160,000, Lactation length: 268 days
Climate	Daily rainfall pattern: 592 mm rainfall per year, Mean annual temperature: 11.8°C, PET: 909 mm
Soil description	Soil by order: Brown, Soil group: default (sedimentary)
Soil profile	Top soil texture: silt loam, Soil texture group: medium, Non-standard layer: stony, Depth to non-standard layer: 25cm
Soil tests	ASC or PR: default (43%), TBK reserve K: default (0.31 me/100g)
Crop block history	Years in pasture: 1, Prior land use: pasture, grazed by farm stock
Crop rotation	Fodder beets sown in November, 19.2t/ha, conventional cultivation practice at sowing. Fertiliser (both year 1 and reporting year): November Year 1: Cropzeal 16N (incorporated) 175 kg/ha, salt (sodium chloride) 125 kg/ha. December, January, February Year 1: N-rich urea (surface applied) 90 kg/ha. Grazing: June, July. Grazed in-situ by Farm stock (see Enterprise numbers panes)

6.3.2 Nutrient budget results

Nutrient budgets are produced in Overseer® version 6.1.3 as a table of nutrient inputs and outputs, as shown in Table 17. Also accounted for in the model are differences in internal organic and inorganic pools. For crop blocks, as used in both the historical and proposed systems, the difference in the amount of nutrients in standing crop and stover are accounted for between the beginning and end of the year. The value which determines nitrate leaching is the 'N to water' calculation. In the historical system it is predicted to be 65 kg N/ha/year.

Table 17: Nutrient budget

(kg/ha/yr)	N	P	K	S	Ca	Mg	Na
Nutrients added							
Fertiliser, lime & other	167	14	18	17	0	0	49
Rain/clover N fixation	2	0	2	4	2	4	19
Irrigation	0	0	0	0	0	0	0
Supplements	310	39	258	30	67	23	18
Nutrients removed							
As product	92	16	21	6	22	2	6
As supplements and crop residues	0	0	0	0	0	0	0
To atmosphere	63	0	0	0	0	0	0
To water	65	0.0	5	17	87	4	9
Change in block pools							
Standing plant material	182	21	162	36	105	18	78
Root and stover residuals	-125	-13	-49	3	-5	-3	-2
Organic pool	203	-11	0	-11	0	0	0
Inorganic mineral	0	12	-11	0	-1	-1	-2
Inorganic plant available	0	28	150	0	-139	9	-5

6.4 Proposed system

6.4.1 Overseer® input information

As per the previous analysis, this system is based on the Ashley Dene property, wintering 400 cows in a restricted grazing regime on fodder beet (6 hours) for a total of 61 days, during June and July. The remainder of the day (18 hours), the cows are stood off the crop on a standoff pad where they receive silage. This system was detailed in Chapter 4.

Table 18 outlines the critical assumptions with the adaptations included in the Overseer® model for the proposed system with adaptations included. A full report of Overseer® inputs can be found in the appendices (A.2).

Table 18: Summary of Overseer® information for proposed system

Location	Christchurch
Blocks	Pastoral: 116.0 ha, Crop: 10.17 ha, Total area: 132.0
Structures	Wintering pad
Supplements imported	146t DM average quality purchased silage on crop
Numbers	Numbers: July: 400, August: 400, September: 390, October: 380, November: 375, December: 375, January: 370, February: 370, March: 360, April: 330, May: 300, June: 400 F x J Cross breed, Median calving date: 14 August, Maximum weight: 501 kg
Production	Milk solids: 160,000, Lactation length: 268 days
Wintering pad	Uncovered wintering pad, Pad surface: carbon rich, lined, subsurface drained and effluent captured. Solids and effluent all exported, in storage facility for three months (open to rain)
Management	Feeding regime: wintering pad + grazing, 100% of milking herd on pad in June, July, 0% in all other months, Hours per day grazing: 6.0 hours in June, July, 0% in all other months.
General	24 km from coast,100% cultivated area
Climate	Daily rainfall pattern: 592 mm rainfall per year, Mean annual temp: 11.8°C, PET: 909 mm, Seasonal variation: moderate PET
Soil description	Soil by order: Brown, Soil group: default (sedimentary)
Soil profile	Top soil texture: silt loam, Without stones and not compacted. Soil texture group: medium, Non-standard layer: stony, Depth to non-standard layer: 25
Crop block history	Years in pasture: 1, Prior land use: pasture, Source of animals grazing pasture: farm stock- see enterprise numbers panes
Crop rotation	Fodder beets sown in November, 19.2t/ha, conventional cultivation practice at sowing, Fertiliser: November Year 1: Cropzeal 16N (incorporated) 175 kg/ha, salt (sodium chloride) 125 kg/ha. December, January, February Year 1: N-rich urea (surface applied) 90 kg/ha. Grazing: June, July. Grazed in-situ by Farm stock (see Enterprise numbers panes) for 6.0 hours a day.

6.4.3 Nutrient budget for the proposed system

The result of the adapted model is a nutrient budget, also containing nutrient inputs and outputs as well as changes in internal organic and inorganic pools. In this system it is predicted nitrogen loss to water to be 28 kg N/ha/year, as shown on Table 19.

Table 19: Overseer® block report for the proposed system

(kg/ha/yr)	N	P	K	S	Ca	Mg	Na
Nutrients added							
Fertiliser, lime & other	167	14	18	17	0	0	49
Rain/clover N fixation	2	0	2	4	2	4	19
Irrigation	0	0	0	0	0	0	0
Nutrients removed							
As product	91	16	21	5	22	2	6
As supplements and crop residues	0	0	0	0	0	0	0
Net transfer by animals	279	32	238	54	168	27	122
To atmosphere	30	0	0	0	0	0	0
To water	28	0.0	4	6	58	4	9
Change in block pools							
Standing plant material	182	21	162	36	105	18	78
Root and stover residuals	-125	-13	-49	3	-5	-3	-2
Organic pool	-316	-11	0	-84	0	0	0
Inorganic mineral	0	12	-44	0	-1	-1	-2
Inorganic plant available	0	-43	-312	0	-344	-42	-145

6.5 Differences between the systems

The proposed system leaches 56.9% less nitrogen than the historical system as shown on Table 20. The nitrate leaching difference between the two systems is 37 kg N/ha/year, with a total annual difference of 376 kg N between the two systems. As the financial difference between the two systems was $64,605 annually, this equates to a cost of $171 per kg of nitrogen mitigated. This value can be used to compare this system to other systems which mitigate nitrate leaching.

Table 20: Nitrogen loss to water in historical and proposed systems

System	N loss to water (kg N/ha/year)
Historical	65
Proposed	28
Cost of mitigation per kg N	$171

Chapter 7:
Discussion and Conclusions

7.1 Introduction

The purpose of this project was to examine the environmental and economic effects of grazing a fodder beet crop by wintering dairy cows in Canterbury, New Zealand. A mitigation technique involving a standoff pad was analysed. The literature review in Chapter 2 identified that there appeared to be a gap in the knowledge for a fodder beet/standoff pad system in New Zealand. This led to the research questions:

- What are the financial implications of the adoption of a fodder beet/standoff pad system versus the historical LUDF fodder beet wintering system?
- What are the levels of nitrate leaching from a fodder beet/standoff pad system versus the historical LUDF fodder beet wintering system?

In order to answer these questions, assumptions were obtained and budgets prepared to determine the cost of the current system versus the cost of a mitigation strategy (standoff pad and controlled grazing). The financial and environmental effects of the mitigation strategy on the leaching of nitrate to water and on the farm's economic results were analysed.

7.2 Financial findings

7.2.1 Results

The proposed system had greater annual costs than the historical system. The proposed system is 82.3% more expensive than the historical system, with the difference between the two systems being $64,605 annually or $18.54 per cow per week. When production in both systems was assumed at 475 kg MS/cow, the costs per kg of MS were $0.41/kg MS for the present system and $0.75/kg MS for the proposed system or the standoff system increases the farms cost of production by $0.34/kg MS. With a total of 376 kg of nitrogen mitigated, this equates to a cost of mitigation of $171 per kg of nitrogen.

7.2.2 Comparison to literature

The cost of building this particular roofless structure and effluent system was considerably cheaper than those reported in the literature. While Journeaux (2013) reported costs of $1,200-1,500/cow, the proposed system for this project cost $574/cow for the standoff pad and $155/cow for the effluent system, totalling $729/cow. This is likely to be attributed to the savings from the standoff pad being uncovered, due to Canterbury having low rainfall. This was also less than other structures, such as a wintering barn quoted at $4,000/cow (B. Miller, personal communication, 18 September, 2014). Despite the reduced cost for the proposed system, its inclusion raised the cost of wintering per cow per week and hence the cost of production for the farm.

7.3 Environmental findings

7.3.1 Results

Despite the problems encountered with Overseer®, the alternative analysis which featured standing cows off for 18 hours per day reduced the nitrogen lost to water. The leaching levels of the proposed system were 56.9% lower than the current system, with the nitrogen loss to water being 28 kg N/ha for the standing off and 65 kg N/ha for the historical system. This analysis indicates that standoff facilities that collect effluent will reduce nitrate leaching.

7.3.2 Comparisons to literature

These findings aligned with what was reported in the literature review in Chapter 2. It was reported by Dalley (2011), Monaghan *et al.* (2007) and Monaghan (2012) that winter forage crop systems result in high levels of nitrate leaching due to the high density of urine patches when plant growth and uptake of nutrients is low and rainfall and drainage is high. This was quantified by SIDDC (2013), which reported that in Canterbury, winter fodder beet systems result in nitrogen losses to water of 55-60 kg N/ha. While the historic system in this project reported slightly higher levels of leaching, this could be attributed to soil type or stocking rate which differed to the system reported.

There was no data relating to a fodder beet/standoff pad which quantified nitrate leaching. However, de Klein and Ledgard (2001) reported that if grazing time on pasture is reduced during winter, nitrogen losses reduce by 35-50%. While this project found that nitrogen loss to water decreased by 56.9%, this could be attributed to higher leaching in a fodder beet system compared to a pasture system. In a full year experiment in the Manawatu region of New Zealand, Christensen *et al.* (2010) found that by reducing the time cows spent on pasture by 50%, nitrogen loss to water levels were reduced by 41%.

It was reported by Journeaux (2013) that wintering barns have a high financial cost, thus high financial returns are required in order to meet debt repayments. It was suggested by Journeaux (2013) that while this is possible in years with a high milk payout, debt repayments may not be able to be met when the milk payout is lower. It was suggested that a realistic means of ensuring debt repayments can be achieved every year is through intensification by increasing cow numbers. However, when this was analysed by Journeaux (2013), it resulted in a greater leaching loss on a whole farm basis than prior to building the structure. While the proposed system in this study was less expensive than the system in Journeaux (2013), it still may result in the system requiring to be intensified which may increase leaching.

7.4 Brief statement of findings

These results conclude that while a fodder beet/standoff pad system provides a means of reducing nitrogen to water as a wintering system in Canterbury, the cost of this system is significantly higher. The proposed system's levels of nitrogen loss to water were 56.9% lower than the historical system, with losses of 28 kg N/ha compared to 65 kg N/ha for the historical system. The cost of the proposed system was $41.07 per cow per week, 82.3% higher than the cost of the historical system at $22.53. The cost of mitigation is $171 per kg of nitrogen.

7.5 Analysis of alternative scenarios

This research predicts that a standoff facility in a wintering system in Canterbury will reduce nitrate leaching but it increases the costs of wintering. A number of alternative scenarios have been prepared to determine their influence on costs. They include changes to standoff pad and silage costs, interest rates, silage utilisation and the effluent system. A best case scenario has also been prepared.

7.5.1 Standoff pad cost

The standoff pad was the greatest capital cost of the proposed system. If the cost of the standoff pad were to decrease by 10%, the resulting savings in interest would result in the cow per week cost decreasing by $0.79 from $41.07 to $40.28 and reduce total costs by $2,753. If the costs of the standoff pad were able to be reduced by 15% or 20%, the costs per cost per week would decrease by $1.02 and $1.25 respectively as compared to the original calculation of $41.07. This is shown on Table 21.

Table 21: Reduction in standoff pad costs

	-10% standoff pad cost		-15% standoff pad cost		-20% standoff pad cost	
Standoff pad @ 7% interest	$	14,453	$	13,650	$	12,847
Effluent storage @ 7% interest	$	4,340	$	4,340	$	4,340
Standoff pad depreciation @ 5%	$	10,323	$	9,750	$	9,176
Effluent storage depreciation @ 5%	$	3,100	$	3,100	$	3,100
Fodder beet	$	18,125	$	18,125	$	18,125
Tractor and feed out wagon costs	$	4,496	$	4,496	$	4,496
Silage	$	40,992	$	40,992	$	40,992
Straw	$	9,000	$	9,000	$	9,000
Straw removal and spreading	$	1,500	$	1,500	$	1,500
Effluent spreading	$	26,022	$	26,022	$	26,022
Standoff pad repairs and maintenance	$	5,000	$	5,000	$	5,000
Labour	$	3,050	$	3,050	$	3,050
TOTAL ANNUAL COST	**$**	**140,400**	**$**	**139,024**	**$**	**137,647**
COST PER COW PER WEEK	**$**	**40.28**	**$**	**39.88**	**$**	**39.49**
COST PER KG MS	**$**	**0.74**	**$**	**0.73**	**$**	**0.72**

7.5.2 Silage costs

Silage is the most expensive annual cost in both systems therefore changes in the price will impact upon the results. Due to better utilisation in the proposed system than the historical system less silage was fed. If silage costs $0.30, $0.25 or $0.20 per kg DM, in both systems then total costs are reduced as compared to the original calculations. However, the reduction in silage costs lowers the total costs for both systems thus there is no improvement in the competitiveness of the proposed system as compared to the historical system.

Table 22: Reduction in silage price

	Historical system			Proposed system		
Silage priced at:	$0.30/kg DM	0.25/kg DM	$0.20/kg DM	$0.30/kg DM	$0.25/kg DM	$0.20/kg DM
Standoff pad @ 7% interest				$ 16,058	$ 16,058	$ 16,058
Effluent storage @ 7% interest				$ 4,340	$ 4,340	$ 4,340
Standoff pad depreciation @ 5%				$ 11,470	$ 11,470	$ 11,470
Effluent storage depreciation 5%				$ 3,100	$ 3,100	$ 3,100
Fodder beet	$ 18,125	$ 18,125	$ 18,125	$ 18,125	$ 18,125	$ 18,125
Tractor and feedout wagon costs	$ 6,744	$ 6,744	$ 6,744	$ 4,496	$ 4,496	$ 4,496
Silage	$ 43,920	$ 36,600	$ 29,280	$ 35,136	$ 29,280	$ 23,424
Straw				$ 9,000	$ 9,000	$ 9,000
Straw transportation				$ 1,500	$ 1,500	$ 1,500
Effluent transportation				$ 26,022	$ 26,022	$ 26,022
Standoff pad repairs and maintenance				$ 5,000	$ 5,000	$ 5,000
Labour	$ 2,440	$ 2,440	$ 2,440	$ 3,050	$ 3,050	$ 3,050
TOTAL ANNUAL COST	**$ 68,788**	**$ 61,468**	**$ 54,148**	**$134,247**	**$128,391**	**$122,535**
COST PER COW PER WEEK	**$ 19.73**	**$ 17.63**	**$ 15.53**	**$ 38.51**	**$ 36.83**	**$ 35.15**
COST PER KG MS	**$ 0.36**	**$ 0.32**	**$ 0.28**	**$ 0.71**	**$ 0.68**	**$ 0.64**

7.5.3 Interest rates

With the proposed system requiring a standoff pad and effluent system to be constructed for operation, a change in interest rates impacts the difference between the systems. If the interest rate decreases from the proposed 7% in the model to 6%, the proposed system cost per cow per week decreases by $0.66 to $40.41. If the interest rate was to increase to 8%, the proposed system cost per cow per week increases by $0.66 to $41.73. This highlights the importance of securing a competitive interest rate when capital items are required.

Table 23: Variation in interest rate

	Proposed system		
	6% interest rate	7% interest rate	8% interest rate
Interest on standoff pad	$ 13,764	$ 16,058	$ 18,352
Interest on effluent storage	$ 4,340	$ 4,340	$ 4,340
Standoff pad depreciation @ 5%	$ 11,470	$ 11,470	$ 11,470
Effluent storage depreciation @ 5%	$ 3,100	$ 3,100	$ 3,100
Fodder beet	$ 18,125	$ 18,125	$ 18,125
Tractor and feed out wagon costs	$ 4,496	$ 4,496	$ 4,496
Silage	$ 40,992	$ 40,992	$ 40,992
Straw	$ 9,000	$ 9,000	$ 9,000
Straw transportation	$ 1,500	$ 1,500	$ 1,500
Effluent transportation	$ 26,022	$ 26,022	$ 26,022
Standoff pad repairs and maintenance	$ 5,000	$ 5,000	$ 5,000
Labour	$ 3,050	$ 3,050	$ 3,050
TOTAL ANNUAL COST	**$ 140,859**	**$ 143,153**	**$ 145,447**
COST PER COW PER WEEK	**$ 40.41**	**$ 41.07**	**$ 41.73**
COST PER KG MS	**$ 0.74**	**$ 0.75**	**$ 0.77**

7.5.4 Silage utilisation on standoff pad

An advantage of a standoff system is the high utilisation of silage. In adverse conditions, the utilisation of the silage fed on the crop can be significantly reduced. In the historical scenario, utilisation of the silage fed on the crop is assumed to be 80% while the silage fed on the standoff pad in the proposed system was assumed to be closer to 100%. Table 24 shows the impact of the reduced utilisation of the silage fed on the fodder beet crop. Accounting for these losses increases the cost of the historical system. Increasing the level of silage fed in the historical system to account for losses by 10%, 20% or 30%, increases the cost of this system to $24.18, $25.65 and $27.12. This may make the proposed system more attractive.

Table 24: Decreased utilisation of silage in the historical system

	Historical system	-5% utilisation	-10% utilisation	-15% utilisation
Standoff pad @ 7% interest				
Effluent storage @ 7% interest				
Standoff pad depreciation @ 5%				
Effluent storage depreciation @ 5%				
Fodder beet	$ 18,125	$ 18,125	$ 18,125	$ 18,125
Tractor and feed out wagon costs	$ 6,744	$ 6,744	$ 6,744	$ 6,744
Silage	$ 51,240	$ 56,364	$ 61,488	$ 66,612
Straw				
Straw transportation				
Effluent transportation				
Standoff pad repairs and maintenance				
Labour	$ 2,440	$ 2,440	$ 2,440	$ 2,440
TOTAL ANNUAL COST	**$ 78,548**	**$ 84,282**	**$ 89,406**	**$ 94,530**
COST PER COW PER WEEK	**$ 22.53**	**$ 24.18**	**$ 25.65**	**$ 27.12**
COST PER KG MS	**$ 0.41**	**$ 0.44**	**$ 0.47**	**$ 0.50**

7.5.5 Effluent system

The proposed system operates under the assumption that all effluent is exported. An alternative to this assumption is that an effluent disposal system is built so that effluent can be spread on the block. This would increase the costs of the effluent disposal. As detailed in Table 25, additional expenses would be dual-walkway/raft assembly with effluent pump and stirrer, effluent main line and hydrants, travelling irrigator, pipe-trenching and electrical services and controls. Costs were obtained from a company involved in the design and installation of effluent systems (M. Lotter, personal communication, 4 August, 2014).

Table 25: Increased costs for effluent spreading system

Dual-walkway/raft assembly with Yardmaster 18km effluent pump and 1.1kw Clipon stirrer	$	25,000
Travelling irrigator with cable anchor and 150m x LD50mm drag-hose	$	9,000
Pipe trenching	$	5,000
Excavations and ground works for saucer	$	10,000
900m x MD90mm effluent mainline with 9 x hydrants	$	18,000
TOTAL ADDITIONAL SYSTEM	**$**	**67,000**
ADDITIONAL ANNUAL INTEREST @ 7%	**$**	**4,690**
ADDITIONAL DEPRECIATION @ 5%	**$**	**3,350**

Despite this system being more expensive to install, it reduces annual costs by 17.8% as shown in Table 26. This is due to the increased interest payments on the effluent system being less than the annual cost of transporting the effluent via commercial firm utilising tankers.

Table 26: Full effluent system installed

	Effluent transported		Effluent spread on block	
Standoff pad @ 7% interest	$	16,058	$	16,058
Effluent storage @ 7% interest	$	4,340	$	9,030
Standoff pad depreciation @ 5%	$	11,470	$	11,470
Effluent storage depreciation @ 5%	$	3,100	$	6,450
Fodder beet	$	18,125	$	18,125
Tractor and feed out wagon costs	$	4,496	$	4,496
Silage	$	40,992	$	40,992
Straw	$	9,000	$	9,000
Effluent transportation and spreading	$	26,022		
Straw transportation	$	1,500	$	1,500
Standoff pad repairs and maintenance	$	5,000	$	5,000
Labour	$	3,050	$	3,050
TOTAL ANNUAL COST	**$**	**143,153**	**$**	**125,171**
COST PER COW PER WEEK	**$**	**41.07**	**$**	**35.91**
COST PER KG MS	**$**	**0.75**	**$**	**0.66**

Applying effluent to the block would provide nutrients to the area on which it was applied. The value of effluent was quantified in the work of DairyNZ (2014) as $45/cow when cows were wintered on a structure for 24 hours per day, with effluent collected. While this is not realised in this partial budget, it is likely to impact the whole farm budget.

7.5.6 Best case scenario

While the other alternatives examined factors changing in isolation, Table 27 predicts what would happen if a number of the assumptions occurred together in a 'best case scenario.' Assumptions included were; interest rates decrease to 6%, standoff pad cost decreases by 10%, silage costs decrease to $0.30/kg DM and effluent spread through own system. This results in the difference between the two systems decreasing to a difference of $11.63 per cow per week. However, the inclusion of the wintering pad system still increases the annual cost per kg MS by $0.22.

Table 27: Best case scenario: Interest rates decrease, standoff pad costs decreases by 10%, silage costs decrease to $0.30/kg DM and effluent spread through own system

	Historical system		Proposed best case system	
Standoff pad @ 6% interest on capital cost			$	12,388
Effluent storage @ 6% interest on capital cost			$	7,740
Standoff pad depreciation @ 5%			$	10,323
Effluent storage depreciation @ 5%			$	3,100
Fodder beet	$	18,125	$	18,125
Tractor and feed out wagon running costs	$	6,744	$	4,496
Silage	$	43,920	$	36,600
Straw			$	9,000
Straw removal and spreading			$	1,500
Standoff pad repairs and maintenance			$	5,000
Labour	$	2,440	$	3,050
TOTAL ANNUAL COST	**$**	**71,229**	**$**	**111,751**
COST PER COW PER WEEK	**$**	**20.43**	**$**	**32.06**
COST PER KG MS	**$**	**0.37**	**$**	**0.59**

7.5.7 Potential non-economic effects

There are other potential benefits that are difficult to quantify, these include:

1) Having a standoff pad structure may be advantageous as a management tool in winter in the case of an extreme weather event, where animals can be totally fed on the pad. Being able to stand the cows off the crop may allow for increased animal welfare, health and feed utilisation. If the wintering system was on the same property as the milking platform, opposed to a separate wintering block, it could also be used as a management tool during extreme weather events (rain or snow) during the milking season. Keeping cows off pastures during these events will help to prevent pugging which can severely impact pasture production (Drewry *et al.*, 2008).

2) Higher utilisation of silage fed on the standoff pad compared to the historical system, and the subsequent higher energy intake, may result in a greater BCS. The flow on effects of this could be

increased milk production, an increase in fertility or an improvement in animal health. A 2% increase in conception rate was anticipated in the works of Journeaux (2013), due to the increase in BCS from a total wintering housing system.

7.6 Conclusions

As identified in the literature review in Chapter 2, there appeared to be a gap in the knowledge of the economic and environmental effects of a fodder beet/standoff pad system in Canterbury. This study addressed the gap by modelling a change to the LUDF wintering system from an *in situ* fodder beet/silage programme to controlled grazing of the fodder beet with the silage fed on a standoff pad. This was modelled using budgets and analysis in Overseer® to quantify the economic and environmental effects.

This dissertation sought to answer the following research questions, as identified in Chapter 3.

- What are the financial implications of the adoption of this system versus the historical system?

It was concluded in the study that the proposed system resulted in a cost of \$41.07 per cow per week, 82.3% more expensive than the historical system at \$22.53 per cow per week. The total wintering costs increases to become \$64,605 more expensive than the historical system. The cost of nitrate leaching mitigation is a developing concept which considers the cost of mitigation. However, it is a value that is likely to be more frequently reported in literature as the regulations concerning nitrate leaching tighten and farming businesses are forced to choose between systems which mitigate nitrate leaching. In this study the cost was \$171.

- What are the levels of nitrate leaching from this system versus the historical system?

Despite problems encountered with modelling the proposed system in Overseer® version 6.1.3, a modified version of the proposed system predicted substantially lower levels of nitrogen to water compared with the historical system. The proposed system's levels of nitrogen loss to water were 56.9% lower than the historical system, with losses of 28 kg N/ha and 65 kg N/ha recorded respectively.

Therefore, the results conclude that a fodder beet/standoff pad system provides a viable means of reducing nitrate leaching in a wintering system in Canterbury; however, the cost of this is significantly higher than a traditional paddock based system. While this supports the hypothesis, at the current difference in costs, it is debateable whether the system can be deemed as a 'viable' means of reducing nitrogen leached. However, as regulations concerning nutrient losses from a property tighten, reducing nitrate leaching may be mandatory for a farming business and this wintering system proves a means of doing so. An analysis of alternative costs to the original financial assumptions showed the potential for the costs of the proposed system to decrease.

7.7 Limitations

7.7.1 Overseer®

Using the Overseer® modelling software was a major limitation to this study. Like all modelling software, the results projected can vary from what would happen in reality. The Overseer® programme has a particularly high margin of error at +/- 30%. This may result in the environmental results being inaccurate by up to 30% which would have substantially impacted upon the results.

Other limitations related to using Overseer® were a result of 'bugs' in the programme. The Overseer® development team are aware these bugs exist but were not able to fix the problems in a timeframe that would fit in with this dissertation. As a result, adaptations had to be made to the property and the farm system data which varied from what was happening in reality.

In order for the programme to accept the feeding level in the proposed system, the silage had to be fed on the crop paddock opposed to on the standoff pad. Silage going onto the paddock would be considered by Overseer® as a source of nitrogen and therefore may have increased the levels of nitrate leaching from the proposed system. If an amended version of Overseer® eventuates, the nitrate leaching from the standoff pad and fodder beet system may be reduced.

Another problem that Overseer® has identified is the inconsistency between the AWC in the S-map factsheets and the AWC values produced by Overseer®. AWC is an important driver of drainage and thus an important driver of nitrate leaching so inaccuracies in this information is likely to have impacted on the results.

7.7.2 Timeframe

The model was constructed under the tight timeframe of an honours project (approximately eight months). In order to get the project completed within the timeframe, the research may not have been conducted as extensively as desired which may have led to inaccuracies.

Evaluating the project from a whole farm system perspective was not possible within the short timeframe and the method used. Modelling the results in a whole farm system model such as Farmax® may have provided different economic results.

7.7.3 Modelling study

Using modelling software as opposed to carrying out a practical trial and collecting actual results is a limitation to the accuracy of the results in this study. The environmental results were mainly limited to the assumptions that exist within Overseer®. The financial results were limited to the accuracy of the assumptions made about the cost of products and services, which may have varied to what they would have cost in reality in the systems.

7.8 Future research

7.8.1 Trial replication

This trial could be replicated in future in order to ensure the accuracy of assumptions and analysis. In doing so, it will ensure the results are reliable and have not occurred by chance or through miscalculations. Replicating this trial when the errors identified in Overseer® in Chapter 6 are resolved would allow for a more accurate environmental analysis of the systems. A practical implementation of systems with actual results recorded would also allow for a more accurate analysis of these systems.

7.8.2 Surface material

Straw is only one surface material that is used on standoff pads. Other common surface materials that could be investigated in future research include bark chips or a rubber mat. This could be investigated in a similar system, to see what impact they would have on the both the environmental and financial results. This may also impact upon the animal welfare of the system.

7.8.3 Timing of urination and faeces deposition after grazing

The study of nitrogen content in urine throughout the day is another area of potential research. If it was found that nitrogen content in urine varied throughout the day, the timing of grazing could be manipulated to ensure that the cows were grazing when nitrogen content was at the lowest and on the pad when it was highest. In doing so, the timing of grazing could prove a worthy means of reducing projected nitrate leaching levels. While urination and defecation patterns have been studied on pasture and forage crops, future research could be undertaken to study the urination and defecation patterns on pads and other structures. This could also prove a means of mitigating nitrate leaching.

7.8.4 Profitability

Current guidelines provided by Environment Canterbury suggest that properties cannot leach more than a 10% above their leaching baseline which was collected between 2010 and 2013. By 2022, Environment Canterbury aims to have decreased these baselines levels by 30%. Decreasing leaching levels by 30% could result in farm system changes, such as reducing stocking rates or fertiliser applications. However, reducing stocking rate and fertiliser applications could decrease production and income. A thorough analysis of associated farm profitability with various means of reducing nitrate leaching, such as removing cull cows earlier or the timing of nitrogen fertiliser, is an area of potential research which will be relevant in the future as these regulations are implemented.

APPENDICES

Overseer input data

A.1 Historical wintering system Overseer® input details

Location	Christchurch
Blocks	Pastoral: 116.0 ha Crop: 10.17 ha Total area: 132.0
Enterprises	Dairy
Structures	Nil
Animal distribution	No difference between blocks in animal distribution
Dairy effluent system	Management system: holding pond Pond solids management: spread on selected blocks, pond emptied every 2 years Liquid effluent management: Stir & spray regularly
Supplements imported	146t DM silage Destination: crop Supplement source: purchased Category: silage Supplementary feed: pasture average quality silage Storage conditions: excellent
DCD nitrification inhibitors	None
Wetlands	None
GHG footprint	Used 'specify unique greenhouse gas emission factors
Report settings	Typical dairy farm, GHG reported in CO2 equivalents, 0 kg/ha as effluent areas, default setting for fertiliser costs
Dairy: Numbers	Numbers: July: 400 August: 400 September: 390 October: 380 November: 375 December: 375 January: 370 February: 370 March: 360 April: 330 May: 300 June: 400 Class: Milking herd Breed: F x J Cross Median calving date: 14 August Maximum weight: 501 kg
Production	Milk solids: 160,000 Once a day milking: Never Lactation length: 268 days Milk volume yield: 1,811,200 litre/yr Fat yield: 90,762
Health supplements	-
Milking shed feeding	-
Crop 1: General	Distance from coast: 24 km from coast Block land use: 100% cultivated area Final month of crop rotation: January
Climate	Daily rainfall pattern setting: <730 mm (low) Daily rainfall pattern: 592 mm rainfall per year Mean annual temperature: 11.8°C PET: 909 mm Seasonal variation: moderate PET

Soil description	Soil by order: Brown. Soil group: default (sedimentary)
Soil profile	Top soil texture: silt loam Without stones and not compacted. Soil texture group: medium Non-standard layer: stony Depth to non-standard layer: 25
Soil tests	ASC or PR: default (43%) TBK reserve K: default (0.31 me/100g)
Soil settings	K leaching potential: default (low 1.0)
Crop block history	Years in pasture: 1 Prior land use: pasture Source of animals grazing pasture: farm stock- see enterprise numbers panes, animal class pasture consumption equals ratio of intake on farm
Crop rotation	Crop (both year 1 and reporting year): Fodder beets sown in November, 19.2t/ha, conventional cultivation practice at sowing. Fertiliser (both year 1 and reporting year): November Year 1: Cropzeal 16N (incorporated) 175 kg/ha, salt (sodium chloride) 125 kg/ha. December Year 1: N-rich urea (surface applied) 90 kg/ha. January Year 1: N-rich urea (surface applied) 90 kg/ha February Year 1: N-rich urea (surface applied), 90 kg/ha Grazing: June, July. Grazed in-situ by Farm stock (see Enterprise numbers panes)
Effluent	-
Pastoral: General	Topography: flat Distance from coast 25km
	Daily rainfall pattern setting: <730 mm (low) Daily rainfall pattern: 592 mm rainfall per year Mean annual temperature: 11.8°C PET: 909 mm Seasonal variation: moderate PET
Soil description	Soil by order: Brown. Soil group: default (sedimentary)
Soil profile	Top soil texture: silt loam Without stones and not compacted. Maximum rooting depth: 0cm Depth to impeded drainage layer: 0cm Soil texture group: medium Non-standard layer: stony Depth to non-standard layer: 25
Drainage/runoff	Profile drainage class: Moderately well Hydrophobic condition: Use default Susceptibility to pugging or treading damage: occasional Drainage method: None
Soil tests	Olsen P: 30, QT K: 8, QT Ca: 10, QT Mg: 10, QT Na: 10 Organic S: 10 mg/kg ASC or PR: default (43%) TBK reserve K: default (0.31 me/100g)
Soil settings	K leaching potential: default (low 1.0)
Pasture	Pasture type: ryegrass/white clover
Supplements made	-
Fertiliser	January: Fertiliser form, 35 kg N/ha February: Fertiliser form, 35 kg N/ha

	March: Fertiliser form, 60 kg N/ha April: Fertiliser form, 45 kg N/ha September: Fertiliser form, 55 kg N/ha, 45 kg P/ha, 55kg S/ha October: Fertiliser form, 40 kg N/ha November: Fertiliser form, 40 kg N/ha December: Fertiliser form, 40 kg N/ha
Irrigation	January: Centre pivot/lateral, 90 mm/month February: Centre pivot/lateral, 90 mm/month March: Centre pivot/lateral, 60 mm/month April: Centre pivot/lateral, 40 mm/month October: Centre pivot/lateral, 45 mm/month November: Centre pivot/lateral, 50 mm/month December: Centre pivot/lateral, 75 mm/month Source of nutrient data: Overseer® default (fixed)
Animals	Dairy: grazing months January-May, August-December. June and July unchecked
DCD applications	-
Effluent	Liquid effluent from farm dairy Application method: low application method Pond solids/sludge effluent applications: November

A.2 Proposed wintering system Overseer® input details

Appendix BLocation	Christchurch
Blocks	Pastoral: 116.0ha Crop: 10.17ha Total area: 132.0
Enterprises	Dairy
Structures	Wintering pad, animal shelter or housing
Animal distribution	No difference between blocks in animal distribution
Dairy effluent system	Management system: holding pond Pond solids management: spread on selected blocks, pond emptied every 2 years Liquid effluent management: Stir & spray regularly
Supplements imported	146t DM silage, destination: wintering pad Supplement source: purchased Category: silage Supplementary feed: pasture average quality silage Storage conditions: excellent
DCD nitrification inhibitors	None
Wetlands	None
GHG footprint	Used 'specify unique greenhouse gas emission factors
Report settings	Typical dairy farm, GHG reported in CO2 equivalents, 0 kg/ha as effluent areas, default setting for fertiliser costs

Enterprises – dairy

Numbers	Numbers: July: 400 August: 400 September: 390 October: 380 November: 375 December: 375 January: 370 February: 370 March: 360 April: 330 May: 300 June: 400 Class: Milking herd Breed: F x J Cross Median calving date: 14 August Maximum weight: 501 kg
Production	Milk solids: 160,000 Once a day milking: Never Lactation length: 268 days Milk volume yield: 1,811,200 litre/yr Fat yield: 90,762
Health supplements	-
Milking shed feeding	-

Wintering pad, animal shelter or housing

General	Pad type: uncovered wintering pad Pad surface: carbon rich, lined, subsurface drained and effluent captured

	Solids management method: other (exported) Storage method before solids are spread: open (to rain) Time in storage: 3 months Treatment method: all exported
Management	Feeding regime: wintering pad + grazing Percentage of milking herd: 100% in June, July. 0% in all other months Hours per day grazing: 6.0 hours in June, July. 0% in all other months.

Crop

General	Distance from coast: 24 km from coast Block land use: 100% cultivated area Final month of crop rotation: January
Climate	Daily rainfall pattern setting: <730mm (low) Daily rainfall pattern: 592 mm rainfall per year Mean annual temperature: 11.8°C PET: 909mm Seasonal variation: moderate PET
Soil description	Soil by order: Brown. Soil group: default (sedimentary)
Soil profile	Top soil texture: silt loam Without stones and not compacted. Soil texture group: medium Non-standard layer: stony Depth to non-standard layer: 25
Soil tests	ASC or PR: default (43%) TBK reserve K: default (0.31 me/100g)
Soil settings	K leaching potential: default (low 1.0)
Crop block history	Years in pasture: 1 Prior land use: pasture Source of animals grazing pasture: farm stock- see enterprise numbers panes, animal class pasture consumption equals ratio of intake on farm
Crop rotation	Crop (both year 1 and reporting year): Fodder beets sown in November, 19.2t/ha, conventional cultivation practice at sowing. Fertiliser (both year 1 and reporting year): November Year 1: Cropzeal 16N (incorporated) 175kg/ha, salt (sodium chloride) 125kg/ha. December Year 1: N-rich urea (surface applied) 90kg/ha. January Year 1: N-rich urea (surface applied) 90kg/ha February Year 1: N-rich urea (surface applied), 90kg/ha Grazing: June, July. Grazed in-situ by Farm stock (see Enterprise numbers panes) for 6.0 hours a day.
Effluent	-

Pastoral:

General	Topography: flat Distance from coast 25km
	Daily rainfall pattern setting: <730mm (low)

	Daily rainfall pattern: 592 mm rainfall per year Mean annual temperature: 11.8°C PET: 909mm Seasonal variation: moderate PET
Soil description	Soil by order: Brown. Soil group: default (sedimentary)
Soil profile	Top soil texture: silt loam Without stones and not compacted. Maximum rooting depth: 0cm Depth to impeded drainage layer: 0cm Soil texture group: medium Non-standard layer: stony Depth to non-standard layer: 25
Drainage/runoff	Profile drainage class: Moderately well Hydrophobic condition: Use default Susceptibility to pugging or treading damage: occasional Drainage method: None
Soil tests	Olsen P: 30, QT K: 8, QT Ca: 10, QT Mg: 10, QT Na: 10 Organic S: 10mg/kg ASC or PR: default (43%) TBK reserve K: default (0.31 me/100g)
Soil settings	K leaching potential: default (low 1.0)
Pasture	Pasture type: ryegrass/white clover
Supplements made	-
Fertiliser	January: Fertiliser form, 35 kg N/ha February: Fertiliser form, 35 kg N/ha March: Fertiliser form, 60 kg N/ha April: Fertiliser form, 45 kg N/ha September: Fertiliser form, 55 kg N/ha, 45 kg P/ha, 55kg S/ha October: Fertiliser form, 40 kg N/ha November: Fertiliser form, 40 kg N/ha December: Fertiliser form, 40 kg N/ha
Irrigation	January: Centre pivot/lateral, 90mm/month February: Centre pivot/lateral, 90mm/month March: Centre pivot/lateral, 60mm/month April: Centre pivot/lateral, 40mm/month October: Centre pivot/lateral, 45mm/month November: Centre pivot/lateral, 50mm/month December: Centre pivot/lateral, 75mm/month Source of nutrient data: Overseer default (fixed)
Animals	Dairy: grazing months January-May, August-December. June and July unchecked
DCD applications	-
Effluent	Liquid effluent from farm dairy Application method: low application method Pond solids/sludge effluent applications: November

References

Agricom. (2012). Agrinote: Fodder beet. from http://www.agricom.co.nz/assets/files/nz/content_files/Fodder%20Beet%20Fact%20Sheet%20-%20Agricom.pdf

Baskaran, R., Cullen, R., & Colombo, S. (2009). Estimating values of environmental impacts of dairy farming in New Zealand. *New Zealand Journal of Agricultural Research, 52*(4), 377-389. doi: 10.1080/00288230909510520

Beukes, P. C., Gregorini, P., Romera, A. J., & Dalley, D. E. (2011). The profitability and risk of dairy cow wintering strategies in the Southland region of New Zealand. *Agricultural Systems, 104*(7), 541-550. doi: http://dx.doi.org/10.1016/j.agsy.2011.04.003

Botreau, R., Veissier, I., Butterworth, A., Bracke, M., & Keeling, L. (2007). Definition of criteria for overall assessment of animal welfare. *ANIMAL WELFARE-POTTERS BAR THEN WHEATHAMPSTEAD-, 16*(2), 225.

Christensen, C., Hanly, J., Hedley, M., & Horne, D. (2010). *Reducing nitrate leaching losses by using duration-controlled grazing of dairy cows.* Paper presented at the 19th World Congress of Soil Science, Soil Solutions for a Changing World, Sydney, Australia.

Clark, D. A., Caradus, J. R., Monaghan, R. M., Sharp, P., & Thorrold, B. S. (2007). Issues and options for future dairy farming in New Zealand. *New Zealand Journal of Agricultural Research, 50*(2), 203-221. doi: 10.1080/00288230709510291

Clutha Vets. (2012). Dairy feeding of fodder beet to dairy cows. from http://www.cluthavets.co.nz/animal-health/295-dairy-feeding-of-fodder-beet-to-dairy-cows.html

Cook, N., & Nordlund, K. (2009). The influence of the environment on dairy cow behaviour, claw health and herd lameness dynamics. *Veterinary Journal, 179*(3), 360-369.

Cottier, R. (2000). *The winter: the alternatives.* Paper presented at the SIDE conference.

DairyNZ. (2010). *Facts and figures for New Zealand dairy farmers*. Hamilton, New Zealand.

DairyNZ. (2013a). Farm dairy effluent- How to use the Dairy Effluent Storage Calculator (DESC).

DairyNZ. (2013b). New Zealand Dairy Statistics 2012-2013. from http://www.dairynz.co.nz/publications/dairy-industry/new-zealand-dairy-statistics-2012-13/

DairyNZ. (2014). Southern Wintering Systems Investment analysis summary.

Dalley, D. E. (2011). *The challenges of animal wintering from a sustainability perspective* (Vol. 71): New Zealand Society of Animal Production.

Dalley, D. E. (2013). Southern Wintering Systems. In DairyNZ (Ed.).

Dalley, D. E. (2014). Achieving wintering system performance targets. *DairyNZ: Technical series,* 1-4.

Dalley, D. E., Verkerk, G. A., Geddes, T., Irwin, A., & Garnett, E. (2012). *Impact of wintering system in the southern South Island of New Zealand on the lying behaviour of dairy cows*. Tallygaroopna, Australia: Australasian Dairy Science Symposium.

de Klein, C. A. M., & Ledgard, S. F. (2001). An analysis of environmental and economic implications of nil and restricted grazing systems designed to reduce nitrate leaching from New Zealand dairy farms. I. Nitrogen losses. *New Zealand Journal of Agricultural Research, 44*(2-3), 201-215. doi: 10.1080/00288233.2001.9513478

de Klein, C. A. M., Monaghan, R. M., Ledgard, S. F., & Shepherd, M. (2010). *A system's perspective on the effectiveness of measures to mitigate the environmental impacts of nitrogen losses from pastoral dairy farming.* Paper presented at the Proceedings of the Australasian Dairy Science Symposium.

de Klein, C. A. M., Smith, L. C., & Monaghan, R. M. (2006). Restricted autumn grazing to reduce nitrous oxide emissions from dairy pastures in Southland, New Zealand. *Agriculture, Ecosystems & Environment, 112*(2–3), 192-199. doi: http://dx.doi.org/10.1016/j.agee.2005.08.019

Di, H. J., & Cameron, K. C. (2002). The use of a nitrification inhibitor, dicyandiamide (DCD), to decrease nitrate leaching and nitrous oxide emissions in a simulated grazed and irrigated grassland. *Soil Use and Management, 18*(4), 395-403. doi: 10.1111/j.1475-2743.2002.tb00258.x

Drewry, J. J., Cameron, K. C., & Buchan, G. D. (2008). Pasture yield and soil physical property responses to soil compaction from treading and grazing — a review. *Soil Research, 46*(3), 237-256. doi: http://dx.doi.org/10.1071/SR07125

Environment Canterbury (Producer). (2014). Soil report: Lismore stony silt loam Retrieved from http://smap.landcareresearch.co.nz/factsheet

Environment Waikato. (2008). *The condition of rural water and soil in the Waikato region – risks and opportunities*.

Jenkinson, B., Edwards, G., & Bryant, R. (2014). Grazing behaviour, dry matter intake and urination patterns of dairy cows offered kale or fodder beet in winter. *Proceedings of New Zealand Society of Animal Production, 73*, 23-28.

Journeaux, P. (2013). *Economic Analysis on the Value of Winter Housing for Dairy Farming in Tararua District*. Paper presented at the New Zealand Agricultural & Resource Economics Society (Inc.), Lincoln University- Canterbury, New Zealand.

Judson, H. G., & Edwards, G. R. (2008). *Survey of management practices of dairy cows grazing kale in Canterbury.* Paper presented at the Proceedings of the New Zealand Grassland Association.

Kay, J. (2014). Feeding for condition score gain. *DairyNZ: Technical series,* 5-8.

Kemp, P., Condron, LM., Matthew, C. (Ed.). (1999). Auckland: Oxford University Press.

Landcare Research. (2014). Maps and Factsheet. from http://smap.landcareresearch.co.nz/smap#layers=text_cache_nztm,water,transport,text,topobasemap_notext,topo_hyb_relief,topo_mono_hyb_relief,smap_overview,topobasemap_monochrome_notext,landscape_eco_painted_relief,landscape_shaded_relief,coastpoly,smap_paw_1m,smap_depth,smap_soil_drainage,smap_polys_anno

Macdonald, T., Scrimgeour, F., & Rowarth, J. (2014). Cow housing systems- an economic analysis: University of Waikato.

Matthew, C., Nelson, N., Ferguson, D., & Xie, Y. (2011). Fodder beet revisited. *Agronomy New Zealand, 41*, 39-48.

McConnell, D. J., & Dillon, J. L. (1997). *Farm management for Asia: a systems approach*: Food & Agriculture Org.

McFarlane, A. (2013). Nutrient Management on Farm- Practical Solutions.

McLaren, R., & Cameron, K. (1996). *Soil Science: Sustainable production and environmental protection*. Victoria, Australia: Oxford University Press.

McLeod, S. A. (2008). Qualitative Quantitative., from http://www.simplypsychology.org/qualitative-quantitative.html

Ministry for the Environment. (2009). National groundwater quality indicators update: State and trends 1995-2008.

Ministry for the Environment. (2014). National Policy Statement for Freshwater Management 2014 – questions and answers. from http://mfe.govt.nz/rma/central/nps/freshwater-management-questions-answers.html

Monaghan, R. M. (2012). The impacts of animal wintering on water and soil quality: AgResearch.

Monaghan, R. M., Beare, M., & Boyes, M. (2009). The Environmental Impacts of Dairy Cow Wintering in Southland (pp. 25). AgResearch review document prepared for DairyNZ.

Monaghan, R. M., Wilcock, R. J., Smith, L. C., Tikkisetty, B., Thorrold, B. S., & Costall, D. (2007). Linkages between land management activities and water quality in an intensively farmed catchment in southern New Zealand. *Agriculture, Ecosystems & Environment, 118*(1–4), 211-222. doi: http://dx.doi.org/10.1016/j.agee.2006.05.016

Newman, I. (1998). *Qualitative-quantitative research methodology: Exploring the interactive continuum*: SIU Press.

Norman, D. (2002). *The farming systems approach: A historical perspective.* Paper presented at the Presentation held at the 17th Symposium of the International Farming Systems Association in Lake Buena Vista, Florida, USA.

Overseer. (2013). What 'Overseer' does. from http://www.overseer.org.nz/OVERSEERModel/WhatOverseerdoes.aspx

Pinxterhuis, J., Dalley, D. E., Tarbotton, I., Hunter, M., & Geddes, T. (2014). *Supporting on-farm change to protect the environment and animal welfare while maintaining productivity and profitability of dairy farms in Southern New Zealand.*

SIDDC. (2013). Lincoln University Dairy Farm- Farm Walk Notes- Tuesday 2nd July 2013. http://www.siddc.org.nz/assets/LUDF-Focus-Days/11th-July-2013.pdf

SIDDC. (2014a). About SIDDC. from http://www.siddc.org.nz/about-siddc/

SIDDC. (2014b). LU Dairy Farm. from http://www.siddc.org.nz/lu-dairy-farm/

Speciality Seeds. (2014). Fodder beet growing and grazing guide. from http://www.specseed.co.nz/downloads/FodderBeetGuide-SpecialtySeedsNZ.pdf

Tarbotton, I., Bell, P., Mitchelmore, K., & Wilson, J. (2012). Farmer Network Project South Otago/Southland Region (pp. 68). Newstead, Hamilton: DairyNZ.

Webster, J. (2014). The effects of stand-off surfaces. *DairyNZ: Technical series* 9-11.

Westwood, C., & Mulcock, H. (2012). *Nutritional evaluation of five species of forage brassica.* Paper presented at the Proceedings of the New Zealand Grassland Association.

Personal communication references

Blair Miller. Rakaia Engineering Limited. Rakaia.

Keith Cameron. Lincoln University. Lincoln.

Ron Pellow. SIDDC. Lincoln.

Ian Domigan. Lincoln University. Lincoln.

Miranda Hunter. Roslin Consultancy. Woodlands.

Marvin Pangborn. Lincoln University. Lincoln.

Jeremy Clayton. ANZ bank. Christchurch branch.

Lyndsay Dick. Staples Rodway. Christchurch.

Matt Cullen. Fonterra. Canterbury.

Michael Lotter. Pluck's engineering. Rakaia.

Paul Davey. Farmer. Te Pirita.

Matt Lovett. Lovett Contracting. Canterbury.