PURPOSE BUILT STANDOFF ON DAIRY FARMS FOR ENVIRONMENTAL PROTECTION AND EFFICIENT PRODUCTION

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Abstract

Farmers are increasingly concerned about pasture and soil protection and nutrient loss from their farms to receiving surface and ground waters. The practise of standoff using purpose built facilities is one potential solution to these twin problems. However, the adoption of standoff is expensive as it incurs numerous costs such as those associated with the construction of the feed and loafing areas and the handling of the extra volumes of effluent that are produced. This study investigates the implementation of standoff on four case study farms in the Manawatu region. One of the farmers is contemplating adopting standoff for soil and pasture protection, one of the farmers is considering the use of standoff to lower leaching from his farm while two of the case study farms are wondering about the use of standoff for both purposes i.e. soil/pasture and environmental protection.

A range of tools was used to simulate the role and impact of standoff in the four cases study farms including; the soil water balance, the Farm Dairy Effluent Storage Calculator, Overseer and the DairyNZ investment tool. The soil water balance was used to identify the timing and extent of standoff, which are in turn important inputs into other the other models. The two major benefits of standoff in winter and spring for farm profitability are a potential increase in milk production and improved utilisation of supplements. Where standoff was practised for soil and pasture protection it was assumed that milk yield would increase by a relatively modest amount (10%) over the months August to October inclusive. The conservative nature of the analysis performed here recognises that the cases study farms are currently well managed.

The simulations suggest that standoff for soil/pasture and environmental protection would be effective in helping the farmers meet these objectives. The case study farms with poorly drained soil would stand cows off for significant periods in order to protect soils and pastures. The cost of standoff is dependent on a number of factors. In this study, the impact of standoff on the costs associated with managing increased volumes of effluent were investigated in more detail. Standoff obviously results in the generation of more effluent. The costs associated with handling this effluent varied across the case study farms. Farms where large periods of standoff occurred in winter and where the effluent was irrigated to high risk soils required large increases is storage volume. Farms where standoff was only practised in summer and autumn to reduce leaching from free draining soils required very little increase in storage volume.

The required expansion of the effluent block varied across the cases study farms but was typically 500 to 710 m^2 per cow. Overseer suggests that standoff would decrease N leaching from the farms by 4 to 26%.

The DairyNZ tool suggests that there is the risk that standoff will not be a good financial investment on the case study farms. Only one of the scenarios explored here had acceptable values for the financial parameters such as NPV. For all other scenarios, standoff was not a financially viable proposition. This would be expected for the farm where standoff was only practised over the summer and autumn periods as standoff at this time of the year has few other financial benefits. In this case, standoff should be compared with the cost of other mitigation options.

Given the complexity of identifying the advantages and costs of standoff, any farmer contemplating adopting standoff needs to perform their own comprehensive and detailed analysis. If milk production is greater than the value assumed here or the standoff facility can be constructed and operated more cheaply than assumed here then standoff may well be a sound financial investment.

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Chapter 1 Introduction

Over the past 15 years or so, New Zealand's dairy sector has evolved in an attempt to meet the global market demand for milk products which are produced with a minimal environmental footprint. The increasing demand for milk is leading to an increase in intensification in many dairy systems. This intensification often involves increases in stocking rate, fertilisers and energy resources (Bilotta, et al., 2007; Monaghan et al., 2005). The intensification of dairy farming in New Zealand often has negative impacts on the environment. In New Zealand, the current focus is on the adverse effects of dairying on water quality. Declining water quality is mostly due to the nutrients lost from farms, mainly nitrogen (N) from urine patches (Haynes & Williams, 1993). There is also concern about treading damage to pastures and soils which may result in the erosion of sediment from dairy farms (Steinfeld et al., 2006). Intensification on dairy farms, particularly initiatives involving increased cow numbers, often result in the generation of larger volumes of farm dairy effluent.

Therefore, a range of tools have been developed for New Zealand conditions to help plan, evaluate, analyse, and manage numerous farming practices. These include; Overseer, feed budgets,the Farm Diary Effluent Storage Calculator and the DairyNZ off-paddock investment calculator.

In order to reduce environmental pollution and to increase milk production from dairy systems, different mitigation strategies have been proposed. To protect soils and reduce nutrient leaching, many farmers are interested in implementing standoff facilities. A standoff area is a pad which is designed to hold animals for long periods of time when paddocks are too wet to be grazed and/or over the summer and autumn. This pad is usually constructed of materials (sawdust, woodchip) that absorb liquid effluent. It is built over an impermeable subsoil or lined with an underground drainage system which delivers effluent to a storage pond (Smith et al., 2010). The implementation of standoff allows for the collection of effluent, which is returned to paddocks for nutrient recovery (Luo et al., 2006).

This research investigates the adoption of standoff practises or strategies on a range of dairy farms in the Manawatu region. Standoff was adopted on these farms for one of the following purposes:

(i) pasture and soil protection,

(ii) reduction of nutrient leaching (i.e. environmental protection) or

(iii) pasture and soil protection + reduction of nutrient leaching.

This research uses a case study approach. Four farmers in the Manawatu region who were contemplating the adoption of standoff practices were identified. Prior to, and in preparation for, this analysis, a number of farms with standoff facilities were visited and the experiences of these farmers and the costs associated with standoff were recorded.

The objectives of this study were to identify the reasons that case study farmers were considering adopting standoff, and the advantages and disadvantages of implementing standoff on the case study farms. The potential advantages on imperfectly drained soils include increases in milk production and improved utilisation of supplements as a consequence of soil and pasture protection. On all soils, including free draining soils, standoff in the summer – autumn period is likely to result in marked reductions in nitrogen leaching. There are a number of costs associated with standoff including those associated with the infrastructure and effluent management.

Firstly, the purpose of standoff for each farm is identified. Secondly, the extent of standoff is modelled using a soil water balance. The FDE Storage calculator is used to simulate the extra storage requirements to facilitate standoff and the cost of irrigating the extra effluent is also calculated. Overseer is used to identify the reduction in nitrogen leaching rates as a result of implementing standoff. Finally, the overall financial viability of standoff on each of the case study farms is analysed using the DairyNZ off-paddock investment calculator.

Chapter 2 Literature review

2.1 Introduction

New Zealand livestock industry is mostly pasture-based, involving stock spending all or most of their time grazing out in paddocks due to the temperate climate (Monaghan et al., 2008). The ability to use pasture as the primary source of feed allows lower cost milk production (Holmes et al., 2007). Nevertheless, the demanding characteristic of the global market has led farmers to increase the farm area as well as pursue greater intensification (Monaghan et al., 2008). Increased intensification and expansion of dairying has resulted in greater use by dairying of soils that have a high susceptibly to treading damage, such as Pallic soils. Treading damage degrades soil physical quality and increases the losses of nutrients and pathogens to surface waters. Intensive pugging events can also cause considerable pasture damage.

As farms intensify, the use of fertilisers or supplementary feed also increases, leading to a greater return of nutrients to paddocks as excreta (i.e. dung and urine) (Ledgard et al., 1999). This increase in nutrient inputs causes a significant environmental impact on water bodies due to accelerated nitrogen (N) leaching and phosphorus (P) runoff (Romera et al., 2012). The main source of N leaching in grazed pastures is mostly from the high concentrations of N returned in cow urine spots, which is then at risk of moving to ground and surface waters when drainage occurs (Di & Cameron, 2002; Pacheco & Waghorn, 2008). The risk of N leaching depends on the combination of soil mineral N accumulating in urine spots and the occurrence and magnitude of drainage. It is essential to identify when the critical periods that farm practices contribute to N leaching are, so that mitigation strategies can target them in order to be effective at reducing N leaching losses.

The aim of this literature review is to provide an overview of the current information about the role of the cow urine patch as a major source of N leaching and factors that influence treading damage of grazed pastures. The review will also include an overview of the use of standoff facilities as a tool to allow farmers to implement grazing management practices to reduce both N leaching and treading damage.

2.2 Role of the cow urine patch on Nitrogen leaching

The presence of mineral N in soil is essential for plant development, its availability and quantity is a balance between inputs and outputs. Main soil mineral N input sources are fertilisers, animal excreta, and soil organic N mineralisation (including N fixed by white clover). Mineral N outputs from the soil system are mainly by its movement in leaching, runoff/erosion, gaseous losses, plant uptake and immobilisation (Decau et al., 2004).

The occurrence of N leaching starts when pasture or supplementary feed N is ingested by grazing animals and processed within the body, and due to partitioning processes, a proportion of N is used for animal products (i.e. meat, milk, wool) and the rest excreted. Nearly 60% of ingested N is excreted in urine and about 20% in faeces (Ledgard & Steele, 1992). The urine deposited on the ground by animals is known as urine patch (Selbie, 2014). The urine patch is the primary source of N leaching, has an equivalent rate ranging from 200-1200 kg N/ha in the area of the urine spot (Di & Cameron, 2002; Haynes & Williams, 1993; Jarvis & Pain, 1990).

The urine patch returns N to a small loading area, uncoupling the N cycle due to the majority of the grazing area not receiving urinary-N over a year (Schnyder et al., 2010). Over a period of approximately two weeks after urine deposition, most of the N applied in the urine patch is converted to nitrate (NO_3^-), being the predominant form of mineral N present in well-aerated soils (Bolan & Kemp, 2003). The negative charge of this ion prevents it being retained at the cation exchange sites, and it is also not held on anion-specific sorption sites in the soil. Therefore, the nature of this ion makes it readily prone to leaching down the soil profile when drainage occurs (Follett, 2008).

The incidence of N leaching is determined by climatic factors throughout the season. Therefore, it is well known that the amount of NO_3^- leached is higher when the drainage season starts particularly after winter grazing compared with spring. The latter according to Houlbrooke (2005) is due to the improvement of the pasture uptake of N during spring. Additionally, the N non-taken by the plant from late summer/autumn exacerbates the levels of NO_3^- during drainage periods. These are critical times when grazing events are most likely to contribute to an accumulation of the soil mineral N for the next drainage period (Christensen, 2013; Snow et al., 2011).

2.3 The influence of cow diet N returned in urine

The N content of pastures and forages depends on the plant species, maturity, soil fertility, climate, fertiliser use and pasture management. Mixed pastures (typically white clover and perennial ryegrass) in New Zealand contain high levels of N, which varies throughout the year due to climate and seasonal growth stage (Pacheco & Waghorn, 2008). This climatic effect occurs in all the regions, causing an annual cycle with wetter and low-temperature soils during winter and warm/drier soils in summer (Holmes et al., 2007).

The variability in temperature and moisture affects pasture quality (i.e. digestibility and protein). Digestibility influence the proportion of the nutrients from food that become available for absorption in the digestive tract (Pacheco & Waghorn, 2008). Due to climatic effects, digestibility of pastures varies from 75% in early spring to 63% in late summer (Ulyatt, 1970). Likewise, crude protein (CP), which influences the N content of the feed, increases during winter and early spring to 28% CP in dry matter and then gradually reduces to 20% of CP in the dry matter by late summer and early autumn (Holmes et al., 2007).

Commonly the CP of pastures exceed the animal requirement, influencing animal production and leading to a metabolic cost for the animal to flush out the excess N (Pacheco & Waghorn, 2008). In addition, excess N returned in urine contributes to the accumulation of high concentrations of soil mineral N. The CP content in the diet influences directly the concentration of urinary N because the animal is not able to store the excess of N as it does with energy. When diets contain high levels of energy the animals store it as body fat, whereas, for CP only a small part is retained for production and the rest is excreted. Therefore, increases in dietary N will typically result in increased urinary N rather than animal production (Kebreab et al., 2002). The process of N transaction within the body involves rumen degradation of about 70% the forage CP resulting in ammonia. This ammonia is used by the rumen bacteria for production or redirected to the blood stream. Then the ammonia once in the blood stream is recycled or transformed into urea to be then excreted as urine urea (Pacheco & Waghorn, 2008).

2.4 Supplementary feed use

Pasture growth and quality vary with the time of the season. When pasture growth slows, and becomes insufficient to meet feed demand, then cow diet is typically supplemented with conserved feeds (e.g. hay or silage) (Homes & Roche, 2007). The use of supplementary feed provides an opportunity to balance the nutritive value of the total diet when pasture quality is low (White & Hodgson, 1999). As well as the chance to control the N intake of the livestock and as a means of mitigating urine-N returned and the accumulation of soil mineral N during the period prior to starting the drainage season. Energy-rich concentrates can be degraded at different rates in the rumen, potentially capturing more degraded N from forages. Thus, supplementary feed use potentially reduces urinary nitrogen, but this depends on the management (Colin-Schoellen et al., 2000).

2.5 Cow urine characteristics

2.5.1 Composition

The composition of the urine is affected mainly by the N content present in the feed. Therefore, as the N intake increases, the urinary N excreted increases, while it remains constant in faecal matter (Mulligan et al., 2004). Likewise, the intake of water affects the N concentration of urine due to the dilution effect. Water consumption will be higher during high-temperature periods, such as summer, diluting the N concentration in urine (Selbie, 2014). Cow urinary N is mainly in the form of urea, being 50-90% for grazing cows of the total urinary N (Bristow et al., 1992). Additionally, the urine contains other N compounds such as hippuric acid, uric acid, allantoin, xanthine, hypoxanthine, creatinine, creatine, free amino acids and ammonia. Some of these compounds have key roles in the transformation of N within the urine patch. Moreover, they follow the same degradation path as urea but in a longer process of decomposition (Selbie, 2014).

2.5.2 Size, volume and frequency of urine spots

The urine patch area can be divided in to the wetted area, where the urine is directly excreted to and is in direct contact with soil, and the area outside of the wetted area where pasture growth can also be influenced (Lantinga et al., 1987). When urine is deposited on pasture, the wetted area is typically in the range of 0.14-0.49 m^2 with an average of 0.24 m^2 (Moir, et al, 2011; Haynes & Williams, 1993). Usually, the volumes per urination typically ranges from 1.6-2.2 L, with an average volume of 2.1 L/cow (Selbie et al., 2015; Clark et al., 2010). The frequency of urination is between 10-12 times a day onto both paddocks and unproductive areas, such as yards/races respectively. Typically, about 80-90% of the urination events occur in paddocks and 10-20% in yards or races. Nevertheless, these values are variable depending mostly on the cow, water intake, use of standoff facilities, time of the day and the season (Betteridge, et al, 2013; Dennis et al., 2011). If for example, 200 cows are grazing one hectare per grazing, with an average urine patch of 0.24 m^2, the area covered by urine will on average depend on the number of hours in paddock per grazing. Therefore, according with the previous information there is one urination/cow/2 hours, then the area covered in a 6-hour morning grazing would be 0.028 hectares (i.e. 2.8 % of the area) or 0.057 hectares (i.e. 5.7% of the area) in a 12-hour night graze. Leading to have larger areas of the paddocks with small amounts of returned nutrients.

2.6 Influence of climate and soil type on N leaching from urine patches

Nitrogen leaching its influenced by the accumulation of soil nitrate coinciding with the timing and magnitude of drainage. The timing and amount of drainage are influenced by climate and soil characteristics such water holding capacity, profile available water, drainage characteristics (free, poorly draining or artificial drainage). For example, in coarse-textured soils with low profile available water reaches saturation sooner than fine texture soil with higher profile available water. Therefore, these soils start to drain sooner under the same climate conditions. Likewise, soils with lower profile available water capacities will have greater depths of drainage (Haynes & Williams, 1993).

2.6.1 Soil

The soil texture controls water behaviour in soils because texture influences soil porosity, which controls water movement in the soil. The total porosity of the soil includes micropores and macropores. Coarse textured soils contain a high proportion of macropores while the proportion of micropores are high for fine textured soils. The micropores are in charge of the water holding capacity of the soil, while the macropores drain water rapidly and, therefore, don’t contribute to water storage in soils (McCarty et al., 2016; Osman, 2012). Additionally, internal modification of soil structure such as cracks and channels formed either by earthworms or roots increases water drainage through the soil (Silva et al., 2000).

2.6.2 Climate

Climatic conditions also have an important influence on drainage rate and the intensity of nitrogen leaching. Losses of nutrients commonly occur in wet periods, such as the late autumn to early spring period, which is typically the time of drainage events in many parts of New Zealand. This is due to this time of year being the period of lowest evapotranspiration rates, allowing greater soil moisture to accumulate with subsequent rainfall events. The evapotranspiration from main agricultural regions in the North and South Island ranges from 5.2 mm/day during summer to 0.3 mm/day in winter. These values result of the high sunshine hours and a deficit in vapour pressure, and the low evapotranspiration in winter is low wind speed (Di & Cameron, 2002; Scotter & Heng, 2003). There can also be a large variation in the total annual drainage depths that occur in different regions of New Zealand due to the large variation in annual rainfall. The average rainfall ranges from 500 mm in Central Otago to 4000 mm on the West Coast of the South Island. However, most dairy farming typically occurs within areas where rainfall is 640 - 1500 mm (Environmental Indicators, 2017). In regions with low rainfall, irrigation is used to allow greater pasture production, however, this contributes to the drainage season starting sooner and to greater volumes of drainage. Both the length of the drainage season and the magnitude of drainage contribute to greater leaching losses of N.

2.7 Standoff structure and management

2.7.1 Standoff strategy

The New Zealand dairy industry aims to develop profitable and productive farming systems while minimising their impacts on the environment (Beukes et al., 2013). The use of off-paddock systems, for example using facilities such as barns or standoff pads, has been increasing in New Zealand. In the Waikato region, 22% of dairy farmers use standoff pads, primarily to help reduce the incidence of stock causing treading damage of pastures (Longhurst et al., 2013). Standoff facilities provide farming systems the ability to protect soil and pasture from treading and pugging damage, improve utilisation of supplementary feed and help to reduce nutrient and pathogen losses to water (Beukes et al., 2013).

2.7.2 Standoff Pad Construction

A standoff pad is a constructed loafing area where livestock can be held for extended periods of time, which provides resting areas and access to supplementary feed. Standoff pads typically have two main types of drainage; those build on free draining soils with no capture of effluent, and those built on soil with impermeable drainage or have a manufactured liner installed to allow collection of the effluent. With increasing concerns about the potential for nutrient and pathogen leaching losses, good practice construction criteria for standoff pads designs involves the collection of effluent (Merrilees & Donnelly, 2007). Standoff pads are usually constructed with a natural material that is free draining and provides comfort to the animal. The more common bedding material is bark or wood chips, with sand and straw being other options used (Luo et al., 2006). Considerations with choice of material include cow comfort, the ability of the material to retain effluent and maintain a dry clean surface, and cost of management and bedding material replacement (DairyNZ, 2014). The thickness of the bedding layer is also important, with some recommendations being a minimum of 50 cm (Edwards et al., 2003).

2.7.3 Woodchips

Woodchips are commonly used as bedding material due to their relatively low cost, but also because of the comfort they provide to livestock and because of the material's absorptive capacity. Woodchips are able to hold 200% – 300% of their weight in water, however, this capacity will depend on the type of wood, chip size and initial moisture content (Haataja et al., 1989).

The size of the chip is the main factor affecting the overall performance of the standoff pad ranging from 1 to > 12 cm. Its influence is significant for both animal welfare and for excreta movement within the bed. The ability of the bedding material, such as woodchip, to retain nutrients has been reported in previous studies at the Waikato region. According to Luo (2006), the ability of woodchips to retain nutrients from excreta increases when their size is above 5 cm, being able to retain up to 60% of the N deposited as excreta on the standoff pad. When small chips are less than 5 cm, the bed provides more comfort to the cows (Smith et al., 2010). However, the small size of the chips prevents the pass of the excreta solids through the bed, therefore, the excreta builds up on th surface of the loafing area. The accumulation and surface sealing leads to dirtier animals, foot and udder problems (mastitis) and a requirement for frequent renovation of the woodchips. When the standoff uses medium (5-10 cm) or large (10-12 cm) chip sizes the excreta moves more in to the woodchips, but is still mostly retained in the top ~10 cm of the bedding material. With larger chip the bed lasts longer because the excreta penetrates the surface of the bed evenly, keeping the surface cleaner (Merrilees & Donnelly, 2007).

The woodchip quality influences effluent treatment and biological activity due to its function as a medium for organic waste digestion. The woodchips act as a bulking agent maintaining porosity and aerobic conditions, providing a good substrate for bacterial growth (Smith et al., 2010). Adequate bedding material allows bacterial retention during wet conditions when water flow is high. Hence, nutrients and pathogens can be retained leading to a bacterial die-off before reaching the soil/plant/water system. Likewise, the nutrient retention capacity allows the bedding material as a nutrient source, either directly or composting (Luo et al., 2006).

2.7.4 Site selection

The selection of the site is essential for the success of the standoff pad within the system and influences the design, construction and further management. Therefore, some important points must be taken into account before and during the plan application (Buss et al., 2011). The site must be allocated preferably in a sunny area, open to wind and with no natural barrier nearby to allow drying of the surface of the bed. Its construction must avoid low-lying areas to prevent any surface runoff to flood the standoff area. Likewise, it is important to avoid construction over rocky subsoils which will exacerbate the nutrient leaching rate compromising the drainage system (Buss et al., 2011).

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The ideal gradient of the standoff area should be 2-3^{o} to allow effluent to be gravity fed via the drainage system to the storage facility. A standoff area should be located at least 50 m distance away from any sensitive ground water, such as a water course or water supply (Buss et al., 2011). Likewise, the facility must be close to the milking shed to prevent long walks to the animals after milking and close to feed facilities (i.e. silage/maize bunker). There must be an easy access and easy way out for stock movement and machinery for cleaning and for bedding removal. It is also useful for the facility to be provided with electrical power and water. Finally, feeding inside of the standoff is possible, however, it is better to do it in a feed area or along feeding lanes/troughs at the external sides of the facility. The latter is highly recommended to reduce soiling of woodchips, cleaner surfaces inside of the facility and increases feed utilisation (Buss et al., 2011).

2.7.5 Design

The standoff design is based on animal type and age, number of animals, space required per animal, feeding requirements, and the duration of standoff. A main consideration that these factors influence is the space required per animal. Failure in providing the adequate space per cow can result in resource competition (i.e. water, food and space), which can result in aggression between cows, inadequate rest and cleanliness issues (DairyNZ, 2014; Buss et al., 2011). (Appendix 8.3)

The adequate area per cow also depends on whether cows are non-lactating or lactating. For example, lactating cows need a larger area because they spend more time laying compared with non-lactating cows. In like manner, larger areas allow lactating cows to keep their udders cleaner, reduce the incidence of injury or the incidence of mastitis (DairyNZ, 2012).

Table 1 Area required per cow (dry and lactating). Adapted from (DairyNZ, 2012).

Time on pad	Space for non-lactating cow	Space for lactating cow
Short term **< 12 hrs/day (up to 2 days)**	3.5 m^2	4.5 m^2
Long term **>12 h/day (> 3 days in a row)**	5 m^2	6-8 m^2
Permanent **No on-off grazing**	8m^2 + 1 m^2**	15-20 m^2

*Values based on a cross-bred size cow (450 Kg), add 1 m^2 /cow if Friesian.
** Extra for feeding area.

2.7.6 Drainage

Independent of the surface type of the pad, the standoff facility needs to be well drained. In standoff pads with woodchips it is important to install a liner and drainage to collect rain water and effluent. An example of a drainage system involves drainage using 80 mm diameter plastic pipe perforated installed with 3.5 m spacing from each other, with a gradient of 2%. The pipe is covered by a gravel layer of 200 mm depth. This gravel layer is deposited only in the pipe trenches, which reduces cost because gravel is not required across the entire pad area (DairyNZ, 2012; Buss et al., 2011).

2.8 Management

2.8.1 Pad management and maintenance

Maintenance of a standoff pad is critical to protect the investment and ensure good performance. The process starts with a standoff pad disinfection and the allocation of the new bedding material, before the season starts. It is important to keep heavy vehicles off of the pad to prevent compaction or damage the drainage system (DairyNZ, 2014). It is recommended to allocate 0.5 m^3 per cow as a spare material and hold it at the back of the pad for replacement (DairyNZ, 2005). During its use, the pad typically requires to clean the surface from excreta accumulation which can be scraped or incorporated depending on the management. If calving is planned to occur inside of the standoff pad it is essential to determine a specific area for this that is filled with clean fresh material. By the end of the wet period, the bedding material needs to be removed leaving bare soil to dry out, when the pad is not lined due to soil low permeability, or for lined pads to allow drainage system to be checked and to allow it to be fixed if necessary (DairyNZ, 2014) .

Re-chipping of the pad is typically conducted every year, but this will depend on the level of use. In some cases, rippers can be used to incorporate the surface excreta allowing aeration and longer use of the material. However, it is better to replace all the bedding material to allow use for longer durations of standoff if necessary (DairyNZ, 2014). An open well-drained bed provides a better performance of the standoff. The management must aim to reduce overcrowding and use the adequate size of woodchip. The correct stocking rate prevents the excessive accumulation of faeces and extra cleaning work. Additionally, when re-chipping the bed the allocation of the bedding material should be in the central area of the pad where most of the animals commonly will be lying down (Merrilees & Donnelly, 2007).

2.8.2 Effluent management

During the design of standoff pads, effluent management must be considered to prevent potential problems due to the large accumulation of manure. Rules and regulations of the Regional Council must be known and understood to obtain an appropriate consent if needed. The regulations are related to the location of the effluent pond, drainage system and subsoil sealing of the standoff pad (Smith et al., 2010).

The use of standoff is a potential environmental hazard due to the large amounts of concentrated nutrients in animal manure. The manure produced needs to be managed carefully to minimise losses to water (Smith et al., 2010). The effluent produced is characterised by high levels of ammonia, phosphate and pathogens, along with high Biological Oxygen Demand (BOD) representing a risk for the aquatic ecosystem (Smith et al., 2010).

The volume of effluent produced in a standoff area can vary greatly depending on use and rainfall. After deposition of excreta, the solids are trapped in the top ~10 cm, while the liquid passes through the bedding material and is collected by drains above an impervious layer or liner (DairyNZ, 2012). However, the natural absorptive capacity of the bedding material absorbs part of the effluent (DairyNZ 2012). Besides nutrients, the bedding also absorbs pathogens, reduces odour and allows microbial degradation (Luo et al, 2004).

2.9 Treading and pugging

Over the past three decades in New Zealand there has been a significant increase in dairy cow numbers from ~2 million cows in 1980/81 to ~5 million cows in 2015/16. This has resulted from both the expansion and intensification of dairying. The land area used for dairying has increased over this time from 1.08 million hectares to 1.70 million hectares (DairyNZ, 2015). The stocking rate has increased from 2.30 cows per hectare to 2.87 cows per hectare (DairyNZ, 2015). As a result, there has been an expansion of dairying onto soils that have a high susceptibly to treading damage.

Treading damage results from the impact of animal hooves on the surface soil (Mackay, 2016). On imperfectly drained soils in temperate regions where cattle graze all year around, treading damage can cause deleterious effects on soil structure and pasture production (Pande et al, 2000). During treading, the soil's porosity and permeability are decreased and the pasture plant and its root system are vulnerable to injury. As a result, there is increased susceptibility of the soil to ponding, run-off and erosion; which in turn accelerate the losses of nutrients and pathogens to surface waters. Considerable pasture damage can also result from intensive pugging events. Under these circumstances, pasture utilisation and recovery are reduced, which impacts on animal production (Pande, 2002).

2.9.1 Soil changes caused by treading damage

Soil consistency describes the form/state of the soil and how it behaves (i.e. solid, plastic or liquid) in response to an applied external force (e.g. machinery, animal hooves) (Bilotta et al., 2007). When soils are dry, their consistency is very firm and cultivation is difficult. In contrast, when a soil is moist it becomes friable and breaks up and it is relatively easy to cultivate. However, if soil water content increases further then the soil is in a plastic state and cultivation is not practicable. Finally, when the moisture content approaches saturation the soil may be in a liquid state and may flow under external pressure such as those imposed by animal hooves (McLaren & Cameron, 1996).

Treading damage is the result of the complex interaction between animal type, soil structure, plant cover and soil moisture content. Treading damage causes detrimental effects on soil physical properties (Tuñon et al., 2014). The main effects of treading damage on soils are pugging and compaction. Pugging occurs when saturated soils (pores filled with water) are subjected to loads from animal's hooves which surpass its bearing strength (Bilotta et al., 2007). During this process, the soil surface is remoulded by the hoof of the animal causing plastic deformation, which destroys macropores and buries and tears pasture plants until the hoof reaches a stable/solid layer (Mackay, 2016). As a result of pugging, the soil surface is often uneven and the pasture density can be reduced, which affects both the soil hydrological cycle and pasture growth (Patto et al., 1978). Whereas, soil compaction occurs when unsaturated soils (pores filled with water and air) are compressed reducing its air volume (Hillel, 1980). During compaction, large pores or macropores are reduced by the external load imposed (Drewry et al., 2008; Willatt & Pullar, 1984).

2.9.2 Factors affecting the level and intensity of treading damage

The main factors affecting the level and intensity of treading damage are described below.

Soil texture

The texture of a soil helps regulate its behaviour, for example, sandy or light-textured soils are easy to work allowing rapid absorption and drainage of water through the soil profile. In contrast, clay or heavy-textured soils usually become sticky when wet, which makes them difficult to work. In addition to the texture, the soil structure also helps control soil functioning directly, including soil strength, which is the ability of the soil to withstand external forces

(Osman, 2012). Soil strength is provided by soil cohesion and internal friction. The former is in charge of bonding soil particles, and the latter is the friction between particles when they slide over each other, which is influenced by soil texture. For example, sandy soils present higher internal friction than cohesion, reducing treading damage compared with clay soils, which have better cohesion than internal friction (McLaren & Cameron, 1996).

Animal type and stock density

Soils are required to withstand the load or weight of an animal during grazing. This load or force applied depends on the interaction between the weight of the animal and the area covered by the animal hoof on the soil surface (Bilotta et al., 2007). The pressure force applied varies with the animal type or species, for example the pressure exerted by a static cow weighing between 350 to 450 kg ranges from 200 to 350 kPa (Bowler, 1981). While for sheep the pressure force ranges from 50 to 80 kPa. This force is increased when the animal moves or when the hoof is placed on uneven surfaces. The force exerted by the animal contains two components. First, the normal component, acting in a vertical direction. Second, the tangential component acting in a horizontally direction resulting in soil shearing (Greenwood et al., 1997; Patto et al., 1978).

Stocking density

Stocking density and duration of grazing are important factors affecting the extent of treading damage. At high stocking densities, the animal trafficking and the number of hooves on the paddock is increased, making the soil prone to a greater intensity of damage (Patto et al., 1978). This damage often results in the loss of pasture cover due to the high defoliation rates, and consequently the protection provided by the pasture is reduced at further grazings in wet conditions. At the farm system level, the extent of treading damage also depends on the accumulation of grazing events/frequency occurring on the farm throughout the season. Therefore, both stock density and grazing frequency need to be considered together to assess the risk of damage to soil physical properties over the winter/spring period (Drewry et al., 2008; Greenwood et al., 1997).

Soil moisture content

The moisture content of the soil during grazing influences the degree of soil damage caused by grazing animals, as moisture content affects soil consistency (i.e. cohesion and internal friction of the soil particles). As soil moisture content increases the soil strength diminishes. When soil has slow permeability, the internal friction is lost and a reduction in soil strength occurs (Patto et al., 1978). Therefore, when paddocks with saturated soils are grazed or during rain, poaching is most likely to occur (Mulholland & Fullen, 1991).

Pasture cover and plant species

Pasture cover provides protection to the soil in different ways, acting as a physical barrier between soil and animal hoof. Likewise, the root and stolon of the plant enhance the bearing capacity of the soil and, finally, the decomposition of the plant residues and binding of soil mineral components, through the formation of water stable soil aggregates, reduces deformation effects (Bilotta et al., 2007). However, the protection is variable and depends on the quality and quantity of vegetation. For example, dense pasture mats, which occur in low fertility conditions such as kikuyu, provide good protection. Meanwhile, highly productive species, such as perennial ryegrass and white clover, tend to be more open and allow more contact between hoof and soil (Bilotta et al., 2007). In a comparison between high producing grasses, such as perennial ryegrass with grasses such as Yorkshire fog, sweet vernal and Bromus, the former was more resistant to treading damage. However, all the species were affected by treading, often making its growth flatter after damage. Nevertheless, the ryegrass pasture production post treading was higher by about 30% compared to the other grasses. Therefore, its persistence and capacity to keep producing allows this species to achieve better productivity in situations where treading damage is likely (Houlbrooke et al., 2010; Willatt & Pullar, 1984).

2.9.3 Impact of treading damage and the use of standoff on soil physical properties and pasture production

When treading intensity increases, (Pande, 2002) macroporosity of the soil is reduced and as a consequence, aeration and drainage decreases. The level of compaction and decrease in porosity can sometimes be evaluated from the change in the bulk density of the soil. According to Drewry and Paton (2000), there is about 70% more macro-porosity in ungrazed than grazed pasture soils after a four-month recovery period. During treading, macropores are compressed pushing the air out, then the medium-pores can be compressed, which expels the remaining water. Consequently, there is a reduction in the infiltration and percolation rate of the soil, which increases the potential for runoff and erosion. Under these circumstances, plant growth may also be restricted due to oxygen reduction in the soil and a lack of space for root system development (Pande, 2002), as well as reduced water holding capacity.

In New Zealand during winter, grazed paddocks are subdivided for rotational strip grazing to maximise pasture utilisation and control pasture intake by animals. In wet conditions, each subdivision has a high stocking rate grazing on wet soils, creating a combination of treading and defoliation (Pande, 2002). Thus, as the stocking rate increases there is an increasing susceptibility of soils to be pugged (Willatt & Pullar, 1984). The occurrence of pugging varies between seasons and between paddocks within the farm, with some areas more susceptible to pugging than others (Haynes, 1995).

The effect of treading damage on pasture growth can be high, even with a single grazing event, when susceptible soils are grazed in wet conditions. Animal treading has been shown to cause up to 45% in pasture yield reduction on an annual basis (Drewry et al., 2008; Menneer et al., 2005), but this reduction in growth is strongly influenced by the severity of damage (Menneer et al., 2001) observed annual pasture reduction ranging between 35% to 45% from severe pugging, while there was a pasture reduction of 13% to 21% with moderate pugging. Nevertheless, as discussed above, the extent of the damage will depend directly on the grazing length, soil type, type of animal, stocking rate, the pasture species present on the paddock and its interaction for each situation and management (Haynes, 1995; Menneer et al., 2001).

Therefore, to prevent pasture damage and to protect soils, on-farm options such as standoff pads, barns and herd homes are available to keep livestock off paddock during sensitive periods where soil moisture content is high (Longhurst et al., 2006). There is large variability in the duration of recovery periods following treading damage with typical ranges from weeks up to a year, depending on the severity and frequency of damage. When the farm system can keep cows off paddock during wet periods, pasture production potentially increases by 20% annually compared with standard grazing systems. Therefore, there must be a balance within the system between the use of standoff and grazing management. (de Klein, 2001).

2.10 Tools

This study has used a number of software tools/calculators to model different aspects of the farm system, which have contributed to the analysis of evaluating various aspects of the standoff facilities. The tools used include; OVERSEER® Nutrient Budgets, the Dairy Effluent Storage Calculator (DESC), a Soil Water Balance model and the DairyNZ Standoff Investment Calculator, which are summarised the following sections.

2.10.1 OVERSEER® Nutrient Budgets

OVERSEER® Nutrient Budgets (hereafter referred to as 'Overseer') is a software model that calculates/estimates all nutrient inputs and outputs from a farm or block within a farm, including nutrient losses, such N leaching and greenhouse gas emissions (Shepherd & Wheeler, 2012). Overseer also provides the ability to assesses different farm management scenarios to quantify the impact of changes on nutrient use efficiency and losses. In this study, Overseer was primary used to determine the impact of increased standoff on N leaching and to quantify the additional effluent nutrients generated, the latter influencing the area required for land application of effluent. The use of Overseer made it possible to assess, for the farm case studies, how sensitive N leaching losses were to modifications in the use of standoff and to changes of other farm parameters. Likewise, Overseer was used to assess whether changes in standoff use influenced the need for additional expenditure on plumbing new farm areas with an effluent reticulation system.

2.10.2 Dairy Effluent Storage Calculator (DESC)

The use of good management practices for effluent management requires adequate effluent storage to allow farmers with the flexibility to only apply effluent on the days where soil moisture conditions are suitable. If dairy effluent generated by farm facilities (i.e. dairy shed, feed bunkers, off-paddock facilities, races and yards) is mismanaged, then it can affect water quality (Longhurst et al., 2000). Therefore, Horizon Regional Council and Massey University developed the Dairy Effluent Storage Calculator (Horne et al., 2011). The DESC provides an estimation of the annual effluent volume generated and annual storage requirement over each of thirty historic years for individual farms. To do this the model uses farm specific information and long-term district daily climate data. This allows the range of annual effluent storage requirements to better guide decisions determining what volume of storage will be adequate for a particular farm. A key aspect of the DESC is that it determines that rate at which effluent can be irrigated based on irrigator management parameters and when the soil is at an appropriate water deficit level based on the soil risk factor. The main data used by this software is the soil risk factor, rainfall catchment areas of the effluent system, wash water used at the farm dairy, pond size (current in the farm or new) and other farm details (DairyNZ, 2013).

2.10.3 Soil Water Balance model

A soil water balance model is an estimation of the daily soil water deficit determined using the data from climate and the capacity of the soil to retain water. The most important information to generate a soil water balance is the amount of rainfall and the evapotranspiration per day. Evapotranspiration is determined from a range of site specific climate data, including: air temperature (maximum and minimum), sunshine hours per day and wind speed (Fao, 2006). By providing an estimation of the daily soil water deficit, this tool can be used to guide when effluent can be safely applied, based on soil risk factor and the potential impact that grazing will have on treading damage. In this study, a soil water balance was primarily used to identify the critical periods to use standoff to avoid treading damage for each of the case study farms.

2.10.4 DairyNZ Standoff Investment Calculator

DairyNZ Standoff Investment Calculator was developed to provide an approximate estimate of the financial returns available from investing in off paddock infrastructure in a dairy farm system. This calculator provides an initial assessment to compare two different systems (current and proposed). This comparison requires the input of parameters of the system, such as feed brought to the farm, number of animals, crops, stock grazing on and off the farm and staff costs. Depending on the system, the tool balances the proposed scenario in its different parameters and mixed with the implementation of the standoff (DairyNZ, 2017). This process allows economic benefits from this investment to be obtained by the calculation of data from background information to provide a better picture of the economic implications of this investment. However, an additional full feasibility study should be carried out for a farm business before investing in a new standoff infrastructure.

Chapter 3 Methods

This research investigates the key design criteria and costs associated with the adoption of standoff practises or strategies on a range of dairy farms using a case study approach. Four farmers in the Manawatu region who were contemplating the adoption of standoff practices were identified. Prior to, and in preparation for, this analysis a number of farms with standoff facilities were visited and the experiences of these farmers and the costs associated with standoff were recorded.

3.1 Farm selection

This part of the study was divided into two phases:

- Phase one: gather background information from farms with standoff facilities, and
- Phase two: investigate the instillation of standoff facilities on case study farms (i.e. farms considering installing the infrastructure necessary to practice standoff).

3.1.1 Phase one

Four farms with different standoff facilities were chosen for phase 1. These farmers were identified by DairyNZ. The farmers were contacted by the researcher to set an appointment for the interview. A questionnaire was developed to help guide this interview (Appendix 8.1). Aspects of the system's management, prior to and after the adoption of standoff were explored in the interview to help establish a 'big picture' of the advantages and costs of standoff and its management. These interviews were conducted in accordance with the Massey University's ethics process. The farmers were made aware of the purposes of the study. The interviews were recorded and later transcribed.

3.1.2 Phase two

The following criteria were employed to select the case study farms:

- Farms in the Horizons Regional Council region.
- The farmer was interested in building or modifying current structures for standoff.
- Willingness to provide farm data.
- Farms facing challenges managing pasture and soils during wet periods and/or the requirement to reduce nitrogen (N) losses to water.

The farmers were contacted by the researcher to explain the purpose of the study and to make an appointment date for the interview. The objective(s) of the potential standoff and farm information was gathered during the interview. The interviews were recorded and transcribed.

3.2 Model, tools and calculation

The information gathered from each farm was analysed and modelled using four different tools including; Overseer® Nutrient Budget software (v 6.2.3 hereafter called Overseer), the Dairy Effluent Storage Calculator (v 1.47, hereafter called Storage Calculator), the soil water balance (SWB) and the DairyNZ off-paddock investment calculator (v 1, hereafter called DairyNZ Tool).

3.2.1 Overseer® Nutrient Budget (v 6.2.3)

The Overseer software is a farm-scale nutrient budgeting tool that models nutrient cycling including losses to the environment. Overseer is the ‘industry standard’ tool used by farmers, industry professionals, such as the fertiliser company field officers, and regulatory authorities, such as Regional Councils, hence, its use in this study to model nutrient management, especially N losses to water.

3.2.2 Dairy Effluent Storage Calculator (v 1.47)

The Storage Calculator software calculates the quantity of farm dairy effluent produced and the storage requirement (i.e. size of the storage pond). This tool identifies the storage requirement using: a data base of New Zealand soil types, which have been categorised as ‘high’ or ‘low’ risk; a large collection of climate data; along with numerous features of the milking process, standoff duration and irrigation management. One of the characteristics of effluent management on dairy farms is that each farm has a unique set of circumstances that result in individual storage requirements.

There is a large cost associated with managing the extra effluent generated during standoff. The Storage Calculator was used to identify the extra storage required for the implementation of standoff on the case study farms.

3.2.3 Soil Water Balance (SWB)

The SWB model was used to predict the soil water deficit (Scotter et al 1977). This tool bases its calculation on climate data, such as rainfall and evaporation, and the soil’s water holding capacity. The SWB was used to identify the standoff days on the case study farms which were seeking to protect soil and pasture.

3.2.4 DairyNZ off-paddock investment calculator (v 1)

The DairyNZ Tool generates an estimate of financial returns on investment in standoff facilities by accounting for advantages, such as increased milk production and improved utilisation of supplements, as well as increased costs, such as those associated with management of greater volumes of effluent, more labour etc. This tool has a relatively sophisticated output of investment indicators, such as net present value, internal rate of return, investment return, payback period and the risk of the financial operation.

Chapter 4 Result

4.1 Phase 1

The interviews in Phase 1 were based on a semi-structured questionnaire: data was analysed, recorded and transcribed. The interviewees were designated a number to maintain confidentiality (i.e. Farm 1).

As a result of interviewing farmers with standoff facilities and the subsequent analysis, the most cost-effective standoff facility was identified. This is a roofed loafing area with a woodchip floor, and a concrete feed pad. The roofed standoff (woodchips) facility was chosen due to its versatility and relatively low cost compared with cow barns. This facility provides shelter, a loafing area and a feeding area for the cows. Furthermore, depending on the farm management, it can be used strategically at different periods of the years. During winter, it is used to reduce treading and pugging, while summer-autumn standoff can reduce N leaching. Standoff in summer might also help to decrease pressure on pasture and cows by providing shelter and a comfortable area during periods of hot weather. The interviewed farmers also provided information on a range of different construction and operation costs. These values were then compared with those quoted by commercial suppliers (i.e. Redpath and Herdhomes). This method provided confidence in the prices used in this analysis and they have been standardised to keep them constant. The data used for the cases study calculations is explained as follows.

4.2 Assumptions

The assumed price per cow comes from the price of the facility divided by the number of cows. We decided to allocate \$ 800/cow for the complete construction of the standoff facility and to deduct \$ 200/cow when the farm resent feed pad. the latter due to the space required for the animal in the feed pad leading to \$ 600/cow for farms with feed pad. Nevertheless, these prices are subject to variation due to some other factors for each case such as effluent cost, consent and capital feed. The cost of site works, cost of bedding material load and spreading were obtained from commercial suppliers and from farmers information gathered during phase one of the project, therefore, the prices assumed are summarised in Table 2 and 3.

Table 2 Assumed and standardise cost for standoff calculations

Area per cow (m^2) *	Price ($/cow)	Site work ($/$m^2$)	Bedding height (m)	Cost per load ($) **	Spreading ($) ***
6	600	25	0.45	600	5000
8	800	25	0.45	600	5000

** 6 m^2 and $600 for farm with feed pad, * 8m^2 and $800 farm no feed pad,*
***1 load = 70 m^3*
****Average value for spreading farmers.*

Table 3 Calculation formulas

Area (m^2): Area per cow (m^2) x number of cows	**Structure cost ($):** Price per cow ($) x number of cows
Site works cost ($): Area ($m^2$) x $ 25	**Bedding material volume (m^3):** Area (m^2) x bedding height (m)
Bedding cost ($): (Bedding material volume (m^3) / 70 m^3) x cost per load	

This extra volume required, if any, was calculated using the storage calculator and the cost associated with managing this increase in effluent quantity was calculated using costs outlined in Appendix 8.1.

The consent cost is accounted for in the DairyNZ Tool, as is the capital feed, which depends on the feed utilisation before and after the introduction of standoff. These two values are added to obtain the final price per cow cost in the DairyNZ Tool.

Production Milk Solids (MS)

For Farms A, C and D, where standoff would be employed for soil and pasture protection, incremental increases in MS production in spring (i.e the period when standoff would benefit milk yield) of 5%, 10% and 15% were investigated. These increases in spring milk production would translate into increases of 1.6%, 3% and 4.4% in annual MS yield, respectively.

4.3 Phase 2

4.3.1 Case study 1

4.3.1.1 Farm A: Pasture and Soil Protection

This farm is in the Manawatu region and in the general area of Bunnythorpe Road, Palmerston North. Some of the farm's major characteristics are given in Table 4.

Table 4 Case study farm description

Area (ha)	152
Effective area (ha)	146
Rainfall (mm/yr)	893
Peak cows milked	460
Total milk production kg MS	250,926
Milk production kg MS/ha	1718
Milk production kg MS/cow	545
Supplements (T DM/yr)	875
Nitrogen leaching loss (kg N/ha/yr)	26

4.3.1.2 Farm soil map and soil description

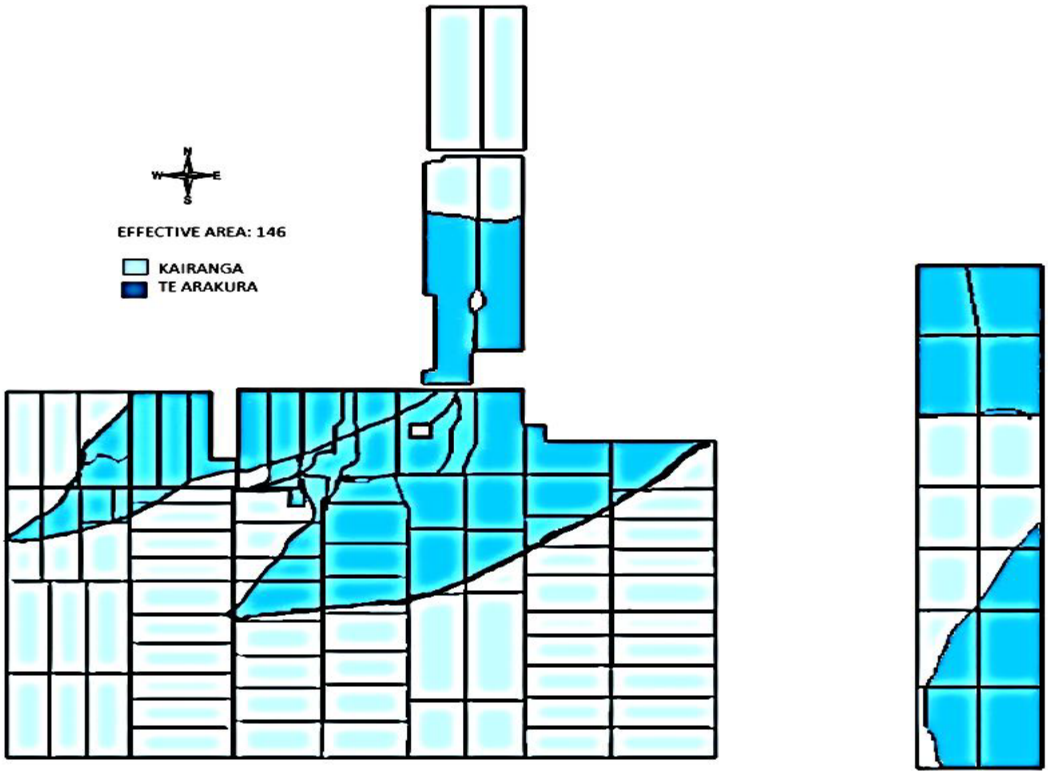


Figure 5 Farm A map

The soil types on the farm are Kairanga silt loam and the Te Arakura silt loam. The Kairanga soil is an imperfectly to very poorly drained gley recent soil (McLaren & Cameron, 1996) occurring in places near rivers and streams. This soil has a silt loam texture with grey to olive subsoil with brown mottles. However, its drainage status improve with artificial drainage and pasture responds well to lime application. This soil is mostly used for dairying and cropping (Cowie, 1978; Cowie & Rijkse, 1977).

The Te Arakura soil is a fine to medium textured soil with poor drainage and medium fertility. Pasture growing on this soil also responds well to lime and phosphate applications. This soil corresponds to a transition from silt loam to sandy loam types. It is improved with artificial drainage. It's formed in transitional areas between old rivers levees and higher lying flats. It's used for dairying, livestock fattening and some cropping (Cowie, 1978; Cowie & Rijkse, 1977).

4.3.1.3 Analysis of Case study farm A: Soil and pasture protection

As Farm A is not in one of Horizons Regional Council's priority catchments, there is no immediate imperative to reduce N leaching. However, due to the soil types, as described above, protecting soil and pasture during winter and spring is a major challenge on this farm.

Three scenarios were considered and modelled for Farm A:

- "Base scenario": current situation of the farm (wintering off, no standoff)
- "Scenario 1": this scenario is the same as the base scenario (i.e. wintering off as for the base case) plus the addition of standoff in early lactation. The cows are placed in the standoff facility when the soil moisture deficit is smaller than 2 mm for the period August to October. It was assumed that, as a result of this standoff for soil and pasture protection, improved pasture growth and utilisation during this period would result in increases in milk production. The effects of increases in milk production of either 5%, 10% or 15% during these three months were explored in this analysis.
- "Scenario 2": in this scenario, all the cows were wintered on the farm. The same grazing criterial was employed in this scenario as for S1 i.e. cows were stood off in winter and spring when the soil moisture deficit was less 2 mm. In this scenario, the advantages of standoff for milk production were investigated by assuming increases in milk production of either 5%, 10% or 15% for the months August to October inclusive.

4.3.1.4 Base Scenario (BS) (wintering-off, no standoff)

The farm is 146 ha of poorly drained soils with 460 crossbred cows (475 kg average live weight) producing, on average, 250926 kg MS/year. During summer, cows are fed 5.5 ha of kale and turnips, and 875 t DM in supplements (maize silage, grass silage and PKE) which is fed on paddocks with 75% utilisation. Approximately, 80% of the herd is wintered-off farm for eight weeks during June and July, and the remaining animals stay on the farm. The farm N loss to water, as estimate by Overseer, 26 kg N/ha/yr or a total 3912 kg N/yr.

4.3.1.5 Scenario 1 (S1) (wintering-off + standoff)

In this scenario, the farm produces either 255,088, 258,650 or 262,213 kg MS reflecting a 5, 10 and 15% increase in milk production between August and October, with 460 cows at peak lactation. Standoff would require 690 t DM of supplement to be fed in the feeding area of the standoff facility, which is assumed to increase its utilisation to 95%. Additionally, cows are fed 5.5 ha of kale and turnips in summer with a utilisation of 82%. The wintering policy of the S1 farm remains identical to the one in the BS: the main difference between the BS and S1 is that when the herd is back on farm after wintering-off, the standoff used as previously described with S1 to help reduce treading damage. The water balance model revealed that the average number of days of standoff would be 15, 10 and 5 for August, September and October, respectively. Tools such as the FDE storage calculator and Overseer require standoff to be inputted as average hours per day. Therefore, values of 12, 8 and 4 hours a day for August, September and October, respectively, were used in these models. The FDE storage calculator estimated that S1 would generate approximately 3853 m^3 of extra effluent and Overseer predicts an average farm N loss to water value of 25 kg N/ha/yr.

4.3.1.6 Scenario 2 (S2) (wintering-off + standoff)

In this scenario, the farm produces either 255,088, 258,650 or 262.213 kg MS (i.e. a 5, 10 and 15% increase in milk production for August to October), with 460 cows at peak lactation. As all the cows are wintered on farm, an extra 846 t DM of supplement is required. This is fed on the feed area with 95% utilisation. A summer crop of kale and turnips of 5.5 ha is grazed with 82% of utilisation. The supplement is fed in the standoff facility and the entire herd is kept on farm during winter. Standoff occurs during winter and is extended to spring when the soil moisture deficit is less than 2 mm, as identified by the soil water balance for the past 25 years. On average, this gave 12, 12, 12, 8 and 4 hours per day standoff for June, July, August, September and October, respectively. The FDE storage calculator predicts that S2 would generate 3909 m^3 of extra effluent and Overseer models the farm average N loss water value is at 26 kg N/ha/yr.

4.3.1.7 Storage calculator

The Storage calculator estimates that BS, with zero stand-off and wintering-off, requires 4,624 m^3 of storage. Whereas S1, with standoff during spring and wintering-off farm, requires 4,710 m^3 and S2, with stand-off during winter and spring, needs 5,255 m^3.

4.3.1.8 Soil Water Balance (SWB)

The soil water balance first described by Scotter et al. (1977) was modified to predict the number of standoff days in the spring (S1) and winter-spring (S2) periods. Climate data for the past 25 years was used to identify the days that the soil water balance was less than 2 mm.

When the moisture deficit is less then this critical value, the soil and pasture are at risk of experiencing significant damage during grazing, which adversely impacts on the quantity of pasture that is available during the spring period (J. Howes, *pers com.*). If the soil moisture deficit is greater than 2 mm, then any damage that does occur is less likely to reduce pasture intakes by grazing cows over the spring months (J. Howes *pers com*).

A detailed feed budget was constructed in Excel for the three scenarios considered for this farm. This budget was used to identify the quantity of supplements required in each system. The number of standoff days per season and per month varies between years, depending on the climate. In years of frequent winter-spring rainfall, standoff occurs on many more days than in dry years. The average number of standoff days per month was calculated to help facilitate this analysis. Then, as mentioned above, these values in turn were converted to the average number of hours of standoff per day each month for use in the Effluent storage calculator and Overseer.

4.3.1.9 Overseer

The farm (BS) is currently leaching an estimated 26 kg N/ha/yr or 3,912 kg N/yr in total. This scenario has no stand-off facility and winters off about 80% of the herd. The farm has 3 pastoral blocks (Platform, Effluent and Kierens) and a cropping block (turnips), which rotates around the pastoral blocks. The dairy effluent is collected from the milking shed and yards and stored in a holding pond before application. All of the pastoral blocks receive the solids removed from the bottom of the effluent pond in October and the effluent block is irrigated with the liquid effluent throughout the year.

The standoff strategy was added to the farm to create S1 and S2 files in Overseer. It was assumed that 10% more pasture was utilised as a consequence of spring standoff and this resulted in an increase in production from 250,926 kg MS to 258,650 kg MS for both scenarios. Wintering-off for S1 was similar to BS, which was for 8 weeks, and after that the herd used the standoff facility. For S2, the herd was wintered on the farm. The implementation of the standoff in both scenarios is translated into "feed pad hours per day", which for S1 was; 12, 8 and 4 during August, September and October, respectively, and for S2 was; 12 hour for June and July (winter) and 12, 8, 4 hours for August, September and October, respectively. Supplements were fed in the covered feed pad instead of in paddocks, thereby, increasing the utilisation up to 95%. The supplement requirements were 629 t DM for S1 and 846 t DM for S2. There was an increase in the volume of dairy effluent directed to the current farm effluent system and irrigation area. To prevent N leaching losses from the effluent block from escalating, this block was enlarged from 31 ha to 63 ha for S1 and to 69 ha for S2. Therefore, the estimated N loss to water from the whole farm for S1 is 25 kg N/ha/yr or 3,853 kg of N/yr in total and for S2 is 26 kg N/ha/yr or 3,909 kg of N/yr in total (Appendix 8.2).

4.3.1.10 DairyNZ standoff investment calculator

The DairyNZ standoff investment calculator was used to analysis information for the current system (BS) and the proposed systems (S1 and S2). Information was obtained from the feed budget of the farm and modified as follows

- Increments of 5%, 10% and 15% increases in milk solids production per cow for the months of August to October, inclusive due, as a result of using standoff in spring for S1 and S2.
- Increases in supplements in S2 required to winter the entire herd on farm.

The capital needed to build the standoff facility and purchase capital feed for both scenarios is shown in Table 5.

Table 5 The investment required for standoff facility on case study farm A

Investment Required	*S1*	*S2*
Structure	276,000	276,000
Site works/Drainage system	92,000	92,000
Cost of expanding effluent area	32,000	36,000
Cost of enlarging pond volume	13,139	35,803
Consent *	10,000	10,000
Capital Feed	-9,540	21,336
Total Investment	**413,599**	**471,139**
$/cow	899	1,024
$/ha	2,833	3,227

**Consent: constant from the DairyNZ tool.*

The total investment cost for the establishment of the standoff facility for S1 is $ 413,599 and for S2 it is $471,139 with a cost per cow of $899 and 1,024, respectively (Table 5). The total cost involves the cost of the structure (metallic frame, roof plastic, canvas for lateral protection, water troughs, power and cement feeding lines), site works/drainage system, the cost of enlarging the pond volume, the cost of expanding the effluent irrigation area to accommodate the extra nutrients captured in the increased effluent volume, consent for the construction and capital feed. For calculations see section 4.2. The capital feed refers to the amount of money saved (in S1 due to improved utilisation of supplement fed on feed area) or spent (due to increased supplement required to winter all cows on farm in S2) as result of standoff implementation and this value is calculated directly by DairyNZ tool data base.

The differences between the income and the investment cost of the facility between S1 and S2 for the 10% increase in milk production are shown in Table 6.

Table 6 Financial differences between S1 vs S2

Financial Differentials	**S1**	**S2**
Long-term Payout ($/kgMS)	6.10	6.10
Long-term Dividend ($/kgMS)	0.25	0.25
Milk Income	49,047	49,047
Differential Income*	**49,047**	**49,047**
Increased Costs		
Labour	13,750	27,500
Feed (Incl crop & winter grazing)	-74,800	-79,600
Machinery & Fuel Costs	-2,380	5,240
Bedding	14,194	14,194
Manure Spreading	5,000	5,000
R&M on Structure	7,180	7,180
Insurance	2,760	2,760
Effluent operating cost	321	921
Reduced Costs		
Fertiliser	-2,090	4,600
Regrassing	1,430	1,430
Differential Costs	**-33,315**	**-17,835**
Differential Benefit	**82,362**	**66,882**

**The comparison or differential here is between the base scenario (BS) and S1 and between BS and S2.*

Table 6 shows the financial difference between BS and S1 and between BS and S2. Milksolids production was kept constant at 49,047 kg MS for S1 and S2 because it was reasoned that standoff would have the same impact on milk yield in both scenarios. This is because the frequency of housing in the spring period would be the same in both scenarios, and winter standoff in S2 simply replaced wintering off in S1. Both systems have the same costs related to bedding, manure spreading, insurance and R&M. The main driver of costs here is the standoff area, which is identical in both scenarios. While S2 involves a greater amount of standoff time, the marginal cost associated with increased bedding and manure spreading in S2 were not thought to be significant. However, there is a difference in costs associated with effluent management (irrigator movements) $32/year and $921/year for S1 and S2, respectively. The costs of labour and feed also increase in both scenarios. The reason for the higher value in S2 is because the facility is used during both winter and spring, while in S1 it is only used during spring. Prior to the implementation of standoff (BS), supplements were fed in the paddock. However, when feed is allocated to the roofed standoff facility utilisation is estimated to increase from 75% to 95%. The differential benefit suggests that the savings in cost associated with supplementary feed and the extra milksolids income covers exceeds the increased costs of the standoff in both S1 and S2.

Table 7 Operating, Investment and risk returns between S1 vs S2

Financial Returns on Proposed System		
Operating Returns	***S1***	***S2***
Payout ($/kgMS)	***$6.35***	***$6.35***
Current System		
Operating Profit ($/ha)	3,010	3,010
Net Farm Income ($/ha after interest)	1,890	1,890
Proposed System		
Operating Profit ($/ha)	3,460	3,340
Net Farm Income ($/ha after interest)	2,050	1,900
Differential (Current - Proposed)		
Operating Profit ($/ha)	450	330
Net Farm Income ($/ha after interest)	160	10
Investment Returns	***S1***	***S2***
Net Present Value	38,500	-74,000
IRR	9.7%	5.0%
Return on Investment	15.9%	10.2%
Payback period (years)	5	10
Risk		
	S1	***S2***
Probability of Positive Net Farm Income	78%	76%
Probability of Positive NPV	100%	78%

Table 7 shows that for a payout of $6.35/kg MS, the Net Farm Income (NFI) is $160/ha for S1 and $10/ha for S2, which supports that the addition of standoff is economically beneficial for both of these scenarios. Likewise, the NPV is also positive for S1 ($38,500) which means that this scenario creates long term value for the business. However, the NPV was negative for S2 meaning that this scenario should not proceed. However, NPV is not the sole measure of financial viability neither is it definitive. Financial costs need to be weighed against non-financial benefits. The cost-benefit of S1is clearer than for S2: this may reflect the cost-effectiveness (i.e. relative cheapness) of wintering cows off farm. It would appear that keeping cows on the farm during winter eroded some of the advantages afforded by standoff over the spring period.

4.3.2 Case study 2

4.3.2.1 Farm B: Environmental Protection

This farm is adjacent to the Manawatu River and has the major characteristics described in Table 8.

Table 8 Case study farm B description

Area (ha)	157
Effective area (ha)	117.3
Rainfall (mm/yr)	980
Peak cows milked	260
Total production kg MS	92783
Kg MS/ha	719
Kg MS/cow	352
Supplements (TDM)	250
Nitrogen losses (Kg N/ha/yr)	31

4.3.2.2 Farm soil map soil description

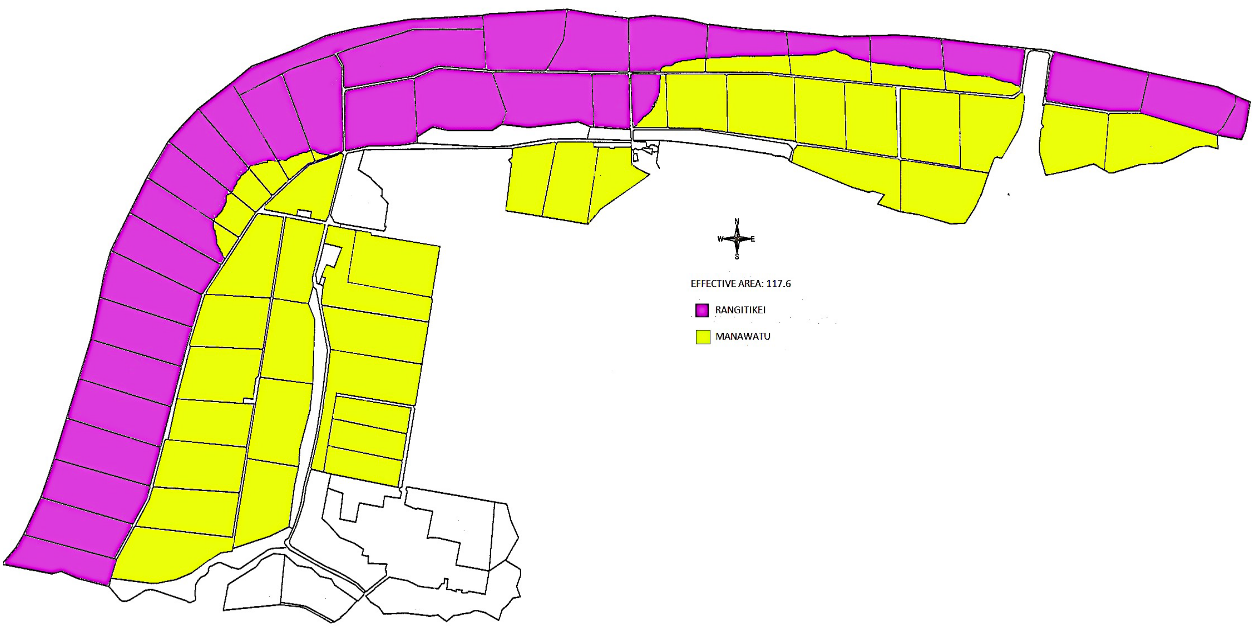


Figure 6 Farm B map

There are two major soil series on this case study farm: these are the Rangitikei and Manawatu series. The Rangitikei soils are classified as rapidly accumulating recent soil with sandy texture and low organic matter content. High stocking rates and intensive cultivation may cause soil compaction. Theses soils are prone to occasional flooding. These soils are mostly excessively well drained and often have stony subsoils (Cowie, 1978).

The Manawatu soils are also moderately to excessively well drained and tend to be on terraces that were subject to previous flooding events. The topsoil is a deep, dark brown silt loam to sandy loam. The subsoil is a silt loam to loamy sand. These soils are classified as slowly accumulating recent soils and tend to have high natural fertility. Their good internal drainage means that these soils are workable all year round and so lend themselves to dairying, fattening, and cropping. As with the Rangitikei soils, the structure of the Manawatu soils can be vulnerable to damage and so cultivation must be carefully managed (Cowie, 1978)

4.3.2.3 Analysis of Case study farm B: Environmental protection

The free draining nature of the soil on Farm B means that soil and pasture protection in winter and spring is not a major issue. Rather, the problem for this farm is the quantity of nitrogen leached from its coarse textured, free draining soils. Therefore, the primary purpose of standoff on this farm is to reduce the amount of N that is lost in drainage.

Two scenarios were considered for farm B:

- “Base scenario”: with 2 hours stand-off use (BS)
- “Scenario 1”: with 9 hours stand-off use per day March to August (S1)

4.3.2.4 Base Scenario (BS) (2 hours) stand-off

The farm operates a ‘once a day’ (OAD) milking system and has a relatively low stocking rate. These practices were adopted for a number of reasons, including their supposed benefits to N leaching rates. The farm is 117.3 ha with 260 cows, which produce 93600 kg MS. The current system uses 100 t DM of maize silage and makes 150 t DM of pasture silage, lucerne silage and hay. Apart from the hay, which is fed on paddocks, the supplement is fed on an existing un-roofed feed pad with an assumed 90% of utilisation. The feed pad is currently used for 2 hours per day from March to August. During winter, 58% of the herd is grazed off the farm for

4 weeks. Overseer estimates that current N loss to water from this farm is 30 kg N/ha/yr or 3,044 kg of N/yr from the whole farm in total (Appendix 2).

4.3.2.5 Scenario 1 (S1) 9 hours standoff

The duration of daily standoff in this scenario increases from two to nine hours from March to August. To achieve nine hours of standoff, a loafing pad would be required and this could be constructed adjacent to the current unroofed feed pad.

As a result of this increase in standoff time, a greater volume of effluent will be produced. Overseer estimates that the effluent area will need to increase from 9.7 to 22.7 ha. In addition to expanding the effluent block, the solids from the pond would be applied to the non-effluent paddocks. As environmental protection is the major objective of standoff on this case study farm, it is assumed that there is no increase in MS production.

4.3.2.6 Storage calculator

The Storage calculator suggests that S1 with daily standoff between March and April of nine hours does not require any more storage than BS, with two hours of standoff per day, i.e. they both require 668 m^3 of storage.

4.3.2.7 Soil Water Balance

There was no need to employ the soil water balance for case study farm B because standoff was not based on protection of pastures, but in S1 was based only on reducing N losses to water. Therefore, over the period from period March to August a daily standoff duration of 9 hours was used every day irrespective soil moisture conditions.

Features of S1 (to reduce Nitrogen leaching)

- An increase in standoff time from two to nine hours per day from March to August. The initial period was modelled for February to May, however, Overseer did not estimate an N leaching reduction during this period, so the period changed to March to August.
- Addition of the loafing pad to the system

- Increase in the effluent irrigation area (to account for the increase in effluent production)
- Allocation of extra solids effluent to a pastoral block

4.3.2.8 Overseer

The Overseer file for S1 was adapted to reflect the features described above including; the increase in standoff time, increase in the effluent area and the allocation of solid effluent to other pastoral blocks. As stated above, there was no change in the amount of supplements brought onto the farm, MS production or any other additional component of the farm. Following these changes, Overseer predicts the N loss from the whole farm to water is 25 kg N/ha/yr or 2553 kg of N/yr in total. This is a reduction of 5 kg N/ha/yr or 491 kg of N from the BS values.

4.3.2.9 DairyNZ standoff investment calculator

The DairyNZ standoff investment calculator was used in this case study farm to find the possible benefits of standoff when used for the purpose of environmental protection.

Table 9 The investment required for standoff facility on case study farm B

Investment Required	***S1***
Structure	117,000
Site works/Drainage system	39,000
Cost of expanding the effluent block	13,000
Consent	10,000
Capital Feed	0
Total Investment	**179,000**
$/cow	688
$/ha	1,526

The total investment cost is $179,000 of which $117,000 accounts for the structure, $39,000 for site works/drainage, $13,000 for expanding the effluent area, $ 10,000 consent for construction and $ 0 for capital feed (Table 9). For the calculations see section 4.2. As the farm currently has a feed pad there is no change to capital feed requirements, animal diet, feed utilisation (95%) or MS production.

The differences between income and the investment costs associated with the facility for S1 are outlined in Table 10.

Table 10 Financial operative cost S1

Financial Differentials	**S1**
Increased Costs	
Labour	0
Feed (Incl crop & winter grazing)	0
Machinery & Fuel Costs	-730
Bedding*	6,017
Manure Spreading	5,000
R&M on Structure	2,000
Insurance	1,560
Effluent operating cost	456
Reduced Costs	
Fertiliser	0
Regrassing	3,450
Differential Costs	**10,853**
Differential Benefit	**-10,853**

**See section 4.1.1 for calculations*

Table 10 shows the costs of standoff on case study farm B. For S1, labour and feed costs are zero because there is no change to the overall management of grazing, animal movements or feeds. The farm in the current system (BS) has a feed pad and, therefore, the labour costs incurred with standoff in S1 are mostly related to management of this area rather than the loafing pad. The costs resulting from bedding and manure spreading are based on the assumptions outlined in Section 4.2 while R&M and insurance are generated by DairyNZ Tool. There is no increase or reduction in fertiliser use, however, there is the cost of regressing, which is calculated by the DairyNZ Tool as well.

The financial disadvantage of S1 is $10,853. This result is anticipated because with S1 there is only the increase in operating costs of more standoff and no attempt was made to offset these expenses with an increase in MS production (as was achieved on case study farm A).

Table 11 Operating, Investment and risk returns farm B S1

Financial Returns on Proposed System	
Operating Returns	***Your Values***
Payout ($/kgMS)	***$6.35***
Current System	
Operating Profit ($/ha)	1,490
Net Farm Income ($/ha after interest)	370
Proposed System	
Operating Profit ($/ha)	1,330
Net Farm Income ($/ha after interest)	10
Differential (Current - Proposed)	
Operating Profit ($/ha)	-160
Net Farm Income ($/ha after interest)	-360
Investment Returns	***Your Values***
Net Present Value	-$334,800
IRR	0.0%
Return on Investment	-10.5%
Payback period (years)	-10
Risk	
	Your Values
Probability of Positive Net Farm Income	50%
Probability of Positive NPV	0%

There is a negative net farm income of ($-360/ha) when S1 used is compared with BS. This leads to a negative NPV of -$334,800 and a low percentage of Positive Net Farm Income (50%). These results are a consequence of implementing the loafing area in this farm and its maintenance. Therefore, standoff practised for environmental protection in a manner similar to S1 described here is likely to be at a net cost to the farm business. Some of these costs may be met by increasing MS production, but then there is the risk that this will result in an increase in N leaching, which would be counterproductive. However, on some farms it may be imperative to reduce N leaching to reach some imposed allocation or limit. In this case the cost of standoff would have to be weighed or compared against other strategies for reducing N losses to water. In this case, the net cost of standoff may compare favourably with other strategies.

4.3.3 Case study 3

4.3.3.1 Farm C with feed pad: Standoff for a combination of pasture and soil protection and environmental protection

This property is made up of two adjacent farms (case study farm C and case study farm D) and is located near Eketahuna, Tararua District. Although these farms are owned by the same family, they are operated independently of each other. Case study farm C has a feedpad and some of the other main characteristics of this farm are described in Table 12.

Table 12 Case study farm C description

Area (ha)	83
Effective area (ha)	78
Rainfall (mm/yr)	1737
Peak cows milked	200
Total milk production (kg MS)	62069
Milk production - kg MS/ha	796
Milk production - kg MS/cow	310
Supplements (TDM)	150
Nitrogen leaching losses (kg N/ha/yr)	50

4.3.3.2 Farm soil map and soil description

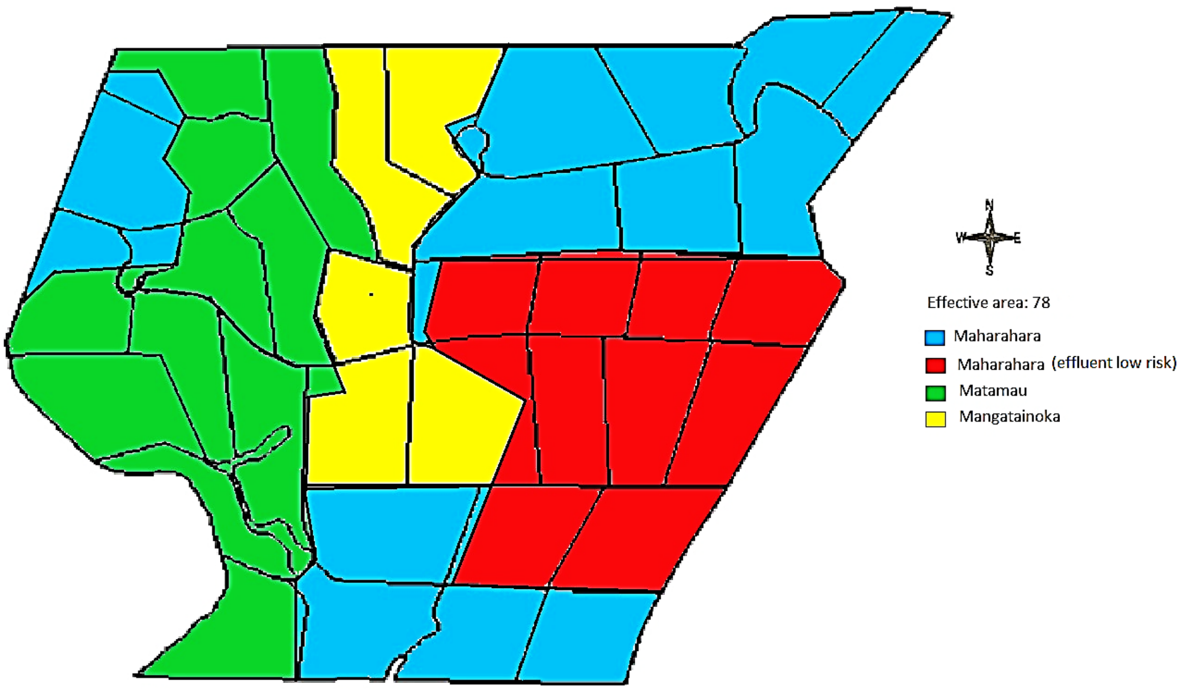


Figure 7 The distribution of soils on Farm C

This distribution of soils on this farm are shown in Fig. 3 and their main properties are described below.

The Maharahara soil is found on the higher terraces and it is mostly developed in loess. It is a moderately well drained soil. An important characteristic of this soil is that the grey and orange mottling is located below 60 cm soil depth. The surface soil is friable but structure tends towards 'blocky' in the lower profile. Due to the low quantity of allophone this soil has a moderate P retention.

The Mangatainoka soil is developed from loess and is characterised by its imperfect drainage. It is common to find this soil on rolling landscapes in the Tararua District. The grey mottles in this soil are located at below 40 cm soil depth. Therefore, it is prone to waterlogged conditions for some parts of the year. It has a friable topsoil but the subsoil is compact.

The Matamau soil is formed from loess and is also present on rolling slopes. Again, this is an imperfectly drained soil with a moderate susceptibility to wind erosion. The subsoil is often compacted, which reduces its permeability and gives rise to a perched water table. Therefore, the Matamau soil is highly susceptible to pugging in wet conditions, particularly when stocking rates are high.

4.3.3.3 Analysis of Case Study Farm C

Two scenarios were considered for Farm C:

- "Base Scenario" BS – the current farm which includes the existing feedpad and a crop of winter oats
- "Scenario 1": S1 - no winter crop, and the construction of a loafing pad facility alongside the existing feed pad.

4.3.3.4 Base Scenario (BS)

The farm is currently producing 62,069 kg MS on an effective area of 74 ha from 200 cows, which weigh an average 460 kg/cow (Table 1). The farm purchases about 150 t DM of supplements of which 63% is allocated to cows on the covered feed pad and 37% on paddocks. Additionally, cows graze 3.8 ha of turnips with a yield of 10 t DM/ha of turnips during summer and 10 t DM/ha of oats during winter. During winter, 80% of the herd is wintered-off for 6 weeks while the rest of the herd grazes the winter crop (oats). The animals spend at least 9-10 hours in the crop paddock overnight, and the next day's grazing are planned according to climatic conditions and soil moisture content. The farm has a covered feed pad which is used during autumn and spring for 2 hours per day, but the increases in time depending on the weather and farm management.

For the BS farm scenario, the Overseer Nutrient Budget model estimates nitrogen loss to water to be 50 kg N/ha/yr or 4162 kg N/yr. The effluent is currently partitioned between two blocks: one block has 10.3 ha of high risk soil, while the other block is comprised of 18.1 ha of low risk soils. Both blocks receive liquid and solid effluent, the latter being applied in October.

4.3.3.5 Scenario 1 (S1)

The introduction of the loafing pad facility will mean that S1 no longer needs to practise winter cropping. The S1 farm is estimated to produce 63931 kg MS, which is about 1862 kg of MS higher than BS, on the same area with the same number of cows as BS due to better pasture growth and utilisation because of greater pasture protection. At 139 t DM, the S1 system imports less supplements than BS due to improvements in feed utilisation. All of this supplement is allocated on the covered feed pad, which increases utilisation up to 95%. During summer, cows graze 3.8 ha of turnips with a yield of 10 t DM/ha. In winter, 80% of the herd is grazed off farm and the remaining 20% is kept on the farm. The cows that are kept on the farm, only graze paddocks when soil moisture and climatic conditions are suitable otherwise they are in the loafing pad facility. Likewise, once lactation commences, cows will be housed if soil moisture conditions prevent grazing.

4.3.3.6 Soil Water Balance

In S1, cows are modelled in Overseer to use the loafing pad facility for 10 hours per day from late-summer to mid-winter, mostly overnight, to mitigate N losses to water. In addition, the use of a soil water balance demonstrated that for improved protection of soil and pastures, then additional periods of standoff would be required over winter and spring. This would involve increasing cow standoff on the loafing pad to an average of 12 hours per day in July and 10 hours per day in the spring months. When these increases in standoff are modelled in the FDE Storage Calculator and the Overseer model, then an effluent area of 36.4 ha would be required, which comprises 10.3 ha of high risk soil and 26.1 ha of low risk soil. This represents an increase in the area of effluent block of 20 ha compared to BS, with all of this increasing being areas of low risk soil.

4.3.3.7 Storage calculator

The FDE storage calculator suggests that the current farm (BS) require a storage volume of 1714 m^3. After the loafing area is added to the existing feed pad and the standoff protocols developed here for soil, pasture and environmental protection (i.e. S1) are adopted then 1980 m^3 of storage will be required.

4.3.3.8 Overseer

In this case study, S1 was based on the addition of the loafing pad to the system. Therefore, the time the animals spend in the loafing pad facility increases over the late-summer to spring period. Over this period, the scale of standoff increases from a present maximum time of 2 hours per day up to an average of 10 to 12 hours per day (Section 4.3.3.5). As a consequence of greater durations of standoff, the winter crop was removed and the animals were fed all supplementary feed in the facility. The quantity of supplements required was reduced to 139 t

DM due to the increase in utilisation, compared to feeding a proportion on paddocks. Due to the increase in the quantity of effluent captured during standoff, the effluent area was enlarged from 18.1 ha to 26.1 ha. Additionally, the solid effluent was spread on other paddocks on the farm rather than the effluent blocks. The combination of changes made to S1, including the use of wintering-off, removing the winter crop and greater use of standoff, have resulted in a decrease in N losses to water modelled by Overseer to 39 kg N/ha/yr, from 50 kg which is a reduction of 11 kg N/ha/yr compared to the BS value.

4.3.3.9 DairyNZ standoff investment calculator

Table 13 shows the investment required for the implementation of the S1 standoff on case study farm C. For this cases study only a new loafing pad is required, as the farm already has an existing feed pad.

Table 13 The investment required for standoff facility on case study farm C

Investment Required	***S1***
Structure	90,000
Site works/Drainage system	30,000
Consent *	10,000
Cost of increased expanding area	23,186
Cost of enlarging pond volume	8,000
Capital Feed	-392
Total Investment	**160,794**
$/cow	804
$/ha	2,061

The investment needed for the loafing pad is $160,794; this value consists of costs of; $ 90,000 for the structure, $30,000 site works and drainage, $10,000 for consent, $23,186 for increasing the effluent area, $8,000 cost for storage pond enlargement and $-392 for capital feed. The later saving is related to the reduction in the amount of supplementary feed required due to improvements in utilisation from 75 % to 95% when it is fed in the standoff facility (see calculation in section 4.2). There was also a reduction in feed expenses due to the removal of the winter crop.

The purpose of standoff in S1 for case study farm C was the combination of pasture and soil protection and environmental protection. Due to soil and pasture protection, standoff in S1 results in an increase in MS production to the value of $11,824 (Table 14). It was assumed that labour costs would not increase for S1 as time spent moving cows on and off the crop is substituted for time spent managing the standoff facility, and because less supplements are fed in S1 compared with BS. The cost of managing the extra effluent was calculated to be $1,070. The differential cost was $5,389 which was covered by the extra milk production leaving a net benefit of $6,435. For the details of the calculations see section 4.2.

Table 14 Financial operative cost S1 farm C

Financial Differentials	
	S1
Long-term Payout ($/kgMS)	6.10
Long-term Dividend ($/kgMS)	0.25
Milk Income	11,824
Differential Income	**11,824**
Increased Costs	
Labour	0
Feed (Incl crop & winter grazing)	-8,000
Machinery & Fuel Costs	-100
Bedding	4,629
Manure Spreading	5,000
R&M on Structure	3,120
Insurance	1,200
Effluent operating cost	1,070
Reduced Costs	
Fertiliser	0
Regrassing	1,530
Differential Costs	**5,389**
Differential Benefit	**6,435**

When the proposed system (S1) is compared with the current system (BS) in the DairyNZ financial DairyNZ tool, there is an operating profit of $10 and a negative net farm income of $220. The net present value is negative meaning that standoff as described for S1 is not a sound investment. Likewise, the probability of a positive net farm income is about 55% alongside a

0% probability of a positive net present value, suggesting that S1 is an economically risky proposition.

Table 15 Operating, Investment and Risk returns farm C

Financial Returns on Proposed System	
Operating Returns	***S1***
Payout ($/kgMS)	***$6.35***
Current System	
Operating Profit ($/ha)	1,440
Net Farm Income ($/ha after interest)	460
Proposed System	
Operating Profit ($/ha)	1,450
Net Farm Income ($/ha after interest)	240
Differential (Current - Proposed)	
Operating Profit ($/ha)	10
Net Farm Income ($/ha after interest)	-220
Investment Returns	***S1***
Net Present Value	-$155,100
IRR	-12.8%
Return on Investment	0.5%
Payback period (years)	206
Risk	
	S1
Probability of Positive Net Farm Income	57%
Probability of Positive Net Present Value	0%

4.3.4 Case study 4

4.3.4.1 Farm D with no feed pad: Standoff for combined Pasture and Soil Protection + Environmental Protection

The main characteristics of Farm D are given in Table 16.

Table 16 Case study farm D description

Location	Eketahuna
Area (ha)	79
Effective area (ha)	68
Rainfall (mm/yr)	1737
Peak cows milked	200
Total milk production (kg MS)	67000
Milk production - kg MS/ha	985.2
Milk production - kg MS/cow	335
Supplements (TDM)	127
Nitrogen losses (Kg N/ha/yr)	57

4.3.4.2 Farm soil map and soil description

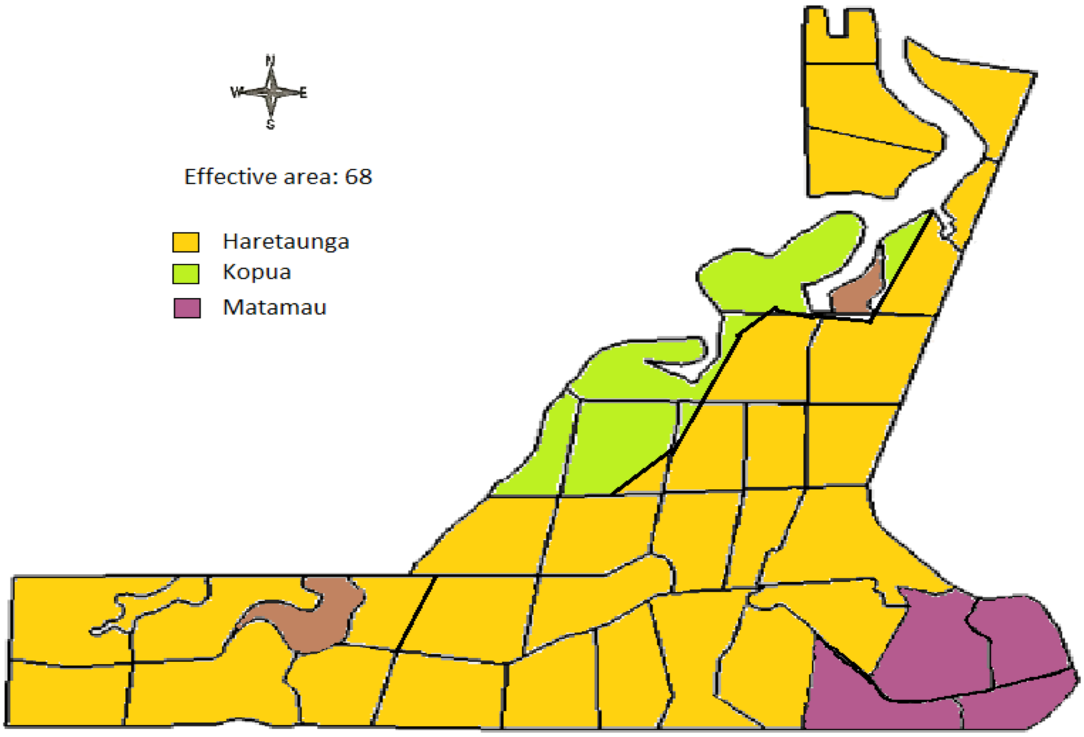


Figure 8 The distribution of the soils on case study Farm D

The Kopua soil is formed from volcanic ash from Tongariro alluvium. It is found on gently sloping terraces with good drainage. The soil's texture is reflected in its water holding capacity, and it has a rapid infiltration rate and permeability. It has a very low susceptibility to pugging, but is prone to erosion caused by the wind if cultivated. It has a natural low fertility with high phosphate retention due to its high allophane content.

The Matamau soil is formed from loess and is present on rolling lands. This is an imperfectly drained soil with moderate susceptibility to wind erosion when cultivated. The available water holding capacity ranges from 50-75 mm. However, the subsoils are often compacted, which reduces permeability. Therefore, this soil is highly susceptible to pugging when wet and particularly with large animals and/or high stocking rates.

4.3.4.3 Analysis of Case study farm D

Case study Farm D was modelled in two scenarios:

- “Base” (BS): current situation of the farm with wintering crop
- “One” (S1): no wintering crop and the implementation of complete standoff facility.

4.3.4.4 Scenario Base (BS)

The farm is currently producing 67,000 kg MS with 200 cows, which have an average weight of 460 kg/cow. During summer the farm grows turnips, which yield about 10 t DM/ha, on 4.5 ha. There is also a crop of oats/triticale with a similar yield (10 t DM/ha) on 4.2 ha. The supplementary feed brought on to the farm is about 127 t DM and fed on the paddocks with 75% utilisation. During winter 80% of the herd is wintered off the farm for 6 weeks. The cows that remain on the farm for the winter, spend the night (9 to 10 hours) on the winter crop paddock, and during the day they graze pasture on other paddocks. The farm is currently leaching about 57 kg N/ha/yr or 4535 kg N/yr, as estimated by Overseer. The farm has an effluent block divided into low risk (9.1 ha) and high risk (7.4 ha) areas. Both blocks also receive solid effluent from the storage pond in January.

4.3.4.5 Scenario 1 (S1)

In this scenario, due to soil and pasture protection afforded by the construction of the standoff facility, the farm produces 69010 kg MS (i.e. an increase of 2010 kg MS relative to BS) with the same number of animals and effective area as BS . The only crop present on the farm is summer turnips, which has the same yield and area as described for the BS. The supplements imported onto the farm is 105 t DM and this is now fed in the covered feed pad with a utilisation of 95%. As with the BS, 80% of the herd is grazed-off the farm in winter, but the rest of the herd uses the standoff facility rather than a winter crop. Overseer estimates that S1 will leach approximately 42 kg N/ha/yr or 3350 kg N/yr. The low risk effluent block in this scenario is increased to 23.3 ha, which receive liquid effluent, while the rest of the blocks only receive solid effluent from the pond and the feed pad. The area of the high risk effluent block is increased up to 10 ha, receiving solids from the feed pad in January

4.3.4.6 Storage calculator

The FDE storage calculator estimates that the current farm (BS) requires a storage capacity of 540 m^3. The adoption of standoff practices (i.e. S1), to protect soil and pasture along with decreasing N losses to water would require 852 m^3 of storage.

4.3.4.7 Soil water balance

The soil water balance suggest that cows would be kept in the standoff facility for an average of 10 hours/per day for the late summer months through to July when they would be stood off for an average period of 12 hours/day. During the late-winter and spring months the daily standoff period is again 10 hours/day before decreasing to one hour/day in December.

4.3.4.8 Overseer

Standoff was implemented in this study case farm to reduce soil and pasture damage and to descrease N losses to water. The increase in standoff time along with the reduction in supplements brought to the farm, the removal of the winter crop (oats) and the increase in the effluent area resulted in a decrease in the quantity of N lost to water of 15 kg N/yr so that S1 is estimated to lose 42 kg N/ha/yr or 3350 kg N/yr to water.

4.3.4.9 DairyNZ tool financial analysis

The financial costs of establishing the standoff facility on farm D are presented in Table 17.

Table 17 The investment required for standoff facility on case study farm D

Investment Required	***Your Values***
Structure	120,000
Site works/Drainage system	40,000
Cost of increased expanding area	16,800
Consent	10,000
Capital Feed	665
Total Investment	**187,465**
$/cow	937
$/ha	2,403

The table above shows that investment in the implementation of standoff on this farm costs $187,465. This value comprises; the structure $120,000, site works $40,000, the increase in the area of the effluent block $16,800, construction consent $10,000 and the capital feed $665. The last two values are calculated by the financial tool while the other components are calculated using information gathered from farmers and commercial companies (for calculations see section 4.2).

The differences between S1 and the BS, for both income and expenditure, are outlined in Table 18.

Table 18 Financial differences for farm D

Financial Differentials	
	Your Values
Long-term Payout ($/kgMS)	6.10
Long-term Dividend ($/kgMS)	0.25
Milk Income	12,764
Differential Income	**12,764**
Increased Costs	
Labour	13,750
Feed (Incl crop & winter grazing)	-17,200
Machinery & Fuel Costs	170
Bedding	6,171
Manure Spreading	5,000
R&M on Structure	3,120
Insurance	1,200
Effluent operation cost	2305,5
Reduced Costs	
Fertiliser	0
Regrassing	1,530
Differential Costs	**12,837**
Differential Benefit	-73

As standoff on this case study farm will protect soil and pasture from damage in the wet months of the year, there is an increase in MS production and, therefore, $12,764 of extra income. Management of this standoff will incur a labour cost of $13,750 due to the increased demand on staff time due to this being a new labour requirement as the farm does currently need to manage a standoff facility. There is a reduction in feed expenses due to the removal of the winter crop and a reduction in the quantity of supplements required due to the increase in utilisation (up to 95%) of supplements fed on the feedpad. The remaining values, except for bedding, manure speeding and the cost of effluent operation, were calculated using information gathered in Phase 1 of this study. The difference in costs between S1 and the BS is $12,837, which is higher than the extra income from the milk production and, therefore, the net differential benefit is $-73.

Table 19 Operating, Investment and Risk returns for farm D

Financial Returns on Proposed System	
Operating Returns	***S1***
Payout ($/kgMS)	***$6.35***
Current System	
Operating Profit ($/ha)	1,460
Net Farm Income ($/ha after interest)	480
Proposed System	
Operating Profit ($/ha)	1,410
Net Farm Income ($/ha after interest)	190
Differential (Current - Proposed)	
Operating Profit ($/ha)	-90
Net Farm Income ($/ha after interest)	-340
Investment Returns	***S1***
Net Present Value	-$211,600
IRR	-16.8%
Return on Investment	-3.7%
Payback period (years)	-27
Risk	
	S1
Probability of Positive Net Farm Income	50%
Probability of Positive Net Present Value	0%

The key financial performance indicators for S1 relative to the BS are given in Table 18. Both the differential operating profit and net farm income have negative values. Accordingly, the net present value is also negative, as are the investment return rate and payback period. The DairyNZ Tool calculates that over time, there is a 50% probability of a positive net farm income but 0% probability of a positive net present value

Chapter 5 Discussion

5.1 The objectives of standoff and the standoff facility

Unsurprisingly, the identification of the purpose(s) or objective(s) of standoff was an important process and had a major impact on the implementation of standoff and its overall role in the case study farm system. The purpose of standoff is determined by the main problem or issues confronting the farm and how these can be addressed by the strategic use of a standoff facility. This study illustrates the effectiveness of standoff strategies. In other words, standoff can be used to protect soils from the adverse impacts of grazing in wet conditions, and/or to reduce the impact of dairy farming on water quality.

The survey conducted at the commencement of this study identified that a covered loafing area constructed of woodchips, with associated concrete feed areas, is one of the most practicable and best 'value for money' options for standoff. The survey also revealed the costs associated with the construction of such a standoff facility. These costs were used in the DairyNZ investment tool.

5.2 Milk solids production and supplement utilisation

The interactions between standoff and other features of the farms system differed according to the purpose(s) of standoff. For example, where the use of standoff was for pasture and soil protection, it is very likely that milk solids (MS) yield will increase. The magnitude of this increase in production is an important consideration. Although there were no direct measurements in this study, there is likely to be a range of responses in pasture utilised and/or milk production to the introduction of standoff on poorly drained soils and this will, in turn, have a major effect in the financial viability of adopting standoff. Standoff is likely to be more profitable on those farms where there is a very marked increase in either the quantity of pasture utilised and/or milk production.

In comparison, in case studies where the standoff was used to reduce nitrogen leaching, it was less likely that milk solid production would increase and there is the risk that there would be little compensation or financial benefit associated with standoff. Farms where standoff is adopted for dual purposes, potentially, stand to gain the most from this practice.

It was assumed that the implementation of standoff in early lactation results in an increase in annual milk yield of approximately 3%. This increase comes from the use of the standoff during wet periods such as winter and spring i.e. standoff was used to diminish the adverse effects of animal treading on soil and pasture. A value of 3% reflects the observation that the case study farms were being as well managed as possible in the absence of a standoff facility. For farms where this is not the case, the advantages of standoff to milk production may be very much greater. It is important to note that the evaluation of the benefits of standoff presented in this study are conservative.

It was assumed that the utilisation of supplements goes up to 95% after standoff implementation. The allocation of feed under the covered feed pad prevents feed wastage occurring on paddocks. Moreover, due to the increase in supplement utilisation there is a reduction in the required amounts of extra feed of 3, 7 and 17% for farm A (S2), farm C and D respectively, while for farm A (S1) there is a reduction of 28%. This improvement in utilisation of supplements is a significant saving in costs to the farm.

The requirement for supplement depends on the period where standoff is applied. For example, the standoff in S1 for farm A is highly beneficial because animals are still wintered off meaning that there is no need for supplementation during winter and during spring the supplements are utilised better that the current system (up to 95%). For S2 of the same farm, the animals are wintered on farm increasing the supplement demand. Therefore, there is an increase in feed brought onto the farm.

The case study farm A was modelled with an increase in milk production of 5, 10 and 15% and it was repeated in two different scenarios. While for S1 standoff was used only during spring, in S2 it was used during winter and spring. The total production of both scenarios remains the same at 258650 kg MS because for both scenarios the increase of 5, 10 and 15 % were applied during August, September and October. The difference was that for S2 extra supplementation was needed for the winter period and for August to cover the reduction of pasture cover coming from July. The increase between scenarios was about 20% higher for S2. During the study, it was decided to use the 10% increase in milk production because this value was more realistic for the case study farms. Additionally, a value of 10% coincides with literature and with the information provided from farmers in phase one of this project.

5.3 Nitrogen leaching

All the study cases were modelled with Overseer and for each scenario N leaching was noted as it is the nutrient that Horizons Regional Council is currently focusing most attention on. According to Overseer, the implementation of standoff for environmental protection can result in substantial reductions in N leaching. For example, there is a 20% reduction for combined farms C and D, 16% for farm B. However, it is interesting what is happening in farms C and D where there is a reduction of 22% and 26% (Table 20). The latter are achieved by removing winter cropping from their system. The removal of oats only reduced the total N lost into water up to 4 kg. Hence, when this is complemented by the use of standoff instead of allocated overnight in the oats block during wet conditions, results in a meaningful reduction of N leaching. Furthermore, the study also showed that in order to reduce the amount of nutrient on the effluent blocks it was useful to allocate effluent solids on different blocks. This also presents an advantage that other parts of the farm will receive some nutrient return.

It is possible that Overseer underestimates the reduction in N leaching following the implementation of summer and autumn standoff. Simulations of N leaching by Overseer are often greater than corresponding measurements made at Massey University's No 4-dairy farm (D Horne *pers com*). Therefore, actual N leaching rates from the case study farms practising summer/autumn standoff could be greater than the values reported here.

5.4 Effluent management

The increase in storage volume is dependent on the time of year that this extra effluent is produced and the 'risk' category of soils receiving the extra effluent. In some cases, the storage volume will need to be expanded to accommodate the extra effluent generated as a result of standoff and in other cases the existing pond size will be adequate. The increase in effluent volume resulting from the study cases is due to the increasing standoff time. For example, for farm C, standoff time went up to 10 hours from late summer to mid-winter and up to 12 hours for July and 10 hours in the spring months. Because this farm has a mix of low and high risk soils the storage pond increases 17%. On the other hand, despite the increase in the volume of effluent produced in farm B, the storage pond volume remains the same because the extra effluent is collected during dry season and can be applied at this time when soil conditions are conducive to effluent irrigation.

The adoption of standoff has implications for effluent management that vary from farm to farm. In all cases, standoff will increase the quantity of effluent that is generated and that, therefore, must be irrigated. Hence, due to the increases in effluent volumes and the nutrients that it contains, effluent irrigation areas must be increased. The results of this study show that farm A S1 increases its effluent area by 103% (32 ha) while S2 increases by 122% (38 ha). This difference reflects the fact that the animals will spend more time in S2 on the standoff than in S1. Likewise, farm B which would standoff for environmental protection would need to increase its effluent area by 134% (13 ha). Finally farm D requires a major increase in effluent block area by 156% (14.2 ha). These increases in area are equivalent to rates ranging from 500 to 710 m^2 per cow (Table 20).

5.5 Economic analysis

The economic analysis in this study was obtained using the DairyNZ tool for financial analysis which calculates the cost benefit of implementing the standoff vs the current system. Here, the most important value obtained is the Net Present Value (NPV) from the modelling tool which explain how feasible and viable the project is. Therefore, the results of the study show that the farm A S1 is the most likely to succeed. In this scenario, the cost of standoff implementation per cow is $899 and the NPV is $38000. The rest of the study cases present negative NPV which means that the project might result in a net financial loss and therefore the project is not viable.

As a result of the information gathered in the survey, two prices were established for the cost of constructing the standoff facility. A cost of $600 per cow was allocated for farms that need to add a loafing pad to an existing feed pad and $800 for farms need to build the entire facility (i.e. both feed and loafing areas). To this cost was added the expense associated with managing the extra effluent volume (increase in the storage volume and effluent block area and the cost of irrigating the extra volume). For example, for farm A S1 the cost was increased to $1024 per cow, as influenced by the cost of the change in effluent area and increase in effluent pond volume. In comparison, farm B S1 shows a lower cost per cow of about $688 due to the small increase in effluent area and the nil increase in pond size.

The reason for a negative NPV is due to the fact that the internal rate of return is lower than the 8% standard in real terms which is commonly used for farmers from a 10 years average compounded return. Which is what happened in cases A S2, farm B, C and D. Therefore, we can say that there is not enough financial support to cover the costs and the risk of the project, which do happen in S1 of farm A with an internal rate of return of 9.7%. Nevertheless, it is important to check again the financial and non-financial factors that affect the project to proceed.

Changes in values as a result of the application on the standoff strategy

The table below shows different data which is explained as follows.
In the table 20, farms were categorized as AS1, AS2, BS1, CS1 (FP) and DS1 (NFP). The first letter shows the case farm and the second letter with number means the scenario of the farm. For the last two farms FP and NFP were added which means fee pad or no fed pad. Moreover, the table 20 shows the increment in percentage compared with the base scenario for each study case. For example, in AS1 there was an increment of 3% in milksolids per cow, an increment of 2% in effluent area and storage pond volume. However, there was a reduction of 4% in N leaching

Table 20 The percentage change to the farm characteristics modelled here as a result of the adoption of standoff on the case study farms. The actual change is shown in brackets

Farm Scenario	Objective of standoff (kg MS)	Change to milksolids production per cow (m^2/cow)	Change to effluent area (m^2/cow)	Change to storage pond volume (m^3/cow)	Change to N leaching (Kg N/ha)	Cost of standoff $/cow	NPV
AS1	Pasture and soil protection	3%	2%	2%	4%	899	38000
AS2	Pasture and soil protection	3%	2%	14%	NONE	1024	-74000
BS1	Environmental protection	NONE	4%	0	16%	688	334800
CS1 (FP)	Combined	3%	5%	17%	22%	809	155100
DS1 (NFP)	Combined	3%	5%	57%	26%	937	211600

Chapter 6 Conclusions

The objective of standoff varied across the four case study farms. One farmer is contemplating adopting standoff for soil and pasture protection; one farmer would use it for environmental protection and two of the farmers would potentially benefit from both soil/pasture and environmental protection.

A survey of farmers practising standoff identified that a facility comprising a concrete feed area along with a loafing area constructed of woodchips is among the most cost-effective structures for standoff.

The simulations performed in this analysis suggest that the implementation of standoff on the case study farms would prevent the grazing of wet soils and pasture and reduce the quantity of nitrogen leaching. On the case study farms where standoff would be employed for soil and pasture protection, the soil water balance identified significant periods when the soil moisture deficit necessitated standoff. This standoff time was used to gauge the likely response in milk production, the volume of effluent generated, the effluent storage requirement and, via Overseer, the decrease in N leaching.

The Overseer nutrient budget tool estimates that the adoption of standoff on the cases study farms would reduce leaching by 4 to 26 % (Table 20). The largest reduction in N leaching, 26% N, was on case study farm D where standoff also meant that a winter crop would no longer be required. Where standoff was practised for soil and pasture protection, an annual increase of 3% in annual milk production was assumed i.e. farms A, C and D. The lack of increase in milk production on farm B is due to the fact that the standoff on this farm was in summer and autumn.

The impact of standoff on effluent management also varied across the case study farms. Obviously, standoff resulted in the production of more effluent on all case study farms. However, this did not translate into similar increases in storage volume. Farms with low risk soils or where standoff was mostly practised in summer needed only relatively small increases in pond volume. Where cows spent larger periods in standoff in winter and spring, and effluent was irrigated to high risk soils, very large increases in storage volume were required.

Adoption of standoff on case study farms AS2 would have meant an expansion of the storage facility by 57%. Overseer suggested that the increase in the quantity of nutrients harvested in the effluent would require increases is the size of the effluent block ranging between 500 to 710 m^2 per cow (Table 20).

Finally, the economic analysis conducted using the DairyNZ investment tool shows that the financial viability of adopting standoff is dependent on a number of factors. Implementation of standoff has two major benefits that might improve farm profitability; an increase in milk yield and an improvement in the utilisation of supplements. The case study farms modelled here were all well managed and all were endeavouring to reduce the extent and effects of treading damage. Therefore, a relatively conservative approach was taken to the estimation of any likely increase in milk production. Accordingly, the adoption of standoff was a sound business proposition for only one of the scenarios (AS1). On all of the other farms, standoff would not be a good investment. For farms where standoff is only practised for environmental protection i.e. over summer and autumn, it is difficult to see how standoff would be anything other than a net cost as there are few other advantages to standoff at this time of year, In these cases the cost of standoff needs to be compared with the cost of alternative mitigation techniques.

The implications of the above conclusion that standoff was not a good investment on most of the case study farms needs to be tempered by the acknowledgment of the conservative nature of the analysis carried out here. As stated above, the increase in milk yield on farms adopting standoff for soil and pasture protection was relatively small and, furthermore, many farmers may be able to build or adapt existing standoff facilities at lower costs then those assumed here. In the final analysis, any farmer contemplating adoption of standoff should conduct their own detailed and comprehensive analysis of the disadvantages and costs of standoff.

7 References

Betteridge, K., Costall, D., Li, F., Luo, D., & Ganesh, S. (2013). *Why we need to know what and where cows are urinating–a urine sensor to improve nitrogen models.* Paper presented at the Proceedings of the New Zealand Grassland Association.

Beukes, P. C., et al. (2013). "Evaluating the benefits of standing cows off pasture to avoid soil pugging damage in two dairy farming regions of New Zealand." New Zealand Journal of Agricultural Research **56**(3): 224-238.

Bilotta, G., Brazier, R., & Haygarth, P. (2007). The impacts of grazing animals on the quality of soils, vegetation, and surface waters in intensively managed grasslands. *Advances in agronomy, 94*, 237-280.

Bowler, D. (1981). *The pugging of grasslands.* Paper presented at the Proceedings of the New Zealand Grassland Association.

Bolan, N. S., & Kemp, P. (2003). *A review of factors affecting and prevention of pasture-induced nitrate toxicity in grazing animals.* New Zealand Grassland Association Incorporated.

Bristow, A. W., Whitehead, D. C., & Cockburn, J. E. (1992). Nitrogenous constituents in the urine of cattle, sheep and goats. *Journal of the Science of Food and Agriculture, 59*(3), 387-394.

Buss, J., et al. (2011). Improved design and management of woodchip pads for sustainable out-wintering of livestock., British Grassland Society

Christensen, C. L. (2013). *Duration-controlled grazing of dairy cows : impacts on pasture production and losses of nutrients and faecal microbes to water : a thesis presented in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Soil Science at Massey University, Palmerston North, New Zealand*.

Clark, C., McLeod, K., Glassey, C., Gregorini, P., Costall, D., Betteridge, K., & Jago, J. (2010). Capturing urine while maintaining pasture intake, milk production, and animal welfare of dairy cows in early and late lactation. *Journal of Dairy Science, 93*(5), 2280-2286.

Colin-Schoellen, O., Jurjanz, S., & Laurent, F. (2000). Metabolizable protein supply (PDIE) and restricted level of ruminally degradable nitrogen (PDIN) in total mixed rations: effect on milk production and composition and on nitrogen utilization by dairy cows. *Livestock Production Science, 67*(1), 41-53.

DairyNZ. (2017). Standoff pad investmen calculator. Retrieved from http://www.dairynz.co.nz/farm/off-paddock-facilities/stand-off-pad

DairyNZ, L. (2015). New Zealand Dairy Statistics. Hamilton, New Zealand. Retrieved from http//http://www.dairynz.co.nz/media/3136117/new-zealand-dairy-statistics-2014-2015.pdf

DairyNZ (2014). "Dairynz standoff pads booklet." Retrieved from: https://www.dairynz.co.nz/.

DairyNZ. (2013). Farm Dairy Effluent. How to use the Dairy Effluent Storage Calculator (DESC). Retrieved from http://www.dairynz.co.nz/environment/effluent/effluent-storage/dairy-effluent-storage-calculator/desc/

DairyNZ (2012). "Stand off pads design construction 2012." Retrieved from:

https://www.dairynz.co.nz/media/256071/84_Stand_off_pads_design_construction_2012.pdf.

DairyNZ (2005). "Minimising muck, Maximising money." DairyNZ(New Zealand).

Decau, M., Simon, J., & Jacquet, A. (2004). Nitrate leaching under grassland as affected by mineral nitrogen fertilization and cattle urine. *Journal of Environmental Quality, 33*(2), 637-644.

Dennis, S., Moir, J., Cameron, K., Di, H., Hennessy, D., & Richards, K. G. (2011). Urine patch distribution under dairy grazing at three stocking rates in Ireland. *Irish Journal of Agricultural and Food Research*, 149-160.

Di, H., & Cameron, K. (2002). Nitrate leaching in temperate agroecosystems: sources, factors and mitigating strategies. *Nutrient Cycling in Agroecosystems, 64*(3), 237-256.

Di, H. J., & Cameron, K. C. (2002). Nitrate leaching in temperate agroecosystems: sources, factors and mitigating strategies. *Nutrient Cycling in Agroecosystems, 64*(3), 237-256. doi:10.1023/a:1021471531188

de Klein, C. A. M. (2001). An analysis of environmental and economic implications of nil and restricted grazing systems designed to reduce nitrate leaching from New Zealand dairy farms. II. pasture production and cost/benefit analysis. *New Zealand Journal of Agricultural Research, 44*(2-3), 217-235. doi:10.1080/00288233.2001.9513479

Drewry, J., Cameron, K., & Buchan, G. (2008). Pasture yield and soil physical property responses to soil compaction from treading and grazing—a review. *Soil Research, 46*(3), 237-256.

Edwards, A., et al. (2003). "Review of the scientific rationale underpinning the establishment of woodchip corrals." Report for Scottish Executive Environment and Rural Affairs Depatment: 17.

Fao. (2006). Determination of evapotranspiration. Retrieved from http://www.fao.org/docrep/X0490E/x0490e08.htm

Follett, R. F. (2008). Transformation and transport processes of nitrogen in agricultural systems. *Nitrogen in the environment: sources, problems, and management. USDA/ARS, Soil-Plant-Nutrient Research Unit: Fort Collins, CO, USA*, 19-50.

Greenwood, K., MacLeod, D., & Hutchinson, K. (1997). Long-term stocking rate effects on soil
physical properties. *Australian Journal of Experimental Agriculture, 37*(4), 413-419.

Haynes, R. (1995). Soil structural breakdown and compaction in New Zealand soils. *MAF Policy Technical Paper, 95*(5).

Haynes, R., & Williams, P. (1993). Nutrient cycling and soil fertility in the grazed pasture ecosystem. *Advances in agronomy, 49*, 119-199.

Holmes, C. W., Wilson, G. F., Mackenzie, D., Flux, D., Brookes, I., & Davey, A. (2007). *Milk production from pasture*: Butterworths of New Zealand Ltd.

Holmes, C., & Roche, J. (2007). Pastures and supplements in dairy production systems.Hillel, D. (1980). Fundamentals of Soil Physics Academic. *San Diego, CA*.

Houlbrooke, D. J., Drewry, J. J., Monaghan, R. M., Paton, R. J., Smith, L. C., & Littlejohn, R. P. (2010). Grazing strategies to protect soil physical properties and maximise pasture yield on a Southland dairy farm. *New Zealand Journal of Agricultural Research, 52*(3), 323-336. doi:10.1080/00288230909510517

Horne, D., Bretherton, M., Hanly, J., & Roygard, J. (2011). The FDE storage calculator - an update. In: Adding to the knowledge base for the nutrient manager. (Eds L.D. Currie and C.L. Christensen). http://flrc.massey.ac.nz/ publications.html. Occational Report No. 24. . *Fertilizer and Lime Research Center, Massey University, Palmerston North, New Zealand.*, 9 pages.

Haataja, H., et al. (1989). "Deciduous wood chips as bedding material: Estimation of dust yield, water absorption and micro-biological comparison." Scand J Lab Anim Sci **16**(3): 105-111.

Jarvis, S., & Pain, B. (1990). *Ammonia volatilization from agricultural land.* Paper presented at the Proceedings-Fertiliser Society.Longhurst, B., et al. (2013). "Evaluation of physical, chemical and microbial characteristics of
stand-off pad materials during winter use and relationship with cow behaviour." Accurate and efficient use of nutrients on farms.

Kebreab, E., France, J., Mills, J., Allison, R., & Dijkstra, J. (2002). A dynamic model of N metabolism in the lactating dairy cow and an assessment of impact of N excretion on the environment. *Journal of Animal Science, 80*(1), 248-259.

Longhurst, R., Roberts, A., & O'Connor, M. (2000). Farm dairy effluent: a review of published data on chemical and physical characteristics in New Zealand. *New Zealand Journal of Agricultural Research, 43*(1), 7-14

Lantinga, E., Keuning, J., Groenwold, J., & Deenen, P. (1987). Distribution of excreted nitrogen by grazing cattle and its effects on sward quality, herbage production and utilization *Animal Manure on Grassland and Fodder Crops. Fertilizer or Waste?* (pp. 103-117): Springer.

Ledgard, S., Penno, J., & Sprosen, M. (1999). Nitrogen inputs and losses from clover/grass pastures grazed by dairy cows, as affected by nitrogen fertilizer application. *The Journal of Agricultural Science, 132*(02), 215-225.
Ledgard, S., & Steele, K. (1992). Biological nitrogen fixation in mixed legume/grass pastures. *Plant and Soil, 141*(1-2), 137-153.Mackay, A. (2016). Managing stock on wet soils. (Taranaki, New Zealand).

Longhurst, B., Miller, D., Williams, I., & Lambourne, A. (2006). On-farm wintering systems - issues to consider. *Proceedings of the New Zealand Grassland Association, 68:*, 289-292.

Luo, J., Donnison, A., Ross, C., Ledgard, S., & Longhurst, B. (2006). "Control of pollutants using stand-off pads containing different natural materials." Proceedings of the conference New Zealand grassland association **(Vol. 68,**: p. 315).

Luo, J., et al. (2004). "Control of gaseous emissions of ammonia and hydrogen sulphide from cow manure by use of natural materials." New Zealand Journal of Agricultural Research **47**(4): 545-556.

McLaren, R. G., & Cameron, K. C. D. (1996). *Soil science : sustainable production and environmental protection*: Auckland : Oxford University Press, 1996 New ed.

Menneer, J., Ledgard, S., McLay, C., & Silvester, W. (2001). Animal treading during wet soil conditions reduces N2 fixation in mixed clover-grass pasture. *Plant & Soil, 275*(1/2), 317-325. doi:10.1007/s11104-005-2583-y

McCarty, L. B., Hubbard, L. R., & Quisenberry, V. L. (2016). *Applied soil physical properties, drainage, and irrigation strategies*: Springer.

Menneer, J. C., Ledgard, S. F., McLay, C. D. A., & Silvester, W. B. (2005). The effects of treading by dairy cows during wet soil conditions on white clover productivity, growth and morphology in a white clover-perennial ryegrass pasture. *Grass and forage science, 60*(1), 46-58. doi:10.1111/j.1365-2494.2005.00450.x

Merrilees, D. and S. Donnelly (2007). "Woodchip Corrals." Technical Note Scotland Rural

College(01427695).
Moir, J. L., Cameron, K. C., Di, H. J., & Fertsak, U. (2011). The spatial coverage of dairy cattle urine patches in an intensively grazed pasture system. *The Journal of Agricultural Science, 149*(04), 473-485.
Monaghan, R., De Klein, C. A., & Muirhead, R. W. (2008). Prioritisation of farm scale remediation efforts for reducing losses of nutrients and faecal indicator organisms to waterways: A case study of New Zealand dairy farming. *Journal of Environmental Management, 87*(4), 609-622.
Mulligan, F., Dillon, P., Callan, J., Rath, M., & O'mara, F. (2004). Supplementary concentrate type affects nitrogen excretion of grazing dairy cows. *Journal of dairy science, 87*(10), 3451-3460.
Mulholland, B., & Fullen, M. (1991). Cattle trampling and soil compaction on loamy sands. *Soil Use and Management, 7*(4), 189-193.

Osman, K. T. (2012). *Soils: principles, properties and management*: Springer Science & Business Media.
Pande, T., Valentine, I., Betteridge, K., Mackay, A., & Horne, D. (2000). *Pasture damage and regrowth from cattle treading.* Paper presented at the Proceedings of the conference-new zealand grassland association.
Pande, T. N. (2002). Pasture dynamics under cattle treading: a thesis presented in partial fulfilment of the requirements for the degree of Doctor of Philosophy (Ph. D.) in Plant Science, Institute of Natural Resources, Massey University, Palmerston North, New Zealand.
Patto, P., Clement, C., & Forbes, T. (1978). Grassland poaching in England and Wales. *Permanent Grassland Studies (UK). no. 2.*Shepherd, M., & Wheeler, D. (2012). OVERSEER® Nutrient Budgets - The Next Generation In: Advanced Nutrient Management: Gains from the Past - Goals for the Future (Eds L.D. Currie and C L. Christensen). *. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand*, 9 pages.
Pacheco, D., & Waghorn, G. (2008). *Dietary nitrogen–definitions, digestion, excretion and consequences of excess for grazing ruminants.* Paper presented at the Proceedings of the New Zealand Grassland Association.
Romera, A. J., Levy, G., Beukes, P. C., Clark, D. A., & Glassey, C. B. (2012). A urine patch framework to simulate nitrogen leaching on New Zealand dairy farms. *Nutrient Cycling in Agroecosystems, 92*(3), 329-346. doi:10.1007/s10705-012-9493-1
Smith, K., et al. (2010). Woodchip pads for out-wintering cattle-technical review of environmental aspects. Report—"Improved Design and Management of Woodchip Pads for Sustainable Out-wintering of Livestock" Under the DEFRA Sustainable Livestock LINK Research Programme (Project LK0676).
Schnyder, H., Locher, F., & Auerswald, K. (2010). Nutrient redistribution by grazing cattle drives patterns of topsoil N and P stocks in a low-input pasture ecosystem. *Nutrient Cycling in Agroecosystems, 88*(2), 183-195.
Scotter, D. R., & Heng, L. (2003). Estimating reference crop evapotranspirations in New Zealand. *Journal of Hydrology.*, 42, 41-10.
Selbie, D. (2014). *The fate of nitrogen in an animal urine patch as affected by urine nitrogen loading rate and the nitrification inhibitor dicyandiamide.* Lincoln University.
Selbie, D. R., Buckthought, L. E., & Shepherd, M. A. (2015). Chapter Four-The Challenge of the Urine Patch for Managing Nitrogen in Grazed Pasture Systems. *Advances in agronomy, 129*, 229-292.

Silva, R., Cameron, K., Di, H., Smith, N., & Buchan, G. (2000). Effect of macropore flow on the transport of surface-applied cow urine through a soil profile. *Soil Research, 38*(1), 13-24.

Snow, V., Shepherd, M., Cichota, R., & Vogeler, I. (2011). *Urine timing: Are the 2009 Waikato results relevant to other years, soils and regions.* Paper presented at the FLRC Conference.

Tuñon, G., O'Donovan, M., Lopez Villalobos, N., Hennessy, D., Kemp, P., & Kennedy, E. (2014). Spring and autumn animal treading effects on pre-grazing herbage mass and tiller density on two contrasting pasture types in Ireland. *Grass and forage science, 69*(3), 502-513.

Ulyatt, M. (1970). *Evaluation of pasture quality under New Zealand conditions.* Paper presented at the Proceedings of the New Zealand Grassland Association.

White, J., & Hodgson, J. G. (1999). *New Zealand pasture and crop science*: Oxford University Press.

Willatt, S., & Pullar, D. (1984). Changes in soil physical properties under grazed pastures. *Soil Research, 22*(3), 343-348.

8 Appendix

8.1 Appendix A Farm questionnaire Phase One

1. How or why did you decide to adopt a stand-off facility?
2. What are the changes in the system after implementation of the stand-off in animals, pasture and soil management?
3. There is and increment in labour, equipment and cost?
4. What is the main purpose of the stand-off use:
    - Pasture and soil protection
    - Nutrient loss reduction
    - Both
5. If pasture and soil protection what is the criteria?
6. If nutrient loss reduction what is the criteria?

Stand-off characteristics

7. What is the type, total area, area per cow, cost?
8. How is the management during the season?
9. Which bedding material is used?
10. What is the cost of the material and the source?
11. It is difficult to find the bedding material? If so why?
12. Which is your bedding material management?
13. How is the drainage system?
14. Did you need more storage? If so how much?
15. How is the effluent of the farm managed?
16. Irrigations was affected how is the management?
17. Bedding material used for composting?
18. If used what is the nutrient content?

Farm management

Question number	Farm 1	Farm 2	Farm 3	Farm 4
Q1	Inherited	From the beginning when the farm was transformed from dry to milk	Was in use before	Consulting with other farmers we decided to do it
Q2	Less messy paddocks, better welfare of the cows	Less messy paddocks, better welfare of the cows	Treading reduction	Less messy paddocks, better welfare of the cows
Q3	Mostly in winter but for few hours not demanding	Mostly in winter but for few hours not demanding	No	Mostly in winter but for few hours not demanding
Q4	Pasture and soil protection	Pasture and soil protection	Pasture and soil protection	Pasture and soil protection
Q5	Maintain the cows out of the paddock during extremely wet days Prevent reduction in pasture yield Stand-off depend on the amount of rain	Maintain the cows out of the paddock during extremely wet days Prevent reduction in pasture yield Stand-off depend on the amount of rain	Maintain the cows out of the paddock during extremely wet days Prevent reduction in pasture yield Stand-off depend on the amount of rain	Maintain the cows out of the paddock during extremely wet days Prevent reduction in pasture yield Stand-off depend on the amount of rain
Q6	none	none	none	none
Q7	Previously was a free stall barn now adapted to stand-off pad (200 cows) 2400 m^2 12 m^2/cow Price unknown Feed pad adjacent	Redpath roofed with feeding area stand-off (woodchips) (302cows) 2775 m^2 9.18 m^2/cow 250,000 NZD	Unroofed area at the paddock with fences. (208 cows) 1200 m^2 5.7 m^2/cow none no feeding area	Redpath roofed with feeding area stand-off (woodchips) now changing to post peeling. (220 cows) 1708 m^2 8 m^2/cow 15000 NZD
Q8	During winter, overnight for 9 to 10 hours then grazing, after as required	During winter, overnight for 9 to 10 hours then grazing, after as required	Overnight during winter, during the day grazing	During winter, overnight for 9 to 10 hours then grazing, after as required

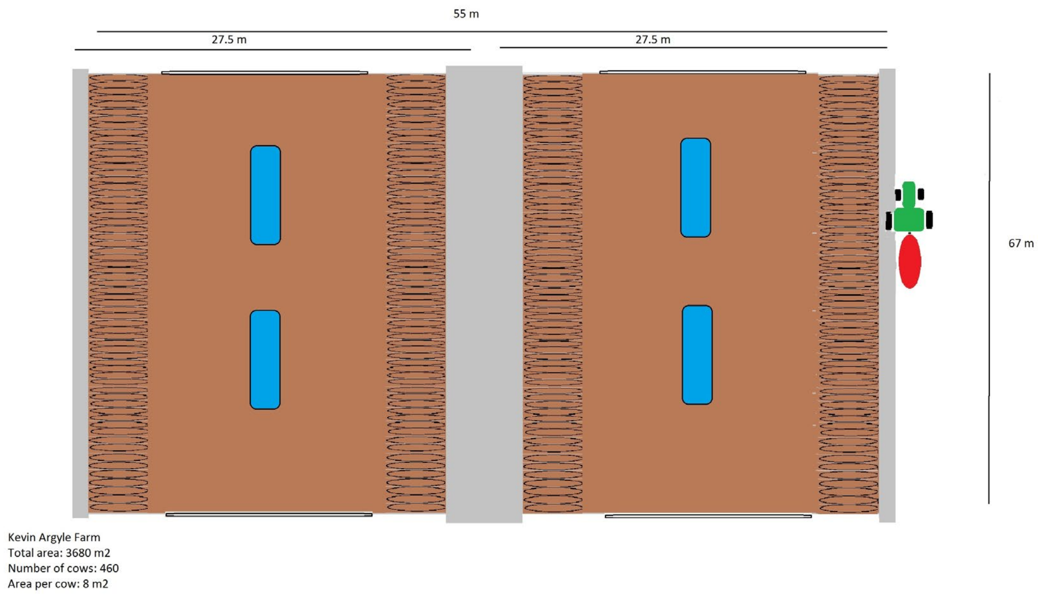
Q9	Woodchips	Woodchips	Post peeling	Woodchips before, now post peeling
Q10	600 NZD per load. Total needed One load = 70 m^3 Total loads needed = 27 Cost= 16000 NZD	600 NZD per load Total needed One load = 70 m^3 Total loads needed = 14 Cost= 10800 NZD	30 NZD m^3, Needed= 480 m^3 Total= 14400	600 NZD per load, Total needed One load = 70 m^3 Total loads needed = 11 Cost= 6600 NZD
Q11	No	No	Yes, easy to find post peeling	Yes, now post peeling was free
Q12	Re-chipping every two seasons	Re-chipping first time after three years and only half. Use rippers to mix and aeration of bed	Every season	Every season
Q13	No drainage system	Liner that collects at the end effluent in sump	No drainage system	Impermeable soil small amount of effluent collected in the sump.
Q14	None	None	none	none
Q15	Effluent is collected from milking shed and yards in to a pond and stored	Effluent is collected from milking shed and yards in to a pond and stored	None	Effluent is collected from milking shed and yards in to a pond and stored
Q16	No	No	No	No
Q17	Yes	Yes	Yes	Yes
Q18	Unknown	Unknown	Unknown	Unknown

8.2 Appendix 2 Nitrogen leaching

Farms	Scenarios	Kg N/ha/yr	Kg N/yr
A	**BS**	3912	26
	S1	3853	25
	S2	3909	26
B	**BS**	3044	30
	S1	2553	25
C	**BS**	4162	50
	S1	3266	39
D	**BS**	4535	57
	S1	3350	42

8.3 Appendix 3 Standoff design

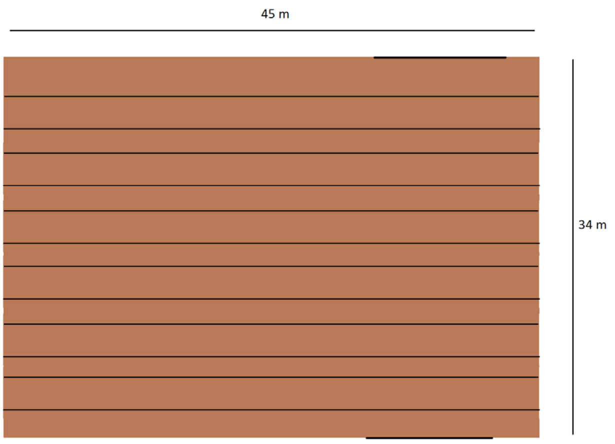
Farm A



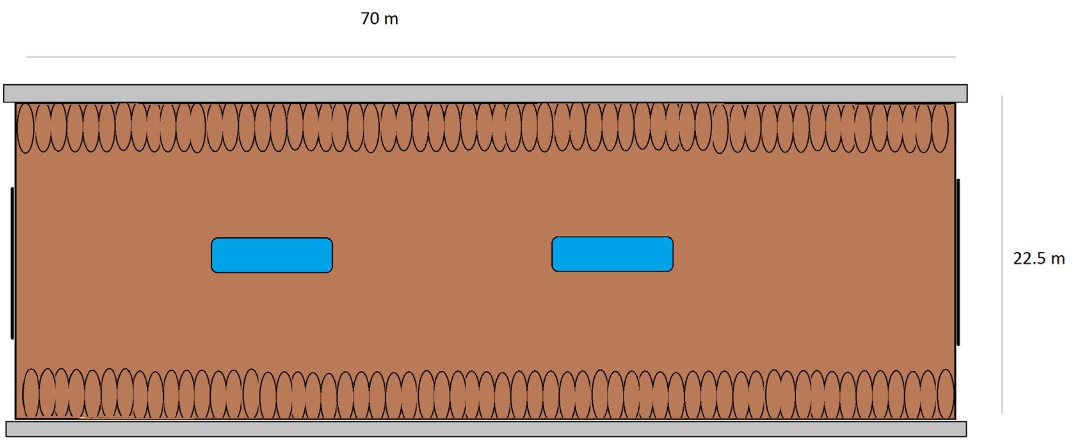
Farm B

Dairy No 1

Loafing Pad
Total area: 1560 m2
Number of cows: 260
Area per cow: 6 m2

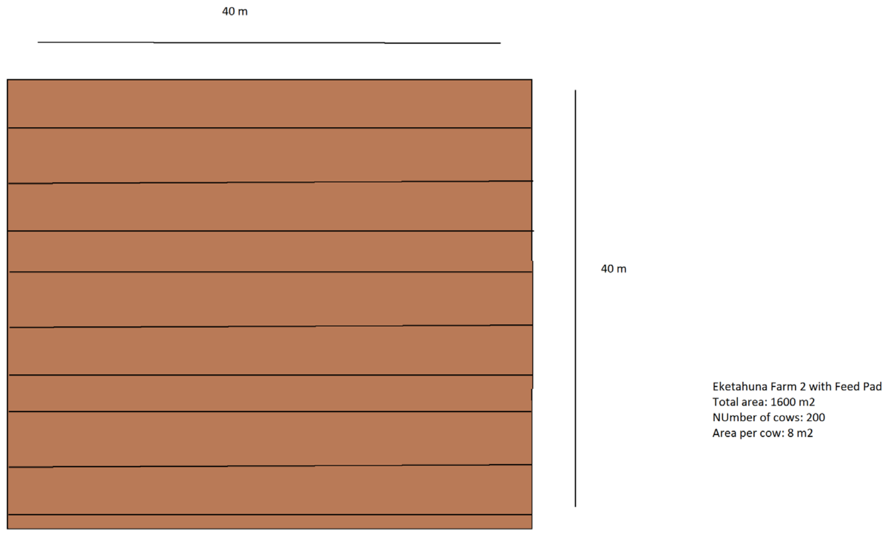


Farm C



Eketahuna Farm 1 No Feed Pad
Total area: 1600 m2
Number of cows: 200
Area per cow: 8 m2

Farm D


40 m
40 m
Eketahuna Farm 2 with Feed Pad
Total area: 1600 m2
NUmber of cows: 200
Area per cow: 8 m2