MEMORANDUM **Job 10684**

To:	Darren de Klerk (Central Hawke's Bay District Council)
From:	Sam Morris (Lowe Environmental Impact)
Date:	20th of July 2021
Subject:	P:C.14a – Existing/Future Farming System and OverseerFM Analysis

This memo relates to and follows the 'Existing Farming System' memo (LEI, 2021:P:B.13)[1], providing an overview of nutrient losses under the existing farming system as modelled in OverseerFM. Additionally, the memo shows nutrient losses for three modelling stages incorporating wastewater irrigation.

BACKGROUND

Central Hawke's Bay District Council (CHBDC) are responsible for the management of the Porangahau (PWWTP) and Te Paerahi (TPWWTP) Wastewater Treatment Plants. Treated wastewater for Porangahau is currently discharged via a drain entering the Porangahau River under consent DP030233W. For Te Paerahi, treated wastewater is discharged to culturally significant coastal sand dunes under consent DP030234La. As part of the consent renewal process, CHBDC are investigating alternative discharge environments with one of these to land owned by the Stoddart's.

As detailed in the memorandum 'Existing Farming System' (LEI 2021:P:B.13)[1] there are two parcels owned by the Stoddarts to receive Porangahau and Te Paerahi's wastewater (Figure 1). These parcels contain 114.3 ha (including buffers) for the land treatment area. There is additional land owned by the Stoddart's that is included in their farming system, however the focus here is the two parcels located north of Beach Road as shown in Figure 1.

Due to the development of the irrigation system for the communities being significant, a staging approach has been implemented. This staging has been done to align with funding availability and timing for the procurement and construction to occur. Three stages have been proposed with Table 1 showing the naming conventions for these used in this memo. The following section provides a summary for each of these stages.

[1] LEI. (2021:P:B.13). *Existing Farming System.*

Figure 1: Proposed Land Application Site

Table 1: OverseerFM Assessment Stages

Project Stage (Name)	Flows
Stage 0	Baseline (Existing System – No Wastewater)
Stage 1	Existing System – 2019 Te Paerahi Flows ONLY
Stage 2	Existing System – 2028 Porangahau and Te Paerahi Flows
Stage 3	Existing System – 2057 Porangahau and Te Paerahi Flows

IRRIGATION SYSTEM

The proposed irrigation system is a combination of fixed sprinklers attached to fenceposts and small moveable pods. These systems have been strategically chosen to align with the existing farming system and landowner aspirations and are designed to allow irrigation to as much of the property as possible. However, there are some areas of the property close to roads and surface water features where wastewater will be excluded.

Typical irrigation rates will be adopted mostly, where water is applied in sufficient volumes to adequately grow crops and not generate drainage. However, when storage is not possible there may be the need to use a non-deficit irrigation to wet soils system which will utilise the same irrigation infrastructure but see higher volumes applied, to the point where there will be drainage. Such 'over' irrigation will only occur on the sandy soils.

MODELLING APPROACH

Wastewater irrigation is to increase farm production and this could potentially result in greater nutrient losses. The extent of losses can be described using OverseerFM. Had wastewater not been applied to this property, no nutrient modelling would be necessary.

- **Stage 0** allows for the current discharge for both communities to their respective receiving environments to occur for up to four years at Te Paerahi and six years at Porangahau from consent granting while the subsequent stages are enacted;

- **Stage 1** involves provision of 500 m^3 of storage within the Te Paerahi WWTP and development of a minimum 4 ha on the Stoddart property, allowing irrigation to sandy soils (IMU 3) under typical irrigation conditions for approximately 43 % of the **current** Te Paerahi average annual wastewater discharge volume and 57 % of the annual volume under a non-deficit wet soils regime. This stage **only** includes Te Paerahi flows and applies all to the Stoddart property, while the existing river discharge for Porangahau will continue.

  The discharge regime assumes that the currently occurring wastewater flows occur (no allowance for future growth), up to 500 m^3 of storage is available at the Te Paerahi WWTP and discharge under a non-deficit wet soils regime can occur when soils cannot receive wastewater under typical irrigation conditions;

- **Stage 2** involves development of an additional 6 ha of irrigation for sandy soils (IMU 3), allowing for a minimum 10 ha of irrigation at Stage 2. Stage 2 allows for irrigation to IMU 3 (wet and dry soil regimes) of between 61 % to 100 % of the **future (2028)** Porangahau and Te Paerahi annual wastewater discharge volumes. This stage includes **both** Porangahau and Te Paerahi flows, but allows for between 0 % to 39 % of all flows to continue to the Porangahau River (when storage is not possible and soil conditions are too wet).

- **Stage 3** involves development of an additional 10 ha of irrigation for sandy soils (IMU 3) and incorporation of 20 ha of silty/clay soils (IMU 1), allowing for a minimum 40 ha of irrigation at Stage 3. A new combined WWTP and storage pond is to be built at the land application site to receive Porangahau and Te Paerahi flows with a capacity of (up to) 35,000 m^3. This storage allows for irrigation of between 66 % and 100 % of the **future (2057)** average annual wastewater discharge volume to the dry soils system (typical irrigation) and between 0 % to 36 % to be applied under a non-deficit wet soil regime.

DISCHARGE SCENARIOS

As part of the staging process, a series of discharge scenarios have been developed for Stages 2 (Stage 2a and Stage 2b) and 3 (Stage 3a and 3b) which assess farm nutrient losses under varying discharge criteria. These are as follows:

Stage 2 features two discharge scenarios; Stage 2a and Stage 2b. Due to no storage available, these scenarios assess a higher annual volume discharge to the non-deficit irrigationto wet soils system vs the inclusion of a partial continued discharge to the Porangahau River respectively.

Stage 2a applies 100 % of Porangahau and Te Paerahi's flows to the irrigation property with flows not applied to land under standard deferred/non-deficit conditions, directed to the non-deficit irrigation to wet soils system. Stage 2b sees wastewater flows directed to the irrigation property, however a partial continued discharge to the Porangahau River for a portion of Porangahau's flows is maintained. This partial river discharge allows for excessive wastewater

volumes previously directed to the non-deficit irrigation to wet soils system (Stage 2a), to instead be discharged directly to the river. These two scenarios essentially represent the extremities of a land and river discharge under Stage 2 conditions.

Stage 3 sees irrigation applied to an area of 40 ha, expanding IMU 3 by a further 10 ha, and the development of IMU 1 allowing for 20 ha of irrigation. The discharge regime to IMU 3 will remain as deferred/non-deficit conditions, with IMU 1 being a deficit irrigation regime.

Stage 3 also sees construction a new WWTP at the discharge property servicing both communities, as well as a 10,000 – 35,000 m^3 storage pond enabling the optimisation of irrigation to occur. As with Stage 2, Stage 3 features two discharge scenarios; Stage 3a and Stage 3b. These scenarios assess a 10,000 m^3 for Stage 3a, and a 35,000 m^3 storage pond for Stage 3b and their influence on the discharge regime. These stages see all flows from both communities, with incorporated future 2057 population projections directed to the discharge property, with no river discharge occurring.

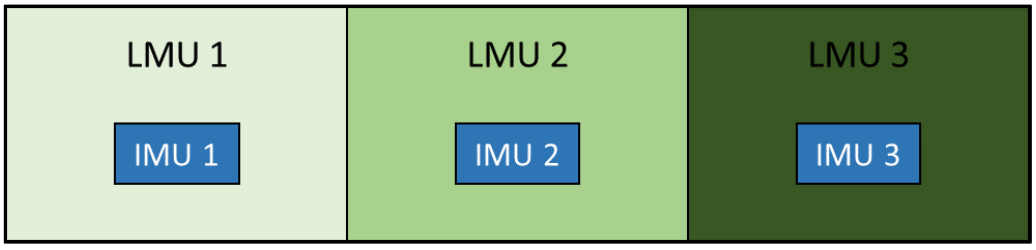
LAND TYPES

The property has been divided into three Land Management Units (LMUs). The LMUs are a combination of landforms and characteristics into practical areas for management. The designation of LMUs is mostly based on the landforms allocated in the site investigation report and associated soil map (LEI, 2021:P:B.15)[2].

Essentially the three landforms have been identified:

- LMU 1 dominant landform is poorly drained silty/clayey soils to the south;
- LMU 2 dominant landform is poorly to moderately draining loamy alluvium to the north east; and
- LMU 3 dominant landform is well drained central sand dunes.

For Stages 1-3 and the commencement of irrigation, Irrigation Management Units (IMUs), a subset of the larger LMUs have been developed. IMUs are essentially the region within the LMU where irrigation is to occur, as illustrated below. IMUs are not necessarily fixed in place but rather have the ability of moving within the larger LMU depending on farm management and landowner aspirations. They do not include the non-irrigatable portion, such as waterways, that occupies areas with the LMUs.



Of the available area within the LMU, only a proportion of the area is required for wastewater discharge. This has the advantage of enabling the irrigated areas to avoid sensitive areas or areas which are unsuitable to receive irrigation on any given day. It also provides for areas to be excluded for farm management reasons, such as regrassing.

[2] LEI. (2021:P:B.15). *Evaluation of Soils to Receive Porangahau and Te Paerahi's Wastewater.*

Figure 2 shows the OverseerFM blocking representing the LMU distribution as described above. Within each of the LMUs sit the rotating IMU of varying areas depending on the Stage.

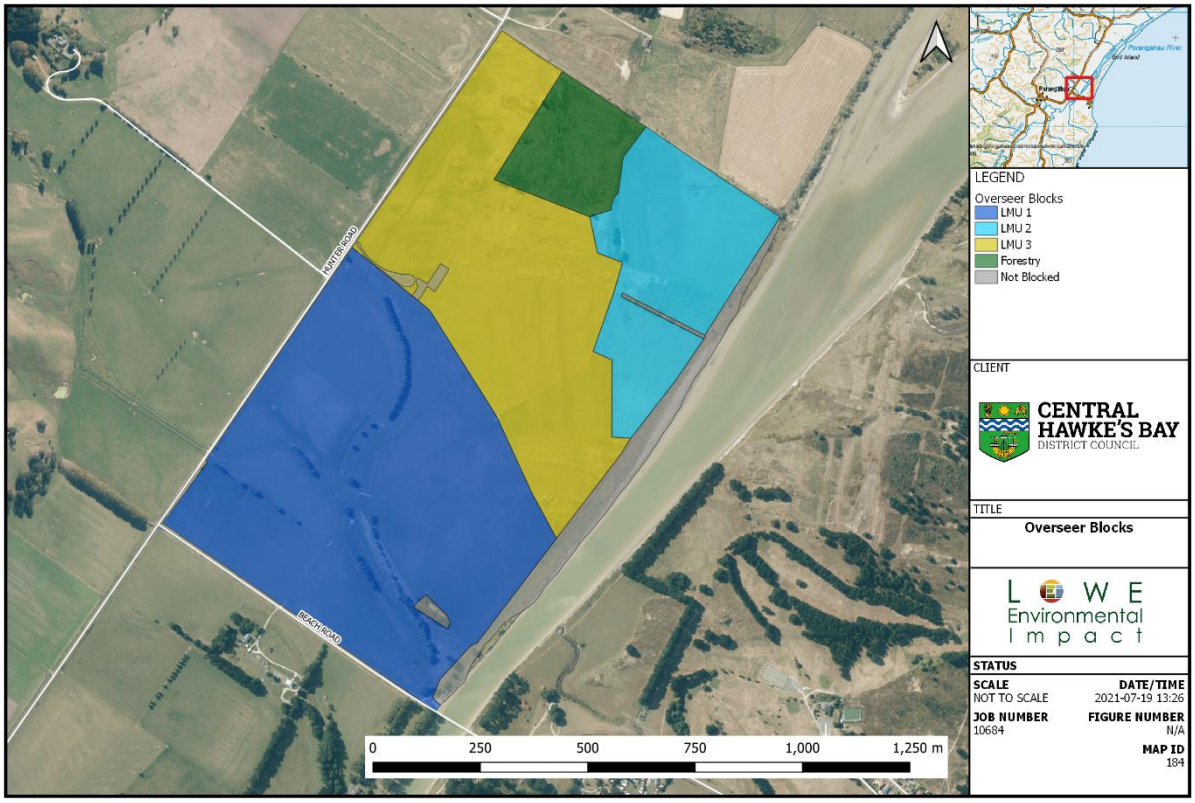


Figure 2: Overseer Blocks

STAGE 0 – BASELINE (CURRENT FARMING SYSTEM)

For modelling of nutrient losses by stage to occur, a baseline model of the current farming system was created for Stages 1-3 to be compared against. To create this, information relating to the current farming system was provided by Gordon Stoddart over a series of phone calls. At the time of these calls, Gordon mentioned that the property outlined within LEI, 2021:P:B.13[1], was run in partnership with another farm north of Porangahau and that recorded information relating to animal numbers were combined across the two properties. This partnership has ceased as of the 1st of July 2021. Therefore, numbers relating to those grazing on land shown in Figure 1 were estimates which have since been refined to represent a realistic farming operation for the property shown in Figure 1.

Table 2 represents the nutrient budget summary for the current farming system as a baseline model. Attachment 1, Table 9 represents the block summary and nutrient losses for the model, with Attachment 1, Table 10 showing the OverseerFM inputs.

Table 2: Nutrient Losses for Stage 0

Area (ha)	N Loss Total (kg)	N Loss per ha (kg N/ha)	P Loss Total (kg)	P Loss per ha (kg P/ha)
114.3	2,349	21	71	0.6

Across the Stoddarts property, N losses were relatively low, particularly for land on the alluvial plains to the south and northeast, with N losses being higher for land across the central sand

dunes. A 3 ha block for winter grazing of oats by beef on the sand country has been included within this model, which is the primary driver for the higher than expected N loss value for the property. Without this winter grazing oats block, N losses would be approximately 14 kg N/ha, indicative and typical of a low intensity sheep and beef farming system within the Hawke's Bay region.

STAGE 1 – IRRIGATION OF 2019 TE PAERAHI FLOWS ONLY

Following development of a baseline farming system, incorporation of wastewater flows from Te Paerahi under Stage 1 were modelled. Table 3 represents N losses for Stage 1. Attachment A, Table 11 shows nutrient losses by block, Table 12 shows OverseerFM inputs and Table 13 shows nitrogen and phosphorus loadings within wastewater to IMU 3, within LMU 3.

Table 3: Nutrient Losses for Stage 1

Area (ha)	N Loss Total (kg)	N Loss per ha (kg N/ha)	P Loss Total (kg)	P Loss per ha (kg P/ha)
114.3	2,564	22	94	0.8

Stage 1 uses the existing farming system however incorporates wastewater irrigation to 4 ha within IMU 3. No wastewater irrigation was applied to the 3 ha winter oats block in LMU 3. Modelled irrigation volumes were calculated using a separate water balance model, with exact monthly irrigation volumes being entered into OverseerFM. For blocks receiving wastewater relative productivity was increased by 0.5, thus IMU 3 productivity increased from 0.5 to 1. Pasture growth for the now irrigated 4 ha IMU 3 block increased from 3.7 t DM/ha/yr (LMU 3) under Stage 0 to 7.2 t DM/ha/yr under Stage 1.

This stage sees an N loss of 22 kg N/ha, an increase of 1 kg N/ha following the inclusion of wastewater irrigation compared to the existing baseline farming system.

STAGE 2 – IRRIGATION OF 2028 PORANGAHAU AND TE PAERAHI FLOWS

Stage 2 sees the implementation of a total of 10 ha for irrigation (6 ha additional to Stage 1) and applies Porangahau and Te Paerahi's wastewater to land. Applied wastewater volumes for the communities incorporate 2028 population projections. Between Stage 1 and Stage 2, the farming system has remained largely the same, however IMU 3 has expanded. Table 4 and Table 5 represent N losses for Stage 2a and Stage 2b respectively. For Stages 2a and 2b, Attachment A, Table 14 represents nutrient losses by block, Table 15 shows OverseerFM inputs and Table 16 shows nitrogen and phosphorus loadings within the applied wastewater to IMU 1 and IMU 3.

Table 4: Nutrient Losses for Stage 2a

Area (ha)	N Loss Total (kg)	N Loss per ha (kg N/ha)	P Loss Total (kg)	P Loss per ha (kg P/ha)
114.3	3,490	31	155	1.4

Table 5: Nutrient Losses for Stage 2b

Area (ha)	N Loss Total (kg)	N Loss per ha (kg N/ha)	P Loss Total (kg)	P Loss per ha (kg P/ha)
114.3	2,819	25	113	1

With Porangahau's flows now coming to the Stoddarts, in addition to Te Paerahi's flows, and no storage outside of the existing oxidation ponds, this stage results in a higher land irrigation volume to the designated application site for Stage 2a and a culturally undesired discharge to the Porangahau River for Stage 2b. These two scenarios represent the extremities for both land and river discharges with the likely discharge regime and associated nutrient loss likely to be in between these but to be determined. For both stages, pasture growth for IMU 3 increases from 3.7 t DM/ha/yr (LMU 3) under Stage 0 to 7.3 t DM/ha/yr under Stages 2a/2b. Additionally, due to an increase in pasture production of the irrigated area, an extra 5 steers graze on the property of the modelling period.

With the inclusion of Porangahau's wastewater, flows to the Stoddart's property have increased. Although the application area has expanded compared to Stage 1, the irrigated area is still relatively small, thus the application volume to IMU 3 is high (for Stage 2a), as compared to Stage 1. As mentioned, under Stage 2b, a large proportion of what was previously discharged to the non-deficit irrigation to wet soils system, is instead directed to the Porangahau River, resulting in a lower application volume to IMU 3 and thus lower nutrient losses values.

This stage sees an N loss of 31 ka N/ha and 25 kg N/ha, an increase of 10 kg N/ha and 4 kg N/ha respectively compared to the pre-existing baseline farming system (Stage 0).

STAGE 3 – IRRIGATION OF 2057 PORANGAHAU AND TE PAERAHI FLOWS

Stage 3 sees development of the new WWTP and no less than 10,000 m^3 and up to 35,000 m^3 worth of storage at the Stoddart's property. This storage allows for optimisation of the irrigation system, meaning wastewater flows can be stored when soil conditions are not suitable for irrigation. Additionally, storage allows for greater irrigation potential over summer months, where wastewater flows coming in winter can be stored until summer, aligning with pasture growth and suitable soil conditions. Stage 3a assesses nutrient losses with construction of a 10,000 m^3 storage pond, with Stage 3b assessing losses with 35,000 m^3 of storage.

Additional to the development of a new WWTP and storage, Stage 3 sees implementation of a total of 40 ha for irrigation (30 ha additional to Stage 2), through the establishment of IMU 1. Applied wastewater volumes for the communities incorporate 2057 population projections. Of the 40 ha of total irrigation for Stage 3, this is evenly distributed across IMU 1 and IMU 3 (20 ha each). With irrigation at capacity for Stage 3, further farm intensification has been incorporated to manage increased pasture yields. For both stages, pasture growth for IMU 1 increases from 7.3 t DM/ha/yr (LMU 1) under Stage 0 to 13.7 t DM/ha/yr under Stages 3a/3b. From Stage 2 numbers, a further 20 steers graze on the property between Jul-Sep, with an extra 25 from Oct-Jun.

For Stage 3, the rotating winter oats within LMU 3 has been removed from the farming system. Under wastewater application, pasture production is expected to increase substantially which is likely to substitute the need for this oats crop providing additional feed over this winter period.

Table 6 and Table 7 represent N losses for Stage 3a and Stage 3b respectively. Attachment A, Table 17 represents nutrient losses by block and Table 18 shows OverseerFM inputs

collectively for both stages. Table 19 and Table 20 show nitrogen and phosphorus loadings within the applied wastewater to IMU 1 and IMU 3 under both stages.

Table 6: Nutrient Losses for Stage 3a

Area (ha)	N Loss Total (kg)	N Loss per ha (kg N/ha)	P Loss Total (kg)	P Loss per ha (kg P/ha)
114.3	3,301	29	205	1.8

Table 7: Nutrient Losses for Stage 3b

Area (ha)	N Loss Total (kg)	N Loss per ha (kg N/ha)	P Loss Total (kg)	P Loss per ha (kg P/ha)
114.3	3,014	26	201	1.8

Stage 3 is similar to Stage 2 in that flows are from both communities, with the only difference being both the incorporation of storage at Stage 3, and the inclusion of 2057 population projections for Stage 3, as opposed to 2028 for Stage 2. Furthermore, storage allows for better optimisation of the irrigation system, allowing wastewater to be held for when soil conditions are suitable for irrigation, preventing a partial discharge to both the Porangahau River (Stage 2b) and high volumes to the non-deficit irrigation to wet soils system. Under Stage 3b, no wastewater is discharged to the property in the months of July and August to utilise the potential of a 35,000 m^3 storage pond.

Stage 3a sees an N loss of 29 ka N/ha with Stage 3b seeing an N loss of 26 kg N/ha, an increase of 8 kg N/ha and 5 kg N/ha from the pre-existing baseline farming system (Stage 0) respectively.

DISCUSSION

The baseline farm system model (Stage 0) provides a good and realistic baseline to which the following Stages 1 to 3 can be compared against. From the four OverseerFM models, Stage 2a represents a worst case scenario for nitrogen leaching (31 kg N/ha & 1.4 kg P/ha). This is expected given the incorporation of all flows from the now two communities, to a relatively small land area and no storage to optimise the irrigation system reducing drainage. Stage 2a sees a nitrogen loss increase of 10 kg N/ha compared to the baseline model (Stage 0).

Following completion of the entire irrigation system to irrigate 40 ha once future growth has been allowed for, Stage 3 will see a nitrogen loss increase of between 5-8 kg N/ha compared to Stage 0 under a 'business as usual' farming system. This represents that although N losses from wastewater irrigation increase drainage and thus leaching, having a larger land area to which irrigation can occur, reduces the volume of nitrogen and phosphorus being applied to the land surface per block. Table 8 provides a nutrient loss summary of the project stages and scenarios.

Table 8: Stage Nutrient Loss Summary

Name	N Loss Total (kg)	N Loss per ha (kg N/ha)	P Loss Total (kg)	P Loss per ha (kg P/ha)
Stage 0	2,349	21	71	0.6
Stage 1	2,546	22	94	0.8
Stage 2a	3,490	31	155	1.4
Stage 2b	2,819	25	113	1
Stage 3a	3,301	29	205	1.8
Stage 3b	3,014	26	201	1.8

Each modelled stage represents a 'business as usual' farming approach with minimal mitigation options following wastewater irrigation being implemented, despite being modelled to align with best farm management practices. These models have incorporated minor farm intensification regarding stock numbers for Stages 2 and 3, however large scale farming mitigation options relating to crop type and distribution, stock type and distribution, cut and carry systems, fertiliser applications etc have not been modelled but could be implemented to reduce nutrient losses. Due to modelling of mitigation options being limited, these scenarios largely reflect 'worst case scenario' models for each of the respective stages.

CONCLUSIONS

The following are key findings:

- For each of the stages nutrient modelling would suggest:
    - The collective land use of the two parcels owned by the Stoddart's (Figure 1) has an existing N loss rate of 21 kg N/ha. This higher than expected N loss is due to 3 ha of winter grazing oats in LMU 3 (this block is present within all models, except Stage 3a/3b). Without this block, existing N losses are 14 kg N/ha across the property.
    - Irrigation of Te Paerahi's existing (2019) flows to a 4 ha block in LMU 3 (Stage 1), increases N losses from 21 kg N/ha (Stage 0) to 22 kg N/ha (Stage 1).
    - Incorporation of Porangahau, in addition to Te Paerahi flows, under 2028 population projections, with irrigation to 10 ha of land (10 ha of IMU 3), sees N losses increase from 22 kg N/ha (Stage 1) to 31 kg N/ha (Stage 2a) and to 26 kg N/ha (Stage 2b). This variation between 2a and 2b is due to varying discharge criteria between the non-deficit irrigation to wet soils system and the Porangahau River and essentially represent the extremities of the future discharge regime under Stage 2.
    - Under Stage 3, with irrigation of both communities under 2057 population projections to 40 ha (20 ha IMU 1 and 20 ha IMU 3), N losses reduce from Stage 2 to 29 kg N/ha at Stage 3a and 26 kg N/ha at Stage 3b. This reduction in losses is due to varying storage sizes being implemented at each of the stages, optimising the irrigation system, as well as an increase to the irrigation area and removal of the winter oats crop.
- Each of these models represent a 'worst case scenario' with regards to N loss rates. No significant farm system changes following wastewater irrigation have been modelled to mitigate nutrient losses. If any farm system changes were to be modelled, it would be expected for these N loss rates to reduce.

If you have any questions, please do not hesitate to get in contact.

Yours sincerely,

Lowe Environmental Impact

Sam Morris
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ATTACHMENT A

BLOCK SUMMARIES & OVERSEERFM INPUTS

STAGE 0:

Table 9: Nutrient Losses for Stage 0

Name	Area (ha)	N Loss Total (kg)	N Loss per ha (kg N/ha)	N in Drainage (ppm)	P Loss Total (kg)	P Loss per ha (kg P/ha)
LMU 1	50.8	333	7	2	9	0.2
LMU 2	16	281	18	6	10	0.6
LMU 3	33.3	816	27	5	45	1.5
Winter Oats*	3	883	294	51	1	0.2
Forestry Block	6.6	16	2	-	1	0.1

* Winter oats block rotates within the LMU 3 block.
**Green = Pasture/Forestry, Orange = Cropping

Table 10: Overseer Inputs for Stage 0

Overseer Parameters	
Blocks	**Pasture** LMU 1 (50.8 ha) LMU 3 (33.3 ha) Forestry Block (6.6 ha) **Crop Blocks** LMU 2 (16 ha) Winter Oats (3 ha) – Rotates within LMU 3 **Other Blocks** Forestry (6.6 ha) *7.6 ha not declared as blocks.
Soil	Soils were added based from Smap names. A separate soil map for the farm has been produced following field investigations (LEI, 2021:P:B.15)[2]. LMU 1 and 2 were modelled as Flax_69a.1 with the topsoil texture changed from unknown to a silt loam, with LMU 3 modelled as Kyra_15a.2. Soil tests were added as follows: LMU 1 – Olsen P: 18, QT K: 14, QT Ca: 11, QT Mg: 42, QT Na: 7, Organic S: 4, ASC: 24% LMU 2 – Organic S: 5, ASC: 19% LMU 3/IMU 3 – Olsen P: 46, QT K: 9, QT Ca: 9, QT Mg: 13, QT Na: 4, Organic S: 2, ASC: 14 %.
Drainage	No drainage method assumed for the irrigation areas
Pasture/Crops	LMU 2 contains a raphno fodder crop (entered as kale) for the period Nov (Year 1) to Sep (reporting year). This was direct drilled with a yield of 9 t/ha. Defoliation by sheep occurred for the period Jul-Sep. Following raphno, a chicory fodder crop (entered as rape) for the period Oct (reporting year) to May (reporting year) was grown. This was direct drilled with a yield of 5 t/ha. Defoliation by sheep occurred for the period Mar-May. Within LMU 3, a 3 ha forage oats crop rotates. This was sown in Mar (Year 1) and replanted in pasture in Sep (reporting year). Crop yield was set at 3.5 t/ha with months since fertiliser/effluent applied to pasture set at 6 months. LMU 1 was grown in ryegrass/white clover pasture, with LMU 3 being Browntop.

	Figure 5 represents existing cropping rotations for Stage 0.
Animals	35 18 month old 300 kg beef type steers were on the property between Jul-Sep. 15 375 kg live weight steers sent to works in Oct, leaving 20 steers for the remaining of the reporting year. Grazed on LMU 3 year round, and LMU 1 for all months except Jul and Aug. Defoliation events occurred on winter oats block in Jul and Aug for 6 hrs a day. 600 4 yr old 65 kg Romney breeding ewes were on the property between Jul-Oct. All ewes sent to works in Nov. Grazed on LMU 1 and 3 year round and on LMU 2 crop blocks for periods Jul-Sep for kale and Mar-May for rape. Defoliation events occurred on winter oats block for 6 hrs a day. Greasy wool production for the 600 breeding ewes set at 4000 kg/yr. 800 1 month old 10 kg mixed sex Romney lambs arrived on the property in Aug, with 200 sent to works at 30 kg live weight. Remaining 600 grazed till end of reporting year under same conditions as breeding ewes. Relative productivity set at relative pasture yield for the blocks with % of pasture eaten set at same as ratio of total animal intake. LMU 1 set at 1, LMU 3 set at 0.5. 1,000 kg/yr lime flour given to beef as per OverseerFM recommendations with Calcium error message.
Structure/Effluent	No dairy effluent system.
Supplements	No supplements supplied.
Fertiliser	300 kg/ha of Ravensdown Dicalcic High S applied to LMU 1, LMU 2, LMU 3 and Winter Oats blocks in Mar (reporting year). 50 kg/ha of Cropmaster DAP applied to LMU 3 and the Winter Oats block in Oct (Year 1). 100 kg/ha of Urea applied to the Winter Oats block in Apr (Year 1) and to LMU 2 in Dec (Year 1) and Nov (reporting year).
Irrigation	No irrigation applied.
GHG	Default not overridden.

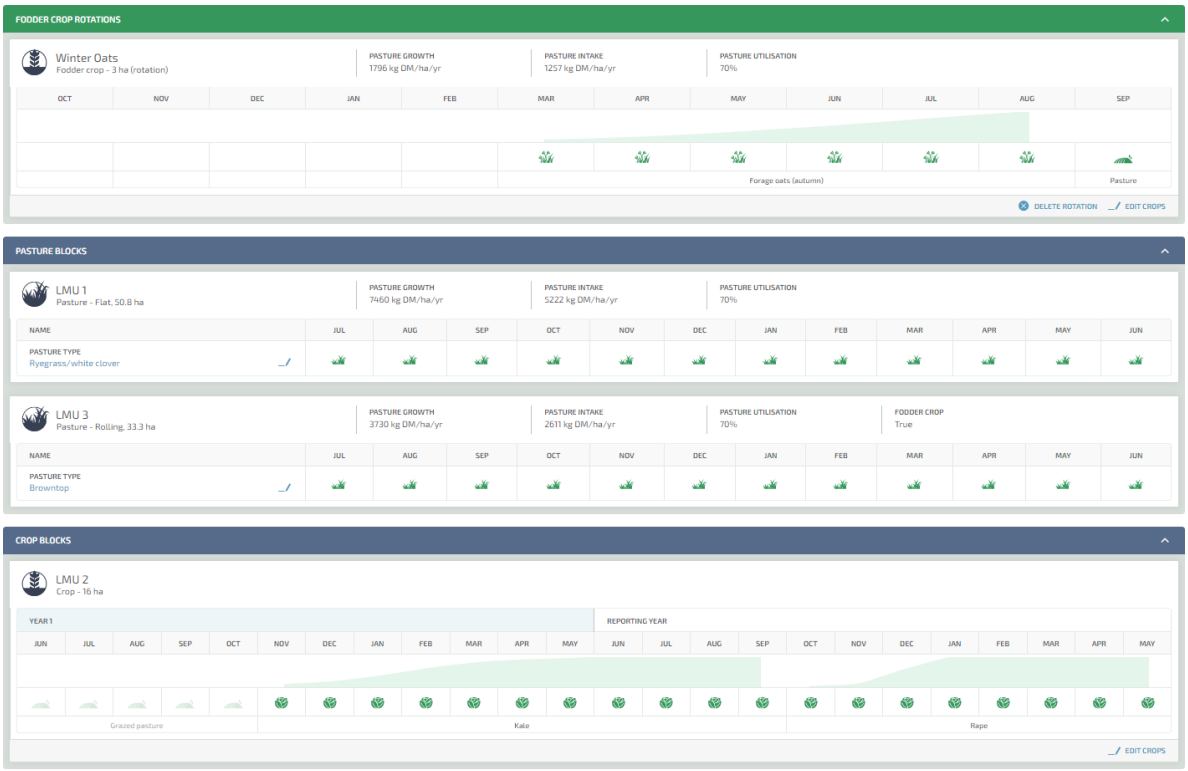

Figure 3: Crop rotations for Stage 0

STAGE 1:

Table 11: Nutrient Losses for Stage 1

Name	Area (ha)	N Loss Total (kg)	N Loss per ha (kg N/ha)	N in Drainage (ppm)	P Loss Total (kg)	P Loss per ha (kg P/ha)
LMU 1	50.8	331	7	2	9	0.2
LMU 2	16	281	18	6	10	0.6
LMU 3	29.3	692	26	5	39	1.5
IMU 3	4	358	90	10	29	7.2
Winter Oats*	3	866	289	50	1	0.2
Forestry Block	6.6	16	2	-	1	0.1

* Winter oats block rotates within the LMU 3 block.
**Green = Pasture/Forestry, Orange = Cropping

Table 12: OverseerFM Inputs for Stage 1

Overseer Parameters	
Blocks	**Pasture** LMU 1 (50.8 ha) LMU 3 (29.3 ha) IMU 3 (4 ha) Forestry Block (6.6 ha) **Crop Blocks** LMU 2 (16 ha) Winter Oats (3 ha) – Rotates within LMU 3 **Other Blocks** Forestry (6.6 ha) *7.6 ha not declared as blocks.
Soil	Soils were added based from Smap names. A separate soil map for the farm has been produced following field investigations (LEI, 2021:P:B.15)[2]. LMU 1 and 2 were modelled as Flax_69a.1 with the topsoil texture changed from unknown to a silt loam, with LMU 3/IMU 3 modelled as Kyra_15a.2. Soil tests were added as follows: LMU 1 – Olsen P: 18, QT K: 14, QT Ca: 11, QT Mg: 42, QT Na: 7, Organic S: 4, ASC: 24% LMU 2 – Organic S: 5, ASC: 19% LMU 3/IMU 3 – Olsen P: 46, QT K: 9, QT Ca: 9, QT Mg: 13, QT Na: 4, Organic S: 2, ASC: 14 %.
Drainage	No drainage method assumed for the irrigation areas
Pasture/Crops	LMU 2 contains a raphno fodder crop (entered as kale) for the period Nov (Year 1) to Sep (reporting year). This was direct drilled with a yield of 9 t/ha. Defoliation by sheep occurred for the period Jul-Sep. Following raphno, a chicory fodder crop (entered as rape) for the period Oct (reporting year) to May (reporting year) was grown. This was direct drilled with a yield of 5 t/ha. Defoliation by sheep occurred for the period Mar-May. Within LMU 3, a 3 ha forage oats crop rotates. This was sown in Mar (Year 1) and replanted in pasture in Sep (reporting year). Crop yield was set at 3.5 t/ha with months since fertiliser/effluent applied to pasture set at 6 months.

	LMU 1 was grown in ryegrass/white clover pasture, with LMU 3/IMU 3 being Browntop. Figure 4 represents existing cropping rotations for Stage 1.
Animals	35 18 month old 300 kg beef type steers were on the property between Jul-Sep. 15 375 kg live weight steers sent to works in Oct, leaving 20 steers for the remaining of the reporting year. Grazed on LMU 3/IMU 3 year round, and LMU 1 for all months except Jul and Aug. Defoliation events occurred on winter oats block in Jul and Aug for 6 hrs a day. 600 4 yr old 65 kg Romney breeding ewes were on the property between Jul-Oct. All ewes sent to works in Nov. Grazed on LMU 1 and 3 year round and on LMU 2 crop blocks for periods Jul-Sep for kale and Mar-May for rape. Defoliation events occurred on winter oats block for 6 hrs a day. Greasy wool production for the 600 breeding ewes set at 4000 kg/yr. 800 1 month old 10 kg mixed sex Romney lambs arrived on the property in Aug, with 200 sent to works at 30 kg live weight. Remaining 600 grazed till end of reporting year under same conditions as breeding ewes. Relative productivity set at relative pasture yield for the blocks with % of pasture eaten set at same as ratio of total animal intake. LMU 1 and IMU 3 set at 1, LMU 3 set at 0.5. 1,000 kg/yr lime flour given to beef as per OverseerFM recommendations with Calcium error message.
Structure/Effluent	No dairy effluent system.
Supplements	No supplements supplied.
Fertiliser	300 kg/ha of Ravensdown Dicalcic High S applied to LMU 1, LMU 2, LMU 3 and Winter Oats blocks in Mar (reporting year). 50 kg/ha of Cropmaster DAP applied to LMU 3 in Oct (Year 1). 100 kg/ha of surface applied Urea applied to the Winter Oats block in Apr (Year 1) and to LMU 2 in Dec (Year 1) and Nov (reporting year). Wastewater applied as soluble fertiliser. Monthly application of N and P shown in Table 13 below.
Irrigation	Irrigation applied as a solid set irrigation system and is based on calculated application depths for IMU 3.
GHG	Default not overridden.

Table 13: IMU 3 N and P Wastewater Loads (Stage 1)

	N WW Load (kg N/ha)	P WW Load (kg P/ha)
January	8.8	2.2
February	5	1.3
March	6.4	1.6
April	9.8	2.5
May	8.8	2.2
June	11.4	2.9
July	15.6	3.9
August	14.4	3.6
September	14	3.5
October	12.2	3.1
November	7	1.8
December	8	2.0
Total	**121**	**30**

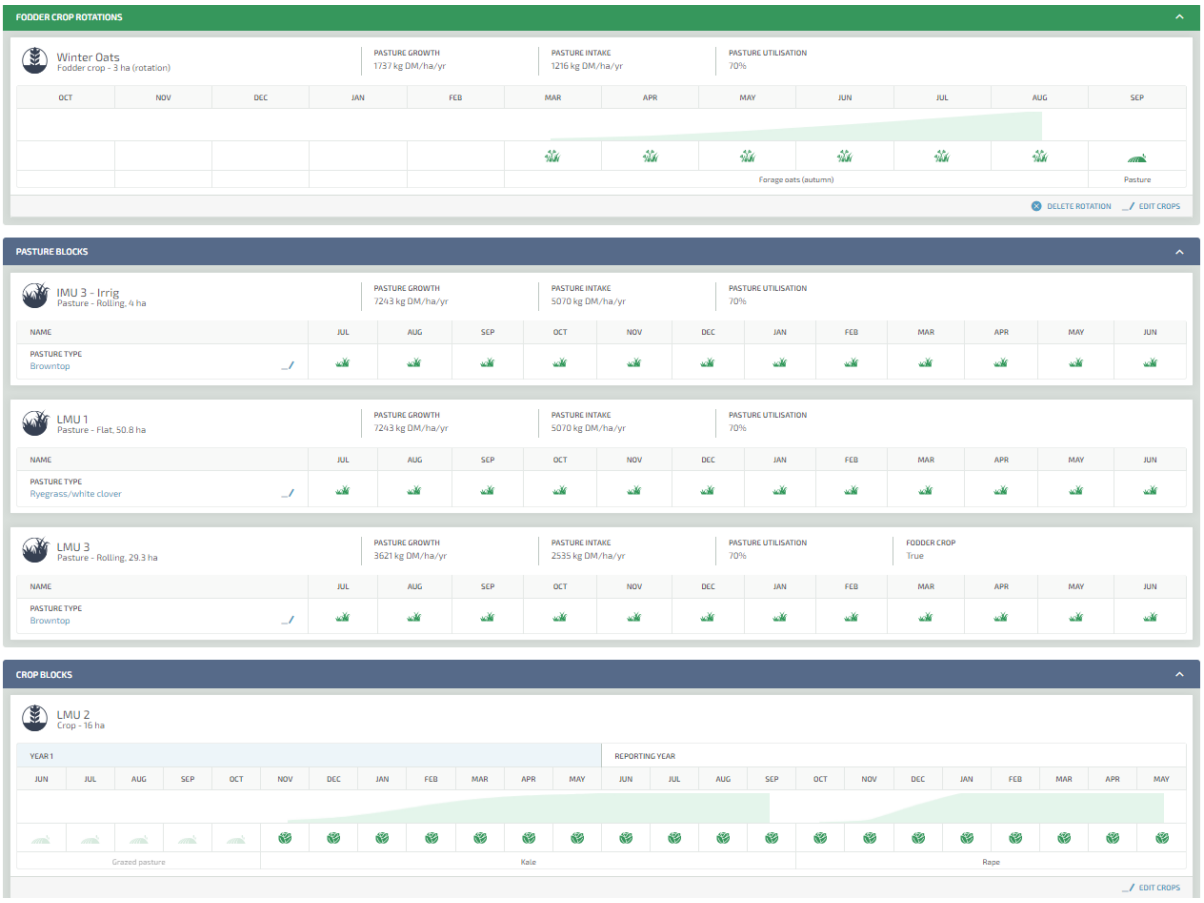

Figure 4: Crop Rotations for Stage 1

STAGE 2

Table 14: Nutrient Losses for Stage 2a/Stage 2b

Stage 2a						
Name	**Area (ha)**	**N Loss Total (kg)**	**N Loss per ha (kg N/ha)**	**N in Drainage (ppm)**	**P Loss Total (kg)**	**P Loss per ha (kg P/ha)**
LMU 1	50.8	340	7	2	9	0.2
LMU 2	16	281	18	6	10	0.6
LMU 3	23.3	546	27	5	30	1.5
IMU 3	10	1,441	144	12	98	9.8
Winter Oats*	3	845	282	49	1	0.2
Forestry Block	6.6	16	2	-	1	0.1
Stage 2b						
Name	**Area (ha)**	**N Loss Total (kg)**	**N Loss per ha (kg N/ha)**	**N in Drainage (ppm)**	**P Loss Total (kg)**	**P Loss per ha (kg P/ha)**
LMU 1	50.8	339	7	2	9	0.2
LMU 2	16	281	18	6	10	0.6
LMU 3	23.3	542	27	5	30	1.5
IMU 3	10	777	78	10	56	5.6
Winter Oats*	3	844	281	49	1	0.2
Forestry Block	6.6	16	2	-	1	0.1

* Winter oats block rotates within the LMU 3 block.
**Green = Pasture/Forestry, Orange = Cropping

Table 15: OverseerFM Inputs for Stage 2a/Stage 2b

Overseer Parameters	
Blocks	**Pasture** LMU 1 (50.8 ha) LMU 3 (23.3 ha) IMU 3 (10 ha) Forestry Block (6.6 ha) **Crop Blocks** LMU 2 (16 ha) Winter Oats (3 ha) – Rotates within LMU 3 **Other Blocks** Forestry (6.6 ha) *7.6 ha not declared as blocks.
Soil	Soils were added based from Smap names. A separate soil map for the farm has been produced following field investigations (LEI, 2021:P:B.15)[2]. LMU 1 and 2 were modelled as Flax_69a.1 with the topsoil texture changed from unknown to a silt loam, with LMU 3/IMU 3 modelled as Kyra_15a.2. Soil tests were added as follows: LMU 1 – Olsen P: 18, QT K: 14, QT Ca: 11, QT Mg: 42, QT Na: 7, Organic S: 4, ASC: 24% LMU 2 – Organic S: 5, ASC: 19% LMU 3/IMU 3 – Olsen P: 46, QT K: 9, QT Ca: 9, QT Mg: 13, QT Na: 4, Organic S: 2, ASC: 14 %.
Drainage	No drainage method assumed for the irrigation areas

Pasture/Crops	LMU 2 contains a raphno fodder crop (entered as kale) for the period Nov (Year 1) to Sep (reporting year). This was direct drilled with a yield of 9 t/ha. Defoliation by sheep occurred for the period Jul-Sep. Following raphno, a chicory fodder crop (entered as rape) for the period Oct (reporting year) to May (reporting year) was grown. This was direct drilled with a yield of 5 t/ha. Defoliation by sheep occurred for the period Mar-May. Within LMU 3, a 3 ha forage oats crop rotates. This was sown in Mar (Year 1) and replanted in pasture in Sep (reporting year). Crop yield was set at 3.5 t/ha with months since fertiliser/effluent applied to pasture set at 6 months. LMU 1 was grown in ryegrass/white clover pasture, with LMU 3/IMU 3 being Browntop. Figure 5 represents existing cropping rotations for Stage 2a/Stage 2b.
Animals	40 18 month old 300 kg beef type steers were on the property between Jul-Sep. 15 375 kg live weight steers sent to works in Oct, leaving 25 steers for the remaining of the reporting year. Grazed on LMU 3/IMU 3 year round, and LMU 1 for all months except Jul and Aug. Defoliation events occurred on winter oats block in Jul and Aug for 6 hrs a day. 600 4 yr old 65 kg Romney breeding ewes were on the property between Jul-Oct. All ewes sent to works in Nov. Grazed on LMU 1 and 3 year round and on LMU 2 crop blocks for periods Jul-Sep for kale and Mar-May for rape. Defoliation events occurred on winter oats block for 6 hrs a day. Greasy wool production for the 600 breeding ewes set at 4000 kg/yr. 800 1 month old 10 kg mixed sex Romney lambs arrived on the property in Aug, with 200 sent to works at 30 kg live weight. Remaining 600 grazed till end of reporting year under same conditions as breeding ewes. Relative productivity set at relative pasture yield for the blocks with % of pasture eaten set at same as ratio of total animal intake. LMU 1/IMU 3 Irrig set at 1, LMU 3 set at 0.5. 1,000 kg/yr lime flour given to beef as per OverseerFM recommendations with Calcium error message.
Structure/Effluent	No dairy effluent system.
Supplements	No supplements supplied.
Fertiliser	300 kg/ha of Ravensdown Dicalcic High S applied to LMU 1, LMU 2, LMU 3 and Winter Oats blocks in Mar (reporting year). 50 kg/ha of Cropmaster DAP applied to LMU 3 in Oct (Year 1). 100 kg/ha of surface applied Urea applied to the Winter Oats block in Apr (Year 1) and to LMU 2 in Dec (Year 1) and Nov (reporting year). Wastewater applied as soluble fertiliser. Monthly application of N and P for both stages shown in Table 16 below.
Irrigation	Irrigation applied as a solid set irrigation system and is based on calculated application depths for IMU 3.
GHG	Default not overridden.

Table 16: IMU 3 N and P Wastewater Loads (Stage 2a/Stage 2b)

	Stage 2a		Stage 2b	
	N WW Load (kg N/ha)	P WW Load (kg P/ha)	N WW Load (kg N/ha)	P WW Load (kg P/ha)
January	11.6	2.9	9.8	2.5
February	8.8	2.2	7.0	1.8
March	10.9	2.7	8.0	2.0
April	15.9	4.0	7.8	1.9
May	15.8	3.9	5.6	1.4
June	20.7	5.2	6.8	1.7
July	29.8	7.4	6.4	1.6
August	25.5	6.4	5.8	1.5
September	23.6	5.9	7.9	2.0
October	18.4	4.6	10.8	2.7
November	11.5	2.9	10.5	2.6
December	11.0	2.8	10.5	2.6
Total	**203**	**51**	**97**	**24**

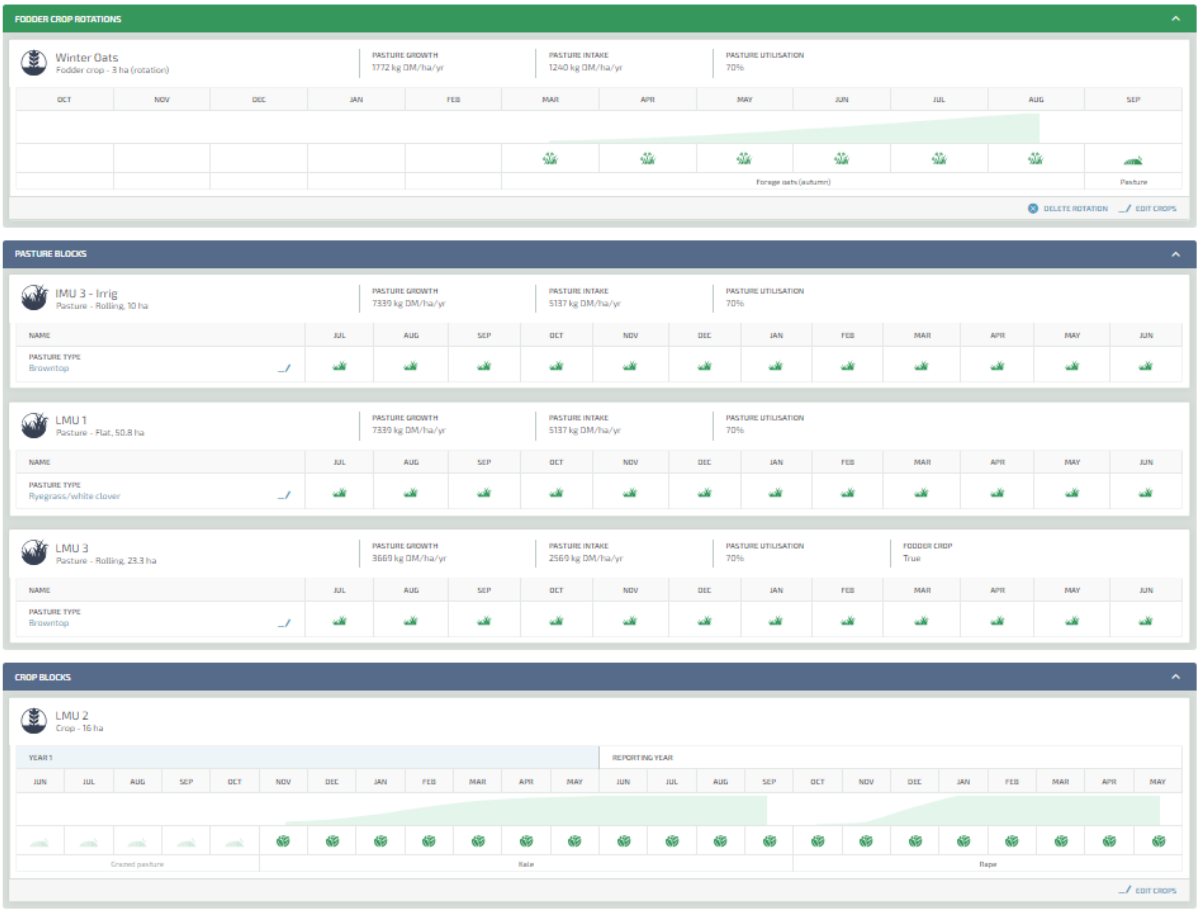

Figure 5: Crop Rotations for Stage 2a/Stage 2b

STAGE 3

Table 17: Nutrient Losses for Stage 3a/Stage 3b

Stage 3a						
Name	**Area (ha)**	**N Loss Total (kg)**	**N Loss per ha (kg N/ha)**	**N in Drainage (ppm)**	**P Loss Total (kg)**	**P Loss per ha (kg P/ha)**
LMU 1	30.8	233	8	3	6	0.2
LMU 2	16	281	18	6	10	0.6
LMU 3	13.3	392	29	5	20	1.5
IMU 1	20	265	13	3	10	0.5
IMU 3	20	2,091	105	10	152	7.6
Forestry Block	6.6	16	2	-	1	0.1
Stage 3b						
Name	**Area (ha)**	**N Loss Total (kg)**	**N Loss per ha (kg N/ha)**	**N in Drainage (ppm)**	**P Loss Total (kg)**	**P Loss per ha (kg P/ha)**
LMU 1	30.8	233	8	3	6	0.2
LMU 2	16	281	18	6	10	0.6
LMU 3	13.3	387	29	5	20	1.5
IMU 1	20	261	13	3	10	0.5
IMU 3	20	1,813	91	9	146	7.3
Forestry Block	6.6	16	2	-	1	0.1

*Green = Pasture/Forestry, Orange = Cropping

Table 18: OverseerFM Inputs for Stages 3a/3b

Overseer Parameters	
Blocks	**Pasture** LMU 1 (30.8 ha) LMU 3 (13.3 ha) IMU 1 (20 ha) IMU 3 (20 ha) Forestry Block (6.6 ha) **Crop Blocks** LMU 2 (16 ha) **Other Blocks** Forestry (6.6 ha) *7.6 ha not declared as blocks.
Soil	Soils were added based from Smap names. A separate soil map for the farm has been produced following field investigations (LEI, 2021:P:B.15)[2]. LMU 1/IMU 1 and 2 were modelled as Flax_69a.1 with the topsoil texture changed from unknown to a silt loam, with LMU 3/IMU 3 modelled as Kyra_15a.2. Soil tests were added as follows: LMU 1 – Olsen P: 18, QT K: 14, QT Ca: 11, QT Mg: 42, QT Na: 7, Organic S: 4, ASC: 24% LMU 2 – Organic S: 5, ASC: 19% LMU 3/IMU 3 – Olsen P: 46, QT K: 9, QT Ca: 9, QT Mg: 13, QT Na: 4, Organic S: 2, ASC: 14 %.
Drainage	No drainage method assumed for the irrigation areas

Pasture/Crops	LMU 2 contains a raphno fodder crop (entered as kale) for the period Nov (Year 1) to Sep (reporting year). This was direct drilled with a yield of 9 t/ha. Defoliation by sheep occurred for the period Jul-Sep. Following raphno, a chicory fodder crop (entered as rape) for the period Oct (reporting year) to May (reporting year) was grown. This was direct drilled with a yield of 5 t/ha. Defoliation by sheep occurred for the period Mar-May. LMU 1/IMU 1 was grown in ryegrass/white clover pasture, with LMU 3/IMU 3 being Browntop. Figure 6 represents existing cropping rotations for Stage 3.
Animals	70 18 month old 300 kg beef type steers were on the property between Jul-Sep. 20 375 kg live weight steers sent to works in Oct, leaving 50 steers for the remaining reporting year. Grazed on LMU 3/IMU 3 year round, and LMU 1/IMU 1 for all months except Jul and Aug. Defoliation events occurred on winter oats block in Jul and Aug for 6 hrs a day. 600 4 yr old 65 kg Romney breeding ewes were on the property between Jul-Oct. All ewes sent to works in Nov. Grazed on LMU 1 and 3 year round and on LMU 2 crop blocks for periods Jul-Sep for kale and Mar-May for rape. Defoliation events occurred on winter oats block for 6 hrs a day. Greasy wool production for the 600 breeding ewes set at 4000 kg/yr. 800 1 month old 10 kg mixed sex Romney lambs arrived on the property in Aug, with 200 sent to works at 30 kg live weight. Remaining 600 grazed till end of reporting year under same conditions as breeding ewes. Relative productivity set at relative pasture yield for the blocks with % of pasture eaten set at same as ratio of total animal intake. LMU 1/IMU 3 set at 0.8, LMU 3 set at 0.4, IMU 1 set at 1.5. 1,000 kg/yr lime flour given to beef as per OverseerFM recommendations with Calcium error message.
Structure/Effluent	No dairy effluent system.
Supplements	No supplements supplied.
Fertiliser	300 kg/ha of Ravensdown Dicalcic High S applied to LMU 1, LMU 2, LMU 3 and Winter Oats blocks in Mar (reporting year). 50 kg/ha of Cropmaster DAP applied to LMU 3 in Oct (Year 1). 100 kg/ha of surface applied Urea applied to LMU 2 in Dec (Year 1) and Nov (reporting year). Wastewater applied as soluble fertiliser. Monthly application of N and P shown in Table 19 (Stage 3a) and Table 20 (Stage 3b) below.
Irrigation	Irrigation applied as a solid set irrigation system and is based on calculated application depths for IMU 1 and IMU 3. No irrigation occurred for the months of June and July to IMU 1 in Stage 3a/3b. Additionally, no irrigation occurred for the months of July and August to IMU 3 for Stage 3b.
GHG	Default not overridden.

Table 19: IMU 1/IMU 3 N and P Wastewater Loads (Stage 3a)

	IMU 1 N WW Load (kg N/ha)	IMU 1 P WW Load (kg P/ha)	IMU 3 N WW Load (kg N/ha)	IMU 3 P WW Load (kg P/ha)
January	8.8	2.2	2.0	0.5
February	7.1	1.8	1.4	0.3
March	7.7	1.9	2.8	0.7
April	4.8	1.2	8.5	2.1
May	1.7	0.4	14.5	3.6
June	0	0	18.2	4.5
July	0	0	25.6	6.4
August	0.7	0.2	22.5	5.6
September	3.7	0.9	17.7	4.4
October	9.6	2.4	8.1	2.0
November	9.2	2.3	1.2	0.3
December	9.5	2.4	2.0	0.5
Total	**63**	**16**	**125**	**31**

Table 20: IMU 1/IMU 3 N and P Wastewater Loads (Stage 3b)

	IMU 1 N WW Load (kg N/ha)	IMU 1 P WW Load (kg P/ha)	IMU 3 N WW Load (kg N/ha)	IMU 3 P WW Load (kg P/ha)
January	8.0	2.0	2.1	0.5
February	6.6	1.7	1.3	0.3
March	7.4	1.8	2.5	0.6
April	5.3	1.3	8.1	2.0
May	1.7	0.4	13.3	3.3
June	0	0	18.7	4.7
July	0	0	0	0
August	0.7	0.2	0	0
September	4.4	1.1	44.8	11.2
October	9.4	2.4	30.6	7.7
November	9.2	2.3	0.9	0.2
December	9.0	2.3	2.6	0.6
Total	**62**	**15**	**125**	**31**

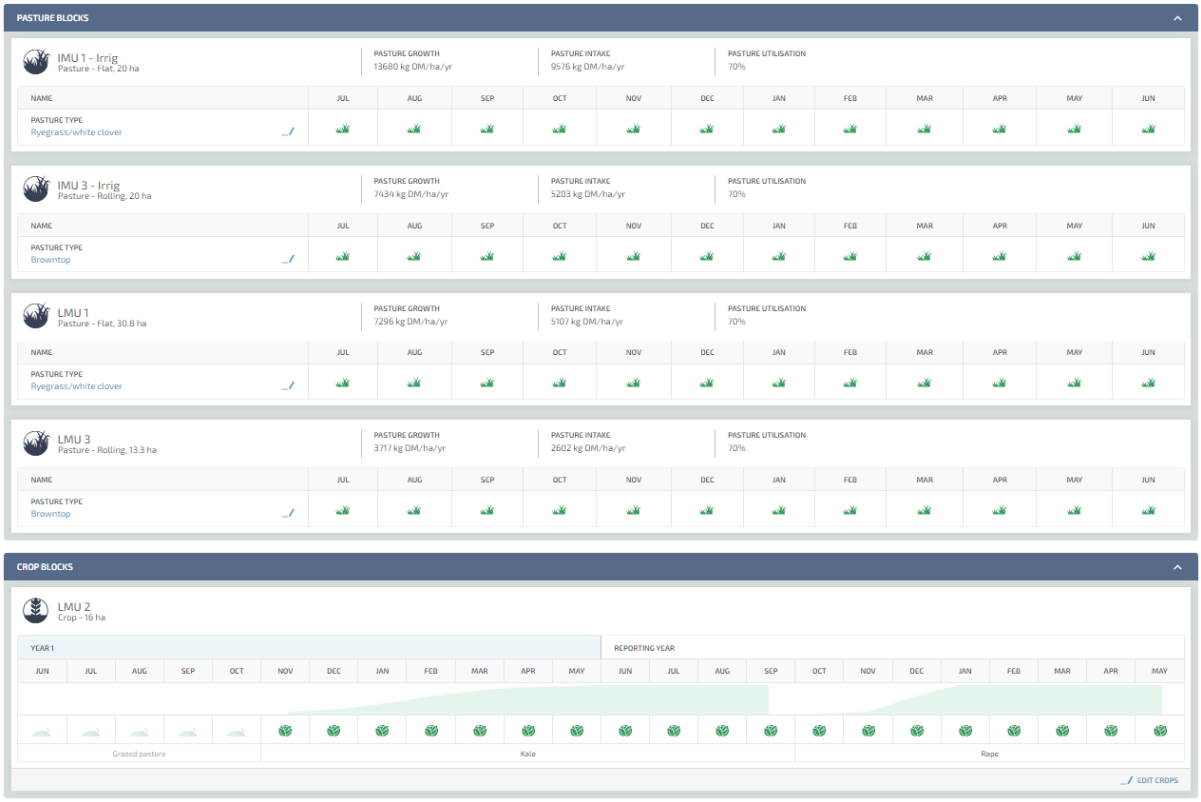

Figure 6: Crop Rotations for Stage 3a/Stage 3b