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Raglan Wastewater Discharge Consenting: Reuse of Wastewater through Supplementary Irrigation – Potential Land Use Suitability Assessment

Watercare Services Limited

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Raglan Wastewater Discharge Consenting: Reuse of Wastewater through Supplementary Irrigation - Potential Land Use Suitability Assessment

Prepared for

Watercare Services Limited

September 2020

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Executive Summary

The Raglan Wastewater Treatment Plant (WWTP) is owned by Waikato District Council (WDC) and operated by Watercare Services Limited (WSL). Treated wastewater from the WWTP has historically been discharged to the marine environment under a marine discharge consent. To assess future treated wastewater disposal options, WSL is completing a Best Practicable Option (BPO) review for the WWTP discharge consent. As part of the options assessment, irrigation of wastewater to land is being investigated as a short-listed option for wastewater discharge.

This report comprises a technical assessment of land use options, for the potential reuse of the treated wastewater through land treatment in the surrounding Raglan area. Specifically, the irrigation onto third-party owned sites of the wastewater, for the purposes of harvesting the nutrient and water supply value to support land use.

The properties which have been identified as having potential for land treatment are within a 10 km radius of the Raglan WWTP site. The soils in the area are largely imperfectly drained to well drained soils, with some poorly drained areas around the WWTP and to the southeast of Raglan township. The areas around Raglan are generally hilly, with topography ranging from slightly sloped through to steep hills.

To explore potential land use options that could be utilised by the third party landowners, five 'primary' land use options were identified, each of these options containing two or more 'secondary' crops or species types. The land use options selected for assessment are (in no order):

- Pastoral grazing – Sheep & Beef |Dairy | and Deer;
- Non-Consumptive crops – Hemp | Oilseed Rape (for biofuel) | Vetiver (for essential oil);
- Cut and Carry – Lucerne | Maize | Sunflowers;
- Forestry – Exotic (Pine) | Christmas Trees | Native (Mānuka/Kānuka); and
- Non-Contact Consumptive Crop (Orchard/Viticulture).

To evaluate potential suitability and effectiveness of each of the land use options, the following aspects were considered:

- Suitability of the land use e.g. site requirements including climate, slope and seasonality.
- Hydraulic demand e.g. capacity of the land use to uptake water and reduce the hydraulic loading of the soil.
- Phytoremediation (nutrient uptake) e.g. nutrient utilisation efficiency.

- Land system risk e.g. potential market risk and land use risks.
- Land system income estimate e.g. estimation of annual return.

The summary table below outlines the key findings of the land use assessment.

Land Use Assessment Summary Table

Criteria	Option 1: Grazed Pasture	Option 2a: Non-consumptive: Hemp	Option 2b: Non-consumptive: Rapeseed, Biofuel	Option 2b: Non-consumptive: Vetiver	Option 3a: Cut & Carry: Lucerne	Option 3b: Cut & Carry: Maize	Option 3c: Cut & Carry: Sunflowers	Option 4a: Native Forestry Oil & Honey	Option 4b: Timber Plantation	Option 4c: Christmas Trees	Option 5: Non-Contact Consumptive: Orchard
Soils & Environment Suitability	Common land use to the area, proven to perform well. Not necessarily limited by slope.	Suited to well-structured soils.	Most suited to well-structured soils, has a deep rooting system and grows well on a wide variety of well-drained soils. Crop is useful increasing aeration in subsoils because of the root system	Excellent nutrient uptake, hardy plant, well suited to most growing environments	Lucerne doesn't perform well on heavy, waterlogging (or prone to) soils, it will perform better on free draining, light textured soils.	Maize performs well on a wide range of soil types; provided soil water and nutrients are not limiting, does not perform as well on slopes.	Sunflowers are typically considered a restorative crop help in maintaining the fertility and structure of the soil.	Can be established on essentially all soil types in the region, including the steep slopes.	Forestry has been proven to perform in the area.	Forestry has been proven to perform in the area.	Orchards are common in the Waikato - Feijoa are adaptable trees that likely will grow and fruit well
Likely Treatment Required	Existing Ponds	MBR/ultrafiltration or Existing Ponds	Existing Ponds	Existing Ponds	Existing Ponds	Existing Ponds	MBR/ultra filtration	Existing Ponds	Existing Ponds	Existing Ponds	MBR/ultrafiltration
Hydraulic Demand - AET/PET Ability Comparison (1)	Medium	High	Medium	High	High	High	Medium	High	High	High	Medium
Hydraulic Demand (AET/PET)	1.00	1.25	1.07	1.20	1.20	1.20	1.15	1.20	1.20	1.20	1.05
Relative Nitrogen Demand	Medium	High	High	High	Medium	Medium	Medium	Medium	Medium	Medium	Low
Nitrogen Leaching Loss kg N/ha/yr	Sheep & Beef: 6 - 50 Dairy: 20 - 150 Deer: 6 - 50	Unknown	15 - 23	Unknown	80 - 150	Unknown	Unknown	5.7 - 10.4	1.2 - 2.7	1.2 - 2.7	Unknown - considered to be low
Irrigation System	Few limitations - can be irrigated with k-line, pivot etc	Likely limited to centre pivot	Likely limited to spray e.g. centre pivot	Few limitations - can be irrigated with k-line, pivot etc	Few limitations - can be irrigated with k-line, pivot etc	Likely limited to centre pivot	Likely limited to centre pivot	Limited to drip or solid set irrigation	Best suited to drip or solid set irrigation	Best suited to drip or solid set irrigation	Must be low-line irrigation e.g. Drip
Establishment Cost	Medium - High	Medium	Medium	Medium	Low	Medium	Medium	Very High	High - Very High	Medium - High	Very High
Estimated Annual Land-Use Income $/ha	Sheep & Beef: $200 - $500 Dairy: $1,500 - 3000 Deer: $200 - $500	$1,000 - $5,000	$1,000 - $4,499	$500 - $1,000	$10,000 - $12,000	$2,00 - $3,000	$3,100	$1,000 - $1,500 (5)	(4) Pines: $1,200 (28 year rotation)	$1,700	$24,000

Land Use Assessment Summary Table

Criteria	Option 1: Grazed Pasture	Option 2a: Non-consumptive: Hemp	Option 2b: Non-consumptive: Rapeseed, Biofuel	Option 2b: Non-consumptive: Vetiver	Option 3a: Cut & Carry: Lucerne	Option 3b: Cut & Carry: Maize	Option 3c: Cut & Carry: Sunflowers	Option 4a: Native Forestry Oil & Honey	Option 4b: Timber Plantation	Option 4c: Christmas Trees	Option 5: Non-Contact Consumptive: Orchard
Bio-Solids Suitability	Suitable as a slurry application with careful consideration of end product quality assurance standards and animal health.	Suitable as a soil conditioner	Suitable as a soil conditioner	Suitable as a slurry application	Suitable as a slurry application	Suitable as a soil conditioner	Suitable as a soil conditioner	Suitable - must be planted to enable vehicle passage for spreading	Suitable - must be planted to enable vehicle passage for spreading	Suitable - must be planted to enable vehicle passage for spreading	Suitable as a soil conditioner
Nitrogen Fertiliser Tax $/ha (2)	$0.00	-$0.41	-$1.72	$0.00	$0.00	-$0.20	$0.00	$0.00	$0.00	$0.00	$0.00
ETS/CO2 returns ($/ha/yr) (3)	Sheep & Beef: -$4.0/ha/yr Dairy: -$12/ha/yr Deer: Unknown	Null	Null	Null	Null	Null	Null	$216 /ha/yr	$498 /ha/yr	Null	Null
Overall Pros	Proven land use in the region.	Greatest hydraulic capacity of the options assessed.	Will provide good ground cover and continue to grow well over winter when other crops may slow/halt growth.	Hardy plant, able to be grown in most environments and conditions.	Proven land use in the region, performs well in drought prone conditions.	Proven crop in the region.	Restorative crop, helps in maintaining the fertility and structure of the soil	Existing vegetation in the region, suitable for steep land treatment sites	Proven performer in the region, suitable to steeper slopes.	Proven performer in the region	Orchards are common in the Waikato, Feijoas in particular are hardy and likely suited to Raglan area.
	When actively growing pasture has a reasonable N uptake	Excellent crop for nutrient uptake (phytoremediation)	Good nitrogen demand/uptake, provides good soil cover over winter.	Excellent for nutrient uptake (phytoremediation)	Good nitrogen demand/uptake, atmospheric and wastewater nitrogen should be sufficient for a good yields	Good nitrogen demand/uptake and removal when silage is cut	Good nitrogen demand/uptake and removal when crop is cut	Early studies are showing promising results for manuka's ability to reduce nitrate leaching	Good storage of nitrogen and carbon within the woody biomass	Good uptake of nitrogen, highest years of N uptake in pines are optimised	
	Market demand for meat, milk and fibre	Versatile crop, multiple end uses.	Alternative markets to biofuel for non-consumptive oil production exist such as seed production		Good market demand for silage produced. Could be worked in with a pasture rotation for pasture cut & carry.	Good market demand for maize silage. Could be worked in with a pasture rotation for pasture cut & carry.	Potential for dual use - sunflower oil and sunflower meal for supplementary feed for animals.	High intrinsic value & contributes to the region's biodiversity. Possible income from leaf oil extraction or honey production.	Timber sales, carbon sequestration and ETS income	Potentially high per hectare income	

Land Use Assessment Summary Table

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Overall Cons	Additional risk due to the interdependent relationship between management, product and the market.	Limited to < 15 degrees sites	Limited to < 15 degrees sites	Not (or rarely) grown in NZ for commercial purposes, tends to be for erosion or sediment control	Limited to < 15 degrees sites	Limited to < 15 degrees sites.	Limited to < 15 degrees sites		Yield may be impacted by soils with poor drainage.	Difficulty of Raglan's location in securing a reliable 'gate sale' market. Transport of trees would decrease profit margins	High per hectare establishment cost, not an immediate return on investment
	Urine patches particularly from cattle and uneven return of nutrients to soil and excessive nutrient leaching.	Downtime after harvest increasing possibility of nitrogen losses. After harvest mgmt will impact on any resulting nutrient leaching.	Must be implemented in a rotation. Downtime after harvest increasing possibility of nitrogen losses	Likely limited to < 15 degrees sites if grown for harvest. If not harvested would suit > 15 degree land treatment sites.	Growth will likely reduce in winter meaning seasonal yield will be variable.	Would likely need to be grown in a rotation and therefore would have downtime in between harvests and sowings	Would likely need to be grown in a rotation and therefore would have downtime in between harvests and sowings	Slow growing & lower carbon sequestration rate than exotic species			Nitrogen uptake per hectare isn't as high as some of the other land uses.
	Public perception of milk & meat produced using treated wastewater irrigation	Highly regulated, annual licensing and regular testing is required.	Ensuring a market/biofuel refineries processing the crop into biofuel may be challenging.	Challenging to grow enough supply to generate an economic export product without distilling own oils.		Would likely require additional nitrogen fertiliser to obtain optimal yields.		Long-term investment, uncertain income, high cost of establishment, slow growth rate	Long-term investment	Relatively labour intensive, likely limited to < 15 degrees sites due to the labour requirements	Public perception of product produced using treated wastewater irrigation

Notes:

1 *AET/PET = Actual Evapotranspiration / Potential Evapotranspiration. Based on "mid-season stage" of the peak production/growth period for land use.*

2 *Crops do not directly emit greenhouse gases or sequester carbon meaning that there is no explicit GHG cost, or benefit, in cropping. Costs are calculated based on the possible urea fertiliser tax that the carbon-zero legislation proposes. Assumed a 5% liability.*

3 *Positive number generates ETS income, and a negative number is a cost in the form of tax.*

4 *Includes annually averaged income from Timber sales*

5 *Estimated income, likely to be variable*

The evaluation has developed a preferred/recommended land use. This recommendation is based on the technical suitability and favourability, based only on aspects covered in this assessment. Preferred land use may differ from this recommendation based on the third-party owners, each will likely have their own personal motivations and desired outcomes for irrigating treated wastewater on their property.

The recommendation has been developed on the basis that the slope will be the limiting factor. In summary:

- On the flatter land treatment sites, where the slope is less than 15 degrees, the recommended land use is Cut and Carry (Lucerne, Maize or Sunflowers).
- For the greater than 15-degree land treatment sites, Exotic or Native Forestry is the recommended land use.

The summary table below outlines the technical preferability rank separated by the limiting factor, slope. 15 degrees has been used as the point at which specialised machinery would be needed.

<table>
<tr><th colspan="3">Land Use Options - Technical Preferability Ranking</th></tr>
<tr><th>Rank</th><th>< 15 Degrees Slope</th><th>> 15 Degrees Slope</th></tr>
<tr><td rowspan="2">1</td><td>Cut & Carry – Lucerne, Maize or Sunflowers</td><td rowspan="2">Forestry – Exotic/Native</td></tr>
<tr><td>Non - consumptive crop: Hemp</td></tr>
<tr><td>2</td><td>Forestry – Exotic/Native</td><td rowspan="2">Pastoral Grazing – all types</td></tr>
<tr><td>3</td><td>Pastoral grazing</td></tr>
<tr><td>4</td><td>Non - consumptive crops: Rapeseed & Vetiver</td><td rowspan="2">Non-contact consumptive, Non-consumptive land, Cut & Carry uses are not considered practicable due to the slope</td></tr>
<tr><td>5</td><td>Non-contact consumptive</td></tr>
</table>

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1.0 Introduction

1.1 Purpose and Scope of this Report

The purpose of this report is to identify potential land-use options that are suitable for the reuse of treated municipal wastewater from the Raglan Wastewater Treatment Plant (WWTP) at nearby Land Treatment Sites. The potential land treatment sites that have been identified within a 10 km radius of the WWTP are all owned by third parties. The reuse of wastewater through land treatment provides an opportunity for these landowners, should they seek the treated wastewater to support existing or to develop new land use on their properties. This report will provide key technical and feasibility information of land-use options and their suitability for the identified land treatment sites and will provide a high-level cost assessment and recommendation of suitability. This is for the potential utilisation of the treated wastewater for irrigation purposes by third parties.

This report has been prepared to identify potential wastewater reuse opportunities for the Raglan wastewater management system, based on land-based utilisation. It provides a high-level assessment only and should any of the reuse options be developed further, more in-depth investigation will be necessary.

1.2 Land Treatment

Land treatment is the irrigation of wastewater to land (pre-treated/treated), with the purpose of supporting a land use (crop) and with the soil and crop providing further treatment/uptake. Application of dried, dewatered, or wet biosolids to land is also captured under land treatment and provides an alternative to landfill disposal.

District councils and water utilities, managing municipal wastewater schemes, commonly practise land treatment throughout New Zealand, as well in agricultural industries such as dairy farms, and dairy and meat processing plants. Land treatment is commonly considered as an alternative to direct discharges of treated wastewater to surface water or marine environments, due to the potential benefits, including; potential nutrient and pathogen reduction, the removal or assimilation of other contaminants such as suspended solids and biochemical oxidation demand, beneficial re-use aspect e.g. freshwater and fertiliser reductions.

While land treatment systems help reduce the need for point source discharges into surface water environments, the viability of land treatment systems are dictated by local factors such as topography soil type and weather conditions. The management of nutrients and other potential contaminants is another key factor, and this requires careful planning and management within any land treatment scheme.

Land treatment sites and land uses vary throughout the country from sites dedicated to land treatment, that are owned and operated the wastewater generating party; through to third-party sites irrigating wastewater in a symbiotic arrangement for the nutrient and irrigation value to their operation. This report considers explores the latter option, investigating potential land uses for third-party landowners surrounding the Raglan WWTP to access the treated wastewater for irrigation at will.

It is important to consider that while a land use may enhance the effectiveness of a Land Treatment; it is unlikely to influence the feasibility of a Land Treatment system as significantly as physical factors such as climate, soil type and topography for example.

1.3 Wastewater Treatment Options

Based on the alternative treated wastewater discharge options that are being assessed as part of the reconsenting process, Watercare Services Limited are assessing three wastewater treatment options, depending on the assessed discharge option. The wastewater treatment options being considered are:

- The existing Aqua-Mat pond based system with UV disinfection (status quo)
- The existing Aqua-Mat pond based treatment system with membrane filtration upgrade and UV disinfection;
- A membrane bio-reactor (MBR) system, including a ultra-filtration membrane system and UV disinfection.

Landuse options incorporating non-consumptive crops will likely only require a wastewater quality equivalent to what is provided by the existing wastewater treatment plant. However, for crops that incorporate an indirect crop for human consumptions, such as an orchard, a wastewater quality provided by an MBR system or ultrafiltration may be necessary.

1.4 Examples of Irrigation Types

To provide some basic details on what the common irrigation methods involve, examples are provided below.

Centre Pivot:

Centre Pivot is a radial pipe with a series of sprinklers along the length which pivot around a fixed centre point.

Figure 1: Centre Pivot Irrigator[1]

Solid Set:

Solid set (or Fixed Grid) irrigation involves installing above ground sprinklers on posts, or in-ground hydrants, in a grid pattern.

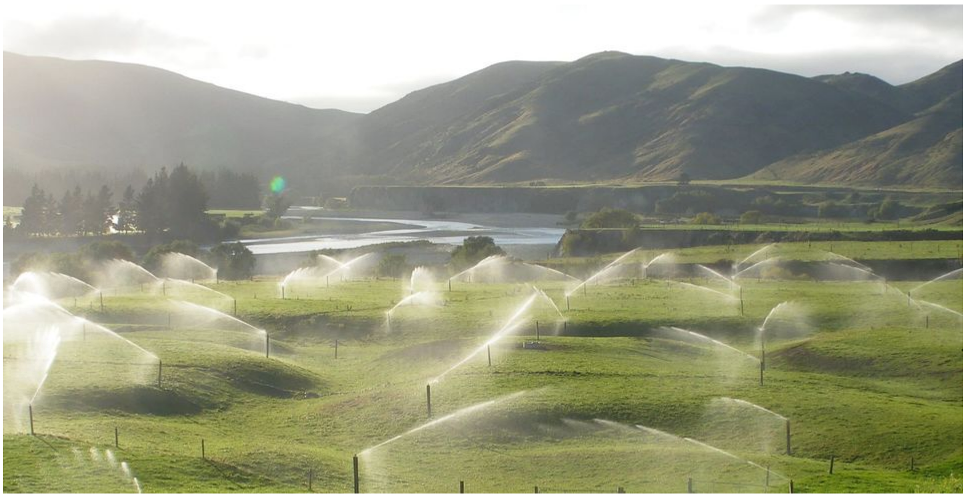


Figure 2: Solid set (or Fixed Grid) irrigation[2]

K-Line

K-line irrigation are on-ground sprinklers, irrigation involves towing sprinklers on skids or pods around a pre-determined area, the sprinklers are typically shifted in 12- or 24-hours intervals.

1 https://irrigazette.com/en/news/invest-centre-pivot-or-lateral-move-systems
2 https://thinkwatercanterbury.co.nz/services-and-solutions/irrigation/solid-set-fixed-grid-irrigation

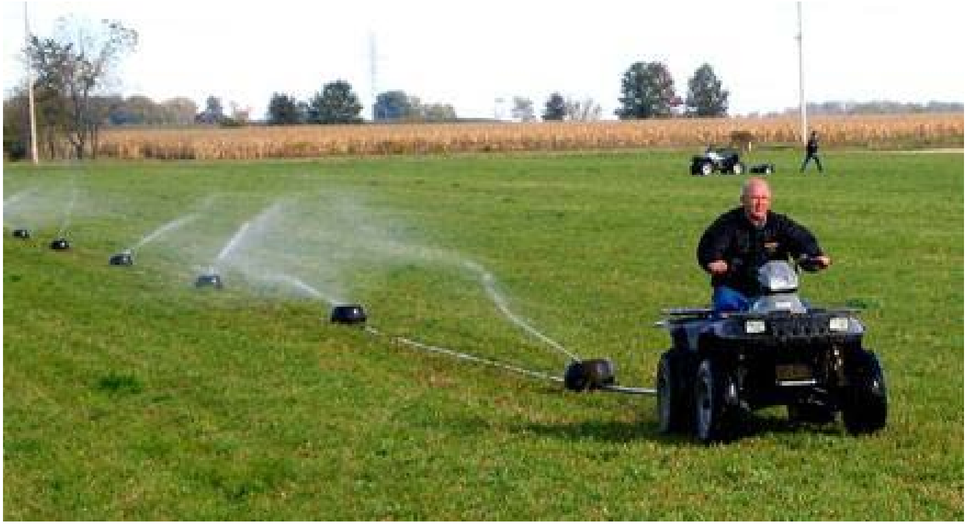
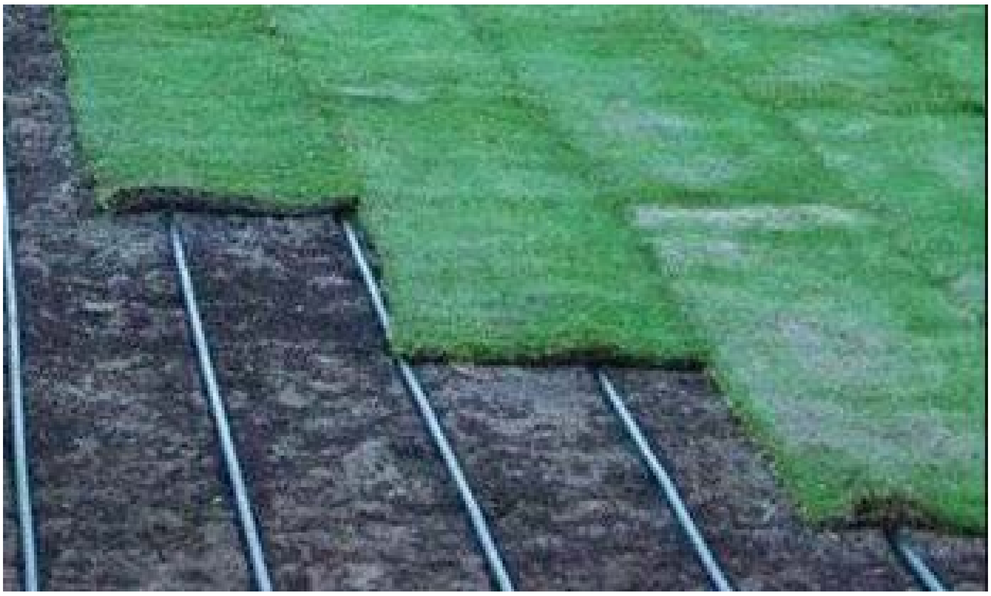


Figure 3: K-line Irrigation being shifted[3]

Subsurface Drip Irrigation

Drip line irrigation is a type of a micro-irrigation system, water is irrigated as a slow drip from buried piping beneath the surface within the plant root zone. Drip lines can also be surface laid e.g. within forestry.



[3] http://www.circlebirrigation.com/k-line-irrigation.html

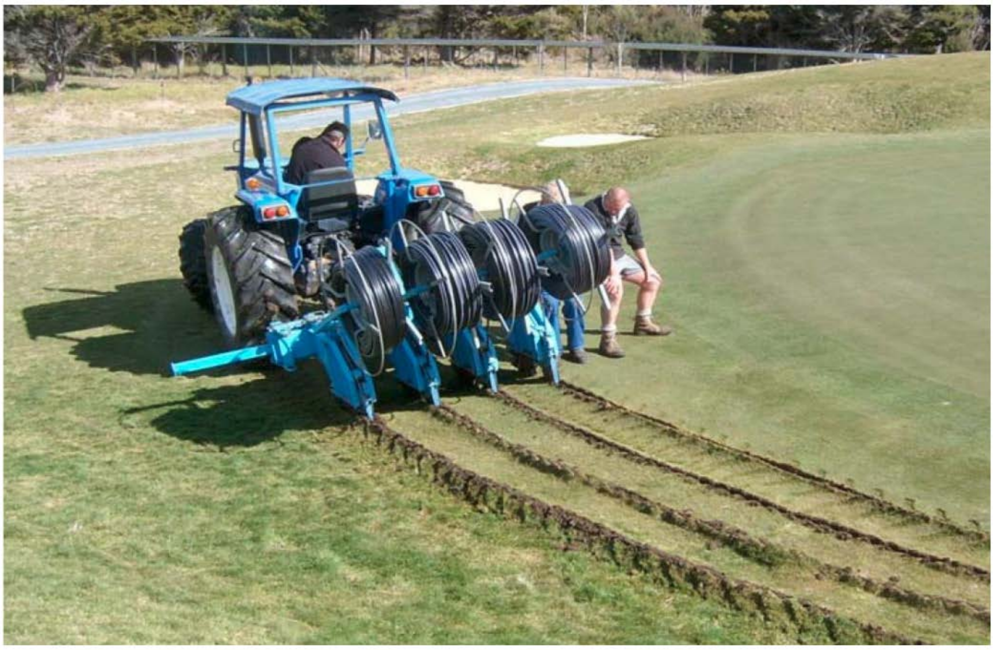


Figure 4: Top: Subsurface Drip Irrigation beneath Pasture[4] Btm: subsurface drip beneath a golf course [5]

[4] https://www.waterforce.co.nz/dripline-irrigation

[5] Omaha Beach Gold Course Inc.

2.0 Potential Land Treatment Sites

The Raglan WWTP is located slightly south-west of the Raglan township, the potential land treatment sites identified are all within a 10 km radius of the WWTP, on the South side of the harbour. A description of the Raglan area and the land treatment sites is provided below.

2.1 Soils

The soils in the area surrounding Raglan, underlying potential land treatment sites consist of moderately-well to well-drained soils, in areas to the south of Raglan, further up the Mt Karioi slops, deriving from volcanic parent materials from the Karioi volcanic formation. The soils on the lower slopes, closer to Raglan township, including the Wainui Reserve and the Raglan Golf Course were observed as being less well drained (imperfectly drained), being more highly weather soils of volcanic origin, potentially of the Okete Formation. This observation differs from Landcare Soil information, which indicates moderately well drained soils in this area. There are also pockets of poorly drained soils, largely concentrated around lower valley floors and low-lying areas to the south east of Raglan. The soils surrounding the WWTP site are typically poorly drained soils. Further detail on the soils surrounding the site can be found in the land treatment options assessment report (PDP2020).

2.2 Climate

Raglan has a unique microclimate, the area has a tepid climate with an average high of 24 degrees and a low of 8 degrees with an average rainfall of 1,184 mm/year.

There are two significant features in the Raglan area which contribute to the formation of a microclimate from nearby cities such as Hamilton and Auckland. These are Mount Karioi and the surrounding hills and the Tasman Sea, Mount Karioi and the surrounding hills provide shelter from winds and the Tasman Sea provides the function of moderating the summer heat and curbing the cold of winter.

2.3 Slope

The Raglan township sits at sea level, Mount Karioi situated to the South-West of the town rises to an elevation of 756 m ASL. The topography of the potential land treatment sites is typical of the area, it is hilly with gullies and rises, there are some areas of flat, or slightly sloped land. The slope of all the potential land treatment sites identified is below 30 degrees.

Flatter land is generally better technically suited to land treatment (and irrigation), this is because the irrigation water has a greater opportunity to infiltrate the soil surface than on sloped sites; on sloped sites where systems are not well designed, and managed, irrigation water tends to run-off taking nutrient and sediment with it. The opportunity to diversify into a broader range of land uses is also present on flatter land as there are typically fewer physical limitations to the efficient and economic use of the land and infrastructure.

2.4 Existing Land Use

There are a variety of existing land uses in the area; these consist of Urban areas and Lifestyle blocks, there are also pockets of Forestry and drystock grazing.

2.5 Grants and Subsidies

For all of the land uses there could be potential for research trial grants, and establishment subsidies or funding, if the third-party landowners were interested in participating.

Some of the grants that are available currently through the central government are Sustainable Food & Fibre Futures, Sustainable Land Management and Climate Change (SLMACC), Productive and Sustainable Land Use (MPI, 2020). There are also a number of regional and local government grants such as the Waikato District Council Discretionary Grants Fund, this grant provides funding for projects that are important to and will benefit the wider community[6] (Waikato District Council, 2020).

It would be important that the third-party landowners invested in researching potential grants and on-going/potential research projects and assessing the applicability to their property or land use. Where appropriate, comment has been made in Section 5.0 on available (currently) grants and/or subsidies.

[6] Applications for commercial entities will not be accepted.

3.0 Potential Land Use Options

The aim of this section is to identify broad categories of land use options and potential sub-categories such as specific crops which may assist in finding a balance for the third-party land owners between the environmental, cultural and financial needs of land treatment.

The location of the potential land treatment sites has been based on the high-level geospatial assessment. The results of this evaluation and the criterion of the assessment are discussed in the report, *'Raglan Wastewater Treatment Plant Discharge Options – Long List Assessment for Land Treatment and Deep Bore Injection.'* (PDP, 2020). As mentioned in Section 2.0, the slopes of all of the sites are below 30 degrees.

3.1 Option 1: Grazed Pasture

A grazed pasture system is where grazing livestock are used to convert grass and other forage into meat, milk and fibre products.

The grazed pasture option will broadly consider grazed pastoral systems of:

- Sheep & Beef;
- Deer; and
- Dairy.

All grazed pasture options have unique operational requirements. However, when assessing at high level, grazed pastoral systems and the transfer of nutrients, can be considered to overall operate in a similar manner.

3.2 Option 2: Non-Consumptive Crops Human End-use

Human non-consumptive crops are crops grown with the intention of sale but they typically form part of an end-use product. These crops typically undergo processing or form part of a manufactured product. There are a variety of crops which can be grown for non-consumptive purposes, some examples include:

3.2.1 Hemp

A recent trial study undertaken by Fonterra in Darfield, Canterbury, saw the irrigation of dairy factory wastewater irrigated to a 10-ha Hemp crop. The trial results indicated promising results with a successful crop that was able to be profitability grown (Fonterra, 2020). This trial, to Fonterra's knowledge, is one of the first in New Zealand involving Hemp and wastewater irrigation, this is because commercial Hemp production is however relatively new to the New Zealand market. Hemp also has a number of barriers to growing the crop, such as growers are required to obtain an annual license from the Ministry of

Health to grow the crop[7] and there restrictions around the type and quality of the cultivars able to be imported and grown.

It is a strong fibre with many non-consumptive marketable options e.g. the manufacture of rope, textiles. Some examples include; Hemp hurd (pulp) which can be used to produce paper, as well as construction materials such as hempcrete (Hempbrokers, 2019). Hemp can also serve for consumptive end uses such as food products like flours and oils, however, for the purposes of this report non-consumptive end uses have been considered only.

The multitude of end uses, growing interest and the success of Hemp at Fonterra's dairy factory wastewater trial suggest that Hemp could potentially be a suitable land use for land treatment in Raglan.

Figure 5: Hemp Crop[8]

3.2.2 Oilseed rape for Biofuel

Biofuel[9] is a generic term for fuels that can be produced from or are made up of a renewable material of plant or animal origin. The market demand for biofuels is growing and so it may be an economically viable land use. The assessment will consider the possibility of growing oilseed rape as a feedstock for biodiesel production. Consideration of the existing infrastructure requirements and location of biorefineries will be important.

[7] Licensing required under the Misuse of Drugs (Industrial Hemp) Regulations 2006 Act

[8] https://www.hempfarm.co.nz/ambassadors/

[9] Biofuel includes both Biodiesels which are made from vegetable oil or animal fat and Bioethanol, made from sugars and starches.

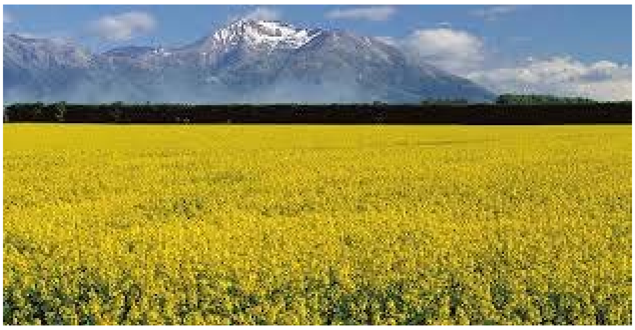


Figure 6: Oilseed Rape Crop[10]

3.2.3 Vetiver

Vetiver is a perennial bunchgrass; it is from the same botanical family as lemongrass and citronella. Vetiver is a vegetative absorbent and erosion barrier it is a tough, natural, non-invasive grass like plant. Vetiver has a deep penetrating fibrous root structure that grows up to 5 metres deep in most soil conditions with minimal care (Vetiver Systems , 2020). The plants will readily grow to around 180 cm tall and 60 cm wide (Sjoquist, 2020). Vetiver is recommended to be planted in temperate regions of New Zealand, the plant itself is a sterile clone meaning it has to be planted vegetatively and it will not seed.

The plant has been used internationally for a variety of uses including wind and soil erosion control, stabilisation of river banks and drains and bioremediation involving pollution control from waste and contaminants (Vetiver Systems , 2020). It is commonly harvested, and the roots are used the extraction of essential oil for commercial sale (doTerra, 2020).

Vetiver is considered as a potential land use given its hardiness and effective ability to uptake and utilise nutrients or any potential contaminants applied. Given the potential height of a Vetiver crop irrigation would likely be limited to centre pivot/lateral irrigation or fixed grid.

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[10] https://www.agscience.org.nz/wp-content/uploads/AgScience-PDF/agscience-33-web.pdf

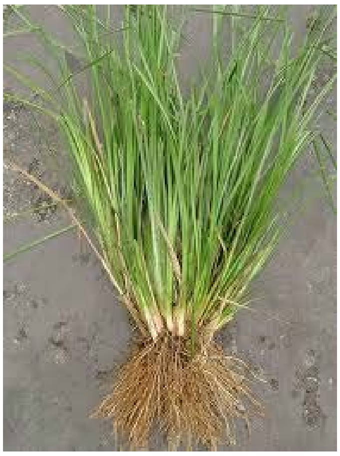

Figure 7: Vetiver Plant[11]

3.3 Option 3: Cut and Carry

Cut and carry involves cultivating a crop that can be harvested on an annual cycle, potentially more than once a year, the crop is then sold offsite as a dry stock fodder or feed crop. For the crop to be feasible it ideally needs to be easily harvestable into hay or silage and be able to re-grow following harvest. Efficient harvesting of cut and carry crops typically requires flat to moderate slopes, that enable safe access for machinery. Some examples of crops which could be suitable for cut and carry from the land treatment sites are discussed below.

3.3.1 Lucerne

For the extraction of wastewater nutrients, the crop or pasture should have a good (high) nutrient demand. An example of a common cut and carry crop is lucerne. Lucerne is typically harvested and sold as supplementary feed for farms in the form of baleage. Typically, lucerne does not perform well on heavy, waterlogging (or prone to) soils, it will perform better on free draining, light textured soils.

[11] http://treatmentwetlands.blogspot.com/2011/01/vetiver-plant-and-wastewater-treatment.html

Figure 8: Lucerne Crop[12]

3.3.2 Maize

Maize is commonly grown for supplementary feed for farms. Maize grows best when exposed to high radiation and long growing seasons. Similarly, to lucerne, maize thrives on free draining soils.

The harvesting equipment needed for the cut and carry, and the cyclical sowing/growing nature of the crops, limits the effectiveness of fixed irrigation systems such as drip or fixed grid. Both lucerne and maize could be irrigated easily by centre pivot/lateral, lucerne could also be irrigated by k-line, however, the height of mature maize limits the effectiveness of irrigation systems like k-line. It is likely that the install cost of drip irrigation relative to systems such as centre pivot or k-line would outweigh the benefit of the system. Maize would need to be grown as a part of the crop rotation which may possibly cause inefficiencies in the seeding and harvests of the crops.

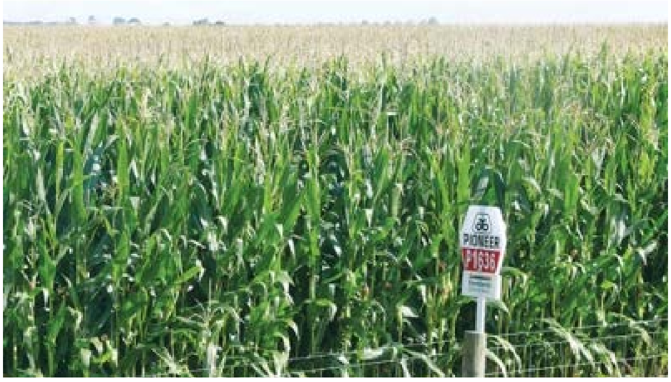

Figure 9: Maize Crop[13]

[12] https://www.syngenta.co.nz/news/forage/managing-weeds-lucerne

[13] https://www.ruralnewsgroup.co.nz/dairy-news/dairy-management/making-a-good-maize-silage-crop

3.3.3 Sunflowers

Like lucerne and maize, sunflowers can be grown as a cut and carry crop for the purposes of being sold as a supplementary feed. Sunflowers are typically fed as sunflower meal or the oil from the seeds is incorporated into animal health products and feeds. Sunflower meal is the by-product from cold press process in sunflower oil production.

Sunflowers are typically easy to grow in most climates. They thrive in sheltered, well-drained soils, the plants typically require six to eight hours of sunlight a day. Internationally there has been success in the irrigation of wastewater to sunflowers, both in the reuse of the wastewater and in lifting sunflower production. Like maize, sunflowers would be best suited to centre pivot irrigation due to the crop height.

It is considered that sunflowers could also potentially fall within the Non-Contact Consumptive Crops category of land uses. This is if drip irrigation to avoid contact with the plants was able to be economically established to support the annual crop.

3.4 Option 3: Forestry

Forestry is also a possible option. There are two primary types of forestry which are potentially suitable, these being exotic and native forestry. Both the exotic and native forestry options are eligible for incorporation into the NZ Emissions Trading Scheme (ETS). The financial aspects of this (as per present NZ carbon price estimates) are further discussed in Section 5.3.6.

3.4.1 Exotic Forestry

Potential saw logging of Radiata Pine could apply to this context. Forestry for commercial firewood production is a feasible alternative, however, this land use has proved to be relatively unsuccessful historically, so will not be explored further.

Figure 10: Pine Tree Plantation[14]

[14] https://foresttech.events/optimising-radiata-pine-stand-density/

3.4.2 Christmas Trees

Aside from the potential for saw logging of exotic forestry is the use of the land treatment sites is Christmas Tree plantations. Christmas Trees have a shorter rotation period than saw logging forestry which may have a greater appeal to smaller third-party land treatment site owners.

The sale of trees to the local market and to nearby cities such as Hamilton could provide a source of income.

Figure 11: Christmas Tree Plantation[15]

3.4.3 Native Forestry

While saw logging of native species is possible, it is presently considered unlikely that a native forest would develop with the intent of commercial harvesting. Mānuka/Kānuka species, and potentially other native species, do however offer alternative benefits e.g. honey production, as well as cultural and social amenity value (which can provide economic benefits in the future).

Oil production for beauty and health products is another alternative option for native forestry.

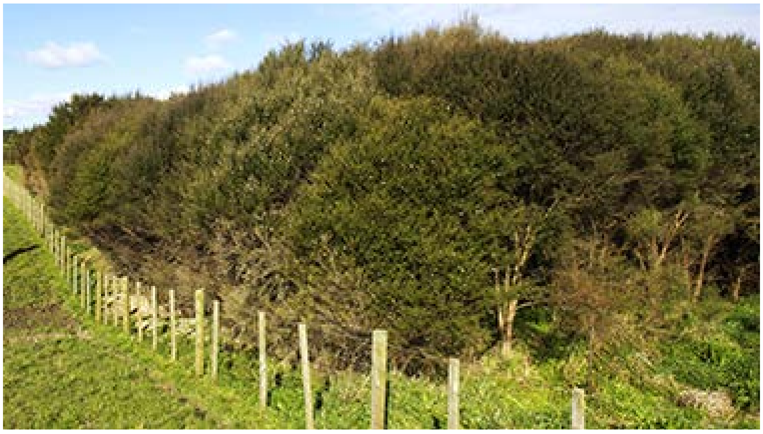

Figure 12: Mānuka Plantation[16]

[15] https://jury.co.nz/tag/pinus-radiata/

[16] https://landusenz.org.nz/mānuka/

3.5 Option 4: Non-Contact Consumptive Crops

In terms of wastewater irrigation, it is expected that the market demand for product produced for human consumption; meat and milk, would likely be limited due to negative public perception of food crops irrigated with treated wastewater, despite the high level of treatment achieved. For this reason, crops and products intended for human consumption that have been produced through irrigation that is applied directly to the proportion of the crop or plant that is intended for harvest, have been excluded from further assessment.

However, indirect irrigation of wastewater could provide an opportunity for third-party landowners to produce crops and product for human consumption. Indirect irrigation is where the irrigation water does not come in direct contact with the harvestable portion of the plant or product. Indirect irrigation is achieved by placing the irrigation beneath the soil surface, using systems such as drip irrigation, Figure 3 demonstrates a drip irrigation system. By placing the irrigation water away from the harvestable proportion of the plant, the plant is provided with an opportunity to assimilate and filter the nutrients and any potential contaminants present in the water, reducing the risk that these will be passed on, or accumulate within the end product.

Products grown in both Orchards and in Viticulture can be sensitive to over-watering and over-fertilising. If the third party owners utilised these land uses it would be important that precision was applied in both the irrigation loadings and timings to ensure they meet the tree or the vines moisture and nutrient requirements.

3.5.1 Orchards

Orcharding is a possible land use, orchards are an example of a land use that can effectively utilise non-contact drip irrigation. Generally, non-contact irrigation is achieved through drip irrigation, however, in some instances where there is a need for the irrigation system to be removed at harvest, the orchard could also be irrigated using low angle k-line irrigation. To achieve non-contact irrigation the k-line system would need to be well designed accounting the stage of growth and height of the plants or trees and well maintained.

Figure 13: Feijoa Orchard[17]

3.5.2 Viticulture

Grapes are another land use which provide the opportunity to supply a product for human consumption that is suited to non-contact irrigation.

Grapes are best planted in sites with full sun and protection from strong winds. The vines will typically tolerate salty air but require protection from frosts during the cooler months. Depending on the variety, type and quality of vine planted, vines can last up to 100 years. Grapes can be susceptible in warm, humid climates, to fungal diseases. Careful canopy management is important to reduce the chance of diseases building up. A fungicide spray may also be needed, from bud burst through to early summer.

Similarly, to Orchards, Viticulture would provide an opportunity for non-contact irrigation supplied to the plant through drip irrigation. Grapes cultivated and harvested could be sold wholesale should the third-party owner not wish to partake in winemaking.

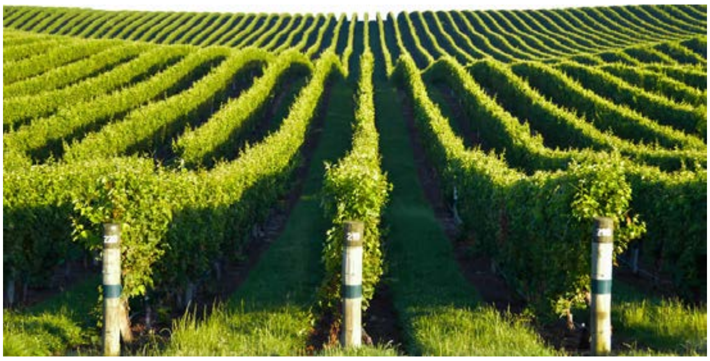

Figure 14: Viticulture Crop[18]

[17] https://www.sp.co.nz/rural_news/articles/feijoa.html

[18] https://www.boydwilsonelectrical.co.nz/electrical-solutions-for-viticulture/

4.0 Assessment Criteria

To evaluate potential suitability and effectiveness of the potential land use options identified in Section 3.0, each of the land uses has been considered against criteria described in Section 4.1.1 to 4.1.7.

In summary the criterion are:

a. Suitability of the land use e.g. site & irrigation requirements, climate, slope, seasonality.

b. Hydraulic demand e.g. capacity of the land use to uptake water and reduce the hydraulic loading of the soil.

c. Phytoremediation (nutrient uptake) e.g. nutrient utilisation efficiency.

d. Land system risk e.g. potential market risk and land use risks.

e. Land system income estimate e.g. estimation of annual return.

f. Emissions Trading Scheme.

Land use options have been assessed on a per hectare basis. Where the individual land uses at a high-level are similar, they have been compared against the criteria as a single land use. For example, for the pastoral grazing land uses, dairy, sheep & beef and deer have been grouped together. Orchards and viticulture have been grouped together on the basis that both in end product are human consumptive crops which can be produced through non-contact irrigation of wastewater.

4.1 Suitability of the Land Use

- Climate suitability: The suitability of the land use for the region.
- Site requirements: General requirements of the land use for optimal performance.

4.2 Land System Risk

- Market risk: The general demand in New Zealand and/or region, or the market for export, for the product produced by the land use.
- Land use risk: Key risks associated with a land use such as sensitivity to pests or drought & biosecurity etc.

4.3 Hydraulic Demand (Water Uptake)

The capacity of each land use option to take up water from the soil, and/or reduce water entering the soil, is a key consideration for the needs of this project.

Estimates of the land uses' Actual Evapotranspiration to Potential Evapotranspiration (AET/PET) ratio (as derived from FAO Penman-Monteith evapotranspiration) will be considered for identifying and comparing the hydraulic uptake capacity/demand of the different land use options.

As a definition: *"Evapotranspiration"* is the process where liquid water is converted to water vapor and removed from sources such as the soil surface or wet vegetation. Whereas, "*Transpiration"* consists of the vaporisation of water within a plant, and subsequent loss of vapor through leaf stomata. Both processes occur simultaneously (Zotarelli, 2018).

The AET/PET ratio used here relates the evapotranspiration of a crop to the evapotranspiration of the reference crop, which is pasture (i.e. AET/PET for pasture = 1.0). This allows comparison between land use options.

4.4 Phytoremediation Potential (Nutrient uptake)

Phytoremediation is a technique whereby plants, that preferentially accumulate nutrients such as N, P, metals or micronutrients, are planted to enhance, remediate, and/or management high rates of soil nutrient loading (Zhang. H., 2006). The assessment will primarily consider the uptake of soil Nitrogen (N).

Assessment of nitrogen uptake potential includes:

- Utilisation of the irrigated nitrogen in plant growth; and
- Nitrogen fixation from atmospheric nitrogen by plants (a plants' ability to extract N from the atmosphere).

The nitrogen uptake capacity of land use alternatives has been assessed based on a maximum annual average nitrogen loading rates received from the wastewater in Table 1. Where feasible, the nitrogen losses have been estimated using the OverseerFM modelling programme. Overseer is used extensively for nitrogen balances of agricultural systems throughout New Zealand (OverseerFM, 2019), and is also the model referenced for land based nitrogen assessments in the region of interest.

4.5 Expected Annual Average Nitrogen Loading

Nitrogen is an essential nutrient for plant growth. Municipal wastewater is usually high in nutrients, particularly nitrogen.

Depending on the land use, nitrogen loading for land treatment systems generally range from 150 kg N/ha/yr for a grazed or forestry system, through to approximately 400 to 500 kg TN/ha/yr for a cut and carry system. Cut and carry systems typically can receive greater nutrient loading as there is a higher rate of nutrient export from the system through the crop harvested.

Phosphorus loading could typically range between 30 kg P/ha/yr to 40 kg P/ha/yr concentration ranging from 4 g P/m^3 to 8 g/m^3. Sodium levels are generally not an issue for municipal wastewater irrigation systems in areas of elevated rainfall and no significant trade waste sources, however, lime addition can be required to manage sodium levels if they increase in the soils over time.

It has been assumed in the land use assessment that the third-party land treatment sites will receive wastewater for irrigation on an on-demand basis, allowing for the land treatment sites to practise efficient irrigation by utilising irrigation scheduling practices that match the demand and needs of the specific land use.

Table 1: Expected Annual Nitrogen Loading by Land Use

Land Use	Average Annual Average Nitrogen Loading (kg N/ha/yr)
Grazed or Forestry system	< 150[1]
Cut and Carry	400 - 500

Note:

1. *Based on a grazed or forestry systems, an average nitrogen concentration in the wastewater of approximately 18 g TN/m³ to 30 g TN/m³ would be required, for a hydraulic loading rate of approximately 500 mm/yr to 800 mm/yr.*

4.6 High-Level System Income & Cost Estimate

High-level cost and potential income has been assessed on a per hectare, per year basis. All cost estimates are to be considered rough order costs. There is significant variation around the cost/income estimates depending on the assumptions and circumstances of each of the land uses options. The estimates are based on the general infrastructure, including a broad consideration of the irrigation system required, set-up costs such as specialised equipment, stock purchase, fencing, tree purchase & planting etc.

Detailed costs for irrigation systems such as pumps, reticulation and irrigation lines have been considered outside of the scope of this assessment and have not been included. Where possible high-level information on grants, funds or subsidies for the available to the land use have been considered.

4.7 Emissions Trading Scheme

The Emissions Trading Scheme (ETS) is a tool to enable New Zealand to meet domestic and international Green House Gas (GHG) climate targets. Agriculture is presently not considered as a part of the ETS; however, some indirect liability is proposed to be implemented in 2025.

Forestry, both exotic and native, is likely to qualify for the ETS, and may provide an alternative income pathway.

For the other land uses consideration will be given to the Zero Carbon bill as some of the land uses may be implicated by the proposed nitrogen fertiliser tax.

5.0 Detailed Land Use Assessment

5.1 Land Use Option 1: Grazed Pasture

Pastoral systems are one of the most common agricultural land uses in New Zealand, with approximately 51% of agriculture in New Zealand being Grassland (pastoral) farming (Statistics , 2011). The land uses to be considered are Sheep & Beef, Deer, and Dairy.

5.1.1 Land Use Suitability

Sheep & Beef and Dairy are two of the most common land uses in the Waikato, Deer farming is not as prevalent but is practiced in region (FigureNZ, 2019).

For the purposes of the assessment, given the existing commonality of pastoral farming it has been assumed that the Raglan area will most likely be suitable for all the pastoral land use options.

In terms of irrigation, there are few limitations for irrigation systems on pastoral farms once established. Most irrigation systems could irrigate the sites; however, centre pivot or lateral irrigation would likely offer the lowest managerial requirement. Where non-deficit irrigation occurs in pastoral farming there is potential for the pasture production to be reduced resulting from waterlogging and excessive drainage from the soil.

5.1.2 Land System Risk

All the pastoral land uses, when assessed at a high level, are exposed to similar risks. Some of these risks are considered manageable/controllable, whilst other are considered uncontrollable.

External Risks:

- Seasonal influences impacting on production;
- National or local biosecurity threats;
- Market demand changing and impacting farm’s income; and
- Restrictive national or local environmental regulation.

Internal Risks:

- Poor management impacting on production; and
- Human resource management.

When compared to the other land uses, pastoral farming carries additional risk due to the interdependent relationship between farm management, product and the market.

In terms of wastewater irrigation, it is expected that the market demand for product produced for human consumption; meat and milk, may be limited or potentially reduced due to negative public perception of food crops irrigated with treated wastewater, despite the high level of treatment achieved. It is unlikely that the fibre produced would carry the same connotation, however the market for wool is variable and cannot necessarily be relied upon as a sole income.

5.1.3 Hydraulic Demand

It can be expected that the pasture will have a greater hydraulic demand during summer months due to the higher daily AETs and increased pasture growth. The hydraulic demand will significantly reduce in winter when pasture growth and daily AETs are reduced. The reduction in hydraulic demand over winter months will limit the amount of irrigation water that can be efficiently applied to the pasture during this time.

Table 2: Hydraulic Demand (AET/PET) of Each Land Use

Land use	AET/PET Ratio[1]	Hydraulic Demand
Hemp	1.25	High
Vetiver[2]	1.20	High
Cut & Carry Lucerne	1.20	High
Cut & Carry Maize	1.20	High
Native Forestry	1.20	High
Exotic Forestry	1.20	High
Cut & Carry Sunflowers	1.15	Medium
Rapeseed Oil	1.07	Medium
Orchards - Feijoa	1.05	Medium
Grazed Pasture	1.00	Low
Viticulture	0.70	Low

Notes:
1. *AET/PET Ratio Derived from Crop coefficients mid growth values (FAO. 2019).*
2. *Sorghum used as a proxy for Vetiver.*

5.1.4 Phytoremediation (Nutrient uptake)

Legumes such as clover, are common in pastoral swards (ryegrass clover mix). Clover has the capacity to fix atmospheric nitrogen, the nitrogen fixed from the atmosphere is dependent on the pasture management, fixation inputs can range from 100-350 kg N/ha/yr.

For pastoral systems in terms of nutrient uptake, and consequent export, they are not particularly effective at reducing the overall mass balance of soil nutrients. This is because most of the nutrients, especially Phosphorus (P) and Potassium (K), are redeposited as dung and urine (Zhang. H., 2006). As well as redepositing P and K, the urine patch, particularly from cattle, has a high nitrogen loading rate. The nitrogen loading in the urine patch usually exceeds the pasture demand and therefore the excess nitrogen is leached preferentially through urine patches.

Nutrient leaching tends to increase from pastoral systems during the shoulder[19] and winter months as a result of increased rainfall. Nutrient's deposited in high loading rates such as the dung and urine patches tend to be leached from the soil during this period.

Estimated nitrogen leaching values for grazed pastoral systems, for comparison purposes only are below in Table 3. Table 3 has been sourced from the 2017 AgFirst report *Analysis of drivers and barriers to land use change"*.

Table 3: Indicative nitrogen leaching for pastoral grazing

Farming System	N leaching (range) (kg N/ha/yr)
Dairy	20 - 150
Sheep & Beef	6 - 50

Notes:

1. *Actual leaching figures can vary widely, the leaching is dependent on multiple factors such as, climate, soil, nutrient loading, and management systems.*
2. *Deer farming is not detailed; however, the Sheep & Beef losses are assumed to be similar.*

5.1.5 Land System Income Estimate

Pastoral grazing is vulnerable to market factors, it is therefore challenging to reliably estimate the annual per hectare income. Establishment estimates and operating profits for each of the pastoral land use options are in Table 4 below.

The establishment costs are assumed to include:

- Stock purchase.
- Infrastructure – fencing, stock yards, milking parlour etc.

The operating profits are primarily from the sale of products; meat, milk or fibre.

[19] Months leading into and out of winter, late autumn/early spring

Table 4: Pastoral System Cost & Profit per Hectare Estimate

Farming System	Operating Profit/ha	Establishment Cost/ha[4]
Dairy	$3,000[2]	$20,000[1]
Sheep & Beef	$200 - $500[3]	$2,500
Deer	$200 - $500	$2,900

Notes:
1. *AgFirst (2017) "For the sheep and beef to dairy conversion, the capital required is in the order of $20,000 per hectare (including livestock but excluding irrigation)".*
2. *DairyNZ (2019) Based on projected profit per/ha for a Lower North Island 50% irrigated dairy platform.*
3. *Beef & Lamb (2019) Based on performance Benchmarking for an intensive finishing operation in the Manawatu.*
4. *All establishment costs exclude the cost of irrigation infrastructure.*

5.1.6 Emissions Trading Scheme – Pastoral Grazing

Should agriculture be brought into the Emissions Trading Scheme (ETS) it is likely that there will be a cost associated to pastoral farming[20]. This is because pastoral farming produces two key biological greenhouse gas emissions these are Methane (CH_4) and Nitrous Oxide (N_2O). The cost associated with the land use is relative to the total amount of emissions generated from the farm, this is influenced by the type of animals grazed i.e. Dairy Cattle, Deer or Sheep & Beef. The cost will also depend on the percent liability which is the proportion of the GHG emissions farmers would need to pay for. Currently the government is proposing this liability at 5%.

Table 5: Emissions Trading Scheme: Pastoral Grazing

Land Use	ETS/CO2 returns ($/ha/yr)[1]
Sheep & Beef	-$4.00
Dairy	-$12.00
Deer	Unknown[2]

Notes:
1. *Assuming a 5.0% liability under the ETS.*
2. *Assumed to be similar to sheep & beef, possibly slightly higher depending on the type of deer farmed.*

[20] This may be an indirect cost which is levied at processors (i.e. dairy and meat companies) and then passed onto the farm.

5.2 Land Use Option 2: Human Non-consumptive Crop

5.2.1 Land Use Suitability

Hemp

For a successful Hemp crop, it needs adequate sunshine, regular rainfall or irrigation and well-drained soils, Hemp should not be planted until soil temperatures reach at least 6- 8°C. Hemp is typically ready for harvest 90 – 140 days after sowing, the growing time depends on the end use, Hemp grown for high quality fibre typically occurs after the pollen is shed and for seed production harvest occurs when the seed is at least 60% ripe. (NZHIA, 2020)

It is anticipated that Hemp would be suited to the soil types in the area, however, cultivation, sowing and harvest of Hemp may be difficult on the sloped sites. The suitability of the specific site/s once identified would need to be assessed prior to cultivation of Hemp. Hemp is also sensitive to compacted soil conditions.

In terms of irrigation systems, Hemp grows best in moist but not wet soils with high levels of aeration, it is important that the irrigation system does not compromise the aeration of the soil when irrigating (Netafim, 2019). Therefore, Hemp would be best suited to carefully managed centre pivot irrigation. Hemp typically grows up to > 1 m in height this means on-ground systems such as K-lines etc would be ineffective.

Oilseed Rape

Oilseed Rape is also likely to be best suited to centre pivot (or lateral) irrigation. This is due to the seed production of the plant, shifting on-ground irrigation systems would be impractical and could compromise the crop. As a crop it has a deep rooting system and grows best on medium textured, well drained soils. It can be vulnerable during establishment (seedling stage), therefore careful seedbed management is required prior to establishment. Pre and post emergence pest and weed management is also essential to ensuring a successful crop, unlike Hemp, oilseed rape won't smother out competing vegetation.

Efficient sowing and harvesting of both Hemp and Oilseed Rape require flat to moderate slopes/terrain. Like the Cut and Carry crops without specialised slope machinery, the maximum slope would be 15-20 degrees.

Vetiver

Unlike the Hemp and Oilseed Rape crops, Vetiver is a perennial bunchgrass which is planted spring and summer when soil temperatures are high, this is because the plant thrives when soil temperatures are 20+ ^{o}c. Optimal growth is not achieved when plants are shaded or in snow and heavy (regular) frost zones, Raglan does at times have light frosts during winter however, it is anticipated that these won't create growth penalty for Vetiver in the area. (Vetiver Systems , 2020).

Compared to the other land use options, Vetiver is a relatively low maintenance plant. Internationally, the plant is used for water and soil conservation, ground stabilisation, removing pollutants from land and water, sediment control and flood damage prevention (Vetiver Systems , 2020). It has no known pests or diseases, but a basic weed control plan may be required, as when unmanaged, kikuyu grass can grow over the Vetiver affecting its health. In New Zealand, Vetiver is generally used for sediment and erosion control on steep slopes. It is also palatable as stock fodder before it reaches maturity. Vetiver could be used as a sole crop, or it could be used as a complementary crop/plant, skirting the outside of an irrigation area or in less productive areas.

5.2.2 Land System Risk

5.2.2.1 Option 2a: Hemp

Hemp is a strain of the Cannabis sativa plant, because of this it requires an annual licence to be obtained from the Ministry of Health, this costs $511; on application these licenses can be extended to three years. The licenses stipulate that any Hemp crop with Tetrahydrocannabinol (THC) levels higher than 0.5% may be required to be immediately harvested and destroyed. Applicants for Hemp licenses– either individuals or organisations – must meet certain conditions with respect to background and suitability before they are granted a licence (Health, 2006). Being a relatively new crop to the New Zealand market, this increases the market risk of the crop in terms of accessing markets, and ensuring continued growing rights and licensing etc. It is likely that the crop will also require a high degree of management from skilled individuals to ensure its success.

Although a new crop, Hemp offers the benefit (and reduced managerial risk) in that Hemp is relatively resistant to pests and diseases and due to its ability to smoother and suppress weeds, provided the strike rate has been high and evenly distributed it will typically outcompete other plant life (NZHIA, 2020).

Due to the bulky nature of the raw material once harvested to economically process the Hemp, transport to processing would need to be minimised where feasible. The New Zealand Hemp Industries Association (NZHIA) consider this an opportunity for "reverse corporate centralisation of production." This could either be a risk or an opportunity for the area. Local output from the processing phase could range from providing marketable commodities suitable as raw materials for other industries, through to maximum added value, when hemp based, finished goods are produced and sold. (NZHIA, 2020)

5.2.2.2 Option 2b: Oilseed Rape

Oilseed Rape needs a high degree of management to ensure success. If not carefully managed there is a risk of a monoculture developing which could be detrimental to the crop. One of the primary foreseeable risks for Oilseed Rape grown as a feedstock for biodiesel production is a lack of biodiesel refineries capable of processing the crop into biodiesel. At present biodiesels in NZ are primarily produced from whey, tallow and used cooking oils. There are some processing plants capable of producing biodiesel from rapeseed oil. As market demand grows for biodiesels, opportunity may present for more biorefineries with vegetable oil capabilities to be established.

5.2.2.3 Option 3b: Vetiver

In terms of essential oil production of Vetiver, the harvest of Vetiver roots, whether manual or mechanical harvest, is a time and physically demanding process, it will yield 2 – 3 tonnes of root per hectare (Vetiver Network, 2020), one ton of roots yields 10kg of Vetiver oil by steam distillation for 36 hours. The world production of vetiver oil is around 300 tons of oil per annum, the major producers of Vetiver are Haiti, India, Java and Reunion. (NAIP, 2011)

The main risk foreseeable with Vetiver grown for the purposes of essential oil production is the scale of production required to achieve an economic viable land use, and without the availability (and ability) to distil and produce oil locally the availability of market for raw vetiver product increases the risk of growing Vetiver. In addition to the market demand and supply risk, it is likely that because of New Zealand’s climate the Vetiver won’t grow quickly enough for essential oil production, when compared to the tropical countries where the plant is primarily grown.

A possible alternative to essential oil production for Vetiver, could be wholesale growing Vetiver seedlings for nurseries. As demand for the plant increases in New Zealand this could be a lower risk option for Vetiver. As vetiver increases its reputation as an effective method to reduce soil erosion and stabilize steep slopes, the demand for the plant and installation services will continue to increase, if oil production does not present a future option for the sites. Another alternative for Vetiver could be initial trial sites to test the effectiveness of the plant in receiving wastewater irrigation in a New Zealand climate.

5.2.3 Hydraulic Demand

Hemp, Oilseed Rape and Vetiver are all high biomass crops with a good hydraulic demand. The transpiration will be greater for Hemp, the greater transpiration results in a higher hydraulic demand from the plant. Of the land use options in this assessment, Hemp has the greatest hydraulic demand (1.25 AET/PET), followed by Vetiver[21] (1.20 AET/PET). Rapeseed has a good demand (1.07 AET/PET), although not as great a hydraulic demand as Hemp.

For Hemp in particular, when planted the seedlings require 76 – 102 mm of rain or irrigation during the first growing month and 635 – 760 mm per annum, as the seedlings grow the water demand will decrease due to the dense canopy enabling water retention and the deep taproot seeking out the water table (NZHIA, 2020).

5.2.4 Phytoremediation (Nutrient uptake)

As discussed earlier in the report in section 2.0 Fonterra has undertaken a successful wastewater irrigation trial of Hemp in Darfield, Canterbury. When considering the applicability of this trial when assessing potential land use options for land treatment in Raglan, it is important to consider the characteristics of the wastewater, which vary from source to source, for example dairy factory wastewater compared with municipal wastewater.

Hemp and Oilseed Rape are not suited to continuous cropping[22], so would need rotation with other crop and pasture phases to optimise results. Both crops are oilseeds and would ideally be grown in rotation in cereal and legume plants. Crop rotations are an essential practice to preserve the integrity of the site's soil structure and fertility and to avoid possible detrimental microorganism monocultures forming in the soil.

The literature is unclear on the suitability of Vetiver for continuous cycling of plants; however, it appears that the plants could be continually planted and harvested without significant penalty.

Leaching values are for indicative only, as per note 3.

Table 6: Indicative nitrogen uptake & leaching for Non-consumptive crops

Land Use	N Uptake (range) (kg N/ha/yr)	N Leaching[3] (range) (kg N/ha/yr)
Hemp	200[1]	Unknown
Rapeseed Oil	200 – 300[2]	16 - 23
Vetiver	6000 – 10,000[23]	Unknown

Notes:

1. *Approximately 40 kg/ha is taken up in the seed and 160 kg/ha in the stalk.*
2. *Timing of nitrogen application within the growth cycle will impact the total amount of nitrogen that the plant uptakes.*
3. *Actual leaching figures can vary widely, the leaching is dependent on multiple factors such as, climate, soil, nutrient loading, and management systems.*

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[21] Sorghum AET/PET used as a proxy for Vetiver

[22] The growing of a single crop species in a paddock year after year.

[23] (Wagner, n.d)

5.2.4.1 Option 2a: Hemp

For successful Hemp production the crop requires good soil fertility with a supply of nitrogen, phosphorous & potassium to produce maximum economic returns. To achieve an optimum hemp yield, twice as much nutrient must be available to the crop as will finally be removed from the soil at harvest. The high nutrient demand of hemp is because the crop produces a large bulk of plant material in a short period. Hemp's nitrogen uptake is most intensive the first 6 to 8 weeks, while potassium and phosphorous are needed more during flowering and seed formation.

Typically, Hemp uses a total of 200 kg N/ha/yr through the growth cycle, (40 kg/ha is removed in the seed and 160 kg/ha in the stalk) and around 50 – 80 kg/ha of phosphorus and 60 to 80 kg/ha a year of potassium. (NZHIA, 2020). Because of the high biomass production and associated nutrient demand, if Hemp is grown for both grain and fibre production there is a reasonable amount of nitrogen removed from the system (CHTA, 2019). The low nitrogen surplus in the soil remaining after hemp is a result of the high nitrogen uptake. However, Hemp has a low C:N ratio (15:1), which means when crop residue is returned to the soil after harvesting it is quickly mineralized, releasing nitrogen. This may result in high nitrate leaching if another crop is not planted soon after the mineralisation has occurred.

Hemp is also exceptional at phytoremediation, it does this by up taking heavy metals in soil (such as cadmium, copper, chromium, nickel, strontium and zinc) because of its branched, deep taproot and high biomass (Brownlee, 2018).

5.2.4.2 Option 2b: Oilseed Rape for Biodiesel

The optimal range of applied nitrogen for Oilseed Rape production is 200 – 300 kg N/ha/yr. This means that in order to achieve an optimal yield additional fertiliser may be required, based on the nitrogen inputs from the wastewater.

For Oilseed Rape the timing of nitrogen application within the growth cycle will impact the total amount of nitrogen that the plant uptakes. For example, FAR (2011) discuss the timing of nitrogen fertiliser, they report that nitrogen up taken by the plant is 60 kg N/ha higher when nitrogen is applied at the green budding stage and not the yellow. The uptake is due to the additional biomass growth that is encouraged by the nitrogen application. Generally, they found that plants where nitrogen had been applied at the green bud stage contained 313 kg N/ha whereas plants that received fertiliser at the yellow budding growth stage contained 250 kg N/ha (FAR, 2011).

Post-harvest management will affect return rate of nitrogen to the soil once the seed is harvested. The extra 65 kg N/ha accumulated in the crop canopy would be returned to the system as a higher stubble loading at harvest (FAR, 2011). If the stubble is returned to the soil and not removed through other methods such as grazing.

5.2.4.3 Option 2c: Vetiver

As can be seen in Table 6, Nitrogen uptake for Vetiver is extremely high, Vetiver is an excellent phytoremediator with a very high uptake and tolerance for excess nutrients. A study by Wagner *et al* (n.d) suggests that up to 6,000 kg ha/yr there is a correlating yield response in both the shoot and root dry matter, however, between 6 – 10,000 kg ha/yr there was little additional yield response. There was little literature was available on the actual leaching rates from vetiver.

5.2.5 System Income Estimate

Income estimates for Hemp and Rapeseed Oil have been based on the sale of the raw product grown, Hemp fibre and hurd, Rape Seed and Vetiver root for essential oil. As outlined in earlier sections Hemp could also provide alternative consumptive end uses however, for this report only non-consumptive end uses for Hemp have been assessed.

Table 7: Non-Consumptive Crop Estimated Operating Profit

Farming System	Operating Profit/ha
Hemp	\$1,000 - \$5,000
Rapeseed Oil	\$1,000 - \$4,500
Vetiver	\$500 - \$1000

Hemp

Hemp Brokers (2019) suggest that a hectare of Hemp, intended for non-consumptive purposes can produce 3 – 6 metric t/ha depending on the type of Hemp grown. If Hemp formed part of a crop rotation on an annual basis the crop would have an income potential of:

- Hemp fibre valuable for the manufacture of rope and textiles, typically yields 3 t/ha and retails for approximately \$2 per kg (\$2,000 per t or \$6,000 per ha).
- Hemp hurd (pulp), is useful to produce paper and construction materials such as hempcrete, typically yields 6 t/ha and retails for around \$1 per kg (\$1,000 per t or \$6,000 per ha)[24].

Assuming a harvest cost of \$1,000 per ha, the income range for Hemp is \$1,000-\$5,000. This is a broad estimate given that there are a multitude of end-uses for Hemp, and a good portion of the profitability will depend on the proximity of the

[24] Income is assumed to account for establishment costs

processing location. There is potential for value-add opportunities from Hemp because it does have multiple end uses, one of these would be for small scale community based processing/production of Hemp products.

Oilseed Rape

Oilseed rape, having an income of approximately $550 per t and a yield of 3.5 to 8 t/ha for a spring-sown crop and autumn-sown crop respectively, would mean the income range would be $1,000 – $4,500 pending on the market. This is assuming a similar harvest cost to Hemp of $1,000 per ha. Once harvested each tonne of oilseed rape produces about 400 litres of oil which can then be converted to biodiesel. Similarly, to Hemp the Oilseed rape would need to be transported to a processing facility which will affect the profitability of the crop.

Vetiver

Initially, for mechanized Vetiver farming, Vetiver is planted on 1 hectare, in 55 rows 100 meters long (rows are 1.80 m apart to accommodate machinery), equates to 5,555 linear meters. Vetiver is planted in clumps; five clumps can be planted to a meter.

When harvested for essential oil, Vetiver will yield 2 – 3 tonnes of root per hectare, 1 tonne of root will then produce 10 kg of oil. Vetiver as wholesale seedlings cost approximately $0.56 each, these seedlings can undergo propagation, splitting a clump into 5-6 slips. In general, the crop is harvested after 15-18 months during summer for best quality oil. Oil content of root starts decreasing after 20 months age considerably.

For the sale of Vetiver roots, a tonne is worth $4,700 (approximately), assuming a harvest $700 per hectare and a 2 tonne per hectare yield, the income range for Vetiver would be $500 - $1000. The propagation of plants in time could decrease some of establishment costs for the land treatment site owner.

Because Vetiver is a relatively new crop to New Zealand there could be potential opportunity for the third party land owners to seek grants or funding under the research premise of both erosion and sediment control and the remediation properties of the plant for wastewater. Similarly, Hemp is a relatively new crop to New Zealand and grants, or funding may be available for research into the crop and refining its potential for land treatment.

5.2.6 Emissions Trading Scheme – Non-consumptive Crops

As discussed in 5.2.6 cropping is considered carbon neutral meaning there are no obligation under the ETS for Hemp, Vetiver or Oilseed Rape. It is likely that Hemp and Oilseed rape will both require additional nitrogen fertiliser in order to achieve optimal yields. It is estimated that these costs will be $0.10 per ha for Hemp and $0.21 for Oilseed Rape. It is unlikely that Vetiver would require additional nitrogen fertiliser.

5.3 Land Use Option 3: Cut and Carry

As discussed below, the cut and carry options considered are lucerne, maize and sunflowers. All could be grown in rotation with pasture, or a combination of different cut and carry crops. Pasture grown in rotation could also be harvested and sold as supplementary feed, this would increase the versatility of the options.

5.3.1 Land Use Suitability

Typically, lucerne does not perform well on heavy, waterlogging (or prone to) soils, rather it will perform better on free draining, light textured soils. Lucerne is relatively drought resistance and grows well in dry climates. Similarly, to Lucerne, Maize thrives on free draining soils it grows best when exposed to high radiation and long growing seasons, it is important to select an appropriate hybrid for the growing location. For Maize, often steep paddocks are not only difficult cultivate and harvest, often don’t tend to yield well due to the slope.

Sunflowers are deep rooting plants that are typically easy to grow in most climates, they will however warm to hot climates when planted in a sheltered location in well-drained soils, the plants typically require at least six to eight hours of direct sunlight a day. Sunflowers are typically considered a restorative crop, helping to maintain the fertility and structure of the soil.

In terms of irrigation of the cut and carry crops, Centre pivot or lateral would likely be best suited to the maize and sunflowers; lucerne could also be irrigated easily by k-line or centre pivot/lateral. Examples of these irrigation systems is in Section 1.3.

Because efficient harvesting requires flat to moderate slopes/terrain, some of areas identified may be too steep for efficient harvesting of cut and carry crops. Typically, the slope threshold without specialised slope machinery is around 15 – 20 degrees. Therefore, once the specific sites are selected, individual review of each site’s requirements would be needed.

5.3.2 Land System Risk

The potential market for cut and carry crops is likely to be more reliable than the other land use options, as the demand for fodder or feed crops is generally high throughout New Zealand.

Lucerne has a relatively low system management risk, operationally the main daily requirement would be irrigation management. For lucerne, the crop performance would need to be monitored and the crop renewed if yields become impaired. A pasture phase may need to be introduced every 3 – 5 years, the pasture could also be harvested and sold as supplementary feed.

Grass and broadleaf weeds can be a threat to the quality and viability of lucerne stands, cutting of lucerne will encourage weed growth. As such it is likely that the lucerne will have weed management requirements such as spraying.

Maize is sensitive to various pests and diseases; an effective weed and pest management regime is essential to ensure that success of a crop. Maize would require a higher degree of management throughout the growth cycle, like lucerne it also needs on-going weed and pest management.

Sunflower meal is the by-product from the cold press process to extract sunflower oil, it is fed as a supplementary feed to milking goats, equine and dairy cows. Unlike Lucerne and Maize, Sunflower meal may not enjoy the same reliable and broad-based market demand, as it is more of a niche crop. Additionally, Sunflower meal is relatively high in protein, and is typically fed by farmers looking to boost protein levels in their herd's diet. Crude protein beyond the animal's dietary needs, particularly in cows, can significantly increase the urinary N content which contributes directly to N leaching. To reduce the N lost to groundwater in the future, there is going to be a need to reduce crude protein in animal's diets, this may not play favourably to for the demand for Sunflowers as a supplementary feed which increases the risk of the crop.

5.3.3 Hydraulic Demand

For Lucerne, Maize and Sunflowers the soil water demand will vary depending on the growth stage of the plant, generally Lucerne has similar soil water demand to Maize through winter and spring, however during the summer and autumn fallow period it continues to use soil water whereas Maize's demand reduces, and is ceased after harvest and before the next crop is sown. Sunflowers have a slightly lower soil water demand than Lucerne and Maize resulting from the lower biomass of the plant, as with Maize, Sunflower's demand reduces, and is ceased after harvest and before the next crop is sown.

As can be seen in Table 2, Lucerne and Maize have an AET/PET of 1.20 compared with Sunflowers which have an AET/PET of 1.15. When comparing Lucerne to pasture, literature suggests that generally there is a greater evapotranspiration for lucerne crops when compared to pasture (AET/PET 1.00) (Martin, 1984) (Floyd, 2001). This is because lucerne has a leafier biomass than pasture which increases the surface area for transpiration.

5.3.4 Phytoremediation (Nutrient uptake)

Table 8: Indicative nitrogen uptake & leaching for cut and carry

Farming System	N Uptake (range) (kg N/ha/yr)	N Leaching[1] (range) (kg N/ha/yr)
Maize	300	Unknown
Sunflowers	120 – 130	Unknown
Lucerne	150	5 - 26

Notes:

1. *Actual leaching figures can vary widely, the leaching is dependent on multiple factors such as, climate, soil, nutrient loading, and management systems.*

Overall, all the cut and carry options have good nitrogen uptake (removal from system) of approximately 130-165 kg N/ha/yr[25] and 150 kg N/ha/yr[26] respectively. The nitrogen uptake of the crops will range depending on when the crop is sown (i.e. Spring, Winter or Autumn). All the cut and carry land uses are advantageous in terms of nutrient export from the system as there is little nutrient return after harvest in terms of crop residue. Maize silage can remove substantial amounts of nitrogen and potassium from highly fertile soils.

In terms of nitrogen losses, published data for nitrogen leaching on lucerne cut and carry suggests a range of 5 to 26 kg N/ha/yr (McLeod, 2015). Nitrogen leaching as modelled in Overseer for lucerne can be variable depending on the nitrogen fertiliser applied and the yields achieved. There is little literature available on the nitrogen leaching losses from Mazie and Sunflower crops. However, like lucerne, it is expected that nitrogen losses from Maize and Sunflowers will increase during winter when growth and nitrogen demand of the crops slow. This is due to the period of downtime before the following crop is sown, where no nutrients are being up taken after harvest for Maize and Sunflowers is a high-risk period, this period increases the nitrogen losses from these crops.

5.3.5 Land System Income Estimate

The primary costs for the cut and carry land use are the operational and establishment costs and on-going crop maintenance and harvest. However, these costs are offset by the sale of these crops as a dry fodder or feed crop following harvest.

[25] (Yara, 2019)

[26] (Pattle Delamore Partners (2016)

Costs assessed for the cut and carry options included:

- Costs of establishing the crop, considering lucerne must be replanted every five to six years and on rotation for Maize and Sunflowers approximately, 6-8 monthly;
- Costs of growing the crop; herbicide, fungicide, irrigation etc;
- Costs of harvesting.

Excluded is the cost of additional fertiliser over and above the wastewater to achieve the desired yields.

Table 9: Cut and Carry Annual Cost & Profit per Hectare Estimate

Crop	Annual Initial Establishment Cost/ha	Harvest & Post Planting	Annual Gross Income	Gross Margin
Sunflowers	$2,000	$900	$6,000	$3,100
Maize[2]	$3,800	$2,440	$6,240	$2,580
Lucerne[3]	$1,700	$1000 - $2000	$4,000	$2,000

Notes:

1. *Assuming two back to back crops per year*
2. *Assuming the lucerne yields four cuts per year.*

5.3.6 Emissions Trading Scheme – Cut and Carry

Unlike pastoral grazing, crops do not directly emit greenhouse gases or sequester carbon (while the crop takes up carbon from the atmosphere whilst growing, this carbon is released once the crop is harvested and consumed). This means there is no ETS obligation on the cut and carry land uses. However, under the carbon-zero bill, the intent is to levy a tax on nitrogen fertiliser[27]. It has been assumed that lucerne and sunflowers will have a sufficient nitrogen supply from the wastewater and so will have no additional cost, maize however may require additional nitrogen fertiliser in order to achieve an optimal yield, it has been estimated this will be a cost of -$0.20 per ha, assuming 150 kg N/ha/yr is supplied by the wastewater.

[27] This is likely to be levied at a processor level i.e. Fertiliser Companies and then passed on in the sale price of fertiliser

Table 10: Nitrogen Fertiliser Tax - Possible Costs for Each Land Use[1]

Farming System	Fertiliser Tax $/ha
Rapeseed Oil	-$0.21
Hemp	-$0.10
Cut & Carry Maize	-$0.20
Cut & Carry Sunflowers	$0.00
Cut & Carry Lucerne	$0.00
Orchard/Viticulture	$0.00
Native Forestry	$0.00
Exotic Forestry	$0.00
Grazed Pasture	$0.00

Notes:

1. *Tax is likely to be levied at the processor level i.e. fertiliser companies and passed on in the form of increase per unit fertiliser prices.*

5.4 Land Use Option 4: Forestry

5.4.1 Land Use Suitability

For the purposes of the assessment, given the existing commonality of forestry in the west Waikato, it has been assumed that the Raglan area will be suitable for both forestry land use options. Pine plantations (Exotic Forestry) are already established which suggests that the land performs well under the land use.

Christmas Tree plantations are an alternative forestry option that could be utilised. There are a variety of common Christmas Tree species grown in New Zealand, for the purposes of this assessment Pinus radiata will be used. As with a pine plantation the area demonstrates the ability to successfully grow pine, suggesting that Christmas Tree plantations would also succeed.

While similar, mānuka and kānuka have slightly different site requirements in order to achieve optimal performance. Mānuka is tolerant of almost all growing conditions, including dry exposed ridges and coastlines. Where many other species may struggle, mānuka grows well on wet soils and low-fertility soils, the plants also perform well in well-drained soils. Mānuka will usually grow for 30 – 60 years. (Saunders, 2017). Similarly, kānuka will grow in a variety of conditions, however, it grows best on soils of moderate-to-good natural fertility and drainage where it out-competes mānuka. Kānuka will usually grow to 160 years and possibly as old as 300-400 years. (Saunders, 2017). The seeds of both plants will even germinate and grow in the absence of soil.

Neither mānuka or kānuka seedlings will tolerate shade, as such it is important that the plantations are planted accordingly, and the aspect of the site receives sufficient sunlight hours. (Saunders, 2017). Both species are highly tolerant of wind, including salt spray, suggesting that the coastal land treatment sites that have been identified would be a suitable selection.

If the native forestry was used for honey production, it would need to be a minimum of 40 – 50 ha in size in order to achieve a high-quality 'pure native' honey, this is discussed further in section 5.3.5.2.

In terms of irrigation systems, forestry, due to the height of the plantations[28], is the most limited land use option and drip irrigation lines or solid set would need to be installed. When compared to the other potential land uses, forestry has a higher tolerance to accepting shoulder and winter month irrigations without the negative yield responses that the other land uses may demonstrate.

5.4.2 Land System Risk

5.4.2.1 Exotic Forestry

The market risk for pine forestry is considered low with the typically strong demand for pine timber for both the domestic and export market. It is not without risk as it is susceptible to canker disease which effects the quality of wood produced if present.

The market risk for Christmas Tree plantations is considered slightly higher than for timber. This is due to the proximity of Raglan to its closest (and largest) market pool being Hamilton, a 45-minute drive, meaning the demand and therefore the sale price and profitability of the trees may be reduced, or costs increased by transporting the trees into Hamilton. Christmas Tree recycling could be offered post-Christmas to mulch the dead trees, this mulch could then be recycled on site for new trees.

5.4.2.2 Native Forestry

When mature, mānuka, is very tolerant of drought, waterlogging, strong winds and frost, and it can grow at less fertile, colder, wetter and more acidic sites than kānuka. There is an existing biosecurity threat from myrtle rust which is a serious fungal disease that affects plants in the myrtle family, which includes kānuka and mānuka (Sector, 2019).

It is considered unlikely that the native forestry would be harvested for timber production. The primary potential market is expected to be the production and export of mānuka honey which globally is a popular product. This would likely be carried out by a third-party apiarist. In terms of honey harvest for native

[28] Typical mature height of Mānuka is 4 – 8 m and Kanuka is 15 m. Mature height of native forestry will depend on the site characteristics

forestry, the flowering season is relatively short, it is usually 6 to 12 weeks long (and often less) between September and March. The timing and length of flowering varies between regions and between seasons, and cold wet weather can delay its onset and therefore impact on the quantity and quality of the harvest.

Essential oil can also be produced from mānuka plantations. Mānuka essential oil, like honey, is a globally popular product for medicinal, beauty and health purposes. The oil is produced by hand pruning the branches of the trees once a year, this allows the trees to continue growing. The plant material pruned off is left for a few days to wilt then, the foliage is packed into a still and distilled. A hectare of mānuka will typically yield 2 – 3 tonnes of foliage.

5.4.3 Hydraulic Demand

Forestry, both Native and Exotic provide a high hydraulic capacity (1.20 AET/PET), this is because the trees provide a high interception of rainwater when the foliage canopy is established. However, interception will be relatively minor in the initial growth phase of the tree stand. As a result, hydraulic capacity during the initial few years of this land use option will be less than the other options assessed. This relates specifically to the Christmas Tree plantations which are harvested before they become an established plantation.

Like the other land uses forestry is likely to see a reduced hydraulic demand over the winter months when soil temperatures, sunlight hours and plant growth is reduced.

5.4.4 Phytoremediation (Nutrient uptake)

Table 11: Indicative nitrogen uptake & leaching for Forestry

Farming System	N Uptake (range) (kg N/ha/yr)	N Leaching (range) (kg N/ha/yr) [2]
Pine Saw Logging	20 – 40[1]	1.2 – 2.7[3]
Pine Christmas Trees[1]	50	
Native	Unknown	5 - 10

Notes:

1. *The nitrogen uptake in pines is far greater in the early growth stages.*
2. *Nitrogen leaching is influenced by the amount of unutilised plant material left behind on-site during saw logging and thinning operations. Actual leaching figures can vary widely, the leaching is dependent on multiple factors such as, climate, soil, nutrient loading, and management systems.*
3. *(Davis, 2014)*

For pines the nitrogen uptake ranges from 20 to 40 kg N/ha/yr. The nitrogen uptake in pines is far greater in the early growth stages (Davis, 2014). With total accumulation of nitrogen in the tree at 12 years ranging from 200 – 600 kg N from heavily thinned and un-thinned stands respectively (Scion, 1987).

Christmas Tree seedlings are planted at 12 months, then shaping and shearing of the tree begins approximately 6 months after planting, or once the tree reaches 1 m in height (Mount Gabriel Christmas Tree Farms, 2020). Depending on the height of the tree desired it will take just under 2 years for a tree to reach approximately 6 ft, based on this is it estimated that the tree would uptake 50 kg N/ha/yr. Similarly, to the other land uses it can be expected that the growth (and therefore nitrogen uptake) will reduce significantly when soil temperatures and day light hours are reduced during winter months.

There was little literature available on the nitrogen uptake rates mānuka and kānuka. We consider it reasonable to assume, the native forestry would follow a similar demand pattern as the exotic with the demand peaking during the early, rapid growth stage.

Regarding nitrogen losses from forestry, literature suggests that losses from exotic forestry reach their peak at forest maturity and after harvest, as the nitrogen demand plateaus, and litter is returned to the soil after harvest.

Research shows that on average native forestry losses are approximately 5.7 kg N/ha/yr[29] pre-harvest, this increases to 10.4 kg N/ha/yr after harvesting (Davis, 2014). At present there are several studies occurring regarding the potential benefits of mānuka based systems to reduce nitrate leaching, and it is hypothesised that the mānuka is reducing nitrate leaching by slowing the nitrification process.

5.4.5 Land System Income Estimate

The land system income estimates for exotic and native forestry are below in section 4.3.5.1 – 4.3.5.2.

There are government initiatives which the third-party landowners could access for establishment of both exotic and native forestry. Some of these grants include the *One Billion Trees Programme*, *The Emissions Trading Scheme, Hill Country Erosion Programme* and funding for forestry research and innovation.

Table 10 below, sourced from Forestry New Zealand gives an indication of some of the grants available for forestry.

[29] Where native forestry has been planted on land that has historically been used for agriculture.

Table 12: Forestry New Zealand Basic Grant Category Table[1]

Category	Size[2] Ha	Base rate/ha	Top-up/ha			
			Erosion-prone land	High land preparation costs	Fencing	Ecological restoration[3]
Native Planting	1 - 300	$4,000	Up to $500		$500	$2000
Native Restoration	5 - 300	$1,000	Up to $500		$500	N/A
Mānuka-Kānuka Planting	5 - 300	$1,800	Up to $500		N/A	N/A
Exotic Planting	5 - 300	$1,500	Up to $500		N/A	N/A

Notes:

1. *Table sourced from: https://www.teururakau.govt.nz/funding-and-programmes/forestry/one-billion-trees-programme/direct-landowner-grants-from-the-one-billion-trees-fund/direct-grants-funding-categories-for-tree-planting/*
2. *The minimum application size is 5ha which can be made up of any combination of categories (an exemption is Native Planting where the minimum application size is 1ha)*
3. *Top-up cannot be used in conjunction with other top-ups*

Table 13: Forestry Cost & Profit per Hectare Estimate

Farming System	Growth Cycle (years)	Establishment Cost/ha	Operating Costs ($/ha/yr)	Product returns[2] ($/ha/yr)	Annualised ETS/CO2
Pine (Timber)	28	$750-$1500	$50	$1,200	Up to $498[3]
Christmas Trees	2-4	$4,300	$15,000	$1,70010	N/A
Native - Honey	50 – 60[7]	$6,000[1] + $715	Unknown[5]	$1000 [6]	$212[4]
Native – oil	7-8[8]	$6,000[1]	Unknown	$1,500[9]	$212[4]

Notes:

1. *Establishment cost estimated at $10,000/ha less the $4,000/ha government subsidy for native plantation. $715 /ha for honey production related establishment.*
2. *Based on expected sale price per hectare, net of harvest cost of timber or native honey or oil production.*
3. *Estimated up to $498 for the first 18-years of growth, for a new forestry venture and CO2e @ $25 /t, when averaged over a 28-yr rotation. Assumed $0 /ha after 18 years. Assumed $0 for existing forestry.*
4. *Estimated at $212 /ha, for a new or existing native forest planted after 1990 and CO2e @ $25 /t, when averaged over a 28-yr period (to enable comparison to pine).*
5. *Unknown due to the variability in honey harvest per hive and apiarists' costs.*
6. *Assuming 1 to 2 hives per hectare, yielding 30 kg honey/hive @ $40 per/kg for mid-quality honey, after 3 – 4 years growth.*
7. *Mānuka growth cycle, Kānuka can be expected to yield for longer.*
8. *Plants exceeding around 3 m in height become too difficult to harvest effectively.*
9. *Assuming a hectare yields 2.5 tonne of foliage at $600 a tonne*
10. *Assuming 70% of a hectare (2,000 trees/ha) sell at $12 a tree*

5.4.5.2 Exotic Forestry

The costs of the exotic forestry saw logging are expected to be the lowest of all assessed land use options. This is because the operational requirements for saw logging are relatively minor, restricted to planting, weed and pest control, pruning, thinning and felling operations spread over a 28 to 35-year rotational period.

Costs assessed for the saw logging option included:

- Initial cost of establishing the stand including fungicide.
- Cost of multiple pruning and thinning operations.
- Cost of temporarily removing and replacing irrigation lines for logging.
- Costs of saw logging.
- Transport costs associated with transport of product to sawmill.

For pine saw logging the initial capital costs are estimated to be approximately $750 to $1,500 /ha. With an average annual operational cost of $50 /ha, and an average annualised revenue from timber of $1,200 /ha, and potential ETS of approximately $498 /ha. Noting that this is an annualised income, as physical income would only be realised after harvest.

5.4.5.3 Christmas Trees

For the estimated income per hectare of a Christmas Tree plantation, it has been assumed that a hectare would be planted with 2,500 seedlings. The seedlings would be planted at 12 months and be harvested on average at 2 years old or about 6 ft. It has been assumed that each tree would be sold for approximately $12 dollars. As discussed in section 5.3.2 there are a number of variables when considering the cost and potential profit of a Christmas Tree plantation, one of the key factors being an assessment of the market demand given the accessibility of Raglan to larger markets (i.e. Hamilton).

5.4.5.4 Native Forestry

It is more challenging to quantify the cost/income estimate for native forestry, as it is considered more likely that the economic value would be linked indirectly to the intrinsic and biodiversity value of the forest, rather that direct products. If the native forestry was harvested/utilised for honey, mānuka honey prices depend principally on Unique Mānuka Factor (UMF/MGO)[30] content, ranging from $16/kg for low UMF®/MGO honey to $60+/kg for high UMF/MGO honey (Saunders, 2017). Honey yields for native forestry harvest generally range from 25-35kg per hive per year on average, and a typical expectation would be one hive per hectare. Mānuka honey yield generally occurs from Year 3 after planting

[30] MGO - methylglyoxal

and reaches its maximum at Year 6 after planting (Saunders, 2017). It is therefore a large financial outlay which precedes potential income by 3-5 years.

To achieve high UMF/MGO content the plantations would likely need to be >50 ha with well-placed hives to discourage the bees from travelling to more attractive nectar sources such as clover or gorse. (Saunders, 2017). At a minimum the plantation would need to be at least 40 - 50 ha to achieve a good UMF/MGO level. Table 13 details an estimated income range for honey sales.

There is also some commercial interest in the use of mānuka and kānuka in essential oils, however, the industry has not yet attained the marketable impetus of honey. Generally, plants exceeding 3 m in height become too difficult to harvest effectively. As a result, plantations are generally harvested for oil up to around 7 years old, they will generally produce 3-5 litres of oil per tonne of foliage harvested[31] (Saunders, 2017). Essential oil sold to the consumer typically is sold in small amount, for example 5 ml, this retails for around $105, to produce the 5 ml it requires approximately 500 g of dried mānuka, on a larger scale, approximately 50 kilos of mānuka foliage yields a minimum of 500 mls of oil.

Saunders (2017) discussed the income and costs of oil; "For generic mānuka oil, wholesale prices are around $500-600 per tonne of good quality foliage and oil production costs are around $400-450 per kg, but these values vary depending on oil properties and factors such as harvesting costs." Costs relate directly to the time it takes to harvest good quality foliage and harvesting comprises around 50% of production costs.

To increase the income potential of a native forestry plantation there would be potential to build a honey and oil producing plantation, however for the purposes of this assessment they have been assessed separately.

5.4.5.5 Intrinsic Value of Forestry

Forestry as a land use offers a higher intrinsic ecosystem service value[32] (indirect value) relative to other land uses. To illustrate the higher indirect value, AgFirst (2017) discuss the monetary value derived from the indirect value of forestry compared to dairying:

- Dairy: indirect value $404/ha (2006 value inflated to 2016 using the CPI = $493/ha)
- Forestry: indirect value $1,791/ha (2006 value inflated to 2016 using the CPI = $2,184/ha)

It is not stated whether or not the values refer to native or exotic forestry, for the purposes of this assessment it is assumed they refer to exotic forestry. Generally, it could be assumed that native forestry would have a higher intrinsic

[31] Harvest estimate not calibrated to Palmerston North region

[32] Intrinsic value is the value that an entity has, for what it is, or as an end.

ecosystem value than exotic forestry; particularly in terms of enhancing biodiversity. Mānuka/kānuka may also offer an ability to reduce atmospheric nitrous oxide emissions (Fitzgerald, 2012) and offer potential advantages in terms of nutrient and trace element management (Hahner, 2012). It could also be possible to use the native forestry for complementary industry e.g. honey production, but potential income from this has not been incorporated into this assessment.

5.4.6 Emissions Trading Scheme – Forestry

Native forestry has a lower ETS returned than exotic forestry, this is because it has a relatively slow growth rate, which means slow carbon sequestration. However, because the forest is not intended for harvest, 100% of the sequestered carbon is claimable through the ETS.

Whereas for the exotic forestry approximately 70% of the total amount of sequestrated carbon must be repaid at the time of harvest, or only the first 18 years claimed if the new averaging scheme is used. This is a result of the carbon that is released back to the atmosphere at harvest in the form of stump, slash and tree rot.

Due to the short nature of the Christmas Tree plantation it has been assumed that the ETS would not be applicable.

Table 14: ETS Income per hectare for carbon sequestered over 28 years

	Native	Exotic – Timber Plantation
Annualised[1]	\$216[2]	\$0 to \$498[3]

Notes:
1. *Based on carbon sequestered during a 28-year rotation, and CO2e @ \$ 25 /t.*
2. *For a 28-yr period, and assuming 100% of the carbon is claimable as the forest is not harvested.*
3. *For a new forestry venture, for the first 18 yrs. After this, or existing forestry, assumed at \$0 /ha due to carbon repayment liabilities for subsequent harvests, where carbon price fluctuation may present either profit or liability.*

5.5 Land Use Option 5: Non-Contact Consumptive Crops

PDP considers that both viticulture and orchards are a potentially viable land use option for the Raglan land treatment sites. However, for the purposes of the Section 5.0 Detail Land Use Assessment, only orcharding will be assessed.

5.5.1 Land Use Suitability

Orchards are common in the Waikato, for this reason it has been assumed that area will be suitable for orcharding. For the purposes of this assessment Feijoa trees will be considered, Feijoas can be considered as either warm climate or subtropical. (Te Arawa Primary Sector, 2019) Feijoa are adaptable trees that generally will grow and fruit well in most regions of New Zealand. The trees are frost-hardy and will handle temperatures as low as -10°C, although fruit will only tolerate down to -2.5°C. (Te Arawa Primary Sector, 2019) Cool winters and moderate summers are important to the fruit production and taste of Feijoa.

Feijoa trees will grow best in free draining, slightly acidic (pH 6.0-6.5) soils, they fruit best when exposed to full sunlight. Fruit trees tend to suffer yield penalties when the roots are waterlogged for extended periods as this can cause root rot. Most Feijoa varieties should be planted with pollinators, that is another Feijoa which have the same flowering times, variety selection and a planting plan are important to a successful Feijoa orchard. (Te Arawa Primary Sector, 2019).

Where rainfall is infrequent or irregular when planting Feijoa trees a regular water, supply is important. Once established the trees roots benefit from infrequent but deep watering to assist with fruiting.

To achieve non-contact irrigation, the Feijoa trees would need to be irrigated using drip irrigation or low-angle k-line. Another consideration for Orchards is the potential slope of some of the sites; steep slopes can also make pruning, mulching, and picking of the fruit harder and less efficient.

5.5.2 Land System Risk

One of the key risks associated with growing crops for human consumption purposes through non-contact irrigation is the risk of public perception of the food crops irrigated with treated wastewater, despite the high level of treatment achieved.

Any plant product produced and sold for human consumption must meet the requirements of the Food Act 2014 (The Food Act, 2014). In addition, all plant products sold as food in New Zealand must comply with New Zealand's Maximum Residue Levels (MRLs) for pesticides (MPI, 2020). These are established under Food Notice: Maximum Residue Levels for Agricultural Compounds to safeguard consumer health and to promote Good Agricultural Practice (GAP) in the use of insecticides, fungicides, herbicides and other agricultural compounds (MPI, 2020). This means that any fruit produced through non-contact irrigation, would be obligated to meet these standards, if the site's owner sought to sell the fruit for human consumption. Any fruit sold in New Zealand may also need to comply with other requirements, including maximum limits for heavy metals and microbiological contaminants (NZ Food Safety , 2020).

In addition to the market risk, there is also a potential risk to the trees and fruit from pests and disease. Generally, Feijoas are relatively pest and disease free. Leaf rollers, scale and thrips can attack Feijoas, and if severe attack occurs can be controlled with insecticides. Guava moth is also moving slowly down the North Island from Northland and currently has no wide-spread control.

5.5.3 Hydraulic Demand

Although feijoas are fairly drought tolerant they achieve best yields when irrigated, particularly in dry seasons. The most important times to irrigate are just before flowering and during fruit set. Depending on climatic conditions newly planted trees the maximum irrigation rate should not exceed 35 mm/week.

Feijoa provide a medium - high hydraulic capacity (1.05 AET/PET), similar to Forests, the AET/PET is associated with the high interception of rainwater when the foliage canopy is established. (FAO, 2019) Like the other land uses feijoa are likely to see a reduced hydraulic demand over the winter months when soil temperatures, sunlight hours and plant growth is reduced.

5.5.4 Phytoremediation (Nutrient Uptake)

Feijoas will generally demonstrate a positive yield response to nitrogen. However, nitrogen causes excessive vegetative growth which can result in a potassium deficiency causing fruit to drop, it can also cause the trees to produce more leaves and shoots than flowers and fruit. Nitrogen fertiliser should be avoided around fruit production time (Bloomer, 2009).

Table 12 below demonstrates the nutrient demand for feijoa trees over an 8-year lifespan. When compared to the other land use options, the nitrogen demand isn't as high. No research is available for nitrogen leaching of a feijoa orchard; however, it is not considered to be in the high range (Te Arawa Primary Sector, 2019).

Table 15: Nutrient Requirements for Feijoa[33]

Plant Age (years)	Nitrogen Uptake (kg/ha)	Phosphorus Uptake (kg/ha)	Potassium Uptake (kg/ha)
1	25	40	20
2	30	40	20
3	45	40	20
4	60	60	80
5	75	80	100
6	90	100	100
7	100	100	100
8	120	100	100

[33] Thorp 1996, as cited in (Reid, et al., 2006)

5.5.5 Land System Income Estimate

At a 3.5-4.5 m spacing, a hectare can be planted with 500-600 feijoa trees. By year three the plant should yield approximately 2 kg of fruit, doubling each year until providing 20–25 kg of fruit. A feijoas grower's typical infrastructure setup may include packing shed, cooling room, implement shed, irrigation, shelter belts, fencing, mower, sprayer, and miscellaneous equipment (Te Arawa Primary Sector, 2019).

Depending on the degree to which existing infrastructure can be re-used, set up costs may run up to $50,000 per hectare. Potential returns will depend on the number of trees planted, how well the fruit can maintain a premium quality, and the state of the market. Very approximate gross return for 600 trees per hectare: 20 kg fruit/tree at $2/kg x 600 trees = $24,000/hectare (Te Arawa Primary Sector, 2019).

Aside from the potential sale of the feijoas, there could be potential for projects such as community gardens, or open orcharding for the local community to harvest, and utilise the fruit or to donate to local food banks. Community garden type projects have a history of achieving funding from local and central government funds to assist with the development.

5.5.6 Emissions Trading Scheme – Non-Consumptive Crops

To qualify as a forest under the ETS, one of criteria is that the forest species reach at least 5 m in height when mature. The ETS specifies that this does not include trees grown primarily for fruit or nuts, this means there is no ETS obligation or benefits for orchards (MPI, Growing and Harvesting , 2020).

6.0 Bio-Solids Application Suitability

Municipal biosolids are rich in nutrients and can be applied to land to fertilise plants and improve the quality of soil. Ongoing generation of biosolids is only expected for the MBR treatment option, as this relies on a suspended growth activated sludge.

With different management and application methods the cut and carry, forestry and non-consumptive crops land uses could all have bio-solids successfully applied. For pastoral grazing management of the application rate would be essential to ensure that potential risks to human from the meat & milk and animal health is mitigated. Application to pastoral grazing may be restricted by regulations or standards imposed from purchasers of the meat and milk. Applications of biosolids should be made with careful consideration of any possible impact on the soil microorganisms, the crop's nutrient demands and any regulatory standards or requirements.

Table 16: Suitability for Application of Biosolids

Land Use	Biosolids Suitability
Grazed Pasture	Suitable as a slurry application with careful consideration of end product quality assurance standards and animal health.
Lucerne	Suitable as a slurry application
Maize	Suitable as a soil conditioner
Sunflowers	Suitable as a soil conditioner
Native Forestry	Suitable - must be planted to enable vehicle passage for spreading
Exotic Forestry - Timber	Suitable - must be planted to enable vehicle passage for spreading
Exotic Forestry – Christmas Trees	Suitable - must be planted to enable vehicle passage for spreading
Orchard	Suitable as a soil conditioner at establishment
Hemp	Suitable as a soil conditioner
Rapeseed Oil	Suitable as a soil conditioner
Vetiver	Suitable as a slurry application

7.0 Summary

Five primary land use options have been assessed as potential land uses for the third-party owned site identified as potential sites for reuse of wastewater through land treatment in Raglan. The land uses assessed were; pastoral grazing, cut and carry, forestry, and non-contact consumptive crops and non-consumptive crops, with each containing secondary crop/grazing assessment.

Below is an overall ranking of the technical land use favourability, most favourable (1) to least favourable (6).

Table 17: Land Use Options - Technical Preferability Ranking

Rank	< 15 Degrees Slope	> 15 Degrees Slope
1	Cut & Carry – Lucerne, Maize or Sunflowers	Forestry – Exotic/Native
	Non - consumptive crop: Hemp	
2	Forestry – Exotic/Native	Pastoral Grazing – all types
3	Pastoral grazing	
4	Non - consumptive crops: Rapeseed & Vetiver	Non-contact consumptive, Non-consumptive land, Cut & Carry uses are not considered practicable due to the slope
5	Non-contact consumptive	

Pastoral Grazing

Pastoral grazing is considered as one of the least effective land uses. This is primarily due to; recycling of soil nutrients from livestock, lower hydraulic demand, vulnerability to market factors, and high managerial demands.

Pastoral grazing has been ranked higher than non-contact, cut & carry and non-consumptive land uses only on the basis that harvest of the + 15-degree land treatment sites would be inefficient.

Cut and Carry

Cut and Carry is considered viable for the < 15-degree land treatment sites only. For the + 15-degree, ability to harvest is not considered practicable due to the topographic slopes of these area (without specialised slope machinery).

Cut and Carry as a land use option offers a relatively low maintenance system and has generally high nutrient uptake rates. Of the three cut and carry options – Lucerne, Maize and Sunflowers - Lucerne is likely the favoured option due to the lower managerial requirements and its greater versatility for various types of irrigation systems. Maize and Sunflowers would have downtime in between crops where nutrient uptake would cease. There is potential for the three cut and carry crops to be grown in rotation together. The estimated profit margin per hectare is also presently lower for maize and sunflowers than for lucerne.

Forestry

Both exotic and native forestry were considered viable. Both forestry options are long-term investments, meaning that limited return/income will be realised from the capital input until harvest (exotic), or potentially no direct harvest income if there is no harvest (natives).

Exotic forestry particularly saw logging of Pine on a 28-year rotation, offers a clear tangible income in terms of the timber sales and potentially the ETS. For a newly established forestry, a per hectare pine forestry ETS return example, equates to circa $500/ha/yr for the first 18 years after establishment (at present estimated carbon price, using the new carbon averaging scheme). Further potential return after that period are more difficult quantify. However, carbon price fluctuation may alter this income up or down. Additional to potential ETS income is the sale of the timber, with returns subject to the market of the day but present estimate of circa $30,000 /ha. Other end markets e.g. biofuel production, may form an alternative option to timber production.

Christmas Tree plantations also offer a high per hectare income, the labour demand and intensity of care needed for the plantations would need to be offset by an available market. The potential income from a Christmas Tree plantation, if the plantation was planted in hectare blocks, and 70% of one of these blocks was sold annually it equates to $33,200 /ha. The income is estimated based on the assumption that the third-party land treatment site owner is able to secure an available market for the Christmas Trees without having to transport the product, therefore increasing the costs.

Native forestry offers potentially significant intrinsic value. However tangible economic income pathways were more challenging to determine. Income potentially in the form of a hive placement/lease rights to a third party is one that could provide good returns, estimated at $1000 /ha/yr, and potentially more if the honey has a high UMF grade. There is also potential for the native forestry to be harvested for essential oil, essential oil production has the potential to provide a good return of up to $1,500 /ha/yr.

In terms of ETS income, Native forestry has a lower return than exotic forestry, this is because it has a relatively slow growth rate which means slow carbon sequestration. ETS income was estimated to be approximately $216/ha/yr (averaged over a 28-year period to be comparable to a timber harvest for pine).

Non-Contact Crops – Orchards

Non-contact crops irrigated through systems such as Drip irrigation, were considered as the least favourable option for the < 15-degree slope land treatment sites. This was on the basis that the nutrient uptake of the fruit trees wasn't as high as the other land use options, the establishment cost per hectare of the orchard was high relative to the increased market risk in terms of irrigating wastewater to product destine for human consumption.

Similarly, for the > 15 degree slopes the same (potentially increased due to the slope) establishment costs and market risk exist. However, this is in addition of the added inefficiencies of a sloped orchard, increasing the labour and infrastructure demands.

Non-Consumptive Crops

Non-consumptive crops are considered practicable for < 15-degree slope land treatment sites only. This is because without highly specialised machinery, the ability to harvest the non-consumptive crops such as Hemp and Rapeseed is not considered practicable due to the topographic slopes of these area. Vetiver, if hand planted and harvested could be grown on the > 15-degree slopes, this would however be highly labour intensive.

Hemp – Unlike Rapeseed and Vetiver, Hemp has been suggested as one of the more suitable options for the sites < 15 degrees. This is because Hemp has a high nutrient demand and is relatively easy to grow in terms of managerial expertise. Hemp does carry risk in terms of profitability due to the processing of the crop however, it provides a number of end-uses, including consumptive uses (not assessed in this report) there are a number of value-add opportunities with Hemp that has contributed to its place in the preferability ranking. Although, the uncertainty around processing and the newness of the crop to New Zealand are important factors to acknowledge.

Rapeseed - To produce a successful rapeseed crop is it likely that additional nitrogen fertiliser would be required, the amount of additional fertiliser required will impact of the gross profit margins, particularly if an additional tax is added to nitrogen fertiliser. In NZ currently there are few biorefineries with the capability to process rapeseed into biodiesel, however this could present an opportunity to develop a market and a processing industry.

Vetiver – For nutrient uptake and remediation purposes of the wastewater, Vetiver offers exceptional nitrogen uptake. In New Zealand, in terms of growing Vetiver for commercial purposes such as essential oil production the climate and growing condition may not be sufficiently conducive of sustaining the growth rates to most of the Vetiver grown in New Zealand appears to be grown for the purposes of erosion and sediment control purposes, not necessarily for essential oil harvest. If the third-party land treatment site owners had access to or were able to distil and produce their own essential oil from the vetiver harvest, there could be potential to sell to the local market.

Table 18 below provides a comparative summary of the technical land use assessment.

Land Use Assessment Summary Table

Criteria	Option 1: Grazed Pasture	Option 2a: Non-consumptive: Hemp	Option 2b: Non-consumptive: Rapeseed, Biofuel	Option 2b: Non-consumptive: Vetiver	Option 3a: Cut & Carry: Lucerne	Option 3b: Cut & Carry: Maize	Option 3c: Cut & Carry: Sunflowers	Option 4a: Native Forestry Oil & Honey	Option 4b: Timber Plantation	Option 4c: Christmas Trees	Option 5: Non-Contact Consumptive: Orchard
Soils & Environment Suitability	Common land use to the area, proven to perform well. Not necessarily limited by slope.	Suited to well-structured soils.	Most suited to well-structured soils, has a deep rooting system and grows well on a wide variety of well-drained soils. Crop is useful increasing aeration in subsoils because of the root system	Excellent nutrient uptake, hardy plant, well suited to most growing environments	Lucerne doesn't perform well on heavy, waterlogging (or prone to) soils, it will perform better on free draining, light textured soils.	Maize performs well on a wide range of soil types; provided soil water and nutrients are not limiting, does not perform as well on slopes.	Sunflowers are typically considered a restorative crop help in maintaining the fertility and structure of the soil.	Can be established on essentially all soil types in the region, including the steep slopes.	Forestry has been proven to perform in the area.	Forestry has been proven to perform in the area.	Orchards are common in the Waikato - Feijoa are adaptable trees that likely will grow and fruit well
Likely Treatment Required	Existing Ponds	MBR/ultrafiltration or Existing Ponds	Existing Ponds	Existing Ponds	Existing Ponds	Existing Ponds	MBR/ultra filtration	Existing Ponds	Existing Ponds	Existing Ponds	MBR/ultrafiltration
Hydraulic Demand - AET/PET Ability Comparison (1)	Medium	High	Medium	High	High	High	Medium	High	High	High	Medium
Hydraulic Demand (AET/PET)	1.00	1.25	1.07	1.20	1.20	1.20	1.15	1.20	1.20	1.20	1.05
Relative Nitrogen Demand	Medium	High	High	High	Medium	Medium	Medium	Medium	Medium	Medium	Low
Nitrogen Leaching Loss kg N/ha/yr	Sheep & Beef: 6 - 50 Dairy: 20 - 150 Deer: 6 - 50	Unknown	15 - 23	Unknown	80 - 150	Unknown	Unknown	5.7 - 10.4	1.2 - 2.7	1.2 - 2.7	Unknown - considered to be low
Irrigation System	Few limitations - can be irrigated with k-line, pivot etc	Likely limited to centre pivot	Likely limited to spray e.g. centre pivot	Few limitations - can be irrigated with k-line, pivot etc	Few limitations - can be irrigated with k-line, pivot etc	Likely limited to centre pivot	Likely limited to centre pivot	Limited to drip or solid set irrigation	Best suited to drip or solid set irrigation	Best suited to drip or solid set irrigation	Must be low-line irrigation e.g. Drip
Establishment Cost	Medium - High	Medium	Medium	Medium	Low	Medium	Medium	Very High	High - Very High	Medium - High	Very High
Estimated Annual Land-Use Income $/ha	Sheep & Beef: $200 - $500 Dairy: $1,500 - 3000 Deer: $200 - $500	$1,000 - $5,000	$1,000 - $4,499	$500 - $1,000	$10,000 - $12,000	$2,00 - $3,000	$3,100	$1,000 - $1,500 (5)	(4) Pines: $1,200 (28 year rotation)	$1,700	$24,000
Bio-Solids Suitability	Suitable as a slurry application with careful consideration of end product quality assurance standards and animal health.	Suitable as a soil conditioner	Suitable as a soil conditioner	Suitable as a slurry application	Suitable as a slurry application	Suitable as a soil conditioner	Suitable as a soil conditioner	Suitable - must be planted to enable vehicle passage for spreading	Suitable - must be planted to enable vehicle passage for spreading	Suitable - must be planted to enable vehicle passage for spreading	Suitable as a soil conditioner

Land Use Assessment Summary Table

Criteria	Option 1: Grazed Pasture	Option 2a: Non-consumptive: Hemp	Option 2b: Non-consumptive: Rapeseed, Biofuel	Option 2b: Non-consumptive: Vetiver	Option 3a: Cut & Carry: Lucerne	Option 3b: Cut & Carry: Maize	Option 3c: Cut & Carry: Sunflowers	Option 4a: Native Forestry Oil & Honey	Option 4b: Timber Plantation	Option 4c: Christmas Trees	Option 5: Non-Contact Consumptive: Orchard
Nitrogen Fertiliser Tax $/ha (2)	$0.00	-$0.41	-$1.72	$0.00	$0.00	-$0.20	$0.00	$0.00	$0.00	$0.00	$0.00
ETS/CO2 returns ($/ha/yr) (3)	Sheep & Beef: -$4.0/ha/yr Dairy: -$12/ha/yr Deer: Unknown	Null	Null	Null	Null	Null	Null	$216 /ha/yr	$498 /ha/yr	Null	Null
Overall Pros	Proven land use in the region.	Greatest hydraulic capacity of the options assessed.	Will provide good ground cover and continue to grow well over winter when other crops may slow/halt growth.	Hardy plant, able to be grown in most environments and conditions.	Proven land use in the region, performs well in drought prone conditions.	Proven crop in the region.	Restorative crop, helps in maintaining the fertility and structure of the soil	Existing vegetation in the region, suitable for steep land treatment sites	Proven performer in the region, suitable to steeper slopes.	Proven performer in the region	Orchards are common in the Waikato, Feijoas in particular are hardy and likely suited to Raglan area.
	When actively growing pasture has a reasonable N uptake	Excellent crop for nutrient uptake (phytoremediation)	Good nitrogen demand/uptake, provides good soil cover over winter.	Excellent for nutrient uptake (phytoremediation)	Good nitrogen demand/uptake, atmospheric and wastewater nitrogen should be sufficient for a good yields	Good nitrogen demand/uptake and removal when silage is cut	Good nitrogen demand/uptake and removal when crop is cut	Early studies are showing promising results for manuka's ability to reduce nitrate leaching	Good storage of nitrogen and carbon within the woody biomass	Good uptake of nitrogen, highest years of N uptake in pines are optimised	
	Market demand for meat, milk and fibre	Versatile crop, multiple end uses.	Alternative markets to biofuel for non-consumptive oil production exist such as seed production		Good market demand for silage produced. Could be worked in with a pasture rotation for pasture cut & carry.	Good market demand for maize silage. Could be worked in with a pasture rotation for pasture cut & carry.	Potential for dual use - sunflower oil and sunflower meal for supplementary feed for animals.	High intrinsic value & contributes to the region's biodiversity. Possible income from leaf oil extraction or honey production.	Timber sales, carbon sequestration and ETS income	Potentially high per hectare income	
Overall Cons	Additional risk due to the interdependent relationship between management, product and the market.	Limited to < 15 degrees sites	Limited to < 15 degrees sites	Not (or rarely) grown in NZ for commercial purposes, tends to be for erosion or sediment control	Limited to < 15 degrees sites	Limited to < 15 degrees sites.	Limited to < 15 degrees sites		Yield may be impacted by soils with poor drainage.	Difficulty of Raglan's location in securing a reliable 'gate sale' market. Transport of trees would decrease profit margins	High per hectare establishment cost, not an immediate return on investment

Land Use Assessment Summary Table

Criteria	Option 1: Grazed Pasture	Option 2a: Non-consumptive: Hemp	Option 2b: Non-consumptive: Rapeseed, Biofuel	Option 2b: Non-consumptive: Vetiver	Option 3a: Cut & Carry: Lucerne	Option 3b: Cut & Carry: Maize	Option 3c: Cut & Carry: Sunflowers	Option 4a: Native Forestry Oil & Honey	Option 4b: Timber Plantation	Option 4c: Christmas Trees	Option 5: Non-Contact Consumptive: Orchard
	Urine patches particularly from cattle and uneven return of nutrients to soil and excessive nutrient leaching.	Downtime after harvest increasing possibility of nitrogen losses. After harvest mgmt will impact on any resulting nutrient leaching.	Must be implemented in a rotation. Downtime after harvest increasing possibility of nitrogen losses	Likely limited to < 15 degrees sites if grown for harvest. If not harvested would suit > 15 degree land treatment sites.	Growth will likely reduce in winter meaning seasonal yield will be variable.	Would likely need to be grown in a rotation and therefore would have downtime in between harvests and sowings	Would likely need to be grown in a rotation and therefore would have downtime in between harvests and sowings	Slow growing & lower carbon sequestration rate than exotic species			Nitrogen uptake per hectare isn't as high as some of the other land uses.
	Public perception of milk & meat produced using treated wastewater irrigation	Highly regulated, annual licensing and regular testing is required.	Ensuring a market/biofuel refineries processing the crop into biofuel may be challenging.	Challenging to grow enough supply to generate an economic export product without distilling own oils.		Would likely require additional nitrogen fertiliser to obtain optimal yields.		Long-term investment, uncertain income, high cost of establishment, slow growth rate	Long-term investment	Relatively labour intensive, likely limited to < 15 degrees sites due to the labour requirements	Public perception of product produced using treated wastewater irrigation

Notes:

1 *AET/PET = Actual Evapotranspiration / Potential Evapotranspiration. Based on "mid-season stage" of the peak production/growth period for land use.*

2 *Crops do not directly emit greenhouse gases or sequester carbon meaning that there is no explicit GHG cost, or benefit, in cropping. Costs are calculated based on the possible urea fertiliser tax that the carbon-zero legislation proposes. Assumed a 5% liability.*

3 *Positive number generates ETS income, and a negative number is a cost in the form of tax.*

4 *Includes annually averaged income from Timber sales*

5 *Estimated income, likely to be variable*

8.0 References

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