EFFLUENT MANAGEMENT IN OVERSEER® NUTRIENT BUDGETS

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Introduction

OVERSEER® Nutrient Budgets (*Overseer*) calculates the movement of nutrients around a farm. This includes accounting for stock excreta deposited on hard surfaces or in structures such as feed pads, wintering pads, etc, which is then collected and dealt with as effluent. Accounting for effluent nutrients is an essential part of the nutrient budget and enables adjustment of fertiliser rates on effluent blocks, as well as calculating the effluent block area required to meet annual nitrogen (N) loading limits.

The challenges for the decision support tool are (a) having the ability and the flexibility to allow the user to input data that correctly describes the effluent system on the farm and (b) being able to model adequately the nutrient flows through the systems, accounting for transformations and losses at all points in the system.

This paper describes how effluent is dealt with in *Overseer* and uses examples to show the implications of different management approaches on calculated nutrient transfers.

Excreta production

As described by Wheeler et al. (2009) the total amount of excreta an animal type produces is estimated from nutrient intake, which in turn is dependent on the diet of the animal (amount of pasture, crop and supplements eaten). The amount of pasture is determined from animal metabolisable energy (ME) requirements less ME supplied by crops and supplements. Nutrient intake is estimated from pasture using estimated nutrient concentrations based on soil tests and fertiliser application rates, and other feed sources using default nutrient concentrations. Thus, the amount of excreta produced is dependent on diet and animal productivity. A schematic diagram is shown in Figure 1. As this calculation is performed on a monthly basis, this gives kg nutrient/month/animal type as excreta.

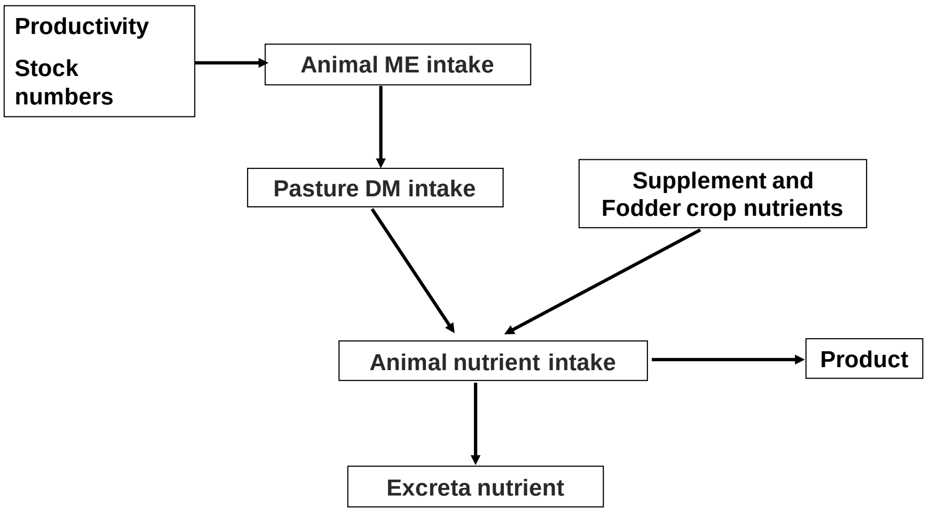

***Figure 1**. Schematic diagram for the calculation of excreta nutrient loadings.*

Calculating excreta distribution

Effluent nutrient concentrations are highly variable, and in most instances, the volume of effluent is not well known. Hence, *Overseer* deals with nutrient loads in the effluent, not volumes of effluent. This also makes it possible to incorporate the effect of different diets on the amount of nutrients in excreta.

Excreta can be deposited at many points in the farm system (Figure 2). A time-based model based on Ledgard and Brier (2004) was used for allocating excreta to structures on the farm. For wintering pads/animal shelters with grazing, nutrient intake can occur on both the pad and the pasture, and excreta can be deposited on both. The model allows for transfer of nutrients in the gut of the animal to the pad after consuming pasture, and the distribution of excreta on both the pad and paddock based on intake from both the pasture and supplements fed on the pad. However, this approach may not always reflect cow management in shed, where the amount of excreta deposited can vary with the design and management of the shed.

On feed pads, depending on input options selected, unutilised spilt feed can also end up in the effluent. This can be a major source of nutrients on systems with low supplement utilisation on pads, as occurs in some dairy goat systems, or where there are high amounts of supplementary feeding.

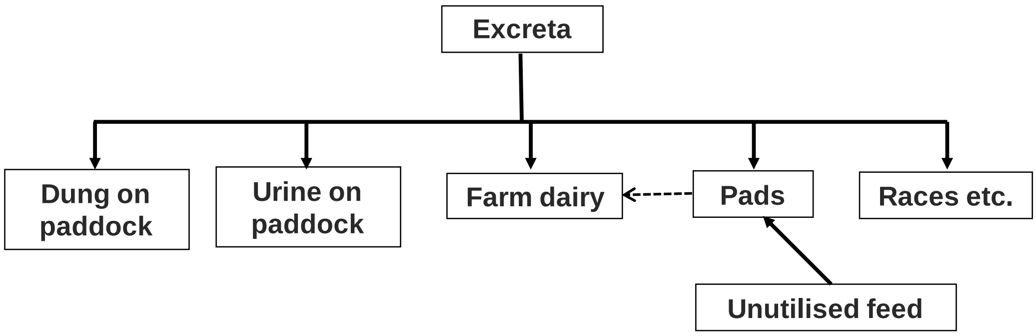

Figure 2. *Schematic diagram for the distribution of excreta nutrients around the farm.*

Thus, the model estimates the kg nutrient as effluent for each animal type for each month.

Effluent sources and their management in *Overseer*

There are two sources of farm effluent, namely from the farm dairy for dairy cow and dairy goat systems, and wintering pads/animal shelters (for all animal systems except sheep).

The farm dairy effluent management system can be split into two components, namely the treatment system and the application of effluent to blocks. The treatment system defines the separation of nutrients into solid and liquid phases, and losses, including gaseous losses.

Wintering pads/animal shelters have a wider range of effluent management options such as cleaning by scraping or flushing, or the use of bunkers or lining for containment. These options define the separation of deposited excreta into solid and liquid phases. The liquid phase can be added to the farm dairy effluent management system for dairy systems, or can be modelled separately using the same options as for the farm dairy. The liquid phase from feed pads is added to the farm dairy effluent by definition.

Accounting for nutrients during effluent management

The rest of this paper will focus on farm dairy effluent and the general methodology used to model effluent with *Overseer*.

As noted earlier, the treatment system defines the separation of nutrients into solid and liquid phases. The separation ratios for each nutrient are based on Luo and Longhurst (2008), and differ for each treatment. There are also links to the greenhouse gas model (see Wheeler et al. 2008) so that direct emissions of methane and nitrous oxide for each treatment system can be calculated (Luo et al. 2008), as well as indirect nitrous oxide emissions from volatilisation or leaching of N (Ministry of the Environment 2011).

Initially, about 6% of the N deposited on the dairy shed yard is assumed to be volatilised. The effect of available effluent treatments options are:

- Sump means direct application to paddock as spray. There is an additional small amount of N (2%) removed due to volatilisation loss during land application.
- Pond + discharge. Effluent nutrients can settle as sludge, and for N 50% of the excreta N is lost as volatilisation and denitrification (Luo and Longhurst 2008). The remaining nutrients are discharged directly to a waterway. The pond sludge can be applied to any farm blocks or exported off-farm.
- Holding pond. See further detail below.
- Export. All nutrients are exported. This export option has been coupled with the ability to add effluent as an organic fertiliser type input on another farm.

For holding ponds, solid separation can occur prior to effluent entering the pond. The non-solid proportion is added to the 'liquid' phase. The solids can be stored in covered or uncovered stacks, and can either be applied to farm blocks or exported. Stored solids also have leaching losses associated with them (Luo and Longhurst 2008). Nitrogen losses by volatilisation and denitrification from stored solids, including bunkers in animal shelters can be large (Luo and Longhurst 2008), and can be more than 50% of the N in the effluent. The model has adopted a moderate loss, assuming 3.3% of N per month is lost by volatilisation and denitrification from stored solids, or about 40% of N/year if stored for 12 months.

The liquid phase (effluent directly from dairy shed yard or liquid after solid separation) can be land applied by using either: 1) sprayed regularly, 2) sprayed regularly with stirring, 3) sprayed infrequently, or 4) exported. Although these are application methods, they define the time the material remains in the pond and hence the proportion of nutrient deposited in the sludge.

There are 2 other options Deferred applications within the model are covered by 'active management' options (see below). There is also an option to avoid land applications in specific months if the 'sprayed infrequently' option is selected.

Rate applied to blocks

For 'liquid' effluent, it is assumed that the month of application is the month of production i.e. when the animals are lactating or on pads. For holding ponds using the 'spraying infrequently' option, the month of application can be specified. To estimate block application rate, the model assumes that farm dairy effluent is applied at the same rate (kg nutrient/ha) each month that effluent is applied. Therefore, the rate of application of a nutrient to a given block ($Eff_{block,\ nut}$, kg nutrient/ha) and the rate applied per month ($EffMonth_{block,\ nut,\ month}$, kg nutrient/ha/month) is estimated as:

$$Eff_{block,\ nut} = \sum_{mon}(EffDairy_{nut} * PropApplied_{block} / TotPropApplied * EffApplied_{mon})$$
$$EffMonth_{block,\ nut,\ month} = EffDairy_{nut} / TotPropApplied * EffApplied_{mon}$$
$$TotPropApplied = \sum_{block,\ mon}(Area_{block} * PropApplied_{block} * EffApplied_{mon})$$

where EffDairy is the rate of nutrient in the liquid effluent phase (kg nutrient/year), PropApplied is the proportion of a block that effluent is applied to (value 0-1, 1 by default), and EffApplied is 1 if effluent is applied in that month or zero otherwise. A similar calculation is applied for effluent in the liquid phase effluent from wintering pads.

The rate $Eff_{block,\ nut}$ is used directly in the nutrient budget whereas $EffMonth_{block,\ nut,\ month}$ is used in the monthly nutrient loss models. Currently it is not possible to apply effluent differentially to blocks, such as twice the nutrient load on one block compared to another.

In practice, solid effluents tend to be applied in only one or two operations per year on a farm. Hence the source (sludge, separated solids, etc) and month of application are specified by the user. The sources generated within the model are pond solids/sludge from farm dairy effluent system and wintering pad effluent system, separated solids from the holding pond option, and solids from wintering pads, animal shelters, feed pads or loafing pads.

The rate and ratio between nutrients applied to blocks as effluent changes with the source. An example of application rates is shown in Table 1, where all inputs, including effluent block size, are the same but the type of effluent applied to the effluent block varies. Note that actual rates will vary from farm to farm. Solid effluents tend to have a lower ratio of N:K but a higher ratio of N:P than liquid sources, and the longer effluent is held in storage, more N is lost through volatilisation and denitrification.

Table 1. *Example of rates of nutrients applied (kg nutrient/year) for effluents from different treatment systems and assuming all other sources are exported*

Treatment	**N**	**P**	**K**	**S**	**Ca**	**Mg**	**Na**
Sump	121	12	143	14	12	8	3
Holding pond spray regularly	88	8	139	11	8	5	2
Holding pond spray and stir regularly	96	11	143	13	12	7	3
Holding pond spray infrequently	68	3	129	7	1	1	2
Liquid phase after separating solids	61	0	125	6	0	1	1
Pond sludge	12	8	14	7	12	7	1
Separated solids	37	11	14	7	12	7	1
Separated solids stored for 6 months	29	11	14	7	12	7	1

The total amount of effluent N is used to estimate the area of farm required for an effluent block to reach a target of 150 kg N/ha/yr applied. This includes both liquid and solid effluent.

Estimating N leaching losses

The underlying background N model in pastoral blocks (see Wheeler et al. 2011), and the N models in cut and carry (see Wheeler et al. 2010) and the fruit block N model are all based on the crop N model (Cichota et al. 2010). By assuming that the inorganic N fraction of effluent behaves like fertiliser N, and the organic N fraction behaves similar to crop residues, then the fate of effluent N can be calculated for all blocks using a consistent model. Using these N models also allows the interaction of fertiliser N, effluent N and other sources of N (excluding urine N, which is modelled separately (Wheeler et al. 2011)), to be modelled. In addition, effluents and composts can be brought in as an organic fertiliser and modelled following the same principles.

The proportion of inorganic N and organic N content required to drive these models is based on typical values for effluent of the type, or can be entered by the user if applied under the organic fertiliser option.

Thus, based on the crop model, N leaching losses are higher if effluent is applied in months with high drainage, for example direct application from the pads in winter, and higher if soil N levels are high due to, for example, low plant uptake and/or high total N inputs from effluent, fertiliser, imported feed and irrigation.

Overseer allows the user to specify the percentage of the farm block that receives effluent ($PropApplied_{block}$ is the proportion). If the percentage is less than 100, the background N model is calculated for both the effluent and non-effluent proportions of the block, assuming that all other inputs are the same, and a weighted N loss estimated.

The N from solid effluents is assumed to be released over a 2 to 6 month period, depending on the month of application, temperatures, and the solids' organic N content.

Effluent N applications can also affect modelled N leaching losses from urine due to additional N being added to the urine patch.

Estimating P runoff losses

Surface runoff losses of phosphorus (P) are dependent on the time of application, rainfall, region (propensity of runoff to occur), the rate of application (low application or mm/day) for liquids, soil characteristics and drainage, and whether a solid or liquid is applied (McDowell et al. 2003). P runoff losses are lower for solids than liquids.

The model assumes that best management practices (BMPs) are followed as defined by the dairy effluent manual (DEC 2006). Researchers have indicated that following BMP, there can still be some runoff loss, particularly from poorly draining soils. Hence, the model assumes that there are some runoff losses from poor draining soils. In addition, an 'active management' option has been added, which in effect indicates 'perfect' BMP. Thus, active management implies that during application, there is regular checking (multiple times a day) of application equipment and of the paddock surface to ensure there is no effluent ponding anywhere. This option also implies there is monitoring of soil moisture and upcoming rainfall to ensure that the application rate is less than the soils' capacity to hold water. In addition, this option also implies the use of deferred irrigation technology, and there are no losses from effluent storage system. Note that, even with active management, there can still be N leaching losses from the background model.

Example of estimated N leaching and P runoff losses on an effluent block

Estimated N and P losses from liquid or solid effluent applied to an effluent block on an example farm using different effluent treatment and application methods, with and without a wintering pad are shown in Table 2 and 3 respectively. The effluent block size was constant. As N leaching is modelled using the background model, plant uptake, as mediated through region, drainage, application methods and rate of N applied all influence the estimated amount of N leached. Wintering pads result in both higher amounts of effluent, and effluent being applied over winter when the pad is in use, resulting in higher leaching rates on the effluent block.

Table 2. *Examples of N leached (kg N/ha/yr) and P runoff losses (kg P/ha/year) from a effluent block when liquid effluent is applied using different effluent treatment and application methods, with and without a wintering pad for 2 sites.*

Treatment and application	**No winter pad**		**With winter pad[3]**	
	N loss	**P runoff**	**N loss**	**P runoff**
Allophanic soil in Waikato				
No effluent applied	20	0.1	17	0.1
Spray from sump - low application[1]	30	0.1	30	0.1
Spray from sump - slow irrigator[2]	31	0.3	31	0.3
Spray from sump - low application, active management	30	0.1	30	0.1
Spray from sump - medium irrigator, active management	31	0.2	30	0.2
Holding pond - spray regularly	28	0.1	26	0.1
Holding pond - spray and stir regularly	28	0.1	27	0.1
Holding pond - spray infrequently	26	0.1	24	0.1
Holding pond - spray infrequently/timing	25	0.1	23	0.1
Pallic soil with mole/tile drainage soil in Southland				
No effluent applied	23	0.8	20	0.8
Spray from sump - low application[1]	40	1.2	40	1.2
Spray from sump - slow irrigator[2]	53	2.7	56	2.7
Spray from sump - low application, active management	38	1.0	37	1.0
Spray from sump - medium irrigator, active management	43	1.6	44	11.7
Holding pond - spray regularly	33	0.9	34	1.1
Holding pond - spray and stir regularly	34	0.9	35	1.1
Holding pond - spray infrequently	31	0.9	30	0.9
Holding pond - spray infrequently/timing				

[1] low application is a K-line or similar systems.

[2] slow irrigator is an effluent irrigator set on slow speed, applying > 24 mm/pass of effluent.

[3] Feed pad plus grazing, no additional supplements, animals on 100% of time in June, July and August, uncovered winter pad, lined and effluent treated the same as farm dairy effluent, no concrete apron

The actual amount of N and P losses and size of the differences between treatment and application methods will vary from farm to farm.

The effect on whole farm large N losses depends on the proportion of farm that is effluent blocks, the fate of effluent not included, and effect of other farm management options. Thus when wintering pads are used, whole farm leaching decreases as indicated by lower losses when no effluent is applied (all exported) in the present of a wintering pad.

The method of loss also varies with treatment and site characteristics. Thus on mole/tile drained blocks, a high proportion of N loss is direct to stream via the mole tile drained system, whereas in the allophonic soil, most of the N losses is from leaching. Although there is low leaching loss from pond solids, there is a high rate of N lost direct to stream (data not shown).

Maintenance fertiliser nutrient requirements

The effluent rate is incorporated as a nutrient input in the calculation of fertiliser maintenance requirements for pastoral blocks. As the amount of effluent applied increases, fertiliser maintenance rates decrease. An example of maintenance fertiliser requirements for the farm and treatments shown in Table 1 is shown in Table 3.

Table 3. *Maintenance fertiliser nutrient requirements for effluent applications shown in Table 1.*

Treatment	**P**	**K**	**S**	**Ca**	**Mg**	**Na**	**Lime**
No effluent	31	62	2	93	19	39	80
Sump	28	0	0	89	12	37	0
Holding pond spray regularly	29	0	0	90	14	37	0
Holding pond spray and stir regularly	27	0	0	87	12	37	0
Holding pond spray infrequently	32	0	1	97	18	37	30
Liquid phase after separating solids	35	0	1	96	18	38	50
Pond sludge	23	46	0	82	13	38	0
Separated solids	22	46	0	85	13	38	0
Separated solids stored for 6 months	21	46	0	84	13	38	0

In the earlier versions of the *Overseer* model, maintenance fertiliser P requirements on effluent blocks receiving 150 kg N/ha/yr as effluent were about 30-60% of non-effluent blocks. However, this varies with effluent type applied and the amount of supplementary P imported or exported from the block. In the new version, immobilisation N and P models have been linked so that the minimum P immobilisation rate is 10% of the N immobilisation rate. This assumes an N:P ratio of 1:10 as immobilised organic matter. In systems where the immobilisation rate of N is high, the consequential higher immobilisation of p results in higher maintenance P fertiliser requirements. In a farm receiving no N fertiliser, the difference in maintenance rates between an effluent and non-effluent block are lower as shown in Table 3. If effluent N is substituted with fertiliser N, then the difference in maintenance rates are similar to earlier estimates.

Conclusion

The implemented model:

1) has the ability and flexibility to allow the user to input data that describes most effluent systems found on farms.
2) deals with nutrient loadings rather than nutrient concentrations.
3) estimates of losses and transformations through treatment, storage and application are modelled based on the best available information.

Further information is required to strengthen these models, and it is expected that the effluent management model will be updated as more information becomes available.

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