OVERSEER®

Technical Note No. 5 (August 2012)

Changes to the pastoral N model

Summary

Overseer has been substantially upgraded. The release notes (www.overseer.org.nz) provide an overview of the changes to this version. Changes have happened throughout the model. Outputs at several points within *Overseer* will change with this version as new knowledge and understanding, new modelling approaches and new features have been built into the model. The changes to some outputs are for several reasons, including:

- Default annual distribution of peak cow numbers has changed to better reflect farm policy (no change if monthly numbers input)
- Greater sensitivity to timing of inputs now that the model has moved to a monthly time step: previous model was not able to capture the full effect of these
- N loss driven by drainage now (not rainfall) and so the model covers many more combinations of rainfall and soil type than the previous version
- A wider range of soil-type/rainfall/drainage options are included in the new model
- Shallow soils were not included in previous versions of the model. A later version of 5.4 applied a 'quick fix' but the new model has a more rigorous scientific basis
- The forage crop block model has also undergone a major upgrade and N leaching losses from grazed forage crops have generally substantially increased.

This Technical Note explains how the new N model works and some of the implications of the changes.

Key changes that users need to be aware of when setting up new files or revising old files:

Shallow soils - The change to driving N leaching from soil AWC and drainage gives more scope to being able to represent N leaching in shallow soils than the previous version of *Overseer*. The consequence of this is that the available water capacity (AWC) has to be representative of the soil. The depth of soil and the type of subsoil for shallow soils has to be set by the user: this is not done automatically by the model.

Pallic soils - the measurements of N leaching on wet pallic soils that are easily pugged are generally lower than from other lighter textured soils, based on the farmlet experiments reported in our validation data sets. This has been attributed to denitrification. To capture this risk and to differentiate between soils, a new compulsory input is required: likelihood of pugging. This sets the level of denitrification.

Irrigation - irrigation adds to the water balance. It is therefore important to set irrigation levels to appropriate values for the average rainfall value entered into the model. We have issued a Technical Note on this (www.*Overseer*.org.nz) and further work is planned on this aspect of the model.

If reading in old files with irrigation values, these should be checked and adjusted according to advice in the Technical Note.

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Background

It's important to remember that the aim of *Overseer* is to estimate nutrient movements around the farm. Farming systems are complex, especially pastoral systems, and nutrients entering at one point in the farm could be transferred to other points in the farm (e.g. Figure 1). *Overseer*, with basic, easily obtainable input data to describe the farm, estimates how much nutrient is transferred where and when. *Overseer* then uses these estimated transfers to calculate:

- Maintenance fertiliser recommendations
- Estimated losses of nutrients and greenhouse gases from the farm

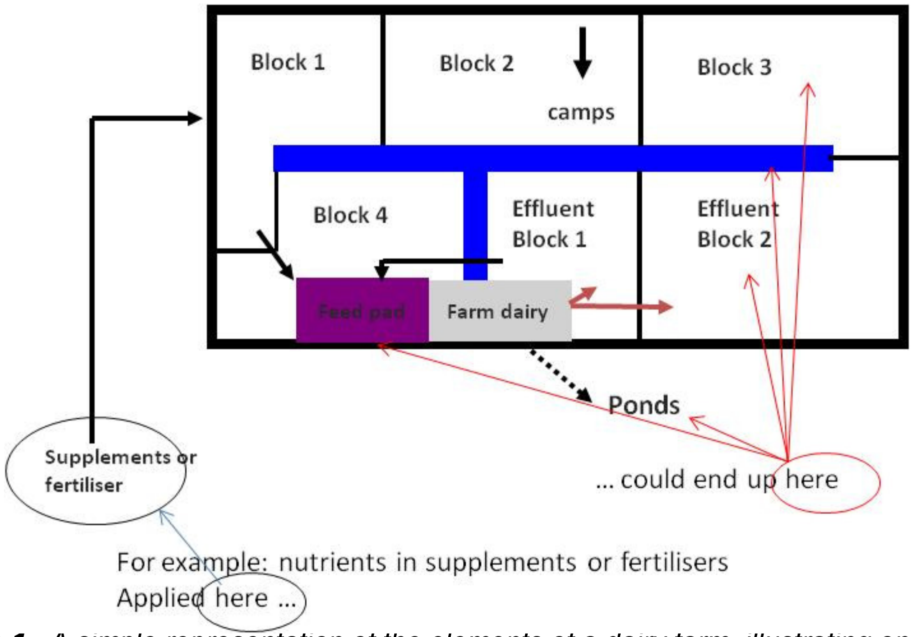


Figure 1*. A simple representation of the elements of a dairy farm, illustrating one example of how nutrients can be transferred around the farm*

Overseer version 6 has undergone a number of changes (see Release Note 1). The most fundamental change has been to integrate the 3 models (pastoral, cropping and horticultural) into one model so that any combination of blocks is now possible on a farm.

This has meant that to align how these different blocks calculate nutrient transfers, the N loss model had to be standardised across the blocks; previously there was a different approach taken between cropping and pastoral models. The result is a change to the pastoral N model, in particular. Previous versions of *Overseer* estimated N losses from empirical calibration curves based on rainfall and 3 broad soil-type bands. Whilst this approach was satisfactory and aligned well with the experimental data, changes were needed to allow linkages with other block types, and for shallow soils and to allow for the monthly time-step for input data.

In summary, changes were necessary because:

- Integration of all block types into one model required a consistent approach to be adopted across all blocks.
- The move to a monthly calculation of nutrient transfers was completed for this version and the previous N model was not compatible with this.

- The move to monthly inputs was adopted so as to better capture effects of timing of operations.
- There was a need to calculate effects across a wider range of soil types than the previous versions of *Overseer*, e.g. shallow soils.
- Aimed to update the model with new science.

We see the benefits as:

- Covering a wider range of environmental conditions and management practices
- Improved integration with non-pasture blocks (e.g. forage crops)
- Improved assessment of mitigation practices
- Future proofed the model – easier to model any new management practices added in the future

The aim of this document is to provide the scientific background to the N model, its calibration and some of the implications of the changes.

Basis of the pastoral N model

Source of N: calculation of how much N, where and when

The method for calculating how much N is excreted and its partitioning between urine, dung and effluent has not changed. A more detailed overview is provided in the introductory chapter of the Technical Manual (www.*Overseer*.org.nz). In summary:

- Animal energy requirements (metabolisable energy, ME) are calculated using a metabolic model based on production data and other inputs.
- The ME supplied by brought in supplements is calculated from the amounts imported and default values for their ME content.
- The remaining ME is assumed to be supplied by pasture. Pasture intake is therefore back calculated from the ME requirements and ME values for pasture types within *Overseer* databases.
- This provides an estimate of seasonal and annual pasture DM intake (annual totals reported for each management block).
- Using these intake patterns, nutrient intake is calculated using nutrient concentrations within the pastures and purchased supplements. Pasture nutrient concentration is based on species, time of year and fertiliser applications. Purchased supplement nutrient concentrations are based on values in the *Overseer* database.
- Excretion is based on a balance between intake, maintenance requirements and nutrients in produce removed from the farm.
- Nitrogen is then partitioned between excreta and urine (when deposited onto the soil surface) or as effluent where excreta are deposited onto hard surfaces (e.g. feed pad, wintering pad) and collected and managed as effluent.
- The amounts of each of these fractions are calculated on a monthly time step. Figure 2 shows an example of the calculated urinary N deposition onto a block.

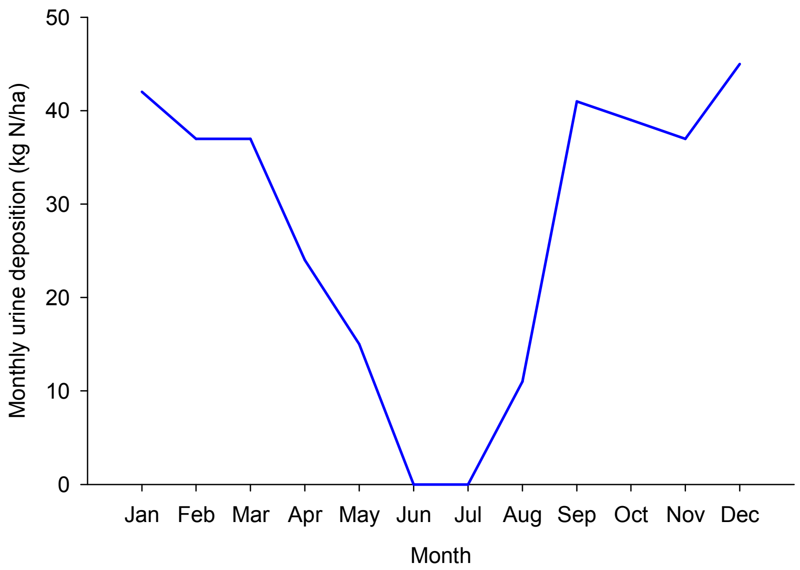


Figure 2. *An example of the calculated monthly deposition of urine onto a pastoral block. Note the animals were wintered off in June and July, so no urine deposition*

NB: this means that *Overseer* doesn't simulate pasture growth, but back calculates it from key input data around animal numbers, production data and purchased feeds. It is a common misconception that *Overseer* simulates pasture growth!

Implications for data entry

A key change to the model that impacts on calculation of source of N is that monthly input data for some inputs is now required:

- Fertiliser
- Irrigation
- Animal numbers (preferred, though can still be based on e.g. peak cow numbers)

Note that peak cow numbers have defined distributions through the year – which have changed from previous versions.

Transport of N: calculation of leaching

The fundamental change to *Overseer* is that N leaching is now driven by drainage, rather than rainfall; and the model uses soil available water capacity (AWC) in this calculation, enabling a much broader range of soils to be represented compared to the three broad categories used in the previous version. The calculation of drainage therefore becomes critical within the model.

Calculation of drainage

Overseer has a daily water balance model that calculates daily drainage based on climate inputs. The hydrological model is described in detail in the Technical manual.

However, it is important to understand how *Overseer* generates the daily climate data for the water balance model. Within *Overseer*, there are 15 representative daily climate datasets that were defined as typical of the main New Zealand regions. When the required input of a single annual rainfall value is input to *Overseer*, this rainfall value is scaled across the years based on these long-term 'typical' distributions. This is why, currently, *Overseer* is considered a long-term average model: the weather (a key driver of N leaching) is based on long-term average distributions whereas we know that annual weather patterns are quite different from the average (For example, see Figure 3).

Figure 4 shows that *Overseer* is good at calculating the long-term average when compared with another daily water balance model (Woodward et al. 2001). Because *Overseer* is a long-term average model, the Woodward model was run for 31 years of climate data at each site to generate a comparable average annual drainage value. Comparison of the two models over 33 site-soil combinations showed excellent agreement, with regression slopes close to 1 and non-significant intercepts ($P>0.05$). When high rainfall sites were excluded (>1600 mm annual rainfall), agreement was still good but with slightly more scatter around the correlation. Agreement in the monthly distribution of the drainage was also reasonable between the models, though Woodward calculated drainage in most months based on a 31 year average, whereas *Overseer* tended to drain mostly between April and October. The drainage calculation within *Overseer* also responded as expected to changes in soil parameters such as degree of stoniness and increased topsoil compaction.

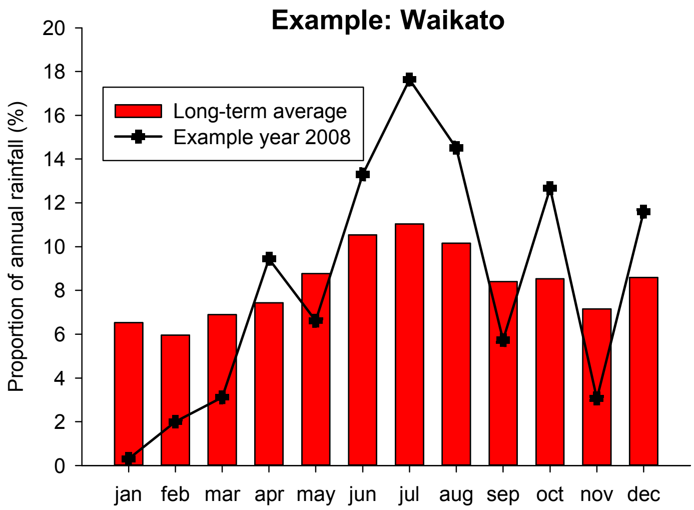
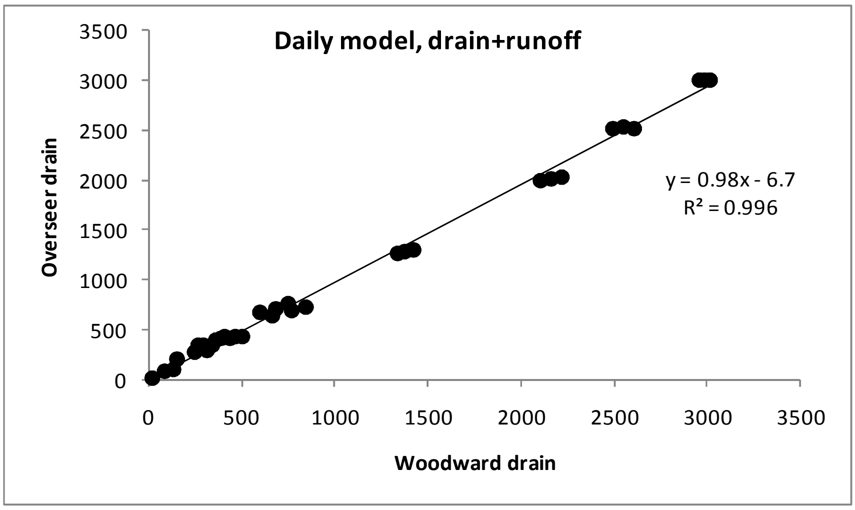


Figure 3. *Illustration of long-term average rainfall patterns and variation with a single year.*



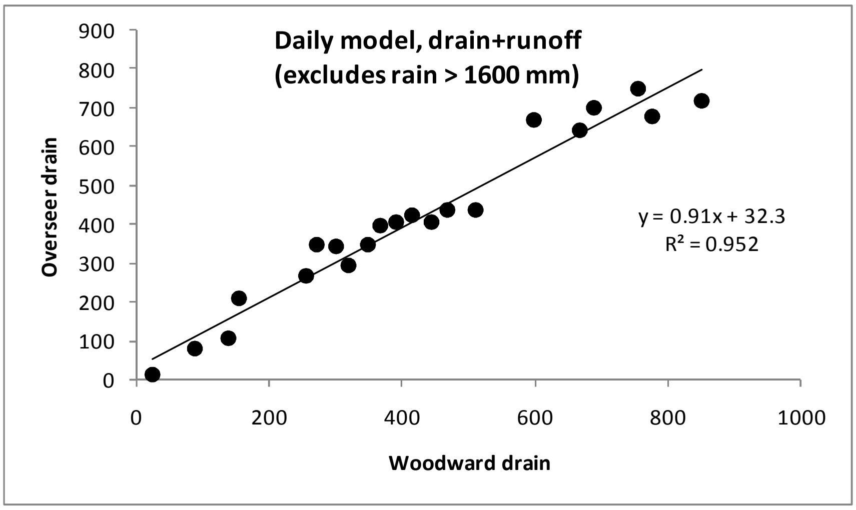


Figure 4*. Comparison of Overseer calculated drainage and the average drainage from 31 individual runs of the Woodward water balance model (Woodward et al., 2001) for 11 locations and three soil-type combinations across New Zealand.*

Implications for data entry

- *Overseer* is good at calculating average drainage when compared with other models but doesn't (yet) deal with one-off atypical years. This is important because both the amount and distribution of drainage affects N leaching.
- Irrigation inputs are entered monthly and are added into the water balance calculation. Irrigation inputs can potentially have large impacts on N leaching if the irrigation amounts are not aligned with the rainfall value entered into the model (extra drainage = extra N leaching). A separate Technical Note (www.overseer.org.nz) has been issued on this topic to provide guidance on how best to manage irrigation inputs into the model.

Use of 'transfer functions' to estimate N leaching

The calculated daily drainage is aggregated to a monthly time step to calculate N movement down the soil profile. The approach that has been developed is the use of 'transfer functions' (Cichota *et al*., submitted). In summary, APSIM was used to simulate N leaching from urine patches across several soil types and many years of climate data at locations across New Zealand. The resulting analysis of the 000s of resulting simulations was a generalised relationship between proportion of the available N source leached and number of pore volumes of soil drainage (Figure 5). The coefficients determining the shape of the 'curve' were soil specific, and in this case, one pore volume was taken as the AWC of the soil profile (to 60 cm for pasture).

Overseer uses a separate calculation to estimate the size of the source of N, taking into account pasture N uptake and other transformations. This is described below.

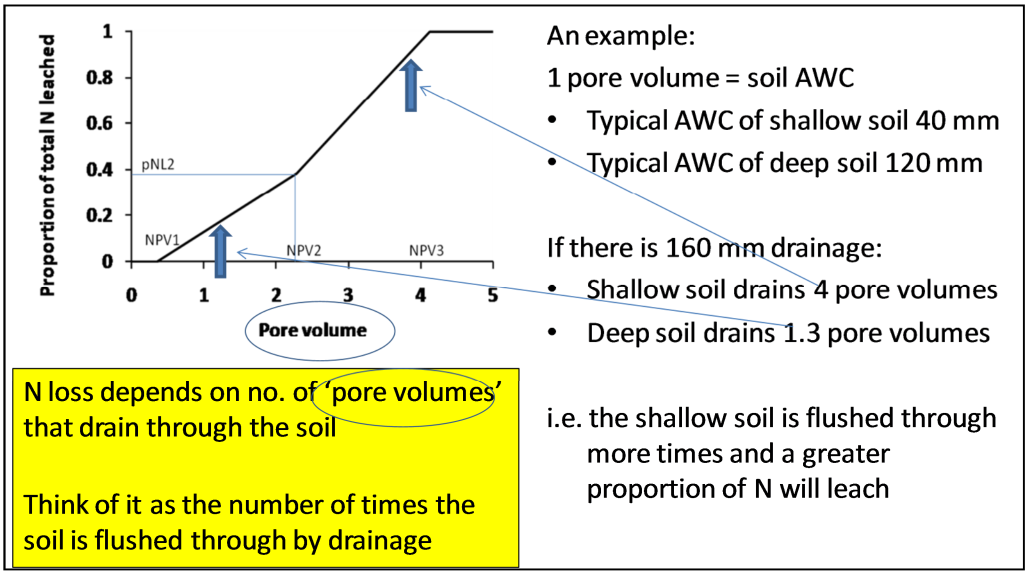


Figure 5*. Shape of N leaching curve as derived by Cichota et al. NPV values vary with soil type*

Implications for data entry

- As well as drainage, calculated N leaching losses will be sensitive to soil AWC. Selecting soil order sets AWC which, in most cases will be adequate.
- However, for shallow soils, it is also necessary to use the soil description pages to set type of subsoil layer and depth to this layer; *Overseer* does not do this automatically, even if, e.g. Eyre soil series is selected.

- Soil AWC is reported as an output so it is worth checking, especially for shallow soils, that the AWC is appropriate.

'Background' and 'Urine patch' models

The amounts of N moved below 60 cm in pasture blocks is calculated by drainage and the appropriate transfer coefficient on a monthly time step. Although *Overseer* has calculated the amount of urine, dung, effluent and fertiliser that is applied each month, clearly not all of this is leached. Balance calculations for these N sources are used to deplete soil N and decrease the amount available for leaching. Two sub-models are used for this calculation:

- Background sub-model – deals with the paddock area between urine patches and deals with additions of dung, fertiliser, effluent or other organic additives to these areas
- Urine patch sub-model – deals with N applied as urine

Background model

Essentially this is the same model that was developed for the cut and carry block (Wheeler et al, 2010), whereby applied N is used efficiently by the growing pasture. N sources are split into two pools, slow release (organic N) and quick release (mineral N sources).

Generally, N leaching losses from this sub-model component are small, because the pasture is efficient at removing N.

Urine patch model

This model aims to calculate the proportion of urinary N applied each month that is subsequently leached The calculated leaching factor is then multiplied by the monthly deposition of urinary N to estimate the N leached. Summing this calculation for each month gives the annual N leaching load. Figure 6 represents this approach.

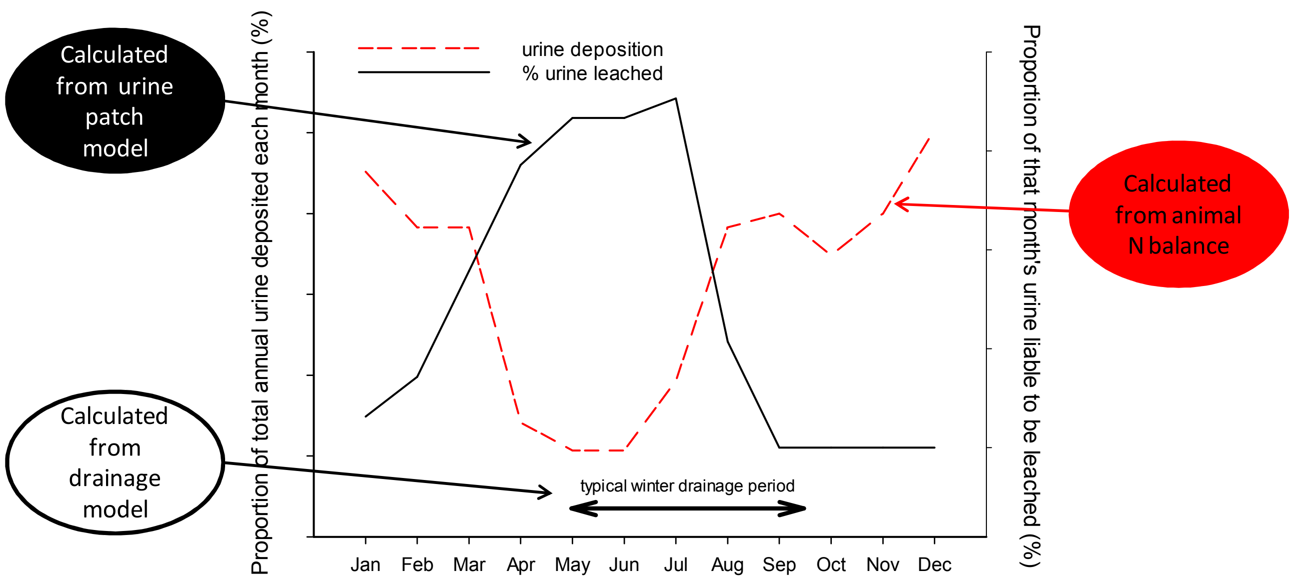


Figure 6. *A representation of how the urinary N leaching component is calculated within Overseer.*

Clearly, both the monthly urinary N load and the proportion of this (%) likely to be subsequently leached will depend on inputs into *Overseer*, but the aim is for the model to be able to represent, albeit it in a fairly simple way, the key processes that will affect N leaching risk from a urine patch (Figure 7):

- N applied as fertiliser or effluent is added to the N balance for the urine patch
- Pasture growth and N uptake – driven by a growth model dependent on temperature, radiation and soil moisture
- Other competing N processes – simplified sub-models for immobilisation, denitrification, ammonia volatilisation
- Environmental conditions – amount of drainage and when this occurs

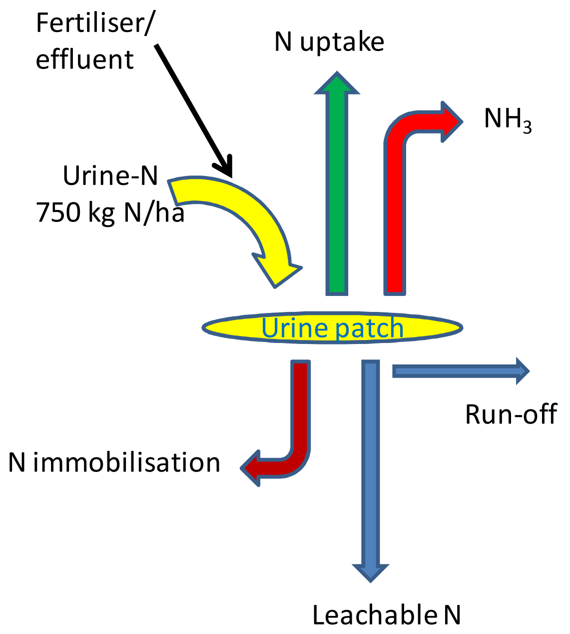


Figure 7. *Representation of the key processes estimated within the urine patch model.*

Note that the model does not aim to model in any detail the distribution of urine patches, risk of overlap or variations in N concentration in urine patches. We assume a standard N load for a dairy cow urine patch to be 700 kg N/ha and calculate the % leaching risk from a monthly N balance calculation based on the principles above.

How the *Overseer* N model responds

Comparisons between versions of the calculated N leaching shows that there is reasonable agreement, as would be expected (see later), so the model still represents the effects of all of the management practices that it did before.

The scientific principles/assumptions that the revised N model is based on can be summarised as:

- N leaching is not just about winter. N deposited in late summer and early spring is at risk
- Nutrient use by pasture between the urine patches is efficient
- N fertiliser or effluent applied to a urine patch is not efficient
- Sheep, deer, goat and male beef urine patches have a smaller N load (kg N/ha) than those of dairy cows

- On very wet soils, significant amounts of N will be denitrified and therefore not available for leaching
- The effects of irrigation are complex: it can decrease leaching risk from from individual urine patches by increasing pasture N uptake in dry periods but will increase the total source of leachable N because more pasture will be grown, consumed and N excreted (more urine patches) compared with an unirrrigated block

Examples of how mitigations operate are shown in Figure 8.

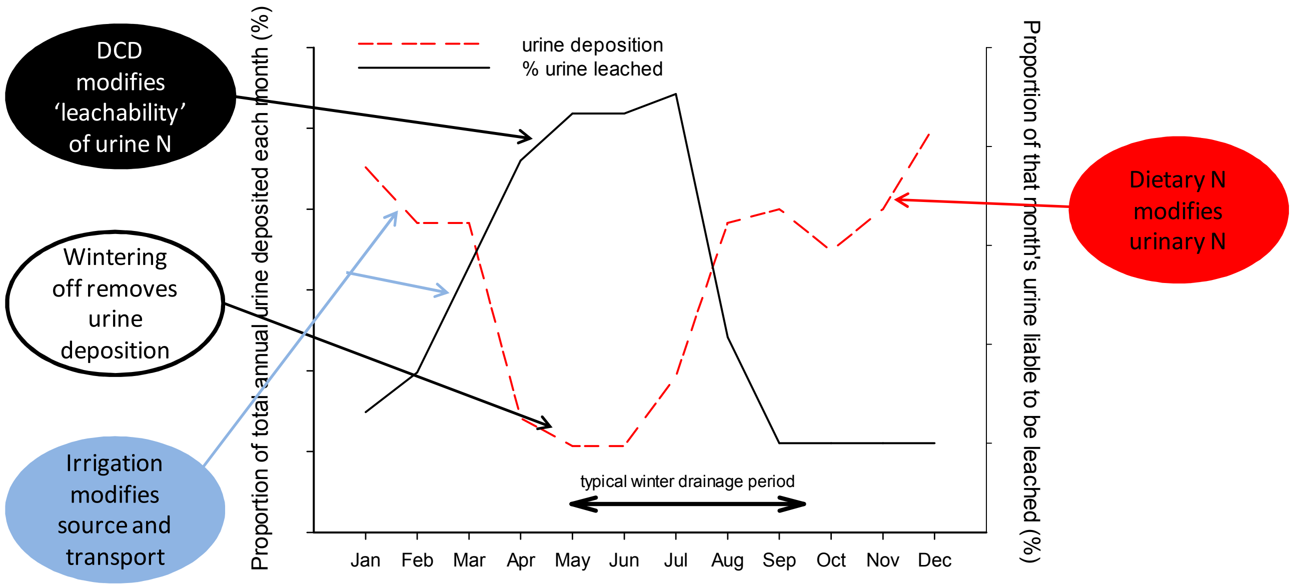


Figure 8. Examples of how *Overseer* simulates the effects of management practices on N leaching.

Response to rainfall and drainage

The previous version of *Overseer* included an empirical relationship to adjust N loss for rainfall. Logically, this relationship was curvilinear with the rate of N change in leaching decreasing with increasing rainfall, as the leachable N pool becomes depleted.

Figure 9a shows that *Overseer* 6 reproduces a similar relationship when rainfall inputs increase (although the driver in the new model is the resultant drainage from the inputted rainfall). The main difference is that the increase in N leaching with increasing rainfall and (drainage) is likely to be steeper.

The reason for responsiveness of N leaching to increasing rainfall in the new model is that rainfall increases the absolute amount of drainage and increases the number of months where drainage occurs – thereby increasing the available urinary N pool available for leaching.

Figure 9b shows the effects of increased rainfall on the calculated monthly drainage to illustrate this point.

(a) (b)

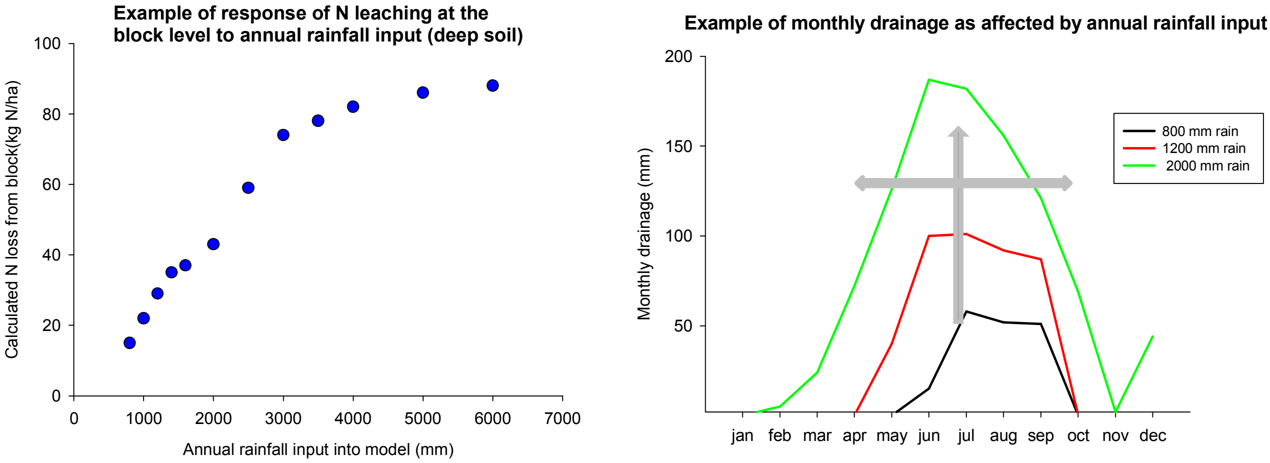


Figure 9. *(a) Typical relationship between rainfall and N leaching. (b) Example of three rainfall inputs and their effects on calculated drainage patterns within Overseer. As annual rainfall increases, amount of drainage in a month increases (vertical shift) and number of months with drainage increases (horizontal shift), i.e. more months of urine deposition will be affected by drainage.*

Summary of implications of model changes

N leaching responds to management practices in the same way as v. 5.4, but the absolute number could change. This is for one of more reasons, depending on the file:

- If using peak cow numbers, *Overseer*'s default distribution of animals on the farm through the year has changed to better reflect farming practice
- N loss is now driven by drainage and soil AWC: the model differentiates between more combinations of rainfall and soil type than the previous version
- The new model is more responsive to high rainfall (larger losses) than the old model
- Shallow soils were not included in previous versions of the model. A later version of 5.4 applied a 'quick fix' but the new model has a more rigorous scientific basis
- Greater sensitivity to timing of inputs now that the model has moved to a monthly time step
- The forage crop block model has also undergone a major upgrade and N leaching losses from grazed forage crops have generally substantially increased.

Circumstances to be aware of change

Shallow soils

The change to driving N leaching from soil AWC and drainage gives more scope to being able to represent N leaching in shallow soils than the previous version of *Overseer*. The consequence of this is that the AWC has to be representative of the soil. The depth of soil and the type of subsoil for shallow soils has to be set by the user: this is not done automatically by the model. The model is sensitive to soil AWC as shown in Figure 10.

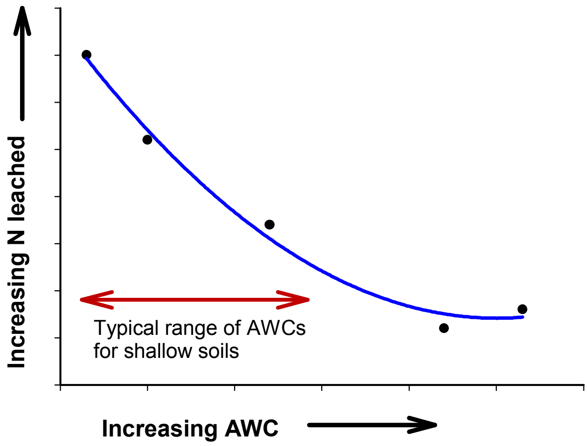


Figure 10*. A schematic illustration of the response of N leaching to soil AWC*

Pallic soils

The measurements of N leaching on wet Pallic soils that are easily pugged are generally lower than from other lighter textured soils, based on the farmlet experiments reported in our validation data sets. We have been advised by scientists working on this soil-type that the most likely reason for the low mwasured leaching is denitrification. To capture this risk and to differentiate between soils, a new input is required: likelihood of pugging. This sets the level of denitrification. For Pallic soils where this is considered a risk, the settings to use are:

- Occurrence of pugging: ‘winter or rain’
- Lower profile soil textural group: ‘heavy’

Irrigation

As explained earlier, irrigation adds to the water balance. It is therefore important to set irrigation levels to appropriate values for the average rainfall value entered into the model. We have issued a Technical Note on this (www.*Overseer*.org.nz) and a further review is planned on this aspect of the model.

If reading in old files with irrigation values, these should be checked and adjusted according to advice in the Technical Note.

High rainfall

The model is responsive to rainfall (drainage). There is a lack of validation data for climates >1600 mm rainfall so, as before, the modelling approaches on these soils is based on first principles.

Forage crops

The forage crop block in previous versions was an initial attempt at modelling this situation. The model has now been updated to capture the few measurements that are available on the effects of grazing forage crops. The result is that the N losses have increased.

Model calibration/validation

Approaches

Overseer has traditionally been calibrated against a set of farmlet trials. The criticism is that the trials database is limited; we would agree that the data set could benefit from more validation sites. The approaches we adopted for testing the model were:

- Validation against the experimental dataset
- Development of a range of logical tests to see that parts of the model were responding as expected and to test for unforeseen consequences of changes
- Expert opinion of the model and its responses.

Here we briefly report only on the comparison with farmlet trial data.

Validation datasets

Data sets covered the following farmlet studies: Ruakura Dairy farm (N rate and stocking rate trials); Scott Farm, 3 farm systems and a range of soil-types); Edendale (intensive beef, a range of N rates); Tussock Creek, Southland (lengths of grazing and DCD); Manawatu (effluent). All of these are published datasets. Additionally, we secured other data from Manawatu and LUDF which are confidential given that the researchers had not yet published the data. The LUDF data was especially welcome given that it included blocks of land both on deeper Templeton soils and shallower Eyre soils: to date, there has been a lack of available data for validation on shallow soils.

We excluded one available dataset form the comparison graph: this was a Ruakura experiment where N leaching showed a negative linear relationship with stocking rate, which is counter-intuitive and it was suspected that other factors e.g. severe pugging at higher stocking rates were involved in affecting the expected trend.

We set up new ovr files, compatible with version 6, by going back to the original data and/or using published data wherever possible. We set up a file for each experiment year, and we adjusted either the rainfall or its seasonality to ensure that *Overseer* calculated a similar amount of drainage to that reported for the experiment. We used this as our validation dataset. Experiments ran for a number of years and therefore experienced a range of weather conditions. Given that *Overseer* is a long-term average model, we averaged the N leaching data from the individual simulations and from the individual years of data.

Results

Figure 11 compares measured N leaching from the farmlet studies with *Overseer* estimates of N leaching at the same level of drainage as the experiments, with and without the 3 trials at 400 kg N/ha. There is a reasonable fit around a 1:1 line (our target), given there is experimental error also against the measurements; and also that the mean value might not have even then represented the long-term average. No ‘field factor’ (fudge factor) has been applied to the model, so this is a straightforward comparison of our scientific principles embedded in the model against measured data.

When including the 400 N rate, the model appears to underestimate losses in the Waikato and overestimates losses in Southland. It is not possible to obtain a closer fit for both of these sets of data, so we think that the line is reasonable in that it passes between all of the data.

Excluding the 400 N rate experiments gives a better fit and will be more representative of the majority of farming systems.

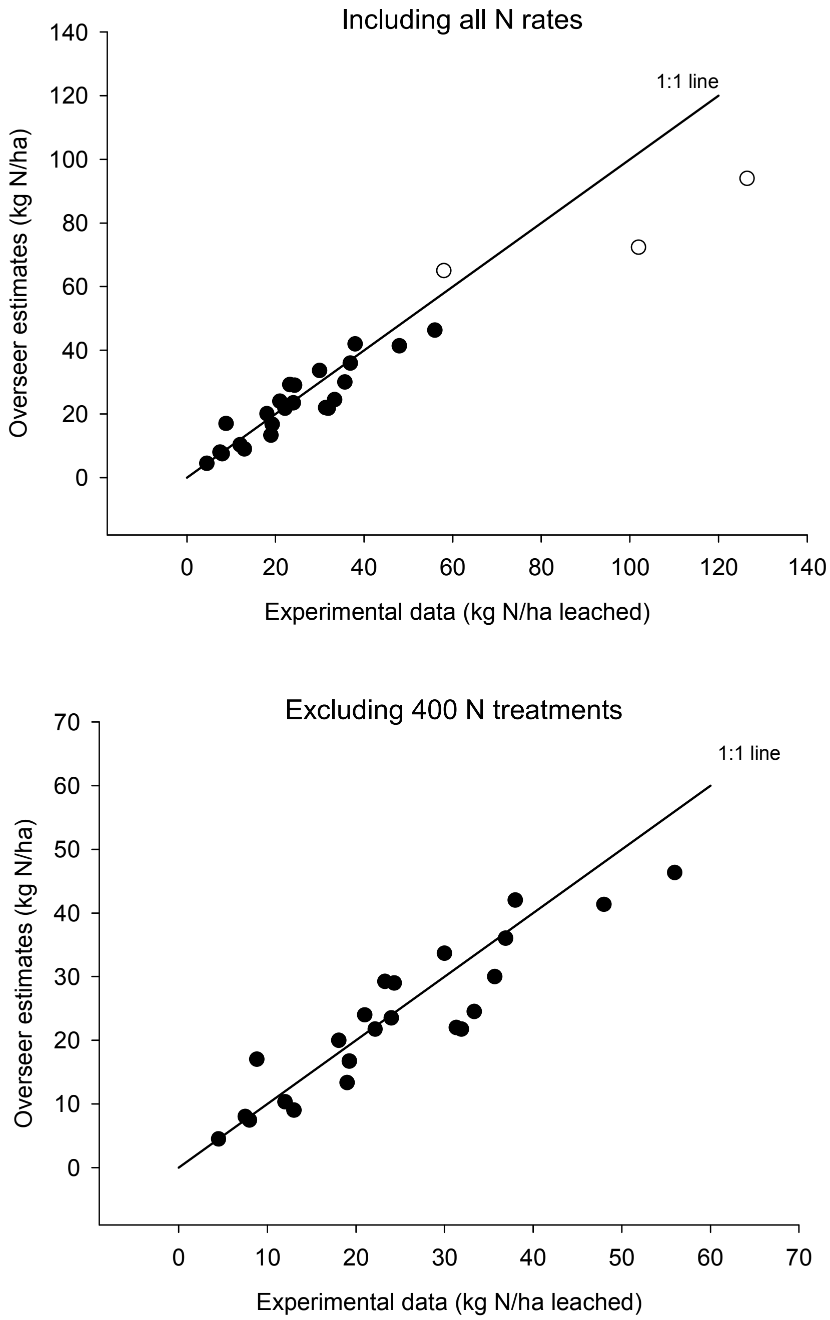


***Figure 11**. Comparison of measured N leaching from farmlet experiments with Overseer estimates of N leaching. Open circles are annual N rates of 400 kg N/ha.*

Our shallow soil site gives good agreement with the modelled value, being within 10% of the mean measured value (8 years of data: data not shown); this is well within the SE of the mean.

The few measurements of leaching from beef, sheep and deer enterprises are quite variable in terms of measured kg N/ha leached. The previous version of *Overseer* used a scaling factor for these species. *Overseer* 6 does the same. An assessment of model performance against these data indicated that it provided a reasonable estimate overall of the available data, underestimating at some sites and overestimating at others. More validation data are required.

Conclusion

A major part of the N leaching calculation is derived from the animal intake component of *Overseer* and that, in turn, is derived from input production data. The challenge then is to develop a model that takes the excreted N (plus effluent plus fertiliser) and scales this to a metric of kg N/ha leached. Whereas this can be done using an annual time step and a scaling equation (as did the previous version), there was an increasing need to better recognise the effects of timing of inputs and also a wider range of soil types (e.g. shallow).

The revised N leaching model takes into account drainage (rather than rainfall) and soil type through AWC. As with the previous model, there is a reasonable fit with the experimental data, given that measuring N leaching in pasture-based systems is also difficult.

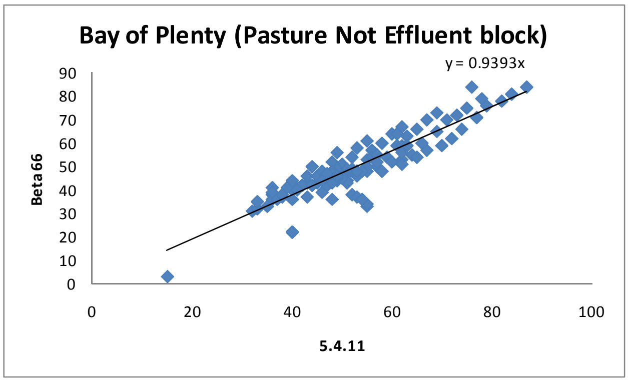
A more detailed publication is being prepared.

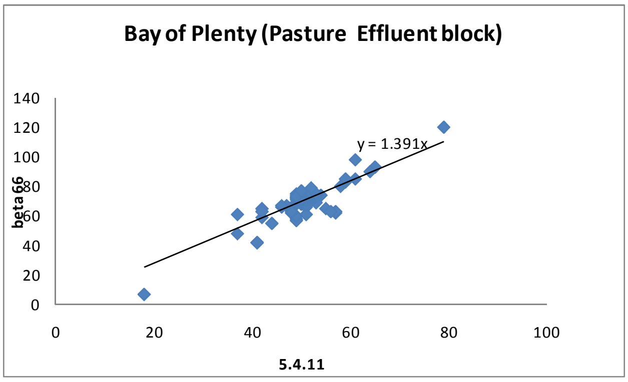
Version comparison

To provide some comparison between versions, a whole range of test files were run through both versions for *Overseer*. The results below show the comparison of these files across soil type and regions for pasture blocks and effluent blocks.

The results show:

- Agreement is generally good, and is at least linearly related
- There is some shift between versions, but there is no consistent bias; the shift will vary depending on a whole range of factors
- Greatest variability is in the effluent block: this is mainly because of the additive effects of N fertiliser, effluent and deposited urine on calculated losses.
- On average, calculated losses from shallow soils will increase.
- There may also be some increase on Pallic soils: here a robust assessment of the likely denitrification status of the soil is required, based on pugging risk.
- Beef and sheep losses are likely to increase, especially under high rainfall situations.
- Our analysis of the model indicates that most change will be observed:
    - Under high rainfall
    - With scenarios where *Overseer* calculates large amounts of surplus irrigation
    - On extremely ‘bony’ low AWC soils


Bay of Plenty (Pasture Not Effluent block)
y = 0.9393x
Beta 66
5.4.11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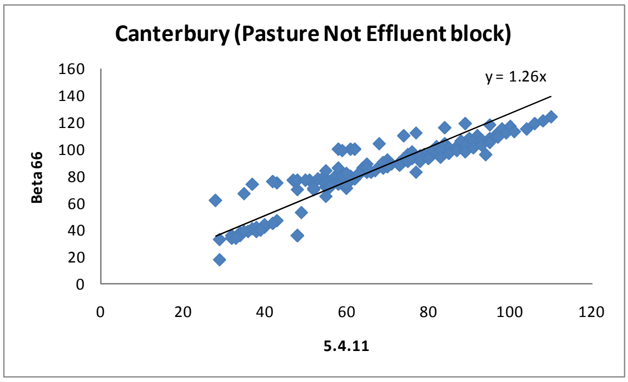
5.4.11


Canterbury (Pasture Not Effluent block)
y = 1.26x
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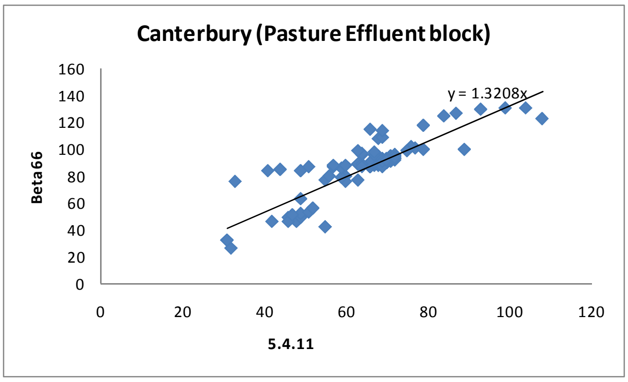
5.4.11


Canterbury (Pasture Effluent block)
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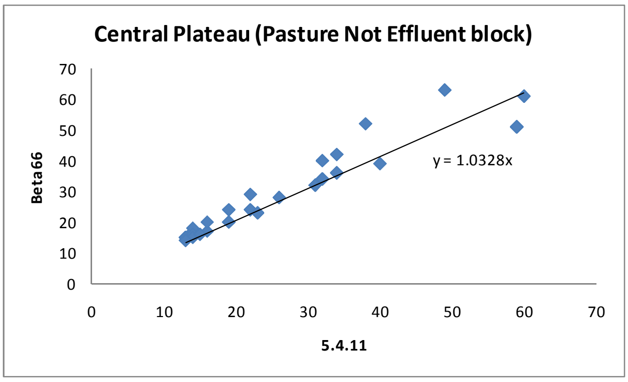
5.4.11


Central Plateau (Pasture Not Effluent block)
y = 1.0328x
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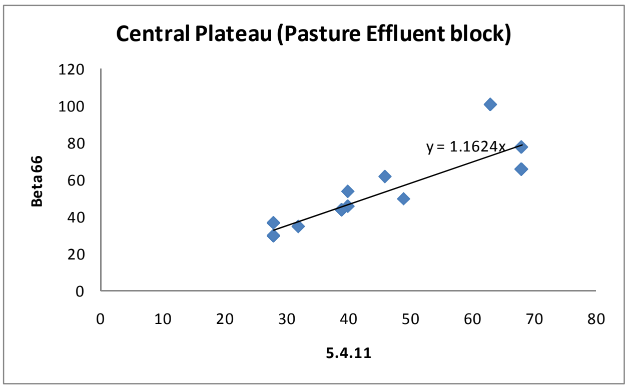
5.4.11


Central Plateau (Pasture Effluent block)
y = 1.1624x
Beta 66
5.4.11