Kellogg's Industry Applied Project

Exploring the design of a Nitrogen Attenuating stand off pad for dairy cattle

Kellogg's Course 2

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3 INTRODUCTION

The focus of this project is to explore the potential design of a nitrogen attenuating feed pad for dairy cattle that are wintered on fodder crops in the lower South Island. I hope to explain some of the reasoning behind how important cost effective environmental sustainability is to the New Zealand dairy industry, and attempt to open up some avenues of further discussion and research.

4 OVERVIEW

New Zealand's prosperity is directly related to the export of primary products to the world and to the influx of tourists that come to sample the magnificent scenery that we possess. Both of these sectors are intrinsically intertwined with each other even if most of New Zealand's population don't recognize it.

Our nation's clean and green image and marketing slogans such as "100% Pure N.Z", and" welcome to middle earth", have caught the attention of many around the world and deliver a value proposition that at present resonates with trading partners and inbound tour operators alike.

Figure 1, New Zealand Marketing

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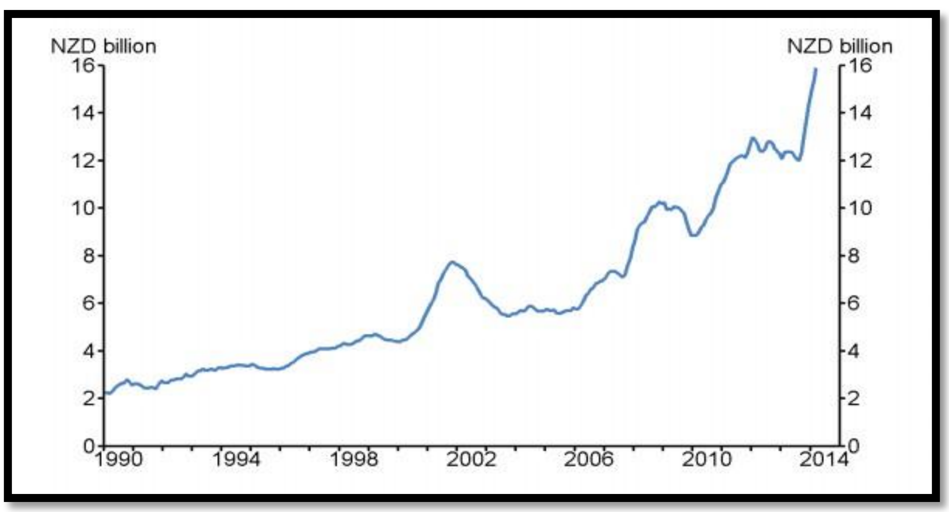
Source, (Tourisim New Zealand, 2013)

This successful marketing of "New Zealand Inc.", is now putting pressure on the primary industries to walk the talk, so to speak, with regards to pollution in the rural environment. At the forefront of these primary industries is the New Zealand dairy industry, which has seen stellar growth over the last fifteen years.

Figure 2, New Zealand Dairy Exports annual N Z dollar terms



Source, Statistics NZ (Wheeler, 2014)

Dairy export revenue has risen dramatically over the last two decades. At $15.5 billion, dairy makes up almost a third of New Zealand's annual merchandise exports (Wheeler, 2014).This unprecedented growth has created pressure on the dairy industry both externally and internally, with the latter being augmented by New Zealand's predominantly urban population base and the rural disconnect that has taken place in the last thirty years since the 1984 Labour government and Rogernomics. As Neal Wallace author of "When the gates were opened", a book focusing on the impact of Rogernomics on New

Zealand's society stated. " There was a lost generation of farming sons and daughters. Having witnessed the turmoil that their parent's lives were thrown, many opted to pursue any career other than farming. Many parents discouraged their children from farming, which led to the demise of the family farm". This disconnect has helped to intensify the public perception of the corporate dairy farm. The merger of the NZ Dairy Board, N Z Dairy Group and Kiwi Co-op Dairies to form the giant dairy co-op Fonterra in 2001 has given the industry a much higher profile than previously, and with that more media scrutiny of the industry as a whole. These factors have helped to focus the spotlight on the negative environmental effects that the dairy industries recent expansion has put on the resources of land and water.

The external pressures being brought to bear on the dairy industry manifest themselves in food and bio security threats. Both of which can be managed to an acceptable level via increased industry wide food safety programs and increased boarder security. These threats although serious to the prosperity of New Zealand have to date actually helped to grow confidence in our responses to food safety. An example of this being the WPC80 scandal that broke in late 2013 which has moved Fonterra to invest in the most advanced systems of food safety in the world. (Poudfoot, 2015).This response from Fonterra and the N Z government has helped to cement our position in emerging markets as a supplier of premium quality safe food. However there is an external threat which is developing and has largely been neglected. This less manageable threat is the direct competition with our primary industries on our "clean green image". For the dairy industry this has moved even further, with some competitors movement towards the use of a "grass to glass" slogan associated with their dairy industries. Denmark and the Netherlands are two country's that come to immediate notice with regards to their adoption of grass based, green imagery for the promotion and marketing of dairy products.

Figure 2, FreislandCampinia {Dutch Dairy Co-op} Marketing Slogan

Source, (Frieslandcampinia, 2014)

Even the marketing spin offs from the" Lord of the Rings "trilogy and" The Hobbit" movies have parallels with Irelands tourism marketing and their ongoing role in the making of the fantasy series "Game of Thrones".

This has gone almost unnoticed by New Zealander public, farmers and our political/industry leaders.

New Zealand's role as a world leader in dairy products has been born out of its ability to turn pasture, fed in situ, into top quality dairy produce that it has exported around the world. Our role as a low cost producer has until relatively recently allowed us to maintain this leading position despite having a relatively small milk pool in world terms. We sit 8th on the world rankings in regards to total milk produced with 3% of the world production (Dairy NZ, LIC, 2014) But New Zealand is the world's largest supplier of milk commodities (Dairy NZ, 2014).

We are now unable to claim the position of a low cost producer and currently sit 20% higher in milk production costs for a typical farm than Argentina and only 20% lower than the U.S and Europe. (Hemme, 2013). New Zealand's dairy industry cannot hope to compete with the likes of the United States of America on scale. Which is the world's largest milk producer at 14.4% of global production. Or on the premise that we can continue to grow our milk pool expediential. Emerging producers such as Brazil have more opportunity for conversion of land to dairying, and It has seen milk growth of 6% from 2012 to 2013 (AHDBdairy, 2014).

What the New Zealand dairy industry needs to be able to achieve is to leverage off our existing position of being the world's largest dairy exporter with a premium quality product and secure supply chain. Whilst at the same time achieving and demonstrating true environmental sustainability. This will create a truly unique and almost impossible to imitate value proposition.

To achieve this all of New Zealand's primary industries need to go through some major changes, not only the dairy industry. Many of these changes have already been prescribed by central Government in the form of the national policy for fresh water. The objective of which is to maintain or improve "the overall quality of fresh water within a region". (Wright J. , June 2015)

The national policy statement for fresh water {NPS} prescribes minimum targets that communities are required to set collaboratively to maintain or improve water quality on a catchment by catchment basis. This process and resultant freshwater standards have to be implemented and regulated by regional councils.

The move to true environmental sustainability will be intergenerational in its nature and although at different stages of implementation throughout the country, we have as a nation only just begun this process. There are many risks associated with such major change, both social, financial and even environmental.

The New Zealand dairy industry is currently facing a major threat in that it is failing to find its own unique solutions to the environmental issues that it faces. In response to declining water quality it has not evolved local solutions, instead it is simply importing overseas systems and their associated cost structures. Wintering barns and semi-permanent structures such as herd homes being two examples of these imported systems [European/North American origin]. Housing of cows, even intermittently, carries with it animal welfare issues such as increased cow lameness. More importantly it also carries with it the public perception of animals living in an unnatural state.

This style of farming is also extremely capital and labour intensive and results in a high cost of production. Investment in off-paddock facilities for wintering only will cost more in future cash flow, in 'todays' dollar terms, than grazing off with a grazier i.e. all infrastructure scenarios returned a negative NPV.{Net present value} (Dairy NZ, 2015) The conclusion of this study is shown in Appendix1,
The higher cost of production and increase in debt/cash needed to build and run such operations lead to an increase of intensification in land use. Generally through an increase in stocking rate and the extensive use of bought in supplements as utilization of the structure is maximized. The main drawback of this solution in terms mitigation of environmental impacts is that the nitrogen loading on a given catchment is actually increased due to the system intensification. As stated by the parliamentary commissioner for the environment, increasing productivity -when it involves increasing inputs-is likely to increase the annual nutrient losses per hectare from land into water. (Wright J. , Water quality in New Zealand: Land use and nutrient pollution, 2013).

Environmentally, financially and socially housing dairy cows in New Zealand will become untenable for public and farmers alike. To continue down this road will ultimately create a carbon copy of the European/North American dairy industry and therefore destroy our unique value proposition that we are working so hard to create.

5 WINTERING DAIRY COWS ON FODDER CROP, A SOUTH ISLAND PROBLEM

Winter grazing of dairy livestock on forage crops in the lower half of the South Island of New Zealand has been the only way to fully feed stock whilst limiting damage to pasture on the milking platform. With the wet and cold weather conditions and lack of any grass growth over the winter period it is crucial that livestock are removed from the milking platform for the winter. Many farmers choose to winter their own stock on part of the dairy platform or send them off farm to either their own specialist run off or to other farmers for grazing.

Therefore in late May a very large movement of dairy cows occur as farmers dry off and transport or walk there cows to winter grazing. Once at the wintering site the cows are electric fenced on the forage crop and moved daily or twice daily. With supplements in the forms of bailage, hay and straw added daily depending on availability, crop yields and cow feeding requirements.

Whilst specialist forage crop grazing offers a relatively low cost solution to wintering of dairy cows it has recently been identified as a major risk factor for nutrient loading and loss into water ways and aquifers. (Smith, 2013) This is magnified when winter grazing takes place on free draining alluvial river flats, which offer the best under hoof conditions for cows to be kept but also has the shallowest soil profile and the quickest movement of nutrients to the water table.

In all cases of winter grazing on forage crops there is a risk for nutrient losses either through leaching or overland flow. The main water quality measures for under the NPS for fresh water is phosphorus, sediment E.coli, periphyton and nitrogen loading. All of these need to be taken into account in a whole of catchment basis.

Excess Phosphorus, sediment and E.coli can be mitigated relatively easily at farm level by riparian fencing, buffer strips, strategic grazing and paddock selection. The recent P21 study conducted at Telford near Balclutha has confirmed this. (Dalley, 2014)

Periphyton is a term to describe the presence and toxicity of algae or slime in streams and lakes. These algae and slimes are tiny plants that rapidly respond to an increase in water born nutrients. (Wright J. , Water quality in New Zealand: Understanding the science, 2012)During the winter period in Southland the risk of algae bloom or increase in toxicity due to algae is extremely low due to the large flux and flow of water sources due to winter weather. This low risk is also helped by the low ambient temperatures and the reduced solar radiation that winter brings

Diffuse Nitrogen leaching is currently only able to be mitigated at farm level by reducing stocking rates, standing off or housing of cows and storage of effluent with application at low risk times of the year. The main issue with reducing nitrogen losses in a winter forage grazing scenario is that stocking rate reduction is not an economically viable solution and mitigation through housing creates the need for effluent collection and spreading. Housing cows adds another level of complexity to the farming system and the need for large amounts of capital to be spent on buildings and associated plant. The net result of this is increased debt on the farm but no reduction in the nitrogen load as it has only been differed to a later date. This could be said of all off paddock solutions from stand off pads right through to free stall wintering barns. The overall nitrogen load of the farm may actually increase as the wintering system changes from dry stock winter grazing to winter milking as a means to fund the new infrastructure.# This change of farming practice leads to an intensification of land use and an increase of farm debt.

What is required to tackle the issue of diffuse nitrogen loss from winter forage grazing system in the South Island is a fresh approach, one which creates environmental solutions that don't fundamentally change the structure of the farmers business through intensification.

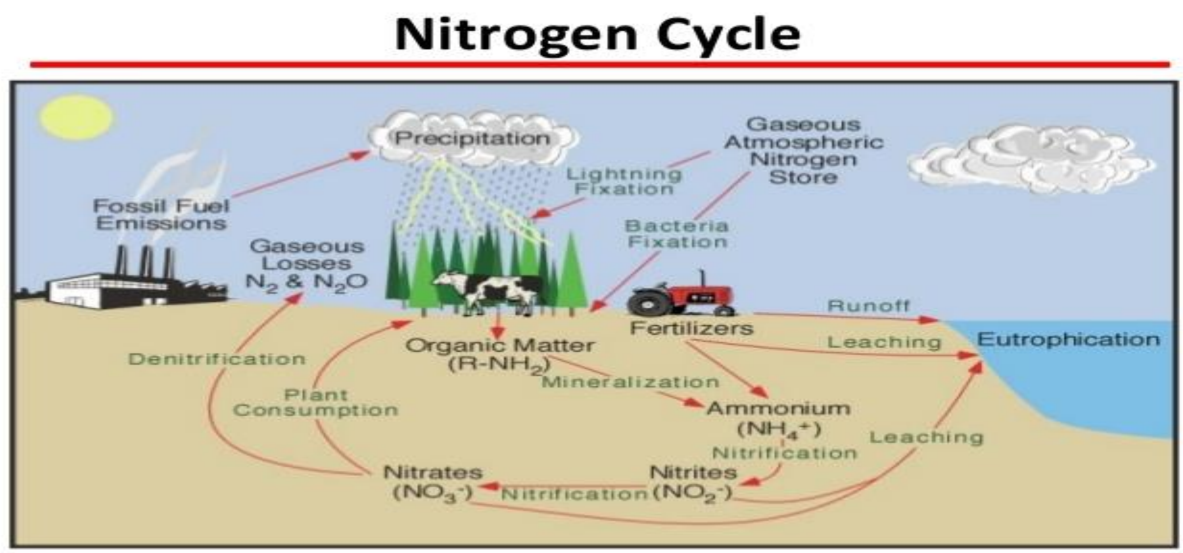
6 METHOD

To reduce the risk of nitrogen loss on alluvial soils in a winter forage grazing system I proposed the investigation of the construction of a simple stand off pad to be used to overnight the cows. To carry out this I embarked on a literature review. The review would attempt to give me a wide view on the subject of nitrogen attenuation methods that are currently employed and allow me to identify any opportunities for the transfer of knowledge into my proposed design. To conduct this review I accessed the library at Lincoln University, read widely in books and articles and accessed sources on the internet.

The proposed design of the pad will include materials that will allow for potential attenuation of nitrogen or at least mitigate n losses without any major intensification of land use, thus reducing the n load on paddock, the overall farming system and ultimately the catchment as a whole.

The standoff pad is to be used in conjunction with fodder beet fed in situ and the cows will be grazed during the day and stood off at night. There will be allowance for some hay or bailage to be made available on pad but 90% of the feed requirements will be meet in paddock as per normal. By standing the cows off overnight a potential reduction of around 15-25% of the total diffuse nitrogen load may be achieved {7.8-13kg N/ha}. This would be based on the premise of 12hrs off paddock capturing ½ of the cows total urine and fecal deposits, and the evidence of an average total nitrogen leaching loss of 78kg N/ha in a typical winter crop grazing system (Smith, 2013). The expectation would be for influent load attenuation rate ranging from 30-45% on the feed pad. These attenuation rates have been measured in naturally occurring wetland (McKergow, 2007)

Figure 3, The Nitrogen Cycle



Source, (Pidwiny, 2006)

My initial reading on methods of nitrogen attenuation lead me to the conclusion that there had been a lot of overseas work done around industrial methods of attenuation of N as a part of waste water treatment systems and industrial contaminants. The method of delivery for this was part of an industrial process and whilst some of the techniques for attenuation were potentially transferable to an on farm system, the overall capital and energy requirements would prove prohibitive for the application I had in mind. A risk I identified in the use of bio reactors for nitrogen reduction is that there is a potential to create nitrous oxide during the attenuation process if it is conducted in an aerobic state, e.g. riparian strips, vegetation sinks. High nitrous oxide emissions have been identified in riparian zones used for N removal and could be a concern which would diminish their overall environmental benefit. (Heflin, 2013) As nitrous oxide is a greenhouse gas it would not be desirable to create a new environmental problem by solving another.

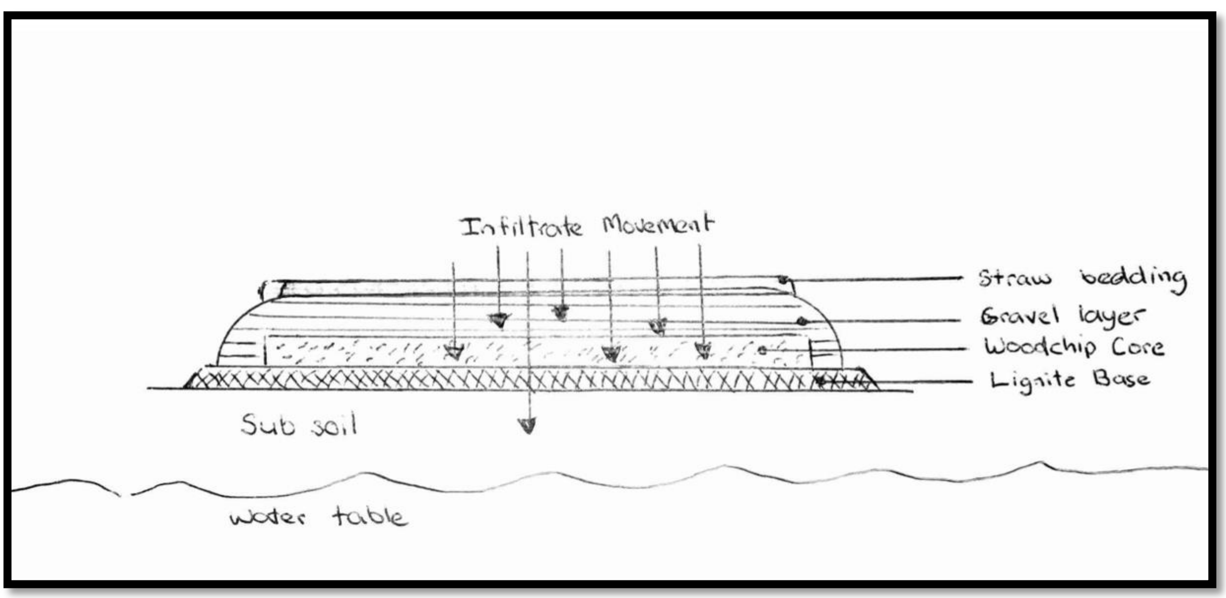
The other reading I had done outlined a considerable amount of work that had been completed on attenuating N by putting low tech bio reactors in stream or as a wall to interrupt water flow. Most of the discussion and research on this method had occurred overseas but some interesting and relevant work had been completed at National Institute of Water and Atmosphere {NIWA}, Hamilton. The reading on these methods indicated that they were a low cost alternative to the industrialized process. (Shipper, 2009) Due to the process of anaerobic denitrification the risk for the creation of nitrous oxide would be reduced.

The relative ease of construction, availability of materials and the attenuation efficiency of these re actors compared favorably to the more industrial methods. I decided that further reading needed to be done but I found no mention of using a bio reactor directly in conjunction with livestock. Rather all the work had been done in an arable context or at the end of drainage networks, or as a method of remediating industrial contaminants e.g. land fill leachate. (Robertson, 1999)

I went through some examples of this attenuation work and drew up a draft design of a pad with an incorporated bio reactor. It occurred to me that denitrification via a reactor wall could offer a prototype to base the design off. Instead of blocking and attenuating infiltrate horizontally it could be placed vertically or directly underneath the source of infiltrate. In this case a stand off pad for cows. The bioreactor would utilize naturally occurring bacteria to denitrify the infiltrate. The standoff pad that would at its core incorporate wood chips as the carbon source. Design and construction of the pad would work on the principal that as the cows overnight any urine deposited would be adsorbed into the core of the pad with precipitation acting to assist this downward movement. The straw topped pad would ensure cow comfort whilst the gravel on top of the wood chips would ensure the absorption of moisture down into the wood chip core. At the core the moist woodchips would absorb and slow down the movement of the infiltrate and as long as the velocity of this was slowed enough the core material would strip out some nitrogen during this process. The addition of a base made out of crushed lignite below the woodchips would aid in construction and possibly some attenuation. The flat contour of the site and high winter water table would mean that the pad would not be able to dug into the soil profile and would need to be lifted up to allow enough fall for infiltrate to be attenuated.

Figure 4 Diagram of Draft Stand off Pad

Conceptual and not to scale.



I felt for this design to be practical and to be widely adopted by farmers the stand off pad needed to meet some basic criteria.

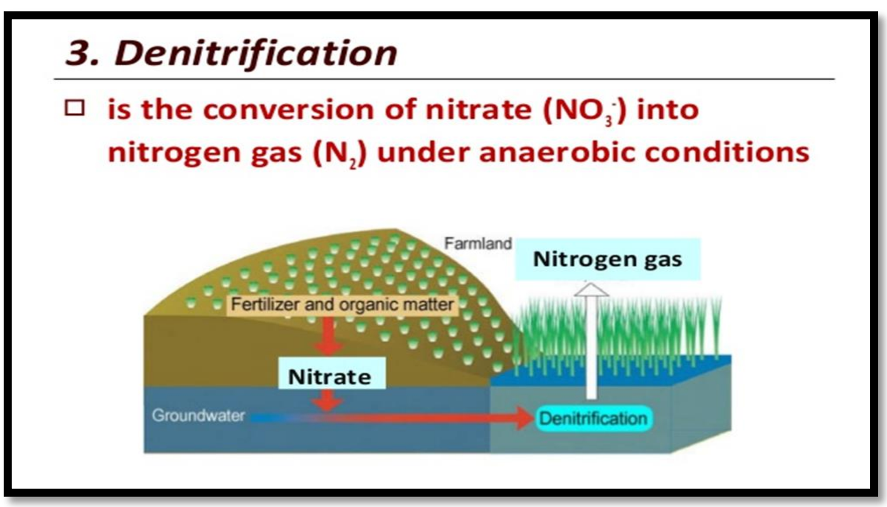
1. Construction and operation of pad must not trigger council or regional consents
2. The materials used to construct the pad must be sourced within the region of construction
3. The operation of the pad must not necessitate the purchase of new equipment or create a system change.

I then made contact with my local land sustainability officer (Dave Conner) at Environment Southland to see if I could circulate my idea through the scientific world for any comment,

My initial thoughts on the design for the pad was floated with some scientists from Ag Research, Invermay {Ross Monaghan and Jane Chrystal}. After discussing the outline for the feed pads operation and proposed method of reducing nitrogen, there feedback was sought.

Initial feedback on this idea was that there would be efficiency problems due to the cold ambient temperature during the winter months. This would result in a lowering of the soil temperature and the core of the reactor. Whilst there was general agreement that the idea of placing a bio reactor under the stand off pad was feasible the low temperature range during the operation of the pad would lower the efficiency of the denitrifying bacteria that would be attenuating the infiltrate from the cows. These lower temperatures combined with the potential for a large slug of infiltrate that may occur during a bad weather event would more than likely deliver a poor result. This would be due to the low population of denitrifying bacteria (due to low ambient temp) being overwhelmed by a large slug of infiltrate during a rainfall event. After some more consideration I also came to the conclusion that there would be a higher risk of the creation of nitrous oxide as some of the denitrification process would begin as the leachate was absorbed in the aerobic portion of the bioreactor. I feel it is worthwhile to note here that in soil temp around 15degc (Top of the South Island and North Island) that attenuation of nitrogen in a stand off pad with bio reactor below would offer enough potential to be explored further.

Figure 5, Basic Principals of Denitrification



Source, (Josephine, 2008)

After receiving this initial feedback on the draft design the major flaws with my initial design were:

1. Low winter temperature limits bacteria function
2. Potential for a large slug of infiltrate to enter reactor and overwhelm bacteria in bad weather.
3. Previously conducted winter grazing trials done on light alluvial soils showed that approx. 50% of nitrogen loss occurs prior to grazing. For any attenuation to be cost effective then a high percentage of the remaining nitrogen loss would need to be accounted for in any design. (Smith, 2013)
4. Denitrification conducted in an aerobic process would create nitrous oxide.

This meeting brought about a need for a re think on design and a focus on improving the overall efficiency of the attenuation process.

7 A Change of Approach

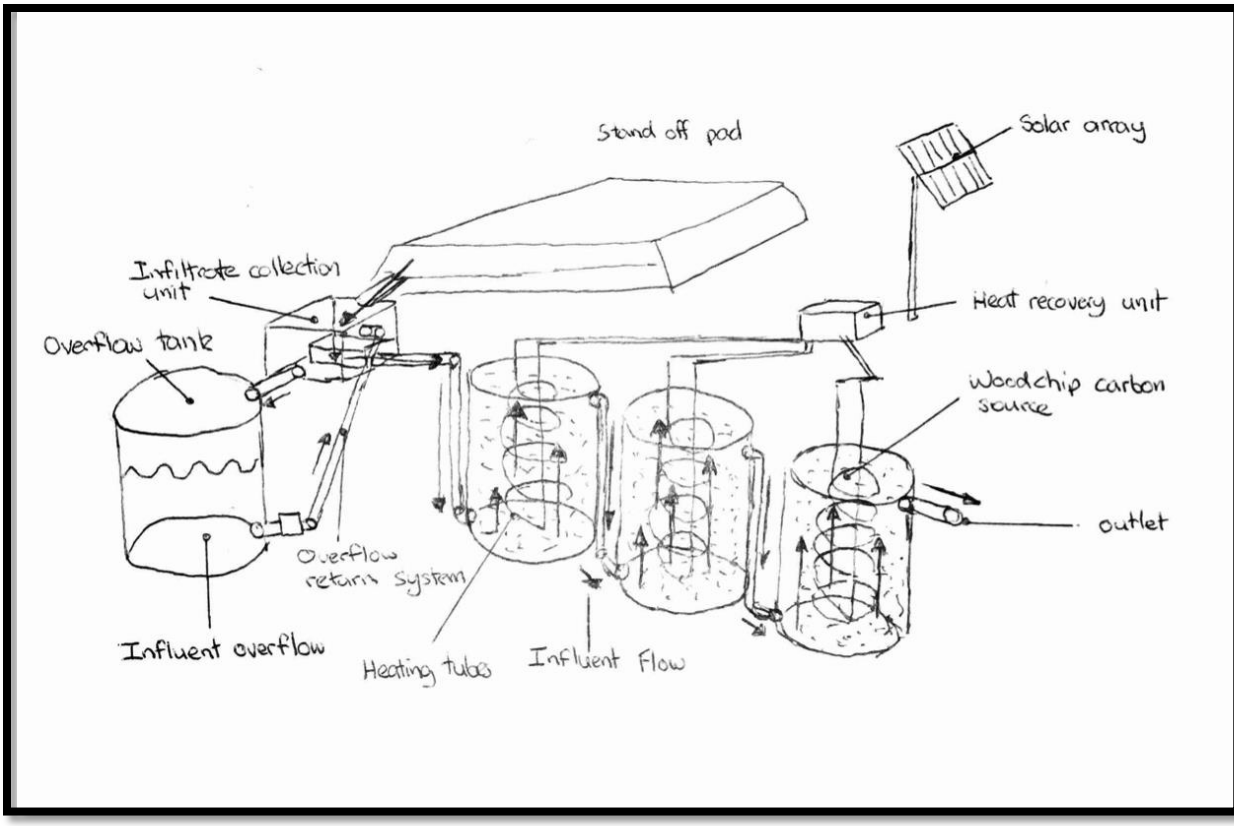
Although my main driver behind the development of a low cost passive method for attenuating nitrogen was the delivery of a solution that could be farmer built and offer a low cost option. I have now come to the conclusion that an engineered solution offers the best return on investment, environmentally and financially. It is still important to provide a solution that farmers can readily adopt and has a relatively low set up cost, minimal ongoing cost and is low maintenance.

After some more research into the subject and some basic observations of water movement, thermal transfer and present feed pad design, a new modular design of a purpose built bio reactor seemed to offer the best prospect for a solution. The new design would be a modular add on design which would sit adjacent to the stand off pad and processes all the effluent/rainwater passively with a tank which collects any slug or extra effluent during a large rainfall event.

The bio reactor itself is constructed using wood chips as a carbon source and this would be housed inside sealed concrete culvert pipes scaled to the size of the pad and amount of influent to be created. The use of concrete in construction of the column reactor is to help insulate the reactor from the cold winter soil temperature. The concrete culvert pipes would be placed in series vertically in the ground and plumbed so as to use gravity to move the influent through the reactor. Inside of each column a heating conduit similar to underfloor heating system will be installed. This will keep the column at the correct temperature. The carbon source of wood chips will then be heated in the column This addition of thermostatically controlled heating in each reactor pipe combined with the insulating effect of the soil will allow optimal bacteria function to be reached. The optimal heat range required in the biomass would be between 18-30degc. Denitrification rates increase by about two fold with a 10 deg c temperature rise. But microbial rates are impaired at temperatures approaching 40 deg c. (Woods Hole Institute, 2006)A tank to collect extra effluent during a large rain event will also be placed in the ground beside the stand off pad. Any effluent collected in this tank will be fed back into the reactor continuously and this will mean a constant flow through the carbon source and will help with bacteria efficiency. The amount and time that the infiltrate spends inside the reactor can be governed by reducing or increasing the flow rate into and at the exit point on the reactor. This would also act as another means to control the temperature in the reactor. Pre heating of the infiltrate as it enters the reactor may also be required to keep the temperature at optimal level.

Figure 6 Diagram of Column Reactor Design

Conceptual and not to scale.



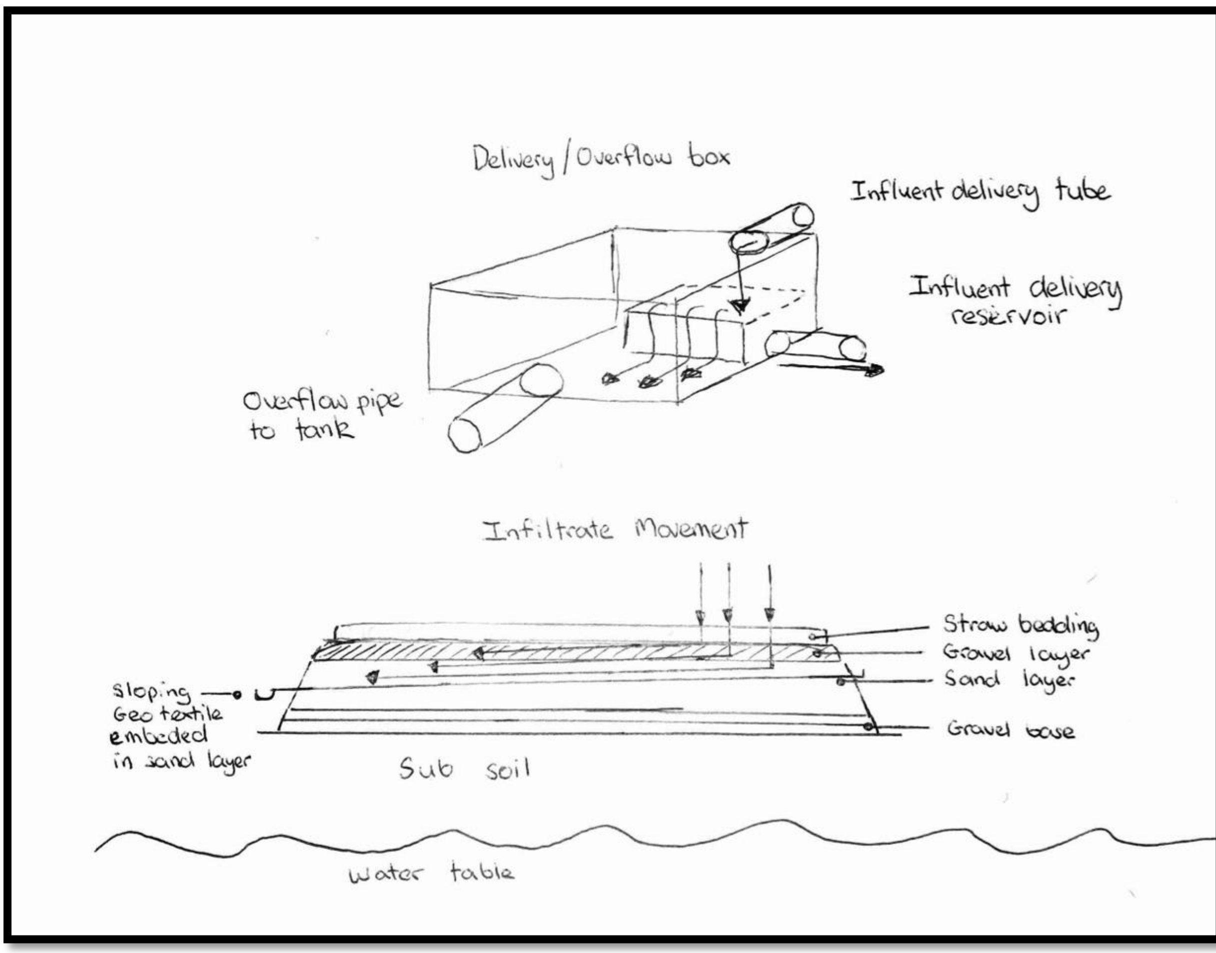
For optimal efficiency the column reactor relies on keeping the carbon source anaerobic, using the infiltrate to do this, and slowing the flow rate of the infiltrate down so as to maximize removal of N. The water retention time is the most critical single factor for the removal of nitrogen. Previous research have identified that 12 hours is the minimum time for denitrification process to work at 10 deg c (Woods Hole Institute, 2006). This time may be able to be reduced due to the increase in denitrifying bacteria when reactor temperatures are raised. By ensuring that the infiltrate is constantly fed into the column from the storage tank as well as the direct flow from the pad the columns can remain anaerobic but not be overwhelmed by a large rain event.

The control of the heat in the reactor and the infiltrate is possible with the use of off the shelf thermostats, moisture probes, solenoid operated taps and telemetry (weather stations). These devices can be operated either on or off the grid, with the option of solar, wind and micro hydro systems readily available in the market. With the speed of advances in cell phone based technology it is conceivable that monitoring and control parameters could be set remotely.

The construction of the standoff pad would be as per normal but would including a geo textile with in the layers of the pad. This geo textile is the non-porous membrane that will capture the effluent and direct it to the edge of the pad and then be processed by the bio filter system. This would be done by using a combination of gravity flow gutter for large rainfall events and using the wick effect to draw moisture from the pad to the collection area of the reactor. A moisture conducting geo textile would also be incorporated into the pad to facilitate infiltrate capture and transfer. It would be preferable to have both systems to overcome any blocking of the guttering that may occur accidentally when the pad is in operation.

Figure 7 Diagram of Standoff Pad and Influent Overflow Mechanism

Conceptual and not to scale.



The management of the infiltrate as it leaves the stand off pad will be conducted so that once the flow increases to a rate that reduces optimal operation of the reactor, the overflow is then diverted to a separate tank. This stored water will then be fed back into the reactor when infiltrate flow is reduced and apart from during a high rainfall event, it will slowly run the contents of the tank down.

As previously stated the key to maximizing the potential of the attenuation process in a bio reactor is to constantly feed the system (infiltrate) and maintain optimal conditions for bacterial growth (temperature).This revised design allows for greater control of the basic elements that enable a bio reactor to operate at near maximum efficiency over a long period of time. This is where the winter rain events would actually aid the process to operate at maximum efficiency over an extended period of time. Instead of these events disrupting the bacteria by overwhelming the reactor the resulting infiltrate can be managed to constantly feed the system. This will aid in reducing the fluxes that would occur, including frost conditions which would be typical of a South Island winter.

The hope is that the control exerted on this natural process will allow over 89.5% of the nitrogen load captured on the pad to be attenuated. Small scale column reactor experiments run at 37 deg c, using landfill green waste indicate that this would be a reasonable expectation. (Price, 2003) This could deliver an overall reduction of approximately 35kg n/ha. Given that the pad will be specked for 99 cows to not trigger any consents, and if the average crop yield of 20ton/dm/ha (fodder beet) is achieved then 4ha of crop will be required for the winter period. This would give a total reduction of 140kg/N per winter from the farm system. The opportunity of siting more pads and specking the reactor accordingly could result in attenuation of a total 848kg/N for an average sized Southland herd of 584 cows (Dairy NZ, LIC, 2014) on a wintering block.

If the reactor was sited in a situation where the cows were feed on the pad then a much higher rate of attenuation could be possible

8 POTENTIAL USES FOR REACTOR

Further refinements and reduction in construction costs may allow for applications and opportunities to attenuate nitrogen from the overall dairy system. The obvious application for using a reactor system would be in conjunction with a feed pad. This could lead to a potential reduction of loading up to 70kg/ha nitrate. With a further reduction in dissolved organic nitrogen due to a change to a silage based feed supply fed on pad rather than a fodder crop fed insitu. Indications from research done on winter crops in Northern Southland indicate this potentially could result in the net reduction of another 40kg TotalN /ha due to the elimination of the fodder crop and subsequent elimination of mineralized nitrogen being lost during crop establishment (Smith, 2013). A total reduction of 100-110kg/TN/ha may be possible. Although this would lead to a system change for the farmer {But without the normally associated environmental consequences of increased overall N loading}.Another example of a potential use would be siting a reactor at the dairy shed to deal with effluent in the spring and autumn when weather conditions preclude the application to paddocks and pond storage is at its limits. Studies overseas have confirmed that the reactor would also serve to mitigate the presence of E.coli at the same time (McKergow, 2007).

The reactor may be scalable to facilitate the removal of dissolved N at a point in the catchment system e.g. tributary, and enable a shared drop in N loading over several farms. Thus allowing for some further land use intensification in that tributary under imposed nutrient caps.

Further applications could involve nonagricultural examples, e.g. storm water treatment, landfill leachate remediation, and industrial site leachate remediation.

9 Summary

The reading and research that I have completed has led me to believe that there is further opportunity for technology and design for bio reactors to be explored. In my opinion engineered bioreactors offer more efficiency and reduce greenhouse gas emissions. Simpler low tech designs may be less efficient but should not be discounted without further research, especially in the more temperate areas of New Zealand. Further solutions to the reduction of the nitrogen cascade (Galloway, 2003) in the agricultural systems of New Zealand need to be identified to ensure the growth of the rural sector. It is vital that these solutions are effective and cost competitive. Bio reactors may offer one of the many tools that will be needed to achieve this.

10 Conclusion

The present solution of nitrogen mitigation via housing cows and collection of effluent in ponds misses a fundamental point. This is that the capital cost of collection and storage far exceeds the environmental pay back in the immediate substitution of importing fertilizer/urea. In fact the belief that housing cows over winter will solve the issue of nitrogen build up in water ways overlooks some basics of physics and is misleading. The reality is that the nitrogen loading of the catchment will not decrease. Rather the intensification of land use required to operate and fund such systems will lead to higher inputs and thus a net increase in catchment wide N load. This style of dairying will only result in higher operating costs but no net benefit to the environment. Given that catchment based nutrient limits are in place or are impending in most of New Zealand, solutions that enable future net reductions in nutrient losses are needed. We now live in a world that is highly connected and disruptive technology is the new normal. Consumers are ever more closely linked to their suppliers, and perception is reality. Now but more so in the future New Zealand needs to be able to differentiate its self in the global market. Both in its primary industry exports and its tourism sector. We have to move as a nation towards true environmental sustainability. The current situation where the dairy industry is embracing off paddock infrastructure as a solution to environmental problems has the potential to further erode its long term profitability .But more worryingly any in market differentiation that we may have presently is being lost. In this regard New Zealand is taking a huge risk by simply replicating foreign systems.

We must innovate and develop our own solutions to our uniquely New Zealand problems in regards of sustainability. The government needs to enable farmers and even the wider public to better understand the “why” behind environmental sustainability. This needs to be achieved so that society and farmers can not only understand the reasoning behind changes to farming systems, but more importantly identify areas of opportunities for further innovation. Only through locally researched technologies and innovation which deliver positive environmental solutions, without replication of foreign farming systems, can we as a nation create a truly unique value proposition. Doing this will go a long way to achieving the marketing slogan of 100% Pure New Zealand and ensuring the future wealth of all New Zealand.

11 RECOMMENDATIONS

-Strategic use of Bio reactors may deliver measurable nitrogen attenuation rates. This technology needs further exploration especially in conjunction with winter fodder crop grazing of dairy cows.

-Industry research and study needs to closer align with farmers to drive research which creates local solutions to environmental issues. In doing this New Zealand needs to harness the No8 wire mentality that exists in the rural sector to help with further Identification of areas for innovation and new technology.

At present there is a gap in knowledge on the negative long term implications of current nitrogen mitigation strategy's on farm. This knowledge gap in my opinion is wide spread and is apparent from farmer level right through to industry good bodies, local government, ministerial and finally all the way up to central government. This fundamental lack of understanding of the wider implications of replicating foreign dairy systems is driving the dairy industry towards wintering barns and long term housing of cows. A current outcome from this knowledge gap is the increased regulation of the dairy industry at local government level. This has the ability to fundamentally change the shape of the New Zealand dairy industry. Such as demanding wintering structures or housing for new conversions or restricting winter grazing options for dairy cows. Off paddock structures are seen as the answer for most in regional council chambers and planning departments. If this knowledge gap is not addressed then replication of foreign dairy systems will be assured as the nation sleep walks it way towards a housed, high input dairy industry, based on the unfounded notion of better environmental sustainability.

-To narrow this knowledge gap a primary industry lead, government backed, national awareness campaign on the positive implications to the New Zealand economy of environmental sustainability should be implemented. It should focus on the "why" in regards to environmental sustainability, and outline to all of society how important it is to achieve this for New Zealand's future prosperity. Namely that of creating a truly unique value proposition and reinforcing our marketing of a "clean & green" New Zealand.

-In the near future a government initiated independent office should be established to plan and model long term strategic goals for the primary industry and tourism sector in conjunction with each other. Both of these sectors have closely aligned marketing strategies and goals, and offer a natural hedge against each other during global price fluctuations. This office should be run along the lines of the parliamentary commissioner for the environment, and remain free of political influence. Its goals should be to inform policy makers and think critically on current threats and opportunities both within New Zealand and globally in the mid to long term. It should outline a long term vision on how to achieve and maintain "N.Z. Incs" value proposition and have a wide ranging view. Reports and measures released by this office on a regular basis will help guide better decision making and offer continuity to central government of all political hues.

12 Works Cited

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Appendix 1
Southern Wintering Systems Dairy Analysis

Southern Wintering Systems Investment analysis summary
Conclusions
Significant improvements in farm profit or reduction in farm costs, relative to wintering with a grazier, are required to generate a positive return on investment in infrastructure for wintering only.
Farmers considering changing their wintering system need to be aware of the full financial implications of any investment to ensure that system intensification is not required for the business to remain financially viable.

Background Information
The purpose of this exercise was to focus on the financial aspects of changing wintering system and to consider the time value of money associated with the change. This is the foundation of Investment Analysis. The base system used for comparison was off-wintering with a grazier.
Cash flow streams that occur in different periods cannot be compared purely at face value because, when taking into account the *time value of money*, money now is more valuable than money later on. Why? Because you can use money now to make more money!
The net present value (NPV) provides an assessment of the long-term profitability of an investment and is calculated by adding together all the revenue that is expected over the lifetime of the investment and deducting all the costs involved, then discounting both future costs and revenue at an appropriate rate to bring the value of the investment into 'todays' dollars. A zero net present value means the project repays the original investment plus the required rate of return. A positive net present value means a better return, and a negative net present value means a worse return, than the return from zero net present value. For an example of an NPV calculation see Appendix 1.
To complete the investment analysis the following information was required for each wintering system scenario that was tested

1. The initial capital investment required to be made (Year 0)
2. The relevant annual cash flows – *incremental cost principle*
3. The anticipated lifetime of the investment (years)
4. The choice of *discount rate*

Incremental Cost Principle (net annual cash flows)
The relevant cash flows are those that are produced as a direct consequence of the system being employed, and any cash flow that exists regardless of whether or not the system is undertaken is not relevant and is excluded. The net cash flow calculations for each scenario also include the savings from not paying a grazier to winter the cows and the nutrient value of the additional manure and bedding material (where applicable). Nutrients were valued at $45 per cow.
Anticipated Lifetime
All calculations were based on a 20 year lifespan of the off-paddock infrastructure.
Discount rate
The discount rate is the opportunity cost of capital. The weighted average cost of capital has been assumed to be 8%.
Assumptions
The basis for the investment in infrastructure was <u>for wintering only</u>. As such the calculations have assumed no change to the production system being operated i.e.stocking rate, lactation length, feed inputs, milksolids production and calving date have remained the same for all scenarios. While this approach can be debated, as often farmers make other changes to their system when investing in

infrastructure, it is important that people understand the financial impact of their investment choices in a status quo situation initially. The choice then becomes what other changes are made to optimise the returns from the investment.

Labour inputs for the different scenarios and associated costs are based on information gathered during the Southern Wintering Systems project.

The annual net operating cash flows are for wintering costs only.

Residual value is the depreciated value (flat rate of 6% per annum) over 20 years for all investment in infrastructure. This may differ from the salvage value so could be considered an area of risk for the farm.

Scenarios

Baseline farm

A 600 cow farm of approximately 205 hectares, with a 70 day wintering period. The grazing price was set at $35 per cow per week including freight. Labour and mileage for a weekly visit to the grazier were added to the weekly grazing costs.

Scenario 1. Leasing a support block for crop wintering

90 ha support block that cows can be walked to for wintering
Land lease price $800/ha
28 ha of crop averaging 15 T DM/ha
Cows offered 10 kg crop and 4 kg baleage (made off the remaining area)
Winter labour – 4 hours per day each for 2 people plus 2 weeks for laying bales out prior to winter

Scenario 2: Wintering pad with self-feed silage

$1000 per cow investment in pad and effluent infrastructure
Bark for the loafing area priced at $60/cow
Effluent/manure/bedding disposal cost of $40/cow
Cows offered 11 kg DM/day pasture silage
1.5 hours/day winter labour input

Scenario 3: Loose-housed barn – bedding material

$1500 per cow investment in barn & effluent infrastructure
Bark for the loafing area priced at $60/cow
Effluent/manure/bedding disposal cost of $40/cow
Cows offered 11 kg DM/day pasture silage
3 hours/day winter labour input

Scenario 4: Loose-housed barn – slatted concrete floor

$2500 per cow investment in barn & effluent infrastructure
Straw for on the slats priced at $25/cow
Manure disposal cost of $35/cow
Cows offered 11 kg DM/day pasture silage
2 hours/day winter labour input

Scenario 4: Freestall barn

$3000 per cow investment in barn & effluent infrastructure
Manure disposal cost of $25/cow
Cows offered 11 kg DM/day pasture silage
3 hours/day winter labour input

Wintering Option	Net present value (NPV)	Investment cost of off-paddock infrastructure	Average annual winter operating cash flow	Average annual winter operating cash flow relative to paying a grazier	Additional capital investment – timing and proportion of cost attributed to wintering	Additional annual profit (or savings) required to generate an 8% return on capital	Residual value of infrastructure after 20 years#
Crop on support block	$54,259	NA	-$204,474	$6,651	Nil	NA	
Wintering pad	-$649,747	$600,000	-$249,102	-$37,977	Nil	$66,178	$174,064
Loose-housed barn – bedding material	-$1,139,543	$900,000	-$261,548	-$50,423	Tractor upgrade Yr 0 – 50% of $90,000; New silage wagon Yr 0 – 100% of $45000; Tractor replaced Yr 10	$116,065	$261,096
Loose-housed barn – slatted floor	-$1,489,212	$1,500,000	-$241,201	-$30,076	Tractor upgrade Yr 0 – 50% of $90,000; New silage wagon Yr 0 – 100% of $45000; Tractor replaced Yr 10	$151,680	$462,935
Freestall barn	-$1,736,731	$1,800,000	-$238,969	-$27,844	Tractor upgrade Yr 0 – 50% of $90,000;	$176,890	$522,191

New silage wagon Yr 0 – 100% of $45000; Tractor replaced Yr 10

Table 1: Impact of wintering system change from grazing off with a grazier to crop on a support block or investment in an off paddock facility, on Net Present Value (NPV), average annual cashflow and residual value

based on 6%/annum depreciation on the initial infrastructure investment

Discussion

All off-paddock wintering scenarios returned a negative NPV, indicating that at the 8% rate of return used in the calculations the cost of the investment and the additional annual operating costs were higher than the benefits or cost savings when compared with wintering with a grazier.

Systems involving infrastructure investment were very sensitive to the cost per cow of the investment. In the current scenarios the higher per cow investment cost of the free-stall barn resulted in the poorest NPV. There is a wide range in cost of barns therefore it is important to do an investment analysis for your individual situation.

The residual value of the infrastructure was calculated as the difference between the investment price and depreciation at 6% per annum. This amount may differ from the actual salvage value. All structures have been depreciated at the same rate and over 20 years. Only time will tell if all structures have the same useful lifespan.

Differences in annual wintering operating cash flow between the systems were driven by the requirement for bedding material for the wintering pad and loose-housed barn and the need to handle more manure and used bedding material from these systems.

The only scenario with a lower annual operating cost than using a grazier was wintering on crop on a lease block. However, the returns for this system were very dependent on the lease cost of the land, crop yields and distance from the milking platform (cartage costs).

The investment analysis was conducted assuming no change to the production system of the farm. The additional profit required to generate an 8% return on investment ranged from $66 000 per year for a wintering pad to $176 000 per year for a free stall barn.

In making the decision to invest in capital for wintering farmers need to be aware of changes to wintering operating cash flows and accept that changes to the production system may be required to ensure the farm remains financially viable.

Appendix 2

NPV calculation example

An investment of $1,000 today at 10% will yield $1,100 at the end of the year; therefore, the present value of $1,100 at the desired rate of return (10%) is $1,000. The amount of investment ($1,000 in this example) is deducted from this figure to arrive at net present value which here is zero ($1,000-$1,000). A zero net present value means the project repays the original investment plus the required rate of return. A positive net present value means a better return, and a negative net present value means a worse return, than the return from zero net present value.