BEFORE THE	Canterbury Regional Council
IN THE MATTER OF	Plan Change 5 to the Canterbury Land & Water Regional Plan

STATEMENT OF EVIDENCE OF DR SAMUEL JAMES DENNIS

On behalf of

BEEF + LAMB NEW ZEALAND

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Introduction

Qualifications and experience

1. My name is Samuel James Dennis. I hold a B.Agr.Sc (First Class Honours) and a Ph.D. (Soil Science) from Lincoln University. I have completed both the Intermediate and Advanced Sustainable Nutrient Management courses at Massey University. I am currently working as an independent agricultural environmental consultant. I have not yet sought formal certification through the Nutrient Management Adviser Certification Programme. My qualifications are in excess of what is required for certification.

2. I have been contracted by Beef+Lamb New Zealand to model farms in OVERSEER in the area defined by the plan, test the portal and prepare a statement of evidence.

3. My Ph.D. thesis was on nitrogen leaching losses from grazed pasture systems.

4. I previously worked as a scientist for AgResearch in the areas of farm systems, farm system modelling, precision agriculture and nutrient leaching loss. Prior to this I worked at Lincoln University as a research technician in the soil science department.

5. While at AgResearch I was a member of an internal expert OVERSEER user group. Specific areas of scientific research experience include:

    a. Nitrogen leaching losses from grazed pastures.
    b. Use of models to determine nitrogen leaching and greenhouse gas emissions from farm systems.
    c. Experimental design and data analysis.
    d. Systematic experimental design of farm system modelling studies.
    e. Pasture sensors, precision spatial management of grazed pastures.

6. Having grown up and worked on Canterbury farms in a range of industries, I am familiar with the practical realities of agriculture and am able to put scientific principles in context. In this case, my evidence focuses on the on-farm implications and difficulties of using OVERSEER to derive and monitor compliance with individual property based nitrogen discharge limits.

Scope of evidence

7. My evidence covers four key themes
    i. The use of Overseer for nutrient modelling v regulation
    ii. The compatibility of the Farm Portal with modelled Overseer output files
    iii. The operation of the portal as it relates to sheep and beef farm systems
    iv. An analysis of the proposed narrative thresholds and potential N loss
    v. Providing for operating flexibility for lower N loss systems

The use of Overseer

8. Overseer modelling is partially an art, informed by science. Translating a real farm into Overseer is as much a simplification as translating a real person into a pen-and-ink caricature. This is because Overseer does not, and will never contain enough options to truly represent every aspect of a farm correctly. The modeller must simplify

reality to squeeze it into Overseer. This involves judgement calls - particularly around the level of simplification to be applied. The Overseer Best Practice Data Input Standards do not say how to make these decisions, just limit the possible options. This has strong implications for all uses of Overseer, including in and associated with the use of the farm portal.

9. For fertiliser recommendations, the primary purpose Overseer has been used for historically; on pastoral farms a high degree of simplification is acceptable. Very basic Overseer inputs can be made and, even if livestock numbers or other factors are slightly incorrect, the final result will be reasonable enough to inform decision-making. If a farm system is poorly supported, it can still be approximated in the model, and expert judgment used to interpret the results. If the result is incorrect, the worst consequence is a slightly too high fertiliser bill or a slightly reduced crop yield.

10. However for regulatory use of Overseer, a far greater level of precision is required. The consequences of errors, both in modelling and in building the farm system appropriately into the model, could have long-reaching consequences affecting the farm owner. Large financial expenses (consents, infrastructure investments, even land purchases) and potential future production could be severely impacted. Financial penalties may also be applied to a farmer in breach of rules. Regulatory use of Overseer severely pushes the boundaries of the model's accuracy, and issues that may never have been a problem in the past become highly significant. When a tool like the farm portal is then applied as another layer over top of the Overseer model, new issues are introduced and existing issues are exacerbated. Some of these issues may be solved, others require alternative approaches, and examples of both are discussed in my evidence.

Overseer file compatibility with Farm Portal

11. I aim to set out in the following section of my evidence the key issues I have encountered with using the farm portal to generate GMP loss rates from existing Overseer files. This includes both areas where the farm portal does not accurately represent real farm systems, and technical issues that prevent reliable use of the portal. I will also discuss the implications of these issues for sheep & beef farmers in the implementation of the plan.

S-map

12. The portal requires all soils to be entered as S-map soil codes. However, many blocks are not covered by S-map. The Overseer Best Practice Data Input Standards state that S-map data is only preferred “Where available”. When S-map definitions are unavailable, the Standards recommend using:
    i. Ideally, farm-specific soil map information as identified by a trained soil pedologist. In cases where a soil is represented in S-map, but the map itself does not extend to the property, this would allow the identification of S-map definitions for a block. However the Standards point out that “most farms are unlikely to have a detailed soil map”.
    ii. Usually, it is recommended to use the soil series name and describe the soil profile within Overseer. This approach is likely to be more accurate than attempting to guess the relevant S-map definition without the input of a soil

pedologist.

13. The portal does not accept all S-map soil codes. Some soils (e.g. peat soils) are described in less detail in S-map than other soils. Such less-detailed soils have S-map codes, with “Level1” appended to the code.

    i. If a soil is described using these “Level1” S-map codes, it will be accepted by Overseer. But the portal will reject the file as invalid.

    ii. For some soil types (e.g. peat) the only suitable soil options are described using “Level1” codes, or it is not obvious to an S-map user how to find a suitable soil that has a standard S-map soil description. In these cases the user is forced to choose a completely different soil type, which can have large implications for leaching losses.

14. These issues with how the portal implements S-map soils mean that:

    i. The portal is not compliant with the Overseer Data Input Standards.

    ii. The portal requires farms that have been modelled accurately in compliance with the Standards to be modified in ways that reduce their accuracy before they can be used in the portal.

    iii. This may result in farms being regulated against artificial nutrient losses rather than the actual modelled loss from the property.

15. The requirement for all soils to be described using a certain subset of S-map soil codes is inappropriate and needs to be removed.

Unusual Systems

16. Some farms contain operations that are not currently supported in Overseer, and have had to be simulated in a non-standard manner in the model. Even if a farming system is considered of little interest to Environment Canterbury today due to comprising a small proportion of the farms in the region, wherever such a system occurred on even part of a property during the baseline period, particularly if the system has changed since then, the losses from these systems must still be estimated in order to derive a reasonable baseline value for the property.

17. However, anything non-standard is considered not GMP by the portal proxies, and is removed entirely from the farm. This causes non-standard farming systems to have far lower portal-derived GMP losses than are realistic. This will also apply to more complex farm systems that have parts of their farms that fall outside of the GMP assumptions in the portal.

18. For some farms, the baseline period is very complex and it is difficult to determine how the regulations apply to the property at all. Two examples:

Farm A: Former pig farm

i. During the baseline period, this farm ran pigs and beef cattle. The pigs were kept in deep-litter huts sitting on the soil surface (a system not supported in Overseer currently, and for which the leaching losses will not be determined by the upcoming free-range pig module in Overseer either). The highest source of nutrient loss from the property was the deep-litter huts themselves, and an area used to compost this litter prior to spreading onto the property.

ii. The farm now has a different farming system, but with comparable leaching losses to the original piggery.

Problems applying the portal and regulations to this property:

i. Overseer has not been validated for use to model the direct leaching losses from the piggery, only the nutrient loss from piggery effluent and compost broadcast onto paddocks. However the majority of nutrient loss from this piggery appears to have been associated with the huts themselves. Ignoring this would ignore the majority of the nutrient loss from the farm and result in an unrealistically low baseline N loss estimate, with severe implications for present-day farm management. So nutrient loss must be estimated as accurately as possible in the circumstances.

ii. Leaching loss from this system can be estimated using published scientific research on the nutrients entering the soil from the bottom of deep-litter beds and from composting operations, and then applying these nutrients in Overseer as “fertiliser” in appropriate forms at the times of the year these nutrients would enter the soil. Overseer can then estimate the nutrient loss from the system. This method has been used for this farm. Alternative modelling approaches would be possible also.

iii. The result is an Overseer file that has a very small area receiving an extremely high rate of “fertiliser” (simulating the excreta from the deep-litter pig operation), and paddocks receiving piggery compost and effluent and grazed by cattle. Total N leaching loss is approximately 50 kgN/ha or greater, this being a very conservative estimate as the uncertainty is understandably much larger than with a standard Overseer N loss estimate.

iv. The portal N rule removes all “fertiliser” (ie pig excreta) from the piggery, and all compost and effluent from the surrounding paddocks. The result is a file with no pigs, only a very low stocking rate of cattle (as the focus was on pig production), and only approximately 20 kgN/ha leaching loss, less than half the estimated actual losses.

v. If the portal is queried for a matrix GMP leaching loss estimate with no Overseer file supplied, the GMP loss is only 5 kgN/ha, far below the loss from any sensible farming system I have modelled on the property.

vi. The current farming system leaches a comparable amount of N to the original piggery, provided direct leaching from the deep-litter huts is accounted for.

19. In a situation such as this, with a current farming system that leaches approximately the same amount as the baseline management of the property, it appears obvious that the nutrient losses have not increased over time. Even with the recognition that this property may be required to undertake changes to reduce N loss over time, the portal's application of a completely unrealistic estimate of GMP losses through the limited ability of the portal to understand a complex farm system significantly disadvantages this property.

Farm B: Free-range hens.

i. Free-range hens stocked at 2200 hens per hectare (which represents GMP, as it is below the maximum stocking rate of 2500 hens per hectare in the code of welfare for layer hens). Run area irrigated to maintain a green pasture cover (again good management for free-range hens). Also a substantial area of cut-and-carry pasture and trees around the hen run area to provide a dust barrier and dilute whole-property N leaching losses.

ii. Nutrient leaching losses simulated using Overseer, by determining hen N excretion rates and applying to pasture as “fertiliser” in appropriate forms and timings. Total application rate of chicken manure equals 338 kgN/ha/yr, well within the range of N application rates that Overseer is commonly used with.

iii. Average N leaching loss from property: 73 kgN/ha. Portal-derived GMP N loss: 5 kgN/ha. In reality, this Overseer file simulates current industry-recommended practice (i.e. something close to what “GMP” would be had it been determined for these systems).

iv. As for the previous farm, the portal interprets the “fertiliser” applications to be beyond GMP, and removes them. In so doing, it effectively removes the entire hen farm from the property, and simulates the likely nutrient loss without any farming activities at all.

Farm C: Missing information and unrepresentative years

i. This property was managed under a relatively intensive system historically, and for the first 2 years of the baseline period. The third year of the baseline period is unknown, as the manager is deceased. The fourth year of the baseline period was managed very extensively as the farm was in a sale process.

ii. The property is now managed in a manner that incurs similar annual nutrient losses to the first two years of the baseline period. If the baseline average is taken to be the mean of the first two years, the farm will be compliant. If the baseline must be averaged over all four years, this is impossible without completely guessing the management in one year. If it must be averaged over the three known years, the baseline losses will be unrealistically low and will severely impact farm management.

iii. The Portal requires Overseer files to be entered for all four years of the baseline period, with no way to account for either non-existent or unrepresentative years.

20. It is to be expected that the portal would not calculate GMP leaching losses from pig and chook farms correctly, because it has not been developed with these in mind. The alternative N fertiliser proxy, brought forward in Ravensdown's evidence, would not account for these correctly either because it too has not been developed for such systems. The primary issue is that the “fertiliser” on these farms is not actually fertiliser, but animal excreta, simulated using “fertiliser” only because Overseer does not yet allow the livestock systems present to be defined in the model.

21. These examples illustrate the need for caution in the approach taken to using the results of the portal and applying them in regulation. It must be recognised that however well the portal is developed, it will not work for some farming systems. There needs to be some exemption for such systems from the portal and a recognition that parts of farms and more complex farming systems will not be correctly interpreted by the portal. Mr Bruce Thorrold has made similar observations in his evidence for DairyNZ.

22. Some years in the baseline period may be unrepresentative of long-term economic management of the property, and in some cases it is inappropriate to require all years to be entered into the portal.

23. Because of this, the portal should only be used as a starting point for conversations between ECan and farmers regarding consents, rather than being trusted to predict the actual baseline GMP N loss allowance for every farming system.

24. A farm that is currently supported in the portal, may have been farmed in an unsupported manner during the baseline period, and flexible options must be available for determining baseline N losses to ensure such farms are not unfairly penalised.

Unpredictable errors, difficult to resolve

25. The portal frequently rejects valid Overseer files, often for reasons that are impossible to identify without resorting to inspecting the raw Overseer XML file in a text editor, something that most users would be unable to do. For instance:

i. Error: “*DataError (CropType.NoCropSequenceCultivation :: Cultivation practice method [Conventional] has been entered but no CropSeqNumber defined for crop detail with ID 1034578.*”

   a) This ID number is not visible anywhere in the Overseer interface. So nothing in this error states what crop or block this error relates to. The only way to work out what crop is in error is to open the raw XML file in a text-editor, search for that ID number, and then use expert knowledge of how Overseer files are coded to determine what block is in error.

   b) In this case, there was actually nothing wrong with the file in Overseer. The portal just did not understand the way Overseer had recorded the block information in the Overseer file. The only way to eliminate the error was to delete the relevant crop block, and re-enter it identically. The resultant file looked identical in Overseer, but had a very slightly different file structure that was accepted by the portal.

c) This error would be completely inexplicable to most users and prevent the portal from being used by them without the expert assistance of a computer programmer.

ii. Error: "*When pastoral blocks are present imported and removed supplements must be provided as a dry weight. Supplement ID 1939623.*"

a. Again, this ID number is not visible in the Overseer interface, and can only be identified using a text editor on the raw XML file.

b. This error kept recurring even when all supplements were deleted from the farm from the Overseer interface, and even when all blocks that had had supplements associated with them were deleted. It was impossible to eliminate from within Overseer.

c. It related to a phantom supplement crop (of "0" tonnes of baleage) which existed in the XML file from some previous workings, and was completely invisible from within the Overseer interface so could be neither viewed nor edited in Overseer, but caused the portal to reject the file.

d. The only way to get the portal to accept this file was to:

1. Identify the relevant lines in the XML file and manually delete them using a text editor (no general user would either know how to do this, or be confident to).
2. Re-import into Overseer (as the portal still considered the modified file invalid, but Overseer accepted it).
3. Re-export from Overseer, to create a new file that the portal now accepted.

i. Error: *"Block "thisblock" must have required climate details defined."*

a. The block in question had identical climate details to all other blocks. There was no obvious reason for this error. It was resolved by using an Overseer tool to replace site, climate and soil block data from another block.

ii. Another farm file processed with no errors, and two weighted files were provided, one with conventional and one with minimum-tillage cultivation. However, both files were actually almost identical, cultivation had only been altered on one block, all other blocks had their original cultivation types.

26. Such errors occur very frequently when using the portal, and indicate to me that the portal is not yet stable enough to be used. At least half the files I loaded into the portal required modification in some way before the portal would accept them, with

at least half of these requiring the raw XML file to be inspected in order to identify and correct the source of the error. Improvements required include:

27.

i. Making the portal more robust so it will accept files that Overseer considers valid, and not reject files due to issues that are ignored by Overseer.

ii. Re-writing error codes to be more meaningful, and refer to things that can actually be identified in the Overseer interface – block and crop names for instance.

iii. Testing on a wider set of real farm files to ensure it treats all files consistently.

Key GMP proxies – effects on S&B farms

N fertiliser

28. In general, when applied to sheep & beef farm Overseer files, the current N fertiliser proxy:

i. Removes all N fertiliser from pastures, assuming that "GMP" means no fertiliser is applied. For example, a farm block that originally had 36 kgN/ha applied in September (a very low annual rate of N), after being run through the portal had no N fertiliser applied at any time.

   a. This tends to make no change to, or slightly *increase*, modelled N leaching. N fertiliser is often strategically applied to sheep & beef pastures in spring to increase pasture production at a particular time of year. Removing this fertiliser results in Overseer assuming increased clover N fixation to achieve the same total annual pasture production, but clover N fixation occurs year-round, including in autumn. Without spring N fertiliser, autumn N inputs are assumed to increase, and winter leaching increases very slightly. However this effect is so slight as to be unnoticeable on most properties.

ii. Removes all N fertiliser from grazed fodder crops. For example, a crop of swedes that had 26kgN/ha applied at sowing in November (as DAP) and 46kgN/ha applied in January (as urea), after being run through the portal had no N fertiliser applied at any time.

   a. N fertiliser is often used at sowing and during the growing period to aid crop establishment and growth. GMP in this case states "Manage the amount and timing of fertiliser inputs, taking account of all sources of nutrients, to match plant requirements and minimise risk of losses". Brassica crops have a high nitrogen requirement, and respond strongly to nitrogen fertiliser. Although the nitrogen requirement does vary depending on initial soil N content, as a general rule, application of a low rate of DAP at sowing to aid establishment, followed by an application of urea once the crop is growing strongly to feed crop growth, as originally modelled, represents GMP. This example is a 12 tonne swede crop, that would be expected to take up 252 kgN/ha. The quantity of N applied to this crop is by no means excessive, and is timed well with crop N requirements. Even with this modest fertiliser application, the majority of crop N requirement is expected to be supplied from the mineralisation of the residue of the previous crop, not from fertiliser.

b. The N proxy in the portal tends to remove all N fertiliser at any stage. This can greatly reduce modelled N leaching losses, even halve loss in some cases. However the high N requirement of brassica crops means that eliminating this fertiliser would be highly likely to reduce crop yield. This would have many flow-on effects for the farming system. If the proxy occasionally predicted that no N fertiliser was required for a brassica crop, that would be understandable, as in some cases there is no yield response to N. But in my testing the proxy removed all N from almost every single brassica crop, and this is unrealistic.

c. One problem is that the proxy is working in the perfect world of a computer model, not the real world. Even if a computer model predicts that on average a soil should be able to supply sufficient N for a crop, in reality the available N may vary greatly across the paddock, and there may be large areas where the crop is under N stress. The model has perfect knowledge of simulated soil N content and thus requires only the bare minimum fertiliser to be applied, but on most farms soils are not tested before every crop (nor does GMP require this), and even if they have been tested the paddock may be variable. A modest and carefully timed fertiliser application helps to fill these gaps in N supply, that may be overlooked by the uniform assumptions of a computer model. A GMP fertiliser recommendation is made by an experienced human, informed by computer models but considering more factors also – it is not dictated solely by a model.

iii. Increases N fertiliser to arable crops

a. The behaviour of the proxy is highly variable. However in general, it reduces or eliminates N fertiliser applied at sowing, but increases N fertiliser applied during the growth of the crop. The result is usually an increase in total N fertiliser applications. This tends to result in an increased modelled N leaching loss from the block.

29. The net result is that the portal calculates GMP N leaching to be approximately similar to the original Overseer file for pasture-based farms, lower for farms using many forage crops, and higher for arable farms.

30. An alternative N proxy is being proposed by DairyNZ. The proposal is to calculate the N surplus from fertiliser and imported supplements minus product removals, and keep the surplus below a threshold, which is suggested to be a sliding scale of 125 kgN/ha + 60% of the original N surplus above 125. This proxy is simple to calculate and seems more transparent than the existing one. For sheep & beef farms, this alternative N proxy generally has the following implications:

31. If applied at the whole-farm level:

i. No sheep & beef or mixed cropping farm tested failed this N proxy test at a whole-farm level. In other words, at the scale of the farm, N surplus was

<125kgN/ha on all properties. This N proxy required no changes in N fertiliser to any sheep & beef or mixed cropping farm.

32. If applied at the level of individual blocks:
    i. Pastures: No sheep & beef pasture inspected failed the proposed N surplus test, so no N fertiliser required removal to meet GMP, all existing N fertiliser applications were retained, and there was no change in leaching losses.
    ii. Fodder crops: Can require anything from no change in N fertiliser, to the removal of all N fertiliser, depending on the quantity of supplementary feed used on the block and the contribution this makes to the N surplus.
        a. Since the N applied in supplementary feed occurs after the crop has grown, it is not available for crop nutrition. This can mean a crop must be assumed to grow with no N fertiliser simply because at a later stage supplementary feed will be used on the paddock.
        b. However this situation occurs on a small proportion of blocks. Far fewer crops are required to be grown with no N fertiliser than with the existing N proxy.
        c. This issue tends to mainly be visible on crops entered as “fodder crop blocks” rotating around pasture, where all N associated with the crop is in the current reporting year. Fodder crops on arable blocks often have the establishment fertiliser and the supplement N additions in different reporting years, reducing the N surplus in any particular reporting year.
    iii. Arable crops: No change in N fertiliser was required on any crop inspected, so no change in leaching. Note that DairyNZ has stated tha different N surplus thresholds may be required for arable crops, but has not suggested any values for this, should a different threshold be used the findings may differ.

33. The general result for sheep & beef farms is that the proposed DairyNZ proxy causes no change in N leaching loss from pastures or arable crops. It can reduce N loss from fodder crops depending on the quantity of supplementary feed used, but this rarely occurs.

34. The current proxy rewards arable farmers who were using less fertiliser than the proxy calculates as GMP during the baseline period - the DairyNZ proxy does not. However the current proxy penalises farmers who were growing forage crops during the baseline period - the DairyNZ proxy penalises them less by allowing more N fertiliser to be applied as GMP, resulting in slightly higher modelled baseline GMP nutrient losses, closer to actual baseline losses.

Irrigation

35. Most farmers do not use soil moisture monitoring equipment. Some do, others use soil water budgets, others irrigate more intuitively. Overseer has difficulty replicating these approaches accurately for a number of reasons, and this influences the portal's ability to simulate GMP.

i. Overseer offers two non-budgetary approaches to irrigation scheduling: "Fixed depth & return period" (in other words, apply irrigation throughout the irrigation season regardless of rainfall), and "Visual assessment / dig a hole" (in other words, use the eyes and brain to determine whether irrigation is required). The first option is obviously inefficient, the second option is what many farmers do. In reality, even for a farm with soil moisture monitoring equipment, with a travelling irrigator covering many different paddocks some of which are not monitored, visual assessment will be used to some degree everywhere. Unfortunately Overseer does not account for farmer intelligence, and assumes that any farmer without a soil water budget irrigates to a fixed schedule and ignores both rainfall and crop needs. Overseer therefore tends to overestimate water applications, and therefore is likely to overestimate nutrient leaching losses, from real farm irrigation management.

ii. Overseer offers three budgetary approaches to irrigation scheduling: "Soil water budget", "Soil moisture sensors: Probes" and "Soil moisture sensors: Tapes". In practice, Overseer simulates all three assuming the farmer has perfect knowledge of the soil moisture content at any time and can schedule irrigation accordingly – effectively simulating a farm with soil moisture sensors in every single paddock. No farmer has this omniscient level of understanding about their soil moisture monitoring.

iii. So Overseer only offers two options – absolute worst-case knowledge, and absolute best-case knowledge – neither of which is likely to occur in reality on most farms.

36. Industry-agreed GMP is to "Manage the amount and timing of irrigation inputs to meet plant demands and minimise risk of leaching and runoff." This definition does not require the use of soil moisture sensors. It is effectively somewhere between the two above extremes simulated by Overseer.

i. At present, a farm that is irrigated using farmer intelligence will be modelled as far worse than GMP, even if the farmer is managing his system well. The current irrigation proxy changes irrigation to a budgetary approach, which Overseer models in a way that is better than GMP. The apparent difference between current practice and GMP is therefore greatly inflated.

ii. This means that an irrigated farm may have a portal-generated GMP N loss value that is far lower than their current Overseer N loss estimate. They may be required to make major changes to irrigation scheduling in order to reduce modelled losses to this level. And all the time, the numbers may simply be wrong – their original losses may never have been as high as assumed, and they may never have had to reduce them that far to truly reach industry-agreed GMP, had they been modelled in a more realistic fashion.

37. For travelling irrigation systems that take many days to move around the farm (rotorainers, guns, pods etc), another issue arises. Overseer is, I understand, a single-paddock model. In other words, each block is modelled as a single paddock. If the irrigation trigger is 50% Profile Available Water (PAW), the moment moisture

is depleted to that level, the model will assume that the paddock is irrigated. Then the model will wait for the set minimum rotation length, and irrigate the paddock again. The entire block is irrigated as perfectly as possible, given the irrigation parameters entered.

38. However this is not what occurs in practice. In reality, such an irrigator will have to move around every paddock in rotation. When the block requires irrigation, it will take possibly 10 days to irrigate the entire block. By the time the irrigator reaches the final paddock, the moisture level will have been greatly depleted. So in practice, most paddocks cannot be irrigated with the precision assumed by Overseer. At times irrigation may need to start before the desired irrigation trigger, in order to avoid soil moisture deficits in other paddocks. At other times a paddock that has a moderate soil moisture content may need to be irrigated despite this causing the soil to exceed field capacity, simply because the irrigator is available then and the application depth cannot be reduced sufficiently. Even if soil moisture sensors are installed, only one paddock in the rotation is likely to have one, so scheduling is done using much less knowledge than assumed by Overseer. In addition, the actual PAW capacity will generally differ between paddocks in the rotation, so an irrigation schedule that is perfect for one monitored paddock will likely be less efficient on some of the paddocks in the rotation, as the system is a compromise between what is desired and what is actually achievable.

39. The portal's current default GMP irrigation parameters (ie the depth of water applied, timing, and trigger soil moisture levels) are designed to achieve 100% application efficiency – in other words, to apply water so that 100% of the water is available to plants and none drains through the soil profile. Because of the reasons outlined above, this is unrealistic and impossible to achieve in practice. In reality, even 80% application efficiency requires very efficient management.

i. The portal GMP proxy is therefore only compatible with farm Overseer files that have been incorrectly entered with parameters that also assume 100% application efficiency, and underestimate the true water usage on a property and the true leaching from that property.

ii. In practice, as Overseer files are used for fertiliser recommendations and need to be accurate, and because the actual irrigation water application is now known through ECan's own mandatory flow metering, good consultants will use this information. They will consider the actual water use on a property and adjust the irrigation parameters to achieve a similar total water use to what actually occurs in reality. The result will be a more accurate assessment of nutrient losses and fertiliser requirements.

iii. However a more accurate file such as this will be penalised by the portal, assumed to not represent GMP, and the farm will be given a GMP loss value in some cases substantially lower than that which actually occurred or is technically feasible.

iv. Given that Environment Canterbury has required all farmers to monitor irrigation water use, it is reasonable to assume that using this actual data in Overseer to inform precise farm management represents “good management”. The portal thus simulates something other than good management, so is not compatible with GMP.

40. The portal should use irrigation parameters that assume, at best, an 80% application efficiency (AE), or a lower AE wherever industry guidelines on a particular system state that a lower AE represents good management of that irrigation system, to ensure compatibility with real-world best use of Overseer.

Fallow

41. Italian ryegrass crops are added into fallow periods by the portal, to reduce N leaching losses. This can substantially reduce calculated leaching loss from some blocks. However these added crops are not necessarily biologically feasible, and may not represent GMP.

42. The following sets out two real examples

    i. A summer crop had the final grazing in April, fallow from May – October, resown in November. Note that this is an extremely long fallow period that would not generally be planned, but can occur for various reasons. The portal sowed Italian ryegrass in May.

    ii. A winter crop had the final grazing in July, fallow from August – October, resown in November. This is a common situation that may occur on many properties. The portal added an Italian ryegrass crop in August.

43. What the portal has simulated is not physically possible, in either case.

    i. Cover crops cannot be generally sown in May on this property, soil temperatures are too low. The farmer attempted to sow oats once in May, and they did not emerge until August. This is why the fallow period existed in the first place on this particular paddock – if it has not been possible to sow a new crop prior to May, for whatever reason, it cannot be sown until spring.

    ii. Cereal or ryegrass crops cannot generally be sown in August on this property due to low soil temperatures, but could be sown in September. However this fallow period is necessary and cannot be eliminated. On a dryland property, a spring fallow period is used to preserve soil moisture to allow a temperature-sensitive crop to be sown in late spring (October or November) while still having sufficient moisture to grow. Such a fallow period is required before sowing fodder beet for example. If a cover crop is sown in spring, this moisture will be removed, and the following crop will fail. Furthermore the risk of leaching losses from a spring fallow is substantially lower than from a winter fallow, so there is less need for these fallow periods to be eliminated for N loss reasons either.

44. What the portal has simulated in each case represents

    i. May sowing: Theoretical good practice (maintaining a crop over winter), but physically impossible in this case so not industry GMP.

    ii. August sowing: Bad management practice that will prevent successful establishment of the subsequent crop.

45. The relevant industry-agreed GMP is to "*Manage* periods of exposed soil between crops/pasture...". This has been falsely interpreted in the portal as "*Eliminate* periods of exposed soil between crops/pasture". The industry-agreed implementation guidance offers cover crops as only one option to manage these periods, while also stating "Consider soil conditions and crop rotation". The portal does not sufficiently consider these factors, and therefore simulates a situation that is beyond GMP.

46. Recommendation: Alter the proxy to

    i. On dryland properties, only sow cover crops into areas left fallow in autumn, not spring, as spring fallows can represent good management, and
    ii. Consider soil temperature to prevent sowing when soil temperature will be insufficient for establishment (or raise the temperature threshold if this already occurs). OR
    iii. Decide this is too difficult to simulate using a simple GMP modelled approach and remove the proxy.

Other proxies with lesser implications

47. Olsen P: The portal changes Olsen P to 20, 15 or 10 depending on the topography of a block. These values are similar to or higher than the Olsen P values found on many sheep & beef properties. So these can tend to slightly increase the P loss risk at GMP.

48. P fertiliser: The portal alters P fertiliser levels to maintenance rates. Where Olsen P has been reduced by the portal, or where the farm was applying less than maintenance P, this can increase P loss risk also at GMP.

49. Grass filter strips are added to all farm blocks. These should not be considered necessary for GMP, they are not required by the industry-agreed GMP definitions and are not necessarily practical. Furthermore mitigation measures such as this are unnecessary when P loss risk is "low", this is an expensive mitigation option (as it takes land out of production and requires fencing) and should only be applied when P loss risk is "high" - in other words when there is a real problem that requires mitigation. However, they do not greatly affect nutrient losses as modelled by Overseer, so despite these assumptions being questionable the effect is negligible. This means there is little purpose in having this proxy in the model. The grass filter strip proxy should at least be removed for blocks where P loss is "low", or it could simply be removed entirely.

50. If all farmers were expected to actually install grass filter strips, this would be a very serious matter that would need to be opposed more strongly than my above statement. However as farmers are required to meet the GMP loss rate rather than

the practice itself, and the practice simulated does not greatly alter the GMP loss rate, the real-world effect is negligible. It is important for ECan to remember that the industry has not agreed that grass filter strips are required for GMP, and accordingly not to require farmers to install them, even if this modelling proxy is retained.

51. Cultivation proxy is not always applied correctly as stated above.

52. Issues flagged by the portal:

i. Small seed crops that are unsupported by Overseer tend to be modelled as “ryegrass” seed crops. Where the actual seed yield of the simulated crop is different to the expected yield of a ryegrass seed crop, the portal can raise a flag about the yield. However this does not appear to affect any calculations.

ii. Where yield is flagged as unlikely, the error message states that evidence of the yield may need to be provided as part of a consenting process. This may be possible for arable crops, but is generally unrecorded for fodder crops, and the yields entered are estimates. What sort of “evidence” is expected, and in what circumstances?

Threshold areas in forage crop & irrigation

53. The stated intent of the thresholds currently set at 50ha of irrigation and 20ha of fodder crops winter-grazed by cattle, is to identify the 20% of farmers with the highest Nitrogen leaching loss risk. I have attempted to set out below some evidence that will inform the adoption of a more suitable threshold for fodder crops to achieve this objective. The following paragraphs are informed by the evidence of Mr Andrew Burtt on behalf of Beef+Lamb New Zealand.

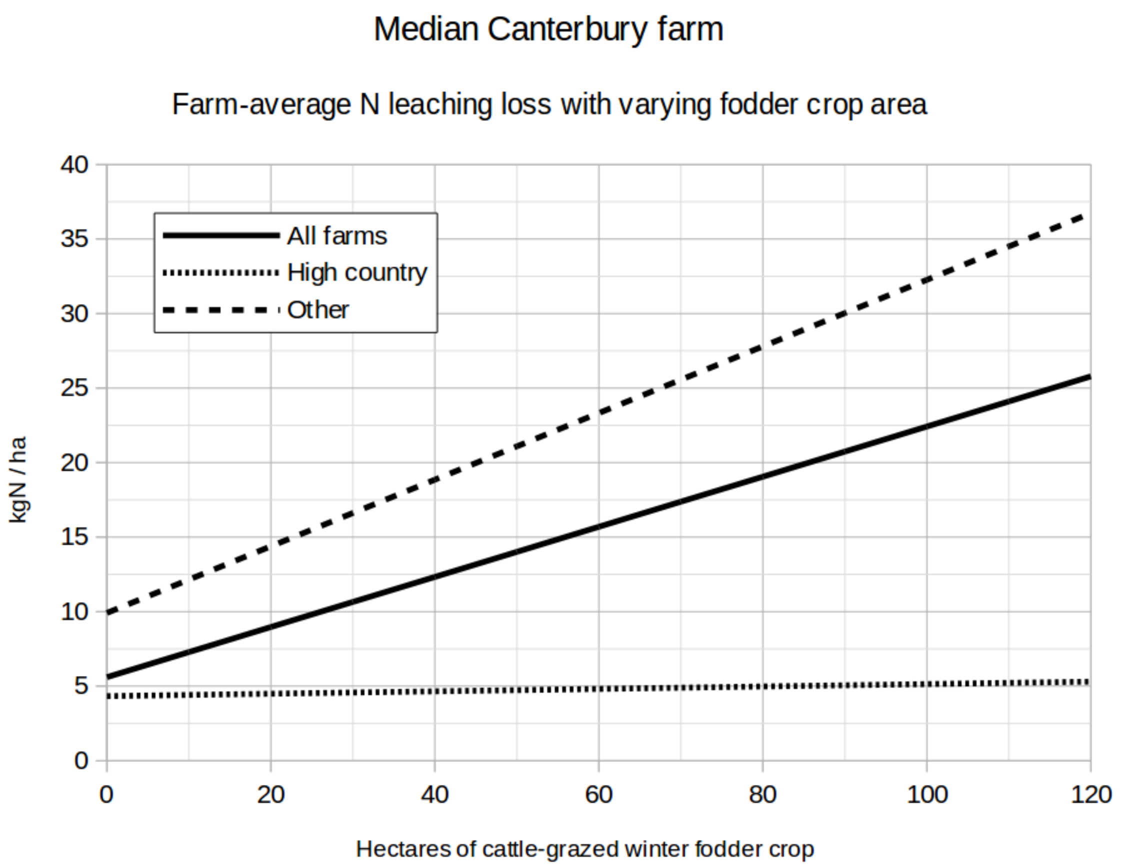
54. If the intent is to identify the top 20% of farmers, and two thresholds are used, I assume that approximately 10% of farmers should be captured by each threshold. In other words, these thresholds should identify the 10% of farmers with the highest winter cropping areas (or more appropriately the highest 10% of modelled N loss), and the 10% with the highest irrigated areas (and or again those with the potential to lose the greatest amount of N). If the top 20% of each were identified, depending on the level of overlap, up to 40% of farmers could be identified by the thresholds, which not meet the stated objective.

55. I have only considered sheep & beef and mixed cropping farmers in this analysis.

56. Taking a representative selection of farms from North to South Canterbury, including the high country and both irrigated and unirrigated properties, I identified all pasture blocks (41 blocks), and all fodder crop blocks that that were grazed at least 50% by dairy cattle, over the winter period (21 blocks). The area-weighted mean N leaching losses (kgN/ha) from these blocks were as follows. The median area of farms in these classes was estimated from Beef+Lamb Economic Service data set out in the evidence statement of Mr Burtt.

	Pasture kgN/ha	Crop kgN/ha	Assumed Median farm area	Farm Class
All farms	5.6	69.8	382 ha	1,2,6,8
High country	4.3	49.3	5595 ha	1
Other	9.9	69.8	305 ha	2,6,8

57. Using this information I determined the average expected change in N leaching losses when a farm in 100% grazed pasture adds different areas of fodder crop to the farming system. This is graphed for all farms, high country only, and farms other than high country:



58. As set out in the evidence of Mr Burtt 20ha of fodder crop approximately represents the 40th percentile of crop area on sheep and beef farms in Canterbury – in other words, with the threshold set at 20Ha, 40% of farms have less fodder crop, and 60% have more. A threshold of 20ha of winter fodder crop would capture

approximately 60% of farms. Furthermore, according to this graph, an average property with 20ha of fodder crop and the remainder of the farm in pasture may leach only 9kgN/ha. If high country farms are excluded, such properties may leach on average 14kgN/ha across the whole property.

59. According to the Sheep and Beef Farm Survey data as set out in the evidence statement of Mr Burtt, setting the threshold at 75 hectares would capture approximately 10% of farms. Farms at this threshold containing only pastoral and fodder crop blocks would be expected to leach on average 18 kgN/ha. The farm survey data indicates that approximately half of the farms with such large areas in fodder crop are Class 1 high country farms, and half are smaller Class 6 or 8 properties. High country farms at this threshold could be expected to leach approximately 5 kgN/ha (as the leaching from 75 hectares of fodder crop is averaged over a very large area), and other properties at this threshold would be expected to leach approximately 26 kgN/ha. As a result, approximately half of the farms captured by a 75 hectare threshold would be likely to have overall N leaching losses of 26 kgN/ha or greater.

60. Alternatively, setting the threshold at 50 hectares would capture approximately 20% of farms. The leaching loss of an average farm at that threshold would be expected to be around 14 kgN/ha (with the leaching loss of high country farms expected to be 5 kgN/ha, and other farms expected to be 21 kgN/ha).

61. These leaching loss values only account for leaching from winter grazed fodder crops, or pasture. They do not account for the leaching from any other activities that may occur on the property. These values are also averages across a large number of farms and do not represent the leaching losses from any particular property.

Enabling Nitrogen management flexibility for sheep and beef farmers

62. The intensity of sheep and beef farming operations varies naturally from year to year, particularly due to fluctuations in climate and farmers response to markets and changing technology and forage types. This fluctuation can drive fluctuations in leaching losses, and to a large degree this fluctuation is out of the direct control of the farmer.

Canterbury High Country (including Upper Waitaki)

63. Overseer models of three high-country stations in an actual, recent year, were modified to simulate situations representing a range of reasonable, expected year-to-year variation in production intensity, based on the actual experience of each farmer over the past decade. Each property was approximately 3000 hectares in area, and ran sheep and beef cattle, with some properties also running deer or conducting arable cropping.

64. Range of leaching losses in different years:

Farm	Low intensity	Moderate intensity	High intensity
A	5 kgN/ha	5 kgN/ha	6 kgN/ha
B	7 kgN/ha	10 kgN/ha	12 kgN/ha
C – varying livestock	8 kgN/ha	8 kgN/ha	9 kgN/ha
C – varying crops	7 kgN/ha	8 kgN/ha	11 gN/ha

65. Although the losses from individual blocks can differ greatly, the overall variation in whole-farm leaching losses was lower than often observed on smaller, more intensive properties, as the large area of these stations tends to average out the fluctuation in loss from individual blocks. However some year-to-year variation was present, particularly when arable cropping was conducted. The reasons for these differences are explored in more detail below.

66. All of these scenarios represent management in the same “system”, but subject to fluctuations in weather and markets that cause livestock to be sold at different times, or cause contracts to be available for a different balance of crops. Such variation in nutrient loss will continue into the future.

67. To date, these farmers have legally had near-complete flexibility to adopt whatever farming system they would like to. In practice, with full flexibility, leaching loss is reasonably stable. However these farms are intensified, under realistic simulations of what has truly been possible historically, nutrient loss only fluctuates by a small number of kg of N per hectare as outlined above. As a result:

    i. These farms require regulations that provide sufficient flexibility to allow for real-world year-to-year fluctuations in N leaching loss. However,

    ii. There is little risk of providing that flexibility to catchment N loads. Even if policy was set in a way that, in order to provide flexibility for high leaching loss farmers, meant that on paper low leaching loss farmers would be legally able to greatly increase nutrient leaching losses, this would be unlikely to actually occur. The intensity of these farms is ultimately limited by the climate, and the intensifications possible within the limitations of the climate do not greatly alter nutrient leaching loss. The only form of intensification that may be an exception to this rule, irrigation, is governed by other consenting processes and would therefore fall out of the bounds of this discussion.

Canterbury hill & plains (most other subregions)

68. The range of leaching losses in different years for more intensively stocked Canterbury sheep & beef and mixed cropping farms was previously determined for submissions relating to the Hinds and South Canterbury Coastal Streams sub-catchments. In these cases, the actual leaching loss in each of the baseline years, and for some farms in additional years or under additional realistic scenarios involving factors out of the farmer's control.

69. Nutrient loss variation 2009 – 2014

Farm	2009/10	2010/11	2011/12	2012/13	Mean
A (mixed cropping)	13.5	14.1	12.8	12.5	13.2
B (mixed cropping)	45.5	44.6	45.0	45.2	45.1
C (beef)	13.2	13.0	13.1	13.1	13.1
D (mixed cropping)	7	7	18	18	12.5
E (sheep & beef)	12	11	11	11	11.3

70. “Management as in the baseline years” and “baseline nutrient leaching losses” are two different things. During the baseline period each of these farms was managed in essentially the same manner (except that farm D installed irrigation in 2011). However leaching losses in any particular year varied. Some variation was climatic, causing variable livestock numbers, however leaching was reasonably stable from pastures even when livestock numbers varied, leaching from pasture-dominated farms tends to gradually change over time rather than fluctuate between years. The primary cause of year-to-year variation was driven by crops, including both forage and arable crops.

71. Most arable crop rotations can be summarised as “grow whatever the market desires and contracts can be obtained to produce, provided it can be practically achieved considering crop rotation and other practical considerations”. Although a farmer may describe their typical “crop rotation”, in practice this never occurs exactly, as the actual crops sown are dependent on both markets and climate. One year there may be a higher demand for wheat, the next year there may be more demand for winter grazing of dairy cattle on fodder crops, and the rotation is adjusted accordingly. So the actual leaching losses from farms that are cropping can vary greatly from year to year. And to a certain extent this variation is out of the control of the farmer, who cannot control the market but must sow whatever crops he will be able to sell. And this variable year-to-year management represents “management as in the baseline years”.

72. Nutrient leaching is extremely hard for a farmer to manage. Across farm D for example, modelled nutrient losses varied greatly in different blocks:

i. Pasture leached 4 – 50 kgN/ha depending on soil types and irrigation.

ii. Wheat alone leached 3 - 22 kgN/ha in different blocks purely depending on which crops were preceding and following the wheat crop and on the wheat yield. The previous crop affects the quantity of N present in the soil and in crop residues and potentially available to be lost. The next crop affects whether the paddock is left fallow or under a cover crop in the autumn after the wheat is harvested, and what cultivation and fertiliser is used to establish that crop, affecting autumn leaching losses. Yield affects how much nitrogen is removed in grain and not available to be leached.

iii. Wheat leached from 3 – 91 kgN/ha when soil and irrigation differences are also considered. All other arable crops were also highly variable, and fell within that range

iv. Kale leached from 9 – 208 kgN/ha depending on yield, grazing species, soil type and irrigation.

73. The fact that leaching loss varies within a particular crop type makes it very difficult to maintain compliance with regulation without heavy use of OVERSEER for forward planning. It is not possible for a farmer to use a simple rule of thumb, such as “barley leaches X kgN/ha so I must have no more than Y hectares of barley to stay under my discharge limit”. Rather, the leaching loss from barley will differ depending on what crop was before or after it in the rotation and the final yield, so any future plan must be explicitly modelled in OVERSEER to determine the likely effect on OVERSEER-derived nutrient leaching estimates. This may not be possible however as the yield will be unknown until the crop is harvested, and the following crop is also unknown as that would be decided at a later date based on market conditions at the time. Even if this information were known, doing this modelling would place a major additional burden on farm decision making, particularly as a professional consultant would generally need to be engaged to use OVERSEER.

74. As the baseline years for the modelled farms do not represent a full selection of the variation that occurs under this management, farm D was also modelled under the influence of realistic factors outside the farmer's control, based on actual experience over a longer period of time.

Wet Autumns

75. Most crops on this farm are sown in autumn, in order to obtain higher yields than if they were sown in spring, and to reduce potential erosion. This also means the crop can act as a cover crop over the winter period and reduce N leaching losses. But this is entirely dependent on weather conditions in the autumn. When the soil is too wet, crops cannot be sown in autumn, and must be sown in spring. When this occurs, nutrient loss is increased due to lack of a cover crop, and also because the crop yield is reduced (it has less time to grow before harvest) so less nutrients are removed in the crop.

76. To illustrate the effect of this on modelled N outputs, the farm was re-modelled assuming that the 2012 autumn had been too wet for any crops to be sown, and all crops had to be sown in spring. This affected both the 2011/12 year (no cover crops that autumn, but also fewer cultivation events) and the 2012/13 year (no cover crops in early spring, reduced yields, more cultivation events moved to this year).

77. Using these modelling scenarios, total N loss in 2011/12 did not change, as the increase in loss from no cover crops was balanced by the reduction in loss from less cultivation. Total N loss in 2012/13 increased by 3 kgN/ha.

(kgN/Ha)	**2011/12**	**2012/13**
Autumn sown	18	18
Spring sown	18	21

78. This occurs occasionally to a greater or lesser extent, and the influence of the weather on decision making is entirely out of the control of the farmer.

Crop failure

79. Inevitably some crops will fail on any property at any one time, for a wide range of reasons: hail, drought, disease, misadventure, or even markets – if the price is too low to justify harvesting so the crop is grazed or ploughed in. Whenever a crop fails, the farmer has still applied fertiliser as usual anticipating a crop, but little or no nutrients are removed in the products, leaving more nutrients available to be lost to water.

80. OVERSEER can simulate a crop failure by reducing crop yield to the minimum value allowed in the model (0.1 t/ha). The 2012/13 year was re-modelled assuming every single arable crop failed.

81. Crop failure caused nutrient loss to increase from 18 to 33 kgN/Ha.
It would be unlikely for every crop to fail in a single year, however it is entirely reasonable to assume that a number of crops will fail simultaneously in some years (e.g. from hail or drought). Any such failure will increase nutrient loss above the baseline values cited above – but actually still represents "management at baseline", because everything the farmer has done is exactly the same as during the baseline period. The higher nutrient loss was unplanned and largely unavoidable.

82. A range of judgement calls must be made when a farm is entered into Overseer, and these also alter nutrient leaching estimates.

Soil definitions using S-map:

i. S-map does not dictate the soils to be used, but supplies a short selection of soils that may represent the soil in an area. Farm D was modelled in one year using the dominant soil in S-map for each block, or a reasonable alternative S-map soil type. The soil choice affects nutrient leaching losses.

ii. Depending on the soil definition chosen, modelled farm-average N leaching loss varied from 17-20 kgN/ha

Level of detail:

i. The actual cropping rotation on an arable farm must generally be simplified for entry into Overseer, as every paddock has a different history and often soil type but it is generally impractical to model every paddock individually. The level of simplification used is a judgement call, that can greatly affect N leaching losses.

ii. Farm D was modelled using 23 blocks to describe the arable cropping rotation, or 14 slightly more generalised blocks instead. Both models represent accurate descriptions of the same farming system, but to different levels of precision.

iii. Modelled N leaching loss from the simplified model was 14 kgN/Ha, in comparison to 18kg/Ha using a more fine grained approach.

Seed crops:

i. Many crops, particularly small seeds, are not yet supported in Overseer and must be simulated using a different crop type. The choice of what Overseer-supported crop is most similar to the actual crop is a judgement call.

ii. A brassica seed crop was simulated using ryegrass, barley, or dried pea crops, with a 1.5 t/ha seed yield, and the residual herbage from each being either "grazed", "retained", "removed" or "burnt". Predicted Nitrogen loss from each of those scenarios was as follows:

kgN/ha	Grazed	Retained	Removed	Burnt
Ryegrass	15	5	5	5
Barley	35	34	34	34
Peas (dried)	34	34	32	32

iii. Depending on how a small seed crop is modelled, nitrogen loss can vary as much as seven-fold, from 5 – 35 kgN/ha in this example. It is very difficult to say what value would be a "correct" prediction of actual loss.

iv. Depending on the area in small seeds in any one year, the modeller's judgement on how to model these crops can have a large effect on estimated whole-farm leaching losses.