Uruti
Remediation NZ Ltd
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Uruti Composting Facility: Nitrogen Balance

Overseer Nitrogen Modelling

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Client: Remediation NZ Ltd

Co No.: 2145171

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1	30-Aug-2019		Timothy Mulliner Team Leader – Geoscience & Remediation Services	
2	13-Sept-2019	Updated Irrigation Areas	Timothy Mulliner Team Leader – Geoscience & Remediation Services	

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Executive Summary

Remediation NZ Ltd operates a facility in Uruti which processes a variety of organic material and drilling mud. AECOM New Zealand Ltd (AECOM) have been engaged to undertake an investigation into the nitrogen loading and losses across the site.

Runoff/leachate from two composting pads is collected, processed and applied as irrigation to areas on site. Compost is also applied to these areas. All other material processed on site is removed in composted forms with runoff treated via wetlands. It was determined that the irrigated areas are the significant source of nitrogen losses from the site.

'Overseer' is a modelling package which was developed as an agricultural management tool. It analyses the nutrient loading versus losses to advise farming yield optimisation. It was determined that this is an appropriate tool to provide an estimate of nitrogen loading and losses across the Uruti site.

Under 2019 (current and projected) operating practices the total nitrogen loading over the irrigation areas was determined to be 7550 kg/year, with a loss – to leaching and runoff of 3574 kg/year. Therefore, approximately 50% of the nitrogen applied to the irrigation areas is lost to groundwater and/or surface water. The modelled leachate concentrations are in line with recently collected groundwater and surface water analytical data. The modelled nitrogen leached from the site between 2018 and 2019 scenarios decreased by 21%. This is due to the greater irrigation area facilitating additional removal of nitrogen as plant matter. A 'best-case' modelled scenario is presented in which a change to current management practises has the potential to reduce the nitrogen leached (compared to the current 2019 scenario) by an additional 64%.

Model sensitivity analysis shows that an increase in irrigation area, increase in production (in the form of removal of hay bales) and decrease in compost application all have a noticeable effect on decreasing the volume of nitrogen leached from the site. Recommendations to improve the accuracy of the model and decrease the volume of nitrogen leached are outlined.

1.0 Background

1.1 Uruti Composting Facility

Remediation NZ Ltd operates a facility in Uruti which processes a variety of organic material and drilling mud. The site is located on the west coast of New Zealand's North Island, approximately 40 km north-east of New Plymouth. The site spans approximately 625 ha comprised mostly of bush and cattle grazing areas. The operational areas pertinent to the composting activities are located within the valley floor.

Hydrological features of note include; Haehanga Stream which passes through the site, and a shallow ground water table at approximately 0.5-0.75 m below ground level (BTW, 2015).

The facility consists of three main processes:

- Pad 1: organic material is composted before being applied to areas on site.
- Pad 2: paunch is composted before being processed by worm beds. The final product (vermicast) is removed from site.
- Pad 3: drilling waste is mixed with organic matter. The volume of drilling waste processed is variable and dependent on the drilling program. The product (soil conditioner) is applied to areas onsite, ie. bunding.

The leachate/runoff from Pad 1 (organic material) and Pad 3 (drilling waste) is collected and processed through three treatment ponds. This treated leachate is applied to land onsite along with compost from Pad 1. These irrigated areas produce hay which is harvested and either removed from site or used in the composting process. The irrigated areas are separate from the grazed areas.

The site layout is shown Figure 1 and the total block areas are summarised in Table 1.

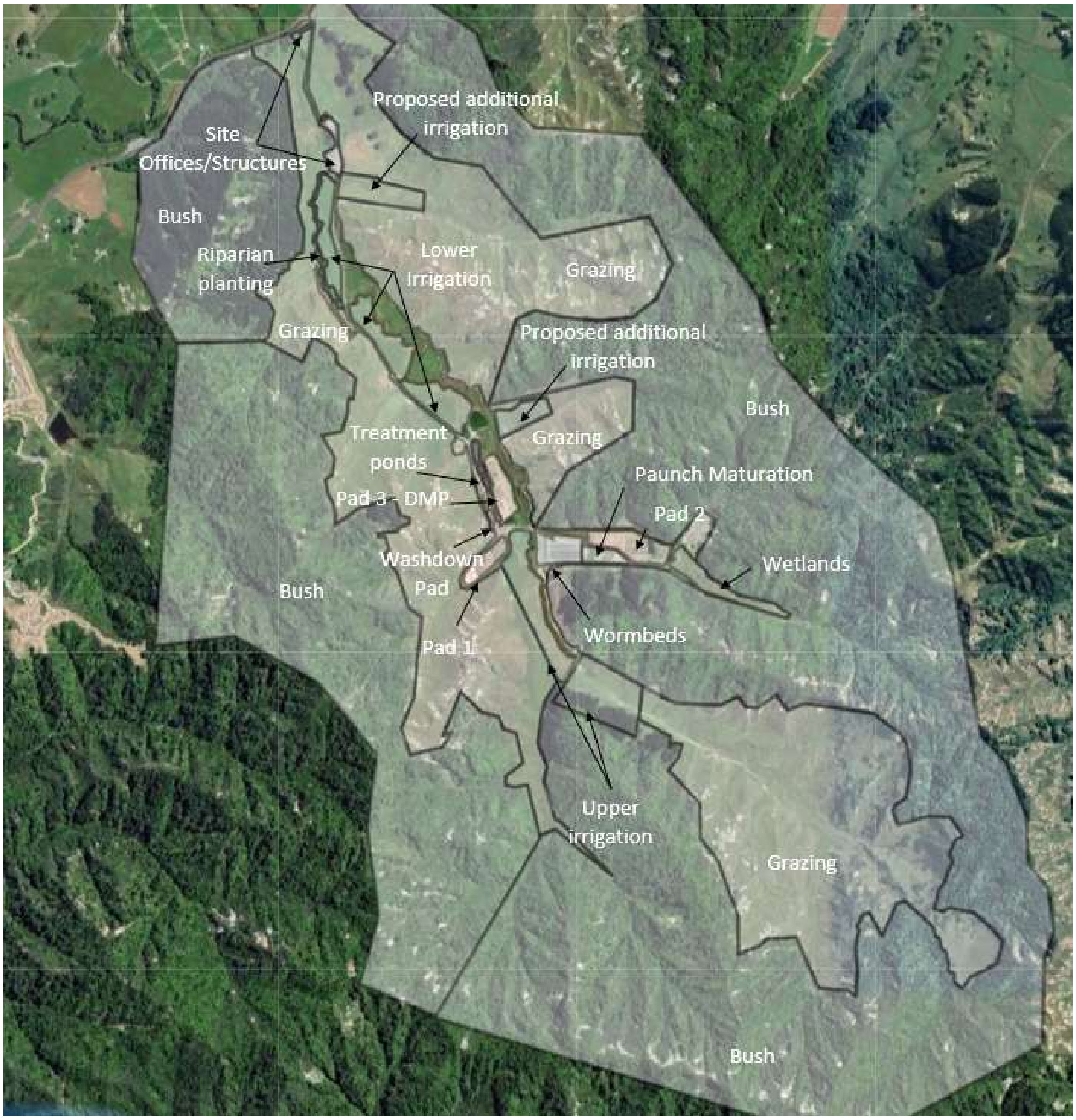

Figure 1 Site Overview

Table 1 Site Area Breakdown

Block	Area (ha)
Grazed Land	166.8
Lower Irrigation	5.2
Upper Irrigation	5.3
Proposed Lower Irrigation	2.0
Proposed Upper Irrigation	1.5
Pad 1	0.8
Pad 2	1.7
Pad 3	1.1
Paunch Maturation Area	0.6

Washdown Pad	0.1
Worm Beds	1.2
Treatment Ponds	0.4
Wetlands	1.6
Bush	431.5
Riparian Planting - Lower Irrigation	0.5
Site Offices/Structures	0.6

Refer to Appendix A for a flow diagram identifying site processes, inputs and outputs.

AECOM NZ have been engaged to undertake an investigation into the nitrogen loading and losses across the site. The goal of this investigation is to provide information to enable Remediation New Zealand Ltd. to predict the effects of current and future site management practices on nitrogen loadings and losses throughout the site.

1.2 OverseerFM Software Overview

Overseer is a modelling package which was developed as an agricultural management tool. It analyses the nutrient loading versus losses to advise farming yield optimisation. Seven nutrients are considered; nitrogen, phosphorus, potassium, sulphur, calcium magnesium and sodium. The aim of the model is to provide a ‘nutrient budget’ which summarises the elemental mass balances across the farm by taking into account soil properties and processes, climatic variables and farm management practices relevant to the site.

It was determined that Overseer is an appropriate tool to provide an estimate of nitrogen loading and losses across the Uruti composting site. While the site is not exclusively a farm, Overseer was selected due to its ability to model complex relationships between nitrogen pools accounting for plant growth, runoff, irrigation, soil properties etc. The composting processes occurring on the pads are not required to be investigated in detail because the primary focus is the nitrogen application to land. The locations of interest are the irrigated areas receiving concentrated nitrogen loads via irrigation and compost.

Overseer accounts for the following relevant parameters:

- ‘Blocks’ categorise areas of the site. Key block types include; crops, pastures, wetlands, trees and scrub, riparian planting and buildings.
- Climate data is taken from NIWA 30-year averages according to the block locations. Data accounted for includes temperature, rainfall, annual potential evapotranspiration (PET) and snowfall.
- Soil data is required to reflect the soil order, group, drainage and other properties for the topsoil and lower profile. Soil tests provide block-specific nutrient compositions.
- Drainage through wetlands and riparian planting accounting for the condition and types of plants, catchment flow distribution, convergence and depth.
- Pasture/crops grown according to plant type, dry matter yield, animal intake, runoff characteristics, topography and annual rotations.
- Animals farmed accounting for stock numbers, distribution, types, grazing off proportions and yields.
- ‘Supplements’ detailing crops harvested and removed from site accounting for the plant type, amount and annual harvest events.
- Fertiliser applications detailing type, nutrient data and monthly application loading.
- Irrigation systems including type, monthly loading, area irrigated and nutrient composition.

The model output reports the total nitrogen losses from the root zone with a breakdown of monthly compositions of the nitrogen pools. Of note to this investigation, the nitrogen pool breakdown outlines nitrogen movement from fertiliser/irrigation to leaching, plant uptake and volatilisation.

Overseer does not account for nutrient losses in the vadose zone (between the root zone and receiving water body). Therefore, there is no distinction made between nitrogen leaching to groundwater versus leaching to Haehanga Stream. Other parameters excluded from the model are sediments and pathogens. For the purposes of assessing overall nitrogen losses from the site, these limitations are not significant. ‘Nitrogen loss’ throughout this report refers to nitrogen entering groundwater and/or surface water.

2.0 Data and Assumptions

2.1 Data Input

Three scenarios were modelled to analyse the facility operating practices in 2018 compared to current and predicted practises in 2019. An additional scenario explores the impact of a ‘best-case’ scenario based on recommendations and what is understood to be technically feasible in the short term (1-2 year period). Aside from the changes outlined, all other site management practises remain as current in the best-case scenario; therefore additional improvements in management practises are feasible and would likely have an additional positive effect (in terms of nitrogen leaching) compared to the ‘best-case’ presented here. All scenarios modelled are outlined in Table 2.

Table 2 Irrigation Area Scenarios – Farm Practises

Area	Scenario		
	2018	2019	Best-Case
Upper Irrigation (5.2 ha)	Area not yet developed	Irrigation applied evenly over upper and lower areas 300 hay bales removed Compost from pad 1 applied to upper area	Irrigation aerated – assumed 20% N volatised 450 hay bales removed No compost applied
Lower Irrigation (5.3 ha)	All Irrigation applied to lower area 200 hay bales removed Compost from pad 1 applied to lower area	Irrigation applied evenly over upper and lower areas 200 hay bales removed	Irrigation aerated – assumed 20% N volatised 300 hay bales removed No compost applied
Proposed Additional Irrigation (3.5 ha)	Area not yet developed	Area not yet developed	Irrigation applied evenly over upper, lower and additional areas

Data was entered into the Overseer model as outlined in Table 3.

Table 3 Overseer Data Input

Overseer Section	Notes
Blocks	Blocks were drawn according to; maps, notes from site visit, and Remediation NZ Ltd Monitoring Programme Annual Report Figure 2.
Climate	Overseer defaults according to latitude and longitude - no changes.
Soil	
Farm Soils	No S-Map data for the area was available (Overseer's default source for soil classification). Soil data was input as; order = Brown, soil group = sedimentary (as per BTW, 2015), section 2.3.1). Model sensitivity to soil drainage class and topsoil texture was investigated. Soil drainage class = poor. Topsoil texture = silt loam. Stony = no. No root barrier depth assumed. Drainage impeded layer assumed at 20cm for lower area and 100cm for upper area (BTW, 2015).
Soil Tests	Soil test data from 12-04-2019(Remediation NZ, 2019). Grazed land uses default soil parameters from Overseer.
Drainage	Treatment ponds for Pad 1, Pad 3 and the washdown pad were modelled as a fenced wetland, aquitard depth of 2-3 m (as per 'drilling mud effluent pond system volumes' document). Moderate catchment convergence assumed. Wetlands for Pad 2 were modelled as a fenced wetland, aquitard depth of 1-2 m. Moderate convergence assumed. All of Pad 2 was assumed to drain to wetland. Riparian planting for lowest section of the lower irrigation block was modelled as a strip along Haehanga stream from the culvert at the road to the site office. Planting was assumed as 1 year old 'trees/shrubs/flax'. All surface flow from the catchment was assumed to interact with the strip. No drainage methods assumed for grazed land and irrigation areas.
Pasture/crops	Grazed land assumed; 'easy hill', 'unimproved/tussock grasslands', cultivated in the last 5 years, animals are present on this block. Runoff characteristics; 'generally soaks in, occasionally runs easily off slopes'. Rare susceptibility to pugging. Is not compacted. Naturally high water table (<0.75 m from surface in water) in accordance with BTW 2015. Lower irrigation assumed; 'flat topography', 'grass only', cultivated in the last 5 years, no animals present. Upper irrigation assumed the same as lower.
Animals	Beef/dairy grazing; RSU stock numbers method, 100% male, 200 total RSU. 25% breeding stock grazed off in Aug, 25% Sept. No feed/health supplements. Dairy; Stock reconciliation stock numbers method. 23% breeding replacement per year (Overseer default). Milk solids taken as 2150 kg/year. 50 cows for Jul-Sep. Friesian breed assumed (common NZ breed). No feed/health supplements. Animals only assumed to be on the grazed land - not irrigated areas.
Structures/effluent	No dairy effluent system.
Supplements	Hay harvested from lower and upper irrigation areas. All distributed offsite. Bale sizing assumed round, 220 kg DM/bale. Harvested in Feb (although harvest season does not impact model).

Fertiliser	Compost; modelled as 'custom organic fertiliser', 'compost/mulches', 60% dry matter, 1% N, 0.5% P, 0.5% Na - data from Uruti compost analysis (19th July 2019 letter to Taranaki Regional Council). 1000 m^3/year applied, this was converted to 42 ton/month calculated from an assumed bulk density of 500 kg/m^3. Irrigation pond nutrients; modelled as 'custom soluble fertiliser'. The loading of nutrients in the irrigated water was calculated on a monthly basis. Due to irregular sampling of the irrigation pond and a large range of nitrogen concentrations, a relationship was determined between the nitrogen concentration in the pond and the rainfall 30 days prior to the sampling event. This was based on 7 ammoniacal nitrogen concentrations measured between October 2017 and April 2019. The relationship has an R^2 value of 74%. Using this relationship, the monthly rainfall from 2018 was used to calculate monthly nitrogen concentrations in the pond. The concentration was converted to a loading rate in kg/ha/month based on the volume irrigated (calculated from 2018 irrigation hours and an application rate of 30 m^3/hour as specified by Remediation NZ). It was assumed irrigation is applied evenly over the entire irrigation areas. Refer Appendix B for irrigation nutrient loading calculations.
Irrigation	Irrigation loading calculated as 'depth per application' on a monthly basis (using 2018 + 2017 recorded irrigation hours and an application rate of 30 m^3/hour as specified by Remediation NZ). Ratio of $\text{depth}_{\text{applied}}$:$\text{depth}_{\text{per application}}$ was determined within the Overseer model and used to ensure the depth 'supplied' was accurate. Note that nutrients from the irrigated water were modelled in the 'Fertiliser' section as per Overseer Best Practice Data Input Standards v 6.3.0, recommends 'fertigation' to be modelled as fertiliser as opposed to irrigation.
GHG	Defaults not overridden.

2.2 Limitations and Sensitivity of Model

2.2.1 Overseer Report Interpretation

While Overseer reports many parameters, only information relating to nitrogen loading over the irrigated areas should be assessed for this project.

The entire site was geographically included in the model, however the complex and unique composting processes occurring could not be accounted for by the agricultural-focused modelling package. The only composted products applied to the site (irrigation areas) are the leachate and runoff from pads 1 and 3, and the compost from pad 1. These product compositions were accurately represented in the Overseer model data inputs. All other products from the composting processes are removed from site, other than the runoff/leachate from pad 2 which is assumed to be adequately processed by the wetlands. Therefore, the focus of the model was the irrigation areas. Other reported data from Overseer should not be relied on in this instance.

It was determined that varying the loading of other nutrients has no impact on the nitrogen losses reported by Overseer. Therefore, it can be concluded that nitrogen modelling occurs independently of other nutrient data inputs in soil tests and fertiliser/irrigation compositions. Sampling data was still included in the model for a variety of nutrients, however where there was no information available for particular nutrients it was concluded to be irrelevant to the aim of nitrogen investigation. Therefore, because nitrogen was the focus of the modelling process, the information reported about other nutrient loading should not be relied on.

2.2.2 Soil Classification Effect

The sensitivity of Overseer to the classification of soil drainage properties was investigated to assess the impact on nitrogen losses modelled.

The topsoil texture options investigated were; silt loam, sandy clay loam, clay loam and silty clay loam. The change in total nitrogen loss across the site was found to vary less than 1% across these options. This determined it was not a key parameter for the model.

Drainage class options (well, moderately well, imperfect, poor, very poor) were also investigated. The change in total nitrogen loss across the site was determined to vary less than 1% across these options. Similarly, to topsoil texture, this was determined to not be a key parameter for the model.

2.2.3 Irrigation Loading Uncertainties

The irrigation loading rates are a key component of the model, therefore the sources of uncertainty should be considered. Key sources of uncertainty include;

- The relationship developed to model the nitrogen concentration in the irrigation pond with respect to rainfall from 30 days prior. There are many factors which contribute to the concentration of nitrogen sampled in the irrigation pond which could not be accounted for by this simple correlation. Other factors may include the composition and volume of compost, ambient temperature, agitation of material, etc. The correlation to rainfall from 30 days prior is a strong relationship but could be improved with more sampling points. It should also be noted that some nitrogen concentrations calculated using this relationship extrapolate beyond the extent of the raw data. The raw data, equation parameters, and calculated values are outlined in Appendix B.
- Inorganic nitrogen was the only form included in the irrigation pond nitrogen concentration calculations. Ammoniacal nitrogen (NH_4) was the main form contributing to this concentration, as nitrite/nitrate (NNN) forms comprise at most 0.1% (0.02% average) and un-ionised ammonia (NH_3) contributed at most 3.6% (2.8% average). Total kjeldahl nitrogen (TKN) has not been sampled for long enough to inform a correlation. A longer period of TKN sampling may improve the model's representation of the site.
- Monthly irrigation hours were provided by Remediation NZ for 2018, however a single year's data may inaccurately represent trends over longer time periods.
- Irrigation hours were assumed to deliver a constant application rate (30 m^3/hour) which may be oversimplifying the actual loading. The irrigator's distance from the pond is likely to impact the loading rate due to an increased pressure drop with distance across a pipeline/hose.
- Irrigation was assumed to be applied evenly across all irrigation areas. This is unlikely to be completely accurate, and unevenly distributed flow may induce more runoff due to areas of soil reaching saturation faster.
- In the best-case scenario, a nitrogen reduction of 20% is predicted to occur via volatilisation facilitated by aeration in the irrigation pond. This rate would be dependent on the pH, temperature and detention time in the irrigation pond and would likely fluctuate seasonally. It is considered that a 20% reduction is a conservative estimate and field trials are recommended in order to further refine this estimate and/or to develop, design and implement a functional aeration system.

3.0 Results and Discussion

3.1 Comparison of Management Practices

The nitrogen balance over the irrigation areas can be simplified into four main streams represented in Figure 2.

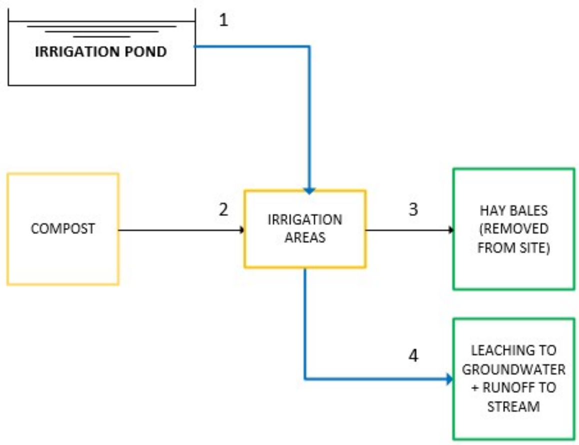

Figure 2 Mass Balance Over Irrigation Areas

The nitrogen loads in of each of the streams were modelled for scenarios according to the facility's operating practices in 2018, 2019 and a 'best-case' (refer Table 2 for summary of differences) to investigate the relevant difference between management practices.

The modelled monthly leachate nitrogen concentrations from the two irrigated areas are provided in Table 4. When compared to surface water and groundwater monitoring data from the site, the modelled results are concordant based on likely dilution characteristics of the receiving groundwater and surface water bodies.

The modelled nitrogen mass flows are summarised in Table 5.

Table 4 Nitrogen Application and Leaching by Month (2018 – 2019 scenarios)

	2018					
	Upper Irrigation		Lower Irrigation		TOTAL	
	N Applied kg/ha	N Leached kg/ha	N Applied kg/ha	N Leached kg/ha	N Applied total kg	N Leached total kg
Jan	0.0	0.3	207.9	19.8	665.3	64.5
Feb	0.0	0.7	195.9	75.1	626.9	243.0
Mar	0.0	1.3	239.4	102.7	766.1	333.6
Apr	0.0	2.2	216.9	136.5	694.1	445.2
May	0.0	2.2	267.3	153.6	855.4	499.9
Jun	0.0	2.3	309.0	197.3	988.8	640.1
Jul	0.0	2.2	147.7	216.1	472.6	699.9
Aug	0.0	1.6	203.7	159.2	651.8	515.5
Sep	0.0	1.3	148.0	122.5	473.6	396.9
Oct	0.0	1.2	131.1	104.2	419.5	338.0
Nov	0.0	0.4	133.5	37.6	427.2	121.8
Dec	0.0	1	179.0	72.1	572.8	234.5
TOTAL	0.0	16.7	2379.4	1396.7	7614.1	4532.9
% Leached/Applied	-		58.7%		59.5%	
N drainage, ppm	1.6		117.3		58.3	

	2019					
	Upper Irrigation		Lower Irrigation		TOTAL	
	N Applied	N Leached	N Applied	N Leached	N Applied	N Leached
	kg/ha	kg/ha	kg/ha	kg/ha	total kg	total kg
Jan	124.3	8.9	60.0	3.7	664.3	45.7
Feb	117.1	19.2	52.0	8.6	611.4	100.5
Mar	134.5	38	79.0	17.6	763.9	200.7
Apr	119.0	68.8	73.0	30.5	685.8	359.0
May	136.7	75.1	103.0	37.9	849.1	406.7
Jun	150.3	94.8	126.0	55.9	974.3	539.1
Jul	75.8	94.9	56.0	57.2	467.2	543.7
Aug	104.5	77.9	78.0	48.6	646.7	451.5
Sep	85.2	61.8	45.0	36.4	467.8	351.3
Oct	85.3	51.8	30.0	27.5	420.1	284.8
Nov	92.8	19.1	24.0	8.1	429.4	98.5
Dec	120.5	38.4	35.0	14.5	569.9	192.3
TOTAL	1346.0	648.7	761.0	346.5	7550.0	3573.9
% Leached/Applied	48.2%		45.5%		47.3%	
N drainage, ppm	58.5		32.8		47.1	

	Best Case					
	Upper Irrigation		Lower Irrigation		TOTAL	
	N Applied	N Leached	N Applied	N Leached	N Applied	N Leached
	kg/ha	kg/ha	kg/ha	kg/ha	total kg	total kg
Jan	32.0	1.1	32.0	1.4	336.0	13.1
Feb	28.0	2	28.0	3.1	294.0	26.7
Mar	42.0	3.9	42.0	6.4	441.0	54.0
Apr	39.0	6.4	39.0	10.4	409.5	88.0
May	55.0	10	55.0	14.5	577.5	128.4
Jun	68.0	18	68.0	23.9	714.0	219.7
Jul	30.0	19.5	30.0	25.3	315.0	234.9
Aug	42.0	17	42.0	21.8	441.0	203.5
Sep	24.0	11.8	24.0	15.9	252.0	145.2
Oct	16.0	7.2	16.0	11.3	168.0	96.9
Nov	13.0	1.6	13.0	3	136.5	24.1
Dec	19.0	2.8	19.0	4.8	199.5	39.8
TOTAL	408.0	101.3	408.0	141.8	4284.0	1274.3
% Leached/Applied	24.8%		34.8%		29.7%	
N drainage, ppm	9.1		13.6		11.3	

Table 5 Modelled Mass Balance Over Irrigation Areas

Stream Number		Annual Nitrogen Loading (kg/year)		
		2018	2019	Best-case
1 + 2	Nitrogen applied	7614	7550	4284
3	Nitrogen removed	3081	3976	3010
4	Nitrogen leached	4533	3574	1274

The nitrogen leached from the site between the 2018 and 2019 scenarios decreased by approximately 21% (4,533 kg in 2018 to a predicted 3,574 kg in 2019). The best-case scenario showed a further 64% reduction in nitrogen leached (3,574 kg in 2019 to 1,274 kg in the best-case) illustrating that changes to current management practises will have a significant impact on reducing the nitrogen leached from the irrigated areas.

The seasonal fluctuation in nitrogen application and leaching is shown in Figure 3. This considers the loading and leaching across both irrigation areas (‘upper’ and ‘lower’). Note that 2018 rainfall and irrigation data was used for all scenarios to accurately compare the impact of changing operating practices.

Other nitrogen removal mechanisms were modelled in Overseer but were found to have a minor overall impact on the nitrogen balance relative to both the rates applied and the modelled leached volumes. In the 2018 modelled scenario, denitrification removes a load of 7-19 kg/ha and volatilisation removes a load of 1-13 kg/ha N depending on season.

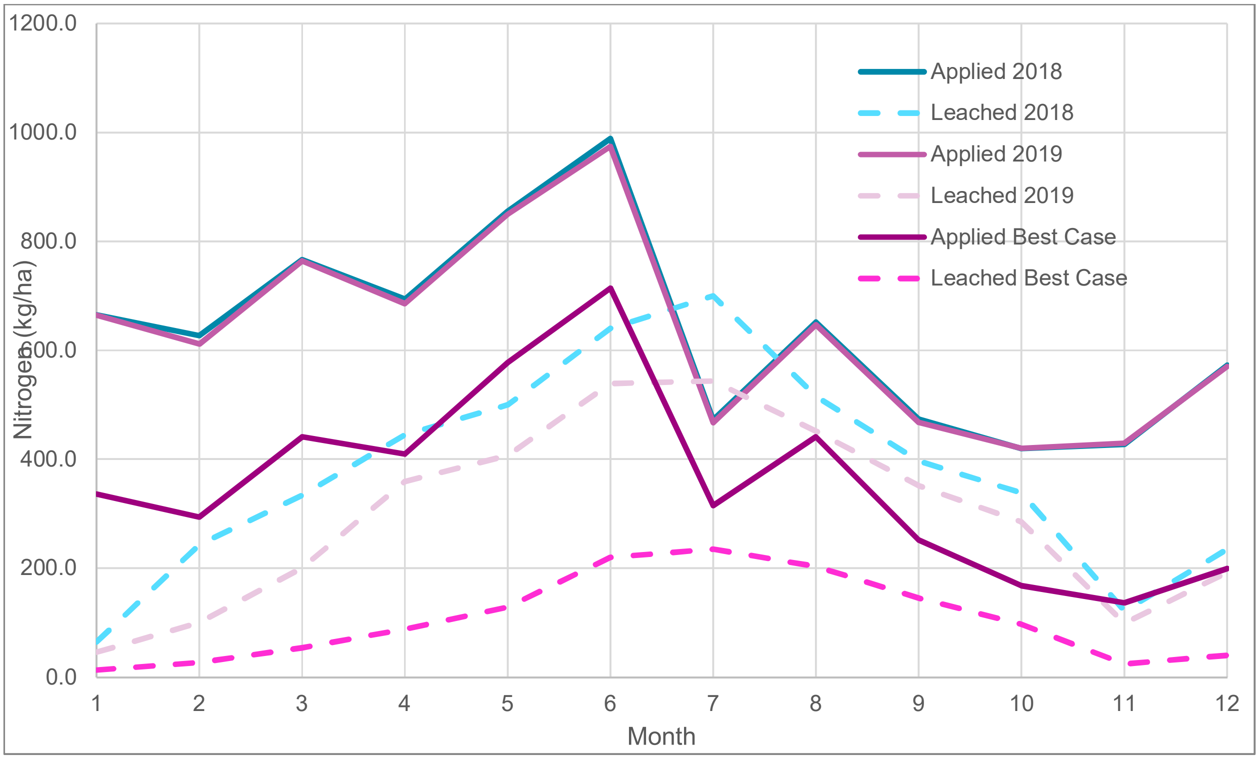

Figure 3 Nitrogen Application and Leaching from Irrigation Areas, 2018 vs 2019 vs Best-case

3.2 Impact of Increasing Irrigation Area and Hay Harvested

A significant change between 2018 and 2019 was the greater area irrigated, yielding an additional 300 hay bales removed from site. Increasing the irrigated area from 3.2 to 7.1 ha over this period (~220%), resulted in an approximate 18% reduction in nitrogen leached with all other factors constant. This is a relatively small reduction (compared to the increase in application area) however the model illustrates that if nitrogen is not sequestered and removed as plant matter, it will be lost via leaching/runoff regardless of the area it is distributed over. This explains why increasing the area of application does not equate to a directly proportional reduction in leaching; far more nitrogen is applied than removed in the additional bales.

The impact of increasing the quantity of hay bales harvested from the upper irrigation area is outlined in Table 6. Note that all scenarios include 200 hay bales removed from the lower irrigation area as per existing practice.

Table 6 Impact on % N loss from Increasing Hay Bales Harvested from Upper Irrigation Area

Hay bales harvested from Upper Irrigation Area	N Lost from Irrigated Areas (kg/year)	Relative % Decrease in Total N Loss from Irrigated Areas
0	4772	0%
100	4482	6%
200	4199	12%
300	3916	18%
400	3620	24%
500	3305	31%

Highlighted scenario is the proposed harvest for 2019.

The relative nitrogen loss decreases linearly as hay bales harvested increases. This is quantified within the tested range as approximately a 6% N loss decrease per additional 100 hay bales harvested. This is applicable up to 500 bales harvested from the upper irrigation area. The practical mass of hay able to be removed from the area would need to be investigated further. It appears that the nitrogen loading would not able to be sequestered fully by a realistic amount of plant matter grown.

In the best-case scenario, 750 bales were assumed to be removed from the same area of irrigated land (300 from the lower areas, 450 from upper areas). This contributed significantly to the reduction in nitrogen leaching.

3.3 Impact of Compost Application

In the 2018 scenario, 1000 m^3 of compost from Pad 1 is applied to the lower irrigation areas and in 2019 it is applied to the upper irrigation areas. The change in location of application makes a negligible difference (~1%) to overall nitrogen loss. However, in a scenario where the compost is completely removed from the site, the total nitrogen loss decreases by 1417 kg/year which is a relative decrease of 32%. The compost is removed from site in the best-case scenario which contributes significantly to the reduction in nitrogen leaching.

3.4 Conclusions and Recommendations

The developed Overseer model illustrates that an excess of nitrogen is applied (in the form of irrigation and compost) to the irrigated fields compared to that removed via harvesting and/or natural processes. The excess nitrogen is lost from the site as leachate and/or surface runoff. The modelled nitrogen leached has reduced from 2018 to 2019 based on the data available and assumptions applied to the 2018 and 2019 scenarios. Sensitivity analysis shows that an increase in irrigation area, increase in production (in the form of removal of hay bales) and decrease in compost application all have a noticeable effect on decreasing the volume of nitrogen leached from the site.

In order for the model to more accurately represent nitrogen application and leaching from the site, it is recommended the following are considered:

- Weekly monitoring of TKN in the irrigation pond and irrigator. Additional data on the nitrogen concentration of the irrigation water will increase accuracy of the models applied nitrogen loadings. This could advise whether seasonal retention/release/dilution could contribute to mitigating nitrogen losses.
- Improving accuracy of the reported mass of hay removed from the site.
- Additional information on the volume, timing and location of applied irrigation water.

In order to reduce and/or limit nitrogen leaching from the site, it is recommended that the following management practises are considered:

- Increasing the area of application from the current 7.1 ha combined with a proportional increase in harvest volume.
- The timing of nitrogen application to pasture has been determined to be most effective (with regard to plant yield) when the soil temperature is above 4°C in spring and above 7°C in autumn. Spring is generally the optimum time for nitrogen fertiliser to be applied due to less leaching and greater N fixing. However, summer applications are likely to increase the volume of nitrogen lost to volatilisation. If storage (of the irrigation water) is sufficient, seasonally variable nitrogen application should be considered taking these factors into account.
- The species grown and the potential to increase the number of harvest events per year could be investigated. Nitrogen uptake efficiency and rate of growth is likely to vary between species grown.
- The volatilisation of nitrogen in the irrigation pond could be enhanced by aeration. Practical and functional measures to aerate the pond water and their effectiveness should be investigated.

- Sensitivity of plant growth to other nutrients in the irrigation/compost e.g. if high sodium or hydrocarbon loading could inhibit growth.
- Investigation to assess whether the compost currently applied to site could be removed and sold. Further processing may have to be implemented to achieve an acceptable composition.

4.0 References

BTW (2015) Uruti Composting Facility Management Plan. BTW Company

Remediation NZ (2019) DRAFT Revision 10: 19 June 2019. Uruti Composting and Vermiculture Facility. Assessment of Environmental Effects. For the discharge of organic material and associated leachate and stormwater to land/water/air in conjunction with the Composting and Vermiculture product processes.

5.0 Standard Limitation

AECOM New Zealand (NZ) Limited (AECOM) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of Remediation New Zealand Ltd. and only those third parties who have been authorised in writing by AECOM to rely on this Report.

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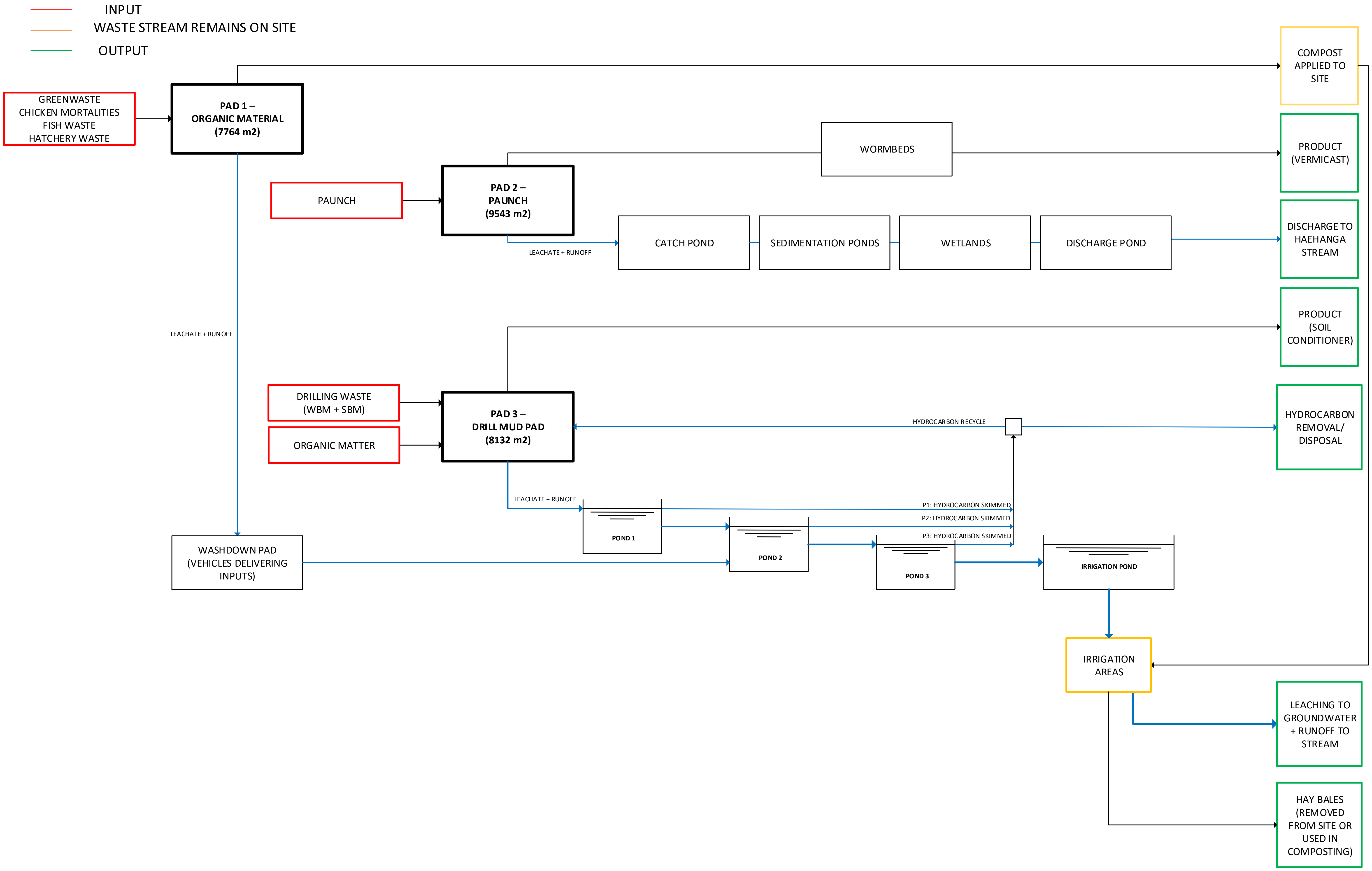
Appendix A

Uruti Site
Process Flow Diagram

REMEDIATION (NZ) URUTI FACILITY. PROCESS FLOW DIAGRAM SUMMARIES OF EXISTING PROCESSES.



Appendix B

Nitrogen Loading Calculations

Uruti Irrigation Pond Nitrogen Concentration

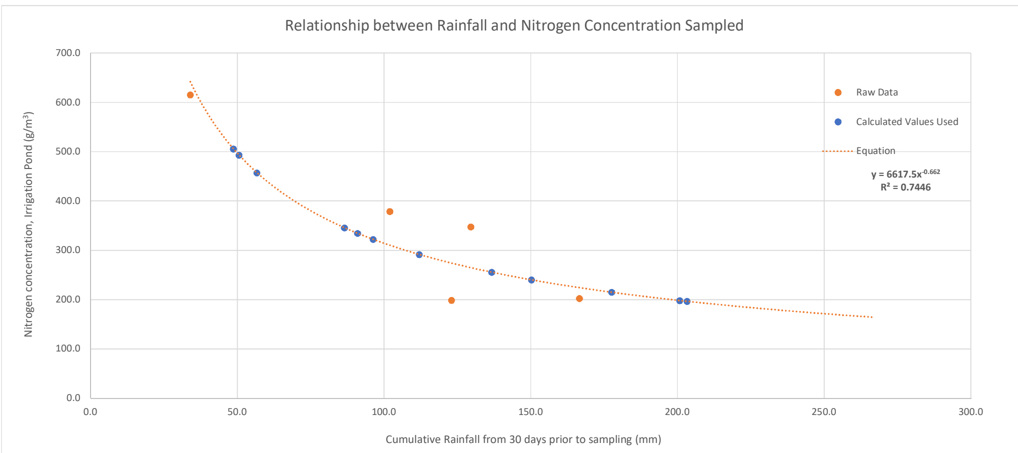
Due to irregular sampling of the irrigation pond and a large range of nitrogen concentrations, a relationship was determined between the nitrogen concentration sampled in the pond and the rainfall 30 days prior to the sampling event. Using this relationship, the monthly rainfall from 2018 was used to calculate monthly nitrogen concentrations in the pond. The calculated nitrogen concentration was then converted to an absolute loading rate
(kg/ha/month) using 2018 monthly reported irrigation hours and standard irrigation rate. The monthly nitrogen loading rate was then input into Overseer.

Rainfall data from Cliflo NIWA, Station Agent number 24694.

Determining monthly nitrogen concentration in irrigation pond:

	Water sampling results (IND 2044 Irrigation pond)				Rainfall Prior to Sample (Cliflo NIWA)	
	NH4 Ammoniacal nitrogen	NNN Nitrite/ Nitrate nitrogen	NH3 Un-ionised ammonia	Sum of Inorganic nitrogen	7 days Prior	30 days prior
	g/m3 N	g/m3 N	g/m3	g/m3	mm	mm
25/10/2017	291	0.2	10.89	302.1	6.3	98.6
24/01/2018	460	0.05	15.80	475.8	48.0	131.2
26/04/2018	373	0.18	5.46	378.6	4.1	102.0
28/08/2018	200	0.013	2	202.0	46.0	166.6
20/12/2018	340	0.009	7.2	347.2	34.6	129.6
22/02/2019	590	0.011	25	615.0	4.5	34.0
12/04/2019	192	0.01	6.4	198.4	40.5	123.0

The relationship between nitrogen concentration sampled and rainfall from 7 days prior was investigated, but this relationship was not as strong as using rainfall from 30 days prior. This is to be expected due to the large holding volume of the treatment ponds prior to the irrigation pond creating deadtime. Therefore the 30 day prior data was used.



	2018 rainfall, mm	Calculated Nitrogen conc, g/m³
Jan	50.6	492.7
Feb	112.0	291.1
Mar	150.3	239.7
Apr	86.6	345.3
May	56.7	456.9
Jun	48.7	505.4
Jul	96.3	321.8
Aug	177.6	214.5
Sep	203.3	196.2
Oct	136.7	255.2
Nov	200.8	197.8
Dec	91.0	334.0

Calculated using relationship from graph above

Converting nitrogen concentration to absolute loading:

Application rate	30	m³/hour
Irrigation area, 2018	3.2	ha
Irrigation area, 2019	7.1	ha
Irrigation area, Best	10.5	

			2018		2019		Best-Case	
	Irrigation recorded by site (hours)	Volume required per month (m³)	Depth per weekly application = volume/area, (mm)	Total Nitrogen loading from irrigation = concentration*volume/area, (Kg/ha/month)	Depth per weekly application = volume/area, (mm)	Total Nitrogen loading from irrigation = concentration*volume/area, (Kg/ha/month)	Depth per weekly application = volume/area, (mm)	Total Nitrogen loading from irrigation = (20% reduction from 2019).
Jan	28.5	855	5.9	131.6	2.7	59.5	1.79	31.9
Feb	42.0	1260	8.7	114.6	4.0	51.8	2.64	27.7
Mar	77.5	2325	16.1	174.1	7.3	78.7	4.88	42.1
Apr	50.0	1500	10.4	161.9	4.7	73.2	3.15	39.2
May	53.0	1590	11.0	227.0	5.0	102.6	3.34	54.9
Jun	59.0	1770	12.3	279.6	5.6	126.4	3.71	67.6
Jul	41.0	1230	8.5	123.7	3.9	55.9	2.58	29.9
Aug	85.5	2565	17.8	172.0	8.0	77.7	5.38	41.6
Sep	54.5	1635	11.3	100.3	5.1	45.3	3.43	24.3
Oct	27.5	825	5.7	65.8	2.6	29.7	1.73	15.9
Nov	28.5	855	5.9	52.9	2.7	23.9	1.79	12.8
Dec	25.0	750	5.2	78.3	2.4	35.4	1.57	18.9

Data from 2018
Data from 2017

Input to Overseer 2018 scenario as irrigation	Input to Overseer 2018 scenario as soluble fertiliser	Input to Overseer 2019 scenario as irrigation	Input to Overseer 2019 scenario as soluble fertiliser	Input to Overseer Best-case scenario as irrigation	Input to Best-Case scenario as soluble fertiliser.