

IN THE MATTER

of the Resource Management Act 1991

AND IN THE MATTER

of resource consent applications to take and use water for irrigation in the MacKenzie Basin

STATEMENT OF ROSS MONAGHAN

EXPERIENCE AND QUALIFICATIONS

1. My name is Dr Ross Martin Monaghan.
2. I am a research scientist working within the Climate, Land & Environment (CLE) Group at AgResearch, based at Invermay, Mosgiel. I have a Bachelor's degree in Agricultural Science (First Class Hons, Lincoln University) and a PhD in Soil Science (The University of Reading, England).
3. I have 14 years work experience with AgResearch plus the research experience gained during my PhD and post-doctoral studies (3 years for each). My research projects focus on (i) defining the impacts of intensive pastoral agriculture on soil and water quality, and (ii) identifying cost-effective options to reduce these impacts where mitigation is deemed necessary.
4. As part of my role with AgResearch, I have contributed to the validation and development of various components of the OVERSEER[®] nutrient budgets model (hereafter referred to as "Overseer"). The model components that I have contributed to and are of most relevance to the case being considered here are the nitrogen (N) and phosphorus (P) loss modules. My experience of measuring and modelling of nutrient losses from soils in the Canterbury region is mainly confined to two areas of work:
 - a. the Waikakahi Dairy Catchment study in south Canterbury (Monaghan et al 2009), which is one of five long-term dairy catchment studies underway across the country; and

- b. the provision of steady-state nitrate leaching predictions for selected soil types, climates and farm systems on the Canterbury Plains (Snow et al. 2008a).
5. I confirm that I have read and am familiar with the “Code of Conduct for Expert Witnesses” in the Environment Court Practice Note (31 July 2006). I agree to comply with the Code.

SCOPE OF EVIDENCE

6. I have been requested by MWRL (6 May 2009) to provide a commentary on the application of the *Overseer* model to the nutrient modelling conducted as part of impact assessments for resource consent applications to take and use water for irrigation in the MacKenzie Basin. I have read the Water Quality Study (WQS) prepared by GHD and reviewed the technical reports completed by Snow et al. (2008b, c, 2009) and Aqualinc Research Ltd (2008).
6. Specifically, in my evidence, I will cover:
 - I. A review and comment on the evidence provided by Dr Val Snow.
 - II. An assessment of the strengths of the *Overseer* model
 - III. An assessment of the limitations of *Overseer*.
 - IV. An assessment of the overall reliability of *Overseer* and its application in the GHD report.

I. REVIEW AND COMMENT ON THE EVIDENCE PROVIDED BY DR VAL SNOW: USE OF OVERSEER

7. I believe the multi-step modelling approach undertaken by Dr Val Snow is the most appropriate approach for estimating nutrient losses from farming systems. The systems approach that she has used ensures that farms are biologically feasible and as near a representation of reality as biophysical and human factors allow.
8. Each of the modelling tools employed has a high level of credibility when applied to grazed farming systems. Model inputs were based upon detailed surveys of existing land users, thus minimizing uncertainty associated with human decision-making.
9. My main concern with the modelling work presented relates to *Overseer* predictions of N leaching from shallow soil types, which are known to be

present within the area proposed for irrigation. This potential weakness is addressed in paragraphs 16, 17 and 22.

II. STRENGTHS OF OVERSEER

10. Reviews of research trials show that the major driver of N leaching in grazed pastures is urine N deposited on the paddock, with rainfall and soil and animal types modifying the amounts leached or lost in gaseous forms. An important part of any N leaching model or sub-model for grazed pasture systems is therefore to estimate the quantities (and timing) of urine N deposited onto pastures. *Overseer* does this by estimating animal N intake (using a metabolic animal intake sub-model, which in turn is driven by productivity data) and the proportion of animal excreta N deposited as urine. The latter is estimated from N concentration in the diet.
11. In many respects the estimation of nutrient losses from pastoral farms is considerably more complex than for arable or horticultural properties. For the latter two property types it is quite valid to consider a single paddock (or similar management unit) in isolation; such a simplification is not appropriate for most pastoral farms. This arises because:
 - a. Within a given farm (with particular soil and climate properties) leaching is primarily a function of the area of urine patches that are created, the concentration of N in the urine patches, and the seasonal pattern of the urine patch creation;
 - b. The factors above are dependent (in a very non-linear way) on the degree of utilisation of the pasture grown and the utilisation arises from the interaction between the feed demand of the animals on the farm and the growth pattern of the pasture;
 - c. While the pasture growth can readily be simulated on a single-paddock basis, because there is a limited 'supply' of animals to consume the pasture, utilisation is a whole-farm problem and must be modelled as such;
 - d. In addition, farmers manipulate feed demand (trading stock, restricting intake) and feed supply (fertiliser, supplements made/fed, forage crops, etc) and this affects utilisation and the area, N concentration, and seasonal pattern of urine patches.
12. For the reasons above, if using a dynamic model it is necessary to model all the paddocks and the farmer management of the farm. Unfortunately it is also necessary to explicitly model the urine patches because the very

high loadings of N in the patches means that they are usually the major source of N leached from grazed pastures. They also have a large effect on pasture growth rates, which cannot be treated as a paddock average given that only a small proportion of the paddock area receives urine at any particular grazing.

13. *Overseer* is the obvious choice for estimating nutrient losses from pastoral farms. The model has been reviewed as part of the regulations surrounding nutrient management in the Lake Taupo catchment (Ledgard 2007; Clothier 2008) and was found to be the most suitable tool available. This was based on there being “a remarkable degree of agreement, among the scientists called on behalf of the parties, on estimates of the total load to the Lake” (Environment Court Decision No. A 123/2008); all parties accepted that *Overseer* should be used to determine the N leaching rates for farming activities. The particular strength of *Overseer* is that considerable effort has gone into ensuring that the model has a good representation of the management of animals on the farm – and it is the animal management that determines the area, timing and concentration of the urine patches and therefore the amount of N leaching.

III. POTENTIAL LIMITATIONS

Uncertainty calculating N leaching

14. There are several aspects of the *Overseer* model which have greater uncertainty associated with the calculated N leaching, as a result of limited validation research. These aspects include winter forage crops (such as swedes and kale) and sites with high rainfall (greater than about 1600 mm/year). The use of winter forage crops for grazing by animals in winter is relatively common although they typically occupy only a small area on farms (e.g. less than 15%). Research has now commenced to address this data limitation, with grazing studies underway in Waikato, Canterbury and Southland to evaluate N leaching from grazed brassica crops.
15. The *Overseer* model is less effective in modelling pastoral systems with a dominance of trading animals (animals that are fattened on the farm for relatively short periods, i.e. often less than a year) and only partly accounts for the strong seasonality in N leaching that can potentially occur in trading systems.

Shallow soils

16. It is difficult to make an assessment of the potential error associated with *Overseer* underestimating N leaching losses from the shallow soils in the MacKenzie basin that have low plant available water (PAW) contents. This is for 2 reasons:

- a. it is difficult to get an accurate estimate of the area covered by these shallow soil types that will be irrigated in future, and
 - b. as yet there are no relevant published studies that directly compare N losses from shallow v. deeper soils managed under a grazing system and equivalent management conditions.
17. However, if it is assumed that shallow soils occupy approx. one-third of the proposed irrigable area, and it is also assumed that N leaching rates from this soil group are between 30 to 60% greater than from equivalent deeper soils, it is likely that the N leaching loss values used in the GHD report are potentially underestimated by 10-20%.

Best practice

18. Various algorithms and relationships defined within *Overseer* were based on research data using good practices for various inputs. Thus, it is stated that the model refers to where farmers are applying best practices to a range of inputs including fertiliser (meeting the Code of Practice for Nutrient Management from the fertiliser industry), farm dairy effluent (not exceeding guidelines as recommended by Regional Councils in relation to mm/application and annual rate of N application), and irrigation (water is applied in relation to soil water deficits and excess applications are avoided). It will therefore be important that these best practice guidelines are adhered to by the relevant farmers.
19. One example of where best practice is assumed by *Overseer* is the application of N fertiliser. Best practice recommends restricting individual applications to less than 50 kg N/ha and to avoid application during winter when temperatures fall below 6°C. If an annual use of N fertiliser of say 150 kg N/ha with split applications on a dairy farm (ash soil, 1200 mm rainfall) resulted in N leaching of 35 kg N/ha/year, this might increase to at least 45 kg N/ha/year if all of it was applied in one application in winter. However, this aspect can be modelled in *Overseer* and the effect accounted for, although it would not account for the greater inefficiency due to one large application.

Input variables

20. Of the list of variables which are inputted into *Overseer*, it is possible to identify those that typically have a large influence on estimates of N leaching losses. High impact farmer-derived input variables typically are: amount of N fertiliser applied; winter application of N fertiliser; stocking rate and animal productivity; winter management practices (e.g. grazing dairy animals off the farm over winter); stock type (sheep, beef and deer farms). For all of these, it is important that the farmer is able to supply good data and records. Through extensive surveys of farmers in the study

area, this issue appears to have been duly considered in the modelling assessments prepared by Snow et al. (2008b,c).

21. The high impact user-derived variables are: annual rainfall; pasture development status; clover content. For each of these variables, it is important that the user takes a consistent approach. *Overseer* has been well validated with pasture development status in the “developed” mode and therefore it is appropriate that this be used as a default input. However, as noted by Snow et al. (2008b,c), in the very long term (>30 years) it could be expected (depending on management) that the pasture development status could reach a “highly developed” state. In this state N immobilisation rates are expected to be minimal and leaching losses would be expected to increase. This potential future scenario has been considered by Snow et al. (2008c) in their modelling assessments under “developed” and “highly developed” scenarios.

Combined model approach

22. While the combination used was the best choice of models for the study, there are limitations to the combined model approach. These include:
 - a. For the farm scenarios modelled, it was assumed that farms were managed under a Best Practice scenario whereby irrigation inputs were matched to soil water deficits and thus little over-watering was assumed to occur. This is quite an optimistic scenario, but given the range of alternative management conditions possible, the most practical option to model in the first instance. However, it needs to be acknowledged that poor management practices, particularly on the low PAW (Plant Available Water) soils, are likely to exacerbate N leaching losses. On the other hand, with due attention to irrigator maintenance and management and the use of current technologies for scheduling irrigation, avoidance of over-watering on these soils should be practically achievable.
 - b. It is probable that *Overseer* will underestimate N leaching losses from the shallow soils that have low plant available water (PAW) contents. Reviews of lysimeter leaching data from low (Lismore) and high (Templeton) PAW soils (albeit managed under different experimental conditions) suggests nitrate leaching losses from the former are significantly greater than from the latter. Field measurements under a commercially-grazed dairy pasture shows that nitrate leaching losses from the Lismore soil are approx. 50% greater than from the Templeton soil (Professor Keith Cameron, pers comm.). The *Overseer* model is currently being upgraded to account for this shallow soil effect.

Accuracy of estimates

23. There has been some confusion over the “accuracy” of estimates from *Overseer*. Accuracy is associated with (i) input information, and (ii) comparison with measured values. A report by Ledgard and Waller (2001) indicated that there is variability in estimates of the amount of N leaching from *Overseer* associated with uncertainty around values for inputs and that in total this is of the order of $\pm 20\%$. This highlights the importance of *Overseer* users having a good understanding of the model and preferably having undergone training in its use, such as through the Massey University Nutrient Management courses.
24. In practice, the effects of the potential inaccuracy associated with input information becomes minor within a farm where the user is examining the effects of changes in on-farm practices as is the case in the Mackenzie Basin applications. This is because many of the parameters (e.g. site factors such as area, soil, slope, rainfall) will be the same under any comparative scenario for the same farm. The most important aspect of accuracy (point ii) is how well it predicts measured data from New Zealand research.

P losses

25. It is important to recognise that, strictly speaking, the P loss estimate reported in the *Overseer* model is a risk assessment index rather than a predicted load (although the index does correlate reasonably well with measured loads for the limited number of sites for which good data is available; refer to McDowell et al. 2005 for further detail). A more accurate assessment of farm-specific losses requires a more detailed consideration of hydrology to better define contributing areas and also consider other sources not dealt with in the model (such as erosion and stream sources). However, without input from specialist expertise, it is difficult for land managers to characterise the hydrology of farms and contributions from erosion. The risk framework partly overcomes this difficulty by incorporating weighting factors for soil, slope and management attributes, all of which have been shown to have an important influence on P losses from grazed pastures.

Other limitations

26. *Overseer* has been developed as a long-term average model and uses long term average rainfall. Its use should thus be within a long-term planning and policy development context. Under its current structure it should not be used for examining seasonal or year-to-year changes in nutrient losses. [Confirm it is not being used for year-to-year changes]

27. Point source emissions are not currently incorporated into *Overseer*. Such emissions may be locally significant if they discharge directly to a waterway. Examples include runoff from feedpads or silage stack leachate.

IV. OVERALL RELIABILITY OF THE OVERSEER MODEL AND ITS APPLICATION IN THE GHD REPORT

28. Despite all the limitations identified above, the *Overseer* model has been validated in a range of farm research studies from throughout NZ and has been shown to be reliable and useful (as shown by the positive endorsement from the Environment Court). Figure 1 shows a highly significant agreement between measured and calculated N leaching using *Overseer* for a range of NZ dairy grazing system studies. Figure 1 is based on data from a range of dairy grazing system studies and covers different sites and treatments (e.g. different N fertiliser inputs). Each data point in Figure 1 represents the average for between two and five years of measurement of N leaching. The actual N leaching rates in Figure 1 were measured using ceramic cup samplers at about 90-100 cm depth in free-draining soils or using hydrologically-isolated paddocks with mole-drains to intercept and collect drainage water in poorly-drained soils.

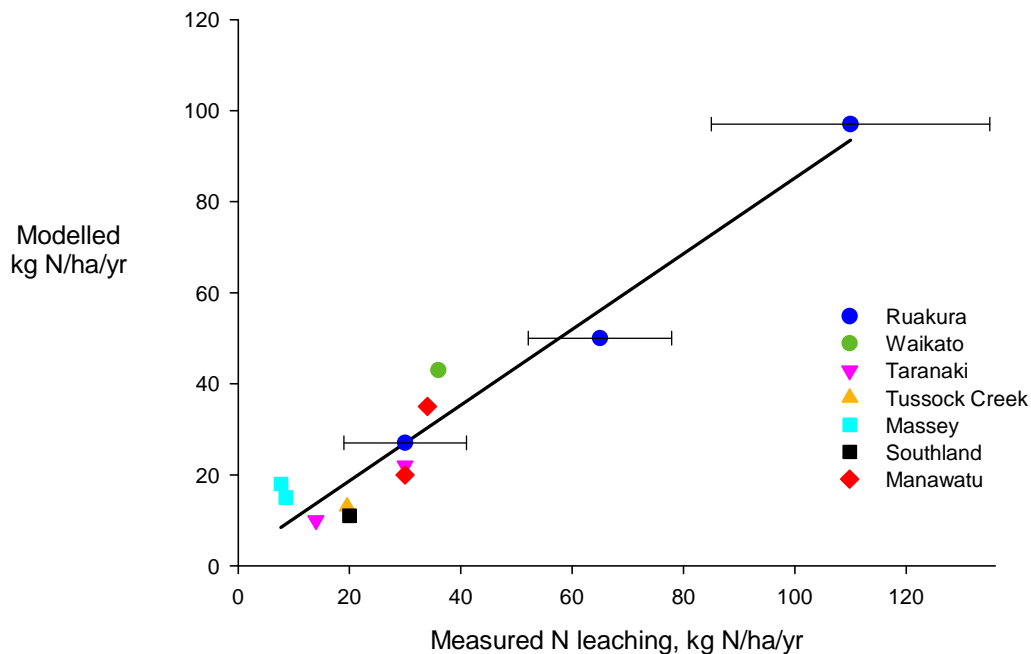


Figure 1: Relationship between the amount of N leaching measured in 7 dairy grazing system studies and that estimated for the sites using *Overseer*. Data for Ruakura, Waikato, Taranaki, Tussock Creek, Massey, Southland and Manawatu studies were from Ledgard et al. (1999 & unpublished), Sprosen et al. (2002), Chadwick et al. (2002), Monaghan et al. (2005), Monaghan (unpublished) and Houlbrooke et al. (2003). Ruakura measured data was an average of 5 years and is shown with \pm Standard Error. Correlation was highly significant ($R^2=0.93$).

29. Measurement of N leaching from an on-going grazing study on a dairy farm on pumice soil near Rotorua in 2005 and 2006 (Ledgard et al. 2007) averaged 63 kg N/ha/yr (84 and 42 kg N/ha/yr in years 1 and 2) compared to the *Overseer*-modelled value of 56 kg N/ha/yr. Again, this is a reasonable fit and the *Overseer* estimate is within the measured range.
30. As shown in Table 1, results for the Sustainable Farming Fund Taupo beef cattle study, which was carried out in the Lake Taupo catchment, also showed close agreement between measured and modelled values.

Table 1: Effect of winter management practices on N leaching estimated using the *Overseer* model compared to field data (average of 2 years) from a beef cow grazing system study in the Lake Taupo catchment (Betteridge et al. 2005).

Winter management	N leaching (kg N/ha/yr)	
	Modelled	Measured
All-grazing	15	16
Winter-off (April-Aug)	8	7

CONCLUSION

31. I believe the modelling process undertaken by Snow et al. is the most appropriate approach for deriving estimates of nutrient losses from existing and possible future farm systems in the Upper Waitaki region because:
 - a. The multi-step modelling process sets some boundaries that ensures potential future farms are biologically feasible,
 - b. Model inputs were based upon detailed surveys of existing land users, thus minimizing uncertainty associated with human decision-making, and

- c. The modelling tools employed have a high degree of credibility for describing grazed farm systems.

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