Nitrogen Recycling Case Study

Hekeao/Hinds Water Enhancement Trust

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Executive Summary

The purpose of this report is to summarise the findings from a case study approach investigating the potential nitrogen fertiliser reductions (and associated cost savings) for two case study farms (one mixed cropping and one dairy) where high nitrate groundwater is used for irrigation.

Two case studies were used. One dairy unit within the Hinds catchment and a theoretical arable system.

A simple equation was used to calculate the likely nitrogen applied (as nitrate-N) through irrigation sourced from high nitrate groundwater in the area. Three concentrations of nitrate-N were used in the work, they were 10 mg/L, 15 mg/L and 20 mg/L. Where mg/L = g/m^3 = ppm.

Key findings have been included below:

- There is a potentially significant contribution of nitrogen coming from high nitrate-N groundwater used for irrigation within the catchment
- There is unlikely to be enough nitrogen in the groundwater to fully replace nitrogen fertiliser inputs & providing a direct substitution formula is very difficult
- The amount of nitrogen applied through irrigation is strongly dependant on the concentration of nitrogen in the water and the application depth applied to the land
- When applying approximately 460 mm per annum of irrigation to pasture with a Nitrate-N concentration of 20 mg/L there is a potential nitrogen loading of 92 kg N/ha/yr. This is equivalent to 200 kg/ha of Urea.
- Within a cropping system the per crop irrigation demand will be comparatively less than that required for permanent pasture as crops are able to explore more of the available water within the soil profile due to rooting depth.
- There is potential for additional nitrogen inputs of 60 kg N/ha within an arable system. This will be higher for areas with increased irrigation demand, or for those with travelling irrigators such as turbo rainers.
- The price of synthetic nitrogen (based on Urea) as at February 2022 is $2.59 per Kg. This is excluding GST and any cartage or spreading costs. At this price the additional nitrogen applied to the case study farm (205 ha) through irrigation with a nitrate-N concentration of 20 mg/L could be worth $48,900.
- Where farmers are actively managing their nitrogen usage with soil/plant nitrogen testing (arable) and feed supply/demand observations it is likely that their applications already take into account the nitrogen applied through irrigation (without realising).
- There is an opportunity for greater adoption of soil N testing & monitoring to support nutrient decisions.
- It would be fundamental for farmers to be able to access water quality information to understand the variations in concentration both annually and seasonally.
- High Nitrate-N concentrations in groundwater can have potential human & ecosystem health implications. Local funding (Hinds Plains) is currently being used to find ways to mitigate these issues through Managed Aquifer Recharge (MAR). Aside from reducing fertiliser costs, increased utilisation of groundwater nutrients is expected to help reduce the negative risks of high nutrient groundwater on the environment & human health.

Contents

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1. Introduction

1.1 Project Background

The Hinds/Hekeao Water Enhancement Trust (HHWET) in collaboration with Environment Canterbury, have engaged Agri Magic to undertake case study work to investigate the potential fertiliser savings and implications of irrigating with groundwater with high nitrate concentrations.

The Hekeao/Hinds catchment is contained within the borders of Mid Canterbury. This farming area is one of the most productive irrigated agricultural districts in New Zealand. Despite on-going improvements in nutrient & irrigation management, the catchment is still facing significant environmental pressures & challenges particularly related to high nitrate concentrations in groundwater. The Canterbury Land and Water Regional Plan (LWRP) includes nitrogen reduction requirements for the Hinds/Hekeao Plains catchment as outlined in Plan Change Two. In addition, the Hinds catchment is funding the use of Managed Aquifer Recharge (MAR) to help reduce the nitrate-N concentrations in groundwater.

There is a nitrate hotspot located near Tinwald. Nitrate concentrations in groundwater have historically been high in an area surrounding Tinwald since at least the mid-80s (Stewart & Aitchison-Earl, 2020). The HHWET team and the local community are invested in finding options for remediating the high nitrate levels.

Excessive nitrate concentrations in groundwater are of great concern for human health and for the environment. New Zealand drinking-water standards set a maximum acceptable value (MAV) for nitrate nitrogen at 11.3 mg/L, based on the risk to bottlefed babies (Ministry of Health, 2008), and in line with the WHO (World Health Organization) guidelines (WHO, 2016, 2017). Although the levels near Tinwald have historically been high, they are being exacerbated by the fact that the area is irrigated with groundwater with high nitrate concentrations. This is in contrast to many other areas in Canterbury where the irrigation water applied is alpine-river water with comparatively low nitrate concentrations.

The concept of irrigating with groundwater from the same area is a term called “irrigation return flow” or “groundwater recirculation” where water is pumped from the underlying aquifer (Stewart & Aitchison-Earl, 2020). The work undertaken by Stewart & Aitchison-Earl has identified that recirculation of irrigation in the areas surrounding Tinwald is likely to be contributing to the high nitrate concentrations in the groundwater. Aside from the environmental & health risks of high nitrates in groundwater, many farmers within the area may be applying unnecessary quantities of fertiliser. As well as reducing the potential for nitrate leaching to groundwater (with the reduction in excess nitrogen) there are economic benefits to reducing fertiliser applications on farm. Where nitrogen is applied in excess of plant/crop requirements it is at risk of leaching to groundwater if drainage occurs.

This document aims to highlight the potential fertiliser savings on two case study farms (one dairy and one arable) and to document the potential implications to on farm management of adopting fertiliser policies that consider the nitrogen applied through irrigation applied. The dairy unit is a real farm example with the owners remaining anonymous. The arable example is a theoretical farm system. Consideration has also been given to the calcium, magnesium and sulphur concentrations in the groundwater used for irrigation following recent water quality test results near Tinwald, where levels of these nutrients were elevated.

1.2 Nitrogen Management on Farms

Nitrogen is essential for life on earth; it is a component of all proteins and can be found in all living systems. Nitrogen is used within New Zealand farming systems to ensure pasture and crop requirements are met, and to increase pasture production to support grazing systems.

Within a dairy system nitrogen is used as a management tool (essentially a form of supplementary feed) to produce additional feed at times when animal demand might exceed pasture growth. The key to profitable nitrogen use is to identify feed deficits early and to apply nitrogen to fill those periods. In order to do this, managers of dairy units need to have a good understanding of grazing & pasture management and animal demand. The amount of nitrogen applied, and the timing of its application are fundamental to ensuring a good response (additional growth of pasture). The National Policy Statement for Freshwater Management 2020 (NPS-FM20) has introduced a nitrogen cap of 190 kg synthetic nitrogen per hectare for pastoral farms. This N cap has raised the importance of good pasture management and the timing of nitrogen applications.

Within an arable farming system, certain crops can easily deplete soil nutrient reserves if poorly managed. Different crops have differing nutrient requirements with many arable crops capable of taking up high quantities of nitrogen from the soil. Within an arable system it is important to apply nutrients to match anticipated yields to ensure that the crop is not restricted. An understanding of the amount of potentially available nitrogen already within the soil along with the nitrogen requirements of the crops grown is important to maximise yields within an arable system. Timing of nitrogen fertiliser applications is equally (if not more) important within an arable system.

2. Dairy Farm Case Study

The dairy unit used for this case study is located near Isleworth road. The property is 215 ha (205 ha effective) irrigated by centre pivot and roto-rainers. The irrigation water source is groundwater from shallow and deep bores. The farm is a high producing dairy unit with approximately 3.8 cows per hectare producing 500 - 525 kg milk solids per cow. There is generally one paddock of fodder beet grown on the platform.

For this case study two scenarios were assessed. The first scenario considers the farm as it is currently run using irrigation volumes & flow rates for the last 5 years. The second scenario considers the farm without restrictions and models irrigation based on an 80% efficient irrigation system utilising Irricalc average annual & monthly requirements.

It needs to be noted that the nitrate-N concentrations used for this dairy case study have not been taken from the farms groundwater supply wells. They are theoretical values for nitrate-N for the purpose of this case study and to establish potential methods for quantifying nitrogen applied and potential cost savings.

There are three dominant soil types on the property as determined by Landcare Researchs SMaps. They are:

- Lismore silt loam (Lism_1a.1) – well drained with a profile available water depth to 60cm of 93mm
- Lowcliffe shallow silt loam (Lowc_1a.1) – imperfectly drained with a profile available water depth to 60cm of 65mm
- Lowcliffe shallow silt loam (Lowc_2a.1) – imperfectly drained with a profile available water depth to 60cm of 82mm

A map of the property has been included below:

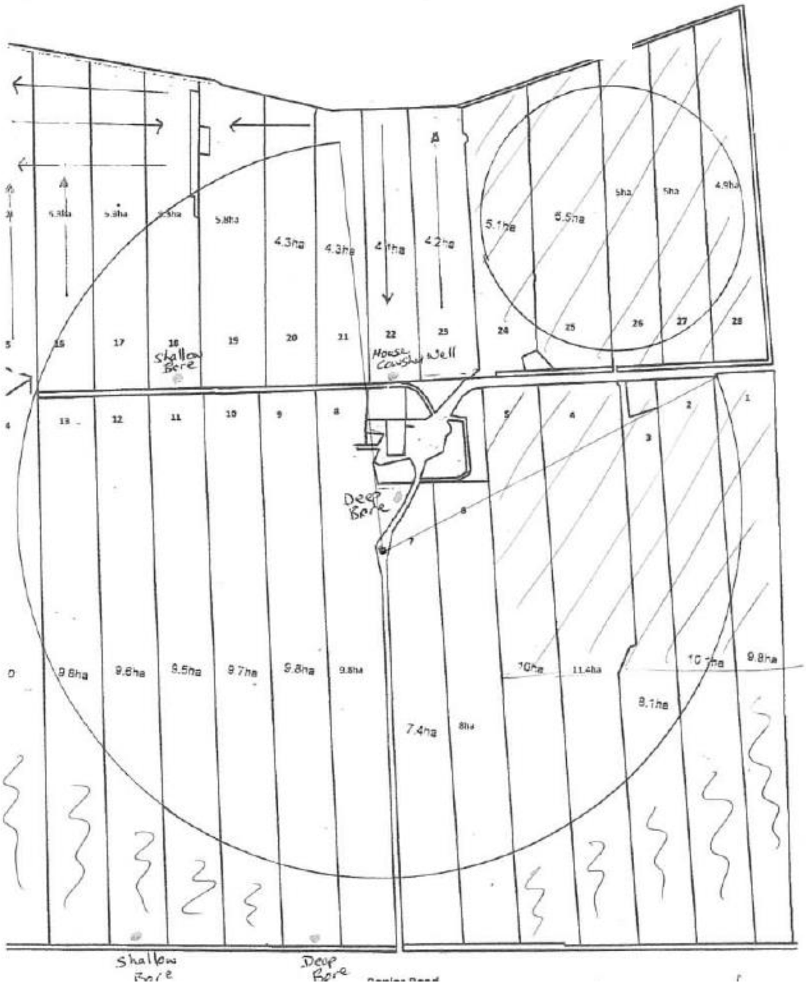

Figure 1 Layout of Case Study Farm

2.1 Current Irrigation Management

The property is irrigated by two centre pivots and roto-rainers. One pivot can complete a full circle as shown on the map and the larger pivot has to run backwards on itself. The roto-rainers are in the corners.

- Small Pivot = 20 ha
- Large Pivot = 118 ha
- Roto-rainer = 67 ha

The centre pivots are managed to apply 15 mm every 3 days (noting that the large pivot has to go back on itself) and the roto-rainers are applying 35mm each pass on a 7 day return (35mm every 7 days). This is essentially a 5mm/day system design. There is one soil moisture tape on the farm to support irrigation decision making, it is located under the large pivot.

In a typical season there is normally a pumped total of 125 litres per second however can be restricted due to groundwater levels in shallow wells. In the 2020-21 season the farm was restricted to 100-110 litres per second. The irrigation consent allows for a total annual volume of 1,262,050 m^3, with no more than 10,800m^3 per day applied. If the total volume is utilised this is equivalent to applying 616 mm for the season.

Total irrigation volumes are monitored by Watermetrics and a summary of irrigation use has been provided below.

Measured annual volumes for the property are listed in the table below. Annual volumes have ranged from 366,921 m^3 to x 1,252,450m^3 over the last five years. The annual volume for the 2017-18 season is significantly lower than for the other seasons so there may have been some recording errors with telemetry systems.

Table 1 Summary of Irrigation Use on Case Study Farm

Irrigation Season	Measured volume (m^3)	mm applied (mm)
2020-21	1,252,450	611
2019-20	1,119,501	546
2018-19	924,105	451
2016-17	1,018,377	497
Average	***1,078,608***	***526***

Data from the 2017-18 season has been removed from the analysis due to suspected recording errors.

2.2 Irricalc Irrigation Demand

The Irricalc model has been used to establish an approximate irrigation requirement for the property (based on pasture) and an 80% efficient irrigation system. The co-ordinates of the farm are input into the model to establish the climate information. The area was modelled with a plant available water (PAW) to 60 cm of 80 mm and a 5 mm per day system capacity. The model outputs both average requirements (monthly & annual) and 90th percentile water use. It also provides an indication of average drainage.

The monthly and annual average requirements for the property have been shown below:

Table 2 Summary of Average & 90th Percentile Irrigation Demand based on Irricalc Model

Month	Average Requirements			90th Percentile		
	mm	**m3/ha**	**Total Volume (m^3) (205 ha)**	**mm**	**m3/ha**	**Total Volume (m^3) (205 ha)**
July	0	0	0	0	0	0
August	0	0	0	0	0	0
September	20	200	41000	50	500	102500
October	33	330	67650	100	1000	205000
November	85	850	174250	100	1000	205000
December	100	1000	205000	150	1500	307500
January	96	960	196800	150	1500	307500
February	71	710	145550	100	1000	205000
March	36	360	73800	100	1000	205000
April	16	160	32800	50	500	102500
May	4	40	8200	0	0	0
June	0	0	0	0	0	0
ANNUAL	461mm	4610 m^3/ha	945,050 m^3	800mm	8000 m^3/ha	1,640,000 m^3

2.3 Current Fertiliser Policies & Use

Fertiliser decisions to inform the application of phosphate, potassium & sulphur are made with the support of a fertiliser representative using soil test information. Applications are different across areas receiving liquid dairy effluent and those that do not receive effluent. Maintenance applications of Phosphorus and Sulphur are made in Spring (November). Nitrogen fertiliser decisions are based on creating a quality feed wedge and accurately matching feed supply to demand particularly through the spring and early summer to maximise production and achieve mating targets. Nitrogen usage is assessed early in the new year with usage set for the remainder of the season at that time.

The 2020-21 fertiliser programme is documented below:

Month	Nitrogen applied total (kg N)	Other Fertiliser
July	0	
August	1990 Applied as Ammo 30N	910 kg Sulphur
September	630 Applied as Ammo 30N	290 kg Sulphur
October	8350 This includes nitrogen applied to crops Applied as urea & ammonium sulphate	190 kg Phosphorus (to crop) 160 kg Sulphur (to crop)
November	4690 Applied as Urea	457 kg/ha Superten7K to non-effluent areas 150 kg/ha Sulphurgain20S applied to effluent areas and the fronts of long paddocks
December	6578 Applied as Urea	
January	3090 Applied as Urea	
February	6790 Applied as Urea	
March	6450 Applied as Urea	
April	2570 Applied as Urea	
May	1860 Applied as Sustain Ammo 30N	860 kg Sulphur
June	0	
TOTAL Nitrogen Applied	42,990 kg Or the equivalent of 210 kg N/ha	

This season (2022-23) the farm is working towards applying no more than 190 kg N/ha in line with the new National Environmental Standards and is on track for achieving this.

2.4 Groundwater Nutrient Concentration

There are consistently high groundwater Nitrate-N concentrations in the area (above 11.3 mg/L) with shallow groundwater generally higher than deeper groundwater. The concentrations for this case study farm have not been used and instead we have modelled three concentrations for the purpose of this case study:

- Nitrate-N concentration = 10 mg/L
- Nitrate-N concentration = 15 mg/L
- Nitrate-N concentration = 20 mg/L

Please note: mg/L = g/m^3 = ppm

Samples taken from a groundwater well near Tinwald reflect both high Nitrate-N concentrations (between 21 mg/L and 23 mg/L consistently since January 2018) and also elevated concentrations of Magnesium, Calcium and Sulphate. It has been requested that the calculations also consider the high concentrations of these nutrients within this case study although it is important to note that these samples are not from the wells associated with this case study property. The average concentration of each nutrient from the water quality results between 2018 to April 2021 have been shown below:

- Sulphate = 31 mg/L
- Dissolved Calcium = 40 mg/L
- Dissolved Magnesium = 12 mg/L

For comparison, the average concentrations of irrigation water typically used for modelling purposes within OverseerFM have been shown below:

N	P	K	S	CA	MG	NA	UNITS
2.5	0.1	1.6	2.5	9.3	2.2	9.5	mg/l

2.5 Nitrogen Applied as a Result of High-Nitrogen Irrigation Water

It is possible to undertake a direct calculation in order to work out the potential nitrogen applied as a result of irrigating with high nitrate-N groundwater. This is the same calculation used in a study undertaken in Culverden, North Canterbury looking at the impact of irrigating with enriched water from St Leonards Drain.

The calculation is:

Nitrogen Applied via Irrigation = Irrigation water volume X irrigation water concentration X irrigation efficiency

An irrigation efficiency of 80% has been used in this work. It is assumed that the 20% not used by plants is lost (either through evapotranspiration or leaching).

2.5.1 Based on Actual Irrigation Usage

Over the past 5 years irrigation has typically started in mid-September and finished mid-April. Based on the total volumes applied the following nitrogen loadings could have been applied (based on the three nitrate concentrations). It has been assumed that 20% of what is measured is lost.

Table 3 Total Nitrogen that could be applied through irrigation at various nitrate concentrations based on actual irrigation use

Irrigation Season	80% applied volume (m^3)	Nitrogen Applied @ 20 g/m^3 (kg N total)	Nitrogen Applied @ 15 g/m^3 (kg N total)	Nitrogen Applied @ 10 g/m^3 (kg N total)
2020-21	1,001,960	20,039	15,029	10,020
2019-20	895,601	17,912	13,434	8,956
2018-19	739,284	14,786	11,089	7,393
2016-17	814,702	16,294	12,221	8,147
Average	***862,887***	***17,258***	***12,943***	***8,629***

At an efficiency of 80% the average volume of irrigation applied is 862,887 m^3. At various nitrate-N concentrations, the amount of nitrogen that could be applied through irrigation on average ranges from 8,629 kg N total at a nitrate-N concentration of 10g/m^3 through to 17,258 kg N total at a nitrate-N concentration of 20g/m^3. Based on the last 5 years of irrigation usage up to 20,039 kg nitrogen total could have been applied had the nitrate-N concentration of the irrigation water been 20 g/m^3. This would equate to 98 kg N/ha across the 205 ha property.

The water usage recorded is across the whole property, however there are two irrigation systems on the farm. It is expected that a greater amount of water is applied per hectare under the roto-rainers compared to that applied by centre pivot. This would corelate to a higher nitrogen loading from irrigation on these areas of the property.

The farm is on track to apply 190 kg N/ha or less as per the nitrogen cap. Nitrogen applications are lower on the effluent area compared to the non-effluent areas.

If the non-effluent areas receive 190 kg N/ha/yr through synthetic fertiliser, with additional nitrogen applied through irrigation this could be up to 288 kg N/ha/yr applied in total. Effluent areas may receive between 190 – 240 kg N/ha (fertiliser + effluent). The nitrogen loading on effluent areas could be in excess of 300 kg N/ha/yr with high nitrate-N irrigation water.

It should be noted that the Nitrogen Cap legislated through the National Environmental Standards, gazetted in August 2020 is only related to synthetic nitrogen. This means that any nitrogen applied through irrigation, supplements, or organic fertilisers/composts etc are not included within the 190 kg N/ha/yr limit.

2.5.2 Based on Irricalc Estimated Irrigation Demand

Table 4 shows the total nitrogen applied through irrigation across the 205 ha area at the three concentrations listed above based on the irrigation demand estimated by Irricalc for an 80% efficient system. Table 5 shows the potential for Sulphur, Magnesium & Calcium applied if irrigation water is also high in those nutrients.

Table 4 Summary of the Nitrogen applied total and per hectare across the 205ha property with varying Irrigation water nitrate-N concentrations

Nitrate-N Concentrations (g/m3)		July	August	September	October	November	December	January	February	March	April	May	June	TOTAL
N @ 10 g/m3	**Total N applied (kg)**	0	0	410	677	1743	2050	1968	1456	738	328	82	0	**9450.5**
	N applied per hectare (Kg N/ha/yr)	0	0	2	3.3	8.5	10	9.6	7.1	3.6	1.6	0.4	0	**46.1**
N @ 15 g/m3	**Total N applied (kg)**	0	0	615	1015	2614	3075	2952	2183	1107	492	123	0	**14175.75**
	N applied per hectare (Kg N/ha/yr)	0	0	3	5.0	13	15	14	11	5.4	2.4	0.6	0	**69.15**
N @ 20 g/m3	**Total N applied (kg)**	0	0	820	1353	3485	4100	3936	2911	1476	656	164	0	**18901**
	N applied per hectare (Kg N/ha/yr)	0	0	4	6.6	17	20	19.2	14.2	7.2	3.2	0.8	0	**92.2**

At the various concentrations of nitrate within the groundwater used for irrigation (when applying 461mm) the equivalent per hectare rates of nitrogen applied for the season are:

- Nitrate-N concentration = 10 g/m^3 would be equivalent to applying 46 kg N/ha/yr or 100 kg/ha of Urea
- Nitrate-N concentration = 15 g/m^3 would be equivalent to applying 69 kg N/ha/yr or 150 kg/ha of Urea
- Nitrate-N concentration = 20 g/m^3 would be equivalent to applying 92 kg N/ha/yr or 200 kg/ha of Urea

Table 5 Summary of Total Nutrient Load applied with average irrigation demand as estimated by Irricalc

Concentration of S, Ca & Mg	July	August	September	October	November	December	January	February	March	April	May	June	TOTAL Nutrient (Kg)	Total Nutrient per hectare (Kg/ha)
Sulphate (31 g/m3)	0	0	1271	2097.15	5401.75	6355	6100.8	4512.05	2287.8	1016.8	254.2	0	**29296.55**	**142.91**
Calcium (40 g/m3)	0	0	1640	2706	6970	8200	7872	5822	2952	1312	328	0	**37802**	**184.4**
Magnesium (12 g/m3)	0	0	492	811.8	2091	2460	2361.6	1746.6	885.6	393.6	98.4	0	**11340.6**	**55.32**

In comparison to alpine river water, the concentrations of Sulphate, Calcium and Magnesium are significantly higher in the tested groundwater near Tinwald. At these concentrations it is likely to contribute to water 'hardness'. Hard water is likely to have higher scale deposition and scum build up compared to water with lower levels of calcium and magnesium (in particular).

The interactions of the various nutrients required for plant and crop growth (and also animal health) are complex. The uptake of cations in particular is very complex. Irrigating with groundwater high in calcium and magnesium could have differing consequences for plant uptake. The implications of this on fertiliser requirements is less straight forward than for nitrogen.

It would be fundamental for a farmer to first understand the nutrient concentrations within their soil using soil test information and to also use herbage tests as a way of understanding how plant uptake is being impacted by the high nutrient concentrations applied by the irrigation water. The relationship is not necessarily linear between high nutrient concentration in groundwater applied to land and high nutrient uptake in plants/crops being grown.

Some of the implications for on farm management have been discussed below:

Magnesium (Mg)

Magnesium is an essential nutrient for both plants & animals. Low blood Mg in ruminants (hypomagnesemia) is a problem within the New Zealand Pastoral industry. Most of the topsoil within New Zealand has significant reserves of Magnesium allowing for optimal pasture production. According to a literature review undertaken by Doug Edmeades, there is evidence to suggest that Mg levels may be declining in some areas (areas with coarse soils & high rainfall) in the absence of Mg fertiliser, however South Island soils in general have abundant reserves of Magnesium. Pasture responses to Magnesium (Mg) are rare except on some pumice soils particularly if the soil test Mg level is less than 5. It is unlikely that there will be a pasture response to elevated Magnesium levels in the irrigation water in the Hinds catchment as it would be expected that Mg levels in the soil are more than adequate for pasture (quick test Mg 8-10).

Feed intake is a fundamental determinant of animal Mg status. Animal Mg requirements (particularly in early spring) can only be met with soil Mg levels QT Mg 25-30 or above & provided intake is adequate. Given the high Mg concentrations in groundwater it is likely that soils in the area have high Mg levels. It cannot however be assumed that this coincides with high pasture Mg given the complex nature of cation exchange & nutrient uptake relationships. It is unlikely that those farming in the area should need to apply additional Mg through fertiliser for pasture production. Irrigating with high Mg groundwater is unlikely to remove the requirement for Magnesium supplementation for animal health purposes as stock (dairy cattle in particular) will be limited by what they can physically eat & therefore careful monitoring of Mg actually ingested is important to avoid animal health issues.

Within an arable farming system Magnesium can often be required at crop establishment & is often applied as Kieserite. This contains both Mg and sulphur in water soluble form for fast available nutrient supply. Crops within an arable system are generally being established in Spring and/or Autumn. Irrigation requirements during both Spring and Autumn are more difficult to predict as the rainfall during this time is more frequent (compared to through the summer months). Due to the timing of the Magnesium requirements, it would be more difficult to reduce fertiliser applications in line with that applied through irrigation as the irrigation requirements through those establishment periods are both lower & much more variable. Irrigation alone is unlikely to replace the requirement for some fertiliser Magnesium to be applied (if required).

If concentrations of Calcium are high in the groundwater (as shown in the water testing information above) it is likely that plant/crop uptake of Magnesium will be negatively impacted. This is because soils have a higher affinity for Calcium than for Magnesium, so Magnesium is displaced into soil solution at risk of leaching. Through research undertaken the Magnesium uptake by plants is almost always reduced when Calcium and/or Potassium is applied. The relatively high concentration of Calcium in the groundwater used for irrigation could negatively impact the uptake of Magnesium by plants.

Calcium (Ca)

The calcium concentrations in current topsoils of New Zealand soils are more than adequate for optimal pasture and animal production & this situation is sustainable given the regular applications of superphosphate and lime to pastures and crops (Edmeades & Perrot, 2004). As a result, calcium fertilisers are not required specifically for pasture production. Calcium is applied through lime and also superphosphate however it is not the reason these products are applied. Liming (calcium carbonate) is an essential management practice to ensure soils have an optimal pH for maintaining pasture/crop growth. The calcium component of lime is not what impacts the pH of soils it is the carbonate component. Superphosphate is applied for phosphate & sulphur. Because of this it is difficult to reduce any fertiliser inputs of calcium in consideration of the high calcium groundwater being applied by irrigation.

The high calcium concentrations in the groundwater could reduce the calcium requirements (from sprays or fertiliser) for some niche arable crops. Calcium plays a vital role in cell structure & can help plants tolerate a wide range of stresses.

Although good liming practices should not be altered, there may be scope for farmers to reduce their calcium inputs through fertiliser if irrigation water concentrations are high.

Sulphur (S)

Sulphur is essential for plant growth. It is present in all plants, involved in photosynthesis, energy metabolism & carbohydrate production. Adequate sulphur levels are also required for optimal nitrogen uptake. What is often diagnosed as an N deficiency in plants may actually be a sulphur deficiency, particularly in early Spring. Inadequate supply of sulphur can also negatively impact the ability of legumes to fix nitrogen from the atmosphere.

Sulphur can be applied as sulphate sulphur which is readily plant available, or elemental sulphur which must be oxidised by soil microbes into sulphate-S before it is plant available. Sulphur behaves similarly to nitrate within soil solution and is readily leached if drainage occurs. Soils are often deficient in available sulphur in early spring following winter. Because of this many pastoral farmers will apply ammonium sulphate in early spring to ensure sulphur is not limiting. Most of the fertilisers recommended for crops will also include sulphur at establishment.

At a concentration of 31mg/l in groundwater that could be used for irrigation there is an adequate amount of sulphur being applied to overcome any deficiencies. The main challenge is that the timing of when the irrigation season commences is not well matched to the key period where Sulphur would be required – early spring. Using Irricalc estimated irrigation requirements for the Hinds area it is likely that irrigation would commence at the end of September in an average year. Irrigation requirements are lower in early spring (and autumn) as rainfall is more reliable at those times. Based on the Irricalc model, only 1270 kg of sulphur would be applied in September. This would equate to 6.2 kg S/ha across the 205 ha case study farm. On the case study farm approximately 14 kg S/ha is required in August with another 14 kg S/ha in September (based on applying Ammo30N at 100 kg/ha) to ensure sulphur is not limiting early spring growth. Given irrigation requirements are low at that time there is little opportunity to reduce the sulphur applied by fertiliser due to the timing.

The fertiliser association recommends that 20-40 kg S/ha/yr is required to maintain soil Sulphur levels at a stocking rate of 3.5 cows/ha. At a concentration in groundwater of 31mg/l there could be up to 142 kg S/ha applied (based on the case study dairy farms irrigation requirements). Given this will be applied through the irrigation season there could be an opportunity to reduce or remove the last application of Sulphur from the round that is applied in Autumn.

Given that the concentration of Calcium is also high, there could be an opportunity for farmers to utilise products such as DAP (Diammonium phosphate) for some of their N and P requirements to reduce the input of both calcium and sulphur, however this is not likely to be a cost saving due to the comparative cost of a high analysis product such as DAP.

Overall, it is much more difficult to prescribe any simple adjustments to fertiliser regimes as a result of the high groundwater concentrations of Ca, Mg & S. The interactions of cations Magnesium, Calcium, Potassium & Sodium within the soil are complex & relationships with high nutrient supply and plant uptake are not always directly corelated. It would be important for both fertiliser advisors and also animal health representatives to understand the potential contribution of high nutrient groundwater in the area; however, it is unlikely that changes in short term availability of these nutrients can be overcome by the application from irrigation water alone (Dr Ants Roberts Ravensdown. 2022).

At high concentrations these nutrients could contribute to water 'hardness' and impact the maintenance & upkeep of irrigators within the area. Irrigation system maintenance is a component of good management practice that helps to ensure that irrigators are operating as well as they can.

2.6 Associated Costings

To calculate the cost of the Nitrogen applied via irrigation water the mass of nitrogen applied has been multiplied by the current price per kilogram of nitrogen in fertiliser. The current price of Urea is $1190 per tonne (excluding GST) (Ravensdown & Ballance, 2022). Urea contains 46% nitrogen, the price per kilogram of nitrogen is therefore $2.59 (excluding GST). It should be noted that this is a very high price for nitrogen in comparison to previous years. In August 2020 for comparison the price of nitrogen per kilogram was closer to $1.26 (excl. GST and freight/spreading costs) or $580/tonne of Urea.

2.6.1 Costings Based on Actual Irrigation Usage

The 2020-21 season has been used to represent the cost of the nitrogen applied through irrigation.

The methodology used to calculate the Nitrogen Applied is as follows:

Irrigation applied (80% efficient) = 2020-21 annual irrigation applied X 80%

80% efficient irrigation applied (m3) X concentration = N applied with irrigation

This assumes that the concentration of N in the irrigation water lost is the same as in the water that is applied.

Table 6 Cost of nitrogen applied by irrigation at various N concentrations using the 2020-21 water usage data

Nitrate Concentration	Nitrogen Applied through irrigation (kg N)	Cost ($) At $2.59 / kg N	Cost ($) At $1.46 / Kg N
Nitrate-N concentration = 10 g/m3	10,020	$25,952	$14,629
Nitrate-N concentration = 15 g/m3	15,029	$38,926	$21,941
Nitrate-N concentration = 20 g/m3	20,039	$51,901	$29,257

At all concentrations and across all years (4 years of data excluding 2017-18) there is a potential cost saving associated with adjusting fertiliser applications to account for some of the N being applied through irrigation.

Table six includes the cost of nitrogen based on a direct substitution for two different nitrogen prices. The current price of nitrogen is $2.59/kg N (excluding GST, transport & spreading costs). The cost of nitrogen is significantly higher at present (Autumn 2022) compared to the price in Spring of 2020 however there is still a potential cost saving.

2.6.2 Costings Based on Irricalc Calculated Irrigation Demand

The calculated mass of nitrogen applied via irrigation based on the Irricalc estimated demand is

- Nitrate-N concentration = 10 g/m^3 would be equivalent to applying 46 kg N/ha/yr or 100 kg/ha of Urea (9,451 kg N total)
- Nitrate-N concentration = 15 g/m^3 would be equivalent to applying 69 kg N/ha/yr or 150 kg/ha of Urea (14,176 kg N total)
- Nitrate-N concentration = 20 g/m^3 would be equivalent to applying 92 kg N/ha/yr or 200 kg/ha of Urea (18,901 kg N total)

The cost of this as fertiliser nitrogen is shown below:

Nitrate Concentration	Nitrogen Applied (kg N)	Cost ($) At $2.59 / kg N
Nitrate-N concentration = 10 g/m3	9,451	$24,478
Nitrate-N concentration = 15 g/m3	14,176	$36,716

Nitrate-N concentration = 20 g/m3	18,901	$48,954

The case study dairy unit applied 42,990 kg Nitrogen in the 2020-21 season. At current Urea prices this would be $111,344. If 18,901 kg of this nitrogen was applied through irrigation (at 20 mg/L) there could have been a saving of 24,089 kg nitrogen or $62,390 for the season. This is assuming that there is a direct substitution which may be more difficult in practice given the differences in timing & requirement for moisture (irrigation) versus nitrogen.

The cost savings are significant given the current price of Urea.

There could be an additional cost saving from not applying Sulphur in Autumn as suggested above if the sulphur concentrations in groundwater were also high. The cost of sulphur is significantly lower than the cost of nitrogen therefore any savings are likely to be realised through the substitution for a different fertiliser product (of a lower price) or from removing/reducing the amount applied. Given the cost of sulphur is very low (compared to other nutrients) there is unlikely to be a direct economic motivator for Sulphur when considered in isolation

The price of Sulphate Sulphur is approximately $0.69 per kg. If applied as an Ammo product (ammonium sulphate & urea) to 205 ha in Autumn (like the case study property) at a typical rate of 100 kg/ha of product this will apply 13.8 kg S/ha. The cost of nitrogen within the Ammo products is approximately $2.76 /Kg N. If the Sulphur is not required, the potential cost saving is realised through utilising a product with a lower cost of nitrogen such as urea (given the comparatively low costs of Sulphur). The cost saving is greater again if the application is removed completely.

2.7 Implications for a Pastoral Based System

There is the potential for a significant amount of nitrogen to be applied through irrigation within a pastoral system. Pastoral based systems typically have a higher irrigation demand than a mixed cropping system, particularly where a large proportion of the rotation includes deep rooted crops capable of exploring more of the soil profile.

The amount of nitrogen applied by irrigation is determined by the concentration in the irrigation water and the amount of water applied. The calculations used can provide a means for working out the amount of nitrogen that could be being applied through irrigation water on a particular farm. In order to do this accurately for each paddock on a farm you would need to know the volume of irrigation applied per irrigation pass (and the number of passes) and the concentration of the irrigation water applied. For irrigators that utilise both deep & shallow groundwater for their irrigation it is more difficult to determine the concentration of water applied as there is the potential for both high & low nitrate-N water to be mixed prior to application.

The timing and amount of nitrogen required by a dairy system is not the same as the timing & requirement for irrigation water. As an example, there is likely to be a high nitrogen response in spring when pasture growth is rapid following winter; however, during this time irrigation requirements are lower as spring rainfall is more reliable. In the heat of summer nitrogen responses may be lower yet irrigation demand is highest. Therefore, in practice it may not be feasible to directly substitute nitrogen applied from fertiliser with nitrogen applied through irrigation for the entire season. It would however be advisable for the nitrogen component of the irrigation water to be understood & considered when working through the nitrogen budget for the season.

As reiterated by Dr Ants Roberts (Chief Scientific Officer for Ravensdown), if farmers are accurately monitoring feed supply the inherent benefit of applying high nitrate-N irrigation water should already be built into their observation of feed supply and demand. It is more difficult for farmers to isolate the response from nitrogen in irrigation water alone given the low rates applied per irrigation pass however if they have considered their feed supply through pasture measurements, observation, feed budgeting etc they would have taken any additional growth into account when deciding on the rate of synthetic fertiliser to apply that round.

It is unlikely that there will be significant cost savings from utilising a fertiliser product with less sulphur, or no sulphur as a result of receiving high sulphate groundwater through irrigation. Sulphur is often treated as a bonus nutrient, applied when other nutrients are being applied (such as nitrogen and or phosphate for example). Farmers can work with their fertiliser representatives on the choice of fertiliser product considering the Sulphur content however substituting one product for another that has a lower sulphur content, but still provides the other nutrients required (such as phosphate) may not be a more cost-effective option. There are similar challenges with Calcium and Magnesium as explained in section 2.5.2.

Farmers need accurate knowledge of the nutrient concentrations in their irrigation water, and the amount of irrigation water applied to calculate potential nutrient loadings. In order to make any changes to their fertiliser policies they need to have an accurate picture of their feed supply & potential nutrient responses.

3. Arable Case Study

The implications of applying high nitrate irrigation water onto an arable crop have been investigated using a theoretical farming system.

The following crop rotations have been used:

Pasture > Autumn Wheat > Greenfeed > Spring Barley or Peas > Ryegrass Seed

Ryegrass Seed > Potatoes > Barley > Pasture

Given crop management is very specific within an arable system, the implications have been assessed for each crop.

It has been assumed that the property consists of mostly Mayfield and Lismore soils, both moderately well to well drained with a profile available water to 60 cm depth of 80 mm. The rainfall used is between 650 – 700 mm per annum on average. Irricalc has been used to estimate average annual requriements and adjusted based on approximate crop requirements. The irrigation has been applied by centre pivot.

For each part of the crop rotation the nitrogen applied as fertiliser, irrigation applied & nitrogen applied through rrigation have been calculated and shown in tables below.

3.1 Average Irrigation Demand for Permanent Pasture

Table 7 below summarises the average irrigation demand based on an 80% efficient system irrigating pasture. This is very similar to the irrigation demand calculated for the dairy unit.

Table 7 Average Irrigation Demand for Pasture as estimated by Irricalc

	July	August	September	October	November	December	January	February	March	April	May	June	Total Applied
Irrigation Demand (mm)	0	0	20	35	74	93	98	63	43	13	4	0	441
Irrigation Demand (m^3/ha)	0	0	200	350	740	930	980	630	430	130	40	0	4410

3.2 Summary of Irrigation and Nitrogen Applied to Crops

The tables below outline the nitrogen fertiliser, irrigation, and nitrogen applied through irrigation to the various crops modelled/investigated. The fertiliser inputs for the crops have been based off local grower fertiliser recommendations and general crop requirements. These rates have not accounted for any significant contribution of nitrogen from irrigation inputs. The table shows the totals applied for that portion of the cropping rotation however we have summarised the impacts for the individual crops within the discussion below each table.

Concentration of N in Irrigation Water (g/m³)		July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	TOTAL
		Ryegrass pasture for seed										**Autumn Wheat**		
	Fertiliser Nitrogen /ha			40	80	80								200 kg N/ha
	Irrigation applied (mm)			15	30	60	90	60	15	30	15			315 mm
	Irrigation applied (m3/ha)	0	0	150	300	600	900	600	150	300	150	0	0	3150 m3/ha
10 g/m³	**N in Irrigation (N/ha)**	0	0	1.5	3	6	9	6	1.5	3	1.5	0	0	31.5 kg N/ha
15 g/m³	**N in Irrigation (N/ha)**	0	0	2.25	4.5	9	13.5	9	2.25	4.5	2.25	0	0	47.25 kg N/ha
20 g/m³	**N in Irrigation (N/ha)**	0	0	3	6	12	18	12	3	6	3	0	0	63 kg N/ha

- For a ryegrass seed crop receiving 200 kg N/ha from synthetic fertiliser and 315 mm/year irrigation the additional nitrogen applied via irrigation could be:
  - 31.5 kg N/ha, 47.3 kg N/ha or 63 kg N/ha respectively with concentrations of nitrate in the irrigation water from 10g/m³, 15g/m³, 20g/m³
- The cost of this nitrogen at $2.59 per kg of nitrogen for a ryegrass seed crop is
  - $81.60/ha at a concentration of 10 g/m³
  - $122.40/ha at a concentration of 15 g/m³
  - $163.20/ha at a concentration of 20 g/m³

The peak of the irrigation demand is from late Nov > January. As more irrigation is applied, more nitrate will be applied. At a higher nitrate concentration this could equate to 40 – 50 kg N/ha being applied through this period.

Concentration of N in Irrigation Water (g/m^3)		July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	TOTAL
		Autumn Wheat								Greenfeed				
	Fertiliser Nitrogen /ha		40		60	90	90			28				308 Kg N/ha
	Irrigation applied (mm)			15	30	60	75	30	0	30	15			255 mm
	Irrigation applied (m3/ha)	0	0	150	300	600	750	300	0	300	150	0	0	2550 m3/ha
10 g/m^3	N in Irrigation (N/ha)	0	0	1.5	3	6	7.5	3	0	3	1.5	0	0	25.5 kg N/ha
15 g/m^3	N in Irrigation (N/ha)	0	0	2.25	4.5	9	11.25	4.5	0	4.5	2.25	0	0	38.25 kg N/ha
20 g/m^3	N in Irrigation (N/ha)	0	0	3	6	12	15	6	0	6	3	0	0	51 kg N/ha

- For an Autumn Wheat crop receiving 280 kg N/ha from synthetic fertiliser and 210 mm/year irrigation the additional nitrogen applied via irrigation could be:
    - 21 kg N/ha, 31.5 kg N/ha or 42 kg N/ha respectively with concentrations of nitrate in the irrigation water from 10g/m^3, 15g/m^3, 20g/m^3
- The cost of this nitrogen at $2.59 per kg of nitrogen for an autumn wheat crop is
    - $54.40/ha at a concentration of 10 g/m^3
    - $81.60/ha at a concentration of 15 g/m^3
    - $108.80/ha at a concentration of 20 g/m^3
- For an autumn sown greenfeed crop receiving 28 kg N/ha from synthetic fertiliser and 45 mm/year irrigation the additional nitrogen applied via irrigation could be:
    - 4.5 kg N/ha, 6.8 kg N/ha or 9 kg N/ha respectively with concentrations of nitrate in the irrigation water from 10g/m^3, 15g/m^3, 20g/m^3
- The cost of this nitrogen at $2.59 per kg of nitrogen for an autumn sown greenfeed crop is
    - $11.70/ha at a concentration of 10 g/m^3
    - $17.60/ha at a concentration of 15 g/m^3
    - $23.30/ha at a concentration of 20 g/m^3

Concentration of N in Irrigation Water (g/m^3)		July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	TOTAL
		Greenfeed		**Barley**						**Ryegrass pasture for seed**				
	Fertiliser Nitrogen /ha			60		120					20			200 kg N/ha
	Irrigation applied (mm)			15	30	60	75	30		30	15			255 mm/ha
	Irrigation applied (m3/ha)	0	0	150	300	600	750	300	0	300	150	0	0	2550 m3/ha
10 g/m^3	**N in Irrigation (N/ha)**	0	0	1.5	3	6	7.5	3	0	3	1.5	0	0	25.5 kg N/ha
15 g/m^3	**N in Irrigation (N/ha)**	0	0	2.25	4.5	9	11.25	4.5	0	4.5	2.25	0	0	38.25 kg N/ha
20 g/m^3	**N in Irrigation (N/ha)**	0	0	3	6	12	15	6	0	6	3	0	0	51 Kg N/ha

- For a spring sown Barley crop receiving 180 kg N/ha from synthetic fertiliser and 210 mm/year irrigation the additional nitrogen applied via irrigation could be:
  - 21 kg N/ha, 31.5 kg N/ha or 42 kg N/ha respectively with concentrations of nitrate in the irrigation water from 10g/m^3, 15g/m^3, 20g/m^3
- The cost of this nitrogen at $2.59 per kg of nitrogen for a Barley crop is
  - $54.40/ha at a concentration of 10 g/m^3
  - $81.60/ha at a concentration of 15 g/m^3
  - $108.80/ha at a concentration of 20 g/m^3

Based on the above crop rotation there is also a small amount of additional nitrogen that would be applied to the Autumn sown ryegrass seed crop following the cereal crop.

Concentration of N in Irrigation Water (g/m^3)		July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	TOTAL
		Ryegrass for Seed		**Potatoes**									**Fallow**	
	Fertiliser Nitrogen /ha		9	45		41	41	41						177 kg N/ha
	Irrigation applied (mm)				15	60	75	75	45	30				300 mm/ha
	Irrigation applied (m3/ha)	0	0	0	150	600	750	750	450	300	0	0	0	3000 m3/ha
10 g/m^3	**N in Irrigation (N/ha)**	0	0	0	1.5	6	7.5	7.5	4.5	3	0	0	0	30 kg N/ha
15 g/m^3	**N in Irrigation (N/ha)**	0	0	0	2.25	9	11.25	11.25	6.75	4.5	0	0	0	45 kg N/ha
20 g/m^3	**N in Irrigation (N/ha)**	0	0	0	3	12	15	15	9	6	0	0	0	60 kg N/ha

- For a spring sown potato crop receiving 177 kg N/ha from synthetic fertiliser and 300 mm/year irrigation the additional nitrogen applied via irrigation could be:
  - 30 kg N/ha, 45 kg N/ha or 60 kg N/ha respectively with concentrations of nitrate in the irrigation water from 10g/m^3, 15g/m^3, 20g/m^3
- The cost of this nitrogen at $2.59 per kg of nitrogen for a Potato crop is
  - $77.70/ha at a concentration of 10 g/m^3
  - $116.60/ha at a concentration of 15 g/m^3
  - $155.40/ha at a concentration of 20 g/m^3

3.3 Implications for an Arable System

At a nitrate concentration of 20 g/m^3 there is the potential for a significant amount of nitrogen to be applied through irrigation. For crops the irrigation demand is typically slightly less than that required for an irrigated dairy pasture however where up to 60 kg N/ha could be applied in addition to synthetic fertiliser it is worth investigating further.

The potential nitrogen applied per pass (irrigation application) at a nitrate concentration of 20 g/m^3 could be:

- 6.4 kg N/ha if 40mm is applied per pass (assumed 20% loss)
- 2.4 kg N/ha if 15mm is applied per pass (assumed 20% loss)

Many growers will be undertaking soil nitrogen testing prior to crop establishment in order to quantify the nitrogen available in the soil and to gauge an idea of what could become available (through mineralisation) through the growing season. Herbage testing & further N tests (such as in-field N strip tests) may also be carried out through the growing season however it is less common for soil N testing to be carried out later in the Spring as crop uptake is so rapid through this time that the test results would be changing too quickly for informed decisions to be made from the results.

Nitrogen requirements are predominantly governed by the yield potential and the intended use of the crop. Additional factors such as soil moisture, soil type, cultivar, and crop management etc are also fundamental. It is important for cereal growers to carefully manage the nitrogen inputs and the balance between achieving the optimum yield and the carryover nitrogen into the grain (protein). Some cereal crops may receive a premium for high protein content whilst others will be penalised for elevated protein levels.

For growers who already undertake a lot of soil/herbage sampling in order to derive & also refine their fertiliser recommendations each season it is likely that they are already taking into account the nitrogen being supplied by irrigation (without realising). This is not through understanding the growth response specifically from the nitrogen in the irrigation water, but through monitoring the crop growth & inherently adjusting fertiliser applications based on observed crop performance.

There could be a benefit to growers who do not undertake N sampling as part of their fertiliser recommendations to incorporate this into their management and/or to calculate the likely nitrogen loading from irrigation at the beginning of the season to help inform their decisions through the season. It would be much more difficult in practice to substitute synthetic fertiliser for nitrogen applied through the irrigation systems. Growers who are making informed fertiliser decisions based on crop requirements, soil test information, crop performance through the season etc are more likely to be inadvertently adjusting their fertiliser applications. As for the pastoral farming situations the focus should be again on tools to understand the nutrient availability, crop uptake & potential loading from irrigation to support fertiliser decision making.

The indicative cost savings if less nitrogen fertiliser were applied have been included below in table 8. The table shows the potential total saving from applying less nitrogen to each part of the crop rotation (as shown above) based on a direct substitution. We have assumed that there is 50 ha of each (200 ha in total). This is a very crude calculation and in practice much more care & consideration would need to be given to specific crop requirements & timing.

Table 8 Indicative nitrogen fertiliser saving within an arable system

	Total savings across 200 ha			Savings per hectare		
	10mg/l nitrate N	**15mg/l nitrate N**	**20mg/l nitrate N**	**10mg/l nitrate N**	**15mg/l nitrate N**	**20mg/l nitrate N**
Ryegrass seed to Autumn Wheat	$4079	$6119	$8159	$82	$122	$163
Autumn Wheat to Greenfeed	$3302	$4953	$6605	$66	$99	$132
Greenfeed to Barley to Ryegrass seed	$3302	$4953	$6605	$66	$99	$132
Ryegrass seed to Potatoes	$3885	$5827.5	$7770	$78	$117	$155
TOTAL	**$14,569**	**$21,853**	**$29,138**	**$73***	**$109***	**$146***

**calculated by weighted average not the sum of the per hectare savings*

4. Discussion

There is rising concern over the high groundwater nitrate concentrations in the Hinds catchment and in particular a 'pocket' of high nitrate groundwater surrounding Tinwald. The scope of this project was to calculate the potential savings to local farmers if the nitrogen applied via their irrigation water (groundwater irrigators) was accounted for within their fertiliser programme on farm. A case study dairy farm and a theoretical arable system were used in order to calculate the potential savings & on farm implications of accounting for the nitrogen being applied by irrigation.

Three concentrations of nitrate in the irrigation water were used, and the price of nitrogen (in the form of Urea) was taken as the spot price at both Ravensdown & Ballance in February 2022.

Within the Dairy system, based on an annual average irrigation demand calculated by Irricalc up to 92 kg nitrogen/ha could be applied through irrigation if the nitrate-N concentration of the irrigation applied was 20 mg/L. The Irricalc estimated irrigation requirements were well aligned with actual irrigation use information. Results from a local well in Tinwald show that the concentration of nitrate-N has consistently been 20 mg/L or higher each time the groundwater has been tested since January 2018. At the current price of $2.59 per kilogram of nitrogen this is equivalent to $48,900 (excluding GST, delivery & spreading costs) given the irrigation applied to the case study farm. It should be noted that the concentrations used are for the purpose of this case study & are not indicative of the nutrient concentrations in the irrigation water on the case study property.

The National Policy Statement for Freshwater Management 2020 and National Environmental Standards have introduced a cap on synthetic nitrogen of 190 kg N/ha to pasture. It is possible to achieve a yield response to additional nitrogen applied above 190 kg N/ha on the dairy farm particularly where moisture is not limiting, and nitrogen is applied little and often. Previous studies have however shown that the risk of leaching losses increase with increasing nitrogen applications, with significant losses occurring when applications are above 200 kg N/ha/yr. In order to operate within the N cap farmers are having to plan & monitor their nitrogen applications more than they have done previously. DairyNZ are observing a reduction in the synthetic fertiliser applied in January & February in particular, in response to the N cap. This coincides with a period of typically high irrigation demand. There could be an opportunity for further reductions in synthetic N applied during the season if there is clarity around the potential nitrogen being supplied through irrigation water & the feed supply and demand. It is important to acknowledge that the nitrogen cap only applies to synthetic fertiliser. It is also likely that nitrogen applied beyond 190 kg N/ha with irrigation is still likely to drive a pasture growth response in Canterbury. There may be opportunities for adjusting fertiliser applications in the later Summer, early Autumn period however it may not be as straightforward as directly substituting on a one for one basis. This would need to be an informed decision for each property.

Within an arable system the irrigation and fertiliser applied will vary depending on the crop sown. The amount & timing of these applications is critical. Depending on the level of soil & plant testing undertaken on individual properties there are likely to be some farmers accounting (by default) for the higher nitrate concentrations in their irrigation water particularly if they have a robust Nitrogen testing regime. For many however, there is an opportunity to understand the potential nitrogen contribution from their irrigation and to consider this when making their fertiliser decisions.

For all farm systems it would be important to understand the following:

- Concentration of nutrients & trace elements in the groundwater used for irrigation
- The variation in the concentration of the groundwater annually and through the season & how this information can be easily sourced. If the levels are variable throughout the season it could be a barrier to adopting a process for accounting for this nitrogen.
- The amount of irrigation applied per pass. This will place further importance on good management practices such as irrigation system maintenance & bucket testing.
- The irrigation system design & management – for example how many wells are utilised & how this may impact the concentration of irrigation water when it leaves an irrigator
- The likely system losses (evaporation, wind spray, potential leaching etc). For this project we have assumed the systems are 80% efficient (that is 80% of what is applied is available)
- The likely irrigation & fertiliser demand for the season to allow for some forward planning. Acknowledging that it is very difficult to predict the requirements for the season particularly as we experience more extremes and variable weather.
- Calculations to work out the nitrogen applied by irrigation.
- The feed supply & demand and indicative pasture growth response
- Who else supports the fertiliser decisions on farm (for example fertiliser representatives, agronomists etc)

5. References

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