under:	the Resource Management Act 1991
in the matter of:	Proposed Waikato Regional Plan Change 1 – Waikato and Waipa River Catchments
and:	Dr Glen Treweek
	Submitter: 72747

Statement of Primary Evidence of Glen Treweek

Dated 15th February 2019

STATEMENT OF EVIDENCE OF GLEN TREWEEK

1. My name is Glen Treweek
2. I have the following qualification and experience:
   2.1. Doctor of Philosophy (Soil Science) from Lincoln University, specialising in denitrification and nitrogen cycling in dairy winter grazing systems;
   2.2. Master of Science (Soil Science) – First Class Honours, from the University of Waikato, specialising in nitrogen leaching
   2.3. Bachelor of Science (Earth Science) from the University of Waikato
   2.4. Certificate of Completion in Advanced Sustainable Nutrient Management from Massey University
   2.5. I have published two papers in scientific journals.
   2.6. I have more than 4 years' experience as an Environmental consultant, first with Aqualinc Research Ltd., and more recently as managing director of Ground Sense Ltd. where I;
      2.6.1. worked closely with farmers helping to prepare or audit more than 200 Farm Environment Plans in the Canterbury region under the recently adopted Land and Water Regional Plan;
      2.6.2. I am a regular user of the Overseer farm modelling software, where I have prepared nutrient budgets for individual farmers, and on behalf of irrigation schemes. I have helped develop consistency standards that are used by other consultants to prepare nutrient budgets, and
      2.6.3. worked with most of the major Irrigation schemes in Canterbury as they negotiate the concepts of nutrient allocation and nitrogen caps. The irrigation schemes operate under nitrogen discharge consents with comprehensive Environmental Management Strategies as consent conditions. The schemes have nitrogen caps, Farm Environment Plans, farm audits, and have annual reporting requirements. I have direct experience trying top implement the type of rules contained in PC1.
3. I grew up in Morrinsville, I am familiar with the farming systems, the communities, and the landscape of the Waikato. I volunteered at the Maungatautari Ecological island for several years before moving south. I swam in the creeks at the back of my friends' farms when I was young. I want to see water quality improve as much as anyone else.

SCOPE OF EVIDENCE

4. In my evidence I provide:
   4.1. A brief look at some published research into the strengths and weaknesses of different approaches to managing fresh water quality; and
   4.2. My assessment of Overseer as a tool to manage farm practices; and
   4.3. Commentary on the Proposed Waikato Regional Plan Change 1 – Waikato and Waipa River Catchments (PC1) rules through the lens of someone trying to implement similar rules in Canterbury.

EXECUTIVE SUMMARY

5. The proposed rules 3.11.5.1-3.11.5.7 are overly complicated and ambiguous. I seek relief to simplify these rules to make them more user-friendly to those affected.
   5.1. The rules potentially capture farms that are too small
   5.2. The activity status of the rules encourages people to do nothing
6. Research and real-world case studies support the concept of collective groups, or Certified Industry Schemes. I would like to see the Plan strengthened so farms are actively encouraged to be part of these schemes.
   6.1. Collective groups can manage contaminants at the catchment/sub-catchment scale, meaning there is flexibility in contaminant discharge from individual farms (provided catchment objectives are being met). The flexibility helps overcome much of the fear and inequity that arises from 'Grandparenting' nutrient allocation rights to individual farms, while still meeting catchment objectives.
7. My experience has highlighted several issues using Overseer as a tool to manage nitrogen discharges from farming activities.
   7.1. Holding farmers to a number is ineffective at driving behavioural change that will lead to long-term water quality improvement.
   7.2. Some farming systems are not able to be modelled with sufficient robustness for compliance purposes;
   7.3. Overseer cannot be used to trend N reductions over time;
   7.4. There is insufficient capability within the industry to prepare nutrient budgets to a level of detail sufficient for compliance purposes.
8. I propose a greater emphasis is given to Good Management Practices as a means to improve water quality than to the Nitrogen Reference Point as proposed in PC1 by:
   8.1. promoting collectives and Industry schemes;
   8.2. recognising and adopting the Industry-agreed Good Management Practices relating to water quality (Sept 2015) (Appendix 1);
   8.3. using Overseer where it is most useful - as a decision-making tool, not a compliance tool;
   8.4. holding farming activities to a base/reference land use description

DRIVING ON-FARM BEHAVIOUR CHANGE

9. I have read through the technical documents supporting PC1 and the key groups that technical reports were filed under were:
   9.1. Groundwater;
   9.2. Matauranga Maori and integrated assessment;
   9.3. Nitrogen, phosphorus and chlorophyll;
   9.4. Scenario modelling; and,
   9.5. Surface water.
10. I noted – due to their absence – the series of documents that focussed on examples of successful behavioural change programmes, and the legal framework needed to support those programmes. Such research has been carried out in New Zealand and overseas yet was missing from the technical documents supporting PC1.
11. In my opinion, PC1 fails to address the human factor when asking farmers to change their practices. Farmers are people, and measures focussed on people, not just in-stream targets, need to be adopted if water quality is to be improved.
12. In my opinion, PC1 needs to be amended to encourage, if not require, farmers to join Certified Industry Schemes. Research shows that groups like Certified Industry Schemes are the most likely pathway to encourage long-term sustainable behavioural change, leading to improved water quality.
    12.1. Rules and regulations need to be simple and easily understandable for people to take them up. Local experience: About 75% of farmers in the Lake Taupo catchment had not made any on-farm practice change between 2005-2009 as they were uncertain of the compliance standards (Botha et al., 2013). Similarly, MacGregor (2006) found that bureaucratic complexity likely led to a general attitude of apathy amongst farmers toward regulations.
    12.2. The planning/consultation process in Canterbury recently has seen a shift away from controlling large numbers of farms to targeting higher-risk activities. In recent years, the Canterbury Land and Water Regional Plan (LWRP) has seen several changes to the scope of size of farm captured. Early versions of LWRP (e.g. Plan Change 1 – Selwyn) sought to capture all farms over 5 ha (similar to PC1). However, the recently operative LWRP only requires farms with >50 ha of irrigation or >10% of farm area in winter crop to seek resource consent to farm (Figure 1), with all other farms Permitted Activity (PA) (unless determined otherwise by a sub-regional plan).

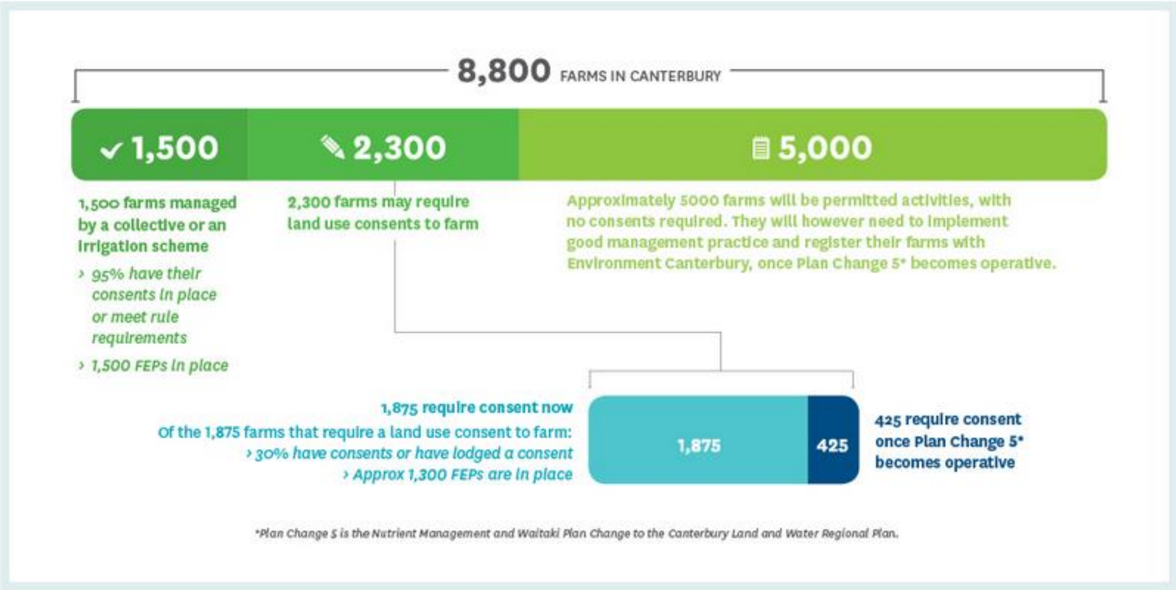

Figure 1: Breakdown of activity status of farms in Canterbury. https://ecan.govt.nz/reporting-back/farming-to-limits-freshwater-management/

12.3. The poor results from dairy effluent monitoring by WRC should serve as a warning as to what is likely to unfold under complicated PA rules for farming. In Canterbury, where I work, all dairy effluent discharges are consented and actively monitored by Canterbury Regional Council. In my view, active monitoring is more effective because 1) it is cost recoverable (helping keep rates down), and 2) non-compliance is more likely to be picked up earlier than if consents/PA were not actively monitored.

12.4. I have submitted that all farms below 40 ha should have PA status (for now), and all farms >40 ha should either require resource consent or be part of a Certified Industry Scheme. If deemed necessary, smaller farms can be included at a later date.

13. Harris (2017) (Appendix 2) found that farmer-led groups and collectives were the most effective vehicle to bring about long-term sustainable change, both in New Zealand and internationally. Harris' (2017) review of strategies for creating and implementing sustainable change programmes found that change processes take time, need the correct people delivering the message, require consistent messaging, and at their heart require quality science. Values must match actions.

14. My experience working with farmers who are part of collectives and working with individual farmers who are not associated with a larger collective group, supports Harris' (2017) assessment. The farmers within the collectives are overall far ahead of the independent Canterbury farmers on their journey towards Good Management Practice. The level of support offered to farmers by many of the collectives is a key component of their success.

14.1. As at 30th September 2018, all 1,500 (100%) farms belonging to collectives or schemes were on the path to improving water quality. However, less than 25% of farms outside collectives had obtained resource consent (Figure 2).

14.2. Further, 85% of FEP audits undertaken in Canterbury during 2017-18 were for farms that were part of collectives, despite these farms making up less than 40% of farms needing an audit (Figure 3).

14.3. Each interaction with a farmer is an opportunity to discuss farm practice and the link with water quality. The 1,500 Canterbury farms that are part of collective groups have had numerous interactions, whereas the independent's who do not yet have resource consent are unlikely to have had those discussions.

Figure 2: Success of Certified Industry Schemes demonstrated in Canterbury – Resource consent obtained. https://ecan.govt.nz/reporting-back/farming-to-limits-freshwater-management/

Figure 3: Success of Certified Industry Schemes demonstrated in Canterbury – FEP Audits.. https://ecan.govt.nz/reporting-back/farming-to-limits-freshwater-management/

14.4. The Motueka Integrated Catchment Management Project, led by Landcare Research, is another example of a successful industry-led approach to improving water quality in New Zealand. It should be noted that the Motueka programme was voluntary – yet was still able to deliver desired outcomes. I have included a summary of the Motueka programme by Andrew Fenemor of Landcare Research as Appendix 3 of this document (Fenemor (2013) - *A Summary of Outcomes and selected formal publications from the Integrated Catchment Management (ICM) research programme: 2000 – 2011*).

15. Building trust and community is critical to achieving long-term sustainable change. Harris (2017) found that "*Farmers frequently look to a trusted leader in their rural community when looking to implement changes in their farming practices. The trusted leaders are typically seen as "good farmers", and being a "good farmer" helps form a sense of self identity and pride within the community (Stock and Forney 2014). Where a trusted group of peers supports a particular behaviour change, and that behaviour becomes normalised, peer pressure from the group will increase the chance that the individual farmer will be more likely to implement that change in order to maintain their "good farmer" status (Blackstock, Ingram et al. 2010, McGuire, Morton et al. 2013)." "Often, each of these aspects are closely linked to their own personal idea of what is a "Good Farmer", which is inherently linked to their self-identity (Burton et al., 2008, Burton and Paragahawewa, 2011, McGuire et al., 2013). By requesting a change in behaviour, we are challenging their sense of self and belief that they are a "Good Farmer"."*
16. The provision of Certified Industry Schemes in PC1 enables collective industry-led groups to exist and take responsibility for improving farm practice. However, these schemes need to be given sufficient time to build social capital and take effect within the communities they are operating in. Mills et al. (2008) suggests successful change programmes should allow up to **10 years** to build and foster relationships. These long timeframes sit nicely with the long-term (80 year) approach to improving water quality that features in PC1, and these timelines need to be remembered when setting timeframes for PC1.
17. Focussing on good management practices (such as those published in the Industry Agreed Good Management Practices relating to water quality (2015) booklet (Appendix 1)), is more effective than focussing on a number. The collective groups are a key component of keeping the focus on the practices (Harris, 2017 (Appendix 2)).
18. In my opinion, farmers should be encouraged (or even compelled) to be part of collective groups that will help them change their practices. I strongly support the Permitted Activity status of being part of these groups that has been proposed in PC1 (Rule 3.11.5.3), and I would like to see a disincentive for not being part of these groups. I have asked for resource consent to farm outside of these groups to be a Discretionary Activity, because the support provided by the group is what will bring about change. Independent farmers who are not part of these groups will have to pay consultants by the hour to receive the same advice and support, and consequently they are less likely to seek out such advice and won't receive the support.

PROBLEMS WITH OVERSEER

19. In theory, Overseer creates certainty by giving a farm a 'reference point' to operate to. But in practice, Overseer outputs vary widely, from farm to farm, and from year to year. The variations in outputs are not trivial – they can mean the difference between one farm being compliant with resource consent conditions one day, and a prohibited activity the next.
20. Some reasons for the varying outputs (with my anecdotes) include:

20.1. Overseer version changes (updates)

20.1.1. Each update to Overseer can bring a substantial change to calculated nitrogen losses, reducing certainty in the number produced, and reducing farmers' confidence in the model that has such a large impact on their farming activities.

20.1.2. Proposed changes to Overseer (the new FM version) will see monthly rolling updates (as opposed to the 6-monthly updates in the current (legacy) version). These continual changes can make it impossible for some farmers to plan and comply with nitrogen loss requirements when the goalposts keep shifting.

20.1.3. In response to the update of Overseer from v6.2.3 to v6.3.0, I recently updated a 'baseline' file (Canterbury's equivalent of the nitrogen reference point) for a client which resulted in an increase in calculated nitrogen loss of 50%. No changes were made to the farming system or inputs from the original file – the 50% increase was solely due to the way in which the Overseer models accounted for nitrogen in crops.

20.1.4. An example – The release note accompanying Overseer v6.3.1 will see changes to fodder crop leaching losses on light soil. Some farmers will have made changes to their farming systems based on previous Overseer versions, but may now be a prohibited activity due to latest version change (Appendix 4).

20.2. Inability to model some systems and workarounds required

20.2.1. Some crops and farming practices are not modelled in Overseer. In these situations, workarounds, or proxies must be used to model the farm. Once these proxies have been introduced, the Overseer file no longer represents that farm, and the outputs are questionable. I have found the majority of arable farming systems and a significant proportion of dairy support properties require workarounds in Overseer. One irrigation scheme I worked with found that 85% of their arable and 50% of dairy support farms needed the Overseer inputs to be modified in some way (a 'workaround') to produce a viable nutrient budget for compliance.

20.3. Differences in user input style

20.3.1. As part of a FEP audit, I needed to review Overseer files for a farm. This farm unwittingly had two Overseer nutrient budgets produced for the same year by two different consultants. The consultants were considered some of the most experienced Overseer users in Canterbury, and despite being given exactly the same information, the two Overseer files had nitrogen losses of 46 and 52 kg N/ha/yr – a difference of 12% due solely to user input style.

20.3.2. The Overseer Best Practice Data Input Standards (BPDIS) have been touted as the method to standardise model inputs, yet in the example above, both consultants followed the BPDIS. Overseer is a complex model with hundreds, if not thousands of potential inputs, meaning variation between users in inevitable.

20.3.3. Such variability is acknowledged by those who work on Overseer. David Wheeler, lead developer of Overseer with AgResearch, has provided evidence to the Board of Enquiry considering the Tukituki catchment that he agrees that Overseer has a prediction error for pastoral farming of about 25-30% (Appendix 5). Pastoral systems are better supported in Overseer than arable or horticultural systems, so I imagine the margin for error for arable, horticultural, and vegetable farms are considerably greater than 25-30%.

21. Freeman et al. (2016) identified a host of difficulties when using Overseer in regulation (Appendix 6), yet these issues, such as model updates and version changes, have not been addressed in PC1.

22. Further, a report released by the Parliamentary Commissioner for the Environment (December 2018) (Appendix 7) reiterated the work of Freeman (2016) and cautioned that

"*…regional councils should take particular care to ensure plans are written in a way that can accommodate changes without disruption to farmers.*"

23. I do not believe Overseer is fit to be used in the manner that has been proposed in PC1, particularly when Policy 3 d of PC1 calls for a 10% decrease in diffuse discharges. Overseer is not capable of estimating a 10% reduction, and should not be used as the mechanism to estimate such a reduction.
24. The use of Overseer should not be written into Waikato Regional Plans until such time as: 1) the issues documented by Freeman (2016) and the Parliamentary Commissioner for the Environment (2018); 2) the methods to deal with prediction error described by the lead developer of the model (David Wheeler); and 3) anecdotes from people who use the model daily (such as myself), have been resolved. Overseer is not yet fit for the purpose asked of it in PC1.
25. The relief I have sought to deal with the immaturity of Overseer is to include a Base Land Use Description/Reference land Use Description, which puts a narrative around the farming activity at a key point in time. The narrative will describe key farm metrics, and maps. At the time of the FEP audit, the auditor will assess the farm against the Base Land Use Description/Reference land Use Description to determine if intensification (within thresholds) has happened. Only if intensification was deemed to have happened, would the farm need to produce an Overseer report. This is the manner in which Overseer is intended to be used – as a comparitive decision making tool. Collective groups in Canterbury (e.g. Mid Canterbury irrigation schemes) currently use a combination of land use description and scenario Overseer budgets to manage water quality outcomes. The system is working and has buy-in from the famers as they can focus their attention on actions needed to improve water quality without the stress of meeting an Overseer number.
26. Rule 3.11.5.2 (4) of PC1 requires all farms >20 ha to have a nitrogen reference point. If nitrogen is not the primary contaminant of concern in a catchment/sub-catchment (e.g. Figure 4), why require farmers to obtain a nitrogen reference point, and face the ongoing cost of maintaining compliance with that reference point? Research shows that farming to a number is not a sustainable mechanism to bring about behavioural change (e.g. Botha et al., 2013). Duncan (2014) suggests that farming to a number may in fact have the opposite effect to what is desired as there is a strong incentive to game the system to avoid change.

Figure 4: Confluence of the Waipa and Waikato Rivers.

27. It now costs $200 per year per farm to use the Overseer programme, as well as the professional service costs required to prepare nutrient budgets. In Canterbury, the average cost of preparing an Overseer nutrient budget is about $1,000 for a simple dairy farm and up to $4,000 for a complex arable farm. Even the lower end of the cost scale is

prohibitive for small and low intensity properties, where their farming operation is often un-economic.

27.1. Money spent by low-intensity hill country farmers preparing Overseer budgets to control nitrogen would be better spent on other mitigation measures such as controlling sediment loss (e.g. Figure 4).

28. In addition to the problems of using the outputs from Overseer, there are not enough suitably skilled people in the country to be able to serve the needs of every Regional Council. In Canterbury, there can be significant wait times (6-12+ months) for farmers wanting a nutrient budget prepared. The problem will only be exacerbated when Waikato need the same services as Canterbury. In my view, producing Overseer reports are a waste of human resources, and their experience better utilised for improving on-farm practices and discussing mitigation measures, preparing Farm Environment Plans, and auditing those plans.

MY COMMENTS ON THE PROPOSED RULES

29. My experience with regulations relating to farming comes from working with farmers trying to implement Canterbury's Land and Water Regional Plan (similar to PC1). I have seen first-hand the frustration and anguish faced by farmers who do not have certainty over the future of their farming operation.

30. In my opinion, it should be kept front of mind that Object 4 and Policy 5 of PC1 calls for a "*staged approach to change enables people and communities to undertake adaptive management to continue to provide for their social, economic and cultural wellbeing in the short term…*". To that end, it is not necessary to try and solve every problem at the early stages of the process. I would like to see (at this stage) attention directed to the areas that will have maximum impact (i.e. larger farms).

31. In general, the proposed rules for farming in PC1 (3.11.5.1 – 3.11.5.7) appear overly complicated and prescriptive and it is not clear what each rule is intended to manage. From my experience, the rules as written will likely be difficult to understand for the majority of land owners affected by these rules.

32. The proposed Permitted Activity (PA) status of farms in rules 3.11.5.1 & 3.11.5.2 puts the burden of monitoring those activities on the general ratepayer, whereas a resource consent would allow a cost recovery mechanism for monitoring those activities. The financial cost on the ratepayer of monitoring several thousand farms will be large.

33. The proposed Permitted Activity (PA) status of farms in rules 3.11.5.1 & 3.11.5.2 are too complicated and give too much grey area for farmers to not seek consent or be part of a Certified Industry Scheme.

34. **Rule 3.11.5.1** – Small 'farms' are much larger than 4.1 ha (4 ha is a lifestyle block), and low intensity farms have higher stocking rates than 6 stock units/ha.

34.1. Small pastoral farms are generally un-economic as standalone units. Because they are un-economic, they are generally low-intensity and probably of low risk to the environment. At some point, these small farms begin to be economic units, however, 4.1 ha, 8 ha, even 20 ha are generally un-economic as a primary means of income.

34.2. I have submitted 40 ha as the minimum size that farms (or 10 ha for commercial vegetable production) should be considered for environmental effect at this stage in the 80-year journey.

34.3. I have estimated that there are nearly 4,000 'farms' between 4.1 and 10 ha, but they make up only 3% of the farmed land area. Whereas there are about 5,000 farms >40 ha, and they make up about 87% of the farmed land area (Table 1, Appendix 8).

Therefore, the contribution from the small farms is minimal, and targeting farms >40 ha will capture nearly 90% of the farmed area in the Healthy Rivers catchment. In line with Objective 4 and Policy 5 of PC1, the minimal resourcing available in the industry to farmers should be directed at these larger farms.

Table 1: Estimated farm number and sizes and proportion of farmed area of Healthy Rivers catchment.

Est. Farm size (ha)	*Est. num. farms*	*% of farms (>4.1 ha)*	*Area (ha)*	*% of area >4.1 ha*
4.1-10	3,748	29%	23,306	3%
10-20	2,115	16%	30,955	4%
20-40	2,131	16%	60,643	7%
40+	5,031	39%	745,788	87%

34.4. In my experience, there would not be many farms >4.1 ha with no arable cropping that have having stocking rates lower than 6 stock units per hectare (rule 3.11.5.1), which means the majority that farms would fail the requirements of 3.11.5.1 and be assessed under 3.11.5.2.

35. **Rule 3.11.5.2 -** The way in which rule 3.11.5.2 (1-3) is written means that the vast majority of farms <20 ha will be considered PA unless otherwise challenged. I question the purpose of rule 3.11.5.2 (1-3) – where will the resourcing come from to check the 6,000 odd farms that fit into this category? What will be the environmental benefit to the community for the large monitoring cost? I have submitted that all farms <40 ha (or <10 commercial vegetable production) be PA at this stage of the 80-year water quality improvement programme (as per Objective 4 and Policy 5: Staged Approach).

35.1. Rule 3.11.5.2 (4c) requires that "*No part of the property or enterprise over 15 degrees slope is cultivated or grazed…*". The vast majority of extensive, low intensity, low impact farms (e.g. sheep & beef) will have some component of grazed slope >15 degrees, and will therefore fail Rule 3.11.5.2 (4c).

35.2. Rule 3.11.5.2 (5) is not necessary and should be deleted. What is WRC going to do with this information? Who will monitor those that do not supply this information to WRC? The ratepayer should not foot the bill for monitoring tens of thousands of farms if the information is not going to be used. What will be the environmental benefit from the cost of collecting this information? Farms <40 ha make up more than 60% of the number of farms, but cover only 13% of the farmed area (Table 1). There will be little environmental benefit to collecting information for small farms < 40 ha, but there will be considerable cost to the community when considering to cumulative time and hassle spent by land owners supplying the information.

36. **Rule 3.11.5.3** – I agree with and support the intent of Rule 3.11.5.3, but it is overly prescriptive.

36.1. Once each Industry Scheme becomes Certified, there will be no need for the list of conditions in Rule 3.11.5.3, because the relevant conditions will have been met when the industry Scheme was Certified.

36.2. The Certified Industry Schemes are not restricted to large groups (e.g. Fonterra) and can be set up in individual catchments. The Motueka Integrated Catchment Management programme shows that cross-sector buy-in can be achieved by collective groups when set up correctly.

36.3. In my experience, the nitrogen reference point will not serve a useful purpose (see previous commentary), and any reference to it should be removed.

36.4. The Certified Industry Schemes need to be flexible and able to adapt to the catchment(s) or groups(s) they represent. There should be a science-based approach to targeting the contaminants of concern in each catchment, therefore the needs for each catchment will be different and unable to be prescribed in Rule 3.11.5.3.

36.5. The large irrigation schemes in Canterbury have been operating audited self-management programmes for a few years now. It would be worthwhile for WRC to talk to Senior Canterbury Regional Council **implementation** staff (not planners) to find out what works and what doesn't. The less prescriptive the collective rules, the more flexible the schemes and the Council can be in adapting to the needs of each catchment. Comprehensive Environmental Management Strategies are prepared in collaboration between the collective and the Canterbury Regional Council to ensure progress towards catchment targets is made. Annual reporting and independent audits of the collectives' Environmental Management Strategies are also used build transparency.

36.6. Catchment or sub-catchment collectives allow catchment objectives to be met while providing flexibility to farmers within the scheme. For example, if 6 dairy farms reduced nitrogen discharges, it may allow one sheep and beef farm higher in the catchment to increase stocking rate slightly to help pay for measures that mitigate sediment loss on the farm. Overall, the catchment objectives can be met while helping ease the tension that has been raised through Grandparenting rules such as nitrogen reference points.

36.6.1. The larger collective groups in Canterbury operate in such a manner. There are 1,500 farms operating under such rules in Canterbury (Figure 1), and the support these collectives provide mean that farmers within the collectives are much further down the path toward improving farm practice (Figure 2, Figure 3).

37. **Rule 3.11.5.4** – In a similar manner to my comments for Rules 3.11.5.1 & 3.11.5.2, Rule 3.11.5.4 appears to add unnecessary complexity and uncertainty with a range of dates.

37.1. The dates will not be able to be complied with (e.g. 1 January 2020) because the plan will not be operative by then. Any dates written into Plans should be extended to a suitable number of months (12? 24?) after the plan is made operative.

37.2. In Canterbury, the rolling changes made to the Land and Water Regional Plan in recent years have meant that one farmer can have different consent conditions imposed upon them compared to their neighbour. For consistency in land use consents across the catchment, long-term consents should not be issued until the entire Plan has been through the legal and consultative process and is fully operative.

37.3. Overseer is not (yet) suitable for tracking long-term nitrogen losses from farms and the reference to the 75th percentile (Matters of control iv.) should be removed (see previous comments).

38. **Rule 3.11.5.5** – I have submitted that this rule be deleted in its entirety. The matters that this rule seeks to address can be accommodated in other rules for general farming activities.

38.1. With a growing population, and being on the doorstep to Auckland, setting a cap on the amount of land that can be used for commercial vegetable growing neglects the needs of a growing population.

38.2. Restricting vegetable growing area seems at odds with the purpose of the RMA – to provide for the social, cultural, economic, and environmental needs of the country.

38.3. The potential income of Waikato farmers will be restricted if vegetable growing area is restricted. Has this lost opportunity cost been factored into the section 32 analysis?

38.4. Restricting the area where vegetables can be grown will drive up prices as demand increases. Has the social, cultural, and economic impact of increased food prices to the consumer been considered in the section 32 analysis? The effects of limiting the food growing potential of the Waikato will have Nationwide effects – has this been considered?

38.5. Restricting vegetable growing area fails to provide for new mitigation technologies that may appear in the future, which could allow vegetable production area to increase without further adverse environmental effects.

39. **Rule 3.11.5.6** – I have submitted that I support Rule 3.11.5.6.

39.1. I think Rule 3.11.5.6 is clearly written and I support the intent. However, I would like to seek clarification/relief that the activity status be increased from Restricted Discretionary to Discretionary in an effort to encourage people to join Certified Industry Schemes. I would like to see every farm as part of a collective Certified Industry Scheme, and there needs to be an incentive for staying in the scheme.

39.2. I would also like to seek clarification/relief that I do not support the nitrogen reference point (Schedule B) and in my submission I seek to replace the Nitrogen Reference Point with a Base Land Use Description/Reference Land Use Description.

39.3. I have discussed previously how the minimum area of farms needs to be increased at this stage of the 80-year journey. I have sought relief to increase the permitted activity status of all farms <40 ha and all commercial vegetable operations <10 ha.

40. **Rule 3.11.5.7** – In my opinion, land use change should be allowed to occur if the environmental effects of the change are managed (here is the appropriate time to use Overseer – when comparing current farming practice to a scenario). The non-complying activity status is too harsh and should be reduced to Discretionary status.

SCHEDULES

41. Schedule A

41.1. Who is going to monitor Schedule A? It is overly prescriptive given ‘farms’ >2ha make up about 1% of the farmed area in the Healthy Rivers catchment What benefit will there be to the Waikato community from collecting all this information? What will be the cost to land owners in providing this information to WRC?

41.2. I estimate there are nearly 4,000 ‘farms’ between 2 and 4.1 ha, yet they only make up 1% of the ‘farmed’ area (Appendix 8). In contrast, there are about 5,000 farms >40 ha which make up nearly 90% of the farmed area. It is not necessary to collect data from small lifestyle blocks at this stage of the 80-year water quality improvement programme.

42. The specified timelines throughout PC1 need to be revised to a time after the plan is made operative. The timelines will not be able to be complied with, e.g. Schedule A – “*Registration must occur between 1 September 2018 and 31 March 2019”.* These dates will have passed before hearings have finished. The dates should be a sensible time after the plan is made operative so that people are able to comply. The proposed timelines are out of step with the 80-year timeframe to improve water quality (Objective 4 & Policy 5: Staged approach).

43. Schedule B

43.1. A good farmer will have accurate animal weights. Livestock traders know what weight they buy livestock at, and what weight they sell livestock at. Actual animal weights should be used whenever possible. Animal weight or growth impacts on the amount of feed Overseer calculates is needed, which can have substantial impacts on modelled nitrogen losses, especially on crops.

43.2. The reasoning in Schedule B for using soil order instead of S-Map sibling is flawed and a huge step backward. If S-Map sibling data is available, it should be used whenever possible. Incorporating S-Map sibling data into Canterbury Overseer files made a huge difference to the nitrogen loss estimates from most farms. Light soils are (generally) at risk of leaching, and heavy soils (generally) are at risk of runoff. These factors need to be considered in farm environment plans and Overseer files (if necessary). If better information exists (i.e. S-Map) then that should be used whenever possible. A better approach would be for WRC to fast track the expansion of S-Map to the entire catchment.

44. Schedule C

44.1. Exclusion of stock from water bodies should be carried out in accordance with the risk-based assessment made during the FEP process. Some farms simply will not be able to comply with the timelines in Schedule C, and these timelines directly contradict Objective 4 and Policy 5 where a staged approach over an 80-year timeframe is called for. All timeframes in Schedule C should be removed and be replaced with a narrative to provide for a long-term staged approach to stock exclusion, using the Farm Environment Plan and Audit process to determine the highest risk areas on each farm. The most sensitive water bodies should be targeted first.

45. **RELIEF SOUGHT** – amend rules to the effect of that set out below (please note that the relief sought here differs from my original submission, however the intent is the same):

~~3.11.5 Rules/Ngā Ture~~

~~3.11.5.1 Permitted Activity Rule – Small and Low Intensity farming activities/Te Ture mō ngā~~
~~Mahi e Whakaaetia ana – Ngā mahi iti, ngā mahi pāiti hoki i runga pāmu~~

~~Rule 3.11.5.1 - Permitted Activity Rule – Small and Low Intensity farming activities The use of land for farming activities (excluding commercial vegetable production) and the associated diffuse discharge of nitrogen, phosphorus, sediment and microbial pathogens onto or into land in circumstances which may result in those contaminants entering water is a permitted activity subject to the following conditions:~~

~~1. The property is registered with the Waikato Regional Council in conformance with Schedule A; and~~

~~2. Cattle, horses, deer and pigs are excluded from water bodies in conformance with Schedule C; and~~

~~Either:~~

~~3. The property area is less than or equal to 4.1 hectares; and~~

~~4. The farming activities do not form part of an enterprise being undertaken on more than one property; or~~

~~Where the property area is greater than 4.1 hectares:~~

~~5. For grazed land, the stocking rate of the land is less than 6 stock units per hectare; and~~

~~6. No arable cropping occurs; and~~

~~7. The farming activities do not form part of an enterprise being undertaken on more than one property~~

3.11.5.~~2~~ 1 Permitted Activity Rule – ~~Other~~ farming activities/Te Ture mō ngā Mahi e Whakaaetia ana – Ētehi atu mahi i runga pāmu

Rule 3.11.5.~~2~~ 1 - Permitted Activity Rule – ~~Other~~ farming activities

The use of land for farming activities ~~(excluding commercial vegetable production)~~ and the associated diffuse discharge of nitrogen, phosphorus, sediment and microbial pathogens onto or into land in circumstances which may result in those contaminants entering water where the property area is greater than ~~4.1~~ 10 hectares ~~or and has more than 6 stock units per hectare or is used for arable cropping~~ and is used for commercial vegetable growing, or where the property area is greater than ~~4~~40 hectares for all other farming activities~~,~~ is a permitted activity ~~subject to the following conditions:~~

~~1. The property is registered with the Waikato Regional Council in conformance with Schedule A; and~~

~~2. Cattle, horses, deer and pigs are excluded from water bodies in conformance with Schedule C and Conditions 3(e) and 4(e) of this Rule; and~~

~~3. Where the property area is less than or equal to 20 hectares:~~

~~a. The farming activities do not form part of an enterprise being undertaken on more than one property; and~~

~~b. Where the land is:~~

~~i. used for grazing livestock, the stocking rate of the land is no greater than the stocking rate of the land at 22 October 2016; or~~

~~ii. not used for grazing livestock, the land use has the same or lower diffuse discharges of nitrogen, phosphorus, sediment or microbial pathogens as the land use at 22 October 2016; and~~

~~c. Upon request, the landowner shall obtain and provide to the Council independent verification from a Certified Farm Environment Planner that the use of land is compliant with either b)(i) or b)(ii) above; and~~

~~d. Upon request from the Council, a description of the current land use activities shall be provided to the Council; and~~

~~e. Where the property or enterprise contains any of the water bodies listed in Schedule C, new fences installed after 22 October 2016 must be located to ensure cattle, horses, deer and pigs cannot be within three metres of the bed of the water body (excluding constructed wetlands and drains).~~

~~4. Where the property or enterprise area is greater than 20 hectares:~~

~~a. A Nitrogen Reference Point is produced for the property or enterprise in conformance with Schedule B; and~~

~~b. The diffuse discharge of nitrogen from the property or enterprise does not exceed either:~~

~~i. the Nitrogen Reference Point; or~~

~~ii. 15kg nitrogen/hectare/year;~~

~~whichever is the lesser, over the whole property or enterprise when assessed in accordance with Schedule B; and~~

~~c. No part of the property or enterprise over 15 degrees slope is cultivated or grazed; and~~

~~d. No winter forage crops are grazed in situ; and~~

~~e. Where the property or enterprise contains any of the water bodies listed in Schedule C:~~

~~i. There shall be no cultivation within 5 metres of the bed of the water body; and~~

~~ii. New fences installed after 22 October 2016 must be located to ensure cattle, horses, deer and pigs cannot be~~

~~within three metres of the bed of the water body (excluding constructed wetlands and drains); and~~
~~5. For all properties greater than 4.1 hectares, from 31 March 2019, in addition to the requirements of Schedule A, the following information must be provided to the Waikato Regional Council by 1 September each year:~~
~~a. Annual stock numbers; and~~
~~b. Annual fertiliser use; and~~
~~c. Annual brought in animal feed.~~

3.11.5~~.3~~ 2 Permitted Activity Rule – Farming activities with a Farm Environment Plan under a Certified Industry Scheme/Te Ture mō ngā Mahi e Whakaaetia ana – Ngā mahi i runga pāmu kua whai Mahere Taiao ā-Pāmu i raro i te Kaupapa ā-Ahumahi kua Whai Tohu

Rule 3.11.5.3 - Permitted Activity Rule – Farming activities with a Farm Environment Plan under a Certified Industry Scheme

~~Except as provided for in Rule 3.11.5.1 and Rule 3.11.5.2~~ the use of land for farming activities ~~(excluding commercial vegetable production)~~ where the land use is registered to a Certified Industry Scheme, and the associated diffuse discharge of nitrogen, phosphorus, sediment and microbial pathogens onto or into land in circumstances which may result in those contaminants entering water is a permitted activity ~~subject to the following conditions:~~
~~1. The property is registered with the Waikato Regional Council in conformance with Schedule A; and~~
~~2. A Nitrogen Reference Point is produced for the property or enterprise in conformance with Schedule B; and~~
~~3. Cattle, horses, deer and pigs are excluded from water bodies in conformance with Schedule C; and~~
~~4. The Certified Industry Scheme meets the criteria set out in Schedule 2 and has been approved by the Chief Executive Officer of Waikato Regional Council; and~~
~~5. A Farm Environment Plan which has been prepared in accordance with Schedule 1 and has been approved by a Certified Farm Environment Planner, is provided to the Waikato Regional Council as follows:~~
~~a. By 1 July 2020 for properties or enterprises within Priority 1 sub-catchments listed in Table 3.11-2, and properties or enterprises with a Nitrogen Reference Point greater than the 75th percentile nitrogen leaching value;~~
~~b. By 1 July 2023 for properties or enterprises within Priority 2 sub-catchments listed in Table 3.11-2;~~
~~c. By 1 July 2026 for properties or enterprises within Priority 3 sub-catchments listed in Table 3.11-2; and~~
~~6. The use of land shall be undertaken in accordance with the actions and timeframes specified in the Farm Environment Plan; and~~
~~7. The Farm Environment Plan provided under Condition 5 may be amended in accordance with the procedure set out in Schedule 1 and the use of land shall thereafter be undertaken in accordance with the amended plan; and~~
~~8. A copy of the Farm Environment Plan amended in accordance with condition (7) shall be provided to the Waikato Regional Council within 30 working days of the date of its amendment.~~

~~3.11.5.4 Controlled Activity Rule – Farming activities with a Farm Environment Plan not under~~
~~a Certified Industry Scheme/Te Ture mō ngā Mahi ka āta Whakahaerehia – Ngā mahi i runga~~
~~pāmu kua whai Mahere Taiao ā-Pāmu kāore i raro i te Kaupapa ā-Ahumahi kua Whai Tohu~~

~~Rule 3.11.5.4 - Controlled Activity Rule – Farming activities with a Farm Environment Plan not under a Certified Industry~~
~~Scheme~~
~~Except as provided for in Rule 3.11.5.1 and Rule 3.11.5.2 the use of land for farming activities (excluding commercial vegetable production) where that land use is not registered to a Certified Industry Scheme, and the associated diffuse discharge of~~
~~nitrogen, phosphorus, sediment and microbial pathogens onto or into land in circumstances which may result in those contaminants entering water is a permitted activity until:~~
~~1. 1 January 2020 for properties or enterprises in Priority 1 sub-catchments listed in Table 3.11-2, and properties or enterprises with a Nitrogen Reference Point greater than the 75th percentile nitrogen leaching value;~~
~~2. 1 January 2023 for properties or enterprises in Priority 2 sub-catchments listed in Table 3.11-2;~~
~~3. 1 January 2026 for properties or enterprises in Priority 3 sub-catchments listed in Table 3.11-2;~~
~~Subject to the following conditions:~~
~~4. The property is registered with the Waikato Regional Council in conformance with Schedule A; and~~
~~5. A Nitrogen Reference Point is produced for the property or enterprise in conformance with Schedule B; and~~
~~After the dates set out in 1), 2) and 3) above the use of land shall be a controlled activity (requiring resource consent), subject to the following standards and terms:~~
~~a. A Farm Environment Plan has been prepared in conformance with Schedule 1 and has been approved by a Certified Farm Environment Planner, and is provided to the Waikato Regional Council at the time the resource consent application is lodged by the dates specified in I-III below; and~~
~~b. The property is registered with the Waikato Regional Council in conformance with Schedule A; and~~
~~c. A Nitrogen Reference Point is produced for the property or enterprise in conformance with Schedule B and is~~
~~provided to the Waikato Regional Council at the time the resource consent application is lodged; and~~
~~d. Cattle, horses, deer and pigs are excluded from water bodies in conformance with Schedule C.~~

~~Matters of Control~~
~~Waikato Regional Council reserves control over the following matters:~~
~~i. The content of the Farm Environment Plan.~~
~~ii. The actions and timeframes for undertaking mitigation actions that maintain or reduce the diffuse discharge of nitrogen,~~
~~phosphorus, sediment or microbial pathogens to water or to land where they may enter water.~~
~~iii. The actions, timeframes and other measures to ensure that the diffuse discharge of nitrogen from the property or enterprise, as measured by the five-year rolling average annual nitrogen loss as determined by the use of the current version of OVERSEER®, does not increase beyond the property or enterprise's Nitrogen Reference Point, unless other suitable mitigations are specified.~~

iv. Where the Nitrogen Reference Point exceeds the 75th percentile nitrogen leaching value, actions, timeframes and other measures to ensure the diffuse discharge of nitrogen is reduced so that it does not exceed the 75th percentile nitrogen leaching value by 1 July 2026.
v. The term of the resource consent.
vi. The monitoring, record keeping, reporting and information provision requirements for the holder of the resource consent to demonstrate and/or monitor compliance with the Farm Environment Plan.
vii. The timeframe and circumstances under which the consent conditions may be reviewed or the Farm Environment Plan shall be amended.
viii. Procedures for reviewing, amending and re-approving the Farm Environment Plan.
Dates:
I. For Priority 1 sub-catchments, and properties with a Nitrogen Reference Point of greater than 75th percentile nitrogen
leaching value, by 1 July 2020
II. For Priority 2 sub-catchments, by 1 July 2023
III.For Priority 3 sub-catchments, by 1 July 2026
Notification:
Consent applications will be considered without notification, and without the need to obtain written approval of affected
persons.

3.11.5.5 Controlled Activity Rule – Existing commercial vegetable production/Te Ture mō ngā Mahi ka āta Whakahaerehia – Te whakatupu hua whenua ā-arumoni o te wā nei

Rule 3.11.5.5 - Controlled Activity Rule – Existing commercial vegetable production
The use of land for commercial vegetable production and the associated diffuse discharge of nitrogen, phosphorus, sediment and microbial pathogens onto or into land in circumstances which may result in those contaminants entering water, is a permitted activity until 1 January 2020, from which date it shall be a controlled activity (requiring resource consent) subject to the following standards and terms:
a. The property is registered with the Waikato Regional Council in conformance with Schedule A; and
b. A Nitrogen Reference Point is produced for the property or enterprise in conformance with Schedule B and provided to the Waikato Regional Council at the time the resource consent application is lodged; and
c. Cattle, horses, deer and pigs are excluded from water bodies in conformance with Schedule C; and
d. The land use is registered to a Certified Industry Scheme; and
e. The areas of land, and their locations broken down by sub-catchments [refer to Table 3.11-2], that were used for commercial vegetable production within the property or enterprise each year in the period 1 July 2006 to 30 June 2016,
together with the maximum area of land used for commercial vegetable production within that period, shall be provided to the Council; and
f. The total area of land for which consent is sought for commercial vegetable production must not exceed the maximum land area of the property or enterprise that was used for commercial vegetable production during the period 1 July 2006 to 30 June 2016; and
g. Where new land is proposed to be used for commercial vegetable production, an equivalent area of land must be removed from commercial vegetable production in order to comply with standard and term f.; and
h. A Farm Environment Plan for the property or enterprise prepared in conformance with Schedule 1 and approved by a Certified Farm Environment Planner is provided to the Waikato Regional Council at the time the resource consent application is lodged.
Matters of Control
Waikato Regional Council reserves control over the following matters:

~~i. The content of the Farm Environment Plan.~~
~~ii. The maximum area of land to be used for commercial vegetable production.~~
~~iii. The actions and timeframes for undertaking mitigation actions that maintain or reduce the diffuse discharge of nitrogen, phosphorus or sediment to water or to land where those contaminants may enter water, including provisions to manage the effects of land being retired from commercial vegetable production and provisions to achieve Policy 3(d).~~
~~iv. The actions and timeframes to ensure that the diffuse discharge of nitrogen does not increase beyond the Nitrogen Reference Point for the property or enterprise.~~
~~v. The term of the resource consent.~~
~~vi. The monitoring, record keeping, reporting and information provision requirements for the holder of the resource consent to demonstrate and/or monitor compliance with the Farm Environment Plan.~~
~~vii.The time frame and circumstances under which the consent conditions may be reviewed.~~
~~viii.Procedures for reviewing, amending and re-certifying the Farm Environment Plan.~~
~~Notification:~~
~~Consent applications will be considered without notification, and without the need to obtain written approval of affected persons.~~
~~Advisory note: Under section 20A(2) of the RMA a consent must be applied for within 6 months of 1 January 2020, namely by 1 July 2020.~~

3.11.5.~~6~~ 3 ~~Restricted~~ Discretionary Activity Rule – The use of land for farming activities/Te Ture mō ngā kōwhiringa mahi e herea ana – te whakamahinga o te whenua mō ngā mahinga pāmu

Rule 3.11.5.~~6~~ 3- ~~Restricted~~ Discretionary Activity Rule – The use of land for farming activities
The use of land for farming activities that does not comply with the conditions, standard or terms of Rules 3.11.5.1 to 3.11.5.~~5~~ 2 and the associated diffuse discharge of nitrogen, phosphorus, sediment and microbial pathogens onto or into land in circumstances which may result in those contaminants entering water is a ~~restricted~~ discretionary activity (requiring resource consent).
~~Waikato Regional Council restricts its discretion over the following matters:~~
~~i. Cumulative effects on water quality of the catchment of the Waikato and Waipa Rivers.~~
~~ii. The diffuse discharge of nitrogen, phosphorus, sediment and microbial pathogens.~~
~~iii. The need for and the content of a Farm Environment Plan.~~
~~iv. The term of the resource consent.~~
~~v. The monitoring, record keeping, reporting and information provision requirements for the holder of the resource consent.~~
~~vi. The time frame and circumstances under which the consent conditions may be reviewed.~~
~~vii.The matters addressed by Schedules A, B and C.~~
~~Notification:~~
~~Consent applications will be considered without notification, and without the need to obtain written approval of affected persons.~~

3.11.5.~~7~~ 4 ~~Non-Complying~~ Discretionary Activity Rule – Land Use Change/Te Ture mō ngā mahi kāore e whai i ngā ture – Te Panonitanga ā-Whakamahinga Whenua

Rule 3.11.5.~~7~~ 4 - ~~Non-Complying~~ Discretionary Activity Rule – Land Use Change
Notwithstanding any other rule in this Plan, any of the following changes in the use of land from that which was occurring at 22 October 2016 within a property or enterprise located in the Waikato and Waipa catchments, where prior to 1 July 2026 the change exceeds a total of 4.1 hectares:

1. Woody vegetation to farming activities; or
2. Any livestock grazing other than dairy farming to dairy farming; or
3. Arable cropping to dairy farming; or
4. Any increase in the area of land used for ~~land use to~~ commercial vegetable production ~~except as provided for under standard and term g. of Rule 3.11.5.5~~

is a ~~non-complying~~ discretionary activity (requiring resource consent) ~~until 1 July 2026.~~

Notification:

Consent applications will be considered without notification, and without the need to obtain written approval of affected persons, subject to the Council being satisfied that the loss of contaminants from the proposed land use will be lower than that from the existing land use.

46. **RELIEF SOUGHT** – Schedules

46.1. Schedule A

Schedule A - Registration with Waikato Regional Council/Te Āpitihanga A – Te rēhita me te Kaunihera ā-Rohe o Waikato

Unless part of a Certified Industry Scheme, Properties with an area greater than ~~2~~ 10 hectares used for commercial vegetable growing, or more than 40 hectares for all other farming activities ~~(excluding urban properties)~~ must be registered with the Waikato Regional Council in the following manner:

1. Registration must occur within 2 years of this plan being made operative ~~between 1 September 2018 and 31 March 2019~~.
2. Registration information set out in clause 5, and where relevant in clause 6, below must be provided.
3. Proof of registration must be provided to the Waikato Regional Council if requested by the Council.
4. Registration information must be updated by the new owner of a property within ~~30 working days~~ one year of the new owner taking possession of the property, or otherwise at the request of the Waikato Regional Council.
5. All property owners must provide:

a. The following information in respect of the land owner, and the person responsible for using the land (if different from the land owner):

i. Full name.

ii. Trading name (if applicable, where the owner is a company or other entity).

iii. Full postal and email address.

iv. Telephone contact details.

b. Legal description of the property as per the certificate(s) of title.

c. Physical address of the property.

d. A description of the land use activity or activities undertaken on the property as at 22 October 2016, ~~including the land area of each activity.~~

e. The total land area of the property.

f. Where the land is used for grazing, the stocking rate of animals grazed on the land.

6. Properties that graze livestock must also provide a map showing:

a. The location of:

i. Property boundaries; and

ii. Water bodies listed in Schedule C for stock exclusion within the property boundary and fences adjacent to those water bodies; and

iii. Livestock crossing points over those water bodies and a description of any livestock crossing structures.

46.2. Schedule B

46.2.1. Delete Schedule B as proposed

46.2.2. Insert Base/Reference land use description

Where the farming activity or farming enterprise is not being managed under Certified Industry Scheme, the base/reference land use description is the land use within the baseline/reference period, and shall include a description of the

(a) Area of property;

(b) Farm system description;

(c) Area and method(s) of irrigation (if any);

(d) Area and timing of winter grazing;

(e) Stock type and Relative stock units per hectare; and

(f) Average nitrogen fertiliser inputs (kg N/ha)

46.3. Schedule C

Schedule C - Stock exclusion/Te Āpitihanga C – Te aukatinga o ngā kararehe

Except as provided by Exclusions I. and II., stock must be excluded from the water bodies listed in i. to iv. below as follows:

1. The water bodies must be fenced to exclude cattle, horses, deer and pigs, unless those animals are prevented from entering the bed of the water body by a stock proof natural barrier formed by topography or vegetation.

2. New fences installed after ~~22 October 2016~~ this plan is made operative must be located to ensure cattle, horses, deer and pigs cannot be within one metre of the bed of the water body (excluding constructed wetlands).

3. Livestock must not be permitted to enter onto or pass across the bed of the water body, except when using a livestock crossing structure.

4. For land use authorised under Rules 3.11.5.~~1~~ 3 or 3.11.5.~~2~~ 4, stock must be excluded from water bodies using the Farm Environment Plan and Audit process to determine the highest risk areas on each farm. The most sensitive water bodies should be targeted first. ~~clauses 1 and 2 must be complied with:~~

~~a. By 1 July 2023 for properties and enterprises within Priority 1 sub-catchments listed in Table 3.11-2.~~

~~b. By 1 July 2026 for properties and enterprises within Priority 2 and Priority 3 sub-catchments listed in Table 3.11-2.~~

~~5. For land use authorised under Rules 3.11.5.3, 3.11.5.4 or 3.11.5.5, clauses 1 and 2 must be complied with by the date and in the manner specified in the property's or enterprise's Farm Environment Plan, which shall be within 3 years following the dates by which a Farm Environment Plan must be provided to the Council, or in any case no later than 1 July 2026.~~

Water bodies from which cattle, horses, deer and pigs must be excluded:

i. Any river that continually contains surface water.

ii. Any drain that continually contains surface water.

iii. Any wetland, including a constructed wetland.

iv. Any lake.

Exclusions:

The following situations are excluded from clauses 1 and 2:

I. Where the entry onto or passing across the bed of the water body is by horses that are being ridden or led.

II. Where the entry onto or passing across the bed of the water body is by a feral animal.

47. REFERENCES

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47.7. Mills, J., et al. (2008). "Evaluation of key factors that lead to successful agri-environmental co-operative schemes." Countryside and Community Research Institute (CCRI), Final Report for Welsh Assembly Government.

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Appendix 1

Industry-agreed Good Management Practices relating to water quality (Sept 2015)

Industry-agreed Good Management Practices relating to water quality

18 September 2015

FAR

New Zealand PORK

DairyNZ

beef+lamb new zealand

Horticulture New Zealand

Deer Industry New Zealand

These industry-agreed good management practices relating to water quality were developed from the Canterbury Matrix of Good Management project and were first published in April 2015. While intended for use in Canterbury, they were developed to be applicable across all regions in New Zealand.

Foreword

The Matrix of Good Management (MGM) project aims to estimate the 'footprint' of nitrogen and phosphorus loss for the range of farm systems in Canterbury today, assuming that they are operating at good management practice (GMP). This means we need to be clear about what constitutes good management on farms.

Our approach to this been to ask the industry partners in the project - DairyNZ, Deer Industry New Zealand, NZPork, Beef + Lamb New Zealand, Horticulture NZ and the Foundation for Arable Research – to consult widely within their sectors to define GMP. Over the past 18 months, a great deal of hard work by a large number of farmers and growers has culminated in the definitions of GMP set out here.

It would not have been possible to achieve this milestone of industry-agreed, pan-sector GMP descriptions without the thoughtful contributions, willingness to listen, and sheer determination of many people from both the Canterbury and national farming community.

This sort of hands-on participation by all the project partners, and many of the farmers that they represent, typifies the 'co-production' of this important project.

As chair of the MGM project Governance Group, and on behalf of the Environment Canterbury Commissioners, I would like to thank all those involved in producing this milestone document.

Tom Lambie
Chair, MGM Governance Group

Version 2, 18 September 2015

Previous version: Version 1, 9 April 2015

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BACKGROUND

The Matrix of Good Management (MGM) project is a collaborative initiative between Environment Canterbury, Crown Research Institutes (AgResearch, Plant & Food Research and Landcare Research), primary sector organisations (DairyNZ, Deer Industry New Zealand, NZPork, Beef + Lamb New Zealand, Horticulture NZ and the Foundation for Arable Research) and is overseen by a cross-sectoral governance stakeholder group. The project aims to quantify the typical nutrient losses that are expected to occur from the range of farming systems, soils and climates across Canterbury when managed to good management practice (GMP). This information is important for two key reasons: to provide more reliable nutrient loss estimates that can be used for catchment modelling, and for regulatory purposes to indicate that all farmers are operating at GMP.

Although there is widespread support for the implementation of good management practices across primary industries, until now there have been no commonly agreed definitions of GMP, nor a good understanding of the nutrient losses that occur on farms operating at GMP. For any particular GMP there will be a range of estimated nutrient losses and these losses will vary with differing land uses and different soil types and climate zones.

The GMPs described here have been prepared following workshops with groups of farmers, rural professionals and industry representatives covering the six sectors involved in the MGM project. The resulting lists of GMPs were compared across industries, and a single set of cross-sector GMPs has been developed along with implementation guidance for these GMPs. Most of the guidance is also cross-sector but some is specific to particular industries.

These GMPs will be applicable to all farms in Canterbury by June 2017. They do not overrule any requirements of council consents, regional plans or land management agreements. As knowledge and technology advance over time, updates to these GMPs, and the associated implementation guidance, is likely to be necessary.

Further information

There are many useful, generic and sector-specific publications that expand on the GMP implementation guidance. Use of these documents is recommended. These include:

Generic

- The Fertiliser Association of New Zealand's Code of Practice for Nutrient Management
- Irrigation New Zealand's Irrigation Design and Installation Codes of Practice and Standards
- Irrigation New Zealand's Performance Test Guidelines

Dairy

- Sustainable Dairying: Water Accord
- DairyNZ FDE Guide to managing FDE and Guides to operating effluent irrigation system
- FDE Design Code of Practice

Sheep and Beef

- Beef + Lamb New Zealand website
- Land and Environment Plan (LEP)

Deer

- The New Zealand Deer Farmers Landcare Manual 2012
- 1999 Deer Industry Guidelines for the Winter Enclosure of Deer
- Deer Industry New Zealand endorses the use of Beef + Lamb New Zealand's Land and Environment Plan (LEP)

Horticulture

- Nutrient Management Code of Practice
- Erosion and Sediment Control Guidelines

Arable

- FAR Focus 6 (2012): Nutrient Management Plans

Outdoor Pigs

- EnviroPork (2005) Pork Industry Guide to Managing Environmental Effects

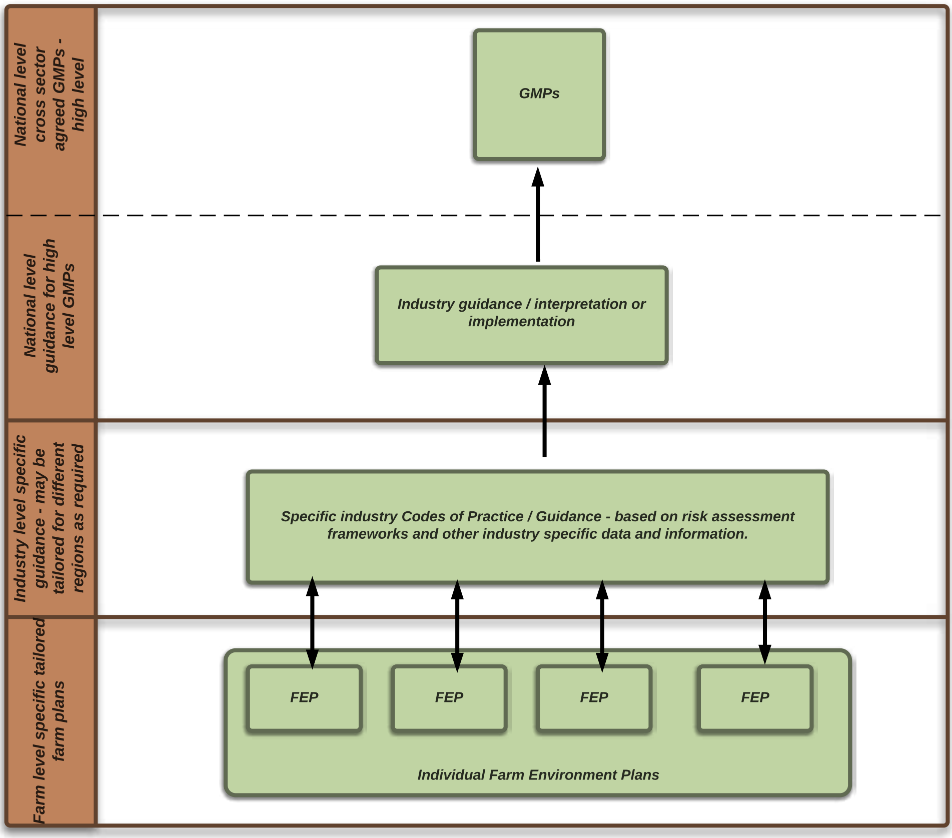
Underpinning concepts

- Understand the nutrient loss pathways on your property;
- Assess risks to water quality;
- Manage appropriately;
- Record actions;
- Review regularly.

Caveats

- This document includes some background information to provide context for the GMPs but it is not intended as a comprehensive report on the steps taken to develop these GMPs. Neither is it intended as a guide for farmers and growers.
- The Implementation Guidance set out here is not a requirement of GMPs, recognising that practices and actions relevant to a particular farm will be determined by risk assessment and intervention with the most appropriate action.
- These GMPs focus on water quality (notably nitrogen, phosphorus, sediment, and faecal contaminants) and may not fully take into account GMPs for other aspects of farm management (e.g. greenhouse gas reduction, health and safety, biosecurity, biodiversity and conservation of natural and cultural heritage).

The context of the Good Management Practices



Glossary of terms

These may be subject to further refinement as the Environment Canterbury Land and Water Regional Plan develops.

Buffer strips	Vegetated buffer strips are land strips adjoining waterways of critical source areas that are managed to maintain their vegetated state permanently; they are not cultivated and are grazed only to manage the vegetation. Width may vary according to level of mitigation required and topography.
Critical Source Area	Areas of enriched contaminant sources and hydrological activity that occur in small parts of a catchment or farm such as a gully, swale or depression, but that contribute a disproportionately large amount of contaminants to the environment.
Cultivation	The preparation of land for growing pasture or a crop and the planting, tending and harvesting of that pasture or crop, but excludes: • Direct drilling of seed; • No-tillage practices; • Re-contouring of land; • Forestry.
Intensive grazing	Intensive grazing is the grazing of stock on fodder crops or pasture, to the extent that the grazing results in significant de-vegetation. This is usually associated with break feeding behind temporary electric fencing.

Waterways, significant waterways, wetlands and significant wetlands

As defined by the relevant Regional Council or Unitary Authority.

SUMMARY LIST OF GOOD MANAGEMENT PRACTICES

WHOLE FARM

Farm planning and records

GMP: Identify the physical and biophysical characteristics of the farm system, assess the risk factors to water quality associated with the farm system, and manage appropriately.

GMP: Maintain accurate and auditable records of annual farm inputs, outputs and management practices.

LAND

Cultivation and Soil Structure

GMP: Manage farming operations to minimise direct and indirect losses of sediment and nutrients to water, and maintain or enhance soil structure, where agronomically appropriate.

Ground cover

GMP: Manage periods of exposed soil between crops/pasture to reduce risk of erosion, overland flow and leaching.

GMP: Retire all Land Use Capability Class 8 and either retire, or actively manage, all Class 7e to ensure intensive soil conservation measures and practices are in place.

Sediment, phosphorus and faecal bacteria

GMP: Identify risk of overland flow of sediment and faecal bacteria on the property and implement measures to minimise transport of these to water bodies.

GMP: Locate and manage farm tracks, gateways, water troughs, self-feeding areas, stock camps, wallows and other sources of run-off to minimise risks to water quality.

GMP: To the extent that is compatible with land form, stock class and intensity, exclude stock from waterways.

GMP: Monitor soil phosphorus levels and maintain them at or below the agronomic optimum for the farm system.

PLANTS

Nutrient management

GMP: Manage the amount and timing of fertiliser inputs, taking account of all sources of nutrients, to match plant requirements and minimise risk of losses.

GMP: Store and load fertiliser to minimise risk of spillage, leaching and loss into water bodies.

GMP: Ensure equipment for spreading fertilisers is well maintained and calibrated.

Irrigation and water use

GMP: Manage the amount and timing of irrigation inputs to meet plant demands and minimise risk of leaching and runoff.

GMP: Design, calibrate and operate irrigation systems to minimise the amount of water needed to meet production objectives.

ANIMALS

Feed

GMP: Store, transport and distribute feed to minimise wastage, leachate and soil damage.

Farm effluent and wastewater management

GMP: Ensure the effluent system meets industry specific Code of Practice or equivalent standard.

GMP: Have sufficient, suitable storage available to enable farm effluent and wastewater to be stored when soil conditions are unsuitable for application.

GMP: Ensure equipment for spreading effluent and other organic manures is well maintained and calibrated.

GMP: Apply effluent to pasture and crops at depths, rates and times to match plant requirements and minimise risk to water bodies.

Intensive grazing

GMP: Select appropriate paddocks for intensive grazing, recognising and mitigating possible nutrient and sediment loss from critical source areas.

GMP: Manage grazing to minimise losses from critical source areas.

GOOD MANAGEMENT PRACTICES AND INDUSTRY IMPLEMENTATION GUIDANCE

WHOLE FARM

Farm planning and records

Our intent: Ensure that significant environmental risks to water quality have been assessed, addressed and documented to demonstrate adherence to GMP.

GMP: Identify the physical and biophysical characteristics of the farm system, assess the risk factors to water quality associated with the farm system, and manage appropriately.

Implementation guidance:
Consider:

- Biophysical characteristics such as soil types, topography, and climate.
- Physical characteristics such as waterways, artificial drainage networks, irrigation.
- Risk factors such as soil loss, nutrient loss and damage to soil structure.
- Management or practices that are required by third parties to be recorded e.g. offal pits, feed storage, effluent storage and application area and irrigation area.
- **Outdoor pigs:** Farm in low rainfall area and on flat land to minimise runoff.

GMP: Maintain accurate and auditable records of annual farm inputs, outputs and management practices.

Implementation guidance:

Maintain accurate and auditable records that:

- set out objectives to be met;
- identify all relevant farming activities and practices, including those that demonstrate that relevant GMPs are being applied;
- demonstrate the assessment of all risks to water quality;
- identify how and when actions to mitigate risks will be undertaken;
- allow the generation of an annual actual OVERSEER® nutrient budget.

Utilise industry templates for recording key information – such as water use, fertiliser inputs, and spray diaries, planting dates, paddock rotation, feed inputs and composition, stock numbers and production outputs or yield.

Review the planned actions annually (e.g. carry out a self-audit).

- Farm Environment Plans (FEPs) may be used to assist with this GMP; FEPs include the industries' specific planning tools such as NZ Pork Farm Environment Plan, Sustainable Milk Plans, NZ GAP or Global GAP, Land and Environment Plans, ProductionWise.
- Some regional councils may have approved consistent templates to assist in preparing FEPs.
- Mixed systems may need to combine or adapt existing FEPs.

LAND

Cultivation and soil structure

Our intent: To minimise direct and indirect losses of sediment and nutrients to water without being prescriptive about cultivation or soil management techniques used, as there are many agronomic considerations to take into account on a paddock-by-paddock and season-by-season basis.

GMP: Manage farming operations to minimise direct and indirect losses of sediment and nutrients to water, and maintain or enhance soil structure, where agronomically appropriate.

Implementation guidance:
Consider:

- Distance from surface waterways, effectiveness of buffers
- Slope of land (degree and length) in relation to waterway
- Soil type and texture, quality (e.g. pugging, or compaction susceptibility)
- Climatic and weather conditions to determine timing of cultivation
- Cultivation methods (pre-, during, and post-cultivation; contour, no- or low-tillage)
- Measures to prevent sediment and nutrients entering waterways (e.g. sediment traps or interception drains, headlands or diversion bunds, grazing techniques)
- Measures to prevent soil loss through erosion, overland flow and wind blow (e.g. space planted trees, windbreaks, cover crops)
- Measures to prevent or remedy soil damage
- Previous use of land, and future use of land
- Using sub-soiling or ripping to remedy compaction of soils

Leave grassed areas around rocks, gullies and riparian margins. If spraying out pasture, first identify areas that won't be worked or re-sown e.g. gullies, runners, riparian margins and rocky areas.

In heavy soils, cultivate soil when conditions are dry enough to reduce compaction and pugging and improve drainage and soil structure.

Ground cover

Our intent: Reduce risk of erosion, overland flow and leaching associated with exposed soil.

GMP: Manage periods of exposed soil between crops/pasture to reduce risk of erosion, overland flow and leaching.

Implementation guidance:

- Consider soil conditions and crop rotation.
- Areas that are harvested, grazed or stock damaged (resulting in bare soil) are re-sown as soon as practical to minimise periods of exposed soil.
- Rest and re-sow erosion damaged areas.
- Use cover crops (green feed, oats, mustard, other biological activates) to reduce losses and nutrient use; this also increases organic matter.
- When developing paddocks, retain native vegetation such as tussock and shrub habitat in gullies, steep and higher country as this will regulate run off of water, help retain water quality, reduce soil movement and provide filter areas prior to water entering streams (a significant co-benefit is that it also provides cover for newborn stock).
- **Outdoor pigs:** Maintain groundcover in accordance with the following.
    - For dedicated outdoor units or those in a pastoral rotation the minimum ground cover is:
        - For dry sows: at least 40% cover on 75% of the land (less than 40% cover permissible on 25% of the land);
        - Each paddock to have on average more than 10% cover;
        - For lactating sows: at least 70% cover.
    - For outdoor units as part of an arable operation the minimum ground cover is:
        - For dry sows: 25% cover (100-0% over 2 years);
        - For lactating sows: at least 70%;
    - Reduce fallow during and immediately after the pig phase of the rotation e.g. by planting a catch crop.

GMP: Retire all Land Use Capability Class 8 and either retire, or actively manage, all Class 7e to ensure intensive soil conservation measures and practices are in place.

Sediment, phosphorus and faecal bacteria

Our intent: Minimise transport of sediment, phosphorous and faecal bacteria to water bodies.

GMP: Identify risk of overland flow of sediment and faecal bacteria on the property and implement measures to minimise transport of these to waterbodies.

Implementation guidance:

- Identify, record and manage risk to and from critical source areas such as wallows, bank erosion, pugging, trampling or slips on steep hillsides to minimise or eliminate sediment entering waterways.
- Where appropriate use methods to minimise or eliminate sediment entering waterways such as:
  - vegetated buffer strips/riparian planting adjusted in width for slope, hydrology, bank stability, land use and proximity to critical source areas;
  - sediment traps;
  - paddock contouring;
  - earth bunds;
  - raised headlands.
- **Deer** - Fence pacing considerations:
  - Maintain appropriate feeding levels to reduce stress and fence pacing.
  - Identify the best stock class to fit the soil types to minimise the risk of soil erosion, as identified in the Deer Farmers Landcare Manual.
  - Maintain pasture length in winter or wet periods, to prevent soil being washed off in heavy rain. In particularly vulnerable areas retain tussock cover or native vegetation to regulate water runoff and to reduce risk of soil loss particularly in gullies or along riparian margins.
  - If fence pacing is bad, fill in area and re-sow or plant with trees and if damage is extreme, re-fence to remove the problem area. If fence pacing continues, review fence placement as this can be a contributing factor.

GMP: Locate and manage farm tracks, gateways, water troughs, self-feeding areas, stock camps, wallows and other sources of run-off to minimise risks to water quality.

Implementation guidance:

- Locate and design laneways so that run-off is filtered by a vegetated strip. Design and manage laneways to minimise water ponding, excessive effluent build-up and erosion.
- In areas exposed to wind erosion, establish shelter belts with trees that will filter the wind and provide added shade and shelter.
- On tracks, allow for cut-offs and slumps that will take the run off away from streams.
- **Deer** - wallow considerations:
  - Identify natural springs and wallows prior to cultivating paddocks and pipe or drain into retired areas;
  - Provide a suitable area away from waterways for safe wallowing.

GMP: To the extent that is compatible with land form, stock class and intensity, exclude stock from waterways.

Implementation guidance:

- Plan and prioritise waterway areas (including wetlands) to fence, based on the vulnerability of the land, significance of the waterway and potential to impact on water quality off-farm.
- Exclusion of extensively farmed stock from waterways in hill and high country areas may not be practical but rather a mix of mitigations and practices can be used to minimise sediment and faecal bacteria losses from farms.
- Actively manage stock, stock density and stock classes adjacent to waterways to reduce risks to water where fencing is not practical.
- Exclude stock from significant waterways, drains and significant wetlands.
- Locate and manage crossing of waterways so it will not result in degradation of those waterways.
- Provide alternative stock-water sources away from waterways where possible.
- Provide shade and shelter away from waterways where appropriate.
- Place salt blocks and supplementary feed away from riparian margins.
- Leave an appropriate buffer depending on slope, to filter runoff, even if only temporarily during vulnerable periods.
- During high risk periods for erosion e.g. winter grazing, fawn weaning, actively manage stock to prevent slumping, pugging or erosion.

GMP: Monitor soil phosphorus levels and maintain them at or below the agronomic optimum for the farm system.

Implementation guidance:

- To determine the level of phosphorus fertiliser needed, conduct regular, on-going soil testing (Olsen P or an equivalent, recognised soil test) at the block scale to monitor trends, patterns and the impacts of nutrient management decisions.
- Leave an unfertilised strip as a buffer zone beside creeks, drains and storm water flood zones. Allow more distance as slopes become steeper.

PLANTS

Nutrient management

Our intent: Balancing the application of nutrients to match plant requirements and minimise risk of losses.

GMP: Manage the amount and timing of fertiliser inputs, taking account of all sources of nutrients, to match plant requirements and minimise risk of losses.

Implementation guidance:

- Manage nutrients supplied from all sources including the soil, brought in feed, previous grazing and crops and any organic sources applied.
- Regularly soil test to identify nutrient needs, particularly paddocks that are going into crop.
- Expert guidelines, for example using crop calculators, expert agronomic advice or codes of practice should be used where appropriate.
- Nitrogen and phosphorus fertiliser is applied strategically to meet agronomic requirements, and to avoid adverse environmental impacts (e.g. strategic use around Critical Source Areas). Detailed guidelines are provided in The Fertiliser Association of New Zealand's Code of Practice for Nutrient Management (with emphasis on fertiliser use).
- Nutrient budgets as a tool to manage nutrient loss can be helpful.
- Practices such as use of side dressings and split applications may be helpful to reduce the risk of leaching and ensure greater utilisation of nutrients by plants.
- **Dairy:** All farmers have and use a predictive nutrient budget (OVERSEER®) as the basis for managing nutrients on their farm (milking platform, and any support land). Predictive nutrient budgets and nutrient management plans are developed by Certified Nutrient Management Advisors, and updated when the farm system changes. The OVERSEER® data input standards are used to create OVERSEER® nutrient budgets.

The Dairy Industry's Audited Nitrogen Management System contains recording and reporting requirements for N fertiliser on dairy farms (including milking platform, and any contiguous support land).

- **Outdoor pigs:** No NPK fertilisers are to be applied to the outdoor pig unit.

GMP: Store and load fertiliser to minimise risk of spillage, leaching and loss into waterbodies.

Implementation guidance:

- Follow fertiliser industry code of practice for fertiliser handling, storage and use.
- Locate storage sites away from waterways.

GMP: Ensure equipment for spreading fertilisers is well maintained and calibrated.

Implementation guidance:

- Any contractors used for fertiliser spreading should be accredited. The current industry standard is Spreadmark.
- Ensure your spreading equipment is calibrated according to its design specifications specific to the product being spread.
- Information on fertiliser applications is kept (or sought from contractors), including product, rate, date, location.

Irrigation and water use

Our intent: To apply irrigation water efficiently to meet plant demands and minimise risk of leaching and runoff.

GMP: Manage the amount and timing of irrigation inputs to meet plant demands and minimise risk of leaching and runoff.

Implementation guidance:

There is a demonstrable reason why irrigation is to be applied, for example:

- to replace soil moisture deficit
- for the purpose of herbicide activation
- to prepare soil for cultivation
- frost protection
- for fertigation

GMP: Design, calibrate and operate irrigation systems to minimise the amount of water needed to meet production objectives.

Implementation guidance:

- Any new development, upgrade or redevelopment is consistent with irrigation industry codes of practice.
- The irrigation system is evaluated annually to demonstrate optimal performance using irrigation industry guidance.
- **Dairy:** Actual irrigation water take is measured with a water meter. Soil moisture levels are tracked throughout the season to justify irrigation events, e.g. using soil moisture balance calculations or soil moisture probes or tapes.
- **Dairy:** Actual annual irrigation use is evaluated for consistency with estimated agronomic needs for the season based on climatic data and pasture/crop requirements.
- **Dairy:** Dairy sheds will use no more water for dairy shed washdown and milk cooling than is necessary to produce hygienic and safe milk (Sustainable Dairying: Water Accord). Actual water use in the dairy shed is measured with a water meter.
- **Horticulture and Arable:** Water is applied to maintain soil between stress point and field capacity - knowledge of evapotranspiration, field capacity and use of soil probes can assist in achieving this.
- **Horticulture and Arable:** Volumes applied are informed by all relevant factors e.g. crop type, plant growth stage, soil type and field capacity.

ANIMALS

Feed

Our intent: Minimise risk of contamination of waterbodies from stored feed.

GMP: Store, transport and distribute feed to minimise wastage, leachate and soil damage.

Implementation guidance:

- Design feed storage facilities to minimise wastage and soil damage, i.e. sealed or compacted surface.
- Minimise leachate generation (e.g. make silage at optimum moisture content) and prevent leachate from entering surface waterbodies, groundwater or stockwater.
- Site silage stacks so that overland flow of water from heavy rain cannot enter the stack.
- Site feed areas away from waterways.
- Distribute feed so as to minimise soil damage (from farm equipment and animals) and potential surface run-off to waterways, i.e. avoid Critical Source Areas.
- **Deer:** Make sure silage is made at the optimum moisture content to reduce possible leaching, recommended at 30% dry matter or more.
- **Outdoor pigs:** Feed diets and feed levels appropriate for the physiologic state of the animal i.e. separate gestating and lactating sow diet.

Farm effluent and wastewater management

Our intent: Minimise risk of contamination of waterbodies from stored and applied effluent.

GMP: Ensure the effluent system meets industry specific Code of Practice or equivalent standard.

Implementation guidance:

- **Dairy:** All new effluent systems are designed to Farm Dairy Effluent (FDE) Design Code of Practice. The main objectives of the system are: to capture all FDE; to spread the FDE at a time that allows uptake by plants; to uniformly spread the FDE to the desired depth, and at the desired intensity; to control FDE application to within the boundaries of the application area; to ensure that FDE systems can be operated safely; and to comply with all regulatory requirements, including consent conditions.

GMP: Have sufficient, suitable storage available to enable farm effluent and wastewater to be stored when soil conditions are unsuitable for application.

Implementation guidance:

- **Dairy:** Suitable storage is calculated using the Dairy Effluent Storage Calculator. This enables FDE to be stored when soil and management conditions are unsuitable for FDE land application. All areas that FDE is collected from are sealed (this includes feed pads). All new effluent systems are designed to FDE Design Code of Practice standard. Storage facilities are sealed and maintained to ensure containment of effluent. Storage is actively management to ensure storage is available when required.
- **Deer:** Enclosure systems should be located and managed to minimise environmental impact of effluent. In particular:
  - Store effluent for later dispersal to land where appropriate;
  - Effluent and run-off water should not enter natural waterways untreated;
  - Solid waste should be kept away from waterways;
  - Faecal/urine surface material should be cleared annually;
  - Paddock enclosure systems should not result in significant or irreparable soil loss or erosion.

GMP: Ensure equipment for spreading effluent and other organic manures is well maintained and calibrated.

Implementation guidance:

- **Dairy:** Spreading equipment is calibrated according to its design specifications specific to the product being spread. The effluent system can apply effluent efficiently. Information on effluent applications is kept (or sought from contractors), including product, rate, date, location. The effluent system is self-evaluated annually to demonstrate optimal performance, e.g. through an application efficiency test (bucket test); see DairyNZ FDE Guide to managing FDE and Guides to operating effluent irrigation system.

GMP: Apply effluent to pasture and crops at depths, rates and times to match plant requirements and minimise risk to waterbodies.

Implementation guidance:

- **Dairy:** FDE is applied to pasture and crops at depth, rates and times to best prevent loss and to increase utilisation; area complies with consent (use OVERSEER® to calculate). Take account of nutrients supplied by effluent or manure when calculating fertiliser requirements, e.g. use the DairyNZ FDE calculator app to determine the amount of nutrients applied. See FDE Design Code of Practice.

- **Outdoor pigs:** No effluent to be spread on the outdoor unit.

Intensive grazing

Our intent: Minimise risk of contaminant loss to waterbodies, and maintain soil structure and quality.

GMP: Select appropriate paddocks for intensive grazing, recognising and mitigating possible nutrient and sediment loss from critical source areas.

Implementation guidance:

- Where possible, select paddocks for winter grazing that are not vulnerable to pugging and compaction, do not have significant artificial drainage such as mole and tile drains, waterways, temporary streams or natural drainage channels (running in times of high rain). Choose wintering paddocks away from waterways if possible.

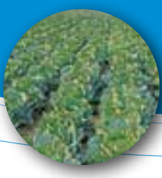
GMP: Manage grazing to minimise losses from critical source areas.

Implementation guidance:

- Sow crops for grazing across slopes if possible rather than up and down hills, to reduce runoff.
- Graze lower lying areas and areas closest to waterways last.
- **Deer:** Where possible, shift deer to dry, sheltered areas before wet weather arrives.
- **Deer:** Monitor animals regularly on self-feed silage pits to make sure all animals retain the required body condition score.

NOTES:

NOTES:







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Appendix 2

Harris (2017), Strategies for Creating and Implementing Sustainable Change Programmes, Kellogg Rural Leadership Programme Project Report Course # 35 – Eva Harris

STRATEGIES FOR CREATING AND IMPLEMENTING SUSTAINABLE CHANGE PROGRAMMES

2017

Kellogg Rural Leadership Programme Project Report Course # 35 – Eva Harr

EXECUTIVE SUMMARY

Water quality issues in New Zealand have become a top political issue, with the public demanding action be taken against the agriculture sector to ensure our rivers and lakes are returned to a *"swimmable"* state. Numerous policies and plans have been developed throughout the country to address these issues, with many regional councils creating rules which require farmers to operate at *"good management practice*" (GMP). For GMP to be effective in improving water quality, potentially thousands of farmers will need to make changes to their day to day farming practices over a sustained period of time. Programmes which are created to support the uptake of GMP by farmers need to ensure the changes become a normal part of the daily farming operation in order to improve water quality in the long-term. I have called these types of initiatives *Sustainable Change Programmes*.

This project has investigated the success (or not) of similar sustainable change initiatives introduced either here or overseas in order to identify the key factors which either enhance or hinder the success of these type of programmes. I have applied these key themes to critically assess two New Zealand case studies, which highlight different types of change programmes; the Motueka Integrated Catchment Management project and Synlait's Lead with Pride programme.

I found no single template will work for all people in all circumstances. Each programme needs to be tailored to address their specific issues or outcomes, the existing capability and knowledge of people involved, the anticipated timeframe to see the change and the resources available.

The most consistent theme I identified in sustainable change programmes was the need to build trust and allow the time to do this successfully. Programme organisers need to ensure farmers could trust the people they worked with, can trust each other and other stakeholders, they need to trust the information they were provided and they need to trust the tools being recommended as a *"solution"*. Without trust, there will be limited engagement and uptake of the desired changes. Every interaction with a participant is an opportunity to build, or lose, trust. Therefore, supporting multiple positive interactions between participants, implementers and key stakeholders will support the development of trust between all those involved. Investment in high quality people, who know how to deliver the message competently is a critical part of building trust.

The structure of the programme needs to be set up to best address the timeframes and community expectations for delivery. Mandatory or regulatory structures are often most effective for large scale, short term projects, which need a result quickly, but not a change in values. Whereas voluntary programmes tend to have higher rates of engagement, but poor participation and market driven programmes tend to have a balance of both.

Throughout the whole process, project developers and implementers need to constantly refer back to the people who are affected to ensure the project is focussing on the right issues, to collect the right information and to communicate everything in the most effective way.

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I would also like to thank the organisers of the Kellogg Rural Leadership programme. Your support and flexibility during this time has enabled me to continue with this programme through this very disruptive time.

To the very special KRLP Group #35 – your positivity and energy have been inspirational and I have enjoyed every minute I have spent with you all. I look forward to having many thought provoking, funny, and enthusiastic discussions with you in the future.

A very special thank you must be sent to AGMARDT, whose financial support and insight into my potential enabled me to make the most of this experience.

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1. FOREWORD

He aha te mea nui o te ao
What is the most important thing in the world?
He tangata, he tangata, he tangata
It is the people, it is the people, it is the people
Maori proverb

I joined the Kellogg Rural Leadership Programme (KRLP) to guide my work as Environmental Manager for a group of Mid Canterbury irrigation schemes. The irrigation schemes I work with hold the first resource consents to be issued in New Zealand which limit collective nitrogen losses. While the concept of nutrient loss caps is pretty straight forward, their implementation requires the development of an Audited Self-Management (ASM) programme to co-ordinate shareholders to change their current on-farm management practices in order to minimise nutrient losses.

I quickly realised managing nutrients was not just an accounting matter, but a rather a retrospective judgement on who was a "good farmer", using a completely different set of parameters to measure success than traditionally used. An effective ASM programme therefore became a social exercise in assisting shareholders with changing how they thought they should farm and promoting alternative visions of what being a "good farmer" looks like in the future.

The concept of ASM collectives of farmers on this scale in New Zealand is reasonably novel, so I have had difficulty finding resources to help me structure the ASM programme in a manner which manages the social aspect effectively. Everything I have created to date has relied on my intuition developed through my previous compliance and extension experience.

Through this KRLP project, I hope to look to other successful initiatives to build upon the knowledge I have already gained in order to refine my own programme with BCIL and to assist others with the development of future ASM programmes.

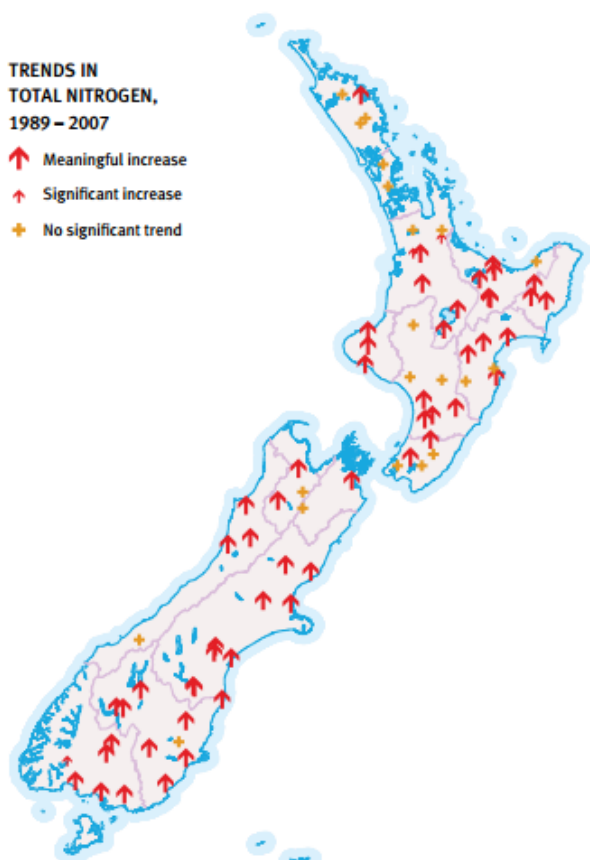
2. BACKGROUND

2.1 Introduction

New Zealanders have become concerned about water quality, to the point where political parties campaigned to *make rivers swimmable again* during the 2017 general election (New Zealand Labour Party 2017, New Zealand National Party 2017). So important are clean rivers to New Zealanders, that a Newshub (2017) poll found voters ranked environmental issues, such as water quality, above education and just behind housing and health.

2.2 Problem

Between 1994 and 2016, freshwater quality in many New Zealand catchments has declined (Ministry for the Environment and Statistics NZ 2017). Levels of contaminants indicative of diffuse discharges generally increased, while levels of contaminants indicative of point source discharges, such as industrial or sewerage discharges, were generally found to decrease (Ballantine and Davies-Colley 2009, Ministry for the Environment 2017).



The key contaminants of concern for diffuse discharges are Nitrate-Nitrogen (NO_3^--N), Dissolved Reactive Phosphorus (DRP) and microbial pathogens from agricultural sources. While DRP concentrations were found to be improving in more monitoring sites than declining (Ministry for the Environment 2017), the opposite was true for NO_3^--N, particularly in catchments where there was a higher percentage of adjacent land in pasture (Figure 1) (Ballantine and Davies-Colley 2009).

Nutrients feed periphyton growth (Figure 2), which consume the oxygen in a waterbody and effectively suffocate the aquatic life within it (Drewry, Newham et al. 2006). In extreme cases, a type of periphyton, called cyanobacteria, can release toxins which can kill dogs and other animals who eat the algal mats or drink the water (Wood, Hamilton et al. 2009). Some rivers and lakes, such as Lake Rotoiti, have been classified as hyper-eutrophic due to the extent of algal blooms caused by anthropogenic sources of nutrients (Vincent, Gibbs et al. 1984).

Figure 1: Changes in Total Nitrogen in New Zealand Surface Waterways 1989-2007 (Ministry for the Environment 2017)

Figure 2: Examples of periphyton growth (Left) (NIWA 2007) and cyanobacteria growth (Right) (Ministry for the Environment 2017) in New Zealand Waterways

Nitrogen, phosphorus and sediments from agricultural land can be lost to surface waterways through run-off, where contaminants, such as fertiliser or animal waste on the paddock, are transported by rainfall or irrigation into waterways on the property.

As well as worrying trends in surface water contaminants, New Zealand groundwater quality measures between 1995-2006 show NO_3^--N concentrations levels exceeded Maximum Allowable Value (MAV) for safe drinking water standards in 4.9% of the sampled wells, and microbial pathogen level MAV were exceeded in 20% of sampled sites (Daughney and Wall 2007). The 2017 MFE water quality report indicated these trends have continued, with nitrate leaching increasing by 29% between 1990-2012 (Ministry for the Environment and Statistics NZ April 2017).

Farming practices are the dominant cause of elevated NO_3^--N levels in groundwater in New Zealand (Parliamentary Commissioner for the Environment 2012). Inputs of nitrogen from farming activities are easily mineralised by soil microbes through to Nitrate-N (NO_3^--N), which is then leached through the soil profile to ground water (Figure 3), particularly where soil water holding capacity has been exceeded. Some catchments are more susceptible to groundwater nitrate contamination than others, as the rate of leaching depends on the soil type, climate, irrigation, plant uptake, and the amount of nitrogen being applied to the soil through stock waste, feed, fertiliser (O'neill 1998).

Blue baby syndrome is a condition which can affect infants and has been linked with high concentrations of NO_3^--N in drinking water (World Health Organization 2004, Cameron, Di et al. 2013). Blue baby syndrome is a condition where nitrates are converted to nitrite in the stomach, irreversibly substituting oxygen in the haemoglobin and prevents effective transport of oxygen throughout the body (O'neill 1998, Cameron, Di et al. 2013). For this reason, the World Health Organisation recommend the safe level of nitrates in drinking water to be no more than 50 mgL^{-1} (World Health Organization 2004). The same safe level has been adopted by New Zealand's Ministry of Health (Ministry of Health 2008).

High levels of nitrate in groundwater, particularly in rural areas where residents rely on shallow wells for drinking water, have therefore become a public health concern. The level of concern held by some public figures is so great that the Canterbury Medical Officer of Health has publically spoken out against current farming practices (RNZ 2017).

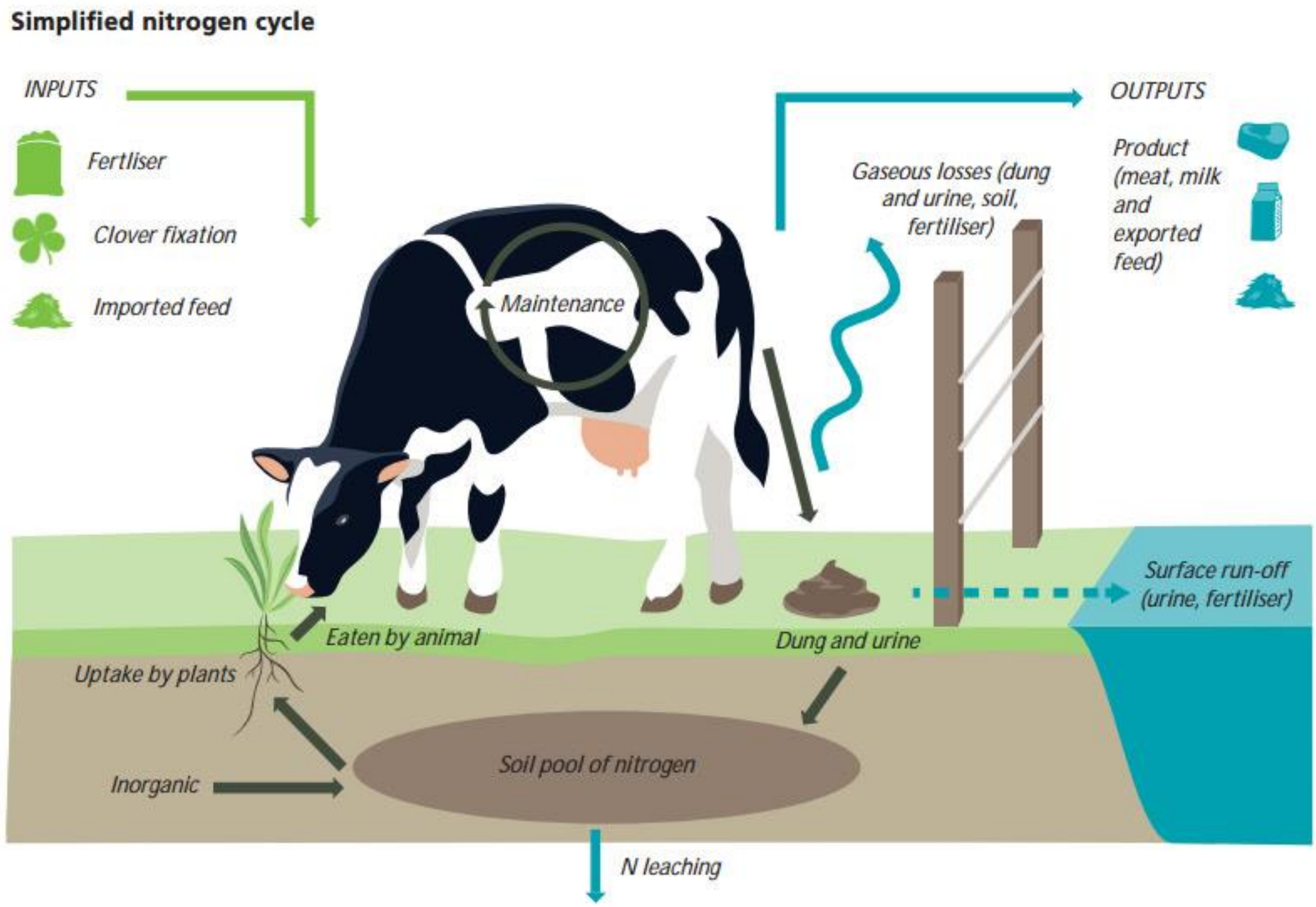


Figure 3: The Nitrogen Cycle on a Dairy Farm (DairyNZ 2017)

2.3 Solution

2.3.1 International Context

Stressors on the environment from diffuse agricultural nutrient discharges is not only a New Zealand issue. For example, in the Netherlands in the 1960s deteriorating water quality started to have an effect on the ability to use the water for drinking water purposes and impact on the fisheries industry (Warmer and van Dokkum 2001). Since then, the Dutch have introduced the Action Programme on Diffuse Sources (1997) and the European Union introduced the Nitrate Directive 1991 (European Commission 2017).

The objective of the Nitrates Directive is *"reducing water pollution caused or induced by nitrates from agricultural sources and - preventing further such pollution."* Each member state has since been required to identify and manage key Nitrate Vulnerable Zones (NVS) and enforce and report on the implementation of Good Agricultural Practice in these areas.

Other examples of international initiatives include Ontario's voluntary Environmental Farm Plans programme (Ontario Crop and Soil Improvement Association 2017) or Australia's National Landcare Programme (National Landcare Programme 2014).

These large scale initiatives have been subject of multiple academic studies and the success of the nutrient management programmes have been reviewed by governments, providing a rich source of data in understanding farmer behaviour relating to change initiatives relating to water quality over the long term.

2.3.2 New Zealand Context

The Ministry for the Environment (2017) identified discharges from the intensification of the agricultural sector as a key contributor to nutrient loads entering waterways. With more than 33,000 commercial farms in New Zealand in 2015 (StatisticsNZ 2015), each contributing to the degradation of water quality to some extent. Managing diffuse nutrient discharges is therefore a widespread and complex issue, involving co-operation and action from tens of thousands of individual farmers, who operate different farming systems, with varied operational goals and objectives.

In 2014, the New Zealand government issued a National Policy Statement for Freshwater Quality (NPSFW), requiring all regional authorities to implement changes which "*maintain or improve*" overall water quality as well as encourage *"the adoption of best practicable option to prevent or minimise any actual or potential adverse effect on the environment of any discharge of a contaminant into freshwater or onto or into land in circumstances that may result in that (or, as a result of any natural processes from the discharge of that contaminant, or any other contaminant) entering freshwater"* (Ministry for the Environment 2014).

With water quality requirements, such as the NPSFW, being a recent addition to the New Zealand regulatory framework, no preferred methodology had been established to guide Regional Councils in implementing the necessary changes to make improvements in water quality. In response to the NPSFW, in 2017, over 70% of Regional Councils were proposing new rules relating to agricultural land uses to meet water quality targets. To date, the approach by each council has varied, from introducing farm-scale nutrient limit caps[1], to requiring Good- or Best- Management Practice to be implemented[2], and/or encouraging the formation of catchment or collective groups to manage nutrients within their area[3].

Such nutrient management programmes to improve water quality are not new to New Zealand, with Waikato Regional Council first introducing nitrogen capping and trading rules for agricultural activities the Taupo Catchment in 2005, with the aim to reduce the amount of nitrogen reaching the lake by 20% (Waikato Regional Council 2017). However, the new provisions under the NPSFW is the first time these types of provisions have been applied on a national scale.

Despite the complex and interpersonal nature of the actions needed to improve freshwater quality, very little work has been carried out by either Central Government or Regional Councils to identify effective methods of implementing the required changes. In general, the majority work done to date has been technical in

[1] For example, Environment Canterbury, Horizons Regional Council and Waikato Regional Council
[2] For example, Greater Wellington Regional Council, Taranaki Regional Council and Gisborne Council
[3] For example, Environment Southland and Tasman District Council

nature, with numerous reports by scientists and advisory bodies describing the physical processes that take place to produce various water quality outcomes (e.g. Environment Canterbury 2017, Waikato Regional Council 2017).

Canterbury's Land and Water Regional Plan (LWRP) rules in particular have a strong focus on ensuring farmers undertake their activities in accordance with Good Management Practices[4] (GMP). Good Management Practices to improve water quality was defined by a number of industry bodies and cover 27 areas of farming management, such as irrigation, fertiliser, effluent, and sediment control. Progress with meeting these GMPs in Canterbury is monitored through an auditing programme, which requires evidential proof the on-farm GMP activities were occurring. While many farmers already do some of the good practices, most will need to make changes, some significant, to their daily operations in order to meet the new requirements.

While the physical aspects of water quality in each region have received considerable attention, the social aspects have been largely ignored. Burton et.al. (2011) noted that sustainable change can only occur when intrinsic environmental values align with the desired activities to be implemented, whereas extrinsic motivators, such as financial incentives or strict regulation, were more likely to forestall any change in behaviour. With this in mind, regulatory requirements expecting farmers to implement GMP will be unlikely to result in the desired water quality outcomes unless the farmers are supported to adopt the intrinsic values the respective plans are intending to uphold. Programmes which assist long-term changes in values or behaviour are what I mean by *Sustainable Change Programmes.*

2.3.3 BCI Context

Canterbury's Land and Water Regional Plan (LWRP) was first notified in August 2012 and was one of the first planning documents in New Zealand to create rules which limited individual property nutrient losses. The LWRP introduced a limit of nitrogen losses to what occurred within the 2009-2013 seasons and work towards reducing the nutrient losses from approximately 8000 properties through the implementation of Good Management Practice (GMP). Due to the significant number of farmers affected, Canterbury Regional Council allowed irrigation schemes to apply for resource consent to aggregate the nutrient losses from their shareholders and manage these nutrients collectively.

Barrhill-Chertsey Irrigation Scheme (BCIL) is a new farmer-owned irrigation scheme, which started providing water in 2010 and now currently irrigates approximately 25,000 ha onto about 180 properties, covering approximately 60,000 ha between the Rakaia and Rangitata Rivers in Mid-Canterbury (Figure 4). BCIL is the first operative irrigation scheme to be issued a resource consent to manage the nutrient losses for a period of five years.

BCIL employed me in February 2015 to create and manage their Audited Self- Management (ASM) programme, with the aim to be a leader in this space in order to make the preparation for the renewal of the resource consent in 2018 simpler.

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[4] Good Management Practice as defined in the booklet: http://files.ecan.govt.nz/public/pc5/MGM_Technical_Reports/Industry_Agreed_Good_Management_Practices_MGM_2015.pdf

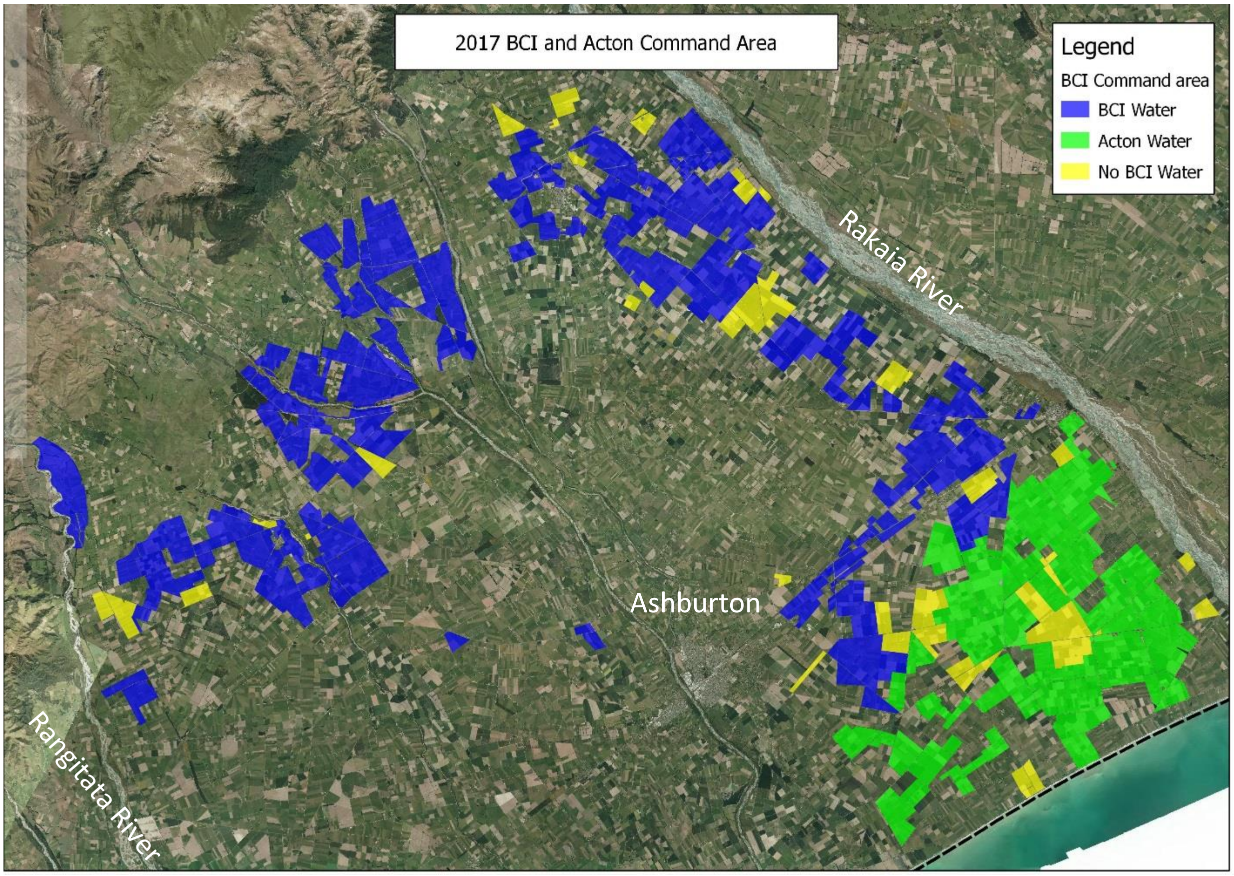

Figure 4: BCI and AFIC Command Area 2017

The discharge consent BCIL is required to comply with sets out the key requirements to be reported against to ensure nutrients are being effectively managed. These include:

- Creation of an Audited Self-Management (ASM) document, setting out the scheme programme to achieve compliance with the resource consent.
- All shareholders required to prepare and implement a Farm Environment Plan to achieve Good Management Practice on-farm
- All Farm Environment Plans were to be audited
- Scheme nutrient losses to be reported annually to determine compliance with the consented nitrogen load limit.

Despite the technical nature of the discharge consent, I quickly discovered our shareholders were unprepared for the changes these requirements would have on their day to day operations. Implementation of *"Good Management Practice"* (GMP) required our shareholders to completely revise their businesses models, their personal priorities and their succession planning. Our shareholders were undoubtedly concerned about the level of detail BCIL needed to know about their businesses and the amount of control they had over the security of their water. I found myself needing to develop a sustainable change programme from scratch.

With this in mind, my priority moved from mere consent compliance to creating a programme to assist shareholders through the transition from individual farmers to collective nutrient managers. We found we needed to work with them individually to create their Farm Environment Plans, provide plenty of information on what GMP looks like (repeatedly), and to regularly update them on these requirements to acclimatise them to the invasion of BCIL into their business. We also sought feedback from shareholders to understand what we could do better and to identify and address the support they needed.

Three years into the programme, shareholders have come to expect (and respect) our involvement with managing their nutrients, but we still have a long way to go to see how this acceptance translates into measurable improvements in water quality.

2.4 Summary and Aim

Nutrient enrichment of waterways in New Zealand from diffuse pollution sources is a complex and multi-faceted issue, with many thousands of properties and individuals contributing a little bit to the enrichment of waterways nationwide. In order to achieve the desired community outcome of *"swimmable rivers"*, new solutions need to be developed to ensure each individual consistently makes the right choices on farm over a long period of time in order to improve water quality.

Fortunately, methods to assist individuals with implementing long term, sustainable change on farms have been used in New Zealand and internationally. However, to date little work has been conducted to bring together these experiences to assist others in creating and implementing these sorts of programmes.

The aim of this research project is to review national and international literature of various sustainable change programmes in the context of my own experience to identify the key features which either enhance or hinder change in order to develop guidelines for the creation and implementation of successful programmes on a large scale in New Zealand.

2.5 Research Approach

I used the general principles of Braun & Clarke's Thematic Analysis (2006) to identify key themes in the literature review and applying these ideas to two New Zealand case studies, to assess different approaches currently in practice. Two case studies have been prepared to assess existing initiatives against the themes identified in the literature.

The first case study relates to the Motueka Integrated Catchment Management (ICM) programme. The Motueka ICM project was initiated as a scientific study by Landcare Research and my case study has been prepared by summarising published academic literature available.

The second case study assesses Synlait's Lead with Pride (LWP) programme, which is a new, market driven initiative, and has not yet been evaluated in the literature. For Synlait's case study, I developed a questionnaire which targeted Synlait's approach around the key themes identified in the literature as key in successful behaviour change initiatives. The questionnaire and response can be reviewed in Appendix 1 – Lead with Pride Questionnaire and Response.

Throughout the exploration of the themes identified in the literature, I will also critically assess how the themes identified in my research impacted on my own experience with the development of the BCIL ASM programme.

3. FEATURES OF SUSTAINABLE CHANGE PROGRAMMES

Through this project, I have assumed programmes designed to improve water quality will be most effective where there is full participation and engagement by those who have an effect on waterways. I wanted to get a better understanding through the literature of the different sustainable change approaches available and how they have worked (or not) in other situations.

3.1 Motivators for Participation

3.1.1 Mandatory/Regulatory Approach

A regulatory or mandatory approach is often the most effective method to enact change in the short-term, as they tend to capture everyone and be enforced to ensure the outcomes are met (Bosch, Cook et al. 1995, Mills, Gaskell et al. 2016). These types of programmes are often initiated by local and national governments to address widespread issues, and can be politically motivated.

Overall, Mandatory/Regulatory approaches to programmes are most effective where a specific action by an individual is required, such as an upgrade in infrastructure. For example, metering of water takes throughout New Zealand was inconsistent between Regional Councils, with only about one third of water takes greater than 5 l/s measured (Ministry for the Environment 2016). There was limited information available to manage water at a national level, or to compare data between regions. The New Zealand government decided accurate water use data was important and introduced the Resource Management (Measurement and Reporting of Water Takes) Regulations in 2010, requiring all water takes greater than 5 l/s to have a water meter installed by 2016 and report the data collected. Regional Councils were then tasked with ensuring the regulations were implemented.

Nearly one year after the regulations have been fully implemented and most water takes have now been metered and reported on, providing consistent data to be used to improve management of water in New Zealand. For instance, the Canterbury Regional Council reported over 90% of the water takes in Canterbury complied with these requirements by April 2016 (Environment Canterbury 2016). It is unlikely water meters could have been installed nationwide and in a consistent manner without a national regulation requiring it to happen.

Over time, regulation can be effective in changing attitudes as noted by Buckley (2012) with Irish farmers under the Nitrates Directive, however acceptance of regulatory requirements do not necessarily equate to adoption of the values being promoted.

In general, engagement in mandatory/regulatory approaches tends to be low as the participants *"do what they have to"* or even *"what they can get away with"* rather than take on board the values the programme is trying to promote (Barnes, Toma et al. 2013). Regulatory authorities also tend to apply general rules over a widespread geographical area, which may or may not be relevant to a specific property, which can further disengage participants (Palmer, Fozdar et al. 2009).

Botha (2013) highlighted a high level of fear and anger over environmental regulation for Taupo farmers, which translated to little improvement on farm five years after the introduction of the nutrient management rules in this area. Botha's research draws attention to the grieving process participants in a mandatory programme will more likely experience when regulations affecting their livelihood is introduced.

Kubler-Ross' (1972) description of the stages of grief provides a useful framework to understand the process a farmer may go through when mandatory environmental regulations are introduced. The first stage of grief is shock and denial, followed by anger, bargaining, depression and acceptance (Figure 5, (Kübler-Ross, Wessler et al. 1972) While the stages of grief model was initially developed to understand what feelings people may experience when facing death, it has also been found to be applicable to any significant life changing event, particularly where the affected person has a lack of choice.

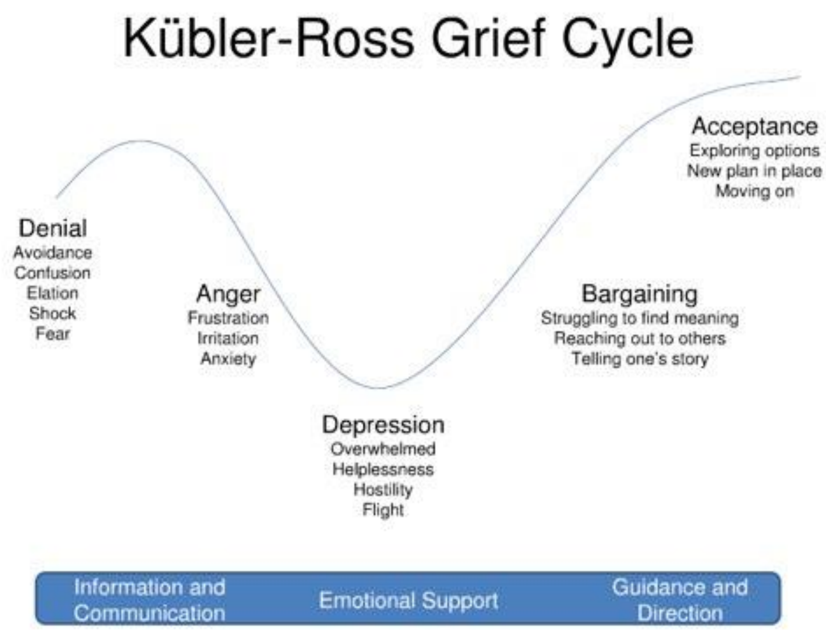

Figure 5: Kubler-Ross Stages of Grief Model (Kübler-Ross, Wessler et al. 1972)

Many farmers will experience some or all of these stages when regulations are introduced, and any mandatory programme will face resistance unless significant support is provided to assist farmers through the process (Botha, Roth et al. 2013). Where there is insufficient or inconsistent support provided, the farmers will be unlikely to implement the necessary changes in the long term and the desired community outcomes are unlikely to be met (Smith, Glegg et al. 2007, Blackstock, Ingram et al. 2010).

3.1.2 Voluntary Approach

Voluntary programmes can be a useful method to improve environmental outcomes, while also providing flexibility and choice to participants (Alberini and Segerson 2002). Engagement of participants within voluntary programmes tend to be high, as their existing values often align with the values promoted by the programme (Blackstock, Ingram et al. 2010). However, participation tends to be low (Burton, Kuczera et al. 2008), particularly when there is no *"threat"* for not participating (Alberini and Segerson 2002). Examples of voluntary agri-environmental programmes in New Zealand include Beef+Lamb NZ's Land and Environment Plan, DairyNZ's Sustainable Milk Plans or Synlait's Lead with Pride programme.

Interestingly, while Moon and Cocklin (2011) noted financial incentives could improve participation in voluntary programmes, Dwyer et. al (2007) and Mills et.al. (2016) found financial incentives to be a poor predictor of sustainable long-term behaviour change. Participants motivated by financial gains will likely do what they have to in order to receive the reward, but unlikely to adopt the values the programme is trying to achieve. Once the programme is completed, they will most likely return to their previous behaviours (Mills, Gaskell et al. 2016).

The most successful predictor of long-term sustainable change in voluntary programmes, was the amount of education and support provided (Blackstock, Ingram et al. 2010).

Common barriers to participation in a voluntary programme include the time required and a lack of understanding of how the requested mitigations will improve the environment (Pahl, Weier et al. 2007). For example, Ahnstrom et.al. (2009) noted many farmers saw themselves as *"conservationists"* and stewards of the environment, but did not understand how their current practices had an impact. Where this attitude existed, the farmers were unlikely to voluntarily make changes as they did not appreciate how their actions related to the problem. Botha's (2013) observations also found a lack of ownership of an issue resulted in a poor uptake of mitigations with Lake Taupo farmers. In this instance, the reasons were often for lack of trust in the science, lack of connection between their actions with the environmental effect, or have sufficient peer support.

3.1.3 Market Driven Approach

Market-driven initiatives lie somewhere between voluntary and mandatory schemes. Participants generally do have a choice, but may struggle to sell their product unless they are part of the programme. Therefore, participants are more strongly motivated to be involved and engaged than with purely voluntary programmes. An example of a market-driven initiative is the NZGAP and GlobalGAP schemes.

The NZGAP and GlobalGAP programmes provide certification of food producers following the Hazard Analysis and Critical Control Points (HACCP) approach to food safety (New Zealand GAP 2017). The GAP programmes set and audit the standards for ensuring the quality of the food grown and the environmental and social impacts of the operation meet the expectations of the receiving customers. Food producers volunteer to participate in the GAP programmes, but will struggle to supply the major supermarkets in New Zealand, such as Pak N Save and New World, without NZ GAP certification (Foodstuffs NZ 2014), nor could they export their produce to Europe without achieving GlobalGAP certification (New Zealand GAP 2017).

Alberini et.al. (2002) noted companies with significant brand exposure were most likely to participate in market driven initiatives. Customer demands for transparency when paying a premium for products often mean these programmes are audited and well resourced (Campbell and Rosin 2008).

Agriculture Research Group on Sustainability's (2011) report on Zespri's kiwifruit quality standards found the standards formed part of the grower's perception of a *"good farmer"*, with uptake improving when orchardists participated in the development of the auditing standards. The combination of improved monetary gain and recognition by the wider community were found to be strong motivations in the adoption of the recommended good practices.

3.1.4 Key Points to Note for Methods of Participation

Method	Pros	Cons
Mandatory/Regulatory	Captures all who need to be targeted	Poor engagement or active dis-engagement of participants
	Tend to see change quickly	Often poorly resourced
	Best for straight forward changes	“One size fits all”, no flexibility with rules
Voluntary	Programme more likely aligns with participant values	Can take time to build social capital
	Can result in sustainable long-term change	Poor participation
	Better model for complex issues	
Market-Driven	Strong incentives to participate and be engaged	May not align with participant values
	Will capture many who	May be difficult to demonstrate effectiveness of project on water quality if spread over a large geographical area
	Often well resourced	

3.2 Programme Structure to Maximise Engagement

Two common structures of change initiatives are the *“top-down”* or the *“bottom-up”* methodologies. *“Top-down”* approaches tend to be authoritative and directive, where instructions are given and expected to be followed. A *“bottom-up”* approach assumes participants already know the solutions to their own problems and merely need coaching to identify the issues and clarify what they can do about it (Black 2000).

Mandatory programmes often use *“top-down”* approaches, particularly where wide-scale changes are needed. *“Top-down”* approaches are most useful for new technology, where the information is too new or complex to be within the realm of knowledge of those needing to implement it (Black 2000). Traditional extension programmes also tended to utilise a “top-down” approach, whereby the scientists completed the research, provided the information to an advisor, who then passed on the information to the farmer (Black 2000). There is often little room for feedback from those undertaking the activity, nor is there room to tailor the information for the context of the property (Black 2000).

In general, there has been a move away from the traditional *“top-down”* approach in extension as uptake is often poor, particularly where the information provided is too broad and not relevant to the specific situation faced by the farmer (Black 2000). In fact, Siebert et. al. (2006) noted arbitrary *“top-down”* approaches tended to elicit negative response from farmers, who often felt disdain when required to make changes and were unlikely to participate in schemes where there was insufficient consultation.

Many farmers appreciate the hands-on, practical aspects of agriculture and enjoy problem solving (Dwyer, Mills et al. 2007). *"Bottom-up",* collaborative processes are therefore engaging for a greater proportion of the farming community, rather than just telling them the answers. Black (2000) and Blackstock et. al. (2010) also note farmers were more likely to continue implementing the solutions which they have been involved in creating (Black 2000).

While *"bottom-up"* approaches can be effective for supporting sustainable, long-term change, there are limitations. Black (2000) noted *"bottom-up"* approaches are only useful where the participants already have the knowledge required in order to derive a clear and practical solution. Where there is new or unknown technology, or the issue is complex, more guidance may be required. Furthermore, effective *"bottom-up"* solutions often require sufficient time and resources to build social capital in order to facilitate the discussions required to identify the best solutions (Fenemor, Phillips et al. 2011).

Group consultation and formation of collectives were identified as a useful mechanisms to support the brainstorming required in a *"bottom-up"* approach, as the group can derive the proposed solutions at a community scale, while also building social capital and create a supportive environment for implementing the change (Blackstock, Ingram et al. 2010).

For group solutions, Marsh and Pannell (2000) noted participants often poorly represented the community, with wealthier and larger farms dominating and few women involved. Participants who were not involved may still be sceptical of the proposed mitigations developed by the group, particularly where they have not built up trust with the farmers representing their interests (Marsh and Pannell 2000).

"Bottom-up" approaches are often characterised by a trial and error iterative process. An iterative process allows the programme to evolve in response to participant feedback and incorporate new information, such as new technology or updated research. There is an assumption within the model that the first attempt will not be perfect and there is room for genuine consultation while it is being implemented (Burton and Paragahawewa 2011).

An example of an iterative process is Motueka's Integrated Catchment Management project (see Case Study 4.1) or programmes which support creation of audited, on-farm Environmental Management Strategies (EMS)(Rosin, Dwiartama et al. 2012).

An Environmental Management Strategy (EMS) is a management systems framework, which can improve efficiency, reduce risks, enhance compliance and improve profitability by providing users with a tool to assess their operation in an integrative manner (Carruthers 2011). Carruthers (2007), Paterson (2011) and Wilson et.al. (2009) recommend use of an EMS type system as a method of implementing a programme of continuous improvement, through a *Plan, Do, Check and Act* cycle (Carruthers 2011). The EMS is particularly useful where the issues are complex and management decisions need to be adapted as research and data becomes available (Carruthers 2011).

As environmental issues increase in complexity, extension programmes will need to shift away from just telling people what to do, to enabling them to think creatively and develop their own solutions (Black 2000). The Extension Spectrum (Figure 6[5]) is a graphical description of this process. *"Top-down"* approaches is largely effective at the technology transfer end of the spectrum, whereas *"bottom-up"* methods is more about problem solving. Truly effective solutions need to be developed by participants, therefore their individual capability will need to be fostered. Education and personal development must therefore become the cornerstone of any change programme in order to achieve the desired community outcomes (Blackstock, Ingram et al. 2010).

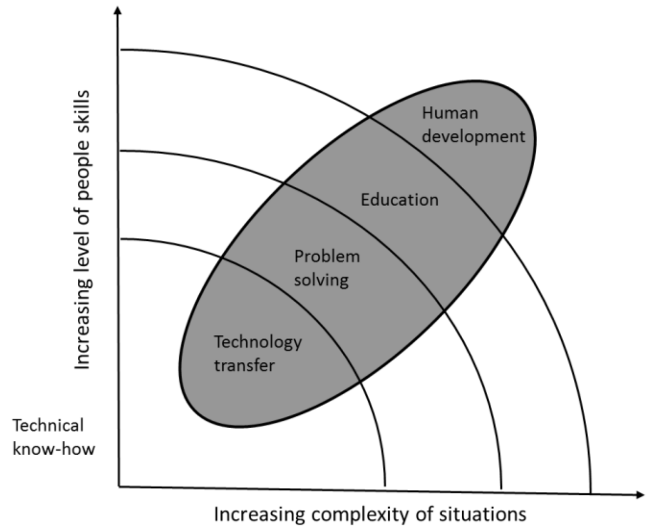

Figure 6: The Extension Spectrum (Campbell and Junor 1992)

One educational theory which could be useful for developing capability within adults is Jensen's *(2008) Brain-Based Learning*, which describes seven steps to optimise the uptake of information by students, based on the sequence which makes most sense to the brain. The steps include:

- Pre-exposure
- Preparation
- Inspiration and Acquisition
- Elaboration
- Incubation and Memory Coding
- Verification and Confidence Check
- Celebration and Integration

Following a process such as this during all extension activities could assist with farmer uptake of ideas by building their knowledge and capability in the most efficient manner.

3.2.1 Key Points to Note for Programme Structure

- Know what needs to be achieved and expected timeframes
- Ensure the values of the programme are clearly communicated, where necessary
- Complex problems need complex solutions
- Human development needs to be at the centre of any long-term sustainable change

[5] Special thanks to Ollie Knowles for letting me use this diagram!

3.3 Trust

3.3.1 Trust in People

> ***"Information is … unlikely to become knowledge unless the recipient trusts the informant"***
> **(Fisher 2013)**

All change programmes must first understand people and the trust they place in their relationships with others. While water quality issues may seem to be a technical problem initially, programmes to improve to water quality will be unsuccessful unless the people contributing to the problem also contribute to the solution.

Fisher (2013) developed a *Conceptual Model of Trust* (Figure 7) based on her own research, and similarly Kasperson and Golding (1992), cited commitment, care, competence and predictability as cornerstones for the formation of trust. Where these values are met consistently, trust between individuals and organisations can be built, acting as a catalyst for passive information to be transformed into usable knowledge (Fisher 2013).

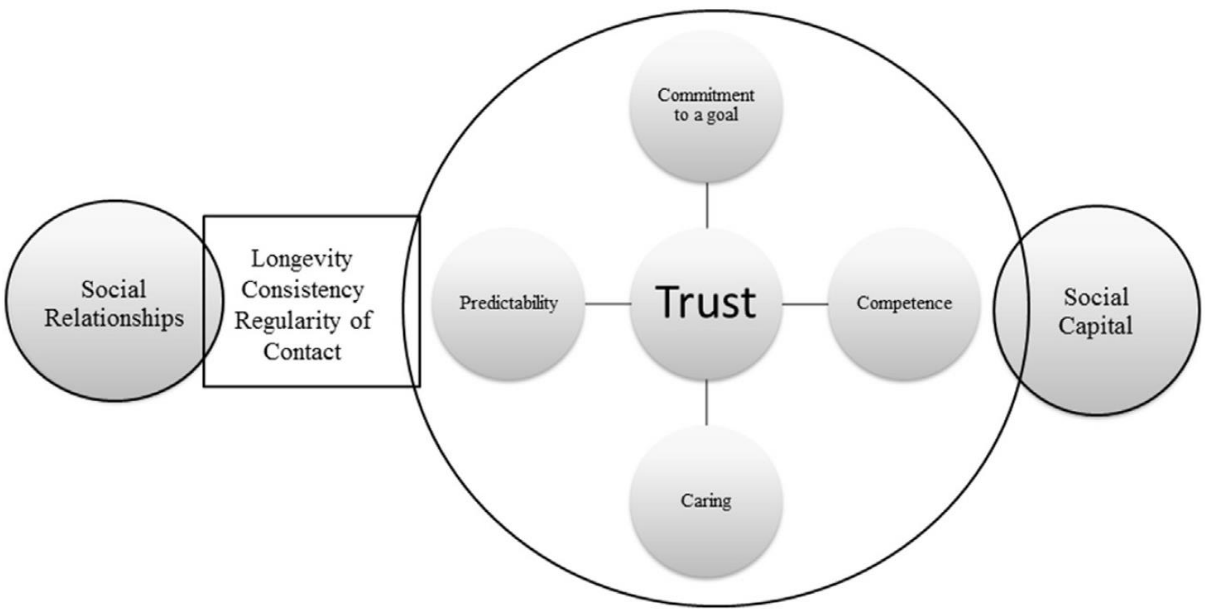

Figure 7: Fisher's (2013) Conceptual Model of Trust

All change programmes should, where possible, leverage existing trusted social networks (Mills, Ingram et al. 2008) or allow time for quality people to build the relationship between the parties (Allen, Fenemor et al.

2011). In fact Mills et.al. (2008) recommend up to 10 years to develop new schemes in order to build sufficient social capital and trust.

For any initiative which relies on group participation and engagement, building trust between members is essential (Allen, Fenemor et al. 2011). In the Motueka Integrated Catchment Management (ICM) project, agreement on the key catchment issues and identifying potential solutions could only occur once a significant level of trust had been built between the different stakeholders (see Case Study 4.1).

The desire to *"fit in"* or to maintain the esteem of peers is well known and studied through the evolutionary theory of commons (Richerson, Boyd et al. 2002), which investigates the reasons humans co-operate and form social structures, despite personal sacrifices in doing so. This effect can be capitalised by collectives and other groups, which can build on the existing social capital of a community (Barnes, Toma et al. 2013). Where the community sets the standards and expectations of behaviour, each individual member feels a sense of obligation to the other members of the group. Furthermore, uptake by members of the group can normalise the behaviour to be adopted, making it more likely others will take on board the changes being promoted (Yang and Sharp 2017).

Oreszczyn et. al. (2010) described the impact a "*web of influencers"* can have on a farmer's behaviour change, whereby much of the information they received and those most capable of influencing decisions can be found within existing networks. The *"web of influence"* is a trusted source of information for individuals and can act like informal feedback, highlighting normal behaviours and expectations.

Farmers frequently look to a trusted leader in their rural community when looking to implement changes in their farming practices. The trusted leaders are typically seen as "good farmers", and being a "good farmer" helps form a sense of self identity and pride within the community (Stock and Forney 2014). Where a trusted group of peers supports a particular behaviour change, and that behaviour becomes normalised, peer pressure from the group will increase the chance that the individual farmer will be more likely to implement that change in order to maintain their "good farmer" status (Blackstock, Ingram et al. 2010, McGuire, Morton et al. 2013).

Farm advisors are also seen as trusted leaders. Where a culture of trust between the advisor and participant has already been established, such as between neighbours or farm consultants, engaging and educating the advisor can be an effective method to improve outcomes (Klerkx and Jansen 2010). One-on-one knowledge transfer, either between peers or between a farmer and their advisor, was identified by Black (2000) and Fisher (2013) as an important method to deliver information. For a participant to accept the information, they will ultimately assess it's quality and form a judgment based on their level of trust with the person delivering the message (Dwyer, Mills et al. 2007).

Dwyer et. al. (2007) notes a participant's acceptance of a message from another person can depend on:

- the experience and practical knowledge of the advisor
- an ability of the advisor to clearly communicate issues in a way which is personally applicable to the participant
- advisor's familiarity of the farming systems being discussed
- the advisor being perceived by the participant as having a similar occupation and experience

The power of the messenger of knowledge was highlighted by Botha et al (2012). Botha (2012) found Taupo farmers' had high levels of trust with their farm consultants, but where the consultants were either not well informed or were unclear of (or didn't trust) the information they should pass on, the uptake of the desired mitigations by the Taupo farmers was low.

While it is essential for change programmes to foster the building of trust between all parties, it is just as essential to ensure any change programme to avoid fostering distrust. Fisher (2013), Botha (2013), De Vries (2014), Macgregor (2006), and Palmer (2009) noted high levels of distrust with government agencies where there was inconsistent messaging around requirements. For example, about 75% of farmers in the Lake Taupo catchment had not made any on-farm practice change between 2005-2009 as they were uncertain of the compliance standards (Botha, Roth et al. 2013), while MacGregor's (2006) interviewees showed a general attitude of apathy towards government regulation potentially due to the complexity of the bureaucratic process. Where positive relationships with government agencies were reported, the primary reason was due to farmer confidence in the staff they dealt with on a day to day basis (Palmer, Fozdar et al. 2009).

Poor communication of regulatory advice or rules, where the requirements were either not applicable to an area or impractical, also assisted with the development of distrust (Smith, Glegg et al. 2007, Fisher 2013). Where the requirements were not perceived to be connected to desired outcomes, the farmers felt the Government lacked sufficient knowledge and were unlikely to implement the changes as they did not trust they would work. These issues were exasperated where the relationship with the regulatory agency was inconsistent, infrequent and/or negative (Fisher 2013).

> ***"There's no point in educating farmers over bio-security when you've got the upper levels, like the politicians and them, making decisions that are really contradictory to what we're going to do down here…"***
> **(Palmer, Fozdar et al. 2009)**

Many behaviour change initiatives will rely on participants being honest with themselves and the programme leaders with actual practices being undertaken (Palmer, Fozdar et al. 2009). Palmer et. al. (2009) found many farmers were distrustful of government agencies and were concerned about repercussions if they reported infectious diseases in livestock. Therefore, change programmes need to ensure farmers feel safe to speak to advisors without repercussions in order to have a frank and honest discussion to find an appropriate solution.

In my opinion, some key features which seemed to result in higher levels of distrust include:

- Inconsistent and/or unclear requirements
- Generic and/or impractical advice
- Lack of knowledge by staff
- Poor existing relationships and communication
- Fear of retribution

3.3.2 Trust in Information

The actual or perceived quality of the information being promoted by a programme is also another key factor in determining whether or not a farmer will take on board the desired practice. Where there is insufficient evidence to convince farmers there of a problem, farmers are unlikely to uptake the actions needed to make improvements (Barnes and Toma 2012). For instance, Barnes and Toma (2012) surveyed over 540 dairy farms about their perceptions of climate change and their willingness to take voluntary action to reduce greenhouse gas emission and found over half were sceptical about the reported effects of climate change and these half were unwilling to engage with programmes to address the issue.

> ***"I'd just have to look at the story and see how real it seemed to my situation at the time" (Moon and Cocklin 2011)***

Furthermore, even if farmers do accept there is an issue, farmers need to be confident the data linking their actions to an environmental effect is robust and made sense to them. Moon and Cocklin (2011) noted even farmers who identified as *"conservationist"* were unlikely to adopt biodiversity practices where they did not accept their actions had an effect on the end outcome.

Another aspect of the use of trusted information to drive change is the use of benchmarking. Benchmarking is generally based on data metrics and KPIs and can provide independent feedback on progress and comparisons with peers and was identified as an effective method to provide feedback to individuals (Lokhorst, Hoon et al. 2014).

Benchmarking could be particularly useful to provide feedback on the success or failure of the actions of the participants. As mentioned earlier, engagement improves where participants trust there is an issue, their actions have an impact on that issue and the proposed alternatives will result in a meaningful improvement. Benchmarking and reporting on metrics in a format which addresses these issues is a useful method to build trust with participants in this area.

Examples of benchmarking in New Zealand is Zespri's dashboard, which reports water usage, sugar content and yields of kiwifruit back to growers so they can understand how they are performing in relation to their peers. In an ARGOS 2007 report (Rosin, Hunt et al.), greatest engagement in benchmarking came where the growers were able to provide feedback on the metrics they wished to measure themselves against. The benchmarking allowed premiums to be paid to the better growers, as well as increased social status within the group.

Provided the benchmarking metrics were verifiable, measureable and had real meaning, the feedback these provide to participants is very useful in encouraging behaviour changes.

3.3.3 Trust in Tools

In addition for farmers to trust the information provided, they must also have faith the time and effort required to implementing the recommended tools will result in the desired improvements to the environment (Bewsell and Brown 2011).

For example, OVERSEER® is a model used in New Zealand to assess nutrient transfers within farm systems and is now commonly used to predict fertiliser requirements and nutrient losses for a particular property. With the release of the National Policy Statement for Freshwater Quality (NPSFW) in 2014, many regional councils are using this tool to set limits for nutrient losses to groundwater and surface water and to improve the efficiency of fertiliser use.

Early studies of dairy farmer perceptions of using OVERSEER® found a general lack of trust in the tool (Bewsell and Brown 2011) to provide sufficiently accurate information to influence their management decisions. Trust in the model improved with on-going usage, as the users became familiar with the information required and were more confident with the data being used. However many farmers felt the assumptions made by the model and inherent uncertainty in the calculations meant the model was best used as a guide. This lack of trust was cited in the study as a primary reason not to implement the recommendations from the model and to only use it to meet regulatory requirements.

Furthermore, when used in regulation, the method of preparation, version changes and inherent uncertainty in the model results in variable calculations of nitrogen loss for the same system (Duncan 2014). As demonstrated above, farmers are unlikely to implement changes on farm where there is inconsistency or uncertainty in the regulatory requirements. In fact, Duncan (2014) suggests the regulatory emphasis on adherence to a nutrient cap calculated by OVERSER® will not result in actual change of practice on farm, but rather motivate farmer to manipulate the model to achieve the desired numerical outcome.

> ***"What might have been clear-cut and easy to decide in terms of data inputs, definitions and input category choices in the past when the stakes were very low in comparison, suddenly become ambiguous and negotiable. This is not unlawful – it is a pragmatic response to 'rule by numbers'" (Duncan 2014)***

3.3.4 Key Points to Note to Build Trust

- Allow time to build social capital and trust
- Support regular interactions with peers and trusted advisors
- Create a safe environment to encourage honesty
- Ensure trusted advisors are well informed
- Be consistent and practical
- Ensure the recommended tools and mitigations will result in desired outcomes
- Provide feedback of progress via trusted sources of information

3.4 Farmer Diversity

When creating any sustainable change programme, it is essential to recognise how the diversity of the farmer community and how closely a farmer's self-identity influences their decision making (Lokhorst, Hoon et al. 2014). Each individual farmer has their own personal and business values, with their own priorities and risk-acceptance profiles for their own reasons. Furthermore, each individual will come into the programme with their own specific education and experience, with a diverse ability to understand and/or accept the information being provided (Mills, Ingram et al. 2008).

Often, each of these aspects are closely linked to their own personal idea of what is a "Good Farmer", which is inherently linked to their self-identity (Burton, Kuczera et al. 2008, Burton and Paragahawewa 2011, McGuire, Morton et al. 2013). By requesting a change in behaviour, we are challenging their sense of self and belief that they are a "Good Farmer".

Any programme must therefore include multiple approaches to encourage participation and engagement, while also respecting how participation within such a programme will affect their personal identity as a farmer.

Furthermore, every farmer will have a different level of education, experience and access and/or capability around technology (Vanclay 2004). The 2013 New Zealand census found over 44% of agricultural employees were aged over 50 years old (StatisticsNZ 2017), with 31% of dairy farmers and 57% in the mixed livestock and grain farming systems (StatisticsNZ 2017).

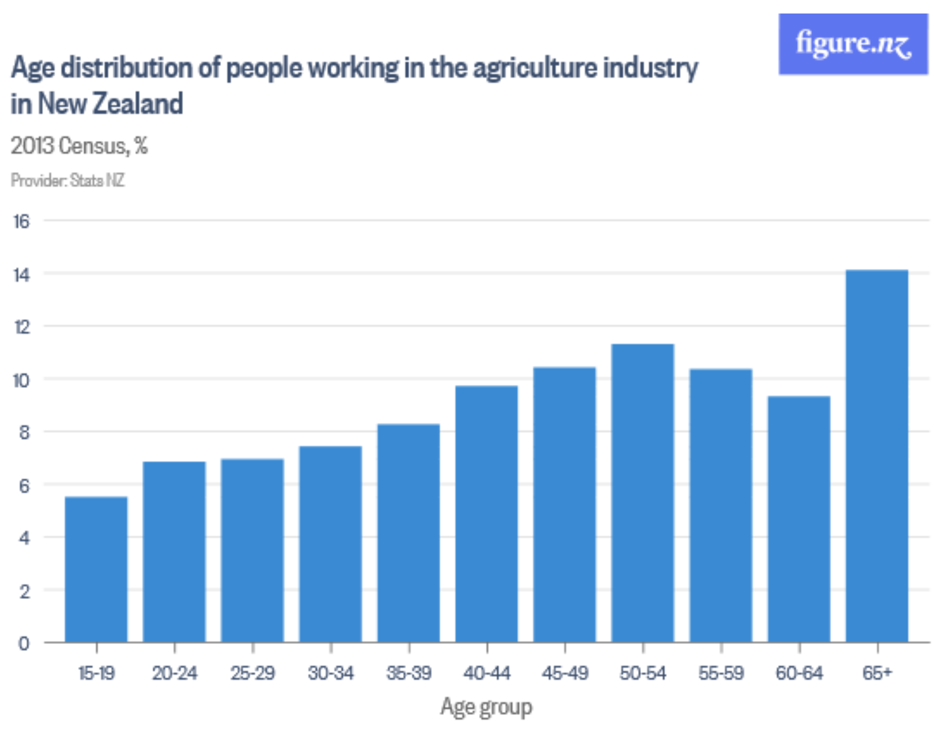

Figure 8: Age Distribution of New Zealand Agricultural Industry Employees (StatisticsNZ 2017)

Many older farmers have extensive experience and knowledge around farming practices, but may be uncomfortable using modern tools, such as phone apps, and have a lower level of education compared their younger peers. In remote areas, there may also be issues with access to broadband and cell phone coverage.

From my experience, I have noted some older farmers may also be wary of making significant capital investments, as they may prefer to minimise debt as they look into retirement and consider the implications for succession planning. However, having a successor may also be a motivation for participating in a scheme as a way to ensure the long-term viability of the farming business (Wilson 1997).

3.4.1 Key Points to Note on Farmer Diversity

- Understand your group
- Provide one on one support
- Provide several different methods of information transfer

4. CASE STUDIES

4.1 Motueka River Integrated Catchment Management (ICM) Project

4.1.1 Background

The Motueka River Valley Catchment covers an area of 2,170 km^2 in the north west of the South Island, with a population of approximately 12,000 people, including the township of Motueka (Fenemor 2013). Land uses in the Motueka Catchment (Figure 9) varied from undeveloped Department of Conservation (DOC) Land, to forestry, to drystock and dairy, orchards and hops as well as the aquaculture industry, which is reliant on the water quality of the Motueka River where it flows into Tasman Bay. (Fenemor 2013). The Motueka River was also world renown for it’s trout fishery.

The catchment was chosen for the Motueka Integrated Catchment Management (ICM) Project in 2000 as there was rapid economic growth in the area, with corresponding pressures on the environment, as well as a diverse range of land use, water quality and quantity issues (Allen, Fenemor et al. 2011). The design of the Motueka ICM project was intended to demonstrate a collaborative, holistic approach to manage regional-wide resource management issues, with a *“ridge to the sea”* focus (Phillips, Allen et al. 2004), which could then be used as a useful template for managing water in other areas. The Motueka ICM project continued until 2011, when funding ceased.

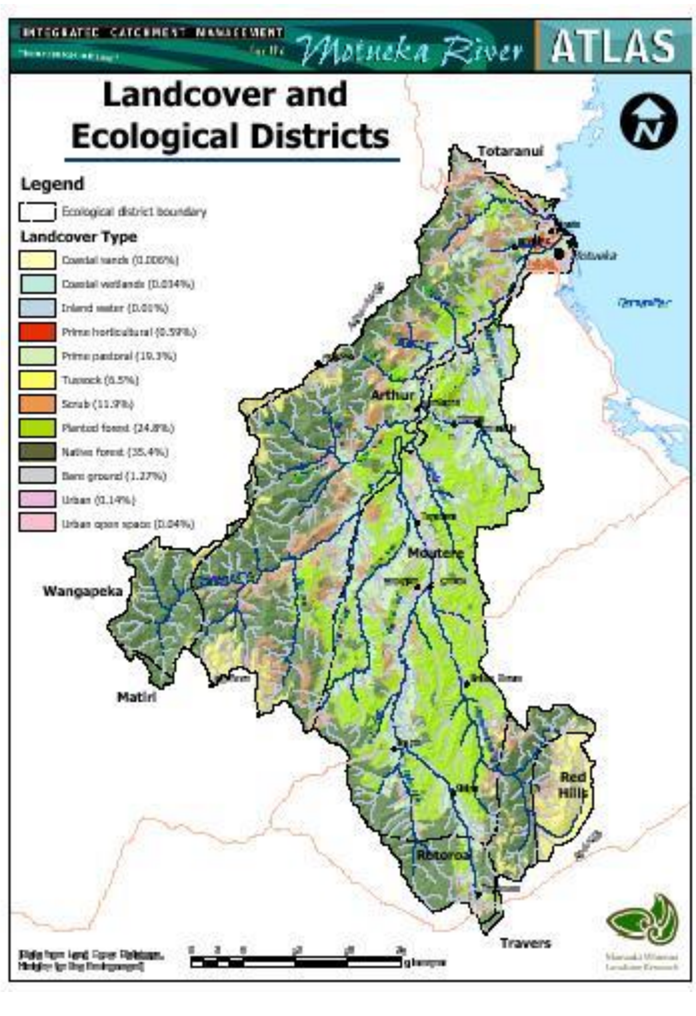

Figure 9: Motueka River Catchment Land Cover (Landcare Research 2017)

The project was led by Landcare Research NZ Limited and primarily funded by the Foundation of Research, Science and Technology (FRST). Other key stakeholders included Crown Research Institutes (Cawthron Institute, GNS, and SCION), NIWA, Tasman District Council and community interest groups, including representatives from local Iwi (Phillips, Allen et al. 2010).

4.1.2 Project Design

Community engagement in the Motueka ICM process started two years prior to the initiation of the project through community meetings and follow up reports and discussions, creation of interest groups, and questionnaires (Bowden, Fenemor et al. 2004). By the time the ICM project was formally launched in 2000, many of the key catchment issues had been identified. The key outcomes agreed by key stakeholders were (Fenemor 2013):

1. Fair allocation of water for competing land uses
2. Effective management of land uses within the catchment to maintain freshwater and marine water quality
3. Develop integrative tools to manage cumulative effects
4. Build human capital to facilitate community action

The collaborative approach used for this project was a three step process: 1. Entry and Contact 2. Knowledge Development and 3. Implementation and Review (Figure 10).

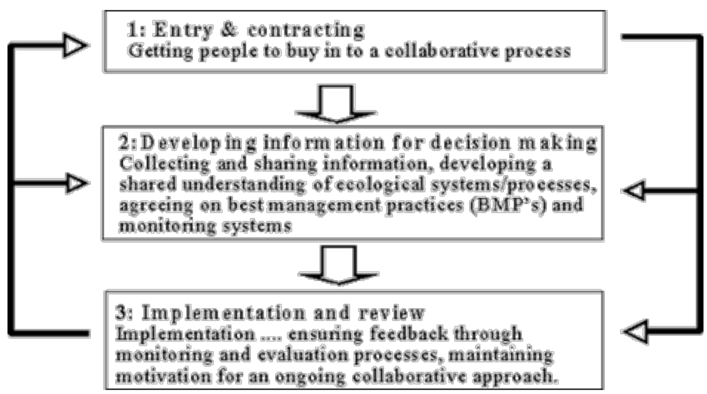

Figure 10: Steps in the Collaborative Process (Allen and Kilvington 1999)

Community Engagement

Step one of ICM process was considered to be the single most important factor in it's success (Phillips, Allen et al. 2010), as stakeholders needed to first build relationships based on trust and respect in order to successfully identify common goals and methods of achieving them.

Allen et. al. (2011) identified the Motueka Catchment as an area with high *"social connectivity"* due to the small and stable population, which had demonstrated a strong engagement in resource management issues prior to the initiation of the ICM project. Despite these advantages, most stakeholders had not participated in a multi-stakeholder process before and the biophysical research team were based around the country, with few having any experience with engaging with the end users of their research.

To ensure on-going community engagement during the ICM project, Davie et. al. (2006) identified three key aspects of communication:

1. Formation of a local Community Reference Group (CRG) to provide a reference point for research
2. Method to disseminate research to resource managers and the community
3. Development of tools to promote continued stakeholder engagement in the process.

The CRG consisted of eight residents of varied interests (e.g. farming, horticulture, fishing and tourism), who met four to six times a year with researchers and policy makers. The CRG assisted researchers with identifying the key areas of concern in the community in which to target knowledge gaps. The researchers were then able to target their projects to address the concerns of the community and communicate the result back in ways which were most useful to them, particularly by utilising informal learning from social networks.

Finally, the ICM project developed and used models for engaging with local Maori (Harmsworth 2001) and evaluating team performance (Kilvington and Allen 2001). A combination of the models and multiple methods of contact with the wider community (Allen, Fenemor et al. 2011) enable on-going collaboration and engagement.

Knowledge Development

Phillips et. al. (2004) suggest the Motueka ICM project as an example of an iterative *Knowledge Management (KM)* process. The first three years consisted of largely research driven objectives, where the results were passed on to stakeholders. Over time, stakeholder understanding of the issues and challenges improved and they were able to contribute to discussions and theories to guide the direction of further research (Figure 11).

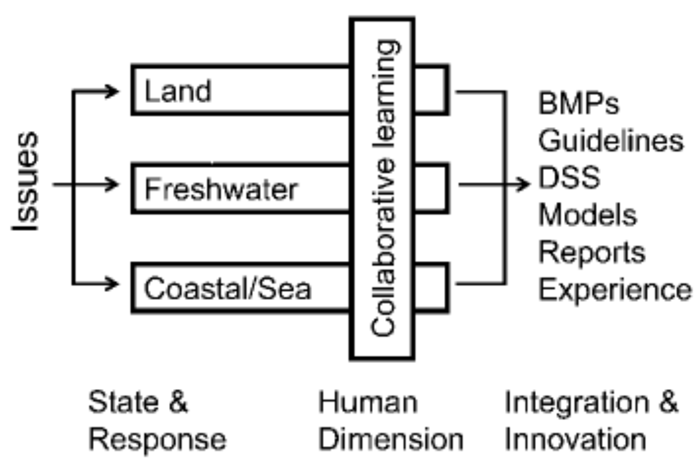

Figure 11: Knowledge Management Approach to Research used in Motueka ICM project(Bowden, Fenemor et al. 2004)

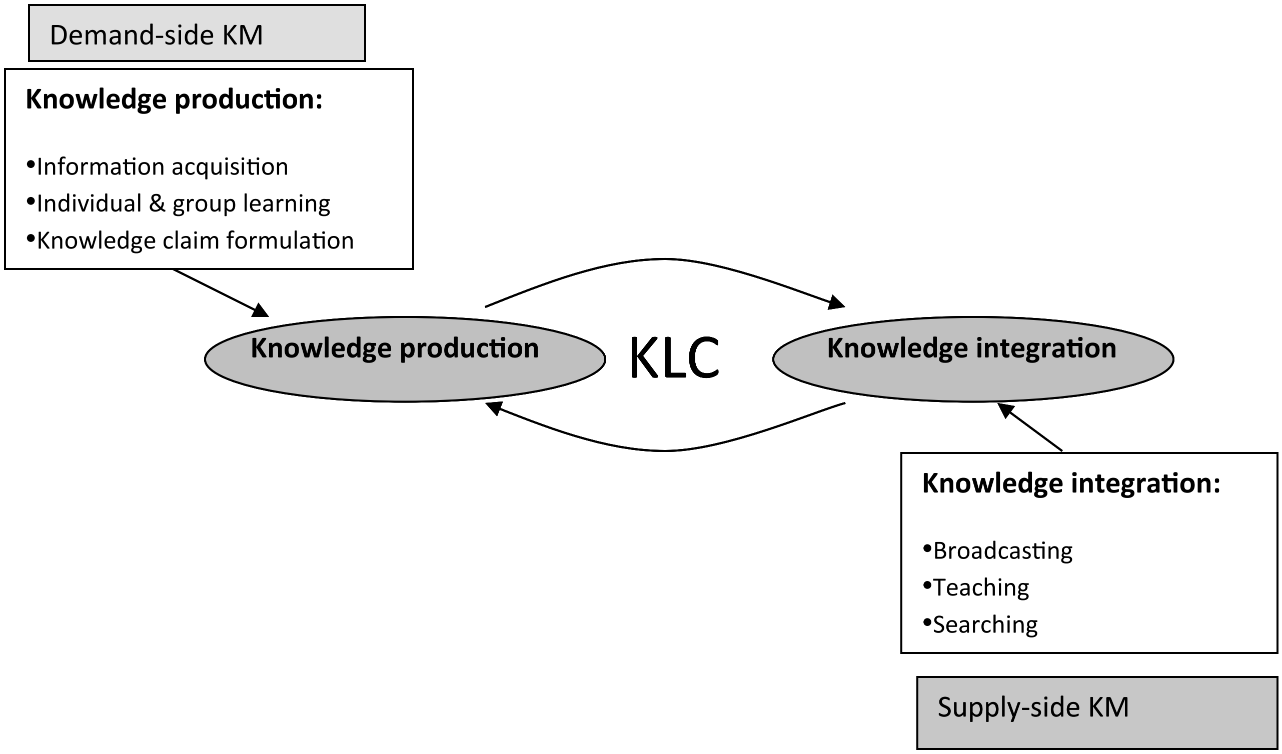

Figure 12: Elements of the Knowledge Management Lifecycle (Phillips, Allen et al. 2004)

Implementation and Review

The last phase of the project was the utilisation of the community driven research outcomes and turn them into practical actions to achieve the desired community outcomes for the catchment. One example of this last phase is the identification of the need to improve riparian planting along the river to improve water quality and create habitat which supports the trout fishery. Researchers worked with farmers in the catchment to identify practical and effective methods of planting and establishing riparian margins (Smaill, Ledgard et al. 2011) and created a series of Good Management Practice guides which could be used around the country.

4.1.3 Project Outcomes

The ICM project also identified, measured and reported a wide range of metrics to determine success (Phillips, Allen et al. 2010) as each stakeholder has their own outcomes they wanted to achieve. Fenemor's 2013 review of the ICM project 10 years after it's initiation (Fenemor 2013) found the key outcomes were achieved and through voluntary community action, rather than regulation. An example of the success of voluntary actions implemented due to this project was seen in the improvement of the water quality in the Sherry River.

Initial monitoring of water quality in the Motueka Catchment found high levels of *E.coli* from the Sherry River, where there were a number of dairy farms bordering the river. All landowners in the area were concerned about these results as they wanted to be able to swim and drink from the river. Further investigation found

E.coli to be higher downstream of river crossings, as a result of the common practice of cows crossing through the river twice a day for milking (Davies-Colley, Nagels et al. 2004).

The results of the investigation into the source of the *E.coli* was presented to the Sherry River landowners, who were then motivated to install culverts at all crossings, which saw a 50% reduction in *E.coli* contamination (Fenemor, Young et al. 2011). Furthermore, the Sherry River Catchment community recognised more work was required to achieve the water quality standards they wanted. Best Management Practices were developed for the catchment (Fenemor, Allen et al. 2013) and all major properties completed environmental plans, designed to achieve an overall reduction in *E.coli* of 80%. Voluntary actions included fencing waterways, riparian planting, and reticulation of stock water supplies.

4.1.4 Factors Influencing the Motueka Integrated Catchment Management (ICM) Project

In my opinion, the Motueka Integrated Catchment Management (ICM) project highlights best practice in the creation of a long-term, sustainable change programme. There are several key components which are likely to have supported the positive resource management outcomes in the Motueka Catchment, and should form an integral part in the development of any future regulation or programme, which are:

1. Long-term project, extending over 10 years
2. Strong culture of trust between stakeholders, with significant time spent building social capital between participants.
3. Catchment had a clear connection between land use activities and water quality and quantity issues
4. Project had a focus on developing the capability of stakeholders
5. Knowledge gaps were identified and research completed to assist decision making
6. Programme was permitted to evolve and standards could be developed as further information and research was undertaken
7. Water quality outcomes were clearly communicated to all stakeholders

Mills et.al. (2008) noted successful programmes should allow up to 10 years to foster these relationships, and should build upon existing networks where possible. The Motueka ICM project is a good example of how successful this approach can be, given enough time. By spanning the project over a period of 10 years, the Motueka ICM project had sufficient time to establish the social capital between stakeholders and build a high level of trust between the organisers, the stakeholders and the scientists in order to achieve the desired water quality outcomes through voluntary measures.

The Motueka ICM also highlights how important it is to have robust information available to support the development of capability and standards in a manner which will promote the uptake of these recommended activities. Bewsell and Brown (2011) found farmers were most likely to adopt practices when they were confident their activities would have a direct effect on the outcomes. This was seen in the Motueka ICM project in the Sherry River, where the source of high *E.coli* was identified, recommended actions were proposed based on this science, which gave the landowners adjacent to the river confidence to invest in the installation of culverts to mitigate these effects. Further monitoring of the river demonstrated to the landowners that these actions were effective, which further built trust by those landowners in the project as a whole. I would suggest this process may have been more difficult if the science was not available to support the development of the recommended actions and provide the feedback of the implementation of those actions.

There are, however, some key factors to the success of the Motueka ICM project which will be difficult to replicate in other catchments in New Zealand. If you were to replicate this project elsewhere there are some things which will need to be considered:

1. Time
2. Small catchment, with existing, stable social networks
3. Direct correlation between land use and water quality outcomes

As could be seen in the 2017 elections, there is a strong public expectation for government agencies to do something to make water quality *"swimmable"* in New Zealand. For instance, in February 2017 the incumbent National Party set a target for ensuring all New Zealand rivers would be swimmable by 2040, which was heavily criticised for allowing too much time to the industries seen to be polluting the waterways. In response to this announcement, a popular freshwater lobby group proposed an alternative plan to improve freshwater quality[6], which would have significant effects on agriculture if implemented. While time is an essential component for ensuring a sustainable outcome, many government regulators may face resistance by their constituents to take action much sooner than is ideal to achieve these outcomes.

Another factor which would assist with the success of the Motueka ICM project, but may not be applicable everywhere, is the highly motivated existing group of stakeholders. Motueka is a small town, with limited mobility, therefore the stakeholder group had high levels of existing social networks. In other areas around New Zealand, for instance in intensively populated cities, it will be considerably more difficult to engage all affected landowners and stakeholders, if at all. Regulations or projects designed to improve water quality need to consider these social aspects when creating these programmes.

Lastly, one major advantage of the Motueka ICM project was the direct correlation between land use activities and water quality. Botha et.al. (2013) highlights the importance with connecting farmer activities with water quality outcomes. There are other catchments in New Zealand where water quality is deemed to be under stress, but the correlation between specific land use activities and water quality are not as clear. For instance, in Mid- Canterbury, groundwater quality has declined over the past 20 years through a general intensification of farming and industrial activities. Effects on water quality through farming activities are not directly related to any one farm, or group of farmers, rather it is the accumulation of nutrient losses from farming over the entire Canterbury Plains over a significant period of time. While programmes in Canterbury can monitor groundwater quality, it is likely any positive results from improving on farm activities will take between 10-20 years to be seen in the groundwater, unlike in the Sherry River catchment, where improvements in water quality were seen within months of the installation of the stock crossing culverts. Any programme in a catchment where on-farm activities are not directly connected with water quality outcomes, needs to still ensure quantitative measurements are still undertaken and fed back to participants in order for them to have confidence their actions will have an effect.

[6] https://www.freshwaterrescueplan.org/the-plan/

4.2 Synlait – Lead with Pride

Synlait Milk Limited's Lead with Pride programme was reviewed through a survey developed by myself to understand their programme in the context of the themes identified in the literature. There have been no scientific reviews of the programme to assess the effectiveness of the programme. Full details of the survey are listed in Appendix 1 – Lead with Pride Questionnaire and Response.

Synlait Milk Limited is a small, Canterbury-based milk supply company which specialises in exporting value-added, high quality milk products, such as A2 infant formula, from about 200 suppliers. Synlait established their ISO IEC 17065 accredited Lead with Pride (LWP) programme in 2013 to produce an industry best practice milk product which could be traced from the grass, to the cow, to the can. The cornerstone of the LWP programme is to reward excellence and achieve best- or leading- industry practice for the four pillars; Environment, Animal Health and Welfare, Social Responsibility and Milk Quality. Synlait want to not just recognise and reward those who would meet all these standards anyway, but to encourage these practises and move the dairy farming "bell curve to the right".

Synlait currently has 47 certified "best" practice suppliers (Gold Plus) and 3 certified "leading" practice suppliers (Gold Elite). Suppliers who achieve "Gold Plus" or "Gold Elite" standards are paid a premium of up to $0.12 per kgMS for the milk they produce. Collectively these 50 farms can supply sufficient milk to deliver a certified "best practice" milk product to market.

Development of the standards set by the programme are reviewed twice a year with farmer representatives, Synlait staff, and AsureQuality[7] staff to discuss progress and effectiveness of the programme, with updates given to a stakeholder group once a year.

To maximise engagement by suppliers, Synlait provide a complete set of the expected requirements to be achieved and a records book to assist with the collection of the information needed to demonstrate the requirements are being met. Synlait also provides dedicated and highly qualified staff to assist suppliers on a one on one basis, and run focus days twice a year to support further education. All suppliers receive a monthly newsletter and access to a social media page to highlight successes and communicate good practice ideas. The one on one contact enables Synlait to treat each farmer differently, according to their individual needs. The frequent, positive contact with Synlait staff allows the development of the relationship and build trust over time.

Synlait's measure of success for the Lead with Pride programme is to have sufficient volume of "certified" milk to create a separate product stream, which is then purchased by a customer at a premium. With the 50 certified suppliers, there is currently sufficient volume to achieve this outcome, but work now needs to get started to market this product.

[7] Accredited auditing authority

4.2.1 Factors influencing the Sustainability of the Lead with Pride Programme

Synlait's Lead with Pride programme is unique within New Zealand's dairy industry and is to be commended for investing the time, effort and resourcing to ensure the programme is a success.

The key factors of the programme which will enhance their success include:

1. On-going one on one support with stable, knowledgeable and experienced staff
2. Voluntary programme with clear incentives to participate
3. Holistic, whole farm approach
4. Clear objectives and targets to be met
5. Auditable outcomes developed with farmer representatives
6. Regular auditing and follow up ensure outcomes are being met and maintained
7. ISO
8. Creating a community of certified suppliers provides on-going support

One of the most positive aspects of the LWP programme is the on-going support provided by the company by competent and knowledgeable staff. Fisher (2013), Mills et. al. (2016), and Botha (2013) were just a few who indicated trust in people was the most significant factor in whether or not a farmer would take on board the message and values of a programme. The stable and constructive relationship between suppliers and Synlait staff will underpin the overall success of the programme.

The other factor which will enhance uptake of better practices by suppliers are the clear and auditable standards and incentives, which are reviewed by the company and farmer representatives. Black (2000) and Blackstock et.al. (2010) noted the need to have clear standards, which are relevant to the participants, preferably through including them in their development. By including farmer representatives with the on-going development of the LWP standards, Synlait will be more likely to improve their uptake.

From a marketing perspective, the ISO structure of LWP provides a robust, internationally recognised standard, which can be trusted by future customers to ensure the proposed standards are being met. Furthermore, by limiting LWP to Canterbury dairy platforms, there is less likelihood of the standards becoming irrelevant to the suppliers, which was highlighted by Palmer et.al (2009) as needing to be avoided to maintain supplier trust in the programme.

The final theme of the LWP programme which could be particularly useful for improving the long-term sustainability of the programme, is the creation of a LWP-certified supplier community. While a LWP community in it's infancy at the moment, Mills et.al. (2008) highlighted a strong correlation between participation in a group and participant uptake of the group's values and expectations. Synlait could also take advantage of Yang and Sharp's (2017) finding of the best practice *"contagion"*, whereby best practices are *"caught"* by neighbours.

I would strongly recommend Synlait continue with creating opportunities for LWP-certified suppliers to learn from each other, and participate in the development of the auditable standards to enhance the potential uptake of the behaviours and values the LWP programme is trying to foster.

While Synlait's LWP programme includes many factors which enhance the potential for suppliers to make sustainable, long-term changes to their farming practices, there are a few areas which may be inconsistent with the literature, which could undermine the overall success of the programme. I would recommend Synlait reconsider the following aspects of the LWP programme to maximise the positive influence of the programme on their supplier's practices and ensuring overall success of the programme:

1. Drivers for uptake participation in LWP
2. Measurements for success of the programme
3. Have a clear process determining how standards for *"best-"* or "*leading-"* practices are set.

The primary reason for a supplier to become LWP certified is to earn the $0.12/kgMS premium for their milk. While Moon and Cocklin (2011) suggest financial incentives improve the participation rates in voluntary programmes, Dwyer et.al. (2007), Mills et.al. (2016) and Burton (2011) found extrinsic motivators, like financial incentives, taxes or regulations, tended to be unsuccessful with imparting the values the programme was trying to promote. Furthermore, with only a 25% participation rate for Synlait suppliers, I question whether the financial incentive is currently sufficient to meet the long-term outcomes of the programme. If Synlait wishes to increase participation in LWP, I would recommend they re-evaluate the barriers and motivators of those who are not involved and tweak the incentives and communications with suppliers to address these issues.

One other area where I believe Synlait may be able to make improvements to encourage long-term, sustainable practice changes by suppliers is to re-assess how success is measured. Programmes where there are clear links between the farmer activities and desired outcomes are shown to have higher uptake of the required practices (Wilson 1997, Pahl, Weier et al. 2007). By measuring success solely on meeting marketing drivers, the farmers doing the work on-farm may not understand the tangible improvements their efforts are contributing too. I recommend Synlait re-consider their measurements for success of the LWP programme to include Key Performance Indicator's which highlight the specific collective outcomes achieved by the LWP-certified suppliers, and to ensure these success are communicated back to the participants.

The last factor which occurred to me, relates to ensuring the on-going marketing potential of the LWP programme. It was unclear to me how *"best-"* or *"leading-"* practice was initially defined in order to create the standards within each of the four pillars. I would recommend Synlait continue to work with national and international industry good organisations to ensure the standards being set meet consumer expectations of *"best-"* or *"leading-"*management practices.

Overall, Synlait's Lead With Pride programme has the foundations to ensure sustainable, long-term uptake of the industry best practices are being implemented by their LWP-certified suppliers and provides New Zealand dairy companies with an excellent example of how voluntary programmes can drive the changes the community wants to see.

5. CONCLUSION AND RECOMMENDATIONS

I have come to the conclusion that sustainable change programmes are not about KPIs, or data metrics, regulations or, indeed, water quality, but are in fact about people. Once we engage the hearts and minds of the participants in the programme, then the rest will follow.

Improving water quality to be *"swimmable"* is a complex issue and complex issues require complex solutions, collaborative thinking, and growth of human capacity. As seen with the Motueka ICM and Synlait Lead with Pride case studies, no one method is more successful than any other, provided the programme is tailored for the group needing to implement the changes. No single approach will be suitable for every circumstance, however this project has identified some common themes which should be considered in the development and implementation of these types of programmes to improve the chances of success.

The most consistent theme I identified was the need to build trust. Programme organisers need to ensure farmers could trust the people they worked with, can trust each other and other stakeholders, they need to trust the information they were provided and they need to trust the tools being recommended as a *"solution"*. Without trust, there will be limited engagement and uptake of the desired changes. Every interaction with a participant is an opportunity to build, or lose, trust. Therefore, supporting multiple positive interactions between participants, implementers and key stakeholders will support the development of trust between all those involved. Investment in high quality people, who know how to deliver the message competently is a critical part of building trust.

An essential component for any high-trust programme was therefore *time*. Sufficient time allows for the development of social capital, build trust between participants and organisers, create and communicate new technology and to invest in research. Development of social capital supports collaboration between key stakeholders to clarify the vision to ensure the project achieves targets the desired outcomes. The literature also identified a need to engage participants early on and enable their contribution at the development stage of any programme, where possible.

The next step is to identify the values of the community involved with the programme. Are they aligned with the goals and objectives of the programme, or is there a significant disconnect? It is useful to focus on the common goals of various stakeholders and identify and address knowledge gaps which may account of differences in values.

Any group of people will also have a diverse range of values, goals in life, ideas of success, capability and education. Organisers also need to understand the dynamics within their particular group, as well as key stakeholders who are involved with setting the expectations. Once the demographic of the group is identified, organisers need to ensure all key messages are delivered in a varied fashion in order to maximise the potential for improving capability.

Furthermore, it is also useful for creators of programmes to understand how much needs to be achieved, by when and also understand the existing capability of the group in order to develop a structure which is suitable for that particular context. For instance, a group of highly engaged, well-educated and technically savvy farmers may have the best results with a bottom-up, iterative process, whereas a group of farmers who are closer to retirement and uninterested in change may need to have a more top-down approach. Where there is a large group to co-ordinate, it may be more appropriate to have something in between.

Expected timeframes and available resourcing is another consideration for organisers when establishing whether more regulatory, top-down approaches are more fitting than labour- and time-intensive collaborative or bottom-up approaches. Top-down approaches are often effective in the short term, but are less likely to result in enduring, sustainable change in participants. Alternatively, bottom-up or extension focussed programmes tend to build capability and have a greater likelihood of the values of the programme being accepted by participants, however these programmes need highly qualified people and tend to be much more expensive and time-consuming to implement.

Participants also need to understand what success looks like and the outcomes of the project need to be fed back to (ideally) show how the actions taken are achieving the desired outcomes. Feedback could include benchmark reporting of KPIs and monitoring results, by enabling discussions between peers or provide one on one support. The method of feedback needs to vary according to the needs of the group expected to make the changes.

The structure of a programme is another key consideration which will depend on what outcomes the organisers intend achieve through the programme. Synlait’s Lead with Pride programme is focussed on engagement of suppliers, so it makes sense in their case to have a voluntary programme. However, when the New Zealand government wanted to collect standardised water usage data, then a mandatory approach was more appropriate. It is important to understand the drivers and barriers to participation and engagement when using these different methods to ensure the most appropriate structure is utilised for the programme.

5.1 Recommendations

Based on these key points, I recommend the following:

1. Sustainable change programmes need to consider who trust, values, diversity, expected timeframes, and measures of success
2. Project developers and implementers need to ensure they focus on the right issues, to collect the right information and to communicate everything in the most effective way

I have summarised these points in Figure 13 and Figure 14 in order to highlight some of the questions which need to be answered when creating and implementing a programme successfully.

I know I will use this information to reflect on what I have created for Barrhill-Chertsey Irrigation Limited and identify how I can improve my relationships with shareholders and enhance their engagement with the ASM programme.

He aha te mea nui o te ao
What is the most important thing in the world?
He tangata, he tangata, he tangata
It is the people, it is the people, it is the people
Maori proverb

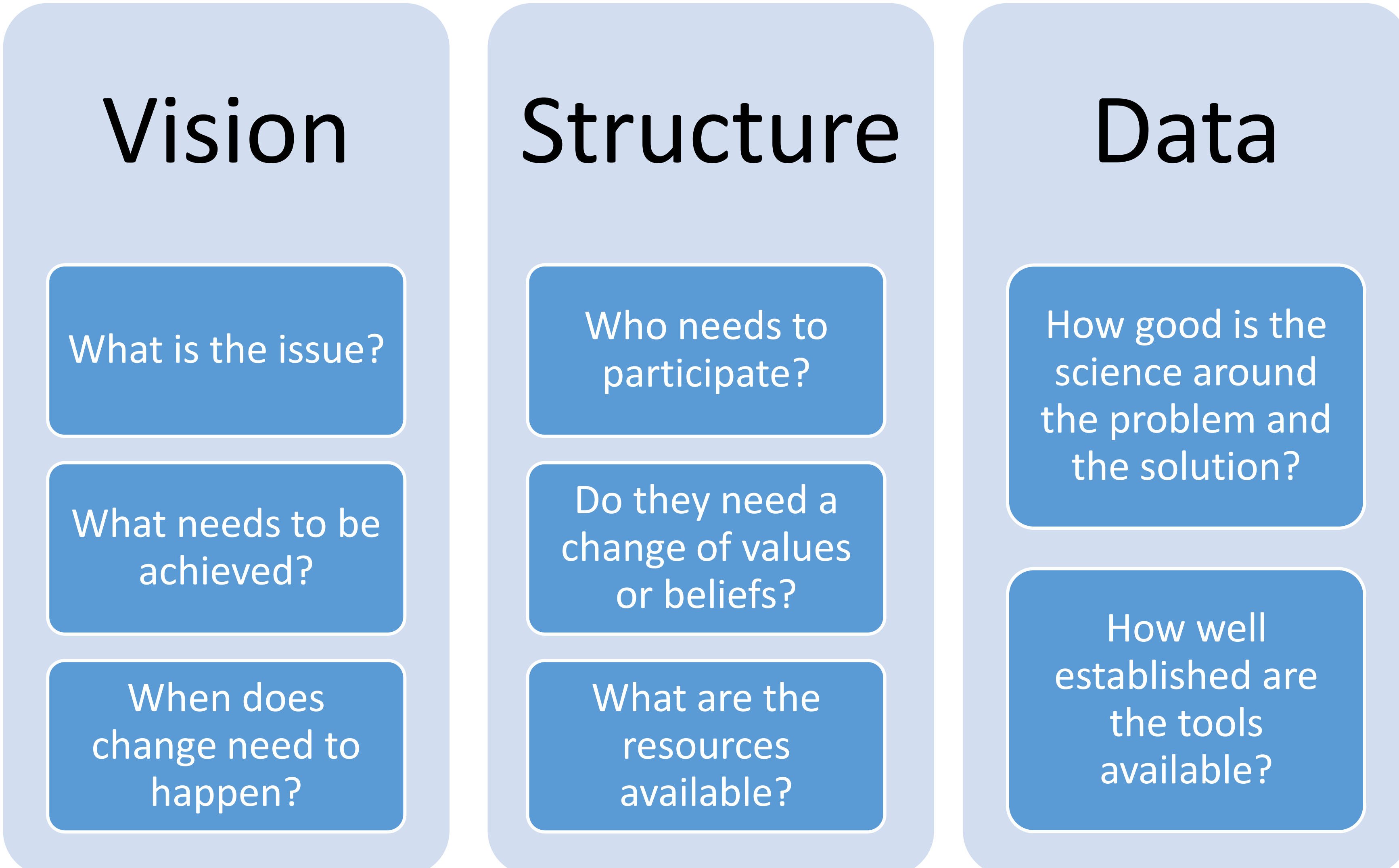

Figure 13: Points to Consider when Creating a Programme

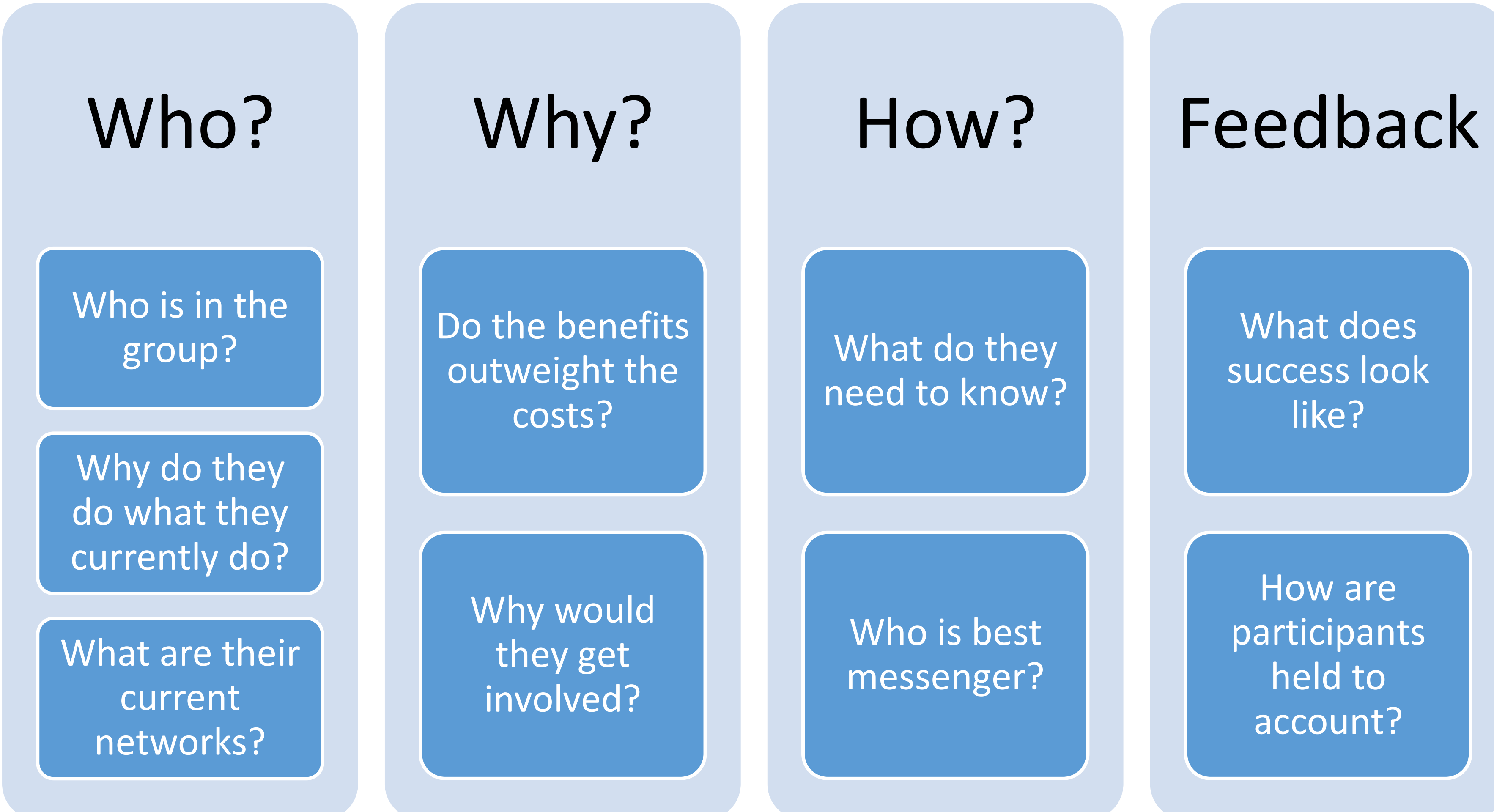

Figure 14: Points to Consider when Implementing a New Programme

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APPENDIX 1 – LEAD WITH PRIDE QUESTIONNAIRE AND RESPONSE

Contact Details	
Company	Synlait Milk Limited
Contact Name	Emma Brand & Mark Wren
Contact Position	Environmental Advisor & LWP Manager
Contact Details	emma.brand@synlait.com
Programme Details	
What is Synlait's vision for their Lead with Pride programme?	To capture and prove best practise dairy farming over the four pillars of farming with our suppliers and to extract a value chain through to the customers in our markets. We want to not just recognise and reward those who would meet all these standards anyway, but to encourage these practises and move the dairy farming "bell curve to the right".
When did the current programme start?	Launched Lead With Pride (LWP) 2013
What prompted Synlait to initiate LWP?	There is a growing focus from consumers across the globe about where their products originate from. The program was developed so that we can prove that there has been good practice and policies in place right from the grass, cow, to can.
How many properties and suppliers are involved?	We currently have 42 certified suppliers, 39 at the Gold Plus level, 3 at the Gold Elite level.
Has Synlait attempted something like LWP before? If so, how does the current programme differ?	No
What are the key values of Synlait's LWP programme?	Integrity, transparency, collegiality and commitment to continual improvement.
What are the key principles of your approach to LWP?	The principles are aligning the program outcomes with the suppliers vision for their farm, to facilitate the progression through to certification and celebrate the achievement.

Motivation	
Is the programme mandatory or voluntary?	Voluntary.
How do you ensure the programme is implemented by suppliers? - Carrots? - Sticks? - Support? - Follow Up/Audits?	The programme is advertised throughout many Synlait campaigns. For those that decide to apply to be a part of the programme, 1 on 1 support and guidance is given till their initial audit, then follow up support is given if required from then on, with a re-audit once a year from certification.
What steps have you taken to communicate the values behind the LWP programme to Synlait suppliers?	LWP is a core programme within the Synlait vision. The programme is communicated in many different ways: newsletter, conference, field days, media releases.
How have you tried to incorporate good practice into being a "Good Farmer"?	No
Engagement and Participation	
How does Synlait engage suppliers with the LWP programme?	Prior to certification, constant engagement with suppliers to track their progress and give any assistance required. Once certified, communication with the suppliers for implementation is as required by supplier. If they need assistance, then they communicate directly to either Mark or Emma. Two LWP Focus days are organised throughout the year which are designed to educate.
How much influence do suppliers have on the development of: - Identifying key outcomes through LWP? - Synlait LWP auditable practices? - Property practices?	Twice a year there is a LWP Standards group. In this meeting, SML staff, AsureQuality staff and some farmer representatives come together to discuss the progress of LWP and if there are any changes required to be made. This could be through the complete requirements, the auditing etc.
What steps have been taken to encourage suppliers to uphold the values behind LWP?	There is a financial benefit for those that are on the LWP program. 6c in total, broken down into 2c for being certified, 2c for having low SCC, 2c for being grade free. Once a year suppliers have an audit to ensure that they are keeping up with on farm requirements.

How do you encourage suppliers ownership of issues on their property?	Suppliers that are on the programme are generally very open to 'constructive feedback'. At the initial visit we look at the infrastructure and high costing elements to ensure that there are no 'deal breakers' to joining the program. For other things that are required, the LWP team generally advise and encourage changes to be made, and suppliers are very open to change if they can be shown the benefits to on farm good practice.
Education and Support	
What support do you provide to suppliers to ensure good LWP practices are being implemented?	As above, ongoing support prior to certification, then as required post certification with re-audits annually. LWP focus days twice a year to provide regular contact.
Who provides on-going support to suppliers? What personal attributes does this person(s) have which support: - Building a trusting relationship with suppliers - Tailors approach to different learning styles	LWP team, and the Area Managers are in constant communication with all suppliers (not just those on the programme). Each farm is worked with differently once the style of learning and organisation is recognised. A trusting relationship is formed as time spent with them increases, and following through with assistance when required.
How do suppliers know the information you have provided to them will assist with meeting the overall outcomes of the programme?	Trust.
What systems or tools have you put into place to assist suppliers and managers with meeting your requirements?	There is a LWP records book that is given to every farm either certified or working through the programme. A Complete Requirements is also given to each farm which outlines the full set of requirements to comply with the programme. As the programme develops on farm, some farms make their own check sheets / books that keep them on track with tasks.

Trust	
How do you build trust with your suppliers so they feel comfortable reporting issues to you?	Building a relationship with them by matching the right personalities to the right people. Gain an understanding of what the farmers are trying to achieve, and assist them to get to that place.
Reporting and Benchmarking	
What is your measure of success?	When auditing, there is a score out of 100 for each pillar, to pass the audit, they need to get at least 70 points per pillar. The number of farms certified is now at a stage where there is enough volume of milk to be able to stream and produce a product, success will be when a customer has been signed up to stream the milk into a particular product.
How do you provide feedback of success (or not) to: - Synlait board? - Group Managers? - Complex Managers? - Farm Managers? - Suppliers?	There is a stakeholders group once a year which involves the CEO and General managers at Synlait to give an update on the programme. Any update to suppliers on success is communicated via the monthly supplier newsletter. If anything needs to be urgently communicated, then it is done via email.
General Comments?	

Appendix 3

Fenemor - A Summary of Outcomes and selected formal publications from the Integrated Catchment Management (ICM) research programme: 2000 – 2011

INTEGRATED CATCHMENT MANAGEMENT for the Motueka River

• ridge tops to the sea •

A Summary of Outcomes and selected formal publications from the Integrated Catchment Management (ICM) research programme:

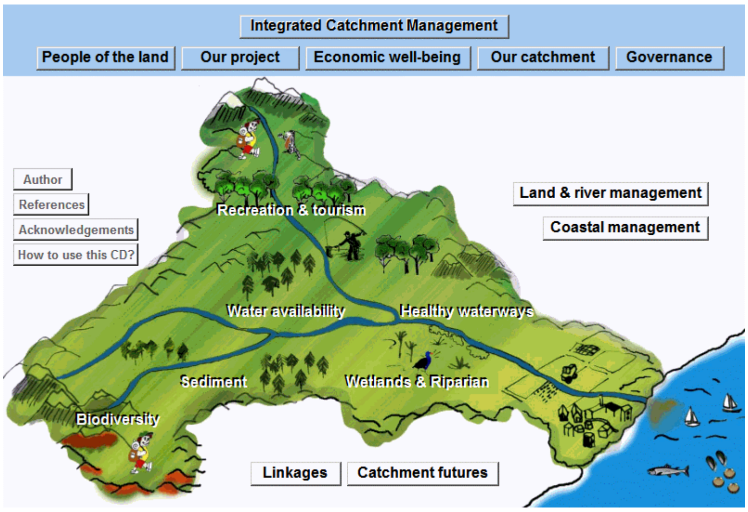
2000 – 2011

Andrew Fenemor
Programme Leader ICM
Landcare Research

2013

Research issues addressed

1. Allocation of Scarce Water Resources among Competing Land & Instream Uses



- How do local land uses affect the availability of ground and surface water over the entire catchment?
- What is the most defensible way to plan for the allocation of water resources among competing alternative uses?
- How much water is required to maintain instream values?
- How do economic returns affect landowners' and recreational uses of water?

2. Managing land uses in harmony with freshwater resources

- How is sediment mobilised to reach rivers, and what impacts does it have?
- What information is needed to best manage river gravel allocation?
- Why has the Motueka catchment trout population declined then partially recovered?
- How can water quality be maintained or improved with intensifying land use?
- Are there some fundamental solutions to water quality contamination?
- Is riparian re-vegetation the 'silver bullet' for improving water quality?

3. Managing Land and Freshwater Resources to Protect and Manage Marine Resources

- What are the risks to marine farming from activities on land?
- What are the factors that increase or decrease the production and values of fish and shellfish?
- Where are the faecal bacteria affecting marine farms coming from?
- What are the relative effects of river flows (especially floods) on scallop and mussel production compared to activities like dredging and marine farming?

4. Integrative tools and processes for managing Cumulative Effects

- What are preferred development pathways to ensure continued sustainable management at catchment scale?
- What are the opportunities for using modelling to predict cumulative effects of land use scenarios?
- How can models help decision-makers balance environmental impacts alongside social, economic and cultural benefits when planning for further development?

5. Building Human Capital and Facilitating Community Action

- What methods would best motivate environmental stewardship by catchment and community groups?
- What methods can we use to promote effective interaction between scientists, resource managers, and the community?
- How can iwi build their capability in the resource management process?
- What are some 'off the wall' examples of innovative and enduring community engagement that we could use to facilitate community action?

What has the ICM research programme achieved?

1. Allocation of Scarce Water Resources among Competing Land & Instream Uses

Water Allocation: Allocation of river flows for irrigation vs the nationally recognised trout fishery was a focal point of the negotiated agreement on the Motueka Water Conservation Order, gazetted in 2004. Water allocation limits were set for the Upper Motueka catchments in TDC's Resource Management Plan and are now being updated based on water allocation scenarios in GNS river-aquifer modelling (see below).

ICM research with the Ecologic Foundation and water stakeholders used the Motueka catchment as a case study to identify how water use flexibility can be enhanced and security of supply better understood, through changes to the RMA or regional council water allocation policy. Options include flow sharing and water quality management through catchment farmer groups, changes to water permit specifications and proposals to encourage transfers of water permits. This work addressed issues now relevant to the Land and Water Forum. Models predicting how in-stream habitat will change with flow have been used to assist flow management decisions.

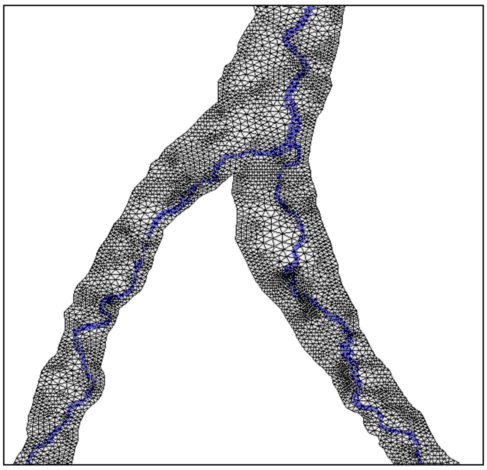
Water governance remains a priority issue for the new Government and the TDC. In 2008-09 we completed a survey of 56 stakeholders from 4 South Island regions and 5 catchments about their RMA water plan development process, and proposed a 'straw man' for improving RMA performance for water allocation and water quality management.

Contacts: Andrew Fenemor (Landcare Research), Jim Sinner (Cawthron Institute), Mary-Anne Baker (TDC)

Fenemor, A.D.; Neilan, D.; Allen, W.; Russell, S (2011). Improving Water Governance in New Zealand – Stakeholder Views of Catchment Management Processes and Plans. Policy Quarterly 7(4):10-19

Fenemor, A.D.; Davie, T.; Markham, S: 2006. Hydrological information in Water Law and Policy: New Zealand's devolved approach to water management. Chapter 12 in Hydrology and Water Law – Bridging the Gap (eds. J Wallace and P. Wouters). IWA Publishing London.

Groundwater Dynamics: Managing increasing demand for irrigation from groundwater in the Upper Motueka valley requires knowledge of how these alluvial aquifers interact with the Motueka and tributary rivers, and how groundwater pumping indirectly impacts aquatic ecology.



With GNS and TDC, a FEFLOW spatial model has been calibrated to predict changing groundwater levels and river flows for the upper Motueka, based on geological mapping, river flow gauging and well monitoring. Soil moisture experiments on Korere and Waiwhero farms quantified the small contribution of hill slopes runoff to groundwater recharge. Dating the alluvial groundwater shows it has been underground only 1-3 years. Irrigation scenarios have been run through the FEFLOW model to understand how different levels of irrigated land use influence river flows and ecology, how climate change may affect river flows and groundwater yields, and what impact a changing river bed level might have on the groundwater table.

Contacts: Chris Daughney(GNS), Joseph Thomas (TDC), Andrew Fenemor (Landcare Research), Jagath Ekanayake (Landcare Research), Mike Stewart (GNS)

Gusyev M;Toews M; Daughney C; Hong T; Minni G; Ekanayake J; Davie T; Fenemor A; Basher L; Thomas J. (in press). Groundwater abstraction scenarios implemented in a transient groundwater-river interaction model of the Upper Motueka River catchment. J Hydrology (NZ).

Water Use Economics: Out-of-stream water allocation for irrigation is driven by returns for primary production. Paul White completed a 5-year survey of 17 agricultural users of groundwater in the Waimea Plains, to assess the economic drivers of groundwater use. This work shows the influence of lifestyle block demand and changes in apple prices on groundwater use.

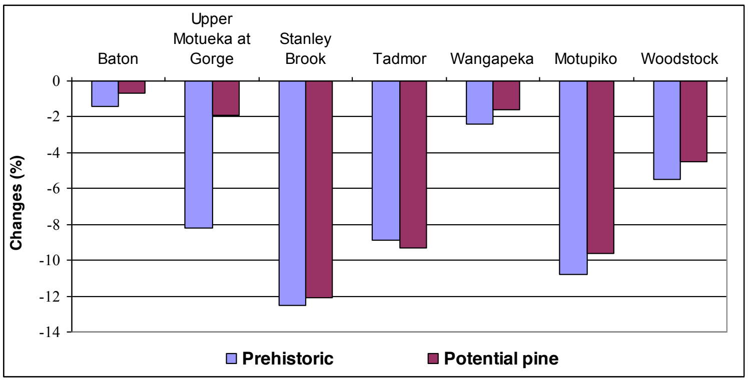
The costs and benefits of the Tadmor water augmentation scheme (Hope River diversion) were evaluated, and indicate net positive financial returns for irrigation water users of diverted water. A companion study of ecological costs and benefits concluded that the river diversion has not affected water quality or river ecology in the Tadmor River.

Contacts: Andrew Fenemor (Landcare Research), Paul White (GNS), Dean Olsen (Cawthron)

White PA. 2011. Economic drivers of land use and groundwater use by irrigators, Waimea Plains Nelson, New Zealand. New Zealand Journal of Marine and Freshwater Research 45:513-524

2. Managing land uses in harmony with freshwater resources

River and coastal hydrology: Changes and intensification of land use have impacted stream flows and water quality. Computer models help us understand why these changes occur. We have calibrated a SWAT catchment water balance model to compare the effects of different vegetation cover throughout the catchment on river flows. We have also developed a simple water balance model WATYIELD for unmonitored catchments to estimate how streamflows will change if land cover is changed (eg planting or cutting down forests).



The Motueka catchment SWAT flow and contaminant model showed that river flow at Woodstock is about 21% higher now than under prehistoric bush land cover, and with maximum possible afforestation would be about 16% higher. Nutrient flows down the river systems have been modelled using SWAT and bacterial inputs to the bay have been predicted using a faecal die-off model. Simulated Motueka river and contaminant flows feed into the Tasman Bay coastal circulation and ecosystem models to understand catchment impacts on the bay. Model results from the IDEAS model (see below) predict broad-scale in-stream and marine impacts of future land use and aquaculture scenarios.

At a more detailed scale, PhD graduate Kiran Kumar has shown that the average daily transpiration (February to April) rate of crack willows in the Waiwhero wetland was more than four times that estimated for pasture,

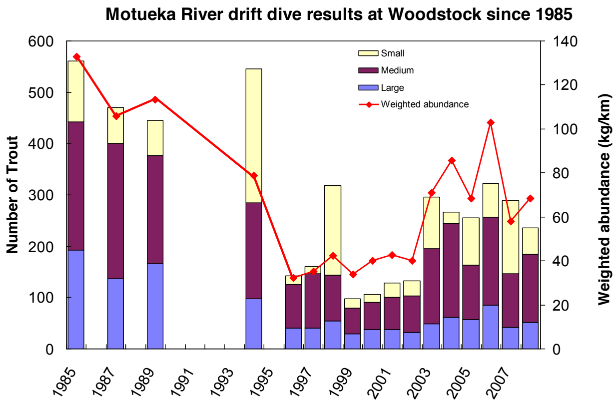
Contacts: Jagath Ekanayake (Landcare Research), Tim Davie (Environment Canterbury), Andrew Fenemor (Landcare Research)

Fahey, B; Ekanayake, J; Jackson, R; Fenemor, A; Davie, T; Rowe, L. 2010. Using the WATYIELD water balance model to predict catchment water yields and low flows. Journal of Hydrology NZ 49(1): 35-38.

Cao W, Bowden WB, Davie TJA, Fenemor A 2008. Modelling impacts of land cover change on critical water resources in the Motueka River Catchment, New Zealand. Water Resources Management, April 2008. SpringerLink

Sediment Impacts in River and Coastal Ecosystems: Sediment is blamed for deteriorating fish habitat in rivers, and has major impacts on scallop resources in areas off the river mouth in Tasman Bay.

Using a monitoring network of suspended sediment samplers in the catchment, set up in conjunction with TDC and NIWA, we have shown the importance of localised large, infrequent floods for sediment generation and dispersal and have also been documenting how sediment generation varies during the forest harvest cycle.



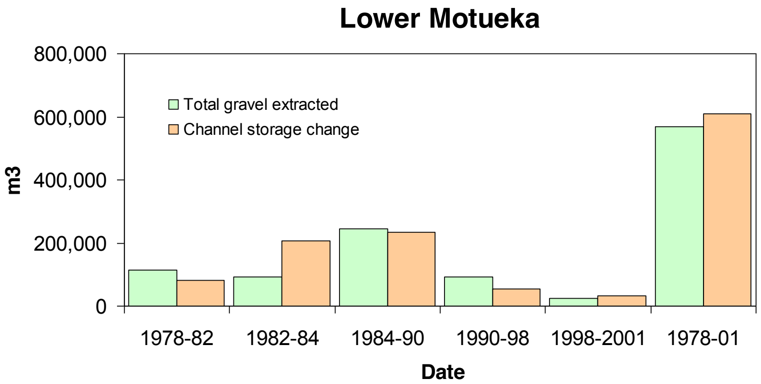
A 50 year storm at Easter 2005 in the upper Motueka/Motupiko raised sediment yields by 10 times in the affected area and by 2-3 times at the coast. This effect has persisted for the last 4 years with yields slowly returning to pre-storm levels. Heavy metals from a mineral belt in the upper catchment have been tracked from that storm down-river into the seabed sediments of Tasman Bay with their concentrations exceeding criteria for ecosystem health within the coastal river plume. These infrequent storms have a profound influence on long-term sediment yields.

We have developed a riverbed substrate monitoring method to quantitatively link fine sediment occurrence with aquatic habitat suitability. It provides data on fine sediment abundance that complements biological surveys such as drift dives to measure trout numbers.

Contacts: Les Basher (Landcare Research), Murray Hicks (NIWA), Chris Cornelisen (Cawthron)

Basher, L.R., Hicks, D.M., Clapp, B., Hewitt, A. 2011. Sediment yield response to large storm events and forest harvesting, Motueka River, New Zealand. New Zealand Journal of Marine and Freshwater Research 45:333-356

Sustainable River Gravel Extraction: Catchment stabilisation works, revegetation since the bush clearance days and gravel extraction have led to a gradual decline in riverbed levels, and the need to limit gravel extraction from rivers.



An ICM study with TDC reviewed bed level changes based on 40+ years of river channel cross-section surveys in the Motueka river. It confirms the general degradation trends but finds that more information is needed on gravel transport mechanisms, especially during floods.

Periodic river cross-section surveys are the primary tool used by most regional councils to monitor river bed levels and to help set gravel extraction limits but these have significant limitations for accurately establishing gravel supply rates. Annual GPS surveys ('3 beaches') have better defined gravel volume changes, and are being used to assess how well the present river cross section network reflects bed level and gravel volume changes. They show that the cross sections under-estimate the changes in gravel volumes stored in the river bed, but the work confirms the continuing lowering of riverbed levels. This type of investigation can establish an average sustainable gravel supply that can be adjusted following large flood events. It also shows how constraining the width of gravel-bed wandering rivers leads to channel lowering and limits replenishment of the gravel resource on bars where gravel is typically extracted from.

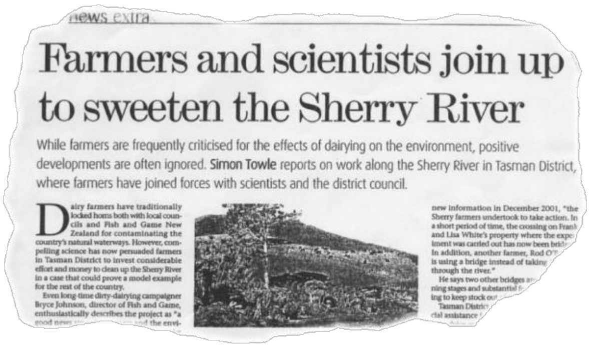
Contacts: Les Basher (Landcare Research), Ian Fuller (Massey Univ), Eric Verstappen (TDC)

Land Use Impacts on Water Quality: Early water quality research identified areas of concern in one part of the catchment, particularly related to the daily crossing of streams by cows.

Through working collaboratively with the dairy farmers, sheep and beef farmers, and forestry companies the bacterial water quality of the Sherry River has been improved by more than 50%, initially through bridging dairy crossings and forestry crossings. This work has been followed by further water quality sampling in conjunction with TDC which shows an improvement in river water quality, though not to swimmable standard at times.

Close ties with the local community and with the NZ Landcare Trust and TDC staff have built trust and a collaborative approach. A 2007-2010 SFF project assisted the Sherry Catchment Group to complete Landowner Environmental Plans now being implemented to improve water quality to a target 80% reduction in *E.Coli*.

Best management practices (BMP/GMPs) for the range of land use types in the Sherry were developed and a BMP library established on the ICM website http://icm.landcareresearch.co.nz. These were used in a partner project with TDC on whole catchment nutrient budgeting with landowners in the Motupipi catchment, funded through Envirolink. Water quality responses have been monitored by TDC and NIWA in the Sherry, and showed that floods transport most of the bacteria and phosphorus, but low flows carry most of the nitrate. Therefore different mitigation approaches are needed to manage both. At a whole catchment scale we have developed and calibrated a model that tracks faecal bacteria movement and die-off.



news extra

Farmers and scientists join up to sweeten the Sherry River

While farmers are frequently criticised for the effects of dairying on the environment, positive developments are often ignored. **Simon Towle** reports on work along the Sherry River in Tasman District, where farmers have joined forces with scientists and the district council.

Dairy farmers have traditionally locked horns both with local councils and Fish and Game New Zealand for contaminating the country's natural waterways. However, compelling science has now persuaded farmers in Tasman District to invest considerable effort and money to clean up the Sherry River in a case that could prove a model example for the rest of the country.

Even long-time dirty-dairying campaigner Bryce Johnson, director of Fish and Game, enthusiastically describes the project as "a good news ... and the envi-

new information in December 2001, "the Sherry farmers undertook to take action. In a short period of time, the crossing on Frank and Lisa White's property where the expe... iment was carried out has now been brid... In addition, another farmer, Rod O'... is using a bridge instead of taking... through the river."

He says two other bridges a... ning stages and substantial f... ing to keep stock ou...

Tasman Distric... cial assistance...

A farmer-maintained riparian restoration trial at Matariki has provided guidelines for farmer-friendly riparian restoration with native plants in weedy environments, aimed at providing stream shade and excluding stock from riverbanks. Aligned with the Sherry work is the database of the stabilising potential and growth characteristics of New Zealand's indigenous plants developed from 2 field trials in Gisborne.

Contacts: Andrew Fenemor (Landcare Research), Barbara Stuart (NZ Landcare Trust), Roger Young (Cawthron Institute), Rob Davies-Colley (NIWA), Chris Phillips & Mike Marden (Landcare Research), Lisa Langer & Nick Ledgard (Scion), Trevor James & Rob Smith (TDC)

Wilkinson RJ, McKergow LA, Davies-Colley RJ, Ballantine DJ, Young RG 2011. Modelling E. coli from livestock in the Motueka and Sherry rivers. New Zealand Journal of Marine and Freshwater Research 45:369-393

Smaill SJ, Ledgard N, Langer ER (Lisa) and Henley D 2011. Establishing native plants in a weedy riparian environment. New Zealand Journal of Marine and Freshwater Research 45:357-368

Shearer KA, Young RG 2011. Influences of geology and land use on macroinvertebrate communities across the Motueka River catchment, New Zealand. New Zealand Journal of Marine and Freshwater Research 45:437-454

Effects on freshwater fish of changing river flows: Decisions on water allocation are often made at a reach scale and neglect the fact that fish populations move throughout a river catchment. Flows that are adequate to protect ecosystem health in one part of the catchment at one time of the year may not be adequate at other times of the year or in other locations.

Movements of radio-tagged trout throughout the Motueka were characterised by Cawthron ICM researchers to understand more about habitat requirements in different parts of the river. A 50+year flood upset the study to some extent, but resulted in an interesting finding – more than half of the adult trout population in the tributary most affected by the flood perished during the flood. The results indicated the importance of flow and water temperature for controlling fish movement, the importance of deep pools for providing refuge from low flows and warm water temperatures, and also the dramatic effects of that large flood on adult trout survival.

Many fish species move throughout catchments to complete their life history, especially those that require access to and from the ocean. ICM research has confirmed the potential of using fish otolith microchemistry – the chemistry of fish earbones - for tracking how fish have moved throughout a catchment. It is now possible to distinguish between fish reared in different parts of a catchment and to determine where a fish has been throughout its life by looking at the chemical signatures laid down in its otoliths. We also conducted a test of a 2-D hydraulic model (River 2D) for defining how habitat availability for different species will vary with flow at several sites throughout the catchment including in some small streams where traditional models have proved problematic. These studies provided advice on appropriate environmental flows throughout the catchment.

Contacts: Roger Young & Joe Hay (Cawthron Institute), Ricky Olley (Otago Univ), Trevor James (TDC), Neil Deans (Fish & Game NZ)

Olley R, Young RG, Closs GP, Kristensen EA, Bickel TO, Deans NA, Davey LN, Eggins SN 2011. Recruitment patterns of brown trout identified by otolith trace element signatures. New Zealand Journal of Marine and Freshwater Research 45:395-412

Doehring K, Young RG, Hay J, Quarterman AJ 2011. Suitability of Dual-frequency Identification Sonar (DIDSON) to monitor juvenile fish movement at floodgates. New Zealand Journal of Marine and Freshwater Research 45:413-422

3. Managing Land and Freshwater Resources to Protect and Manage Marine Resources

The Condition of River Delta Habitat: River outflows to the coast affect the stability, productivity and ecosystem health of the river delta, and this has a flow-on effect on marine fisheries and aquaculture potential. A national protocol for monitoring barrier-enclosed estuaries has been adapted to include river delta systems. Both broad-scale mapping on GIS, and fine-scale assessment of seabed habitats of the Motueka River delta have now been completed for comparison with future repeat surveys.

Contacts: Paul Gillespie (Cawthron Institute)

Catchments Extend Offshore: Our research has shown that the Motueka 'Catchment' effectively extends offshore encompassing more than 400 km^2 of the marine environment of Tasman Bay. Physical and chemical (nutrient) characteristics of the water column within the plume have been shown to stimulate the growth of micro-algae upon which shellfish (including farmed mussels) depend for food.

Suspended sediment from the river mouth has been shown to generate chronic high turbidity conditions in near-bottom waters that can interfere with the feeding of scallops and potentially other commercially and ecologically important benthic suspension feeding animals. This mechanism has been suggested as a major contributor to the poor performance of the Tasman Bay scallop resource in recent years.

Of this 400km^2 of catchment influence, about 180 km^2 of seabed has a demonstrable terrestrial signature arising from the river outwelling plume. Naturally high heavy metal levels (Ni, Cr, Cu) within the sediment flushed from the Red Hills at the head of the catchment may be affecting marine and freshwater life, because they are beyond ANZECC levels for ecosystem health. These catchment-coastal connections demonstrate that management of coastal ecosystems, fish and shellfish resources needs to take account of activities across the entire land/sea continuum comprising our redefined "catchment". This is a major deviation from current coastal management practice.

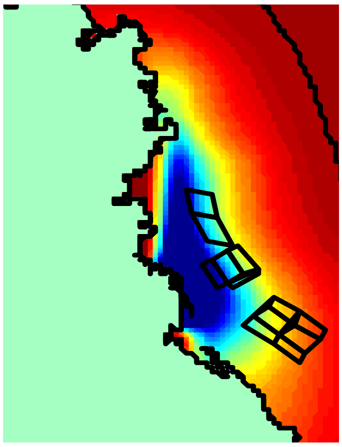
Contacts: Paul Gillespie & Chris Cornelisen (Cawthron Institute)

Gillespie PA, Forrest RW, Peak BM. Basher LR, Clement DM, Dunmore R, Hicks DM. 2011a. Spatial delineation of the depositional footprint of the Motueka River outwelling plume in Tasman Bay, NZ. NZ Journal of Marine and Freshwater Research 45:455-476.

Gillespie P, Forrest R, Knight B, Cornelisen C, Young R. 2011b. Variation in nutrient loading from the Motueka River into Tasman Bay, New Zealand, 2005–2009: implications for the river plume ecosystem. NZ Journal Marine and Freshwater Research 45:497-512.

Effects of the Motueka River Plume on Aquaculture Management Areas:
Water quality and productivity in the 4200 ha of designated Aquaculture Management Areas off the Motueka river mouth is affected by the river discharge, particularly during large floods. The extent and magnitude of freshwater effects on seawater temperature, salinity, density, chlorophyll-*a*, water clarity and nutrients has been mapped to provide a basis for understanding the nature and spatial extent of catchment effects on wild, enhanced and farmed shellfish resources.

Information generated through the ICM Programme proved critical to consenting of a large offshore mussel farm in western Tasman Bay. The first stage of development achieved marketable product size/quality within seven months. High mussel growth rates occurred during spring and autumn 2008/09 with a slowdown, particularly in the upper water column, during summer. This is consistent with predicted chlorophyll-*a* maxima and minima and water column stratification characteristics that are influenced by the river plume. Mussel growing conditions and catchment implications are being tracked over time using long term *in situ* data and nutrient load estimates.



Harvest conditions were developed by the mussel industry using ICM data demonstrating elevated concentrations of faecal indicator organisms after a rainfall event within a plume extending at least 7 km offshore. Using Cawthron's new microbial source tracking (MST) technology, contaminant sources were linked to ruminants using genetic markers. This was the first observation in New Zealand of ruminant faecal contamination from a river plume extending well offshore.

The management applications of our river plume monitoring buoy have strengthened over time with the trialling of new and more robust components. Seasonal and flood-related events shed light on the variability of food for mussel and scallop growth and can now be linked directly to aquaculture responses. Nutrient loading from the catchment to Tasman Bay (reported annually to stakeholders) varies seasonally and between years with resulting ecosystem implications. In the absence of ongoing research funding, Cawthron is self-funding real-time data collection to further develop capability for advising shellfish industries on bacteriological water quality, the fluctuating prospects for successful spat collection/survival, and food availability for shellfish.

Baseline data described above has been applied in models of hydrodynamics (currents and tides), water quality distribution across the bay and with depth, phytoplankton growth and decline (chlorophyll-*a*), and the marine foodweb from algae up to finfish. These models allow evaluation of trade-offs between large-scale land use change onshore and aquaculture scenarios offshore.

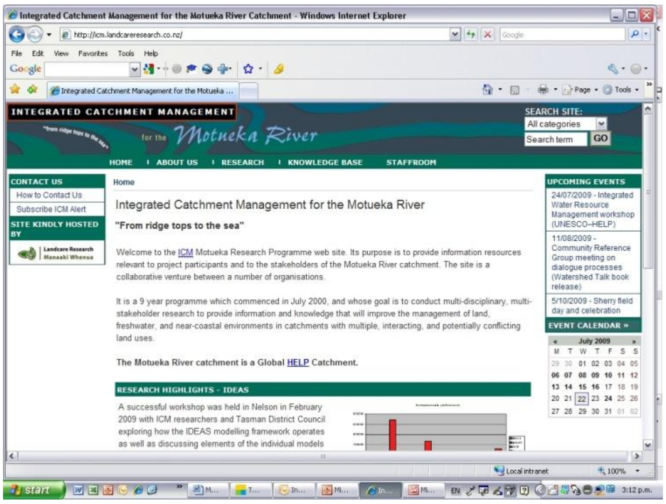
Contacts: Paul Gillespie & Chris Cornelisen & Ben Knight & Weimin Jiang (Cawthron Institute), Neil Jackson & Steve Markham (TDC)

Cornelisen CC, Gillespie P, Kirs M, Young R, Forrest R, Barter P, Knight B, Harwood VJ. 2011. Motueka River plume facilitates transport of ruminant faecal contaminants into shellfish growing waters, Tasman Bay, New Zealand. NZ Journal of Marine and Freshwater Research 45:477-498.

4. Integrative tools and processes for managing Cumulative Effects

Knowledge Base: Establishing a baseline of what we know already is important in any catchment management programme. The ICM programme has published "The Motueka Technical Report, a comprehensive summary of knowledge about the Motueka and Riwaka catchments". ICM research results, findings, and all reports, presentations, and published articles are still available on the programme website http://icm.landcareresearch.co.nz.

The ‘Motueka Toolbook’ CD-ROM has also been developed. This integrates existing and new knowledge of the catchment and links it to global catchment management knowledge. The CD-ROM is dominated by figures and photos, rather than text, and is designed to spread the ICM message to a variety of audiences.



The ICM research programme was the subject of *Country Calendar*, shown on primetime television (TV1) on 21 June 2008. This highlighted ICM as an organising concept for land and water management, and also the benefits of scientists, landowners and communities working together. Research results have been made available through the ICM newsletter *Catchment Connections* with over 700 subscribers (a final edition is possible 2012-13), and a series of videos on ICM topics is available through YouTube or the ICM website.

Contacts: Chris Phillips & Andrew Fenemor & Les Basher (Landcare Research)

IDEAS Modelling: Catchment-scale modelling offers an opportunity to provide councils and sector groups with strategic advice on scenarios which assess impacts not only of future land use mixes, but other types of development impacts as well (e.g. population growth, subdivision), and is being used by Canterbury’s zone committees.

The first foundation for this research was an integrative Triple-Bottom-Line modelling approach trialled using a participatory process (Influence Matrix) with the ICM Community Reference Group. The process identified these critical factors likely to affect the group’s vision for future sustainability of the catchment:

- Nature and extent of primary industries,
- Measures of water quality and supply, and
- Available mix of policy-plans-rules-legislation.

The process and its results raised awareness of the value of such tools which may be useful for informing Long Term Council Community Plans, and for framing up ratepayers’ own perspectives on sustainability.

The second foundation was development of component models: catchment water yield and water quality, catchment transport of faecal pathogens and sediment, exchange of water between rivers and groundwater, coastal productivity and foodweb models, an ‘agent-based model’ which simulates peoples responses to policies, and the Motueka Futures economic input-output model with associated population growth module.

Together these models provided the third foundation, a large-scale modelling framework called IDEAS (Integrated Dynamic Environmental Assessment System). The IDEAS scenario modelling system allowed us to assess cumulative effects of broad-scale development (eg. land use changes) over a 20-50 year timeframe and do this by looking not only at environmental outcomes (eg water quality) but also social (eg. employment), economic (eg. GDP) and cultural (eg. biodiversity) consequences. An IDEAS stakeholder group and the ICM Community Reference Group identified and prioritised the types of issues they see for the catchment in future, and these formed the basis for 6 Motueka catchment scenarios. These were: (1) pre-human (2) present land use (3) present land use with best management practice (4) very intensive agriculture (5) very intensive agriculture with best management practice, and (6) continued present growth until 2020.

IDEAS was applied to assess and compare the environmental and socio-economic impacts of these scenarios, based on the concept of environmental intensity (ratio of environmental impact over economic output). Concept development also included a new indicator of Maori cultural values developed by iwi.

Contacts: John Dymond & Andrew Fenemor (Landcare Research), Ben Knight & Roger Young (Cawthron), Anthony Cole (Pansophy), Oscar Montes de Oca (AgResearch) & Steve Markham (TDC)

Dymond, J.R., Davie, T.J.A., Fenemor, A.D., Ekanayake, J.C., Knight, B.R., Cole, A.O., Montes de Oca Munguia, O., Allen, W.J., Young, R.G., Basher, L.R., Batstone, C.J. 2010: Integrating environmental and socio-economic indicators of a linked catchment–coastal system using variable environmental intensity. J. Environmental Management 46: 484–493.

Fenemor, A.D; Deans, N.A.; Davie, T.J.; Allen, W.; Dymond, J.; Kilvington, M.; Phillips, C.; Basher, L.; Gillespie, P.; Young, R.; Sinner, J.; Harmsworth, G.; Atkinson, M.; Smith, R. 2008. Collaboration and Modelling – Tools for Integration in the Motueka Catchment. Water South Africa 34(4):448-455

Modelling Catchment Futures: The Influence Matrix research described above was extended into an ecological economics model of the whole catchment, founded on an economic input-output model. Using benefit-transfer, non-market valuation methods it was shown that natural ecosystem services annually contribute non-market (indirect) goods and services of $163M, more than half annual catchment gross product. The model, in conjunction with the agent-based model ENVISION, is part of the IDEAS framework, allowing a quadruple bottom line evaluation of various catchment-scale development scenarios.

Contacts: Anthony Cole (Pansophy), Oscar Montes de Oca (Landcare Research)

Cole A.O., Allen, W., Kilvington, M., Fenemor, A. and Bowden, B. 2007. Participatory modelling with an influence matrix and the calculation of whole-of-system sustainability values. International Journal of Sustainable Development 10(4): 382-401.

5. Building Human Capital and Facilitating Community Action

Collaborative learning: Management is a distinctly human process. Social research is developing tools and approaches which can be used by research groups, agency staff and other community leaders to support more effective multi-stakeholder processes for learning and decision-making. Topics worked on include knowledge management, integration, stakeholder analysis, social capital, evaluation and cross-case learning. For example, we developed a methodology labelled Social Spaces for evaluating collaboration among different groups in integrative projects, and for the Auckland Regional Council we applied a logic model to evaluate ICM plans across multiple timescales – an 'Orders of Outcome' approach. A Sediment Learning Group helped stakeholders reach a common understanding of sediment loss and impacts in rivers.

A community resilience project called *Watershed Talk* explored what different people care about and feel a sense of responsibility towards in the Motueka catchment. Often there is a set of practices or values that underpin our wanting to leave the land in better shape, whether it is the people who work and live, who manage or who do science about this place. The *Watershed Talk* project distinguished how resilience approaches to problem solving differ from traditional approaches (eg of some RMA statutory processes), and the 2009 book from Manaaki Whenua Press on this project documents techniques for cultivating ideas and community action for better stewardship of the environment.

Contacts: Will Allen & Margaret Kilvington (social researchers), Maggie Atkinson & Andrew Fenemor & Chris Phillips (Landcare Research)

Allen WJ, Fenemor AD, Kilvington M, Harmsworth GR, Young RG, Deans NA, Horn C, Phillips CJ, Montes de Oca O, Ataria J, Smith RA 2011. Building collaboration and learning in integrated catchment management: the importance of social process and multiple engagement approaches. New Zealand Journal of Marine and Freshwater Research 45(3): 525-539

Kilvington M, Allen W, Fenemor A 2011. Three frameworks to understand and manage social processes for integrated catchment management. New Zealand Journal Marine and Fresh Water Research 45(3): 547-561

Kilvington M, Atkinson M, Fenemor A 2011. Creative platforms for social learning in ICM: the *Watershed Talk* project. New Zealand Journal Marine and Freshwater Research 45(3): 563-577

Atkinson, M; Kilvington, M; Fenemor, A. 2009. *Watershed Talk* - the cultivation of ideas and action. Manaaki Whenua Press. 45pp.

Communicating Research Findings: Design and facilitation of community engagement processes is an important Council function, and vital for catchment research to make a difference. One major method has been through ICM Annual Meetings held at the council and in the catchment around October-November, and including public participation.

Summary of the ICM AGM programmes

2003: Stakeholder Workshop: *Improving Community Engagement;* Public Field Trip: A Day in the Catchment, Science Workshop: *Delivering the Vision through ICM Research*; Open Workshop: *Creating an ICM art-science collaboration*

2004: Workshop: *Linking ICM Research to Management; Planning the Motueka ICM Toolbook*; Public Field Trip: A Day in the Lower Motueka; Science Workshop: *Linking Research into TDC Policy*

2005: National ICM Workshop: *Tools, techniques and lessons for ICM; Pacific HELP Symposium*: Hydrology for the Environment, Life & Policy. International ICM symposium sponsored by Landcare Research and UNESCO; ICM Coastal Workshop: *The river plume ecosystem of Tasman Bay*.

2006: ICM Stakeholder Workshop: *Gravel and River Channel Dynamics;* Tasman Bay ICM Field (Boat) Day: Land-Marine Interactions; Open Workshop: *How are we doing on the 4 BIG ICM research issues?*

2007: Public Workshop: *Celebrating ICM Success;* Stakeholder Workshops: *Integrated Catchment Modelling IDEAS*. Team Workshop: *ICM2-What are the outstanding issues for integrated land & water research across NZ?*

2008: Hosted and ran the NZARM National Conference: *Integrated Catchment Management – are we wiser than we were?* Themes: *Bold governance; Committed Communities; Out of the silos, into the landscape – science for ICM; Catchment Futures – Wisdom for the Transition*. Motueka catchment field trip.

2009: Interactive ICM Science day at TDC with US guest Dr Breck Bowden. Integration workshop – *ICM as a process; Motueka Futures Model hands-on*. Field trip…understanding the river

2010: National ICM workshop: 26-28 April 2010. *Integrated Catchment management – Connecting Research and Practice*. Nelson. With guest Dr Gene Likens, Director Cary Institute for Ecosystem Studies, New York. Comprising: (1) Stakeholder engagement workshop 26 April: *Mobilising-Moderating-Motivating: Engaging People in Collaborative Environmental Management*. (2) Café Scientifique: '10 *Scary & Wonderful Discoveries about Catchments*' 26 April. (3) ICM Research summary workshop 27 April: *The Legacy of ICM Science from the Motueka catchment*. (4) Ridgetops to the Sea: ICM Field Trip, Motueka catchment. 28 April.

Contacts: Andrew Fenemor & Chris Phillips (Landcare Research), Roger Young (Cawthron), Steve Markham & Rob Smith (TDC)

Phillips CJ, Allen W, Fenemor A, Bowden B, Young R. 2010. Integrated catchment management research: Lessons for interdisciplinary science from the Motueka Catchment, New Zealand. Marine & Freshwater Research 61:749-763.

Community Input to Sustainability Decisions: The ICM Community Reference Group was a touchstone for our research direction and research findings. These 8 catchment residents met every 3-4 months. Memorable topics included 'Futures' modelling, and a review of ICM marine research with a vigorous debate about the effects of scallop dredging and catchment runoff on the recent decline in scallop production. The CRG provided their insights into sustainability of the Motueka catchment described above for the IDEAS scenario modelling.

Contacts: Andrew Fenemor (Landcare Research) & Will Allen (social researcher)

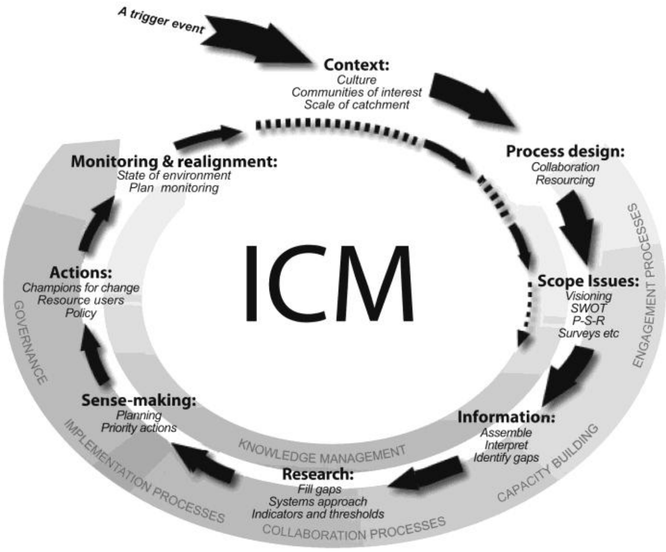
Iwi Values in Integrated Catchment Management: Motueka iwi Te Atiawa, Ngāti Rarua, Ngāti Tama through Tiakina Te Taiao Ltd have a keen interest in building information systems for addressing catchment and economic issues. The programme built a relationship with these iwi, and developed guidelines for iwi consultation. The iwi identified their issues as information collation for iwi management plans, defining the process for undertaking Cultural Impact Assessments of development proposals under the RMA, improved input needed in resource consent decisions, and contaminated sites management. The 3 iwi through the ICM programme have developed GIS-based information systems for environmental management, now used daily. They have also begun to involve their young people in ICM projects relating to water quality, coastal issues and kaimoana.

Cawthron researchers developing new indicators of river ecosystem health. Comparative work between scientific indicators of river health and cultural indicators of river health determined by local iwi is ongoing in the Motueka and Riwaka catchments (and was profiled in a TVNZ *Rural Delivery* programme in October 2007). It shows that scientifically and culturally–based monitoring and assessment can provide an enriched and complementary understanding of freshwater systems. Each approach offers a slightly different worldview and can be used side by side by local government, community, iwi and hapū, and research agencies – for example in TDC's State-of-the-Environment monitoring of rivers.

Contacts: Garth Harmsworth (Landcare Research), Kura Stafford & Dean Walker (Tiakina Te Taiao), Roger Young (Cawthron), Trevor James (TDC)

Harmsworth GR, Young RG, Walker D, Clapcott JE, James T 2011. Linkages between cultural and scientific indicators of river and stream health. New Zealand Journal of Marine and Freshwater Research 45:423-436

Decision-making processes in resource management agencies: Decisions on resource consents and RMA plans do not necessarily follow an objective process utilising all available information. A group within TDC worked with us to develop an institutional learning approach to improve science uptake and information flows. Organisational structure, personal relationships, political influences, decision-making processes and access to information all influence resource management decisions. Improving hard information systems like GIS and databases will not by themselves necessarily result in better decision-making. Insights from this work have been applied in collaborative processes on NZ environmental management issues.



Contacts: Glen Lauder (Common Ground), Rob Smith & Steve Markham (TDC), Andrew Fenemor (Landcare Research)

Fenemor AD, Phillips C, Allen WJ, Young RG, Harmsworth GR, Bowden WB, Basher L, Gillespie P, Kilvington M, Davies-Colley RJ, Dymond J, Cole A, Lauder G, Davie T, Smith RA, Markham S, Deans NA, Atkinson M, Collins A (2011). Integrated Catchment Management – interweaving social process and science knowledge. NZ Journal of Marine and Freshwater Research 45(3): 313-331

Art-Science Collaboration: Most effective among the social learning methods designed and trialled with stakeholders and catchment groups was the *Mountains to the Sea* art-science collaboration. The *Travelling River* exhibition that resulted from this work combined over 250 community photographs, science images and stories from 60 contributors in the Motueka catchment attracting more than 2500 visitors. It built understanding of ICM science and encouraged people to think about how their environment has been modified by human and natural actions.

Travelling River was exhibited at Nelson's Suter Gallery and throughout the catchment, and has received national (Creative NZ) and international recognition (plenary presentations at Dartington/Schumacher College UK; and a US Art-Nature-Culture conference).

Contacts: Margaret Kilvington (social researcher), Maggie Atkinson & Andrew Fenemor (Landcare Research), Suzie Peacock (Nelson Marlborough Institute of Technology)

Atkinson, M.; Peacock, K.; Fenemor, A.D. (eds) 2004. *Travelling River* – a collaboration of artists, scientists and the people of the Motueka River catchment. Catalogue for the *Travelling River* exhibition. Published by the Mountains-to-the-Sea project, Landcare Research, Nelson.

An overview of the Motueka catchment

Motueka River Basin Physical Features

- Total basin area 2,170 km^2
- Located between 41°00’ S and 41°45’ S latitude

Motueka River Physical Features

- Elevation: sea level at Tasman Bay to 1800 m in alpine headwaters
- Length: 110 km
- Delivers 62% of the freshwater inflow to Tasman Bay

Climate and River flows:

- Average annual precipitation: 1040 - 4030 mm measured across the catchment
- Annual sunshine hours: ~2400 h
- Annual days of air frost: 31-92 days
- Mean annual flow: 58.1 m^3 s^{-1}
- Mean annual 7-day low flow: 10.1 m^3 s^{-1}
- 50-year flood event: 2050 m^3 s^{-1}

Geology

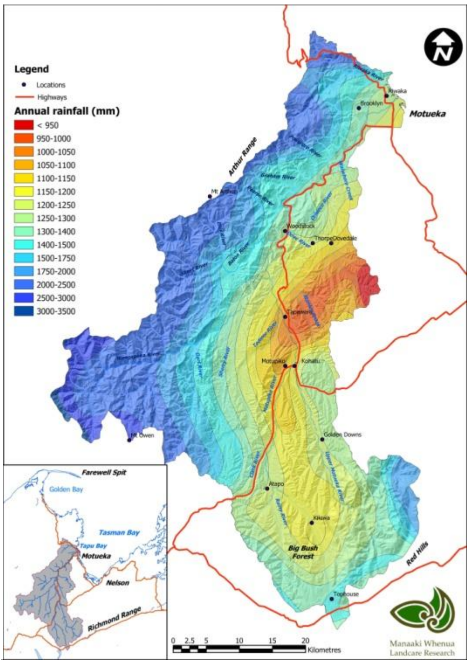
- complex limestone, marble, and calcareous mudstone (Mt Arthur Group), igneous rock (Riwaka complex) formations in the western headwaters
- clay-bound Pliocene-Pleistocene gravels (Moutere Gravel) dominant mid-basin
- erodible Separation Point granites (mid-basin)
- ultramafic rocks (Dun Mountain formation) and sandstone-siltstone (Maitai Group formation) in the southern headwaters
- small areas of young alluvial gravels (mainly coastal area and mid basin)

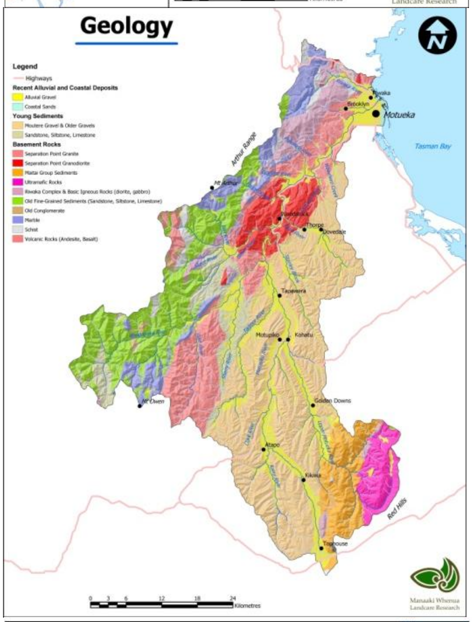
Topography and soils

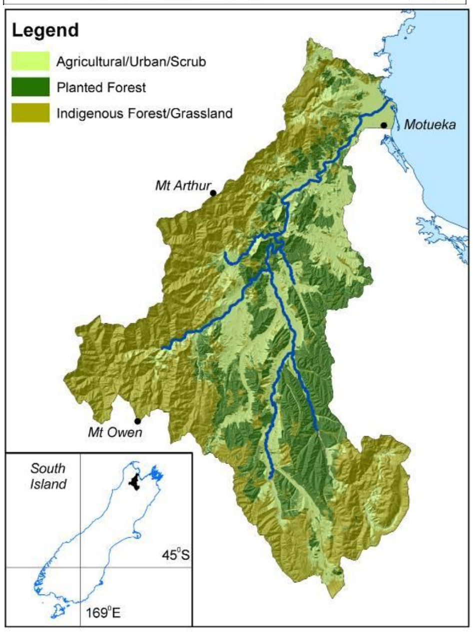
- Flat alluvial plains at mouth, sea-level, young relatively fertile soils
- Rolling and steep hill country in lower basin, low-fertility soils
- Flat alluvial terraces in upper basin valleys, young relatively fertile soils
- Rugged mountainous terrain in headwaters, with a wide range of fertility and permeability

Land-use & Land cover

- Native forest, scrub and grassland in headwaters: southern beech (*Nothofagus*), podocarps (40%)
- Commercial forestry on steeplands and hill country: radiata pine, Douglas fir (25%)
- Dry land pasture and scrub: pasture grasses, sheep
- Valley bottom riparian areas: berry crops, hops (35%)
- Coastal plains: fruit trees, hops







Freshwater resources

- Nationally important blue duck habitat, karst and wild & scenic features in Kahurangi National Park
- Nationally important recreational trout fishery in the Wangapeka, Lower and Mid-Motueka rivers
- Regionally important whitebait fishery
- Water supply for irrigators and townships
- The Water Conservation Order (Motueka River) was formally gazetted by the Minister for the Environment in April 2004
- TDC's Tasman Resource Management Plan (Ch 31) sets water allocation limits in the water management zones throughout the Motueka and Riwaka catchments

Marine resources

- Extensive delta system linking land, freshwater and marine ecosystems
- Internationally recognised birdlife (e.g. bar-tailed godwits, pied and variable oystercatchers on Motueka sandspit)
- Nationally significant oyster and (enhanced) scallop fisheries
- Intertidal cockle fishery
- Rapidly expanding aquaculture : mussel farming
- Recreational and commercial fin fisheries
- Associated nationally important coastal recreation areas (e.g. Abel Tasman National Park)
- Marine reserves: Horoirangi (rocky shore and soft sediment habitats), Tonga Island (marine mammals habitat)

Population

- Sparsely populated: less than 1 person per km^2
  - ~12,000 in catchment, mostly in the town of Motueka
  - ~41,400 in Tasman District (2001 NZ Census)
- One of the fastest growing populations in the country

History of settlement in the Motueka River Catchment

Archaeological evidence suggests that Maori groups first settled the Motueka River area before 1350 A.D. and more permanent camps and fortifications (pa) were gradually established. Settlement was largely restricted to the coastal areas, although Maori travelled through the catchment in search of valued "pounamu" or greenstone and argillite. Inter-tribal conflicts decimated the local iwi in 1828-1830, about 10 years before the first European settlers arrived. Early European settlers were largely interested in sheep grazing land and in gold. Gold operations existed in the area until the early 1900's.

A major flood in February 1877 transformed the shape of the catchment, as a consequence of widespread mass wasting. This event has left a legacy that is important even today. Subsequent flooding prompted local river boards to construct stop banks in the lower river in the 1950's.

Introduction of tobacco in the 1920's brought a period of growth and prosperity. Decline in the tobacco industry in the 1950's was followed by a rise in fruit tree, berry fruit, and hops and by a rise in commercial forestry. Plantation forests – stocked primarily with exotic species such as Monterey pine (*Pinus radiata*) and Douglas fir (*Pseudotsuga menziesii*) were established on less-fertile, steeplands abandoned and purchased from farmers. More recently, vineyards, marine farming, and tourism have added substantially to the diversity and productivity of the local economy, and lifestyle blocks are increasingly being developed.

Appendix 4

Overseer v6.3.1 update note

Notice of Overseer model release (6.3.1) – 12th February 2019

We have updated the Overseer model to correct a defect that has been identified related to fodder crop blocks. This update is being released in both the legacy OVERSEER Online software and in OverseerFM on Monday, 18th February.

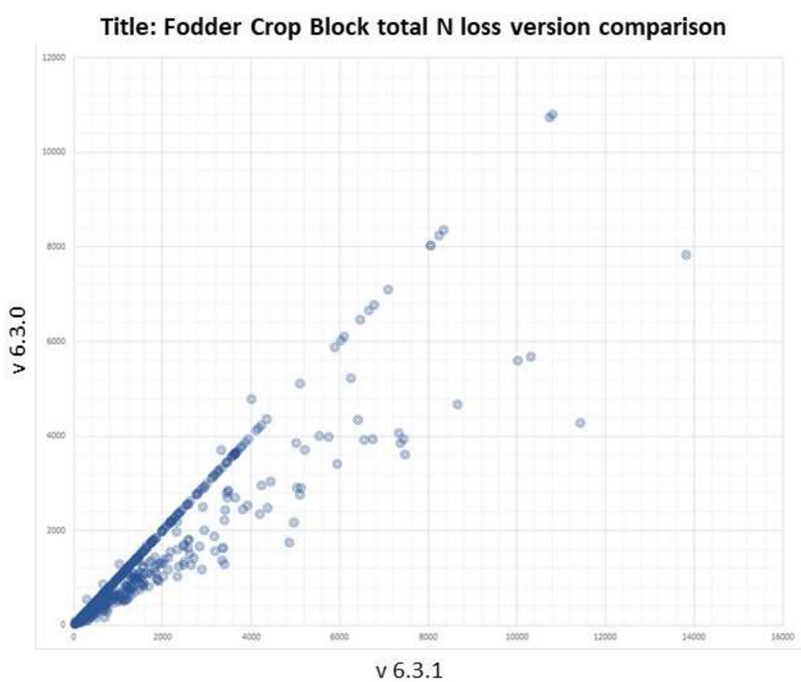
Update summary

Overseer 6.3.0 improved the way soil characteristics are proportioned across fodder crop blocks that rotate through pasture blocks. This introduced a problem with how well-drained soils were proportioned, estimating unrealistically lower N loss numbers for fodder crops on those soils.

We have addressed this problem by correcting the calculation used to proportion saturation connectivity of the soil. This fix changes the estimated losses for fodder crops when they rotate through pasture blocks that have different soils and in particular when the soils are well drained.

Because all farms with fodder crops rotating through well-drained soils were impacted by this defect, we will be rolling out the new version of Overseer (6.3.1) in both the Legacy and OverseerFM software services.

The percentage change in N loss for fodder crop blocks can range from 5% to 60% depending on the system and so please review existing results where you have fodder crop blocks.



Source: OverseerFM year end analyses database

Appendix 5

Wheeler evidence

BEFORE THE BOARD OF INQUIRY

IN THE MATTER	of the Resource Management Act 1991
AND	
IN THE MATTER	of the Tukituki Catchment Proposal

STATEMENT OF EVIDENCE OF

David Mark WHEELER

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1. **INTRODUCTION**

1.1 My name is David Mark Wheeler.

1.2 I hold a Bachelor of Agricultural Science (Honours) from Massey University, gained in 1979.

1.3 I am currently employed as a senior scientist with AgResearch Limited (AgResearch), as lead developer of OVERSEER®[1] Nutrient budgets (*Overseer*).

1.4 I joined MAF (AgResearch's predecessor) as a field technician in 1979, and have worked on nutrient management, aluminium toxicity, and catchment studies related to assessment of nutrient loss. In 2002, I joined the *Overseer* team, and have been lead developer for this model since 2004. During this time, the model has developed from a block scale (i.e. a spatial component within the farm) to a whole farm scale model, and numerous new features added such as greenhouse gas emissions, additional nutrients, wetlands and riparian strips.

Purpose and scope of evidence

1.5 The purpose of my evidence is to describe the work undertaken for the purposes of the Ruataniwha Water Storage Scheme (RWSS), modelling the nutrients produced under a range of land use scenarios using *Overseer*, and comment on matters related to the use of *Overseer* where appropriate.

1.6 Specifically, in my evidence I address the following matters:

a) Scope of work undertaken.

b) Aspects of construction, limitations, and accuracy of *Overseer* in general, and in relation to RWSS that have implications on recommendations on the use of *Overseer*.

c) Recommendations arising from b).

d) Response to submissions on the Tukituki Plan Change 6 (Change 6) including:

(i) the use of *Overseer* in Change 6 – is this an appropriate use of *Overseer* and is it the best model available for this purpose?

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[1] ® OVERSEER is a registered trademark. The trademark and the OVERSEER® nutrient budget software is jointly owned by AgResearch, Fertiliser Association of New Zealand, and Ministry for Primary Industries.

(ii) the appropriateness of a revised benchmarking period for dairying, sheep and beef and permanent horticultural crops of 3 consecutive years (from 2 as notified in Change 6 POL TT4(1)(e)(ii))

(iii) the appropriateness of the benchmarking period for arable farming and cropping of 7 consecutive years as notified in in Change 6 POL TT4(1)(e)(iii)

(iv) comments on POL TT4(1)(f), regarding the % N leaching increase triggers. In particular, are they appropriate in the context of error/uncertainty associated with *Overseer* predictions and the grouping of land uses.

1.7 In relation to the above matters, I was lead author of the OVERSEER® Nutrient Budgets Modelling report for the Tukituki catchment[2] included as report M2 in the RWSS application suite of documents. Where I discuss matters that are covered by that report, I reference it by title and page number in a footnote.

Expert Code of Conduct

1.8 I have read the Code of Conduct for Expert Witnesses in section 5 of the Environment Court's Practice Note (2011). I agree to comply with that Code of Conduct. Except where I state that I am relying upon the specified evidence of another person, my evidence in this statement is within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions which I express.

2. SUMMARY AND CONCLUSIONS

2.1 *Overseer* is based on sub-models, which are simplifications of the biophysical and management processes that affect nutrient use and transport that occur on farms as understood by science. The model simplifications still capture the key drivers of these processes, as we currently understand them. These sub-models are calibrated or validated against experimental data. The model is extrapolated outside the calibrated data range to a wider range of soil conditions and farm management practices based on robust science principles.

2.2 *Overseer* has been developed to cover a wide range of farm management systems. It is a farm-specific model that focusses on nutrient use efficiency and off-farm losses of nutrients (including nutrient losses below the root zone) and

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[2] Wheeler, D., Benson, M., Millner, I., and Watkins, N. (2013). OVERSEER® Nutrient Budgets modelling for the Tukituki catchment (AgResearch client report RE500/2013/016, May 2013).

provides outputs that are annual averages. It is not a short-term (within year) model.

2.3 *Overseer* assumes that a number of 'good management practices' are applied, especially for storage and application of effluent, fertiliser, and irrigation. A limited range of mitigation options for phosphorus can be modelled in *Overseer*. Phosphorus mitigation is dealt with in more detail in the evidence of Dr Richard McDowell.

2.4 A study using an earlier version of *Overseer*, estimated that the prediction error for predicted nitrogen (N) leaching losses for pastoral systems where there is validation data was about 25-30%. A similar prediction error is likely to apply to N leaching losses in the current version of *Overseer* (version 6.0).

2.5 New Zealand pastoral farm systems are complex, and this has resulted in a large number of inputs required to run the *Overseer* model. To reduce variation between inputs by different users, various protocols or guidelines have been developed by different organisations. A more consistent set of 'National standards' is currently being developed by these organisations and I recommend using these when they become available.

2.6 *Overseer* is currently the only tool available for predicting nutrient losses from a wide range of farm management systems, and is widely used by the primary industry. *Overseer* has been used in multiple roles, including as a decision support tool for fertiliser use, assessment of nutrient use efficiency, and in policy development and implementation in a number of regions.

2.7 The multiple roles of *Overseer* mean that upgrades are likely to continue for purposes other than its use in the regulatory environment. The results from *Overseer* analysis are expected to change over time, and some of the changes in output values may be significant, especially for situations outside of the calibration data range. This obviously needs to be considered should *Overseer* be used in a policy implementation context. I recommend the following:

(a) Caution should be exercised about specifying a specific *Overseer* version number in a policy;

(b) A process for updating any baseline, thresholds, targets or limits when a new version of the model is published should be considered;

(c) Wherever possible, use should be made of *Overseer* to assess relative changes, rather than absolute values;

(d) For monitoring purposes, if annual data inputs are used, I recommend the use of a rolling average or trend analysis to reduce the effect of year-to-year variability;

2.8 I was lead author of the OVERSEER® Nutrient Budgets Modelling report (Report M2). This report is a compilation of work undertaken by several people across multiple organisations, including Hawke's Bay Regional Council and AgResearch.

2.9 I managed the creation of *Overseer* files to describe historical, current, and future land uses, and to investigate mitigation options. In my opinion, the assumptions made are reasonable, and are consistent with the supplied data and with other modelling exercises I have undertaken with similar aims and objectives, and the results obtained from *Overseer* analysis were consistent with knowledge and outputs at the time the analysis was done.

2.10 Limitation of available calibration data for stony soils and for irrigated systems means that uncertainty is likely to be higher than normal for the RWSS modelling outputs. For a given farm this uncertainty is likely to be higher for absolute numbers than for relative changes associated with land use change. RWSS predictions for historical, current, and future farm systems are primarily a degree of change between two systems on the same soil with the same climate. This is likely to reduce uncertainty for the RWSS modelling outputs.

2.11 The information generated by the modelling work, along with GIS layers and information on local hydrology were then used in the TRIM 2[3] model to model the effect of nutrient inputs to the river systems.

2.12 I have considered matters raised by submitters and responded within my field of expertise.

3. SCOPE OF WORK UNDERTAKEN

3.1 The report M2 already referred to discusses the use of *Overseer* to simulate a range of land use scenarios in order that the model predictions of resulting nitrogen (N) and phosphorus (P) losses might be utilised in the modelling work undertaken by Dr Kit Rutherford and discussed in his evidence. This report is a compilation of work undertaken by several people across multiple organisations, including Hawke's Bay Regional Council and AgResearch.

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[3] RWSS, Folder 4 of 7, Reports M3 and M4

3.2 The modelling process required generation of GIS mapping layers for land use, soils, and climate. Mr Millner discusses the work underlying generating those GIS layers in his evidence. I collated the methodology and assumptions used to generate the GIS mapping.

3.3 I also managed the creation of *Overseer* files to describe historical, current, and future land uses, and to investigate mitigation options. The assumptions used are described in the appendices to the report. In my opinion, the assumptions made are reasonable, and are consistent with the supplied data and with other modelling exercises I have undertaken with similar aims and objectives.

3.4 I managed generation of the outputs of N and phosphorus (P) loss from these files and the results were compiled and supplied to Dr Rutherford. Those results are set out in the M2 report[4].

3.5 In my opinion, the results obtained from *Overseer* analysis were consistent with knowledge and outputs at the time the analysis was done. Since this work was done, minor changes have been made to the model that would affect the systems modelled. However, I have seen no information since the report was written that causes me to doubt the validity of the overall results.

3.6 The information generated by the modelling work, along with GIS layers and information on local hydrology were then used by Dr Rutherford in the TRIM 2 model[5] to model the effect of nutrient inputs to the river systems.

4. OVERSEER CONSTRUCTION

4.1 Details of the construction of *Overseer* are provided on the publically accessible *Overseer* website[6]. This section focuses on aspects that are used in this evidence. I believe that the model is built on robust science principles which are regularly updated to reflect advances in knowledge and science. The methods used are increasingly being published.

4.2 *Overseer* is based on sub-models, which are simplifications of the biophysical and management processes that affect nutrient use and transport on farms as understood by science. The simplifications aim to capture the key drivers of these processes as we currently understand them. These sub-models are calibrated or validated against experimental data obtained from, for example, field trials or small plot trials. The model is extrapolated outside the calibrated data range to a

4 M2 Report, section 9, starting on page 63 and Appendices 1 to 4.
5 RWSS, Folder 4 of 7, Reports M3 and M4
6 http://www.overseer.org.nz, particularly the technical manual and reference pages.

wider range of soil conditions and farm management practices based on the science principles embedded in the model.

4.3 *Overseer* predicts annual average nutrient budgets assuming a quasi-equilibrium state.

4.4 Quasi-equilibrium means the model assumes that inputs[7] and site characteristics[8] are in equilibrium with farm production (milk, wool, velvet sold) and stock policy (for example, numbers, reproductive performance, animal types[9], weights, and classes[10]) or for crops, their yields.

4.5 Quasi-equilibrium implies that *Overseer* does not cover transition periods between one system and another, for example the change in soil N immobilisation status when switching from sheep to dairy systems, or the change in P requirements when switching from slow release to conventional fertiliser. Experience indicates that these transition periods vary according to the nature of the transition and *Overseer*'s focus is on providing a comparison between farm systems, which are outside of the transition period.

4.6 *Overseer* consists of two key parts. The first part is designed to capture a description of the farm system, based on input data provided by the user. This defines the sources of nutrients and where and how nutrients are moved around a farm. This description has no temporal bounds, but because of the quasi-equilibrium condition, it is important that the input and production[11] data are on the same time scale.

4.7 The second part of the model comprises a number of sub-models that define the processes that occur at each transfer point, such as leaching, runoff, or atmospheric losses, or change in forms, for example, splitting excretal nutrients into urine and dung sources.

4.8 Except as noted below, *Overseer* predicts and is calibrated against annual average outputs.

4.9 For leaching of N, drainage calculated from climate data is an important driver. A required climate input is annual rainfall (mm/year); annual average temperature (°C) and annual PET (mm/year) are optional inputs to the model, with defaults

[7] Inputs include nutrients in fertiliser, supplements brought onto the farm, and irrigation.
[8] These include climate, soil type, drainage conditions, and soil nutrient status.
[9] Dairy, dairy replacements, sheep, beef, deer, dairy goats, others.
[10] Class defines the sex, age range, and breeding status of a mob of animals.
[11] Production data includes milk, wool or velvet sold, and net live weight sold, crop yields, and animal stock carried.

available based on 30-year norms. The model also uses an inbuilt within-year pattern of rainfall, temperature, and PET, based on 30 year-norms.

4.10 For pasture systems, the urine N leaching model (generally the largest source of N leaching loss from grazed pastoral systems), was validated in *Overseer* using the following process:

(a) Validation farm files were set up so that the validation trial was represented in appropriate blocks in *Overseer*.

(b) Rainfall inputs and soil properties were adjusted so that modelled drainage was similar to measured drainage.

(c) Modelled and measured N leaching for the validation block(s) were compared.

4.11 This procedure implies that we have used short-term management and climate data and long-term within-year climate pattern data to calibrate estimated and measured average N leaching losses from field trials. However, the farm management practices in field trials are typically reasonably constant between years. On real farms, farm management practices vary from year-to-year as climate and economic conditions change.

4.12 In effect, by default, *Overseer* estimates an annual average nutrient budget based on the average rainfall entered and inbuilt long-term climate patterns, and assumes that the farm maintains in the long-term the production system as entered.

4.13 An analysis of the implications of using annual or long-term average production with annual or long term climate data and climate patterns has not been undertaken. More work is required around understanding these principles and hence recommendations on how annual data is used as inputs for *Overseer* are likely to change over time.

4.14 The model does not consider climate change effects directly. At a simple level climate change could be modelled by changing the rainfall and temperature input data, and the likely management system. However, large changes in the yearly climate patterns associated with climate change could not be modelled at present, and nor could fundamental changes that climate change might cause to biophysical processes.

5. GENERAL LIMITATIONS ON THE USE OF *OVERSEER*

5.1 *Overseer* has been developed to cover a wide range of farm management systems. However, there are farm management systems which are not covered by the model or which are difficult to include. For example farms with 2-year fodder crop rotation, or specific types of effluent management systems, or the growing of certain crops that are not included in the model.

5.2 *Overseer* is a farm-specific model that provides users with tools to examine the impact of nutrient use and flows within a farm, focussing on nutrient use efficiency and off-farm losses of nutrients, and greenhouse gas emissions. It provides outputs that are annual averages, so it is not a short-term (within year) model and hence does not include day-to-day management decisions. Some of these day-to-day management decisions can increase or decrease N and P losses from farm systems.

5.3 *Overseer* assumes that a number of 'good management practices' are applied, especially for effluent, fertiliser, and irrigation. For effluent, good management practices are outlined in a document produced by Dairy NZ[12] and for fertiliser in the Fertmark and Spreadmark codes of practice[13]. Many of these practices are related to maintenance and monitoring of equipment for effluent, and the method of application and conditions at the time of application for fertiliser and effluent. If these good management practices are not achieved, then losses to the environment are likely to be higher than *Overseer* predicts.

5.4 *Overseer* can however model some instances of 'bad practice', such as over-irrigating causing extra drainage and applying large amounts of nitrogen fertiliser in the winter or applying more fertiliser than is required for the level of production.

5.5 The model estimates N and P loss from races to waterways, but assumes that there is no direct losses because of good management practices such as directing water flow into paddocks

5.6 The model assumes that sources such as runoff from yards, bridges, and silage stacks are all dealt with in a manner that does not result in large point losses to waterways.

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[12] Environment: Managing/Operating Effluent Systems website, including 'A Guide to Managing Dairy Farm Effluent'[12],

[13] New Zealand Fertiliser Quality Council New Zealand Fertiliser Quality website: Retrieved August 2013. Fertmark Code of Practice. http://www.fertqual.co.nz/download.php?view.1 Spreadmark. http://www.fertqual.co.nz/page.php?11

5.7 *Overseer* predicts losses at the edge of the block[14] for surface transport and immediately below the root depth for soil/groundwater transport, so it does not include losses or attenuation within waterways (including groundwater) or the vadose[15] zone.

5.8 *Overseer* also does not include losses due to catastrophic or large storm events, natural events such as earthquakes or volcanic eruptions.

5.9 There are also management practices or mitigation options available that cannot be captured by the *Overseer* model, for example, the channelling of water runoff from raceways, bridges, and yards away from waterways, or changes in stream bank erosion because of stock exclusion from waterways.

5.10 A limited range of mitigation options for P can be modelled in *Overseer*, including changing Olsen P (a measure of available P content in the soil), modifying fertiliser use and timing, reducing direct deposition of excreta in streams by the exclusion of bovine stock from streams, and the connectivity between the source of P due to fence line pacing and wallows and the waterway for deer. P mitigations that are not covered in *Overseer*, the implications of these limitations and the extent of P reduction possible using additional mitigation options are dealt with in more detail in the evidence of Dr Richard McDowell.

6. UNCERTAINTY IN OVERSEER OUTPUTS

6.1 In considering errors or uncertainties in model outputs, I have used the following definitions.

The **accuracy** of a system is the degree of closeness of measurements of a quantity to that quantity's actual (true) value.

The **precision**, also called reproducibility or repeatability, is the degree to which repeated measurements under unchanged conditions show the same results.

Errors are the level of disagreement between a measured value and the true or accepted (where actual measurement is difficult) value.

Uncertainty in the context of a model such as *Overseer* can be defined as a potential limitation in some part of the modelling process that is a result of incomplete knowledge.

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14 *Overseer* models down to the block scale, which is a collection of paddocks with common management and site characteristics.

15 Vadose zone is defined as the zone between the bottom of the root zone and the ground water.

6.2 *Overseer* outputs are primarily used in the study of whole farm nutrient losses. Given that it is not practically feasible to directly measure whole farm nutrient losses, and there are no accepted values to use in lieu of measurement, the terms accuracy or errors are not directly applicable to *Overseer*. The concept of 'uncertainty' is the most applicable concept to the use of *Overseer.*

6.3 Beven[16] defined two primary modelling sources of uncertainty, aleatory and epistemic.

(a) Aleatory uncertainty involved sources that are fundamentally random in nature. It encompasses errors associated with measurement and the modelling process. I believe that it is difficult to reduce the size of this source experimentally.

(b) Epistemic uncertainty results from a lack of knowledge, or 'what we don't know we don't know'. Hence epistemic uncertainty is more difficult to analyse. Experimental work that aims to test epistemic uncertainty frequently results in improved modelling predictions over a wider range of systems. This also tests and improves the underlying science the model is built around.

6.4 There is a known lack of calibration data for farms that are in high rainfall areas, or on stony, sandy or organic soils, or soils with impeded layers other than the drained soils in Southland, and soils under irrigation. This lack of information contributes to the epistemic uncertainty.

6.5 Uncertainty due to differences between users in the way data are entered are best controlled by specifying the source of the data and applying guidelines, standards, or protocols for their entry into the model. This has no implication for the RWSS modelling study described in report M2 as only one person inputted the data, but is an important consideration if used in a regulatory environment where differences in the way inputs are considered and entered by different individuals may be important and result in differences in outputs. I comment further on these aspects on Section 7 of my evidence.

6.6 More generally, New Zealand farm systems use complex management systems that involve complex biological systems. *Overseer* uses simplifications of these complex processes (paragraph 4.2 of my evidence) and hence the predictions will always contain uncertainty. I recently compiled, with my colleague Dr Mark

[16] Beven, K. J. and Alcock, R. E. (2011). Modelling everything everywhere: a new approach to decision-making for water management under uncertainty Freshwater Biology 10:1365-2427.

Shepherd, a detailed discussion of uncertainty associated with *Overseer* predictions[17].

6.7 This report illustrates the point that results from all field trials have measurement errors. Field estimates of N leaching, are difficult and have significant measurement errors associated with them. A colleague, Dr Stewart Ledgard suggested these are in the range of 30-50%. An implication is that when comparing measured and modelled data, the differences may be just as likely due to measurement errors as modelled errors. These measurement errors should be included in the uncertainty analysis.

6.8 There has been no uncertainty analysis undertaken for *Overseer*.

6.9 In a study using an earlier version of *Overseer*, Ledgard and Waller[18] estimated that the prediction error for predicted N leaching losses for pastoral systems where there is validation data was about 25-30%, and this estimate has been widely quoted since then. This estimate probably underestimates the prediction error as the data sets were not independent, that is they were used to calibrate the model as well to estimate prediction error. However measurement errors were included in the analysis, which is likely to have led to over-estimating the prediction error.

6.10 Since the work of Ledgard and Waller, the N leaching model has been significantly revised[19]. Nevertheless, a similar prediction error is likely to apply to N leaching losses on pastoral farms in the current version of *Overseer* (version 6.0) because a similar data set was used to calibrate the model, and the relationship between measured and modelled N leaching losses is similar.

6.11 Dr McDowell gives an estimate of uncertainty for the P loss model in his evidence.

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[17] Wheeler, D. M. and Shepherd, M. A. (2013). OVERSEER®: Answers to commonly asked questions. AgResearch Client report number: RE500/2012/027. http://www.overseer.org.nz/Portals/0/Technical%20notes/Overseer%20questions%20&%20answers.pdf

[18] Ledgard, S. F., and Waller J. E. (2001). Precision of estimates of nitrate leaching in OVERSEER. Client report to FertResearch.

[19] Overseer Technical Note 5 (2012). Retrieved 11 March 2013, from http://www.overseer.org.nz/Portals/0/Technical%20notes/Overseer%20Technical%20Note%205%20August%202012.pdf

7. INPUT STANDARDS, GUIDELINES OR PROTOCOLS FOR *OVERSEER*

7.1 New Zealand pastoral farm systems are complex, and this has resulted in a large number of inputs required to run the *Overseer*. Further, some of these inputs are qualitative, which means that a degree of professional judgement is required of the operator when entering some of the input data.

7.2 To reduce variation between inputs by different users, protocols or guidelines have been developed, for example by AgResearch for internal use, Waikato Regional Council for the Lake Taupo catchment, and Dairy NZ for nutrient budgets provided to Fonterra.

7.3 The primary industry as a whole has commissioned national input standards that are being developed and due for release later this year. I have been involved in the development of these standards, primarily to make sure any standards are consistent with the model. These standards are intended to cover a wider range of inputs than the previously mentioned protocols.

7.4 I believe that standards and model inputs, data sources and modelling methods will align to reduce variability between users, and will inevitably evolve over time to account for new data, model version and farm practices..

7.5 The national standards will include additional material that was not covered in any of the previous protocols and guidelines, particularly around soil and climate inputs that align with the release of a new *Overseer* version in August 2013. These input changes include the use of S-map data and 0.5 km grid data. As noted in paragraph 7.4 these standards will evolve over time.

8. USING OVERSEER IN THE RWSS MODELLING

8.1 The RWSS modelling study involved modelling approximately 59,000 hectares of mixed land uses and farm types in the irrigation consent area.

8.2 Mr Millner discusses the process by which patterns of land uses were built up for the study area and the M2 report discusses the descriptions of historic and current farm types in greater detail.[20] I believe that we received the best available data, while noting that the process Mr Millner describes necessarily involves a simulation of land use patterns that have changed significantly over time.

[20] M2 report, section 8, pages 54-62.

8.3 When undertaking the modelling for the RWSS studies in the M2 report, it was assumed that:

(a) input data represented annual average management systems;

(b) long-term average climate data (rainfall, temperature) and climate patterns were used as input[21] (as recommended in paragraph 9.19(h));

(c) good management practices as discussed in 5.3 were applied in all scenarios;

(d) bad practices that can be modelled as listed in section 5.4 were not applied in any of the scenarios.

8.4 For historical farm systems, assuming good management practices may have led to an underestimation of nutrient losses, as many of these practices would not have occurred at the time. However, this ensured consistent assumptions were made across the different scenarios. I believe that the uncertainty in actual production data is likely to be larger than the uncertainty from assuming consistency in good management practices. Given this, and that historical data were primarily being used to assess the effect of lag times on discharges to rivers, I believe that assuming consistency in good management practices is unlikely to have a large effect on the outcome of the modelling work.

8.5 We also had to deal with discrepancies in soil properties for soil series with the same name but for which the data came from different sources. The method adopted and soil properties used are described in the M2 report[22], and in my opinion, was the best available approach and was consistent with the availability, scale and detail of other data inputs into the model. It is noted however that the future availability of more detailed soil data, such as S-map is likely to result in larger variability between farms than was modelled as part of the study.

8.6 The *Overseer* output being used in the RWSS study is the whole farm nutrient loss. Therefore the uncertainty associated with these estimates reflects the points discussed in section 6.

8.7 The project on the national standards (paragraph 7.3) started after the work on the RWSS was completed and submissions closed. The methods used to input

[21] M2 report, section 6, pages 48-52.
[22] M2 report, section 5.2, pages 45-48.

data into the model for the RWSS were however consistent with the national standards that are in the process of development.

9. USE OF OVERSEER IN A REGULATORY ENVIRONMENT

9.1 *Overseer* is currently the only tool available for predicting nutrient losses from a wide range of farm management systems. I believe that it is also generally recognised as the best available tool for this purpose[23]. That is certainly my opinion, although I acknowledge that, like all models, it is not perfect.

9.2 The model moved to a formal ownership arrangement in 2008. The owners[24] are currently developing a new 5-year strategic management plan and a continuing maintenance and development programme.

9.3 *Overseer* is also widely used by the industry. All fertiliser company representatives are trained in the use of the model. There are also in excess of 450 other users requesting update information. The Sustainable Nutrient Management[25] at Massey University is being considered as a pre-requisite for accreditation in the use of *Overseer*. From 2005 to 2012, 1,119 participants have attended the Massey University intermediate course and 317 attended the advanced course, with participants from fertiliser companies (46%), consultants (35%), regional councils (9%), Crown Research Institutes (CRIs), and individual farmers[26].

9.4 *Overseer* has been used in multiple roles, including as a decision support tool for maintenance fertiliser nutrient recommendations, assessment of effluent application rates and effluent block areas, assessment of nutrient use efficiency, and for use in policy development and implementation in a number of regions. This increases the base of users with capability in using the model.

9.5 Paragraphs 9.1-9.4 mean that *Overseer* is a model with a high likelihood of remaining in the market place, and that there is trained capability on the ground to use the model.

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[23] For example, Cichota, R. & Snow, V.O. (2009). Estimating nutrient loss to waterways - An overview of models of relevance to New Zealand pastoral farms. New Zealand Journal of Agricultural Research 52, 239-260.
[24] AgResearch, Ministry for Primary Industries and Fertiliser Association of New Zealand
[25] Currently there is no official training on the use of *Overseer per se*. The Massey Sustainable Nutrient Management short courses use *Overseer* to demonstrate principles of nutrient management.
[26] Hedley, M. (2013). What skills are required for Nutrient Management Planning. http://www.massey.ac.nz/~flrc/workshops/13/Manuscripts/PowerP_Hedley.pdf

9.6 Farm management systems are inherently complex, but with continued use, inconsistencies between practical and modelling application of systems can in my view be expected to be found and addressed, reducing model uncertainties over time.

9.7 *Overseer* is also evolving as modelling procedures improve, new science is developed, underpinning principles evolve, and new management options are added. Active scientific research is being undertaken on nutrient losses to the environment, and on mitigation of these losses[27]. For example, research work to enable outdoor pig farms to be added to the model has started, and research looking at improved methods to model irrigation is also underway. In a recent release, soil and climate data sources were upgraded to provide more certainty on data sources, and work on these sources of input data is expected to continue.

9.8 The multiple roles of *Overseer* mean that upgrades are likely to continue for purposes other than its use in the regulatory environment.

9.9 Consequently, results from *Overseer* analyses can be expected to change over time. It is expected that some of the changes in output values may be significant, as occurred when the model recently changed from version 5.4 to version 6.0. This obviously needs to be considered should *Overseer* be used in a policy implementation context.

9.10 The model is based on calibration or validation of sub-models against experimental data, and extrapolation to cover the range of New Zealand farm management and site conditions (paragraph 4.2 in my evidence). The science and hence model construction also mean that the effect of management changes within a site tend to be relative to the original 'baseline'.

9.11 In my view, paragraph 9.10 implies that:

(a) the uncertainty of predictions for relative changes in N leaching, such as a 10% decrease, is probably less than the uncertainty of predictions for absolute changes, such as a decrease of 5 kg /ha/yr.

(b) the absolute values correspond as closely as possible to measured values. Absolute values are more likely to change over time due to changes in the model than the relative effects due to changes in farm management.

[27] For example, Lifting Farm profit and production while reducing environmental footprint. P21-11 Programme full proposal. C de Klein and B Barrett, (programme leaders). MBIE project C10X1117. November 2010

9.12 The consequences of the paragraph 9.11, in my view are that:

(a) Should model outputs change, a policy that requires a relative change is likely to have a smaller effect on farm management practices than a policy that requires an absolute reduction.

(b) Wherever possible, I recommend that use be made of *Overseer* to assess relative changes, rather than absolute values.

9.13 Therefore, when looking at the use of *Overseer* in the policy or compliance context, uncertainty and the potential for model outputs to change as new versions are released should be considered, well understood and catered for in the policy or compliance framework.

9.14 I would recommend caution be exercised about specifying a specific *Overseer* version number in a policy or rule because fixing the version number of the model used for assessment means that new mitigation options or the impact of new science or change in epistemic uncertainty may not be recognised in a timely manner. I acknowledge that not fixing versions means there is less certainty about the target values going forward, but in my view, the impact of maintenance of different versions in the market place, and possible resultant confusion between users, should be considered.

9.15 As a consequent of paragraph 9.13 and 9.14, if specific thresholds, targets or limits are set based on *Overseer* predictions are included in a plan, then a process for updating the numbers when a new version of the model is published should be used in preference to the plan specifying a particular version of the model.

9.16 Data sources are likely to evolve over time. These will result in less uncertainty arising from user inputs. For example, the ability to input data from S-map soil database and 0.5 km climate grid database has recently been added. Science analysis and modelling is not fully completed and hence access and use of this data is expected to improve greatly. I recommend using such data sources as they become available, because they will result in less uncertainty due to differences between user inputs. However, to take advantages of these changes, plans will need to be flexible enough to accommodate them.

9.17 It is important that irrigation rates and rainfall inputs are commensurate. Thus, irrigation amounts used in a dry year should not be entered if a value for annual average rainfall is used as this will result in calculated excess drainage (and extra N leaching). If the irrigation rate (mm/month) is not known, it is recommended that the 'method only' input method is used. This assumes that good irrigation practices are applied (no over-irrigation). This is described in more detail in a technical note I was a co-author of[28]. If actual irrigation rate is entered, then I recommend that the annual rainfall corresponding to the year the irrigation is applied is entered. There is project looking at potential improvements to the methods used by the model to receive irrigation data.

9.18 In my opinion, farm management plans should be used in conjunction with *Overseer* to cover tactical decisions that may affect N and P losses (paragraph 5.2 of my evidence), the implementation and monitoring of good management practices (paragraph 5.3) or mitigation options not captured by *Overseer*, for example, the channelling of water runoff from raceways (paragraph 5.5), bridges and yards away from waterways (paragraph 5.6), or changes in stream bank erosion because of stock exclusion from waterways.

9.19 In conclusion, based on my knowledge of the model construction and feedback on use of the model, I recommend that in any regulatory or monitoring environment:

(a) Wherever possible, use be made of *Overseer* to assess relative changes rather than absolute values. This reduces the impact on farm management changes should the model outputs change. This may also mean that a plan that requires a percentage change in nutrient discharges may have less uncertainty than a plan that sets a fixed maximum discharge should Overseer outputs change

(b) A process for updating any baseline, thresholds, targets, or limits when a new version of the model is published should be considered.

(c) If possible, the national standards for input data should be used as these have a wider coverage and are likely to be continual development. Protocols or standards should build on existing industry initiatives such as training[29] and quality auditing systems.

(d) I recommend the use of S-map soil data and 0.5 km climate grid data even though there are some anomalies at the moment.

[28] Technical note 4. Overseer Nutrient Budgets version 6. Sensitivity of calculated N leaching to irrigation inputs on pastoral farms. Retrieved September 2013 from http://www.overseer.org.nz/Portals/0/Technical%20notes/Overseer%20Technical%20Note%204%20August%202012.pdf

[29] Currently there is no official training on the use of Overseer per see. The Massey Sustainable Nutrient Management short courses use Overseer to demonstrate principles of nutrient management.

(e) For monitoring purposes, I recommend that the use of annual data inputs for dairy farms as these aligned with Fonterra's current requirements for annual nutrient budgets. A similar system would be desirable for sheep and beef systems. However, using annual inputs instead of average data over multiple years requires significantly more data entry time, which may require additional capability on the ground. Options can be added to the model to partially automate this procedure.

(f) I recommend 'method only' input method be used if the irrigation rate is not known. If an actual irrigation rate is entered, then I recommend that the annual rainfall corresponding to the year the irrigation is applied is entered.

(g) For monitoring purposes, if annual data inputs are used, I recommend the use of a rolling average or trend analysis to reduce the impact of year-to-year variability when monitoring the degree of compliance with any target or critical value.

(h) When considering the use of *Overseer* for forward prediction (e.g. consent applications), I recommend that the data that describes the typical management system to be adopted is used with long-term average climate data (rainfall, temperature) and climate patterns.

(i) Given the lack of detailed data and the range of modelling uncertainties I recommend that there should be feed-back mechanisms at regular intervals between the state of the catchment, and the degree of mitigation and its efficacy as applied at the farm level. The methods to do this are outside my area of expertise.

(j) I recommend that nutrient management plans are included to cover situations discuss in paragraph 9.18 of my evidence.

(k) I recommend that methods or procedures are adopted to cover farm management systems that are not covered by the *Overseer* model, situations where information is not available or its reliability is poor, and to define acceptable alternative methods to the use of *Overseer*.

10. USE OF *OVERSEER* IN RWSS OR CHANGE 6

10.1 This section covers specific evidence related to the use of *Overseer* in RWSS or Change 6 in addition to recommendations in paragraph 9.19.

10.2 Given the on-ground capability outlined in paragraph 9.5 in my evidence, I believe that *Overseer* is an appropriate tool for the on-going management of nutrient outputs (more commonly called leaching losses) in the Tukituki catchment, both within the RWSS (if it proceeds) and more generally.

10.3 The widespread use of *Overseer*, and the wider coverage and likely continued development of the national standards as discussed in paragraph 7.3 of my evidence indicates that these should be adopted.

10.4 Limitation of available calibration data is discussed in paragraph 6.4 of my evidence. The lack of information for stony soils (which occupy about half the proposed irrigated RWSS area) and for irrigated systems means that the level of uncertainty for nutrient leaching or loss predictions is likely to be higher than normal for the RWSS modelling outputs. As noted earlier (paragraph 9.11), for a given farm this uncertainty is also likely to be higher for absolute numbers than for relative changes associated with land use change. RWSS predictions for historical, current, and future farm systems are primarily a degree of change between two systems on the same soil with the same climate. This is likely to in reduce uncertainty for the RWSS modelling outputs.

10.5 Consequently, I believe there should be Overseer modelling feedback mechanisms for the RWSS farms as discussed in paragraph 9.19 i.

10.6 Overseer does not cover the transition period (paragraph 4.4 of my evidence) from one farming system to another. Overseer predicts nutrient losses as if the farm management was constant (quasi-equilibrium assumption). When farms are irrigated, this could result in changes in immobilisation status as farms intensify or convert, and/or increases in cultivation to improve pasture, or soil disturbance such as levelling. These may result in different N leaching rates from farms over this period than those predicted by Overseer. There is limited data to estimate the transition period but I typically consider it lasts 2-3 years. Thus there may be a temporary increase or decrease in the N loads from the root zone as a result of activities related to setting up farms for irrigation. I cannot comment directly on the implications of this with regards to in-river N concentrations.

10.7 Some of the limitations of *Overseer* listed in section 5 were addressed outside the modelling study. Additional losses and attenuation for instance were included within the TRIM analysis discussed by Dr Rutherford. Additional mitigation options for P[30] have been considered as part of case studies[31], and a wider range of migration options are included in evidence presented by Dr McDowell.

10.8 I believe that it is appropriate to use annual management data with long-term climate data for monitoring N losses from farms, provided a method is used to smooth out year-to-year variation in N losses as a result of variations in climate conditions and management responses. These methods could include the use of trend analysis, or rolling averages, as explained in paragraph 9.19(g).

10.9 The leaching loss that is predicted by *Overseer* that the plan refers to needs to be carefully defined. *Overseer* produces reports that show N leaching loss on a per ha basis (kg N/ha/yr) or total farm losses (kg/yr). Both are calculated on total farm area. The per ha losses are divided between sources, for example for N urine N, background N, N lost direct to drains via direct animal deposition, drain outlets, or pond discharges losses. Reductions in losses due to wetlands or riparian strips are shown after the total farm loss is estimated. In the modelling exercise, the various sources of loss were routed using different paths, but total N and P loss were entered into the TRIM 2 model. Wetlands or riparian strips were not considered. I recommend that the policy wording is clear on the N loss value required for reporting. I would recommend the use of total N loss either before or after wetlands and riparian strips are included.

10.10 In overall terms, I am not aware of any valid reasons why farm systems that occur on the Ruataniwha plains currently or in the future cannot be captured by the *Overseer* model. However, the change to site-specific monthly climate patterns, and more detailed S-map soil properties, are likely to lead to changes in modelled outputs, but the size and location of these changes are still not known.

11. COMMENTS ON SUBMISSIONS

11.1 I have been provided with copies of the submissions received on Change 6 and the RWSS applications. Relevant to my area of expertise I address the following

[30] M2 report, Appendix 4: Phosphorus mitigation options for pre and post-storage farms.
[31] As shown in Ms Mulcock's evidence (Exhibits CMM5, CMM6 and CMM7) three case studies have been provided.

issues raised by the submitters. I have assembled the issues raised into five broad categories:

(a) Period allowed to prepare nutrient budgets.

(b) N leaching increase triggers.

(c) Definition of output values used.

(d) Use of data input protocol.

(e) The use of Nitrogen conversion efficiency.

11.2 Hawkes Bay Fish and Game and Eastern Fish and Game [32] (Fish and Game) has criticised the time that Change 6 allows farmers to prepare nutrient budgets, and seek that these are done by July 2014 or within 3 years.

11.3 It would be technically feasible to provide nutrient budgets within a relatively short period of time (e.g. 12 or 24 months), whether this is realistic or required is a policy issue, which will depend among other things on the on-the-ground capacity to assist farmers to prepare these budgets. I also note that data requirements for some farm systems are more onerous than for others. I cannot comment further on this point.

11.4 Fonterra[33], Fertiliser Association of New Zealand[34] and Dairy NZ[35] have made submissions on the test employed in Policy TT4 (1)(f) of Change 6 for determining when a change in nitrogen outputs from a farm property requires that a resource consent application be made. Fonterra seeks that the trigger for a resource consent should be a 20% modelled increase in N outputs. Fertiliser Association of New Zealand and Dairy NZ refer to the evidence presented at the recent hearing by Drs Edmeades and Roberts on the Canterbury Land and Water Regional Plan hearing and seek similar changes. In contrast Fish and Game seek tighter conditions particularly in over-allocated sub-catchments.

11.5 I have read the evidence given by Drs Roberts in the Canterbury hearing[36] . They recommended, having regard to the quoted uncertainty in *Overseer* predictions of +/-30% I have previously referred to, various alternative tests, one of which would

[32] Hawkes Bay Fish and Game and Eastern Fish and Game, submission #34, p 21
[33] #22
[34] #21
[35] #17 and #378
[36] Roberts A.H. C. (2013). Response to questions asked in relations to evidence on OVERSEER Nutrient Budget model presented by the Dr A. H. C. Roberts on behalf of Fertiliser Association of New Zealand. Submitter #239.

impose different tests depending on the nature of the land use - 30% for sheep, beef and other land uses expected to have a relatively low N loss, and 10 % as the threshold for dryland and irrigated dairying and commercial vegetable production which are expected to have relatively high N losses.

11.6 I discussed the uncertainty of *Overseer* predictions in section 6 of my evidence. For the reasons I set out, I believe it is an over-simplification to treat the Ledgard and Waller estimate of +/-30% made in 2001 in relation to an earlier version of *Overseer* applied to pastoral farm systems as being both current and generally applicable, but nevertheless, I expect the prediction error in the current version of *Overseer* to be of a similar order.

11.7 I agree that the uncertainty in *Overseer* predictions needs to be borne in mind when determining trigger values, but I do not believe it should be the sole consideration. The trigger points should be considered as part of a wider risk analysis, including balancing the risk to farm sustainability, the risk to environmental protection, and where in that that risk profile different benchmark farms sit (whether the benchmark farms represent a low, average or high risk to the environment).

11.8 In addition, the uncertainty of *Overseer* predictions can be reduced if the focus is on a percentage change over time (rather than an absolute change), for the reasons I have previously discussed. If the percentage change is assessed over more than one year, I recommend a minimum of three year rolling average or trend analysis to limit the risk that year to year variations might trigger the rule on a given year while in fact there are no material long-term changes.

11.9 I have read the evidence of Mr Van Voorthuysen. He recommends a similar approach to that proposed by Dr Roberts in Canterbury, summarised above, with dairying, sheep and beef, and permanent horticultural crops assessed on the basis of three consecutive years, arable farming and cropping over a longer timeframe, and production forestry over a longer timeframe again.

11.10 I support basing the policy approach on a multi-year analysis.

11.11 Based on the thresholds suggested by Mr Van Voorthuysen and Dr Roberts, then at 15 kg, a typical value for sheep and beef farms, a 30% change is approximately the same as a 5 kg/ha/yr change. A dairy farm might leach between 30 and 80 kg N/ha/yr, depending on intensity, and management and mitigation options. A 10% change corresponds to a 3-8 kg/ha/yr change, which is again of the same order as the above 5 kg/ha/yr change. These percentage change values appear reasonable provided a multi-year analysis is used, and gives parity across industries in terms of absolute change using current model outputs.

11.12 Fertiliser Association of New Zealand[37] seeks also that Policy TT4(1)(f) refer to 'whole farm nitrogen leaching.' This is covered in paragraph 10.9 of my evidence.

11.13 Dairy NZ [38] seek that the Regional Council use the dairy industry's protocols.

11.14 I have commented on aspects relating to data entry protocols in section 7 of my evidence, with a recommendation to use the national standards, when they become available, as in paragraph 9.19 of my evidence.

11.15 Fish and Game seek deletion of all references to Nitrogen use efficiency.

11.16 Nitrogen use efficiency in *Overseer* is defined as N removed in products divided by sum of N in inputs in a year and is calculated at the farm scale.

11.17 Within a farm, N use efficiency can be used as a means of encouraging efficient use of N inputs through means such as improved feeding regimes, improved animal breeding, nutrient and management, as well as more efficient use of inputs such as N fertiliser or effluent. However, across farms there is a poor relationship between N use efficiency and N leaching loss, as illustrated in a report of which I was an author[39].

11.18 I cannot comment on whether NCE is an appropriate regulatory tool, however, I recommend that Change 6 provisions be assessed to ensure that any references to nitrogen use efficiency reflect my observations above.

DMWheeler

Signature

David Wheeler

September 2013

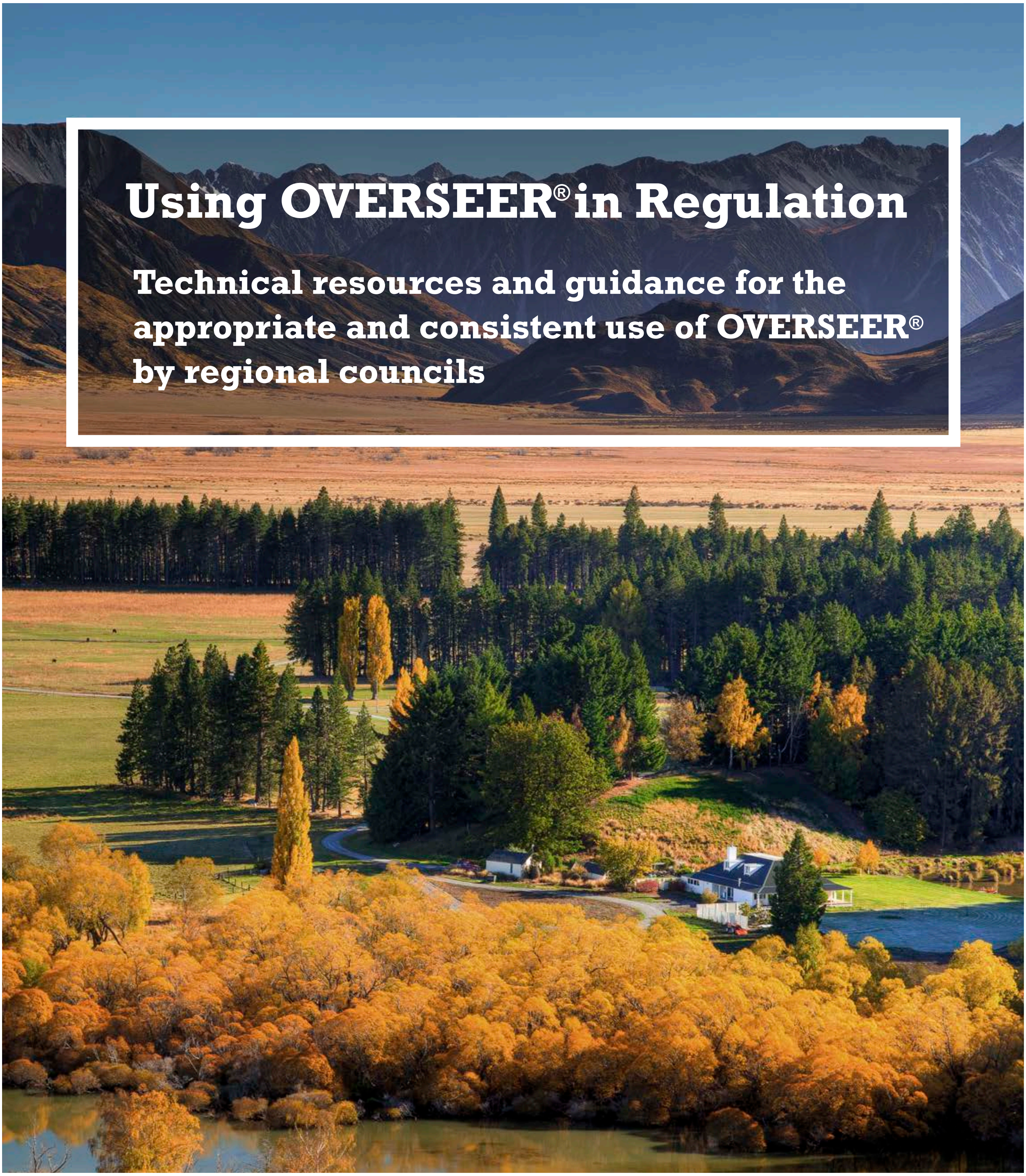
[37] Fertiliser Association of NZ submission #21
[38] (#17) Dairy NZ Submission
[39] Wheeler, D., Power, I. and Shepherd, M. (2011). Nutrient conversion efficiency on farm – lessons from OVERSEER® examples. In: Adding to the knowledge base for the nutrient manager. (Eds L.D. Currie and C L. Christensen). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 24. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 4 pages.

Appendix 6

Freeman, M, Robson, M, Lilburne L, McCallum-Clark, M, Cooke, A, & McNae, D. (2016) Using OVERSEER in regulation - technical resources and guidance for the appropriate and consistent use of OVERSEER by regional councils, August 2016. Report prepared by Freeman Environmental Ltd for the OVERSEER Guidance Project Board.

Using OVERSEER® in Regulation

Technical resources and guidance for the appropriate and consistent use of OVERSEER® by regional councils



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Using OVERSEER® in Regulation

Technical resources and guidance for the appropriate and consistent use of OVERSEER® by regional councils

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Executive Summary

Background

Much of New Zealand's freshwater resources are being adversely affected by diffuse discharges of nitrogen and phosphorus from urban and rural land. Under the National Policy Statement for Freshwater Management 2014 (NPS-FM) regional councils are required to establish freshwater objectives and set freshwater limits for water quality. The NPS-FM also requires regional councils to develop a freshwater quality accounting system to monitor nutrient concentrations/loads, the sources/amounts of nutrients, and where limits have been set, the proportion of that limit that is being used.

Where it is not practicable to measure diffuse discharges directly, the requirements of the NPS-FM will generally require some form of catchment and source nutrient load modelling to provide a basis for identifying and implementing appropriate management measures to achieve water quality objectives. The modelling used can range from simple conceptual models to complex software that models interactions between land use, topography, soils and climate.

OVERSEER® Nutrient Budgets (OVERSEER) is a computer software model that is being used to provide estimates of annual losses of nitrogen and phosphorus from a broad range of farm systems. OVERSEER models nutrient use and movement within a farm system. OVERSEER estimates the nutrient flows in a farming system and specifically includes estimates of nitrogen and phosphorus loss through leaching and/or run-off. The core of OVERSEER is a nutrient budget, which includes the nutrient inputs and outputs of a farm system.

How should OVERSEER be used under the Resource Management Act

OVERSEER is being used in regional plans and resource consents in many different ways throughout New Zealand and while there is some guidance on technical aspects of its use, there has been little guidance on its use in plan-making or in the resource consent process. The decision to use OVERSEER in these situations needs to be made in the knowledge of the model's assumptions and limitations and the issues that may arise with its use. Finding appropriate ways to address issues that arise is critical to ensuring the use of OVERSEER is fit for purpose under the Resource Management Act.

The purpose of this report is to provide information and advice to those who are using or are considering using OVERSEER to assist in informing the establishment of freshwater objectives, in setting and managing to freshwater quality limits under the NPS-FM, and in resource consent processes. Specifically, the report has been prepared to meet two key objectives:

1. To provide guidance for regional councils on the principles governing the use of OVERSEER in plan-making and resource consents.
2. To provide specific guidance for regional councils on how to manage the key modelling limitations that impact how OVERSEER can be used in plan-making and resource consents.

There is no single correct approach to managing the impacts of land use on water quality, and OVERSEER may be used in different ways within these different approaches. This report identifies key principles and practical guidance for using OVERSEER in the context of the overarching imperative to manage the impacts of land use on water quality.

This report is primarily intended for regional council staff (and consultants) who are involved in preparing and implementing regional plans, consultants involved in regional plan-making and resource consent processes, and Resource Management Act (RMA) decision-makers.

This document does not specifically address the question of whether a regional council should or shouldn't use OVERSEER in a regional plan and/or resource consent process, although the information contained should assist with such decisions.

Key Messages

1 Providing the assumptions, limitations (Appendix 3) and principles (Table 1) are taken into account, OVERSEER is suitable to provide estimates of nutrient loss for use in the implementation of the National Policy Statement for Freshwater Management 2014.

2 The decision by a regional council on whether or not to use OVERSEER will be influenced by a range of factors such as:

- the nature and extent of the water quality issue;
- the specific characteristics of the catchments;
- the state of knowledge about the water quality and catchment characteristics and the data available;
- the likely sources of nutrient(s) contributing to the water quality issue and the ability to measure at or near source;
- whether input-based or output-based methods of managing diffuse nutrient discharges are preferred;
- consideration of the relevant assumptions, limitations and principles, particularly those relating to uncertainty and version change management;
- the resources available to the regional council and the community; and
- the overall planning approach and philosophy.

3 The most appropriate approach to using OVERSEER in the development of plan provisions will depend on the specific catchment characteristics, the extent of nutrient water quality issues, the level of information available, the resources available to develop and implement a regional plan, the objectives sought by the regional plan and the consideration of these in the context of the principles outlined in Table 1.

4 Plan objectives and policies specific to nutrient water quality need to be clear and directive to ensure the environmental results sought by the plan are clear and to provide clear guidance for resource consent decisions that involve OVERSEER nutrient loss estimates.

5 The specification of a source nutrient load in plan provisions (e.g., objectives and/or policies) provides a high level of transparency and certainty. However, this is contingent on a robust mechanism to deal with improving information and model version change where the specified load is largely reliant on OVERSEER estimates.

6 In addition to the existing guidance on resource consent conditions, there are important specific matters that need to be considered and incorporated in resource consent conditions that require an OVERSEER nutrient loss estimate, to ensure that the intent of limiting nutrient losses is achieved and ultimately that freshwater quality objectives are achieved.

7 OVERSEER can be a critical part of the process of estimating catchment nutrient source loads. However, it is important to understand the implications of the different estimation methods and the factors that need to be taken into account e.g., uncertainties related to OVERSEER estimates, catchment attenuation factors and OVERSEER version changes.

8 OVERSEER version changes are an essential consequence of improvements to the accuracy of OVERSEER estimates, broadening of its applicability and improving its usability and/or user interface. However, OVERSEER version changes (excluding usability and user interface changes) can result in significant changes to estimates of N and/or P loss. The consequential changes in nutrient loss estimates can vary significantly from property to property, depending on the level of similarity of soils, climate, climate patterns, topography, farm systems, etc.

9 OVERSEER version changes can potentially affect the understanding of source nutrient losses that was relied on in the plan-making process, and can potentially affect the status of activities under regional rules and/or resource consents. A range of methods can be used in regional plan provisions and resource consent conditions to avoid or minimise the consequences of version changes (see Sections 3 & 4).

10 Uncertainty in OVERSEER nutrient loss estimates is inevitable and regional plan and resource consent decisions need to acknowledge and endeavour to reduce uncertainty. Uncertainty is not a reason to take no action. Rather, the higher the uncertainty, the greater the need for robust monitoring and review processes for plan provisions and resource consents.

11 Some uncertainty in OVERSEER nutrient loss estimates will be reduced by undertaking and incorporating further science e.g., collecting more evaluation data under different soils and climates. Other forms of uncertainty are essentially irreducible e.g., biological variability. There are options and methods for using OVERSEER and OVERSEER outputs in a way that recognises and manages uncertainty in planning and resource consent processes.

12 Provided that the relevant assumptions, limitations (Appendix 3) and principles (Table 1) are taken into account, OVERSEER is suitable to model P as well as N source loss at a property and catchment level.

13 The receipt and long-term management of individual OVERSEER property files need well-designed data management and security systems to ensure that all legal, technical, and long-term information needs are met. Significant resources are required to develop and implement the necessary data provision and security measures.

14 OVERSEER modelling requires a detailed knowledge of the New Zealand farming system being modelled and a detailed understanding of OVERSEER. This is particularly significant for scenario modelling. Therefore, only people with the requisite knowledge should undertake OVERSEER modelling to meet regional plan and or resource consent requirements.

15 A high level of assurance about the fitness for purpose of an OVERSEER estimate of nutrient loss needs independent auditing by a person with significant knowledge of the modelled farming system and OVERSEER.

16 The use of OVERSEER requires an understanding of the functions and relationships of component parts of the model. This requires regular publication of the details of those functions and relationships.

Recommendations

Recommendations – Plan-making (Section 3)

1 There is no one best way to apply OVERSEER within a regional planning framework. How and where OVERSEER is used in the plan-making process needs to be considered in the wider context of specific catchment characteristics, the extent of nutrient water quality issues, the level of information available, the resources available to develop and implement a regional plan, the freshwater objectives, and consideration of the principles outlined in Table 1.

2 Regional plan provisions should have clear and directive objectives and policies specific to nutrient water quality (e.g., receiving water nutrient concentrations and algal biomass) and catchment nutrient limits to ensure the environmental results sought by the plan are clear. This would provide clear guidance for any resource consent application process that involves OVERSEER nutrient losses estimates.

3 Where farm environment plans are identified as an implementation mechanism within a regional plan, the provisions should be clear about their specific role i.e., are they intended to be a primary enforceable element of a rule and/or resource consent condition (see Section 3.4) or are they intended to primarily provide information to complement other conditions?

4 Take account of the potential implications of OVERSEER version changes by:

(a) incorporating a process in an implementation plan (see sections 3.2, 3.3 & 3.4) to assess the implications of OVERSEER version changes on estimates of catchment source nutrient loads and any other relevant improved catchment information (e.g., hydrological information) for plan provisions,

(b) avoiding the used of fixed numerical thresholds with no OVERSEER version management method in permitted activity and prohibited activity rules that require OVERSEER estimates to determine compliance with those thresholds,

(c) ensuring that there is a robust method of managing the effects of an OVERSEER version change if thresholds are used in any rules classifying activity categories that require OVERSEER estimates to determine compliance with those thresholds (see Section 6),

(d) to the extent the methods referred to in (c) above are not fully effective in managing the effects of OVERSEER version change, minimising the reliance on activity status definition thresholds that depend on OVERSEER estimates e.g., by minimising the number of classes of activities defined by such thresholds to minimise the risk of a land use or discharge changing activity status as a consequence of an OVERSEER version change,

(e) considering the use of a mechanism to minimise the impact of OVERSEER version changes on regional rule (and resource consent) thresholds, including, but not limited to, a link to an external calculator or reference files, but recognising that (as at July 2016) there is no case law on this type of linked external mechanism (see Section 6), and

(f) recognising that methods of using OVERSEER in regional plans and resource consents are still developing and that approaches adopted by some plans have not been fully tested.

5 Where regional rules are set that rely on OVERSEER estimates to determine compliance, they should include the following requirements:

(a) a requirement to undertake OVERSEER modelling in accordance with appropriate standards and guidelines e.g., the relevant Best Practice Data Input Standards (BPDIS), and in particularly sensitive situations, a requirement for independent auditing as outlined in Table 12.

(b) a defined period(s) of time over which the OVERSEER modelling must be undertaken – generally a minimum of a rolling average of three to five years (see Section 8),

(c) a minimum qualification requirement for the person undertaking OVERSEER modelling of a Massey University Certificate in Advanced Sustainable Nutrient Management, an equivalent qualification, or extensive experience in a specific farming system and detailed understanding of OVERSEER. For OVERSEER modelling of particular significance, independent auditing of modelling should be undertaken by a person with the minimum qualification specified above, against the factors and process outlined in Table 12 (see Sections 10 & 11).

(d) A requirement to provide the relevant OVERSEER XML file and supporting information by a specific date, on request, or if a specific event occurs, to ensure that the consent authority is able to audit the information provided (see Section 10).

6 The following technical matters should be taken into account in the use of OVERSEER in the regional plan-making and implementation processes, along with other considerations such as cost and resourcing implications:

(a) Uncertainty – particularly the uncertainties associated with estimating both source and receiving water nutrient loads, and how this uncertainty should be managed and transparently taken into account in developing plan provisions e.g., using methods for generating source loads with low or moderate uncertainty, using OVERSEER outputs in a way that minimises uncertainty such as in a relative sense, prioritising the sourcing of good quality data for critical OVERSEER variables, incorporating adaptive management policies, having an implementation plan that specifies frequent receiving water quality monitoring and annual reassessment of catchment nutrient loss estimates, etc. (see Sections 5 & 7).

(b) Averaging – the potential for high inter-annual variation in estimated nutrient losses and less accurate nutrient loss estimates where the use of one year's actual farm system data may not be consistent with OVERSEER's long-term climate data means that the development and implementation of plan provisions should generally not rely on one year's actual farm system data (see Section 8).

7 An implementation plan should be developed that among other matters includes a plan for managing data provided to the council (e.g., OVERSEER XML files) (see Section 10).

Recommendations – Resource consent conditions (Section 4)

1 Resource consent conditions that specify thresholds that require an OVERSEER estimate to determine compliance should contain the following components:

(a) A well-defined threshold (see Appendix 4). There can be advantages in also including a pre-threshold 'trigger response' condition that requires a specific action to be taken prior to a critical threshold being reached.

(b) A requirement to undertake OVERSEER modelling in accordance with appropriate standards and guidelines e.g., the BPDIS, and in particularly sensitive situations, a requirement for independent auditing as outlined in Table 12.

(c) A defined period of time over which the OVERSEER modelling must be undertaken – generally a minimum of a rolling average of three to five years (see Section 8).

(d) An OVERSEER version management mechanism e.g., using a threshold defined with a GMP calculator or reference files, by not relying solely on one threshold condition, by providing an updating mechanism (e.g., providing for previously compliant model inputs to remain compliant in a new version, or using an external calculator/reference files system), by providing complementary conditions that would make it relatively easy to apply to change and/or to initiate a review of conditions as a consequence of an OVERSEER version change, a fixed version (if available), etc. (see Appendices 4 & 6 & Section 6).

(e) A minimum qualification requirement for the person undertaking OVERSEER modelling of a Massey University Certificate in Advanced Sustainable Nutrient Management, an equivalent qualification, or extensive experience in a specific farming system and detailed understanding of OVERSEER. For OVERSEER modelling of particular significance, independent auditing of modelling should be undertaken by a person with the minimum qualification specified above, against the factors and process outlined in Table 12 (see Sections 10 & 11).

(f) A requirement to provide the relevant OVERSEER XML file and supporting information by a specific date, on request, or if a specific event occurs to ensure that the consent authority is able to audit the information provided (see Section 10).

(g) A requirement for an FEP – to provide a tangible practical guide on how farm management will be undertaken. However, there needs to be absolute certainty about whether the FEP is a primary enforceable condition or is primarily to complement other conditions, and care is needed to avoid any conflicts between conditions (see Section 3.4).

2 The following technical matters should be taken into account in the use of OVERSEER in resource consent conditions, along with other considerations such as cost and resourcing implications:

(a) Uncertainty –conditions that take uncertainty into account are likely to be needed e.g., adaptive management conditions such as monitoring and consequential 'trigger response' requirements, short duration term combined with appropriate monitoring/ investigations and reporting to provide more information, a review condition that specifies an event that would trigger a review, etc. (see Section 7 and the QP website).

(b) Averaging – there is potential for high inter-annual variation in estimated nutrient losses and less accurate nutrient loss estimates where the use of one year's actual farm system data may not be consistent with OVERSEER's long-term climate data (see Section 8).

Recommendations - Estimating catchment nutrient loads (Section 5)

1 Where source loads calculations are used to inform source and receiving environment nutrient load limits, use information and methods with low or moderate uncertainty, as outlined in Table 4.

2 There needs to be targeted long-term nutrient water quality monitoring to progressively test the modelling assumptions used in the catchment modelling, including attenuation factors, and a process for assessing and, where appropriate, updating those factors as new information becomes available. This would then enable that new information to be considered in a plan review process.

3 The implications of OVERSEER version changes on source nutrient load estimates and calculations used as a basis for setting catchment nutrient load limits should be assessed as soon as practicable after each version change.

Recommendations – Overseer version change issues (Section 6)

1 The implications of OVERSEER version changes for regional plan provisions where OVERSEER was used to inform the development of those provisions should be assessed as soon as practicable after each version change e.g., by checking the effects of the version change on any source nutrient loss estimates and calculations used in developing plan provisions, and checking the effects of the version change on regional rule thresholds that require OVERSEER estimates.

2 OVERSEER version change issues should be taken into account in the development and implementation of regional plans and resource consent conditions (see Sections 3 & 4).

3 The specification of nutrient loss model alternatives to OVERSEER in regional plan provisions or resource consent conditions should be complemented with technical criteria and/or specifications to enable an appropriately qualified person acting on behalf of the regional council (e.g., a senior officer, consultant/commissioner) to certify or not that an alternative model complies with those criteria and/or specifications.

4 OVERSEER Limited should consult with OVERSEER stakeholders and users to review the frequency and content of OVERSEER version changes e.g., to consider the option of having only one version change per year that involves an OVERSEER 'engine' change that could affect N and/or P loss to water estimates.

5 Regional councils, the Ministry for the Environment, and the Ministry for Primary Industries should review the options for developing robust processes for the incorporation of changes to models such as OVERSEER that are regularly updated with new versions and are specified directly or indirectly in regional plan rules or resource consent conditions.

Recommendations – Uncertainty (Section 7)

1 Uncertainty in OVERSEER nutrient loss estimates is inevitable and the development and implementation of regional plans and resource consent conditions should acknowledge uncertainty and endeavour to reduce uncertainty by:

(a) acknowledging in the plan-making process that catchment modelling and OVERSEER modelling involves significant uncertainties and communicating which options and methods are being used to manage uncertainty (see Table 8)

(b) using good quality data inputs, in particular for the more influential inputs (which will vary from situation to situation e.g., by spending more time in sourcing these data, using expert verification and/or independent modelling sources

(c) using qualified and experienced OVERSEER model users, using appropriate standards and guidelines e.g., the appropriate BPDIS, and taking account of other quality factors (see Table 12)

(d) endeavouring to use independent parallel sources of information where OVERSEER is being used significantly beyond its calibration range (system/soil/climate) e.g., through other models and/or relevant robust information

(e) using OVERSEER outputs in a way that minimises the impact of uncertainty e.g., using model outputs in a relative sense or using adaptive management methods (see Sections 3 & 4)

(f) communicating the potential consequences of uncertainties in OVERSEER outputs e.g., undertaking significance analyses and considering the impact of ranges of possible nutrient losses

(g) considering the use of policy, rule and resource consent condition frameworks that support adaptive management (see Sections 3 & 4) and are driven by appropriate indicators, such as the status of the receiving environment, and as more information comes available including from future modelling.

(h) ensuring ongoing targeted monitoring and data collection within a catchment where OVERSEER has been used to generate nutrient source load estimates, and if necessary, testing and revising the modelling and assumptions that underpin the catchment load calculations.

2 Additional investment should be made in research and investigations in priority OVERSEER science to reduce uncertainties, particularly for those situations that are significantly different from original calibration studies used in the development of OVERSEER e.g., locations with different soils, more or less annual precipitation, different farm systems, etc.

Recommendations – Averaging (Section 8)

1 The development of regional rules and resource consent conditions should recognise that one year's actual annual farm system data, as input into OVERSEER, may not be consistent with long-term climate data. Where they are inconsistent, nutrient loss estimates are likely to be highly uncertain and unlikely to represent the actual nutrient loss in that year.

2 Typical representative farm systems or averaging OVERSEER outputs can be used to endeavour to address the potential inconsistency that is otherwise likely to occur using one year's actual annual farm system data with OVERSEER's long-term climate data. If the climate over that averaged period is significantly different from the long-term climate, the result may overestimate or underestimate actual nutrient losses.

3 Any typical representative farm systems used for predictive purposes (e.g., when developing plan provisions) should be well defined e.g., as in the Matrix of Good Management (Robson et al., 2015).

4 Generally, OVERSEER outputs rather than inputs should be averaged. OVERSEER inputs should only be averaged if there is a clear understanding of the limitations and risks involved.

5 For the purpose of assessing compliance with a threshold in a regional rule or resource consent condition, a rolling average of a minimum of the previous 3–5 years of OVERSEER outputs should generally be used to provide a less variable and more meaningful indication of long-term nutrient loss from that farm system.

6 OVERSEER estimates of nutrient losses for farm systems undergoing a significant farm transition period e.g., dryland to irrigation, will have a relatively high uncertainty compared to stable farm systems. Therefore, reporting of nutrient losses should generally not be done for a farm system during a significant farm transition or, if this cannot be avoided (e.g., where reporting is required and a significant farm transition has occurred), appropriate assumptions should be incorporated to reduce that uncertainty (e.g., if the transition is to a more intensive land use with higher nutrient loss, to model that more intensive land use for the transition year).

7 The new capability (in OVERSEER version 6.2.2) to enter monthly climate data should not be used for the development or implementation of regional rules or resource consent condition until the BPDIS indicate that the capability is appropriate for non-research purposes.

8 Where short-term estimates of nutrient losses are required, e.g. seasonal estimates or for target water bodies that respond very quickly to changes in nutrient loading, an alternative to the currently available OVERSEER version should be considered, such as a more process-based model e.g., APSIM (2016).

9 Further investigation of appropriate averaging periods should be undertaken e.g., by reviewing the available pasture farmlet experiments that have measured N leaching and especially by reviewing the data available for non-dairy farm systems.

Recommendations - Nitrogen and Phosphorus modelling (Section 9)

1 The use of OVERSEER should take into account the different processes involved in N and P loss, the different modelling approaches taken in OVERSEER for N and P, and the assumptions and limitations that apply specifically to N and/or P (see Table 11 and Appendix 3) e.g., it is critical to appreciate the specific nutrient loss sources that OVERSEER models in a catchment and the need to use other methods to estimate other nutrient loss sources.

2 The current evidence strongly indicates that OVERSEER modelling of P loss is not inherently more uncertain than OVERSEER modelling of N, and provided that the relevant assumptions, limitations (Appendix 3) and principles (Table 1) are taken into account, OVERSEER modelling of P is suitable to be used in the modelling of property and catchment P loads.

3 Investigations should be undertaken to assess the feasibility of developing guidance for 'blocking' a farm on the basis of P critical source areas. This may also assist with linkage to complementary models with the resolution needed to identify, and target mitigation to, critical source areas.

Recommendations – Data management, security and quality assurance (Section 10)

1 Regional councils should:

(a) Store OVERSEER XML files using a method that enables file data to be extracted using an automated process, and that provides for access controls and logging e.g., in a controlled system (document management system or database) or in a dedicated database table or store machine-readable references to the document, which may be stored in a document management system.

(b) Include additional database information to track:

(i) the provenance (original source) and date of the farm model,

(ii) the OVERSEER version used to develop the farm model/outputs,

(iii) for audit reviewed OVERSEER XML files, the reviewer, date of review, OVERSEER version used, audit rating, and any review notes, and

(iv) for any modification to OVERSEER XML files (e.g., after an audit review or to ensure the farm model complies with required practices), the date, originator and purpose of the modification, as well as the OVERSEER version used.

(c) Consider automated extraction of key farm model data or calculated outputs (such as farm areas, stocking rates, N and P nutrient budgets) to a separate table or area to enable rapid reporting without needing to extract individual results from XML or recalculate (OVERSEER version and date of calculation would also need to be stored with the extracted data).

(d) Consider developing methods to export anonymised OVERSEER file data from the database via a secured process to support use for purposes such as auditing, catchment studies or sensitivity analyses.

(e) Ensure that an information security policy for the organisation defines appropriate policies and controls for the type of data held and allows the organisation to audit or check that those policies and controls are implemented, including mechanisms to determine the authentication or identity of people accessing farm model data along with their authorisation to access such data, and to record such data access.

(f) Once the above information security policy and controls are implemented, consider seeking accreditation under the Farm Data Code of Practice, which would provide further assurance to farmers and advisors regarding the rights and controls surrounding identifiable farm data.

(g) Implement processes to ensure that all parties who provide OVERSEER XML files as part of a regulatory requirement are advised of the processes and protocols used to manage that information.

(h) Consider collectively or individually creating datasets that contain information such as typical range of stocking rates or pasture grown (or consumed) for different soil types of land classes to be used as a quick check for OVERSEER file information.

(i) Develop criteria for apportioning nutrient loss allocations specified in resource consents, if needed as a consequence of property subdivision.

(j) Ensure that OVERSEER modelling undertaken to meet a regional plan or resource consent requirement in a location of particular significance, e.g., for estimating nutrient losses in a catchment with significant nutrient water quality issues with regional plan objectives and policies that require reductions in nutrient source loads, is audited against a comprehensive suite of factors, such as those detailed in Table 12. Only those model outputs that have a modelling audit rating of High or Medium should be accepted for a regulatory requirement. (Also see Section 11).

(k) Consider development of processes to provide detailed guidance for the OVERSEER file audit process outlined in Table 12 e.g., to ensure consistency between auditors.

2 OVERSEER Limited and users such as regional councils and advisors should consider development and implementation of a mechanism that allows the creator of an OVERSEER XML file to identify the purposes for which it was created and released, supported by 'digital signing' so that later modifications could be identified and repudiated.

3 OVERSEER Limited and regional councils should consider developing a simple linking or reference mechanism to assist traceability of data from multiple sources. This could be implemented within the nodes or sections in an OVERSEER XML file.

4 OVERSEER Limited should endeavour to maintain backwards compatibility for at least 4 years i.e., to ensure that OVERSEER XML files generated 4 years previously can still be successfully run on the current OVERSEER model. If the need for significant model improvement/enhancement means that this cannot be achieved, there should be prior consultation between OVERSEER LIMITED and regional councils to enable the development of a methodology to achieve backwards compatibility.

5 Regional councils and OVERSEER Limited should support initiatives to enhance the interoperability of models used in Resource Management Act processes that involve OVERSEER inputs or outputs.

Recommendations - Qualifications and auditing (Section 11)

1 The minimum qualification requirement for undertaking OVERSEER modelling should be a Massey University Certificate in Advanced Sustainable Nutrient Management, an equivalent qualification, or extensive experience in a specific farming system and detailed understanding of OVERSEER.

2 For OVERSEER modelling of particular significance, e.g., for estimating property nutrient losses in a catchment with significant nutrient water quality issues with regional plan objectives and policies that require reductions in nutrient source loads, independent auditing of modelling should be undertaken by a person with the minimum qualification specified above, against the factors and process outlined in Table 12.

3 The functions and relationships of component parts of the OVERSEER model need to be published and those publications updated regularly by OVERSEER Limited to ensure that they are understood by those involved in the use of OVERSEER.

1 Introduction

The cumulative effect of diffuse nutrient discharges from farming on water quality is recognised as a significant resource management issue (LAWF, 2010). Managing the effects of land use on water quality is a national as well as a regional challenge. Under the National Policy Statement for Freshwater Management 2014 (NPS-FM) (MfE, 2014), regional councils are required to establish freshwater objectives and set freshwater quality limits for water quality. This requirement has increased interest in, and use of, a range of tools and models including OVERSEER® Nutrient Budgets (OVERSEER).

As OVERSEER is developed and changes to the Resource Management Act occur, this guidance document may need to be updated.

1.1 Purpose

The focus of this report is to provide information and advice to those who are using or are considering using OVERSEER to assist in informing the establishment of freshwater objectives related to nitrogen (N) and/or phosphorus (P), in setting and managing to freshwater quality limits under the NPS-FM, and in resource consent processes[3]

This report builds on a suite of existing information (see Appendix 1) and has been prepared in accordance with a specific brief (see Appendix 2).

There is no single correct approach to managing the effects of diffuse nutrient loss from land use on water quality, and OVERSEER may be used in different ways within these different approaches. This report identifies key principles and practical guidance[4] for using OVERSEER in the context of the overarching imperative to manage the effects of land use on water quality.

This report is primarily intended for regional council staff (and consultants) who are involved in preparing and implementing regional plans, consultants involved in regional plan-making and resource consent processes, and Resource Management Act (RMA) decision-makers. This guidance is expected to also enhance the level of consistency across New Zealand where, despite the significant differences between catchments, there will be greater scope for regional plans and resource consents to have common frameworks.

[3] Achieving freshwater quality objectives and limits is likely to involve a broad range of activities as well as regulation including education, training, monitoring, non-regulatory mechanisms, farming and industry programmes, and leadership.

[4] The scope of this guidance does not extend to:
- software development
- field trials and scientific investigations
- development of user training or certification material
- general guidance on the development or implementation of catchment nutrient management plans
- general guidance on the development or implementation of regional plans
- nutrient allocation methods.

To understand what OVERSEER may provide for plan-making and resource consents a general level of knowledge of OVERSEER is essential. While this guidance document provides a significant amount of information which draws from a wealth of experienced practitioners, published and unpublished literature, it is recommended that readers first familiarise themselves with the basics of OVERSEER e.g., by reading the background material available on the OVERSEER website.

This document does not specifically address the question of whether a regional council should or shouldn't use OVERSEER in a regional plan and/or resource consent process, although the information contained should assist with such decisions.

1.2 What is OVERSEER?

OVERSEER is a computer software model that models nutrient use and movement within a farm system. OVERSEER estimates the nutrient flows in a farming system and specifically includes estimates of N and P loss to water through leaching and/or run-off. The core of OVERSEER is a nutrient budget, which includes the nutrient inputs and outputs of a farm system. A more detailed description is in Watkins and Selbie (2015).

1.3 Key RMA considerations

The use of OVERSEER, particularly in plan-making processes, needs to be considered in the wider context of regional plan development under the RMA and the implementation of regional plans. As expanded on in Section 3, regional planning is undertaken in the context of regional councils' functions under s30 of the RMA. Regional plans must give effect to the NPS-FM and relevant regional policy statements and proposed plan provisions must be evaluated in accordance with s32 of the RMA before plan notification.

This report is focussed on the use of OVERSEER to estimate the existing or potential diffuse loss of nutrients from land uses into water, which can then be used as a basis for policy and/or regulation through regional plans and resource consents. It is acknowledged that this can result in policy and regulation for land use and discharge activities not being guided by measured effects. However, in many situations, it is not practicable or possible to routinely measure diffuse nutrient losses (Figure 1). The use of OVERSEER enables a focus on estimated effects rather than relying on activities or inputs into a farm system. Providing the challenges of using a model are adequately managed, OVERSEER is considered to be an appropriate tool to use to inform the establishment of regional plan provisions that meet the requirements of the NPS-FM. In this context, this report focusses on how the challenges associated with the use of a model need to be considered in, and managed through, planning frameworks under the RMA.

Figure 1 illustrates in simple terms why models may be needed to manage the effects of diffuse nutrient discharges, depending on which methods of management (input or output) are used (see Section 2.2 for more detail.).

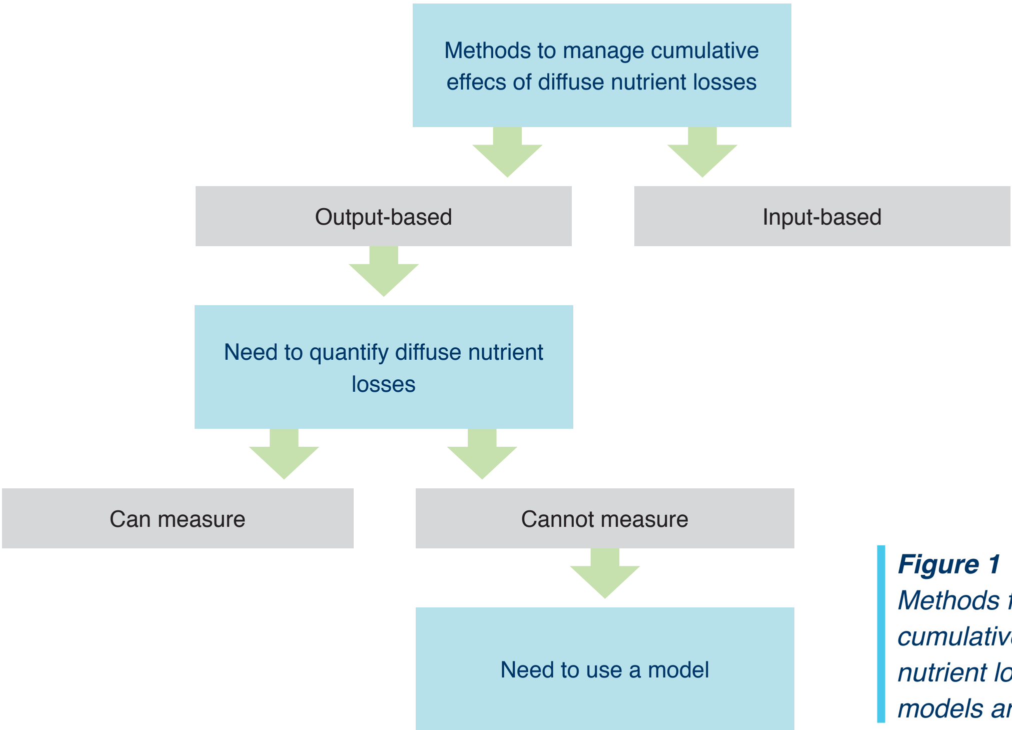

Figure 1
Methods for managing the cumulative effects of diffuse nutrient losses and where models are needed

1.4 Water quality management and using OVERSEER

To manage water quality, the sources of the key contaminants in a catchment need to be established. These contaminants may come from either point sources, discharged at discrete, identifiable locations and usually measurable (Novotny, 2003), or diffuse sources arising from land-use activities (urban and rural) that are dispersed across a catchment (D'Arcy et al., 2000) and usually difficult to measure. Farming is often a significant contributor of diffuse nutrients in a catchment. This report focusses on the nutrients N and P.

To help manage the effects of land use a conceptual model[5] of a catchment can be developed to understand the relationship between nutrient sources and water quality for a specific catchment (Figure 2). Depending on the nature and severity of the water quality problem and the management approach preferred, numeric models that build on these conceptualisations may be useful or necessary tools.

Modelling nutrient losses from land uses into the catchment may not be needed for management of water quality if the relationship between land use and water quality is quite simple, if there is little pressure on the resource, if the nature of the water quality issue is measurable, or if directed management interventions (such as fencing or tree planting) are likely to be successful. However, modelling nutrient losses from land uses into the catchment is likely to be important if the relationship between land use and receiving water quality is complex, if there is high pressure or risk to the resource/wider environment, if the diffuse losses are not directly measurable, or if there are possible future policy options that need to be tested for the development of a regional plan. OVERSEER is the principal available model to estimate the farming land-use portion of the source nutrient load (point 'A' in Figure 2).

[5] These conceptual models are created either implicitly by individuals, where knowledge and experience lead to an understanding of how the catchment works, or they can be created explicitly with detailed technical descriptions of catchment processes.

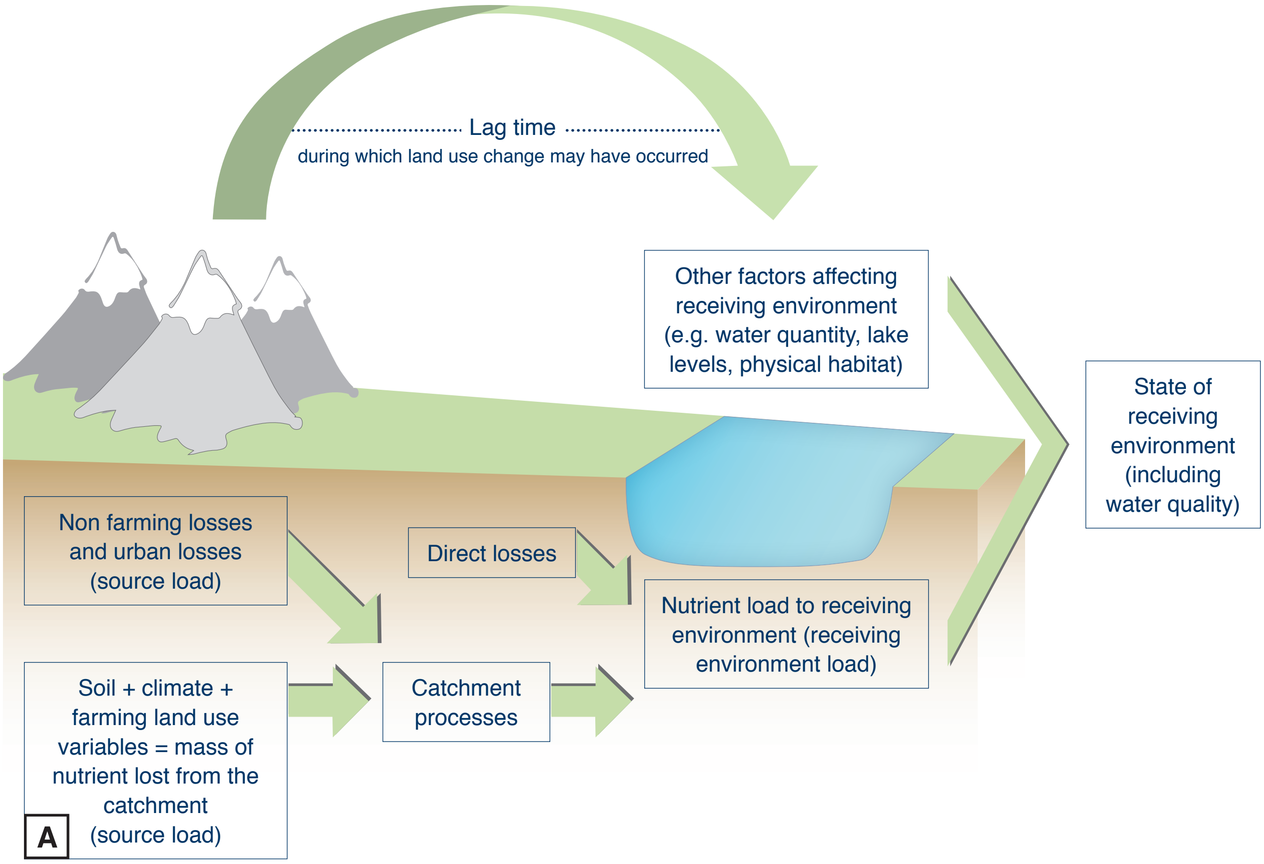

Figure 2
Simplified conceptual relationship between losses of nutrients from the catchment and the state of receiving environment water quality (groundwater, rivers and lakes), 'A' indicates where a model such as OVERSEER can be used to estimate the farming land-use portion of the source nutrient load

There is no single correct approach to managing the effects of land use on water quality, and there will be circumstances where it is not necessary to use a complex numeric model or modelling software, such as OVERSEER, to successfully manage water quality. There will also be circumstances where OVERSEER is not an appropriate model to be used to estimate nutrient losses from farming systems e.g., where the farming system is currently not modelled by OVERSEER.

The decision by a regional council on whether or not to use OVERSEER will be influenced by a range of factors such as:

- the nature and extent of the water quality issue;
- the specific characteristics of the catchments;
- the state of knowledge about the water quality and catchment characteristics and the data available;
- the likely sources of nutrient(s) contributing to the water quality issue and the ability to measure at or near source;
- whether input-based or output-based methods of managing diffuse nutrient discharges are preferred;
- consideration of the relevant assumptions, limitations and principles, particularly those relating to uncertainty and version change management;

- the resources available to the regional council and the community; and
- the overall planning approach and philosophy.

The important questions involved in making that decision are:

1 What is the nature of the issue that needs addressing?

2 What package of data, tools, models and approaches is currently available to address this issue?

3 If there aren't data or other, more effective tools and approaches or models with less uncertainty, can the uncertainties and limitations in OVERSEER be adequately managed for this particular issue?

Whether or not it is preferable or appropriate to use OVERSEER in a particular situation will depend on answers to questions 1, 2 and 3.

1.5 Structure of report and guidance

The report covers the principles and guidance on key topics for the use of OVERSEER in establishing freshwater objectives and setting and managing to freshwater quality limits in regional plans and resource consents. After laying out the key plan-making considerations, the report describes the different approaches to using OVERSEER for managing diffuse nutrient discharges; the supporting principles for the use of OVERSEER; and planning and technical information that provides guidance on the approaches and that underpin the principles (Figure 3).

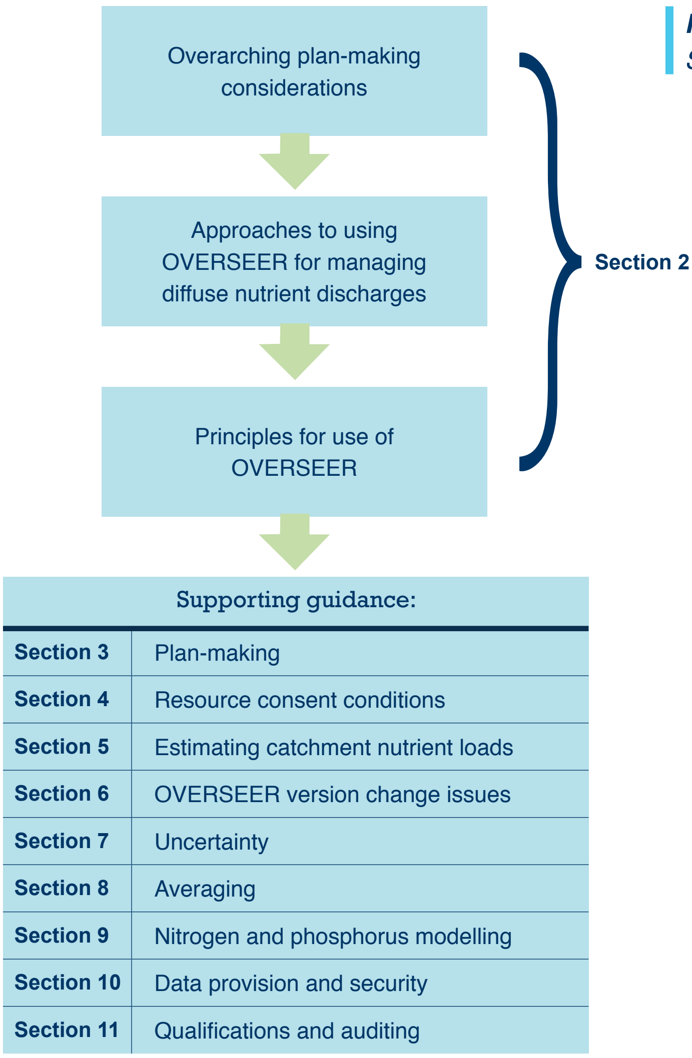

Figure 3
Structure of this report

1.6 Terminology

The following definitions have been used in this report. Definitions used in the RMA are followed here, some NPS-FM definitions have been included, and other commonly used technical definitions have been used. Refer to Watkins and Selbie (2015) for further clarification of some technical terms directly related to OVERSEER.

Accuracy	The accuracy of a measurement system is defined as the degree of closeness of measurements of a quantity to that quantity's actual (true) or accepted value (where actual measurement is impractical). There are significant practical difficulties in comparing whole-farm nutrient loss estimates with actual losses because of the great technical difficulty of measuring these losses, such as N leaching.
Adaptive management	Flexible management that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process.
Allocation	An amount of a resource assigned or distributed to a recipient or group of recipients (such as within a catchment or an irrigation scheme) i.e., the assignment of an estimated total source limit to an individual or group of users.
Allowance	See ‘threshold’.
Auditing	The systematic and independent examination of the inputs and assumptions made in OVERSEER modelling to determine their accuracy and/or appropriateness for the use of the modelling outputs.
Benchmark nutrient loss	A reference annual nutrient loss for a property.
Baseline nutrient loss	A type of reference annual nutrient loss for a property usually estimated for a specific previous period.
Block	An area of land within a property/farming enterprise that has common physical and management attributes. OVERSEER categorises blocks into types e.g. pastoral, fodder crop, trees and scrub, house. There may be multiple blocks of the same type within a property/ farming enterprise reflecting the different physical or management characteristics of each of the blocks.
Calculate	See ‘estimate and calculate’.
Calibration	The process of adjusting numerical or physical modelling parameters in a model for the purpose of improving agreement with experimental data.
Catchment attenuation processes	Processes, such as sedimentation, plant uptake, or denitrification, that can remove nutrients before they enter, or from within a freshwater receiving environment
Catchment attenuation factor	The proportion of the nutrient source load that is removed from the receiving water by catchment attenuation processes.

Catchment load	Generic term for source and/or receiving environment nutrient loads in a defined hydrological catchment.
Critical source areas	Areas of enriched nutrient or sediment sources and hydrological activity that occur in small parts of a catchment or farm, but contribute a disproportionately large amount of nutrient or sediment to the environment (e.g., steep hills, gullies or swales)
Discharge	Refer to Section 15 of the RMA.
Diffuse nutrient sources/ discharges	Nutrients arising from land-use activities (urban and rural) that are dispersed across a catchment.
Engine	The calculation model within OVERSEER. This uses inputs from a user interface or file and produces the outputs.
Error	In a modelling context, error generally refers to the difference between the modelled representation of a system, and the reality of the system. The primary types of error include input, model, and output error, and models could contain combinations of these (see Shepherd et al., 2013).
Estimate and calculate	Nutrient losses from a farm are estimated by OVERSEER; these estimates (along with other sources of information) may be used to calculate a source nutrient load. The use of the word 'calculate' for the catchment load does not denote a greater degree of confidence, only that a calculation has been made.
Evaluation (validation)	All quantitative and qualitative methods for evaluating (or validating) the degree to which a model corresponds to reality.
Farm environment plan (FEP) or nutrient management plan (NMP)	Different regional plans often use different terminology and apply such plans in different ways. However, common features are usually a detailed description of the property including all aspects that can influence nutrient loss, a requirement to undertake and provide an OVERSEER nutrient budget and a detailed plan that identifies how specific nutrient loss objectives/ requirements will be achieved.
Freshwater management unit.	"Is the water body, multiple water bodies or any part of a water body determined by the regional council as the appropriate spatial scale for setting freshwater objectives and limits and for freshwater accounting and management purposes." (NPS-FM)
Freshwater objective	"Describes an intended environmental outcome in a freshwater management unit." (NPS-FM)
Freshwater quality accounting system	"Means a system that, for each freshwater management unit, records, aggregates and keeps regularly updated, information on the measured, modelled or estimated: a) loads and/or concentrations of relevant contaminants; b) sources of relevant contaminants; c) amount of each contaminant attributable to each source; and d) where limits have been set, proportion of the limit that is being used." (NPS-FM)

Good management practices	This term is often defined in regional plans and no one specific definition is used in this report. However, it is important to distinguish between those definitions and the "good management practices" assumed in OVERSEER. These are more appropriately termed "assumed management practices" to avoid confusion. Examples of these assumed management practices include the even application of fertiliser and sealed effluent storage ponds. Referring to such practices as "good management practice" may not match up with definitions used in regional plans. For example, OVERSEER could model the impacts of excessive amounts of fertiliser applied (which is not good management practice), but would assume that the fertiliser is being applied evenly and in a way where additional losses are not incurred.
User interface	The visual website screens that provide the ability for a user to enter data into OVERSEER to enable the OVERSEER engine to run to produce outputs.
Limit	The "maximum amount of resource use available, which allows a freshwater objective to be met". (NPS-FM)
Nutrient load	An amount of nutrient, usually expressed as an annual amount e.g., kg/yr.
Nutrient budget	Report of net nutrient inputs and outputs to a given scale (block, farm), in a defined system over a fixed period of time.
Nutrient discharge allowance	See 'threshold'.
Nutrient management plan (NMP)	See 'Farm Environment Plan'.
Nutrient losses	Nutrient lost from a farm boundary/root zone (may be described as a mass or concentration).
Over-allocation	Is the situation where the resource: a) has been allocated to users beyond a limit; or b) is being used to a point where a freshwater objective is no longer being met.
OVERSEER	OVERSEER® Nutrient Budgets (OVERSEER) is a computer software model that estimates nutrient use and movement within a farm system. OVERSEER estimates the nutrient flows in a farming system and specifically includes estimates of nitrogen and phosphorus loss to water through leaching and/or run-off.
Point source discharges	Discharges that occur at discrete, identifiable locations and can usually be measured.
Precautionary principle	"Where there are threats of serious or irreversible damage, lack of full scientific evidence shall not be used as reason for postponing cost-effective measures to prevent environmental degradation" (Rio Declaration on Environment and Development, 1992).

Profile available water (PAW)	The amount of water potentially available to plant growth that can be stored in the soil to 100 cm depth. PAW takes into account variations in soil horizons and is expressed in units of millimetres of water i.e., in the same way as rainfall. A PAW value (to a depth of 1 m) of 100 mm implies that 10% of the soil volume is water available to plants. Low PAW is <60 mm, moderate is between 60 and150 mm, and high is ≥150 mm (definition from Landcare Research).
Quality assurance (QA)	Part of quality management focussed on providing confidence that quality requirements will be fulfilled.
Sensitivity analysis	The systematic computation of the effect of changes in all model input values or assumptions (including boundaries and model functional form) on model outputs, to determine their relative influence on model outputs.
Significance analysis	A simple analysis to identify which model inputs are likely to have the most impact on the model output of interest. This is neither a full sensitivity nor a full uncertainty analysis.
Source nutrient load	The total annual amount of nutrients (from diffuse and point sources) lost from a catchment prior to any catchment attenuation processes.
Sub-model	A distinct part of the OVERSEER engine.
Receiving environment	A water body (e.g., groundwater, streams, rivers, lakes) that receives diffuse and/or point source discharges that a freshwater objective is applied to.
Receiving environment nutrient load	The total annual amount of nutrients entering a receiving environment i.e., source nutrient load after attenuation.
Target	A limit which must be met at a defined time in the future. This meaning only applies in the context of over-allocation.
Threshold	A maximum allowed amount or rate of resource use specified in a regional rule (that distinguishes between e.g., classes of activities) or resource consent condition. This is usually expressed as kg /ha/yr or kg /property/yr. A threshold in the context of this report is generally numerical, but can be narrative if the narrative threshold incorporates a numerical calculation e.g., a requirement to meet a well-defined 'good management practice' that is used with OVERSEER to calculate the equivalent nutrient loss. This term is used generically in this report to incorporate the term 'allowance' or 'nutrient discharge allowance' and in some situations the term 'limit' e.g., if a resource consent has a condition that specifies a source or receiving water limit.
Uncertainty	The potential limitation in some part of a modelling process that is a result of incomplete knowledge, mathematical formulations and associated parameters, or data coverage and data quality.
Uncertainty analysis	Investigates the effects of lack of knowledge or potential errors of the model (e.g., the uncertainty associated with parameter values or model design and output).
XML file	The file format used by OVERSEER to store specific input and output data.

2 Informing the establishment of freshwater objectives and setting and managing to limits

2.1 Overarching plan development considerations

National Policy Statement for Freshwater Management 2014

It is a requirement under the RMA that a regional plan gives effect to any national policy statement (s67(3)(a)). The NPS-FM sets out a number of objectives for freshwater management, and through its policies directs regional councils as to how these objectives are to be achieved. Of particular relevance, the NPS-FM directs that freshwater objectives are established in regional plans and freshwater quality limits set for all freshwater management units, to give effect to the NPS-FM objectives (Policy A1) (Figure 4). The process for establishing freshwater objectives is detailed in policies CA1 – CA4. The NPS-FM also directs that targets are specified and methods are implemented to improve water quality where a freshwater management unit does not meet the objectives that are established (this is referred to as 'over-allocation'). The NPS-FM also includes requirements for the monitoring of progress towards and achievement of freshwater objectives (Objective CB1 and Policy CB1), and for establishing and operating a freshwater quality accounting system (Objective CC1 and Policy CC1).

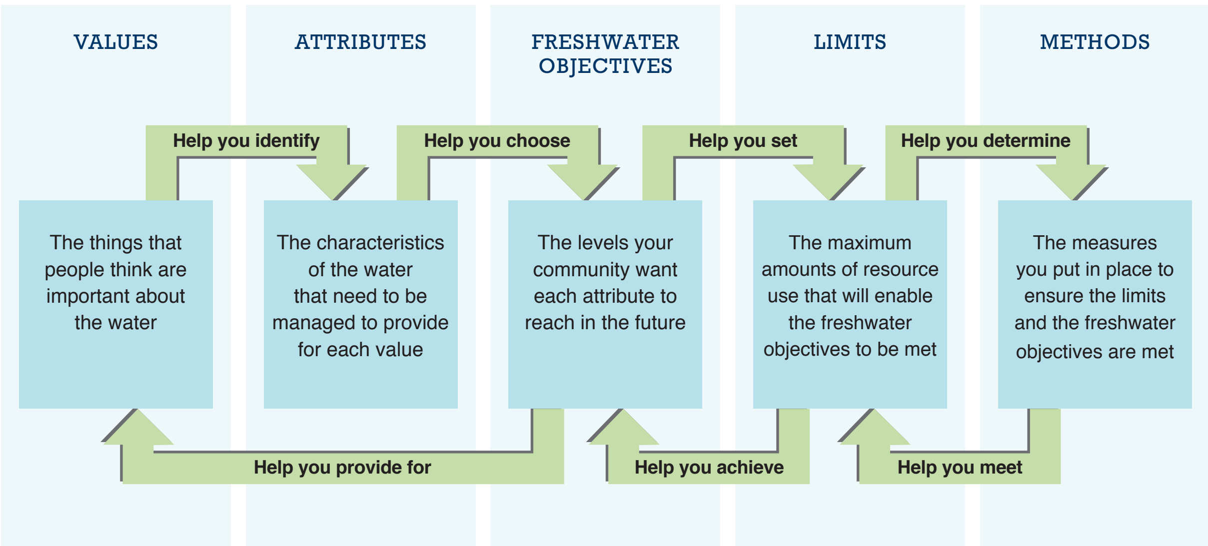

Figure 4
The relationship between freshwater objectives, limits and methods (MfE, 2015) adapted from ECan (2012).

Where it is not feasible or possible to measure diffuse nutrient discharges from land, modelled effects may be required to inform the establishment of freshwater objectives and setting and managing to freshwater quality limits (Figure 4). Similarly, there will be elements of freshwater quality accounting that will be reliant on modelling where measurement is not feasible.

Regional Policy Statement (RPS)

It is also a requirement under the RMA that a regional plan gives effect to any regional policy statement (s67(3)(c)). Therefore, any plan provisions that are developed through the use of OVERSEER must be sufficient to give effect to the relevant RPS. In particular, an RPS may contain objectives and/or policies that include nutrient limits, which if not directly measurable may also necessitate reliance on modelled effects to inform the establishment of limits in the regional planning process.

Section 32 Analysis

Section 32 of the RMA sets out the evaluation that a council must undertake when a proposed regional plan or plan change is prepared (a 'proposal'). In particular, this must assess the provisions (i.e., objectives, policies and rules) in a proposal.

It is important to consider this evaluation early on in the plan development process and it should also be borne in mind as part of any technical analysis undertaken to support plan provisions. This means considering how effective different approaches may be at achieving the plan's objectives. For example, a section 32 analysis requires that the limitations and assumptions resulting from modelling, including the use of OVERSEER, are taken into account as part of the cost-benefit analysis. A section 32 analysis should also explicitly consider the implications of uncertainties in OVERSEER estimates.

Plan Drafting and Activity Status in Rules

There are planning principles and relevant case law that help inform the way a plan is drafted.[6] Any plan provisions that rely on the use of OVERSEER (either explicitly or implicitly) should recognise this best practice. For example, objectives should be a statement of what is to be achieved in relation to a particular issue and policies should set out the course of action to be taken to achieve or implement the objective(s).[7] In relation to rules, there are several commonly accepted principles that apply, namely that they must:

1. be comprehensible to a reasonably informed, but not necessarily expert, person;[8]
2. not reserve to a council the discretion to decide by subjective formulation whether a proposed activity is permitted or not;[9] and
3. be sufficiently certain to be capable of objective ascertainment.[10]

There is also some specific guidance[6] and case law on the very high level of certainty needed for defining permitted and prohibited activities. Some implications of this are expanded on later in this report (see Sections 3, 4 & 6).

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[6] Guidance can be found on the Quality Planning (QP) website: http://www.qualityplanning.org.nz/index.php/plan-steps/writing-plans.

[7] http://www.qualityplanning.org.nz/index.php/plan-steps/writing-plans/writing-issues-objectives-and-policies.

[8] Re Application by Lower Hutt City Council EnvC Wellington W046/2007.

[9] Twisted World Limited v Wellington City Council EnvC Wellington W024/2002.

[10] Ibid.

2.2 General approaches to managing diffuse discharges that use OVERSEER

There are two different types of approach to actively managing N and P loss to water.

- An output-based approach where the quantitative relationship between source nutrient load and receiving environment state is explicitly estimated and nutrient losses are explicitly managed (e.g., N leaching rate thresholds), or
- An input-based or practice-based approach where a series of land-use practices are prescribed (e.g., stocking rate thresholds, nutrient application thresholds).

Within these broad approaches, OVERSEER can be used in different ways (Figure 5) and these are expanded on in Section 3 of this report.

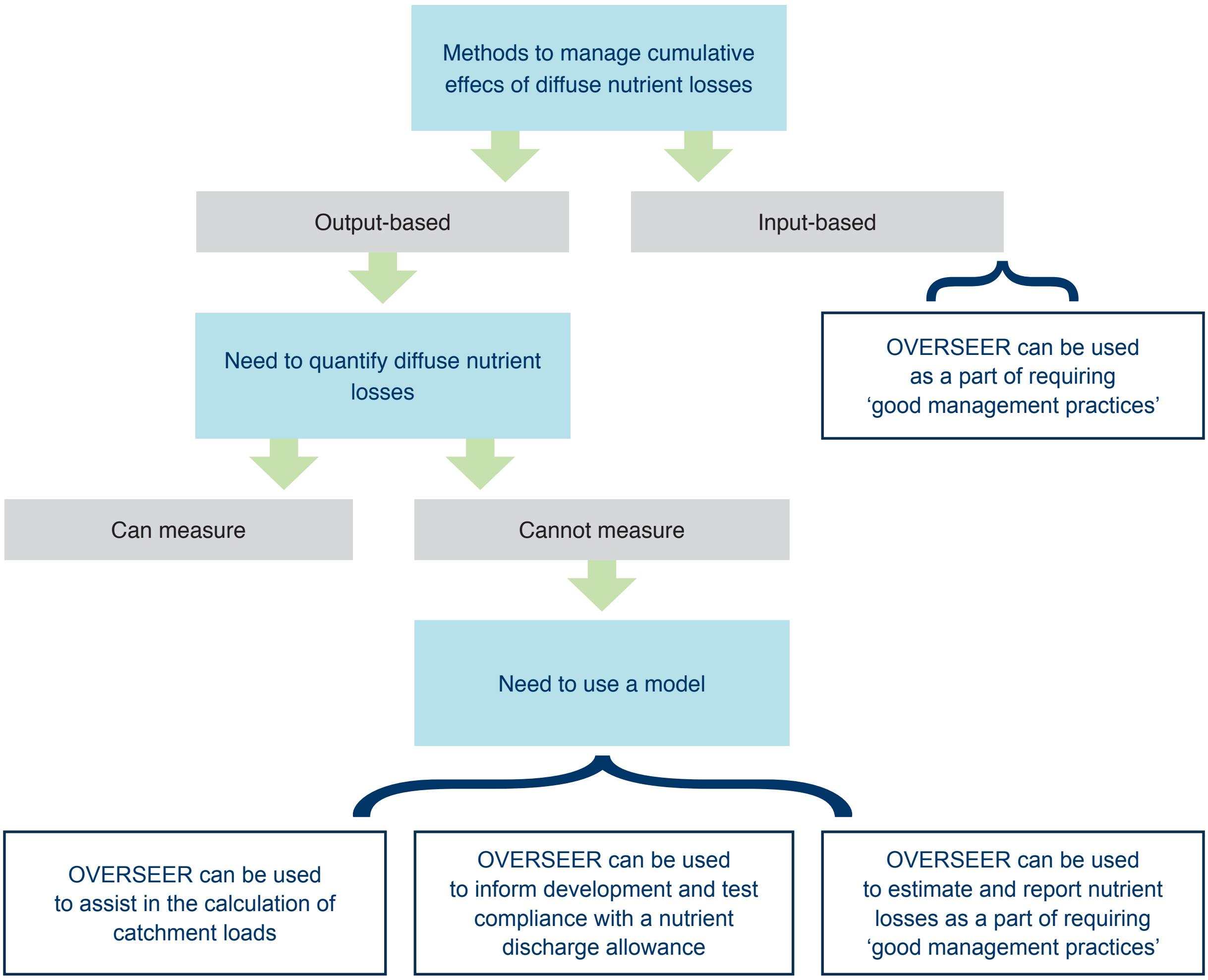

Figure 5
Methods for managing the cumulative effects of diffuse nutrient losses and where OVERSEER can be used

2.3 Principles to assist in establishing freshwater objectives and setting and managing to freshwater quality limits

These principles are specifically intended to guide the use of OVERSEER in assisting the establishment of freshwater objectives and setting and managing to freshwater quality limits (Table 1).

Table 1
Principles for the use of OVERSEER in assisting the establishment of freshwater objectives and setting and managing to freshwater limits

Planning principles	Explanation	Relevant report section
1 If OVERSEER is used to provide estimates of annual nitrogen and/or phosphorus loss from farm systems its assumptions and limitations need to be fully acknowledged and taken into account.	These key assumptions and limitations are addressed in the supporting technical principles detailed below.	Estimating nutrient loads (Section 5), Uncertainty (Section 7), Averaging (Section 8), Modelling N and P (Section 9) Data provision and security (Section 10), Qualifications (Section 11)
2 (i) The use of OVERSEER must recognise that new versions of OVERSEER are released regularly and plan provisions that specify OVERSEER should include a mechanism(s) to manage version change if required. **2 (ii)** Where OVERSEER has been used in calculating source or receiving environment catchment loads there must be a mechanism to periodically re-evaluate and update the assumptions in the supporting catchment science.	OVERSEER is updated regularly (and modelled losses may change) and improved information is expected to result from more water quality monitoring information. A mechanism to accommodate the regular improvements in OVERSEER (through version changes) and the improvements in other data (e.g., through monitoring) is important. This is to ensure that planning provisions can take advantage of improvements in models and other data where those improvements enhance the accuracy and effectiveness of interventions.	Version change (Section 6), Estimating nutrient loads (Section 5)
3 Where OVERSEER is used at multiple stages in a planning process (e.g., in the process of setting nutrient allowances and for assessing compliance), OVERSEER versions and data input standards should be consistent.	OVERSEER is updated regularly (and modelled losses may change) and assumptions used in building an OVERSEER file can affect estimated losses. Therefore, if losses from multiple versions are being compared or using different input standards, any differences may be in part due to changes in the model, not necessarily 'real' differences in nutrient loss. The uncertainty of outcome (for a consent holder or for the environment) is greater if data inputting standards and versions are not consistent.	Version change (Section 6)

4 The use of OVERSEER must recognise that there are uncertainties in estimates of nutrient loss and this uncertainty must be identified, communicated and, as far as practicable, managed.	OVERSEER outputs, like all model outputs, have a degree of uncertainty, and the biological system that OVERSEER is modelling is also variable. Setting and managing to freshwater limits involves dealing with all types of uncertainty (MfE, 2016). The uncertainty in the model outputs can be amplified or managed by the way the model outputs are used. Therefore, where OVERSEER information is used, the uncertainty should be assessed and reduced where practicable, communicated, and reflected/accommodated in plan-making and implementation.	Policy approaches and rule frameworks (Section 3), Uncertainty (Section 7)

Supporting technical principles	Explanation
1 The use of OVERSEER must recognise that OVERSEER only models some sources of nutrients.	OVERSEER currently models seven nutrients including N and P. For these nutrients OVERSEER models losses from agricultural systems; it doesn't model nutrient losses from all activities that may occur in a catchment (e.g., losses from many point sources, land slips, some river bed/bank erosion, and non-agricultural land are not captured). Importantly for P, OVERSEER doesn't explicitly model Critical Source Areas (CSA). If only 'OVERSEER' nutrient sources in a catchment are modelled, this would normally underestimate the actual losses. Therefore, when using OVERSEER in any catchment assessment, consider what sources of nutrients are not modelled by OVERSEER, and whether those sources need to be estimated to account for all sources of nutrients.
2 The use of OVERSEER must recognise that OVERSEER does not model all farm management or mitigation practices and that there are some assumed management practices within the OVERSEER model	There are some farm management practices that are used on farm, and are understood to impact on some nutrient losses, but that are not captured in OVERSEER e.g., contour ploughing or management of break feeding. For P, as CSAs are not explicitly modelled, available mitigations cannot be directly applied to CSAs in the model. There are also some management practices that are assumed within OVERSEER[11]. If practices occurring on farm are not modelled by OVERSEER, or the assumed levels of practice are not happening; the modelled losses may over or under-estimate the actual losses from a farm. Therefore, if OVERSEER information is being used and there is a significant gap between the level of practice actually occurring and those assumed within OVERSEER, or between the practices that occur on farm and what can be modelled, this gap, or its consequences, need to be managed at an information-gathering, plan-making/resource consent or implementation stage.

[11] OVERSEER incorporates "assumed management practice". Refer to definition of "good management practices".

3 The use of OVERSEER must recognise that OVERSEER only estimates nutrient loss from the farm boundary and root zone.	OVERSEER estimates nutrient loss from a farm (through leaching, run-off, direct to streams) as losses from the farm boundary or root zone. A variety of catchment processes can impact on the amounts of N and P that ultimately arrive in a target receiving environment. Therefore, other models need to be used (that include relevant catchment processes) for relating OVERSEER estimated losses to nutrients that arrive at a target receiving environment.
4 The use of OVERSEER must recognise that OVERSEER is a steady-state model and does not model the effects of transition e.g., transition from dryland to irrigated or farm system change such as forestry to pastoral farming.	When a system is in transition e.g., conversion from dryland to irrigation or conversion of pasture to cropping, there are likely to be soil processes occurring that significantly impact on the actual nutrient losses during the transition period. However, OVERSEER assumes near equilibrium farm systems and so these losses that occur as the system changes are not captured. Therefore, OVERSEER may underestimate or overestimate losses during a transition period. Therefore, other information is needed to understand the effects of transition on nutrient losses.
5 The use of OVERSEER must recognise that data inputs to OVERSEER (actual or estimated) need to reflect a long-term, biologically feasible farm system.	In general, OVERSEER doesn't 'sense check' the production data that is inputted to the model. OVERSEER assumes that the system being modelled is biologically feasible. This means that implausible farm systems can be modelled. Also, a farm practice may be viable for a short time e.g., mining soil nutrients. However, if this is not feasible in the long term, the estimated losses of these 'short-term' practices may underestimate the actual requirements and effects of that farm system over the longer term. Therefore, OVERSEER data inputs can be from actual farm data or estimated data. Where actual farm data is used it should be consistent with technical principle 7. Where estimated, data inputs should be supported by either other modelling (e.g., Farmax or crop calculators) or farm system expertise.
6 OVERSEER requires significant expertise to enable farm systems to be modelled accurately and the use must recognise that the quality of the data inputs impacts on the uncertainty associated with the estimated nutrient losses.	As with other models, if the input data and modelling methodologies used to construct an OVERSEER nutrient budget are poor, this will impact on the quality of the modelled result and in turn the uncertainty associated with the estimated nutrient loss. Where OVERSEER is being used and the quality of the data is poor, this should be recognised as a factor likely to increase uncertainty (see planning principle 4). Improved data records will assist with improving the quality of future data. However, this will not improve the quality of historic or absent records. OVERSEER modelling requires significant expertise. See Section 11 regarding the recommended minimum qualifications.
7 The use of OVERSEER must recognise the long-term climate input assumptions built into OVERSEER and choose data inputs consistent with those assumptions.	OVERSEER incorporates a number of significant assumptions based on a stable long-term farm system with similarly stable average climate conditions. Any modelling application that does not match these assumptions must be undertaken with care, and is likely to increase the uncertainty of the estimates. Therefore, OVERSEER data inputs should be consistent with the climate assumptions. Guidance on the choosing appropriate climate data inputs is given in Section 8.

8 The use of OVERSEER must recognise the differences in N and P loss processes and how these are modelled in OVERSEER.	There are significant differences in N and P loss processes and the way OVERSEER models these losses. These differences are important for modelling nutrient losses, and understanding and implementing mitigations. Therefore, catchment modelling and mitigation strategies will need to account for these differences (Section 9)

These principles sit within a context of overarching plan development considerations (Section 3), land use and water quality management assumptions, the general use of models in environmental decision-making, and important information about OVERSEER (Appendix 3).

The principles are supported by the guidance in the remainder of the report. If the limitations, assumptions and uncertainties associated with the OVERSEER model change, the relevant principles may need to be revisited.

3 Plan-making

3.1 Introduction

This section is written primarily for RMA planners involved in the plan making process.

The purpose of this section is to focus specifically on the major ways OVERSEER can be used as part of developing and implementing a regional plan to manage the effects of nutrient discharges to water and to assess the key strengths and challenges of those approaches.[12]

The broad RMA planning framework including the planning principles is outlined in Section 2 of this report.

There are three major broad applications of OVERSEER in regional plan-making and implementation:

1 To assist in the estimation of current and/or future potential source and receiving environment nutrient loads (Section 3.2). For example, OVERSEER estimates can be used in assessing the effects of different land-use scenarios compared to specific water quality objectives (nutrient concentrations/algal biomass). Estimated nutrient source loads may then be explicitly or implicitly used in plan provisions.

2 As the primary[13] method for determining compliance with nutrient loss thresholds in the plan e.g., a threshold within a rule for the average annual amount of N or P that can be discharged for a property (typically specified in kg/ha/yr) (Section 3.3). These thresholds may have been set with some reliance on catchment and/or individual property OVERSEER modelling.

3 As a tool specified to be used by landholders to estimate and report nutrient losses from a farm. This may be required as part of a 'farm environment plan' or 'nutrient management plan' (Section 3.4), as a standalone reporting obligation, or as one of a number of options.

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[12] This section assumes a significant level of knowledge about RMA provisions and their general application in regional plans. This section also assumes that the information here would be an input to a wider RMA section 32 analysis that would be undertaken as part of a regional plan development. For example, this section does not address matters relating to costs and benefits of different policy approaches. This section also does not address matters relating to nutrient allocation methodologies i.e., advantages and disadvantages of different methods such as 'grandparenting', Land Use Capability, peak versus average historical losses.

[13] Alternative comparable models are usually provided for, to enable those land uses or farm systems that cannot be modelled by OVERSEER to be modelled.

Box 1 Key messages – plan-making

1 The most appropriate approach to the use of OVERSEER in the development of plan provisions will depend on the specific catchment characteristics, the extent of nutrient water quality issues, the level of information available, the resources available to develop and implement a regional plan, the objectives sought by the regional plan and the consideration of these in the context of the principles outlined in Table 1.

2 Plan objectives and policies specific to nutrient water quality need to be clear and directive to ensure the environmental results sought by the plan are clear and to provide clear guidance for resource consent decisions that involve OVERSEER nutrient loss estimates.

3 The specification of a source nutrient load in plan provisions (e.g., objectives and/or policies) provides a high level of transparency and certainty. However, this is contingent on a robust mechanism to deal with improving information and model version change where the specified load is largely reliant on OVERSEER estimates.

4 Farm environment plans are important components in the implementation of a regional plan with nutrient water quality objectives. However, plan provisions need to be clear about the specific role that is intended e.g., are they to be complementary to specific thresholds, the primary implementation method, or is the role dependent on specific catchment approaches?

5 OVERSEER version changes mean that a range of innovative approaches (see Sections 3.1–3.5) are needed both to maximise certainty for those who may be affected by plan provisions and to ensure that the objectives of the plan are achieved.

6 There are significant technical matters that need to be considered in the use of OVERSEER in the regional plan-making and implementation processes, specifically: implications of uncertainties in OVERSEER estimates, averaging implications, differences between N and P processes and modelling, OVERSEER data management needs, qualifications needed for OVERSEER modelling, and auditing methodology.

This section should be read in conjunction with the other sections of this report that provide further detail on particular aspects of the use of OVERSEER that need to be recognised in the process of developing and implementing a regional plan. In particular, the need to:

- Understand the uncertainties associated with estimating both source and receiving water nutrient loads and how this uncertainty should be managed and transparently taken into account in developing plan provisions e.g., by using methods for generating source loads with low or moderate uncertainty, using OVERSEER outputs in a way that minimises uncertainty such as in a relative sense, prioritising the sourcing of good quality data for critical OVERSEER variables, incorporating adaptive management policies, having an implementation plan that specifies frequent receiving water quality monitoring and annual reassessment of catchment nutrient loss estimates, etc. (see Section 5 - Estimating catchment nutrient loads, and Section 7 - Uncertainty).
- Appreciate the advantages (and disadvantages) of specifying clear and directive objectives and policies specific to nutrient water quality (e.g., nutrient concentrations and algal biomass), and catchment nutrient limits in plan provisions, to provide direction for plan implementation, particularly for any resource consent application process that features OVERSEER nutrient losses estimates (see Section 4 - Resource consents and Section 5 - Estimating catchment nutrient loads).

- Appreciate the implications of OVERSEER version changes for defining and implementing regional rules, and specifically recognise the significant advantages of (see Section 6 - OVERSEER version change issues[14]):
  - not relying on thresholds that depend on OVERSEER estimates to define permitted activities or prohibited activities, unless a robust version management mechanism is used,
  - minimising the reliance on activity status definition thresholds that depend on OVERSEER estimates e.g., by minimising the number of classes of activities defined by such thresholds, to minimise the risk of a land use or discharge changing activity status as a consequence of an OVERSEER version change,
  - using clear and directive policies and assessment criteria, particularly to support a limited number of activity classes, to provide clear guidance for the resource consent process, and
  - considering the use of a mechanism outside of, but linked to, the plan to minimise the impact of OVERSEER version changes on regional rule thresholds, but recognising that (as at July 2016) there is no case law on this type of linked external mechanism.
- Appreciate the advantages that FEPs can provide to develop a tangible farm plan that is consistent with the regional plan's provisions, including the achievement of the freshwater quality objectives (see Section 3.4).
- Where a regional rule specifies a threshold that depends on OVERSEER estimates, consider:
  - the need for a rolling average over a minimum of three to five years rather than reliance on one year's data (see Section 8 - Averaging),
  - where a rule effectively requires the provision of data to the council (e.g. OVERSEER property files), the management and security of this information (see Section 10 - Data provision and security), and
  - requirements for the qualifications and experience of those preparing or auditing OVERSEER file information (see Section 11 - Qualifications).
- Understand the similarities and the differences between OVERSEER N & P loss modelling, particularly for developing catchment source nutrient loss scenarios (see Section 9 – Nitrogen and phosphorus modelling).

Examples of good practice regional rules

Boxes 2 to 8 provide different good practice examples of how the issues summarised in this section can be addressed and incorporated into different regional rules. These examples do not define how such rules should be developed, rather they illustrate how issues can be addressed in different circumstances to develop rules that not only meet general good practice, but also are consistent in whole or part with the guidance outlined in this report. There is no one right way to formulate such rules.

3.2 Estimating source and/or receiving environment nutrient loads

OVERSEER nutrient loss estimates can be used to help calculate the source nutrient load that is predicted to achieve specific freshwater quality objectives. With additional information, this source nutrient load can be used to predict the nutrients arriving in the receiving environment (Section 5).

[14] Legal advice and analysis on OVERSEER version issues are summarised in Section 6 and has been taken into account in developing this section.

OVERSEER can also be used to estimate future source nutrient loads from different future land use or policy options as part of the plan development framework and setting of freshwater objectives. This allows for the implications of various freshwater objectives and associated limits to be explored, as required under the NPS-FM Policy CA2(f), before freshwater objectives are established within any regional plan.

Within a planning framework, the source nutrient load and/or receiving water nutrient load may be:

- not explicitly stated in the plan provisions, but used as a basis for the policy and rule framework (Approach A).
- used as a limit (Figure 4) and expressed at a policy level or as part of an overarching objective e.g., setting a numerical limit (Approach B).

The key strengths of this general approach (whether using Approach A or Approach B):

- It attempts to make explicit and transparent the relationship between losses from a catchment (and individual farms) and what arrives in the eventual receiving environment, thus enabling the estimation of a source load that would meet the freshwater objectives (e.g., concentration of a nutrient or algal biomass).
- It can assist with clearly giving effect to the NPS-FM.
- Catchment relationship provides a link between a geographic area and an amount of nutrients – potentially facilitating a nutrient allocation framework.
- It can be useful in complex catchments with a mix of rural and non-rural land uses.
- Under Approach A, the plan (depending on its detailed provisions) may be less obviously affected by OVERSEER version change issues.
- Under Approach B, the overall receiving environment and/or source load limits are clear and transparent to all plan users. This load also provides a robust reference point for resource consent applications and enables clear reporting on progress.

The key challenges relating to OVERSEER with this general approach (whether using Approach A or Approach B):

- A high level of information is required about land-use activities in a catchment and their associated nutrient losses, and high-quality receiving environment monitoring data is required, along with at least a conceptual understanding of catchment processes, such as hydrology/hydrogeology, denitrification, sedimentation, and plant nutrient uptake.
- It is comparatively expensive to develop good quality catchment load estimates in terms of both initial and ongoing monitoring, data acquisition and modelling costs. Challenges and strengths of different methods for generating source nutrient loads including their likely uncertainty and resource implications are shown in Table 4.
- There will be uncertainty in the relationship between source and receiving environment nutrient loads e.g., time lags and historical land use, and as new information becomes available this relationship may change (see Section 5.2).
- Version changes in OVERSEER (Section 6) may change estimated nutrient source losses, which may have implications for the plan, particularly under Approach B, and plan implementation. A version change may also result in increased or decreased costs of mitigation to meet threshold requirements and therefore affect economic analyses that may have been relied on as part of plan development.

- A mechanism is needed to incorporate updated and improved information e.g. from additional monitoring (see Section 5.2) or new OVERSEER versions (See Section 6). An example of a proposed mechanism for accommodating OVERSEER version change is where a specified catchment land use configuration (represented as a GIS map or soil/climate/land use table) is used to represent and generate an agreed source nutrient load limit using agreed reference OVERSEER files. When a new version of OVERSEER is released, the files are updated and are used to re-generate the expected source nutrient load, based on the reference land use configuration. This mechanism has been proposed in Plan Change 3, Canterbury Land and Water Regional Plan.
- Under Approach A, there may be less specific direction for resource consent decisions and therefore a risk that decisions might not be as aligned to the achievement of objectives as they could be.

Considerations to address the challenges:

- Clear and unambiguous objectives and policies are needed to ensure that resource consent decisions will be consistent with the plan's intentions i.e., the more direction given by objectives and policies, the greater certainty that resource consent decisions will be consistent with the freshwater quality objectives sought by the plan.
- Ongoing and targeted monitoring is needed to collect data to test expected water quality outcomes and catchment modelling assumptions such as catchment attenuation factors (See Section 5.2).
- A mechanism is needed to incorporate updated and improved information e.g., from additional monitoring (see Section 5.2) or new OVERSEER versions (See Section 6). There will be ongoing costs associated with this.
- Approach B requires careful consideration of how a nutrient load limit is defined in a provision. For example, if it has been largely reliant on OVERSEER estimates, version change issues need managing. However, if such a limit specification has not been reliant on OVERSEER estimates i.e., other robust sources of information were used to estimate source loads, version changes need only be considered as part of any wider review process.
- Under Approach A, any load estimates used in developing plan provisions can still be made transparent although not necessarily specified in a formal provision. However, this would not change the potential implications of version changes for the original assumptions about the linkage between source load estimates and water quality objectives i.e., if a version change results in a change in the estimated source load then, depending on the relationship between source loads and receiving water loads, this may or may not change the estimated water quality outcome.
- Under either approach, there is a need for clear direction in the plan provisions for resource consent decisions, particularly for any non-complying activities, to provide a high level of confidence that such decisions will contribute to the achievement of specific freshwater quality objectives.

3.3 Nutrient discharge thresholds

This section considers the use of nutrient discharge thresholds that are specified in a plan and against which compliance is measured and reported using OVERSEER estimates. The use of these OVERSEER thresholds does not preclude the use of other input-based thresholds.

Per Property Threshold

This approach is based on an allowance of nutrients per unit area or per property that can leach or run-off to water (e.g., the amount (in kilograms) of N or P that can be discharged per hectare per annum). OVERSEER can be used to estimate the nutrient losses that underpin the property allowances.

There are many ways that an individual property threshold can be derived (allocation options): this can be based on land use, on a physical aspect of the land e.g., its natural capital (sometimes referred to as Land Use Capability), grand-parenting, or by mathematically dividing the estimated source load by a mechanism, such as an equal allocation for every hectare of land in a catchment. As noted earlier, the advantages and disadvantages of allocation options are not assessed in this report.

The key strengths of this approach:

- It is conceptually simple – each property has a nutrient threshold or allocation.
- It makes explicit the expectations for the farming activity in terms of losses.
- The relationship between property losses and nutrients in the receiving environment can serve as a basis for assessing required mitigation or allowing increases in nutrient losses in order to meet the freshwater quality limits and freshwater objectives.
- It can assist with clearly giving effect to the NPS-FM.

The key challenges of this approach related to OVERSEER:

- There will be uncertainty in the estimated relationship between losses from individual farms and what arrives in the target receiving environment. For example, there may be management practices that are not currently modelled or, for monitoring against a threshold, the climate assumptions that are used in OVERSEER may not reflect the climate that occurred during the modelled period. These factors impact on the likely uncertainty of the nutrient loss estimates (see Sections 7 & 8).
- Version changes in OVERSEER are likely to change estimated nutrient losses from a farm. This may have implications, particularly where an absolute number derived in a previous version has been specified in a rule, as generally non-current versions of OVERSEER are not available (see Section 6). This may also result in a threshold being easier or harder to achieve than was originally thought at the time a plan was developed.
- On-farm management in plan implementation may be driven by what is ‘recognised’ and modelled in OVERSEER.
- It may be difficult to provide equivalent alternative models for those land uses or farm systems that are not currently modelled by OVERSEER.
- Depending on how a policy and rule framework is implemented (such as the number of properties, the frequency of compliance monitoring, and whether this is administered under a resource consent framework), there will likely be large resourcing implications.
- It can result in a focus solely on the achievement of an OVERSEER threshold and ignoring other methods of reducing nutrient loss that are not currently recognised by OVERSEER.
- The RMA may not be well designed for linking plan provisions to complex computer models and this has potential implications when considering if OVERSEER can be ‘incorporated by reference’ in a plan (Schedule 1 Part 3) because OVERSEER may not meet the required definition of ‘written material’.

Considerations to address some of the challenges:

- Methods to address OVERSEER version changes (see Section 6) are needed e.g., minimising reliance on activity status thresholds that rely on OVERSEER estimates, ensuring that there is a robust method of managing the effects of an OVERSEER version change if thresholds are used in rules that require OVERSEER estimates to determine compliance with those thresholds, regular assessments of the implications of version changes for assumptions about nutrient source losses used in developing a plan, etc[15].
- Methods or options are needed to reduce or manage the uncertainty in OVERSEER outputs e.g., using the model outputs in a relative sense (see Section 7). However, there is very limited case law on the development and application of rules that may rely in part on future OVERSEER versions.
- When rules are set that rely on OVERSEER estimates to determine compliance, an averaging technique e.g., defining a typical farm system, averaging inputs or calculating a rolling average of outputs, can be used to manage some of the uncertainty due to climatic variability (see Section 8). Generally, a minimum of a rolling average of three to five years is considered adequate.
- A mechanism outside of, but linked to, the plan is needed to minimise the impact of OVERSEER version changes on regional rule thresholds, but recognising that (as at July 2016) there is no case law on this type of linked external mechanism. An example of a mechanism for accommodating version change in a nutrient threshold has been proposed in Plan Change 3, Canterbury Land and Water Regional Plan. Numeric thresholds in kg N/ha/year are used to denote, for example, maximum loss rates. When a new version of OVERSEER is released a suite of reference OVERSEER files (>90 files) that are considered to be representative are re-run and the average percentage difference between version is applied to the nutrient threshold.
- Staged implementation is needed to allow industry, council and farmer capacity and capability to be built up e.g., highest risk or largest emitters first.
- There is a need to provide mechanisms that recognise nutrient loss reduction initiatives that are not currently recognised by OVERSEER.
- Robust individual or industry self-monitoring and auditing systems can reduce the resources needed for council compliance monitoring.
- Be aware of the potential limitations of formally incorporating OVERSEER by reference (see Section 6).

Examples of good practice regional rules for per property thresholds are shown in Boxes 2, 3 and 4.

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[15] When there is a version change in OVERSEER the process to determine next steps could include the following steps:

- The new modelling information should be reviewed to understand the nature of the version change (e.g. small change, large change, uniform change, non-uniform change)
- The catchment load modelling should be rerun and the current estimated catchment load should be recalculated with the new OVERSEER information. The differences will be tested to establish if the new information still fits within the conceptual model of the catchment. The possible outcomes of this analysis are:

  → The new information fits plausibly with the current conceptual model and catchment loads or catchment coefficients are updated as appropriate, or

  → The new version of OVERSEER causes a change to the absolute numbers that leads to a re-assessment of the technical understanding about how the catchment works (i.e. an update to the conceptual model of the catchment). This may need to be supported by additional data collection or monitoring. Once an updated conceptual model (and any subsequent numeric models), then catchment loads or catchment coefficients are updated as appropriate.

Box 2 Example model rule for a per property threshold from the Environment Canterbury Proposed Plan Change 5 to the Canterbury Land and Water Regional Plan (notified February 2016):

5.58A Within the Green or Light Blue Nutrient Allocation Zone the use of land for a farming activity on a property greater than 10 hectares in area that does not comply with condition 2 or 3 of Rule 5.57C is a restricted discretionary activity provided the following conditions are met:

1 *A Farm Environment Plan has been prepared for the property in accordance with Part A of Schedule 7 and is submitted with the application for resource consent; and*

2 *Until 30 June 2020, the nitrogen loss calculation for the part of the property within the Green or Light Blue Nutrient Allocation Zone does not exceed a total of 5kg/ha/yr above the nitrogen baseline, and from 1 July 2020 a total of 5kg/ha/yr above the Baseline GMP Loss Rate; unless the nitrogen baseline was lawfully exceeded prior to 13 February 2016, and the application for resource consent demonstrates that the exceedance was lawful.*

The exercise of discretion is restricted to the following matters:

1 *The content of, compliance with, and auditing of the Farm Environment Plan; and*

2 *The content quality and accuracy of the OVERSEER® budgets provided with the application for resource consent; and*

3 *The actual or potential adverse effects of the proposal on surface and groundwater quality and sources of drinking water; and*

4 *The timing of any actions or good management practices proposed to achieve the objectives and targets described in Schedule 7; and*

5 *Methods that limit the nitrogen loss calculation for the farming activity to a rate not exceeding a total of 5kg/ha/yr above the Baseline GMP Loss Rate; and*

6 *Methods that require the farming activity to operate at or below the Good Management Practice Loss Rate, in any circumstance where that Good Management Practice Loss Rate is less than a loss rate equivalent to a total of 5kg/ha/yr above the Baseline GMP Loss Rate; and*

7 *Methods to address any non-compliances that are identified as a result of a Farm Environment Plan audit, including the timing of any subsequent audits; and*

8 *Reporting of nutrient losses and audit results of the Farm Environment Plan to the Canterbury Regional Council; and*

9 *The consistency of the proposal with Policy 4.38A; and*

10 *Methods to prevent an exceedance of any relevant nutrient load limit set out in Sections 6 to 15 of the Plan.*

Box 3 Example model rule for per property threshold from the Waikato Regional Plan (operative as at July 2016):

3.10.5.3 Controlled Activity Rule – Nitrogen Leaching Farming Activities

The use of land in the Lake Taupo catchment for any farming activity existing as at the date of notification of this Rule (9 July 2005) that does not meet the conditions for permitted activities under Rule 3.10.5.1 and which may result in nitrogen leaching from the land and entering water is a permitted activity until 1 July 2007, after which it will be a controlled activity, subject to the following conditions, standards and terms:

Standards, terms and conditions to be met by applicants to enable them to seek consent under this Rule:

Benchmarking in order to determine Nitrogen Discharge Allowance

(a) Benchmark data for a minimum of 12 consecutive months during the period July 2001 to June 2005 shall be submitted to Waikato Regional Council as part of any application for consent under this Rule. The benchmark data shall comprise the parameters and information contained in Table 3.10.5.3. The amount of nitrogen leached from farming activities shall be calculated by Waikato Regional Council's Benchmarking Contractors using the OVERSEERTM Model Version 5.4.3 and the benchmark data. The nitrogen leached shall include any nitrogen arising from the application of farm animal effluent, pig farm effluent, feed pad effluent, stand-off pad effluent, and fertiliser onto land (those activities require authorisation under rules 3.5.5.1 to 3.5.5.5 and rule 3.9.4.11 outside of the Taupo catchment). The amount of nitrogen leached in the single best year (being the 12 consecutive months with the highest leaching value) over the July 2001 to June 2005 period shall be the Nitrogen Discharge Allowance for the land to which the controlled activity consent applies.

Waikato Regional Council reserves control over the following matters:

i. The specification of the Nitrogen Discharge Allowance in kgN/ha/year and total kgN/year for the land to which the controlled activity consent applies as determined under standard and term a);

ii. The requirement for a Nitrogen Management Plan (NMP) for the land to which the controlled activity consent applies if the farm management practices represented by the benchmarking data referred to in standard and term a) are altered. The OVERSEERTM Model Version 5.4.3 shall be used to calculate the nitrogen leached from the land to which the controlled activity consent applies inclusive of the altered farm management practices and this shall form the basis of the NMP. The NMP shall demonstrate that the nitrogen leached from the proposed farming activities complies with the benchmarked Nitrogen Discharge Allowance. The NMP shall be provided to the Waikato Regional Council within 10 working days of the farm management practices being altered;

iii. The self monitoring, record keeping, information provision and site access requirements for the holders of resource consents required to demonstrate ongoing compliance with the Nitrogen Management Plan;

iv. The circumstances and timeframes under which the resource consent conditions may be reviewed, provided that any review of a consent condition specifying the Nitrogen Discharge Allowance shall only occur when regional plan provisions have been made operative which specify a new target for the amount of nitrogen entering Lake Taupo and which requires that target to be achieved by the reduction of the Nitrogen Discharge Allowance specified in any resource consent;

v. The duration of the resource consent;

vi. The circumstances under which resource consents granted under this Rule can be surrendered either in whole or part pursuant to s138 of the RMA.

Box 4 Example model rule for per property threshold from the Environment Canterbury Proposed Plan Change 3 to the Canterbury Land and Water Regional Plan (notified April 2015):

15.5.3 The use of land for a farming activity, except any land that is part of a Nutrient User Group or Farming Enterprise, or land that is within the command area of an Irrigation Scheme where the nutrient loss from the farming activity is being managed by the scheme, that does not meet any of the conditions of Rule 15.4.2 excluding conditions 1(a),1(c) or 4 of Rule 15.5.2, is a restricted discretionary activity provided the following condition is met:

1 A Farm Environment Plan has been prepared in accordance with Schedule 7 Part A, and is submitted with the application for resource consent.

The exercise of discretion is restricted to the following matters:

1 Whether the nitrogen loss from the farming activity will result in the total catchment load limits as per Table 15(p) or the flexibility caps in Table 15(m) being exceeded; and

2 The quality of, compliance with and auditing of the Farm Environment Plan; and

3 The proposed management practices to avoid or minimise the discharge of nitrogen, phosphorous, sediment and microbiological contaminants to water from the use of land; and

4 The potential effects of the land use on surface and groundwater quality and sources of drinking-water; and

5 The appropriateness of the actions and time frames described in the Farm Environment Plan in achieving the maximum cap loss rates in Table 15(n); and

6 The quality and appropriateness of any soil mapping carried out for the property; and

7 The potential adverse effects of the activity on Ngāi Tahu cultural values.

Per Group Threshold

A policy and rule approach may instead (or as well) focus on a threshold per group e.g., irrigation schemes or catchment groups. This allowance can be based on a land use, water permit or a discharge permit. OVERSEER can be used to estimate the nutrient losses that underpin the collective allocation.

An example of this approach would be where the collective scheme or group has been granted a resource consent with an overall discharge allowance (usually a number of tonnes of N per annum) and properties within the scheme/group are then able to be managed flexibly within the overall limit. The land use of individual properties within the scheme would usually be a permitted activity, subject to conditions. Some form of management plan (e.g., an FEP) for each individual farm in the collective may be part of the conditions of the granted resource consent.

In addition to the per property threshold above, the key strengths of this approach are:

- there is increased flexibility for individual landowners in the scheme/group as 'unders and overs' may be accommodated within the overall limits.
- a single allowance covers multiple properties and may reduce the administrative burden on the farmer and council (but this would fall to the scheme or group administration).
- monitoring and compliance within the group can be based on contractual arrangements between the members, rather than through RMA mechanisms.

In addition to the per property threshold above, the key challenge of this approach is:

- the council needs assurance that there are robust and transparent processes for managing performance to ensure compliance.

An example of a good practice regional plan policy and a regional rule for a group threshold is shown in Box 5.

Box 5

(a) Example model policy for nutrient groups from Environment Canterbury Hurunui-Waiau River Regional Plan (operative as at July 2016):

Policy 5.1 To take a tributary and community based approach to managing water quality and improving nutrient management practices.

…the land is subject to:

- *(i) an Industry Certification System; or*
- *(ii) a Catchment Agreement; or*
- *(iii) an Irrigation Scheme Management Plan; or*
- *(iv) a Lifestyle Block Management Plan*

Catchment Agreement [means] … an agreement approved by Canterbury Regional Council that identifies actions to be undertaken to actively manage the use of natural resources in order to achieve high standards of environmental management and optimise production from all properties within a catchment or sub-catchment of the Hurunui, Waiau or Jed Rivers or their tributaries.

…

Any Catchment Agreement must at a minimum, to the extent considered appropriate and corresponding to the scale and significance of the activities within the catchment or sub-catchment contain the elements identified in Schedule 2.

(b) Example model rule for a group threshold from the Environment Canterbury Proposed Plan Change 5 to the Canterbury Land and Water Regional Plan (notified February 2016):

5.41A Despite Rules 5.43A to 5.59A, the use of land for a farming activity where either:

- *(a) the nitrogen loss from the farming activity is being managed under a resource consent that is held by an irrigation scheme or principal water supplier and the permit contains conditions which limit:*
  - *(i) the maximum rate at which nitrogen may be leached from the subject land (as measured in kg/ha/yr); or*
  - *(ii) the concentration of nitrogen in the drainage water leached from the subject land (as measured in ppm or g/m3); or*
- *(b) the land is subject to a water permit that authorises the use of water for irrigation and:*
  - *(i) the permit was granted prior to 18 January 2014; and*
  - *(ii) the permit is subject to conditions that specify the maximum rate of nitrogen that may be leached from the land; and*
  - *(iii) the water permit is subject to conditions which requires the preparation and implementation of a plan to mitigate the effects of the loss of nutrients to water*

is a permitted activity.

3.4 The use of Farm Environment Plans and using OVERSEER to report nutrient discharges

OVERSEER can also be referenced in the policy and rule framework within a regional plan as a tool that is required to be used to report nutrient discharges. This often required as part of a management plan, often known as a 'Farm Environment Plan' (FEP), within which is normally a requirement for the calculation of nutrient losses using OVERSEER. Farm environment plans[16] are farm-specific plans that detail the environmental objectives for the farm and identify the on-farm actions that are implemented to achieve a suite of specified targets or objectives, which can include a threshold or nitrogen discharge allowance (NDA), and can provide important additional context to the data in an OVERSEER budget. A requirement to provide an OVERSEER estimate of nutrient loss can also be made without the need for an FEP or nutrient management plan. However, a disadvantage of this is that it would not demonstrate how an OVERSEER budget fits into a wider integrated farm environmental plan that addresses wider environmental requirements and goals.

The key strengths of this approach:

- Industry group leadership in the development and auditing for FEPs means there are likely to be cost efficiencies for developing FEPs specified in plan provisions. Similarly, there is likely to be less opposition from industry groups about regulatory requirements for FEPs.
- The implementation can be focussed on farm-specific practices that achieve a numeric nutrient loss limit or target that is documented in the FEP.
- Monitoring or auditing of an FEP where OVERSEER reporting is a requirement provides an opportunity for assessing both practices and numeric losses, and therefore can be used to assist in managing uncertainty as a consequence of version change, as underlying practices as well as OVERSEER budgets can be examined. The use of a supporting FEP can also assist in managing the quality of the data inputs.
- Assessment of compliance with good farm management practices required in an FEP has the potential to have higher certainty than compliance assessment focussed solely on OVERSEER estimates. Considering both practices and loss estimates provides a higher level of confidence in the achievement of good farm management practices and achievement of water quality objectives.

The key challenges of this approach:

- Farm environment plans may not be appropriate for a permitted activity rule condition, unless they include very clear and certain requirements that can be enforced, or are clearly only serving to provide supporting information for other primary enforceable conditions. In addition, there are monitoring and compliance resourcing implications for councils as costs cannot be recovered from persons operating under a permitted activity rule.
- There are resourcing implications in terms of the monitoring and auditing required, the number and training of council staff needed and the availability of sufficiently qualified and experienced practitioners.
- Care is needed to ensure that the content and actions to be included in an FEP and auditing pass/fail criteria are clearly set out to ensure the certainty and enforceability of regional rules and resource consents.
- Depending on the wording of a rule, implementation inconsistencies are possible if the farm exceeds a numeric threshold, but the required practices are all in place and being implemented.

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[16] Other terms may be used, such as 'nutrient management plan', to which the discussion on FEPs is still applicable.

An example of a good practice regional rule that includes an FEP is shown in Box 6.

Box 6 Example model rule that incorporates a nutrient management plan from Bay of Plenty Regional Council Proposed Plan Change 10 Lake Rotorua Nutrient Management (notified February 2016):

Controlled – The use of land for farming activities on properties/farming enterprises less than 40 hectares in effective area or that were not previously managed by Rule 11 to 11F that do not meet permitted activity conditions

The use of land for farming activities on properties/farming enterprises in the Lake Rotorua groundwater catchment where:

- *The property/farming enterprise is less than 40 hectares in effective area or was not previously managed by Rule 11 to 11F; and*
- *The activity does not comply with permitted activity conditions in Part LR,*

is a controlled activity from 1 July 2022 subject to the following conditions:

(a) A 2032 Nitrogen Discharge Allowance and relevant Managed Reduction Targets have been determined for the land in accordance with Schedule LR One and Policy LR P8; and

(b) A Nitrogen Management Plan has been prepared for the property/farming enterprise by a suitably qualified and experienced person and that person has certified that the Nitrogen Management Plan has been prepared in accordance with Schedule LR Six.

3.5 Activity status thresholds

As part of the rule framework within a plan, it is important to consider activity status thresholds. There are several commonly accepted common law principles and conventions that apply to rule drafting for activity status thresholds (see the Quality Planning (QP) website www.qualityplanning.org.nz for background information and guidance).

Permitted activities are generally those where the resultant effects are not considered significant enough to justify management through a resource consent process. Nutrient loss estimates derived from OVERSEER can be helpful to justify the level at which a permitted activity status is appropriate. For example, OVERSEER estimates for properties under a certain size threshold, or for certain types of land use, can be used to justify a permitted activity status for activities below that threshold or within that land-use type, respectively.

Prohibited activities are at the other end of the spectrum – activities that cannot be granted a resource consent, such as a further allowance in an over-allocated catchment. A significant level of analysis and justification is required to define an activity as a prohibited activity and nutrient loss estimates from OVERSEER can be helpful to assist in such justification.

There is case law and obiter[17] Environment Court statements on the appropriate use of both permitted and prohibited activity rules. In summary, and as noted in Sections 2.1 and 3.1, a very high level of certainty is required for permitted activity and prohibited activity rules, and such rules should

[17] An observation by a judge on a matter not specifically before the court or not necessary in determining the issue before the court.

generally not provide for a subjective mechanism with inherent uncertainty to determine whether an activity is a permitted activity or a prohibited activity. Therefore, the use of permitted or prohibited activity rules with numerical thresholds that are defined in terms of an OVERSEER estimate should be avoided unless a robust OVERSEER version management mechanism is incorporated (see Section 6). This would be particularly relevant in situations where there is a high level of uncertainty associated with OVERSEER estimates. A potential consequence would be a property's status switching with different model versions between being a permitted activity and one requiring a resource consent, or between being a prohibited activity and one requiring a resource consent.

Sitting between the permitted and prohibited activity status thresholds, are those activities that require resource consent to be obtained. Where it is determined that a resource consent process is appropriate, consideration needs to be given to the appropriate activity status to be used (i.e., controlled, restricted discretionary, discretionary or non-complying) and the supporting policy framework. Care is needed to avoid any potential uncertainty about the activity status of an existing or proposed activity.

There are different ways to define the status of an activity, some of which do not use OVERSEER, or use OVERSEER only as a source of information to assist in determining an appropriate threshold. (These are not considered in detail in this report). Examples of different ways to define activity status that do not require an OVERSEER estimate to determine compliance include:

- land-use activity definitions e.g., 20 ha of irrigation, and
- simple property area definitions.

Examples of good practice regional rules for activity status thresholds are shown in Boxes 7 and 8.

Box 7 Example model rule for a threshold based on activities from Environment Canterbury Proposed Plan Change 5 to the LWRP (notified February 2016):

the use of land for a farming activity on a property greater than 10 hectares in area is a permitted activity provided the following conditions are met:

1. *…; and*
2. *The area of the property authorised to be irrigated with water is less than 50 hectares; and*
3. *For any property where, as at 13 February 2016, the area of land authorised to be irrigated with water is less than 50 hectares, any increase in the area of irrigated land is limited to 10 hectares above that which was irrigated at 13 February 2016; and*
4. *The area of the property used for winter grazing within the period 1 May to 1 September does not exceed a total area of 20 hectares; and*
5. *A Management Plan in accordance with Schedule 7A has been prepared and is implemented within 12 months of the rule being made operative, and is supplied to the Canterbury Regional Council on request.*

Box 8 Example model rule for a threshold based on activities from Bay of Plenty Regional Council Proposed Plan Change 10 Lake Rotorua Nutrient Management (notified February 2016):

Permitted – From 1 July 2017, the use of land for farming activities on properties/farming enterprises greater than 5 hectares in area and up to and including 10 hectares in effective area

The use of land for farming activities on properties/farming enterprises in the Lake Rotorua groundwater catchment:

- *Greater than five hectares in area and up to and including 10 ha in effective area; or*
- *From five hectares in effective area and up to and including 10 hectares in effective area, is a permitted activity from 1 July 2017 subject to the following conditions:*

(a) *The stocking rate that occurs on the effective area does not exceed the stocking rates specified in Schedule LR Two at any point in time; and*

(b) *No commercial cropping or commercial horticulture occurs on the land; and*

(c) *There is no increase in effective area or nitrogen inputs from [date of notification] that may contribute to an increase in nitrogen loss onto, into or from land; and*

(d) *There is no transfer of nitrogen loss entitlement either to or from the property/farming enterprise.*

Recommendations – plan-making

1 There is no one best way to apply OVERSEER within a regional planning framework. How and where OVERSEER is used in the plan-making process needs to be considered in the wider context of specific catchment characteristics, the extent of nutrient water quality issues, the level of information available, the resources available to develop and implement a regional plan, the freshwater objectives, and consideration of the principles outlined in Table 1.

2 Regional plan provisions should have clear and directive objectives and policies specific to nutrient water quality (e.g., receiving water nutrient concentrations and algal biomass) and catchment nutrient limits to ensure the environmental results sought by the plan are clear. This would provide clear guidance for any resource consent application process that involves OVERSEER nutrient losses estimates.

3 Where farm environment plans are identified as an implementation mechanism within a regional plan, the provisions should be clear about their specific role i.e., are they intended to be a primary enforceable element of a rule and/or resource consent condition (see Section 3.4) or are they intended to primarily provide information to complement other conditions?

4 Take account of the potential implications of OVERSEER version changes by:

(a) incorporating a process in an implementation plan (see sections 3.2, 3.3 & 3.4) to assess the implications of OVERSEER version changes on estimates of catchment source nutrient loads and any other relevant improved catchment information (e.g., hydrological information) for plan provisions,

(b) avoiding the used of fixed numerical thresholds with no OVERSEER version management method in permitted activity and prohibited activity rules that require OVERSEER estimates to determine compliance with those thresholds,

(c) ensuring that there is a robust method of managing the effects of an OVERSEER version change if thresholds are used in any rules classifying activity categories that require OVERSEER estimates to determine compliance with those thresholds, unless a robust OVERSEER version management mechanism is used (see Section 6),

(d) to the extent the methods referred to in (c) above are not fully effective in managing the effects of OVERSEER version change, minimising the reliance on activity status definition thresholds that depend on OVERSEER estimates e.g., by minimising the number of classes of activities defined by such thresholds to minimise the risk of a land use or discharge changing activity status as a consequence of an OVERSEER version change,

(e) considering the use of a mechanism to minimise the impact of OVERSEER version changes on regional rule (and resource consent) thresholds, including, but not limited to, a link to an external calculator or reference files, but recognising that (as at July 2016) there is no case law on this type of linked external mechanism (see Section 6), and

(f) recognising that methods of using OVERSEER in regional plans and resource consents are still developing and that approaches adopted by some plans have not been fully tested.

5 Where regional rules are set that rely on OVERSEER estimates to determine compliance, they should include the following requirements:

(a) a requirement to undertake OVERSEER modelling in accordance with appropriate standards and guidelines e.g., the relevant Best Practice Data Input Standards (BPDIS), and in particularly sensitive situations, a requirement for independent auditing as outlined in Table 12.

(b) a defined period(s) of time over which the OVERSEER modelling must be undertaken – generally a minimum of a rolling average of three to five years.

(c) a minimum qualification requirement for the person undertaking OVERSEER modelling of a Massey University Certificate in Advanced Sustainable Nutrient Management, an equivalent qualification, or extensive experience in a specific farming system and detailed understanding of OVERSEER. For OVERSEER modelling of particular significance, independent auditing of modelling should be undertaken by a person with the minimum qualification specified above, against the factors and process outlined in Table 12 (see Sections 10 & 11).

(d) A requirement to provide the relevant OVERSEER XML file and supporting information by a specific date, on request, or if a specific event occurs, to ensure that the consent authority is able to audit the information provided (see Section 10).

6 The following technical matters should be taken into account in the use of OVERSEER in the regional plan-making and implementation processes, along with other considerations such as cost and resourcing implications:

(a) Uncertainty – particularly the uncertainties associated with estimating both source and receiving water nutrient loads, and how this uncertainty should be managed and transparently taken into account in developing plan provisions e.g., using methods for generating source loads with low or moderate uncertainty, using OVERSEER outputs in a way that minimises uncertainty such as in a relative sense, prioritising the sourcing of good quality data for critical OVERSEER variables, incorporating adaptive management policies, having an implementation plan that specifies frequent receiving water quality monitoring and annual reassessment of catchment nutrient loss estimates, etc. (see Sections 5 & 7).

(b) Averaging – the potential for high inter-annual variation in estimated nutrient losses and less accurate nutrient loss estimates where the use of one year's actual farm system data may not be consistent with OVERSEER's long-term climate data means that the development and implementation of plan provisions should generally not rely on one year's actual farm system data (see Section 8).

7 An implementation plan should be developed that among other matters includes a plan for managing data provided to the council (e.g., OVERSEER XML files) (see Section 10).

4 Resource consent conditions

4.1 Introduction

This section is written primarily for RMA practitioners involved in the resource consent process.

Resource consents, and specifically resource consent conditions, are generally a critical component of implementing planning provisions designed to achieve specific freshwater quality objectives. In addition to the existing guidance on resource consent conditions[18], there are important specific matters that need to be considered for resource consent conditions that require an OVERSEER nutrient loss estimate, to ensure that those freshwater quality objectives are achieved.

The purpose of this section is to provide specific guidance for developing and implementing resource consent conditions that include a requirement for an OVERSEER nutrient loss estimate.

This section should be read in conjunction with the other sections of this report that provide further detail on particular aspects of the use of OVERSEER that need to be understood and considered in the formulation and implementation of resource consent conditions. In particular, the need to:

- understand the relevance of any catchment nutrient limits and whether these are explicitly or implicitly referred to in plan provisions (see Section 5 - Estimating catchment nutrient loads). For example, it may be appropriate to have an adaptive management condition triggered by the breach of a nutrient limit and/or a breach of a water quality standard.
- acknowledge the uncertainty associated with OVERSEER estimates and take this into account in resource consent conditions, including consideration of e.g., adaptive management conditions such as monitoring and consequential 'trigger response' requirements, short duration consents combined with appropriate monitoring and reporting conditions, and consent review conditions (see Section 7 - Uncertainty).
- understand the impact OVERSEER version changes can have on a consent condition that specifies a threshold that requires an OVERSEER estimate to determine compliance, and the options to minimise the potential for a version change to change the compliance status (see Table 3 and Section 6 - OVERSEER version change issues). Legal advice and analysis on OVERSEER version issues are summarised in Section 6 and has been taken into account in developing this section.
- appreciate the advantages of specifying a clear FEP requirement in a resource consent condition as a tangible farm plan consistent with all relevant regional plan provisions. However, care is needed to ensure there is certainty about whether the FEP is a primary enforceable condition or primarily to complement other conditions (see Section 3.4) and care is needed to avoid any conflicts between conditions.

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[18] http://www.qualityplanning.org.nz/index.php/consents/conditions

- where resource consent conditions specify the use of OVERSEER, consider:
  - the need for a rolling average over a minimum of three to five years rather than relying on one year's data (see Section 8 - Averaging),
  - the need to specify the OVERSEER information to be provided and the management and security of this information (see Section 10 - Data provision and security), and
  - the need to specify the qualifications and experience of those preparing or auditing OVERSEER file information (see Section 11 - Qualifications).
- understand the differences between OVERSEER N & P loss modelling and how this may be relevant for resource consent conditions e.g., a resource consent condition specific to P loss would usually need to focus on run-off from an individual property and its potential to enter surface water (see Section 9 – Nitrogen and phosphorus modelling).

Box 9 Key messages – resource consent conditions

1 Resource consents, and specifically resource consent conditions that require the use of OVERSEER modelling, are increasingly a critical component of implementing planning provisions designed to achieve specific freshwater nutrient quality objectives.

2 In addition to the existing guidance on resource consent conditions, there are important specific matters that need to be considered and incorporated in resource consent conditions that require an OVERSEER nutrient loss estimate, to ensure that the intent of limiting nutrient losses is achieved and ultimately that freshwater quality objectives are achieved.

4.2 The use of OVERSEER in resource consent conditions

The process of managing to freshwater quality limits and ultimately achieving a plan's objectives is usually critically dependent on implementation through the resource consent process. OVERSEER is increasingly an important tool included in resource consent conditions dealing with nutrient losses and limits, regardless of whether the relevant plan prescribes the use of OVERSEER. For example, conditions may include a nutrient loss threshold for individual properties or groups of properties, or may require the reporting of nutrient losses to be estimated by using OVERSEER. Consent conditions that require the use of OVERSEER need, like any consent conditions, to meet minimum legal requirements (see the QP website[19]) such as being certain, lawful and enforceable.

Resource consent conditions that specify OVERSEER can be broadly categorised into three types (Table 2).

[19] http://www.qualityplanning.org.nz/index.php/consents/conditions

Table 2
Types of resource consent conditions needed to robustly specify the use of OVERSEER

Type of condition package	Usual application
1. **Information provision** i.e., a requirement to provide information where an OVERSEER estimate is specified as one of a number of acceptable alternatives.	In situations where there are no significant current or looming future nutrient water quality issues but an interest in obtaining information to provide a reassurance that water quality issues are unlikely to develop.
2. **Mandatory OVERSEER estimates** to be undertaken and provided as required/ requested	In situations where there is concern about nutrient water quality but no significant current water quality issues related to N or P. Can be utilised for information gathering in advance of catchment limit setting processes.
3. **Mandatory thresholds with compliance defined in terms of OVERSEER estimates**	In situations where there is a significant current nutrient water quality issue.

Where a resource consent condition specifies a nutrient loss threshold that requires OVERSEER modelling to determine compliance, the following components need to be defined and linked in resource consent conditions (Table 3) to ensure that the overall intention is achieved. More information, including resource consent examples and pitfalls, are outlined in Appendix 4.

Table 3
Resource consent conditions needed to enable robust specification of a threshold with compliance defined in terms of OVERSEER estimates.

Required resource consent condition component	Brief explanation
1. A defined threshold.	It is essential to have absolute certainty on what the mandatory threshold(s) is (are). This will require a numerical or narrative quantitative specification (see definition of threshold) with direct or indirect linkages to definitions contained within the resource consent. It may also be appropriate to have an ‘early warning’ trigger threshold to ensure that appropriate action is taken to reduce the risk of breaching the threshold e.g., where there is high uncertainty in the OVERSEER estimates e.g., where it is clear that the modelled situation is significantly beyond the original OVERSEER calibration range.

2. A requirement to undertake OVERSEER modelling in accordance with appropriate standards and guidelines e.g., BPDIS (see Section 10), and in particularly sensitive situations, a requirement for independent auditing to be undertaken as outlined in Table 12.	It needs to be explicit that the consent holder has to ensure that OVERSEER modelling is undertaken in accordance with the BPDIS and other appropriate standards, guidelines and considerations to ensure that the results accurately reflect the farm system (see Section 10 & Table 12). Some situations e.g., scale, significance and/or location, may not warrant independent auditing. The need for auditing may be prescribed in the relevant regional plan. If there are relatively few resource consents required in a catchment and they are for relatively significant amounts of nutrient loss, auditing may be needed for all OVERSEER files; conversely, if there are a large number of resource consents with some individually insignificant amounts of nutrient loss, auditing for all resource consents may not be justified.
3. A defined period(s) of time over which the OVERSEER modelling must be undertaken.	This must be made clear and line up with any specific catchment limit timeframe specifications (see Sections 5 & 8). Specifically, see the limitations of using one year's actual farm data.
4. An OVERSEER version management mechanism.	This is essential to clarify how OVERSEER version changes will be managed e.g., by not relying solely on one threshold condition, by providing an updating mechanism (e.g., providing for previously compliant model inputs to remain compliant in a new version, or using an external calculator/reference system), by providing complementary conditions that would provide for a resource consent holder to change and/or review conditions as a consequence of an OVERSEER version change, etc. (see Section 6).
5. The minimum qualification requirement for the person undertaking the OVERSEER modelling and, if auditing is required, the minimum qualification for the person undertaking the auditing.	OVERSEER is a complex model that requires detailed knowledge of both how the model works and NZ farming systems. A minimum qualification is essential (see Sections 10 & 11).
6. A requirement to provide the OVERSEER XML file and supporting information by a specific date, on request, or if a specific event occurs.	It needs to be clear exactly what and when information must be provided to the regional council. The OVERSEER XML file is essential to be able to audit the information provided.
7. Any circumstances that would trigger a requirement for a complementary FEP	An FEP is usually needed to provide a comprehensive integrated plan of how nutrient loss thresholds will be achieved, and to provide information to support the OVERSEER nutrient loss estimates.

Recommendations – resource consent conditions

1 Resource consent conditions that specify thresholds that require an OVERSEER estimate to determine compliance should contain the following components:

(a) A well-defined threshold (see Appendix 4). There can be advantages in also including a pre-threshold 'trigger response' condition that requires a specific action to be taken prior to a critical threshold being reached.

(b) A requirement to undertake OVERSEER modelling in accordance with appropriate standards and guidelines e.g., the BPDIS, and in particularly sensitive situations, a requirement for independent auditing as outlined in Table 12.

(c) A defined period of time over which the OVERSEER modelling must be undertaken – generally a minimum of a rolling average of three to five years (see Section 8).

(d) An OVERSEER version management mechanism e.g., using a threshold defined with a GMP calculator or reference files, by not relying solely on one threshold condition, by providing an updating mechanism (e.g., providing for previously compliant model inputs to remain compliant in a new version, or using an external calculator/reference files system), by providing complementary conditions that would make it relatively easy to apply to change and/or to initiate a review of conditions as a consequence of an OVERSEER version change, a fixed version (if available), etc. (see Appendices 4 & 6 & Section 6).

(e) A minimum qualification requirement for the person undertaking OVERSEER modelling of a Massey University Certificate in Advanced Sustainable Nutrient Management, an equivalent qualification, or extensive experience in a specific farming system and detailed understanding of OVERSEER. For OVERSEER modelling of particular significance, independent auditing of modelling should be undertaken by a person with the minimum qualification specified above, against the factors and process outlined in Table 12 (see Sections 10 & 11).

(f) A requirement to provide the relevant OVERSEER XML file and supporting information by a specific date, on request, or if a specific event occurs to ensure that the consent authority is able to audit the information provided (see Section 10).

(g) A requirement for an FEP – to provide a tangible practical guide on how farm management will be undertaken. However, there needs to be absolute certainty about whether the FEP is a primary enforceable condition or is primarily to complement other conditions, and care is needed to avoid any conflicts between conditions (see Section 3.4).

2 The following technical matters should be taken into account in the use of OVERSEER in resource consent conditions, along with other considerations such as cost and resourcing implications:

(a) Uncertainty –conditions that take uncertainty into account are likely to be needed e.g., adaptive management conditions such as monitoring and consequential 'trigger response' requirements, short duration term combined with appropriate monitoring/investigations and reporting to provide more information, a review condition that specifies an event that would trigger a review, etc. (see Section 7 and the QP website).

(b) Averaging – there is potential for high inter-annual variation in estimated nutrient losses and less accurate nutrient loss estimates where the use of one year's actual farm system data may not be consistent with OVERSEER's long-term climate data (see Section 8).

5 Estimating catchment nutrient loads

5.1 Introduction

This section is written primarily for scientists and RMA practitioners providing advice for those involved in the plan-making and/or resource consent processes.

The purpose of this section is to assess the strengths and challenges of the general methods for estimating source nutrient loads that use OVERSEER. There is also a short explanation of how OVERSEER information is used in estimating receiving environment loads. This section assumes that other appropriate methods are used to estimate source nutrient loads from activities that cannot be modelled by OVERSEER e.g., from non-agricultural, residential, commercial or industrial activities.

Box 10 Key messages – estimating catchment nutrient loads

1. There are several methods for estimating source nutrient loads that differ in their strengths, challenges, resource implications and uncertainty.
2. A better quality source nutrient load estimation generally has a higher resource requirement.
3. There are many complex processes involved in the attenuation of nutrients as they move from the source to the receiving water. There is often limited information available to assist with developing a catchment attenuation factor, and the understanding of all factors that influence the attenuation of nutrients generally and in specific catchments is still developing.
4. OVERSEER can be used to help derive a catchment attenuation factor. However, this factor will change over time as improved information becomes available.
5. Long-term targeted water quality monitoring is essential to obtain information needed to enhance knowledge about the relationship between source nutrient loads and receiving water loads.

Estimating source nutrient loads

OVERSEER is one model that can be used to estimate source nutrient loads from farming land uses (point A in Figure 2) in a catchment. The individual property losses can be summed to give a farming source nutrient load, and these source nutrient loads can be estimated using OVERSEER in several ways. Examples of different methods, their information needs, strengths, and challenges are tabulated in Table 4. Table 4 is not exhaustive and combinations of these methods may exist. If OVERSEER is used, it is important that other sources of nutrients not captured in OVERSEER are also assessed.

Table 4
Examples of different approaches to estimating source nutrient loads using OVERSEER

Example 1. Use generic or literature nutrient loss values

Description	Industry average or typical nutrient losses are extrapolated to a catchment scale
Main strengths	▪ Easy access to information ▪ Can generate source load estimates quickly
Main challenges	▪ Generic estimates are not specific to the systems, soils and climates in the catchment and therefore may not reflect actual systems, soils or climates ▪ Can be unclear what level of practice has been modelled and what assumptions have been used in modelling ▪ Mitigations can be problematic to apply to these generic estimates if underlying assumptions are unknown
Resourcing implications	Few resources needed
Likely uncertainty of data inputs and ability to manage uncertainty (Appendix 5)	High uncertainty of data inputs. Low ability to manage uncertainty

Example 2. Use anecdotal case studies

Description	Some existing individual OVERSEER budget nutrient losses are extrapolated to a catchment scale
Main strengths	▪ Relatively easy access to information ▪ Can generate source load estimates quickly ▪ If anecdotal (individual) files are available, these can be updated with model version change ▪ Can be used to estimate current source loads
Main challenges	▪ Characteristics and assumptions of the anecdotal systems may not be valid for the whole catchment and subsequent impact on loss rates is compounded with extrapolation to catchment losses ▪ Confidentiality issues can hinder close scrutiny of input data ▪ Anecdotal files are often based on a single year i.e., a snapshot. This can be problematic if the year was atypical (see Section 8 - Averaging) ▪ Anecdotal systems may not cover all of the soils, climates, and systems in the catchment ▪ Current farm management practice encompasses everything from very poor to best management practice. The level of practice would need to be normalised for use in testing policy options and future scenarios ▪ If files were built by multiple modellers, may be difficult to get a consistent level of practice and data input standards ▪ Can be unclear what assumptions have been used in modelling ▪ Mitigations can be problematic to apply to these anecdotal files if underlying assumptions are unknown ▪ Risk of variable quality of information

Resourcing implications	Few resources needed
Likely uncertainty of data inputs and ability to manage uncertainty (Appendix 5)	High uncertainty of data inputs Low ability to manage uncertainty

Example 3. Use representative farms (few)

Description	Some virtual farm nutrient budgets are created to represent the mix of catchment characteristics and are extrapolated to a catchment scale
Main strengths	▪ Can engage farmers/ industry representatives in deriving information for models ▪ As farms are virtual, they can be consistent with OVERSEER assumptions e.g., long-term climate (see Section 8 - Averaging) ▪ Can produce reference files that can be updated with model version change ▪ Can apply consistent level of practice and data input standards
Main challenges	▪ Characteristics and assumptions of few representative farm systems may not be valid for the whole catchment and subsequent impact on loss rates is compounded with extrapolation to catchment losses ▪ The virtual farms are catchment specific ▪ Additional modelling may be needed for the representative farms to be plausibly extrapolated across soils and climates in the catchment ▪ The full range of current land uses in the catchment may not be captured
Resourcing implications	Moderate resources needed
Likely uncertainty of data inputs and ability to manage uncertainty (Appendix 5)	Moderate uncertainty of data inputs Moderate ability to manage uncertainty

Example 4. Use representative farms (many)

Description	Many virtual nutrient budgets are created to cover a range of farm systems, soils, and climates
Main strengths	▪ Can engage farmers/industry representatives in deriving information for models ▪ As farms are virtual, they can be consistent with OVERSEER assumptions e.g., long-term climate (see Section 8 - Averaging) ▪ Can produce reference files that can be updated with model version change ▪ Can apply consistent level of practice and data input standards ▪ Farm systems not confined to a particular catchment
Main challenges	▪ The full range of current land uses in the catchment may not be captured ▪ Farms may need to be aggregated for use in testing policy options and future scenarios

Resourcing implications	Significant resources needed
Likely uncertainty of data inputs and ability to manage uncertainty (Appendix 5)	Low uncertainty of data inputs Moderate ability to manage uncertainty
Additional information	Software has been developed that allows many (hundreds) of OVERSEER files to be generated, run and summarised in very short times (minutes). These tools considerably reduce the resource implications of this approach, but require expert input for initial set up and checking of information produced

Example 5. Use actual farm budgets

Description	All farm nutrient budgets are collected for a catchment
Main strengths	▪ Can be used to assess current source load ▪ Files can be updated with model version change ▪ More closely represents what is occurring in the catchment than representative farms
Main challenges	▪ Current practice encompasses everything from very poor to best management practice – this approach can accommodate this in estimating source loads. The level of practice would need to be normalised for use in testing policy options and future scenarios ▪ If there are many farms, they may need to be aggregated for use in testing policy options and future scenarios ▪ Risk of variable quality of information ▪ If only a single year is collected, this can be problematic if the year was atypical or for systems in transition (see Section 8 - Averaging) ▪ Confidentiality issues can hinder close scrutiny of input data
Resourcing implications	Significant resources needed
Likely uncertainty of data inputs and ability to manage uncertainty (Appendix 5)	Low/Moderate uncertainty of data inputs (Low if model users are experienced, a consistent input standard is used (e.g., BPDIS, 2016) and high-quality data sources are used). Moderate-high ability to manage uncertainty.
Additional information	Software has been developed that allows a consistent set of modelling proxies (intended to represent industry agreed Good Management Practice) to be applied to existing OVERSEER files. This could overcome the challenge of unknown levels of practice with this approach[20].

[20] ECan Farm Portal: https://farmportal.ecan.govt.nz/. GMP tool: https://farmportal.ecan.govt.nz/GMPTool/Auth/Login?ReturnUrl=%2fGMPTool

5.2 Estimating receiving environment nutrient loads

Between N and/or P being lost from a farm and arriving at a specific point in a receiving environment, a wide range of processes, such as sedimentation, plant uptake and denitrification, can occur that can remove those nutrients from the water body or make them effectively unavailable. These processes can be grouped together and termed attenuation. Therefore, the total amount of nutrient that is lost from the farm boundary or root zone is generally not the same as that which is measured in the receiving environment of specific interest. Understanding the likely magnitude of this attenuation is important in establishing freshwater objectives and setting and managing to freshwater limits. Catchment attenuation is expected to vary spatially and with time because the biophysical processes that contribute to attenuation vary spatially and in time. A range of estimates for catchment attenuation factors has been reported in New Zealand for N[21]. A factor in the order of 50% is common but much smaller and greater rates of attenuation have been estimated and used in New Zealand (e.g., Howard-Williams et al., 2010).

Catchment models can use OVERSEER outputs in two ways in estimating receiving environment loads. OVERSEER estimates can be used in conjunction with other information such as monitored receiving water quality, to derive a catchment attenuation factor (CAF)[22]. Or if a catchment attenuation factor has already been developed empirically or independently, it can be applied to a source load estimated by OVERSEER (for a catchment) to estimate the amount of nutrient likely to enter a receiving environment e.g., from future land uses.

A derived catchment attenuation factor is a term used where the amount of N or P attenuated during travel down a catchment is roughly estimated by subtracting the measured receiving environment load at the measurement point at the bottom of the catchment from the modelled source loads. The difference is expressed as a factor i.e., the CAF is 'derived' from these two sources of information and will include both attenuation and the uncertainty in the modelled and measured estimates.

An empirical catchment attenuation factor is a term used where there has been some scientific effort to quantify the attenuation processes through measurement, either at the individual process level or collectively. In some locations, considerable scientific effort has been applied to quantify individual attenuation processes in a catchment e.g., nitrate concentrations have been measured along a section of the Tukituki River in Hawkes Bay where conditions are conducive to large growths (and therefore large nutrient uptake) of periphyton (Wilcock, 2013). However, attenuation factors can be highly complex, and spatially and temporally variable (e.g., Howard-Williams et al., 2010), and there are often multiple types of attenuation processes occurring; therefore, collecting robust data can be time-consuming and costly.

In catchments with no significant lag times (i.e., the time taken for nutrients to move down a catchment to the receiving environment of concern), deriving the catchment attenuation factor estimates the total amount of attenuation. This method does not attempt to quantify the relative contribution of various complex biophysical attenuation processes such as the amount of denitrification versus uptake by riparian vegetation or periphyton. The derived catchment attenuation factor is thus a lumped catchment estimate of all attenuation processes. Importantly, it also includes the uncertainties in the modelled[23] and measured loads. In catchments where there are significant

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21 For example, Singh et al. (2014) reported N attenuation factor estimates in Manawatu catchments ranging from 0.2 to 0.7, and an attenuation factor of 0.5 is assumed in both the Taupo catchment (Waikato Regional Council's Variation 5) and in the Manawatu-Wanganui (Horizons' One Plan); more than ten-fold reductions in nitrate concentrations have been measured along a section of the Tukituki River in Hawkes Bay (Wilcock, 2013).

22 Also termed a catchment coefficient.

23 This relationship is usually derived using predictive OVERSEER nutrient budgets not historical. If historical OVERSEER nutrient budgets are used here, then consideration needs to be given to how representative that historic period was (see Section 8).

lag times, deriving the catchment attenuation factor must also account for that load which is expected to arrive in the receiving environment at some point in the future. Otherwise, there is a risk of overestimating the attenuation factor and therefore underestimating the nutrients that are likely to enter the receiving environment.

OVERSEER estimates change (improve) each time a new updated version is released, and measurement-based estimates improve with more frequent sampling and/or a longer period of monitoring record. Thus, a derived catchment attenuation factor is also expected to continuously improve over time i.e., if either the OVERSEER estimates of the catchment source nutrient losses (for a given land use mix) or the measurement of the receiving environment nutrient estimates change, then the derived catchment attenuation factor will also change. If the attenuation factor has been wholly derived from or based on empirical data, it is not expected to change with updates to modelled information.

Recommendations – estimating catchment nutrient loads

1. Where source loads calculations are used to inform source and receiving environment nutrient load limits, use information and methods with low or moderate uncertainty, as outlined in Table 4.
2. There needs to be targeted long-term nutrient water quality monitoring to progressively test the modelling assumptions used in the catchment modelling, including attenuation factors, and a process for assessing and, where appropriate, updating those factors as new information becomes available. This would then enable that new information to be considered in a plan review process.
3. The implications of OVERSEER version changes on source nutrient load estimates and calculations used as a basis for setting catchment nutrient load limits should be assessed as soon as practicable after each version change.

6 OVERSEER version change issues

6.1 Introduction

This section is written primarily for RMA practitioners involved in the plan-making and/or resource consent processes.

The purpose of this section is to clarify what is involved in an OVERSEER version change, the implications of that for some applications of OVERSEER, and to provide an analysis of options to address version change issues.

OVERSEER is being used in a range of ways in the development and implementation of regional plans and resource consents. Many of these approaches and some of the issues associated with them have been summarised in Arbuckle (2015). An ongoing, potentially significant issue with some of the uses of OVERSEER in regional plans and resource consents is the implications of regular version changes. There are two key issues:

Catchment source nutrient loss estimates and related plan provisions	A version change could result in a different estimate of source nutrient loss compared to an earlier estimate and the relevant policies and rules (including limits) developed (in part) on the basis of those estimates would need to be re-examined to ensure that they would still achieve the plan's water quality objectives. A consequence could be that the implementation of those policies and rules may result in more nutrients entering the receiving water than originally anticipated (meaning the plan is not strict enough), or alternatively, resulting in fewer nutrients entering the water body (meaning that the plan may impose unnecessarily strict policies and rules).
Regional rules and/or resource consent conditions	Where a regional rule or resource consent condition has a threshold and/or limit defined by (an implicit or explicit) reference to the current version of OVERSEER, a version change could result in an activity status changing from one activity class to another e.g., from a land use activity being defined as a permitted activity to being defined as requiring a resource consent application, or from a land use being defined as a non-complying activity to being defined as a prohibited activity, or a consented activity, potentially changing from compliance with a condition to non-compliance as a consequence of a condition threshold effectively changing.

Box 11 Key messages – OVERSEER version changes

1 OVERSEER version changes are an essential consequence of improvements to the accuracy of OVERSEER estimates, broadening of its applicability and improving its usability and/or user interface.

2 OVERSEER version changes (excluding usability and user interface changes) can result in significant changes to estimates of N and/or P loss. The consequential changes in nutrient loss estimates can vary significantly from property to property, depending on the level of similarity of soils, climate, climate patterns, topography, farm systems, etc.

3 OVERSEER version changes can potentially affect the understanding of source nutrient losses that was relied on in the plan-making process.

4 A significant change in the S-map soils database can also result in changes to important OVERSEER inputs and consequential changes to estimates of N and/or P loss.

5 A range of methods can be used in regional plan provisions and resource consent conditions to avoid or minimise the consequences of version changes (see Sections 3 & 4, & Appendix 6).

6 There would be advantages in having RMA processes that provide additional methods for incorporating OVERSEER version changes into a regional plan.

6.2 OVERSEER version change

OVERSEER is usually updated twice per year, with one significant version change usually in May, and a minor one later in the year, usually in November. A version change can involve relatively minor matters such as the model user interface wording or an output report wording, improving the data entry methods, fixing an insignificant software bug, or adding some functionality that doesn't change the 'engine' calculations. These types of changes would not have any impact on nutrient loss estimates. Conversely, a version change can involve a significant new or upgraded module, such as happened in April 2015 with the introduction of the new irrigation module.

A significant version change can also result from incorporation of new research information, changes resulting from reviews of model components, responses to investigations into reported anomalies, updating a model component with new data (e.g., N content of pasture species), addressing a significant software defect or bug, improving an algorithm with new information, etc. These types of changes can result in significant changes in estimates of nutrient loss.

There are also important linkages with information sources such as the S-map soils database (http://smap.landcareresearch.co.nz/home) that is a recommended (BPDIS, 2016) source of soil characteristic input data for OVERSEER. Those soil characteristic inputs can affect the estimates of nutrient loss. The soil characteristics information in the S-map soils database can change as a consequence of improved information, and new S-map information used as an input into OVERSEER can result in changes in OVERSEER nutrient loss estimates.

Version changes that result in changes in estimates of nutrient loss should be considered as moving towards a closer approximation of what the actual losses are likely to be i.e., reducing the uncertainty associated with nutrient loss estimates.

OVERSEER version numbering follows generally accepted software revision control protocols[24] with the numbering (e.g., 6.2.2) indicating the degree/extent of the significance of changes i.e., major. minor.maintenance[25].

The current OVERSEER Limited policy[26] is that when OVERSEER is updated previous versions are made unavailable. The internet version (https://secure.overseer.org.nz/live/) is updated to the new version and older internet versions are archived and not maintained. The standalone version has an expiry date built into it, which ensures that that version expires at the end of the month that is scheduled for the new version to be made available for downloading and installation.

OVERSEER Limited has agreed to allow the Waikato Regional Council to continue to use the standalone OVERSEER 5.4.3 version that is specified in the current (2016) version of the Waikato Regional Plan. In exceptional circumstances an archived version has been made available for limited use e.g., to complete a major technical or research investigation.

Over time, it is possible that OVERSEER's development will become so refined that the significance of version changes will reduce until there are no issues for the application of OVERSEER under the RMA. However, given the complexity of the model, the complexity of many farming systems and the complexity of nutrient cycles, this is unlikely to occur in the foreseeable future.

Model version change issues are not unique to OVERSEER; many other models (e.g., groundwater allocation models, air quality dispersion models, river flow estimation models, etc.) used under the RMA also undergo version changes. Therefore, methods developed to address OVERSEER version changes may be of benefit in other similar situations.

6.3 OVERSEER version change issues

A key issue with OVERSEER version changes is that they can result in changes to estimates of nutrient loss compared to those made with a previous version, and those changes can vary from situation to situation depending on the detailed version changes and the farm systems being modelled. Some changes may only affect some farm systems or a specific component, while some changes may be more broadly applicable. For example, an enhancement of a sub-model related to dairy cow urine N may have an effect on estimates of N loss for a dairy farm but won't affect P loss estimates for an arable cropping farm.

The likely consequences of version changes for nutrient loss estimates are usually investigated and signalled in advance by OVERSEER Limited if they are likely to be significant. However, because of the complexity and range of farm systems, because of the range of soils and climate in New Zealand, and because version changes often incorporate multiple changes to the software, it can be extremely difficult to predict all the consequences of all changes on nutrient loss estimates for all farm systems.

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24 https://en.wikipedia.org/wiki/Software_versioning

25 OVERSEER is referenced by a three number sequence numbering system, currently (July 2016) version 6.2.2. However, these terms (major, minor & maintenance) are relative and because of the complex nature of OVERSEER and the range of farm systems and locations in New Zealand, the relative scale of change signalled by a 'minor' or 'maintenance' change will frequently not indicate the significance of potential changes in estimates of nutrient loss for all farm systems in all locations.

26 The updating of OVERSEER is managed by the OVERSEER General Manager, on behalf of OVERSEER Limited who seeks advice on model development priorities from three advisory groups. Science and software development services are outsourced primarily to AgResearch and Rezare Systems using robust quality assurance requirements. There is a process is already in place for OVERSEER development: "OVERSEER Limited identifies and prioritises the development programme with input from three independent advisory groups (science, user and stakeholder). Development activities follow structured Science and Software Development Lifecycle processes that are specifically designed to maintain quality and understand the impacts of development on the model outputs and communicate these to users" (Caroline Read, OVERSEER General Manager, Personal Communication, March, 2016).

In some catchments with similar soils, similar topography, similar climate and similar farm systems, the effects of a version change on nutrient loss estimates are likely to be similar. Conversely, in a large catchment with many different soil types, different topographies, different climates, and a wide variety of farm systems, the effects of a version change can vary significantly.

There are potentially very significant policy, regulatory and implementation resourcing implications of OVERSEER version changes depending on the specific way(s) that OVERSEER is explicitly or implicitly applied in regional plans and/or resource consents. Three very broad types of application of OVERSEER are summarised below (Table 5), with an explanation of the potential consequences of an OVERSEER version change and the consideration that should be given to these consequences.

Table 5
Potential consequences of an OVERSEER version change for different applications of OVERSEER

Application of OVERSEER	**To assist in the estimation of current and/or future source and receiving environment nutrient loads**
Example	OVERSEER is used as part of catchment modelling to estimate an acceptable catchment source nitrogen load.
Potential consequence of a significant OVERSEER version change	If plan provisions are developed on the basis of the catchment modelling undertaken, a significant change in OVERSEER estimates could result in a catchment load underestimate or overestimate. Provisions developed on the basis of that estimate could accordingly be either ineffective or overly restrictive.
Consideration to address (see Section 6.5)	As part of the plan-making process, the potential impact of version changes should be considered in determining the most appropriate set of plan provisions. Where plan provisions are based on OVERSEER estimates, a regular assessment should be undertaken after significant OVERSEER version changes to assess the extent to which that change impacts on the appropriateness of the provisions[27]. The results of such an assessment can be used to determine whether or not it would be appropriate to undertake a specific review of a plan's provisions.

[27] The appropriate frequency and extent of such an assessment will largely depend on the nature of the regional plan provisions and the extent of model engine changes with a version change. For example, a relatively simple plan for a catchment with no significant current water quality issues, a robust version updating system and only minor OVERSEER engine changes in a version change, would indicate that a detailed assessment would not be needed for those plan provisions in response to that version change.

Application of OVERSEER	**To define the primary method to use for determining compliance with nutrient loss thresholds in the plan**
Example	Catchment source load limit, numerical or narrative regional rule thresholds or numerical or narrative resource consent condition thresholds
Potential consequence of a significant OVERSEER version change	If a regional rule or resource consent condition that is not locked to one OVERSEER version specifies a nutrient loss threshold, a version change could result in a change in the status of an activity e.g., from permitted to requiring a resource consent, or from compliance to non-compliance with a resource consent condition.
Consideration to address (see Section 6.5)	As part of the plan-making process, consideration needs to be given to how the impact of version changes is managed, particularly in relation to the drafting of rules that set out different activity status. Methods should be used in regional plan provisions and resource consent conditions, to minimise the consequences of version changes. Methods that provide for an OVERSEER version change to update a component of a regional rule or resource consent condition need to be carefully formulated to minimise the potential for an OVERSEER version change to result in a change in activity status for a land use/discharge.

Application of OVERSEER	**As a tool specified to be used by landholders to estimate and report nutrient losses from a farm.**
Example	A rule or resource consent requires the reporting of nutrient loss using OVERSEER but does not specify a maximum threshold. This can also include the specification of OVERSEER as one optional method of providing information.
Potential consequence of a significant OVERSEER version change	This type of specification is generally unlikely to result in immediate significant version change management issues.
Consideration to address (see Section 6.5)	No issue to address.

6.4 OVERSEER version specification approaches

Current practices for specifying the use of OVERSEER in regional plans and resource consents can be grouped into the following general approaches:

- Specific version number e.g., Waikato Regional Council – version 5.4.3.
- Current/latest version e.g., Environment Canterbury.
- Partial version number e.g., Otago Regional Council – version 6 (effectively the current version).
- No version specified e.g., Horizons Regional Council – effectively the current version.

Because previous versions of OVERSEER are not generally available, the last three approaches are essentially the same i.e., the only version generally available is the current version.

The Waikato Regional Council has developed policies and rules (in the Waikato Regional Plan) for the management of nitrogen loss to Lake Taupo and is the only regional council that has specified a precise OVERSEER version in an operative regional plan i.e., version 5.4.3. This was done to meet the need for outcome, community and legal certainty (Barns & Young, 2013). However, one disadvantage of this approach is that it makes it challenging to readily take account of model improvements that might, for example, include new N loss reduction strategies or enhance the accuracy of N loss estimates.

6.5 OVERSEER version change response approaches

Response to implications for the information base for regional plan development

The most appropriate approach to respond to an OVERSEER version change that may change the understanding of the relationship between nutrient source losses and receiving water objectives is to undertake a technical examination of the implications of changes for the objectives sought by the plan. The results of such an assessment should identify the significance of changes and assist in determining an appropriate response.

Responses to implications for regional plan provisions and resource consent conditions

A range of approaches have been adopted or proposed to date to respond to the implications of OVERSEER version changes for thresholds that require an OVERSEER estimate to determine compliance specified in regional plans and/or resource consents. These are summarised in Appendix 6 together with the advantages and disadvantages of each approach. Many of these approaches are not mutually exclusive. The appropriateness or otherwise of a specific method is likely to depend on the specific circumstances, for example, the objectives of a plan and the preferred types of rules.

Additional methods have been suggested by various parties that are beyond the current options available to regional councils. These include a change to the version change process and an additional ‘fast track’ method for incorporating changes to models specified in regional plans. These would require significant consultation with other organisations i.e., OVERSEER Limited (version change processes) and the Ministry for the Environment, and the Ministry for Primary Industries (a new fast-track plan change provision). However, because these possible approaches do have some significant potential advantages they are included in Appendix 6.

It is important to distinguish between how a version change may change the estimate of a nutrient loss from a current land use and how a version change may or may not change the interpretation of different types of rule or resource consent thresholds. The consequence of a version change may be different for a rule or resource consent depending on the type of threshold. For example, a threshold could be defined as:

- a numerical maximum defined with the current version of OVERSEER,
- the average nutrient loss for a property during a specified (“baseline”) period using a reference input file for that property and for that period which is recalculated using any new version of OVERSEER, or
- a defined GMP for the current farm system.

In the final example, the risk of an activity changing status solely as a consequence of an OVERSEER version change would be removed because the effect of a version change would be ‘neutralised’.

Different types of OVERSEER version management methods may more suited to different types of rules, and related issues such as the risk of an activity changing activity status would need to be considered. It is not feasible to identify version management systems that would be robust and suitable for all situations. Some methods will be suited to some situations, while others may be more suited to other situations (see Appendix 6).

It is important to appreciate that an OVERSEER version change may affect nutrient loss estimates from properties in different ways depending on the farm system, soils, climate, etc., and the implications of this for different types of rules. For example, where a threshold is defined in terms of a baseline estimate for an earlier period, a version change may result in significant differences between nutrient loss estimates for properties for both the baseline and a current land use. This could result in a version change causing some properties changing activity status while other properties might not change activity status. Depending on the intent of the plan, this may or may not be a significant issue. If for example, the plan is endeavouring to significantly reduce nutrient loss in a catchment then a change in activity status as a consequence of a version change may not be a significant concern. Conversely if the intent of a plan is to not increase a catchment/property nutrient load then a change in activity status as a consequence of a version change may be a significant issue.

Therefore, a threshold based on an historical baseline can be suitable for a range of situations, including where a catchment nutrient loss reduction is a priority and the issues associated with properties potentially changing activity status as a consequence of a version change is understood. Conversely, a threshold based on current land use GMP may be appropriate where a plan is not seeking significant reductions in catchment nutrient loss; a version change in this situation would not result in an activity status change.

OVERSEER version updating methodologies that use linked external mechanisms

A key broad OVERSEER version management approach, outlined in Appendix 6, that has relatively recently been included in proposed plan changes by the Bay of Plenty Regional Council and Environment Canterbury involves use of a mechanism referenced from a plan provision that takes account of the effects of an OVERSEER version change. This is done by having a suite of files (reference files) or a website-based calculator that is referenced from a regional plan provision and can be updated by OVERSEER version changes. More detailed analyses of these two approaches is detailed in the respective section 32 analyses[28].

The linkage to an external mechanism to allow both the current nutrient loss estimate and the comparative threshold to be updated with a version change means that the core plan provisions can remain unchanged but an OVERSEER version change could be accommodated with generally only a small risk that an activity status and/or compliance status of an activity could change as a consequence.

The reason that there could still be a small risk of an activity status and/or compliance status changing under such updating systems is firstly because there is some scope for data inputs to change slightly while still complying with the BPDIS, and secondly because a version change may not result in a proportional change in both the actual land use nutrient loss estimate and the comparative threshold when moving from one version to another. As indicated in the averaging section (see Section 8), OVERSEER has a number of non-linear and stepped processes incorporated into the model that mean that model changes can result in non-linear output responses. Therefore, it is possible for example, that as a consequence of a version change, estimated nutrient loss from a land use might increase proportionally more than an increase in a comparative threshold estimate.

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[28] Bay of Plenty Proposed Plan Change 10 Section 32 analysis: https://www.boprc.govt.nz/media/509000/s-final-section-32-lake-rotorua-nutrient-management-plan-change-10-pdf-copy.pdf
Environment Canterbury Proposed Plan Change 5 Land and Water Regional Plan: http://ecan.govt.nz/publications/Council/09.2-S32-pc5-report-plan-change-5-nutrient.pdf

A potential disadvantage of OVERSEER version updating systems that sit outside a plan is that they are different from the way that RMA plans have conventionally operated and there is very limited case law to provide guidance on these systems. It is also important to appreciate the difference between the resource consent process and the regional plan process. For example, there is significantly more scope in the resource consent process for an applicant to propose and/or agree to an OVERSEER updating system that may not provide the level of certainty needed for a regional rule condition.

The two broad types of regional plan OVERSEER version updating methods that have been proposed are summarised below (Table 6).

Table 6
Two examples of recent proposed regional plan OVERSEER updating methods that use an external mechanism

Threshold	External link and calculator	Example
Comparative thresholds e.g., current N loss estimate compared against specific numerical thresholds, specified in a regional plan.	Reference files are rerun using a new version of OVERSEER and published on a council website.	Bay of Plenty Regional Council Proposed Plan change 10 (BOPRC, 2016).
Current N loss estimate compared to various thresholds e.g. Baseline GMP N loss, GMP N loss, the percentage of a threshold, etc., specified in a regional plan.	Thresholds updated using a website-based calculator that provides for specific farm systems, climate and soil inputs modelled by OVERSEER and uses the current OVERSEER version.	Environment Canterbury Proposed Plan Change 5 (ECan, 2016).

Key legal issues related to version change management

The currently available legal advice and analysis have been reviewed and a number of key conclusions can be summarised as follows:

1. Where ‘incorporation by reference’ of OVERSEER into a regional plan is intended, achievement is problematic because OVERSEER may not be ‘written material’ as required by the Schedule 1 Part 3 process of the RMA.
2. There are no significant legal impediments associated with including a reference to OVERSEER in a regional plan provision as one of the optional methods to provide for nutrient loss estimates.
3. The level of legal certainty required for permitted and prohibited activities indicates that the use of thresholds in such rules that require the use of OVERSEER to determine compliance should be avoided unless a robust version management method is used.
4. Regional plan provisions and any associated OVERSEER version updating methodology used in a plan should be designed carefully, recognising the potential for an activity to have its status changed as a consequence of an OVERSEER version change.
5. There are possible additional processes that could be explored and developed, such as national planning templates and/or regulations to create consultative processes for the purpose of providing for and including updating of models such as OVERSEER, which are increasingly important in the RMA context.

This legal advice and analysis has been considered in this section and also in the development of Sections 3 and 4.

6.6 Other models

OVERSEER is only applicable to a range of land uses (Watkins & Selbie, 2015). Therefore, most regional plans provide for other models to be used to estimate N and/or P loss estimates for those land uses or discharges that are not currently modelled by OVERSEER e.g., outdoor piggeries. However, care is needed to ensure that such alternative models are comparable to OVERSEER. This would require such models to comply with appropriate technical criteria and/or specifications.

Recommendations – OVERSEER version change issues

1 The implications of OVERSEER version changes for regional plan provisions where OVERSEER was used to inform the development of those provisions should be assessed as soon as practicable after each version change e.g., by checking the effects of the version change on any source nutrient loss estimates and calculations used in developing plan provisions, and checking the effects of the version change on regional rule thresholds that require OVERSEER estimates.

2 OVERSEER version change issues should be taken into account in the development and implementation of regional plans and resource consent conditions (see Sections 3 & 4).

3 The specification of nutrient loss model alternatives to OVERSEER in regional plan provisions or resource consent conditions should be complemented with technical criteria and/or specifications to enable an appropriately qualified person acting on behalf of the regional council (e.g., a senior officer, consultant/commissioner) to certify or not that an alternative model complies with those criteria and/or specifications.

4 OVERSEER Limited should consult with OVERSEER stakeholders and users to review the frequency and content of OVERSEER version changes e.g., to consider the option of having only one version change per year that involves an OVERSEER ‘engine’ change that could affect N and/or P loss to water estimates.

5 Regional councils, the Ministry for the Environment, and the Ministry for Primary Industries should review the options for developing robust processes for the incorporation of changes to models such as OVERSEER that are regularly updated with new versions and are specified directly or indirectly in regional plan rules or resource consent conditions.

7 Uncertainty

7.1 Introduction

This section is written primarily for scientists and RMA practitioners involved in the plan-making and/or resource consent processes.

The purpose of this section is to briefly outline the sources of uncertainties associated with OVERSEER and to provide guidance on managing some uncertainties by focussing on how OVERSEER and OVERSEER outputs are used in establishing freshwater objectives and setting and managing to freshwater quality limits and resource consents.

Box 12 Key messages – uncertainty

1. Uncertainty in OVERSEER nutrient loss estimates is inevitable and regional plan and resource consent decisions need to acknowledge and endeavour to reduce uncertainty. Uncertainty is not a reason to take no action. Rather, the higher the uncertainty, the greater the need for robust monitoring and review processes for plan provisions and resource consents.
2. Some uncertainty in OVERSEER nutrient loss estimates will be reduced by undertaking and incorporating further science e.g., collecting more evaluation data under different soils and climates. Other forms of uncertainty are essentially irreducible e.g., biological variability.
3. There are options and methods for using OVERSEER and OVERSEER outputs in a way that recognises and manages uncertainty in planning and resource consent processes.
4. The importance of sources of uncertainty are different for different stages in the planning process.

7.2 Uncertainty in the OVERSEER model

Uncertainty is the situation involving imperfect and/or unknown information. It applies to physical measurements that are already made, to predictions of future events, and to the unknown (MfE, 2016). Uncertainty in the context of modelling can be defined as a potential limitation in some part of the modelling process that is a result of incomplete knowledge (Shepherd et al., 2013) and it is inevitable with any model. The other source of model uncertainty is a function of natural variability. The distinction is important, and uncertainties as a result of incomplete knowledge are reducible, whereas those which are a function of natural variability, while they can usually be better characterised by more sampling for longer, are generally considered not to be reducible (Der Kiureghian & Ditlevsen, 2007) and therefore need to be acknowledged and managed in another way.

Uncertainty (cf. accuracy) is the most useful term to use when talking about annual whole-farm nutrient loss estimates because it is not usually practicable or possible to directly measure whole-farm nutrient losses and, therefore, there is no measured value to compare with a modelled estimate (Shepherd et al., 2013). The sources of model uncertainty are outlined in Table 7.

Table 7
Sources of model uncertainty relevant to OVERSEER (after Shepherd et al., 2013 based on Walker et al., 2003).

Sources of modelling uncertainty	Brief description and comment
Context and framing	This can include choices about the physical boundaries of the system being modelled, the range of factors to incorporate into a model, and specific prediction choices.
Inputs	Uncertainties about inputs that drive the model.
Model structure	Models simplify reality and may be based on an incomplete understanding of the processes and structure(s) being modelled.
Parameters	Parameters used in the model need to be estimated or inferred from sometimes very limited data.
Model implementation	This includes technical modelling choices and software bugs.

Watkins and Selbie (2015) also outline the sources of variability in data input and modelling procedures in OVERSEER that contribute to modelling uncertainty and describe opportunities to reduce uncertainty in the model outputs as well as detailing the level of evaluation of OVERSEER sub-models that has occurred to date. These recommendations for reducing the uncertainty in OVERSEER are focussed on improving data inputs, improving understanding and description of farm systems, and using best practice calibration and evaluation, processes including increasing the number and range of field measurements and farmlet studies.

There are some sources of uncertainty described in Table 7 and in Watkins and Selbie (2015) that can only be reduced with new knowledge. The next sub-section addresses the requirements for new knowledge. However, there are some sources of uncertainty that are essentially irreducible and therefore, the remainder of this section focusses on how OVERSEER can be used in a way that recognises and manages uncertainty in setting and managing to water quality limits.

7.3 Reducing uncertainties in the OVERSEER model

Those uncertainties in the OVERSEER model that are based on incomplete knowledge can be progressively clarified and reduced through undertaking prioritised science. The choice of what additional science to do, and the way it is undertaken and incorporated can have significant impacts for the model and its use. It is, therefore, important to have good, transparent processes for reviewing current model components, deciding what science is needed, establishing the priority of work, and ensuring the robustness of the science. While the OVERSEER development processes and concomitant funding is beyond the scope of this project, they are critical factors in enabling a reduction in uncertainty in OVERSEER outputs.

The science and development processes outlined above are a critical, ongoing and long-term requirement. However, regional councils need to continue to develop plans and make resource consent decisions.[29] Therefore, for the purposes of this section, it is assumed that good and strategic policy for science going into OVERSEER is in place and leading to a continual and incremental reduction in uncertainty of the model outputs.

[29] Ongoing and active involvement by regional councils and other stakeholders in the OVERSEER Ltd development process is an important part of OVERSEER's development.

7.4 Reducing and managing uncertainties in establishing freshwater objectives and setting and managing to freshwater quality limits

In the Ministry for the Environment's draft guidance (MfE, 2016) on communicating and managing uncertainty, a three-stage iterative process is suggested for managing uncertainty in NPS-FM processes: assessing and reducing uncertainty, communicating uncertainty, and incorporating uncertainty into decisions with a feedback loop for monitoring, evaluating and revising to incorporate new knowledge (Figure 6).

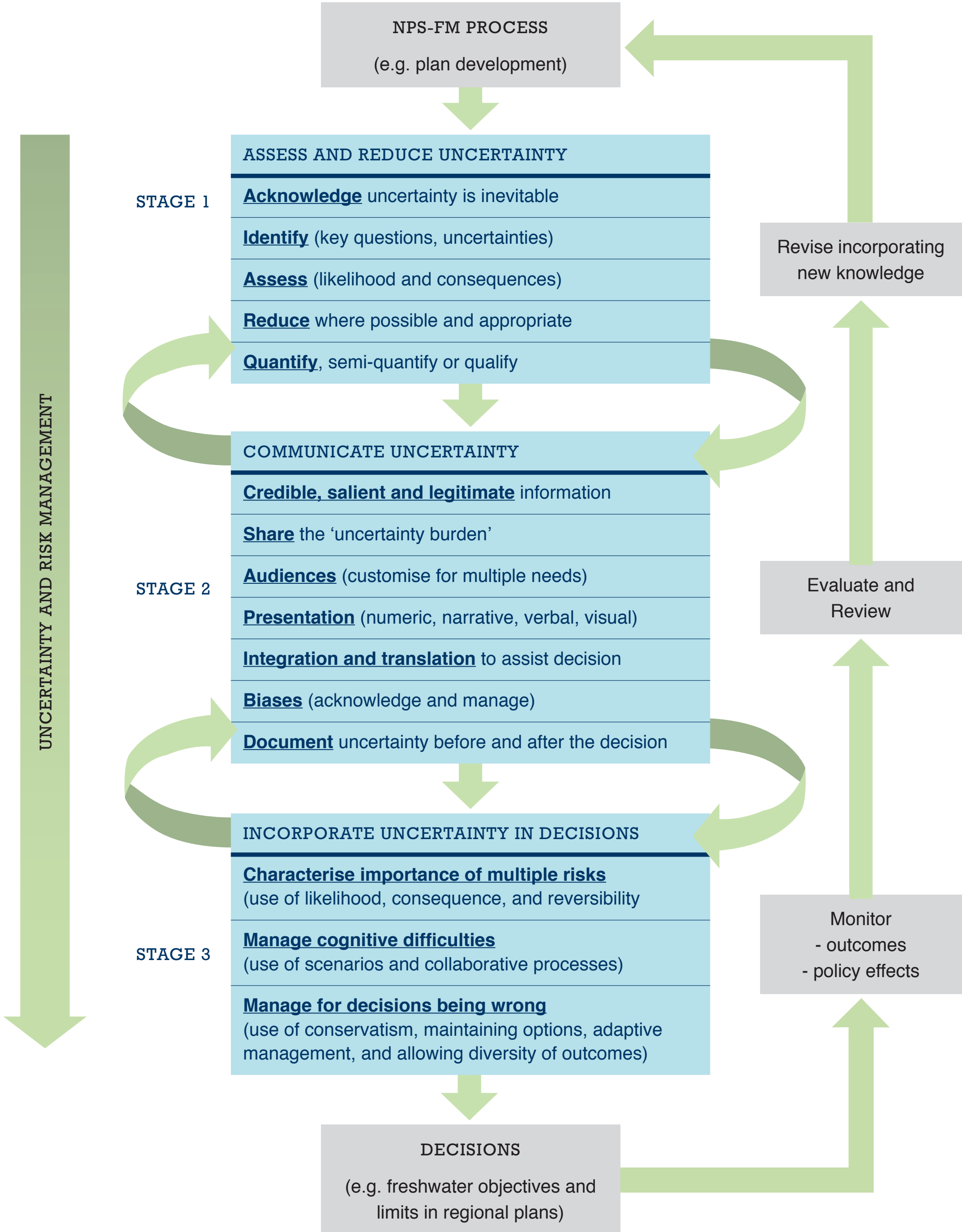

Figure 6
Three-stage iterative process for managing uncertainty in NPS-FM processes from MfE (2016) A draft guide to communicating and managing uncertainty when implementing the National Policy Statement for Freshwater Management.

The stages detailed in Figure 6 illustrate the uncertainty can be managed in different ways and at different stages of a planning process. It is also important to note that the importance of sources of uncertainty and how they can be managed change depending on the stage of the planning process. During plan development, when OVERSEER may be used to estimate nutrient losses, it is important to manage both the quality of inputs as well as how the outputs are used. However, these uncertainties are considered along with all the other uncertainties inherent in setting freshwater limits (MfE, 2016). Once a decision has been made (in light of all the uncertainty) and a plan is in place, OVERSEER may be used more as a calculator and the relevant sources of uncertainty arise from the quality of data inputs and version change (Section 6).

The following sub-sections outline some options and methods for managing uncertainty in the use of OVERSEER at different stages in a setting and managing to freshwater limits process. These options and methods are summarised in Table 7.

7.5 Identifying, reducing and managing uncertainty in model inputs

Quality of data inputs

In simple terms, the quality of what goes into a model affects the quality of what comes out.

The use of unreliable input data (i.e., data that is inputted by the user) is regarded as the major source of uncertainty in modelling. Cichota and Snow (2009) and Watkins and Selbie (2015) have identified a list of the main inputs that OVERSEER nutrient loss estimates are sensitive to.

Uncertainty can be partially managed by using good quality user data inputs that are supported (and/or verified) through accurate record keeping or supported by using other data (e.g., improved soil mapping), other modelling tools (e.g. crop calculators, Farmax, pasture modelling tools) or farm system expertise. As an illustration of the potential impact of quality of data, Figure 7 shows the difference in N losses from 74 farms modelled using OVERSEER with two different levels of soils information: level 1[30] and level 2[31] (Robson et al., 2015). Different sources of soil inputs had a significant impact on the losses predicted by many of these example farm systems.

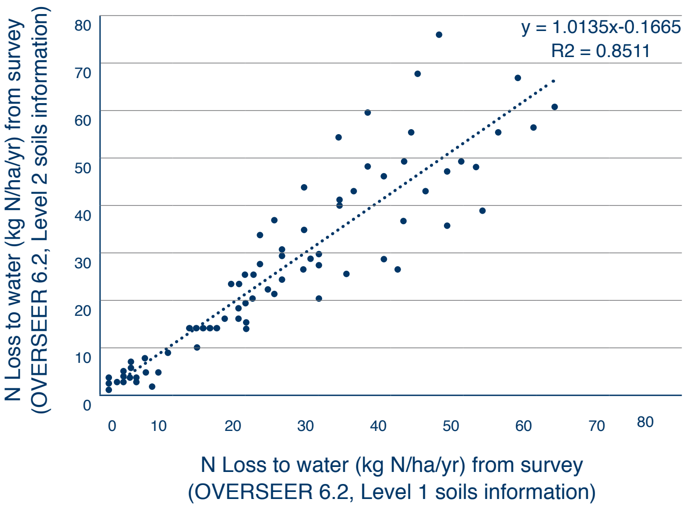

Figure 7
Relationship between N losses from 74 farms when using level 1 and when using level 2 soils information (Robson et al., 2015)

[30] Level 1 soils information is the use of qualitative OVERSEER soil profile categories (Pollacco et al., 2014).

[31] Level 2 soils information is the use of quantitative soil moisture inputs (Pollacco et al., 2014).

In some cases, high-quality data e.g., model inputs that reflect actual management or verifiable records, may not exist. This may occur when trying to establish a benchmark determined by historic activities but where there are no records. In these cases, careful consideration needs to be given to how to generate data for benchmark files, including the quality of data and the resources implications. In some circumstances, the use of generic or reference farm systems has been proposed as a means of generating files to fill these gaps.

Expertise of model users

Wheeler and Shepherd (2013) describe OVERSEER as an expert user system, and the outputs are dependent on many inputs that rely on expert judgement and understanding of NZ farm systems.

Watkins and Selbie (2015) describe differences in user input of data as a source of uncertainty in OVERSEER outputs. The development and use of the Best Practice Data Input standards (e.g. OVERSEER, 2015) are recognised to be an important aspect of managing the uncertainty in outputs created by variations in users' input of data (Watkins & Selbie, 2015; Wheeler & Shepherd, 2013). It is also important to ensure that the correct version of BPDIS is used with the correct OVERSEER version and that the BPDIS version is consistent if OVERSEER is being used in multiple parts of a planning process, or if there are multiple sources of OVERSEER files.

Even with appropriate expertise and qualifications, different users may make different assumptions and judgements, particularly if, for example, they are estimating practices for periods where data are missing. Further development of the minimum expertise requirements for modellers, BPDIS and guidance on potential issues (see Section 11) will assist to reduce uncertainty in model outputs associated with the expertise of modellers.

Representativeness of modelled information

The closer the farm system in OVERSEER is to the actual farm system being modelled, the more the uncertainty about the model outputs will be reduced.

At an individual farm level, the differences between actual and modelled outputs may arise from different sources e.g., quality or source of data inputs (addressed above), assumed level of practice not being achieved, or systems/practices that are beyond the model's current capabilities.

Uncertainty in model outputs may in part arise from the assumed practices or levels of practice that are built into the model not reflecting real farm practice. This can be managed by being explicit about the assumed practices being used in scenario modelling and in other situations e.g., using a farm environment plan to ensure that any differences are identified and addressed to ensure that assumed model practices are implemented.

Differences may also come from constraints in the model where current management practices, cultivation, fertiliser application, irrigation or crop types cannot be fully and accurately represented in the OVERSEER model e.g., a specific fruit crop that is not available in OVERSEER, the exact timing of fertiliser applications in a month relative to OVERSEER assumptions, etc. This uncertainty will only be reduced as the OVERSEER model evolves and more farm systems and management practices are able to be captured. However, the BPDIS (OVERSEER, 2015) contains some strategies, such as surrogate crop types, that can be used to reduce possible inconsistencies when a system can't be fully represented.

At a catchment scale, where OVERSEER is used to estimate nutrient losses for catchment assessments, there are additional scale, resourcing, and practical considerations that impact on uncertainty. For example, in a catchment with 500 farms, generating a source load from actual, high-quality[32] nutrient budgets may have the least uncertainty, but the resource implication of this approach would be great (unless the information was already being generated for other purposes such as catchment accounting). In addition, if policy or land-use scenarios are run, this may involve individual manipulation of each of the 500 files. Therefore, although the uncertainty with individual estimates increases the further away the model is from the actual farm systems, at the catchment scale, especially with large numbers of farms, a pragmatic approach is likely to be needed. The strengths and challenges of different approaches are shown in Table 8.

Similarity of farm system/soil/climate to calibration dataset

Shepherd et al., (2013)[33] describe OVERSEER as a part-empirical, part-mechanistic model. Therefore, OVERSEER can be used beyond the land uses, soils, and climates that were used in the field studies used to calibrate OVERSEER sub-models. However, the greater the difference from these calibration field studies, the more uncertainty there is likely to be in the estimated losses. Most of the field studies used in the N calibration and evaluation to date were carried out on flat, pastoral, dairy enterprises with primarily free-draining soils and moderate rainfall (Watkins & Selbie, 2015).

A way of partially managing the uncertainty of using OVERSEER to estimate nutrient losses for systems, soils and climates that are beyond the calibration range or where the system cannot be described in OVERSEER is to use well-calibrated process-oriented models such as SPASMO (Soil Plant Atmosphere System Model) and APSIM (Agricultural Production Systems sIMulator)[34] to provide supporting information. Models with a higher level of detail, such as process-oriented and mechanistic models can often be set to describe systems with greater specificity, which seems to generally increase the confidence in the model simulations, even though specificity does not necessarily mean greater accuracy (Cichota and Snow, 2009).

7.6 Managing uncertainty in use of model outputs – plan development

Significance analyses of variables to give ranges

Uncertainty can be partially quantified, communicated and accounted for in plan development by the use of statistical tools to identify the possible range of model outputs. For example, significance analyses can be used to indicate the relative influence that changes to key inputs have on outputs. Where there is uncertainty or variability in critical OVERSEER inputs (or a land-use configuration), multiple OVERSEER files can be run to explore the implications of that variability or uncertainty and to produce a range of possible nutrient losses. These ranges can be translated into possible impacts on outcomes, and in particular, assist with understanding the potential impact on the achievement of freshwater objectives. Communicating these ranges helps decision-makers to appreciate the extent of some uncertainties and take that into account in the decision-making process. Significance analyses have been used in some limit setting processes in combination with qualitative uncertainty assessments (Robson, 2014).

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[32] E.g.,model users are experienced, a consistent input standard is used (e.g. BPDIS) and high-quality data sources are used.

[33] Shepherd et al. define empirical models as statistical descriptions of observed data and mechanistic models as aiming to construct mathematical representations of the behaviour of a system based on descriptions of processes.

[34] SPASMO and APSIM are more often used as research tools due to their complexity and greater expertise needed to use them. See Cichota and Snow (2009) for further information on these models.

A significance analysis is neither a full uncertainty analysis nor a full sensitivity analysis, both of which would require significant resources. Watkins and Selbie (2015) acknowledge that although an uncertainty analysis on OVERSEER could usefully be undertaken, it is not possible to quantify all the sources of uncertainty in the nutrient loss value produced, and therefore suggest that reducing uncertainty might be a more appropriate use of resources.

Multiple sources of evidence

The Ministry for the Environment (MfE, 2016) indicate that "employing more than one model to make independent parallel predictions can be useful for establishing converging lines of evidence, thus potentially increasing confidence (i.e., reducing uncertainty) in the predictions". Where OVERSEER has been used to estimate source nutrient losses, well-calibrated process-oriented models such as SPASMO and APSIM (APSIM, 2016) may be useful for providing an independent parallel estimation for nutrient losses. These other models do not necessarily model at a farm systems level and are likely to require expertise to use and draw comparisons. The concept of multiple sources or independent parallel lines of evidence is also useful for reducing uncertainty around key inputs to OVERSEER where 'like with like' outputs can be predicted.

Using model outputs in a relative sense

Models are often better at describing relative differences, such as the increase or reduction of N leaching after a management change, rather than providing the absolute values of leaching (Cichota & Snow, 2009)). The uncertainties in the use of OVERSEER outputs can be partially managed by using OVERSEER to indicate relative changes using the same model version. For example, if incorrect soil information and, therefore, the estimated profile available water (PAW) was used in OVERSEER, the absolute nutrient loss is unlikely to be accurate. However, the relative impact on N leaching of activities such as changing stock type, using a different crop rotation or improving irrigation would be less uncertain.

At a catchment scale, this could involve the use of different land use or policy scenarios to explore the relative rather than absolute changes in estimated catchment nutrient losses.

At a farm scale, this could involve relative change from a known point, e.g., land use during a period of time or benchmark, or loss estimates monitored over time to indicate a trend. A condition of using the model in a relative sense is that all scenarios need to be in the same version of OVERSEER.

The relative sense concept can be used for plan-making and/or resource consent conditions by having provisions that e.g., compare nutrient losses over two separate time periods using the same model version, or that require a percentage improvement beyond a benchmark. However, there is limited case law on this approach.

7.7 Managing uncertainty in use of model outputs – plan-making, re source consents and implementation

Using the Precautionary Principle

In the guide to managing uncertainty in NPS-FM processes, MfE (2016) discuss the approaches to 'managing the certainty of being wrong' and suggest that "all the commonly used elements (of the precautionary principle) can be useful for managing uncertain situations: conservatism, a consideration of irreversibility and adaptive management." Of these, conservatism and adaptive management are specifically relevant to the use of OVERSEER. A consideration of irreversibility is a key factor in the wider limit-setting process, but not specific to the use of OVERSEER.

Conservatism

Conservatism can be exercised when using OVERSEER through e.g., using valid but conservative input data or using the conservative end of ranges of outputs. Conservatism can also be incorporated into decisions about limits as a way of managing uncertainty in model outputs. It is important to be transparent about what conservatism means in the specific context (e.g., environmentally conservative or economically conservative) and also to avoid conservatism being unintentionally used at each stage when conservative estimates or assumptions are used in the processes.

Adaptive management

Adaptive management is often used as a tool for managing uncertainty and involves a cycle of decisions, implementation of decisions, monitoring, review, and changes. It can be used as a mechanism to manage uncertainty in OVERSEER outputs used in setting and managing to freshwater quality limits and resource consent decisions. For example, by setting limits that include environmental triggers (e.g., mg/L of N) that if met by a specified date allow for further land-use change or intensification. If the triggers are not met, further development is restricted or additional requirements are placed on existing users. Adaptive management can also be used in consent conditions e.g., consent conditions that set an environmental trigger that, if exceeded based on monitoring data, prompt a course of action that is detailed in the consent.

This could be used in plan provisions e.g., by specifying that if a freshwater quality objective is not met by a certain date, a specific set of provisions apply; conversely, if a freshwater quality objective is met, a different set of provisions apply. Conceptually this is not different from specifying provisions that apply if a river drops below a prescribed minimum flow, and statutory plans with minimum flow provisions have been in use in New Zealand for over 30 years. Resource consents would need to have adaptive management conditions that align with those provisions, and water permits and discharge permits can be reviewed for purposes specified in such resource consents and more generally as a consequence of new 'minimum standards of water quality' (S128 of the RMA). However, land use consents are not subject to the same broad resource consent review provisions (S128 of the RMA).

Similarly, resource consents can include adaptive management conditions that require certain things to be done e.g., to reduce an estimated nutrient loss in response to an environmental quality threshold level being breached. While this approach is not common, there are examples e.g., water permits in the Lake Benmore catchment in Canterbury. Similarly, resource consent conditions have been applied to require investigations and a response action plan (that might require OVERSEER modelling) with a prescribed timetable set to implement the action plan to improve water quality to above the trigger concentration.

Averaging

Natural variability in the biological system that OVERSEER is modelling is a source of uncertainty. Section 8 on Averaging, illustrates some methods to manage some of this variability through averaging the model outputs over a period of time. These methods may be useful when setting baseline or benchmark nutrient losses, or when testing for compliance with a nutrient discharge threshold.

Short duration resource consents

A short duration resource consent (what constitutes 'short duration' will depend on the specific circumstances) is sometimes used as a mechanism to address uncertainties about potential negative effects and may be appropriate where the receiving environment is likely to become more sensitive over time, or adverse effects are only acceptable for a limited period (Freeman, 2011). However, such short-term resource consents must include specific conditions that require relevant information to be obtained to ensure that there is an adequate body of knowledge available prior to the expiry of the resource consent to assist future decision-making.

Resource consent review conditions

Consent review conditions can be used to address uncertainty, where a general or specific review condition provides for a review in the event of a specific situation and/or an adverse effect occurring. Freeman (2011) notes that there are several limitations to relying on consent reviews as a primary mechanism to address uncertainty and suggests that a review condition be used as a 'backstop' for long-term resource consents. Review conditions would need to be very carefully worded to ensure that the review circumstances are clear and the limitations of the review process are fully understood.

Using Farm Environment Plans and OVERSEER together

Some of the uncertainty in OVERSEER outputs can arise from poor input data or where OVERSEER assumes certain practices that are not actually happening. These sources of uncertainty may be partially managed by using an audited Farm Environment Plan (FEP) together with OVERSEER, where records that are used for the model can be verified and an assessment made as to whether the sought-after practices or level of practice is being achieved. In some cases, the FEP that includes farm system information and practices is relied on as the primary resource consent condition instead of an OVERSEER loss rate (see Sections 3 & 4). However, this requires care to ensure that such conditions are certain and enforceable. Farm Environment Plans may also be a tool to manage the uncertainty associated with version change.

7.8 Ongoing targeted monitoring and revision

Decisions on water quality limits are made with imperfect information and should be regularly revisited through efficiency and effectiveness monitoring and plan reviews. A key way of managing uncertainty when OVERSEER outputs have been used to estimate or calculate catchment loads is to ensure ongoing, targeted monitoring and data collection. This information can be used to test (and revise if necessary) the modelling and assumptions that underpin the catchment load calculations and the understanding of the relationship between source losses and the water quality in the receiving environment.

7.9 Summary of options and methods for reducing uncertainty

Table 8 shows a summary of the options and methods for managing uncertainty in the use of OVERSEER and how these options manage uncertainty using categories from MfE (2016).

Table 8

Summary of methods for managing uncertainty in the use of OVERSEER in setting and managing to freshwater limits against categories from MfE draft guidance on managing uncertainty (MfE, 2016)

Methods to manage uncertainty in use of OVERSEER	How uncertainty is managed					
	Assess and reduce uncertainty	Communicate uncertainty	Incorporate uncertainty in decisions	Reflect uncertainty in plan	Implement and monitor	Evaluate, review, revise
Managing data inputs						
Quality of data inputs	✓			✓	✓	✓
Expertise of model users	✓	✓		✓	✓	✓
Representativeness of modelled information	✓	✓				✓
Similarity of farm system/soil/climate to calibration dataset	✓	✓			✓	
Using OVERSEER outputs – plan development						
Significance analyses and use of ranges	✓	✓	✓			✓
Alternative sources of evidence	✓	✓			✓	✓
Model outputs used in a relative sense	✓	✓	✓	✓	✓	✓
Using OVERSEER outputs – plan-making, resource consents and implementation						
Precautionary Principle	✓		✓	✓	✓	✓
Shortened consent term				✓		
Resource consent review conditions				✓	✓	✓
FEP and OVERSEER used together	✓		✓	✓	✓	
Ongoing monitoring						
Ongoing targeted monitoring and revision	✓			✓	✓	✓

Recommendations – uncertainty

1 Uncertainty in OVERSEER nutrient loss estimates is inevitable and the development and implementation of regional plans and resource consent conditions should acknowledge uncertainty and endeavour to reduce uncertainty by:

(a) acknowledging in the plan-making process that catchment modelling and OVERSEER modelling involves significant uncertainties and communicating which options and methods are being used to manage uncertainty (see Table 8)

(b) using good quality data inputs, in particular for the more influential inputs (which will vary from situation to situation e.g., by spending more time in sourcing these data, using expert verification and/or independent modelling sources

(c) using qualified and experienced OVERSEER model users, using appropriate standards and guidelines e.g., the appropriate BPDIS, and taking account of other quality factors (see Table 12)

(d) endeavouring to use independent parallel sources of information where OVERSEER is being used significantly beyond its calibration range (system/soil/climate) e.g., through other models and/or relevant robust information

(e) using OVERSEER outputs in a way that minimises the impact of uncertainty e.g., using model outputs in a relative sense or using adaptive management methods (see Sections 3 & 4)

(f) communicating the potential consequences of uncertainties in OVERSEER outputs e.g., undertaking significance analyses and considering the impact of ranges of possible nutrient losses

(g) considering the use of policy, rule and resource consent condition frameworks that support adaptive management (see Sections 3 & 4) and are driven by appropriate indicators, such as the status of the receiving environment, and as more information comes available including from future modelling.

(h) ensuring ongoing targeted monitoring and data collection within a catchment where OVERSEER has been used to generate nutrient source load estimates, and if necessary, testing and revising the modelling and assumptions that underpin the catchment load calculations.

2 Additional investment should be made in research and investigations in priority OVERSEER science to reduce uncertainties, particularly for those situations that are significantly different from original calibration studies used in the development of OVERSEER e.g., locations with different soils, more or less annual precipitation, different farm systems, etc.

8 Averaging

8.1 Introduction

This section is written primarily for scientists and RMA practitioners involved in the plan-making and/or resource consent processes.

The purpose of this section is to review and summarise information on when OVERSEER estimates should be averaged and over what periods.

When plan rules and/or resource consent conditions specify the use of OVERSEER and require the provision of OVERSEER estimates based on actual farm data, the question is often asked whether the use of one year of data is appropriate or whether output estimates or inputs should be averaged over a number of years. A critical aspect of this is whether the purpose is for estimating long-term source loads to a catchment, developing some reference benchmarks, and/or for assessing compliance with some specified threshold.

Box 13 Key messages – averaging

1 It is important to be aware of potential mismatch issues when mixing long-term climate data with annual management data.

2 There are a number of reasons why it might be useful to average either OVERSEER inputs or outputs, including as a response to the mismatch issue and minimising annual variation in nutrient losses.

3 When considering averaging inputs, it is important to understand and consider several points, including the underlying steady state assumption, model non-linearity and biological feasibility. Another approach is to define a typical long-term farm system.

4 In a compliance setting, a rolling average of estimated nutrient losses over a minimum of the prior 3–5 years helps estimate the long-term trend and reduce variation in annual nutrient loss estimates.

8.2 The critical importance of climate inputs

OVERSEER inputs include three climate values: rainfall, potential evapotranspiration (PET) and temperature. These are generally obtained by using the ‘climate station tool’ in OVERSEER, which provides three annual long-term mean values from a NIWA generated data layer of 30-year average annual values based on the period from 1981–2010 (Wheeler, 2015a). These annual climate data values can also be specified by the user.

The monthly pattern of the rainfall and temperature variables is also important. The annual rainfall and temperature values are distributed into monthly values based on the temporal pattern of 30-year monthly data for the region or nearest town. The monthly values are in turn distributed into daily values according to 15 climate modifiers describing the range and seasonality (Wheeler, 2015a). In previous versions of OVERSEER, these climate modifiers have been set by default. Since version 6.2.2, monthly climate values can be specified by the user; however, this is not a recommended practice (BPDIS, 2016).

This use of long-term climate data and distribution patterns means that there can be a mismatch between climate and farm management when annual management data is entered into OVERSEER, especially where annual differences in management are due to changes in the actual climate. For example, irrigation inputs in any given year are normally driven by the actual climate in that year, and may not match the long-term climate pattern. Thus, too little irrigation might be applied in a drier than normal year or too much in a wetter than normal year. This mismatch can lead to underestimates or overestimates of nutrient losses (Wheeler et al., 2014).

OVERSEER is driven by user-specified levels of production. This has "an important effect on the calculation of feed and nutrient intakes" (Watkins & Selbie, 2015). OVERSEER assumes the farm is operating in a 'steady-state' and actual and reasonable inputs have been entered. If e.g., annual production, irrigation, and fertiliser inputs are combined with long-term climate data, the resulting farm system may not be viable as the long-term climate may not be consistent with the specified level of annual production.

The impact of using different annual rainfall inputs is illustrated by Journeaux (2014) in a numeric analysis of a dairy farm case study in which the effects of different averaging strategies were compared. Separate OVERSEER runs were made under three annual rainfall inputs of 800 mm, 1200 mm and 1600 mm with corresponding changes to the production, stocking number and fertiliser applications. There was a decrease in nitrogen losses of 51% and 54% for the drier year under two soils, and an increase of 54% for the two soils in the wetter year. Figure 8 shows the smoothing effect of averaging the annual losses over 3 and 5 years where drier and wetter rainfall years are randomly distributed over 20 years. Similarly, an analysis of annual variability in estimated nitrogen losses using actual farm inputs from Lincoln University Dairy Farm found a range in nitrogen loss estimates of 55% (Pellow et al., 2013).

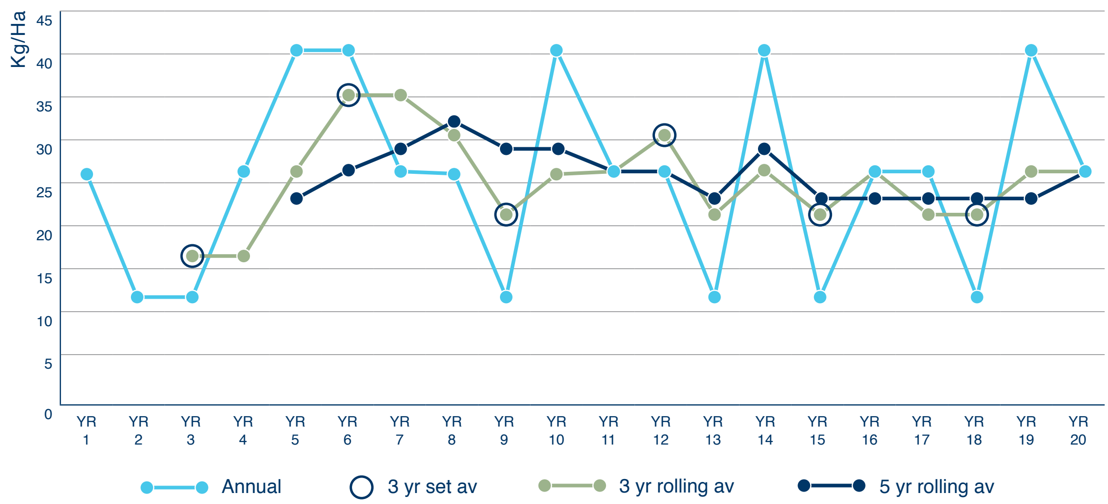

Figure 8
Nitrogen loss estimates (kg/ha) under a random rainfall pattern on a sedimentary soil type where management is changed to reflect the change in rainfall. Annual estimates of nitrogen loss are compared with an average taken every 3 years, and rolling 3- and 5-year averages. Reproduced from Journeaux (2014).

8.3 Existing recommendations for averaging

Regional councils have variously been recommended or advised (e.g., Park, 2014; BPDIS, 2016; Wheeler, 2013) to average OVERSEER inputs or outputs as follows:

a) that farm system inputs from more than one year be averaged to develop average input values for that multi-year period, then those inputs be entered into OVERSEER

b) that an average or typical farm system be defined

c) that annual nitrogen losses for a farm be estimated for more than one year, then averaged.

The rationale for this advice varies but essentially the main reasons behind these recommendations are as follows:

1 Averaging the farm system inputs or otherwise defining an average or typical farm system is a means of:
   - defining a typical year that represents the long-term farm management, and is thus a better fit with the long-term climate data used in OVERSEER
   - managing missing or unknown data e.g., where historical farm management information is too difficult to obtain, or when defining a future farm system for predictive purposes
   - minimising data entry by farmers.

2 Averaging the nutrient loss outputs is a means of:
   - managing the ups and downs in an individual's estimated annual nutrient losses due to year-to-year variations in farm management, particularly in a benchmarking, consenting or monitoring context
   - ameliorating the effects of the mismatch between annual farm data and long-term climate data used in OVERSEER.

Looking at the advice in more detail, the OVERSEER Best Practice Data Input Standards (BPDIS) recommend that the long-term climate data, climate patterns, and production are used when the model is being applied in a long-term predictive mode (BPDIS, 2016). Where OVERSEER is being used in annual mode (e.g., for monitoring purposes) the guidelines recommend that the annual farm inputs be used with long-term climate data and that a rolling average be calculated of the nitrogen losses from multiple years. Note the BPDIS also contains some more specific recommendations e.g., averaging annual fertiliser use over a minimum of 3 years.

Wheeler (2013) in his evidence for the Board of Inquiry into the Tukituki Catchment Proposal recommended the use of rolling averages for monitoring purposes to reduce the effect of year-to-year variability, and suggests a minimum period of 3 years. For forward prediction purposes, he recommended that a farm system that describes typical management in the future be used with long-term average climate data and patterns. Millner (2013) concluded that a 3-year period is appropriate for benchmarking pastoral systems and 7 years for arable farming and cropping. In his evidence for the same Board of Inquiry, van Voorthuysen (2013) supported the use of a rolling 3-year average whilst noting Roberts' (2013) suggestion of averaging estimates over 6 or 7 years for some arable land uses. Van Voorthuysen recognised the long rotation period for forestry might require averaging over an even longer time frame. The final Decision by the Board of Enquiry determined that a 4-year rolling average should be used (EPA, 2015). Park (2014) writes that the expert consensus at a Bay of Plenty Regional Council workshop was to estimate an average nitrogen loss over 3 consecutive years for livestock farm systems, and over 7 years for cropping systems due to the greater variability across crop rotations. Journeaux (2014) recommended averaging input data for a minimum period of 3 years and averaging outputs over a 3–5 year period. The various recommendations highlight that currently the wide range of situations and the limited information available mean that it is not possible to make a firm recommendation for the minimum number of years for averaging inputs or outputs.

8.4 Points to consider when averaging inputs

Steady-state assumption

Wheeler et al. (2014) explain that when calibrating the N sub-model of OVERSEER, farm management inputs for field trials were averaged and put into OVERSEER to compare predicted losses with the mean measured losses. They note that the relatively constant management of the field trials and the lack of long-term trials makes it very difficult to test the effect on model outputs of averaging input data over different time periods e.g., 2 years, 5 years etc., without further investigation.

OVERSEER is a steady state model that has been developed on the basis that, particularly for pastoral farm systems "inputs and site characteristics are in equilibrium with farm production and stock policy". Farm management is assumed to be constant i.e., OVERSEER does not model transitions from one farm system to another (Watkins & Selbie, 2015). This clearly stated assumption means that it may not be appropriate to estimate nitrate losses from a farm system in a major transition by averaging the inputs to a 'halfway' farm system, particularly where nutrients may be carried over from year to year.

Model linearity

While it is interesting that in Journeaux's (2014) analysis, running OVERSEER on averaged rainfall gave a very similar result to the average of the modelled outputs for each of the three rainfall levels for his specific case study farm system, in general, averaging model inputs is only successful where the model response is linear with respect to the input. This concept is illustrated in Figure 9.

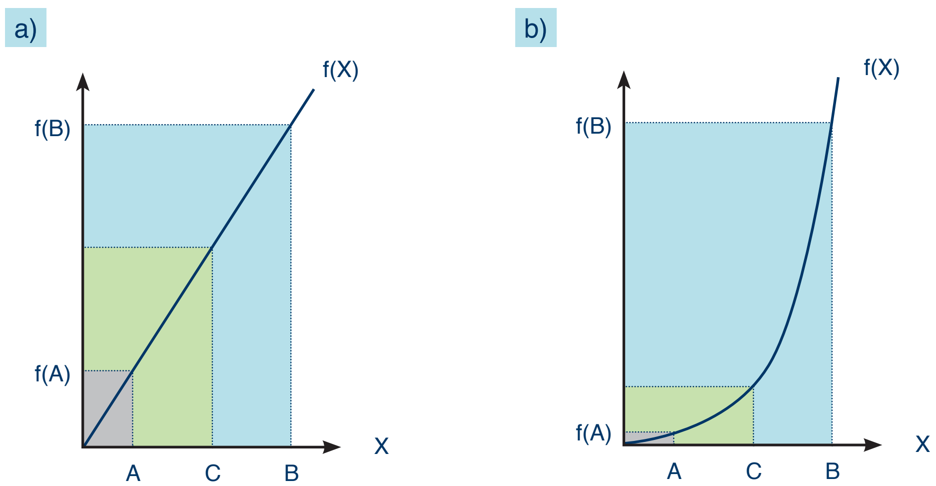

Figure 9
Schematic to show the effect of non-linearity of model response f on averaging. Point C is the average of input values A and B. In plot a) the model response is linear so f(C) (i.e., the point where the red dashed line intersects the vertical axis) is the same value as the average of model outputs f(A) and f(B). In plot b) however, the model response is non-linear, and f(C) is not the same value as the average of model outputs f(A) and f(B).

OVERSEER comprises many modules and algorithms. In some cases, the model response is linear (as illustrated by Journeaux (2014) and Wheeler & Bright (2015). In other situations, it may not be e.g., denitrification is a non-linear process (Wheeler, 2015b, 2015c). Averaging farm inputs that impact on the modelled wetness of the soil into a single OVERSEER file might result in a different nitrogen loss compared to the average of the estimated nutrient losses where each set of farm inputs is modelled separately. In general, the smaller the difference between the farm system inputs that are being averaged, the more likely the model response will be approximately linear (and so averaging inputs may be possible), the larger the difference between farm inputs, the more inappropriate averaging inputs is likely to be.

Biological feasibility

A key point is that OVERSEER assumes that the user-specified farm production is achieved with the specified farm inputs, soil and climate (Watkins & Selbie, 2015). Consequently, changing farm inputs by averaging them, or defining a representative farm system, requires considerable expertise to ensure that the resultant model represents a long-term biologically feasible farm system where levels of production are consistent with the specified inputs. Some of the OVERSEER farm inputs do not lend themselves to being averaged e.g., cropping rotations. Wheeler et al. (2014) also comment that it is not clear how to average some management inputs such as stock numbers and supplement feeding.

A common approach (particularly when the OVERSEER outputs are required for predictive purposes) is to derive a ‘typical’ farm system under typical climate conditions. The Matrix of Good Management (MGM) project followed this approach by defining a set of farm types based on industry surveys of actual farms in Canterbury (Robson et al., 2015). Hawkes Bay Regional Council developed representative farm systems from a range of sources for use in predicting nutrient loads (Millner, 2013). Bay of Plenty Regional Council defined a set of reference files that describe typical farm systems, although these are used for compliance rather than predictive purposes (BOPRC, 2016). Similarly, where actual historical farm input data are not available, it can be appropriate to develop a set of data inputs that are representative of the long-term farm system for benchmarking or regulatory purposes.

Regardless of how the typical farm systems are derived, it is essential to verify that they are long-term biologically feasible farm systems.

8.5 Use of output averaging by councils

Many regional councils have used an averaging approach or selection from a multiple year period for defining ‘baseline’ nitrate losses in regional plans. The various output time frames are detailed in Table 9.

Table 9
Time periods that define ‘baseline’ nitrogen losses as applied by regional councils

Council	Plan	Baseline time period
Waikato Regional Council	Waikato Regional Plan Variation 5 – Lake Taupo catchment (WRC, 2011)	“the single best year (year with the highest leaching value) of nitrogen leached between July 2001 and June 2005”
Canterbury Regional Council	LWRP proposed Plan Change 5	Average of 2009–2013 losses i.e., 4 years
Bay of Plenty Regional Council	Regional Land and Water Plan Rule 11 & Proposed Plan Change 10 (BOPRC, 2016)	For benchmarked properties - average of losses between July 2001– June 2004 i.e., 3 years or For land in catchment not previously covered by nutrient rules: losses from actual land use for 3 years prior to 1/1/2016

Regional councils have, for compliance purposes, adopted different rules that specify how many years of estimated nutrient losses are required (Table 10).

Table 10
Time periods specified in regional rules for OVERSEER-estimated nitrogen losses

Council	Plan	Time period specified in regional rule
Canterbury Regional Council	Canterbury LWRP Plan Change 5	Rolling average of modelled nitrogen losses from the most recent 4 years
Bay of Plenty Regional Council	Regional Policy Water and Land Plan Change 10 – Lake Rotorua Nutrient Management (BOPRC, 2016)	Three-year rolling average of modelled nitrogen losses but also may be assessed on an annual basis
Hawkes Bay Regional Council	Plan Change 6 – Tukituki River Catchment	Losses from each property should be calculated as a 4-year rolling average, derived from nutrient budgets prepared after 1 June 2013
Otago Regional Council	Otago Water Plan Change 6A (ORC, 2014)	One year losses
Waikato Regional Council	Waikato Regional Plan Variation 5 – Lake Taupo catchment (WRC, 2011))	One year losses
Horizons Regional Council	One Plan. Chapter 14	"Cumulative nitrogen leaching maximum" is defined as the total kilograms of nitrogen leached per hectare per year for the total area of the farm (Horizons, 2011) i.e., one-year losses.

8.6 Averaging in the plan-making process

The relevance of each of the three approaches (averaging inputs, defining a typical (or average) farm system, and calculating a rolling average of outputs) to the process for establishing freshwater objectives and setting and managing to freshwater quality limits depends on how OVERSEER is being used. Defining and using typical farm systems is particularly relevant when used in a predictive sense e.g., estimating future catchment loads or deriving benchmark values under good management practices. It is also useful where information on historical or current farm management is unavailable. Averaging outputs is relevant when there is a need to smooth annual variation in estimated nutrient losses e.g., in a compliance or monitoring setting.

8.7 Summary

OVERSEER incorporates a number of significant assumptions based on a stable, long-term farm system with similarly stable average climate conditions. Therefore, any modelling application that does not match these assumptions must be undertaken with extreme care and with a detailed understanding of the issues and implications. An estimate obtained with one single year's actual inputs may not represent the long-term N loss unless the farm system is constant, the climate that year matched the relevant long-term climate data in OVERSEER, and the farm inputs are consistent with the long-term climate from both an annual and monthly perspective.

Recommendations – averaging

1 The development of regional rules and resource consent conditions should recognise that one year's actual annual farm system data, as input into OVERSEER, may not be consistent with long-term climate data. Where they are inconsistent, nutrient loss estimates are likely to be highly uncertain and unlikely to represent the actual nutrient loss in that year.

2 Typical representative farm systems or averaging OVERSEER outputs can be used to endeavour to address the potential inconsistency that is otherwise likely to occur using one year's actual annual farm system data with OVERSEER's long-term climate data. If the climate over that averaged period is significantly different from the long-term climate, the result may overestimate or underestimate actual nutrient losses.

3 Any typical representative farm systems used for predictive purposes (e.g., when developing plan provisions) should be well defined e.g., as in the Matrix of Good Management (Robson et al., 2015).

4 Generally, OVERSEER outputs rather than inputs should be averaged. OVERSEER inputs should only be averaged if there is a clear understanding of the limitations and risks involved.

5 For the purpose of assessing compliance with a threshold in a regional rule or resource consent condition, a rolling average of a minimum of the previous 3–5 years of OVERSEER outputs should generally be used to provide a less variable and more meaningful indication of long-term nutrient loss from that farm system.

6 OVERSEER estimates of nutrient losses for farm systems undergoing a significant farm transition period e.g., dryland to irrigation, will have a relatively high uncertainty compared to stable farm systems. Therefore, reporting of nutrient losses should generally not be done for a farm system during a significant farm transition or, if this cannot be avoided (e.g., where reporting is required and a significant farm transition has occurred), appropriate assumptions should be incorporated to reduce that uncertainty (e.g., if the transition is to a more intensive land use with higher nutrient loss, to model that more intensive land use for the transition year).

7 The new capability (in OVERSEER version 6.2.2) to enter monthly climate data should not be used for the development or implementation of regional rules or resource consent condition until the BPDIS indicate that the capability is appropriate for non-research purposes.

8 Where short-term estimates of nutrient losses are required, e.g. seasonal estimates or for target water bodies that respond very quickly to changes in nutrient loading, an alternative to the currently available OVERSEER version should be considered, such as a more process-based model e.g., APSIM (2016).

9 Further investigation of appropriate averaging periods should be undertaken e.g., by reviewing the available pasture farmlet experiments that have measured N leaching and especially by reviewing the data available for non-dairy farm systems.

9 Nitrogen and phosphorus modelling

9.1 Introduction

This section is written primarily for scientists and RMA practitioners involved in the plan-making and/or resource consent processes.

The purpose of this section is to look at the implications of the differences between N and P loss modelling for the application of OVERSEER in regional plans and resource consents. The earlier section on uncertainty (see Section 7) provides an outline of the broad sources of uncertainty and the methods to manage uncertainty. The report by Watkins and Selbie (2015) discusses the broad assumptions and limitations of OVERSEER. This section focusses specifically on differences between N and P modelling.

Box 14 Key messages – OVERSEER modelling of N and P

1 There are fundamentally different processes driving actual N versus P loss.

2 OVERSEER uses very different sub-models to estimate N versus P loss, and consequently there are some specific limitations and assumptions that apply to OVERSEER N versus P loss estimates.

3 For OVERSEER modelling situations within the respective original sub-model calibration conditions, the uncertainties associated with OVERSEER N and P loss estimates are likely to be of a similar order of magnitude.

4 Modelling of catchment source nutrient loads in OVERSEER is unlikely to include all nutrient sources. This is particularly significant in modelling P source losses as there are generally a significant number of P sources that are not modelled by OVERSEER.

5 Provided that the relevant assumptions, limitations (Appendix 3) and principles (Table 1) are taken into account, OVERSEER is suitable to model P as well as N source loss at a property and catchment level.

9.2 Nitrogen and phosphorus – different processes and different sub-models in OVERSEER

There are fundamentally different processes driving N loss to water i.e., primarily N in drainage water, compared to P loss to water, which is predominantly via run-off to surface water (OVERSEER includes P leaching to sub-surface flows but excludes deep drainage (Gray et al., 2016). The report by Watkins and Selbie (2015) outlines the differences between the methods used by OVERSEER to estimate N and P losses to water.

It is also important to appreciate that P is assumed to run off (defined as surface flow, interflow, and subsurface flow that doesn't drain to deep groundwater) from all blocks of a property to a surface water body. Therefore, significant care is needed in considering P loss estimates for individual properties in a catchment context because clearly, for some properties, this may not be the case.

A recent review of the P loss sub-model (Gray et al., 2016) has identified a number of gaps and limitations in the current P loss sub-models, and opportunities for enhancing OVERSEER's P loss modelling.

It is critical to appreciate the different approaches to N and P sub-models to understand whether or not there are any significant differences in the uncertainties associated with the approaches taken in OVERSEER to modelling P versus N losses. It is therefore also important to appreciate the significance of this for RMA applications. Roberts (2013) notes that OVERSEER models "…N loss to water (leaching), P run-off risk…". It is important to appreciate that a P loss risk approach does not inherently result in greater uncertainties than the drainage estimation basis for the N sub-model. The 'risk' component of the P sub-model involves linking well-established factors that drive P loss e.g., rainfall, topography, soil properties, etc., into a model that has been shown to calibrate well with measured P loss for 23 locations (McDowell et al., 2005).

Occasionally questions are asked about the extent to which OVERSEER models all forms of N or P discharges. For example, is there a significant form of N, e.g., dissolved organic nitrogen, lost from agricultural land that is not modelled by OVERSEER? The current evidence (e.g., Shepherd & Wheeler, 2012; McDowell et al., 2005), particularly the original calibration studies, strongly indicates the forms of N or P that are not modelled by OVERSEER are generally not a significant component of the source nutrient loss[35]. However, a recent study (Smith et al., 2016) reported unexpectedly high contributions of dissolved organic N and P in drainage from a crop and pasture study.

9.3 OVERSEER, phosphorus and CSAs

There is a range of existing publications that highlight the options available for reducing both N and P losses to water e.g., Mackay and Power (2012). Many of these mitigation strategies are focussed at the farm level, block level or at a specific action, such as a riparian strip or wetland, and can be directly or indirectly modelled in OVERSEER. One potentially significant issue with P loss reduction options is that the combination of critical source areas (CSAs) (relatively small areas that can be responsible for a relatively large proportion of P loss) and normal 'blocking' guidelines (basis for identifying the blocks that make up an OVERSEER farm system – refer to BPDIS), can make it extremely challenging to model mitigation strategies that target CSAs. Development of blocking specifically to target CSAs is currently outside OVERSEER's scope. This has been a key driver behind the development of complementary models (e.g., Ballance's MitAgator and Ravensdown's Smart Maps) with a higher resolution that could estimate the consequences of mitigation strategies aimed at CSAs.

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35 The original N leaching calibration was predominantly undertaken using studies where only nitrate N was measured (Wheeler D, Pers. comm.). However, there is strong evidence to support the conclusion that the concentrations of ammonia N or other dissolved organic N in drainage water are usually very low (Wheeler D, Pers. comm.). For P, the model estimates dissolved and particulate P in overland (surface) run-off, or that is leached in some situations (McDowell et al., 2005). The model reports total P loss in overland flow.

9.4 Is OVERSEER suitable for modelling catchment phosphorus loss?

Catchment modelling studies have noted the greater uncertainties associated with catchment P loss estimates (e.g., Rutherford, 2013). However, this report was specific to the estimate of total loading to the receiving water body and recognised the limited sources of P loss that OVERSEER models and the limited simple mitigation options available in OVERSEER for P loss mitigation, rather than an observation of any inherent difference in the uncertainties of OVERSEER-estimated N loss versus OVERSEER-estimated P loss. In a similar manner, Parfitt et al. (2007) used both OVERSEER and NZEEM® (NZ Empirical Erosion Model) to discriminate between P inputs to the upper Manawatu River during major flood events and during the rest of the time.

The issue of N versus P modelling has been commented on through regional plan-making processes. For example, the section 32 analysis for one proposed regional plan change concluded that “For phosphorus, there is a model that we can use for the sources - OVERSEER. The phosphorus module is, however, not as well developed as the nitrogen module.” (ECan, 2014). The concept of the P sub-model developed using a risk component appears to have been interpreted as meaning that there is an inherent quantitative difference in the relative uncertainties of N versus P loss estimates. The results of the original calibration work on these sub-models do not support this interpretation.

A combination of factors (possibly misunderstanding of the use of the term ‘risk’ in the P sub-model calibration, misinterpreting what P sources are modelled, and confusing the drivers for a focus on N) appears anecdotally to have resulted in a relatively common view that OVERSEER is more suitable for modelling N loss than P loss. The technical evidence does not support this simplistic view.

The work of Rutherford (2013) and Parfitt (2007) highlights that it is critical to understand what proportion of a total catchment source load OVERSEER can model and therefore to consider the need to ensure other nutrient sources can be adequately modelled.

Nitrogen loss to water has been the predominant focus of the application of OVERSEER to nutrient water quality management in New Zealand. This has generally been because of catchment specific studies that have identified N as the primary limiting nutrient for plant growth in a specific receiving surface water body (e.g., Lake Taupo & Lake Rotorua). In New Zealand, there is evidence that “… lakes N-limitation and co-limitation occur with greater frequency than P-limitation (Abell et al., 2010; Larned et al., 2011). While in streams and rivers, P-limitation is more common than either co- or N-limitation (McDowell et al., 2009)” (McDowell et al., 2013). In the case of groundwater, the focus on N is generally because of concerns about the concentrations of nitrate-N in groundwater that is used as a source of drinking water.

There have been significant enhancements of, and additions to, OVERSEER sub-models relevant to both N and P since approximately 2009. While the predominant focus has been on N, there have also been improvements to P sub-models e.g., incorporation of P-specific aspects of deer wallowing and fence-line pacing, the use of reactive phosphate rock, winter forage crops, and dairy shed effluent management.

The conclusion from this brief analysis is that provided that the relevant assumptions and limitations are taken into account, OVERSEER can be used to model P as well as N source loss in a catchment.

Table 11 highlights the key differences in how OVERSEER models P loss to water compared to N loss to water and the implications of that for the application of OVERSEER under the RMA.

Table 11
Key differences in N and P modelling in OVERSEER and their RMA implications

Key modelling difference/ consideration	Comments	Significance for application of OVERSEER under the RMA
1. Different sub-models used to model different processes that transport N and P to water. Surface run-off is often the most important pathway for P loss; N is primarily transported in drainage.	P loss sub-model uses a rainfall event risk model compared to N loss sub-model, which uses drainage estimates as a key driver. Significant opportunities available to enhance the detailed P loss sub-models. However, there are also recognised opportunities to enhance the calibration range of N loss studies.	Two very different processes and two very different models don't necessarily mean that either method has an inherently higher uncertainty.
2. Broader range of farm systems and farm management practices modelled that include consequences for N loss but not P loss.	P loss is not adequately modelled for some farm systems. More detailed information is in Gray et al., (2016). However, similar issues apply to modelling N loss from cropping farm systems (FAR, 2013).	Care is needed in modelling P loss from some farm systems e.g., arable and vegetable cropping systems, cut and carry systems and fruit crop blocks. Similarly, care is needed in modelling N loss from cropping farm systems. OVERSEER does not provide for all possible nutrient loss mitigation practices. It is currently relatively easy and intuitive to apply various N mitigation options in OVERSEER (e.g., reduce N fertiliser), while P mitigation options often require more knowledge and understanding of farm systems (e.g., installing riparian strips). This needs to be considered in property or catchment modelling.

Key modelling difference/ consideration	Comments	Significance for application of OVERSEER under the RMA
3. Limited calibration and evaluation studies have been undertaken for both N loss and P loss sub-models.	The primary P loss calibration was undertaken with pastoral, forestry and two arable farm systems and there is a recognised need to extend the calibration and evaluation studies for a broader range of farm systems, soils and locations. More detailed information is in Gray et al. (2016). It has also been recognised that there is a need to update and extend the N loss calibration and evaluation for a broader range of farm systems, climates and soil types (FAR, 2013; Watkins & Shepherd, 2014)	It is not feasible or appropriate to make any generalisations comparing the uncertainties associated with OVERSEER N loss estimates with OVERSEER P loss estimates. However, the closer the modelled scenario is (farm system, climate, soil type, etc.) to the calibration studies, the smaller the uncertainties associated with nutrient loss to water estimates.
4. Farm system transition may be less of an issue for modelling P loss than for modelling N loss.	Transition effects may be less significant for P loss estimates. However, this would depend on the type of transition.	Expert advice would be needed to assess the potential impact of specific likely farm system transitions on catchment modelling. The potential effects of farm system transitions would need to be taken into account in developing specific regulatory approached and their implementation.
5. Methods used to ‘block’ up a farm for OVERSEER modelling	The current guidelines for developing farm blocks for OVERSEER may not always be the best method for estimating and mitigating P losses e.g., blocks may not be setup to ‘capture’ critical P source areas.	If the primary concern is P loss to water, then a P-specific approach to ‘blocking’ a farm would be appropriate.
6. Phosphorus modelling assumes that block run-off will leave the property and enter surface water.	Some blocks or properties may not directly border a surface water body. However, there may be a route for run-off to move to a nearby surface water body.	Significant care is needed to interpret losses from blocks and/or properties with no surface water boundary, and consequently the consideration of source P loss estimates at any catchment scale.

Key modelling difference/ consideration	Comments	Significance for application of OVERSEER under the RMA
7. Phosphorus loss to water from some types of river/ stream /lake bank erosion and mass flow events are not modelled.	These processes require additional different modelling approaches (Gray et al., 2016). These processes can also be an issue for N loss but generally at a much smaller scale.	If an assessment of all significant catchment P sources is needed, these additional sources must also be considered and, where appropriate, estimated by using appropriate methods/models.
8. Limited spatial resolution recognition	The focus of OVERSEER on relatively large block scale nutrient loss limits the ability to focus mitigation on smaller scale priority contaminant source areas, which are often particularly relevant to P loss to water.	The resolution scale needed to identify mitigation opportunities for relatively small critical source areas is not currently available in OVERSEER i.e., OVERSEER will not necessarily give 'credit' for a mitigation aimed at a CSA. Additional, more spatially appropriate models are being developed that should allow the estimation of mitigation measures to specific high-risk contaminant source areas e.g., Ballance's MitAgator and Ravensdown's Smart Maps.

Recommendations – OVERSEER modelling N and P

1 The use of OVERSEER should take into account the different processes involved in N and P loss, the different modelling approaches taken in OVERSEER for N and P, and the assumptions and limitations that apply specifically to N and/or P (see Table 11 and Appendix 3) e.g., it is critical to appreciate the specific nutrient loss sources that OVERSEER models in a catchment and the need to use other methods to estimate other nutrient loss sources.

2 The current evidence strongly indicates that OVERSEER modelling of P loss is not inherently more uncertain than OVERSEER modelling of N, and therefore, provided that the relevant assumptions, limitations (Appendix 3) and principles (Table 1) are taken into account, OVERSEER modelling of P is suitable to be used in the modelling of property and catchment P loads.

3 Investigations should be undertaken to assess the feasibility of developing guidance for 'blocking' a farm on the basis of P critical source areas. This may also assist with linkage to complementary models with the resolution needed to identify, and target mitigation to, critical source areas.

10 Data provision and security

10.1 Introduction

This section is written primarily for RMA practitioners and IT staff involved in the development and implementation of plans and/or resource consents that specify the use of OVERSEER and the provision of OVERSEER data to a regional council.

The purpose of this section is to identify the issues that arise when councils need to receive and manage individual OVERSEER property outputs/files provided as part of voluntary programmes, regulatory requirements or occasionally, catchment modelling investigations. Key issues include the level of prescription on the information required, the criteria for auditing, and receipting, managing and using OVERSEER files for compliance and/or catchment management planning purposes. In addition, privacy and security protocols are identified to ensure that any data collected by a regional council for a specific purpose are not used for any other purpose.

Box 15 Key messages – data provision and security

1. The receipt and long-term management of individual OVERSEER property files need well-designed data management and security systems to ensure that all legal, technical, and long-term information needs are met.
2. Significant resources are required to develop and implement the necessary data provision and security measures.
3. A full OVERSEER XML file is needed to assess the extent of compliance of OVERSEER modelling with the BPDIS and any other relevant standards/guidelines, and to undertake auditing.
4. The quality and fitness for purpose of OVERSEER modelling can be assessed by assessing the modelling against a suite of quality assurance factors.
5. Documented protocols and controls for management of OVERSEER XML files will give farmers and advisors confidence in supplying information. Accreditation under the Farm Data Code of Practice would further enhance confidence in the management of OVERSEER XML files.
6. Enhancing the interoperability of models used in RMA processes that involve OVERSEER inputs or outputs has significant potential to reduce uncertainties in those model outputs and enhance the effectiveness of those RMA processes.

10.2 Legal framework

There are a number of significant pieces of legislation that apply to the collection of information by a regional council that may also contain personal information (i.e., information about an identifiable natural person, as distinct from a company or partnership). The key acts are the Local Government Official Information and Meetings Act 1987 (LGOIMA), the Privacy Act 1993, and the Public Records Act 2005. This section does not review all the detailed relevant legal requirements for how information provided to, or collected by, a regional council should be managed. However, given the importance of Privacy Act principles a summary is provided below (Privacy Commissioner website March 2016):

1. Only collect personal information if you really need it
2. Get it straight from the people concerned where possible
3. Tell them what you're going to do with it
4. Collect it legally and fairly
5. Take care of it once you've got it
6. People can see their personal information if they want to
7. They can correct it if it's wrong
8. Make sure personal information is correct before you use it
9. Get rid of it when you're done with it
10. Use it for the purpose you got it
11. Only disclose it if you have a good reason
12. Only assign unique identifiers where permitted.

There are some additional dimensions to the management of OVERSEER data provided to a regional council e.g., if OVERSEER data and or output information is provided to a regional council as part of a voluntary programme, how would any potential compliance issues be managed? This would need to be managed at both an organisational policy and technical information management system level.

There are also potential intellectual property issues associated with OVERSEER files. Some OVERSEER modelling of complex farm systems can take many days to develop the inputs to accurately represent the farm system, and concerns have been expressed about the risk that such files could be accidentally released to competitors unless appropriate security provisions are established.

10.3 Different sources and types of OVERSEER data provided to regional councils

OVERSEER data is obtained by regional councils from a wide range of sources and for various uses, from specific property information provided as part of a specific resource consent application, to broad-scale catchment information used as part of a catchment modelling process. The context and technical specifications of these data have implications for the methods used to store, access and utilise such information. For example, the scale used to identify soil characteristics for properties at a catchment scale means that that soil data are likely to be inappropriate to use as an input for individual property modelling. Similarly, OVERSEER files provided to meet a specific regulatory requirement may not be able to be used for another purpose, unless permission was obtained.

Similarly, OVERSEER file information (e.g., a full XML file) and/or specific output information (e.g., kg N/ha/yr loss to water for a property) may be provided to a regional council as part of different programmes undertaken for different purposes e.g., averaged over different periods and/or with different levels of quality assurance. Therefore, great care is needed in the interpretation of such data and information management systems need to be developed to ensure that any differences are recognised and catered for.

Regional councils need to:

- specify the information requirements and establish systems for entering and/or transferring data into information management systems, and the subsequent analysis of those data
- have quality management systems to ensure that data comply with the specified requirements and have systems in place for dealing with data that do not fully comply with those requirements
- have data management systems that provide for all information needs.

For example, there is increasing recognition that in many situations only the full OVERSEER XML files contain enough information for an independent assessment of the quality assurance of a provided budget and associated nutrient loss estimate.

10.4 Methods to ensure OVERSEER input data are fit for purpose

There has been significant input into developing standard protocols for all users for the input of data and the specific parameters for the use of OVERSEER. To this end, the OVERSEER Best Practice Data Input Standards (BPDIS) were developed. "The OVERSEER Best Practice Input Standards (the Standards) were developed by a group of seven technical expert users, who drew on their personal knowledge plus that contained in the DairyNZ Input Protocol, the AgResearch Expert User Group Guidelines and the Waikato Regional Councils Protocol for Variation 5 (West Taupo Catchment). The standards are a consensus of the views of the seven technical experts" (BPDIS, 2016).

Although compliance with the BPDIS is a significant part of ensuring consistency across users, adherence to these standards will not guarantee that the files accurately reflect a farm system. The additional following factors are important for ensuring a high level of integrity and accuracy in OVERSEER model inputs.

Assessment of risk and level of input accuracy

If there are significant catchment nutrient loss reduction requirements and/or specific catchment nutrient water quality issues, this increases the requirement for a very high standard of OVERSEER model file preparation i.e., a high accuracy of model inputs. If the total losses, by property, are significant, either because of the size of the property or the losses per hectare, this also increases the need to have a high standard of file preparation.

File Provision

The data to be reviewed as part of a regulatory requirement will generally be a full XML file. There are a large number of variables within an OVERSEER file that can potentially have conflicting impact on the outputs, thus creating an inaccurate file. Therefore, the robustness of the outputs must be viewed in the context of the quality of the data within the XML file.

Other Supporting Data

The provision of additional data to support the XML file can also be used to provide a level of confidence that actual information has been used. These could include:

- annual taxation accounts showing opening and closing stock numbers, stock transactions, feed inputs, cropping and fertiliser usage (However, it is important to appreciate that this information may not have been independently audited.)
- annual fertiliser statement of use
- a summary of cropping activities undertaken.

Once an OVERSEER XML file has been provided as part of a regional plan or resource consent requirement, and it has been determined that an independent audit is needed, the following key audit checks and assessments (Table 12) need to be performed by a person with qualifications and experience at least equivalent to a Certificate in Advanced Sustainable Nutrient Management (see Section 11 - Qualifications and auditing), to determine an audit rating of the modelling:

Table 12
Proposed OVERSEER modelling auditing methodology

Modeller attributes	Protocol Checks
Qualification of modeller	Does the modeller have the minimum qualification of the Advanced Sustainable Nutrient Management Certificate or an equivalent qualification? If not, do not proceed.
Experience of modeller	Does the modeller have sufficient experience in farm systems modelling to ensure that the system being modelled is a long-term biologically feasible farm system? If not, proceed with additional caution.

Key OVERSEER Inputs	Protocol Checks	Model audit rating		
		High	Med	Low
Professional judgement is needed to score some responses into a high/medium/low rating e.g., if the annual average rainfall input is accurate, an audit rating of "high" would be appropriate.				
Best Practice Data Input Standards (BPDIS)	Have the BPDIS been fully complied with and any departures or 'second choices' justified?			
Farm area	Does the total farm area match any relevant FEMP/FEP, copy of title provided to show area, no obvious errors?			
Rainfall	Is the average annual rainfall used representative of the specific location? Was the climate station tool used to generate the rainfall data?			
Block set-up and scale	Has the farm been appropriately split into blocks to represent variable soil type, contour, intensity, and land use including cropping? Are any departures from normal blocking justified? Is the time scale correct?			
Soil inputs	Do the soil inputs used appear to be appropriate for the farm location? Was S-map used? If data was transcribed manually, was it done accurately? If a regional council prescribes a method was that method used?			
Irrigation	Do the irrigation inputs look appropriate (system, management option & application depth)? Are they the long-term averages? Are they normal for such farm systems in that location? If irrigation inputs appear relatively low, have corroborating data been provided e.g., water meter data?			
Stock Numbers / Type	Do the opening and closing numbers match the annual accounts (if provided) and the stock classes (gender and age) appear normal?			
Stock Sales / Production	Do the total sales and purchases and/or farm production figures match those provided within the annual accounts or typical productivity parameters?			
Fertiliser inputs	Do these closely match the annual nutrient statement provided by the fertiliser company (if provided)? Do they match normal industry practice for this farm system in this location? Are they the long-term averages?			
Soil nutrient status	Are soil tests based on three-year average data to ensure this is an accurate reflection of potential P losses? Does this create any issues for an annual nutrient loss estimate?			
Effluent management (Dairy)	Is the system, as reflected in OVERSEER, a workable and realistic effluent solution?			
Clover fixation	Is the input justified? Is it similar to other similar farm systems in that location?			

		Model audit rating		
Key OVERSEER Outputs	**Note: these are checks to help ID any issues, and to assist in resolving issues.**	**High**	**Med**	**Low**
Nitrogen losses	Are nitrogen losses per hectare within accepted/ published/measured ranges for the type of system being modelled for those soils/location?			
Phosphorus losses	Are phosphorus losses per hectare within accepted/ published/measured ranges for the type of system being modelled?			
Pasture production	Is annual pasture production within accepted/ published/ measured/modelled ranges for the locality, soil and pasture involved?			
Stocking rate	Are the stocking rates representative of the system being modelled? Are they within the normal range for the farm system and location? If the stocking rate is relatively low or high, have corroborating data been provided?			
Soil moisture, drainage & run-off	Do these estimates make sense? Are they consistent with information from other relevant reliable/published sources?			
N block pools	Do the estimated values make sense? Are they consistent with information from other reliable/published sources?			
		High	**Med**	**Low**
Overall audit rating Professional judgement needed and explanation required for the overall audit rating.				
Any unusual outputs?	Are there any unusual outputs that might indicate an input error, an unusual situation, or defect/bug in OVERSEER? If any significant anomalies are observed, they should ideally be resolved before an overall rating is made.			
Audit comments	Audit comments should be added to explain any unusual findings and to summarise the reasons for the overall audit rating.			

There may be additional audit requirements set by individual regional councils.

It is acknowledged that further development of this proposed audit system is needed e.g., to develop a process for ensuring consistency between auditors.

Data and Results Manipulation

It is imperative that the audit process removes the ability for any party to manipulate the results or outputs for the gain of one party. Provided that the same methodology is used each year, it is difficult to manipulate results on a year-on-year basis. Therefore, the level of scrutiny of a file must be at its highest for the first audit. Subsequent audits would have that first file and audit as reference points.

OVERSEER version changes

Where OVERSEER files have not been completed to the highest audit rating possible there is a risk of additional variability in outputs occurring between version changes and/or between comparisons with any regulatory thresholds. See Section 6 - OVERSEER version change issues.

Cross check dataset

Regional councils could collectively or individually create datasets that contain information such as typical range of stocking rates or pasture grown (or consumed) for different soil types of land classes to act as a quick check for OVERSEER file information. Specific additional methods could include the following:

1 Development of an anonymised dataset that calculates distributions of stocking rate (or pasture consumed) and other parameters by land class (utilising council GIS systems to locate farms and approximate land class). New farm models received could be checked against these statistical data and outliers flagged for more in-depth review.

2 Use of the Pasture Growth Forecaster (http://www.pasturegrowthforecaster.co.nz/) with NIWA VCSN climate data for the last 40 years to establish a 90th percentile potential pasture growth for each farm model, and compare that to the monthly pasture consumed as calculated by OVERSEER (livestock demand less brought in/stored feed consumed). Again, outliers would be flagged for more in-depth review.

10.5 Database systems for storage and use of OVERSEER data

Farm models are a representation of a specific farm system in a format that can be utilised by systems such as OVERSEER. When a farm system is modelled in OVERSEER the detailed input and output information is stored in an XML file (a type of file that enables data to be readily inputted into the OVERSEER engine and stores key outputs).

Currently, regional councils employ a variety of techniques for storing and utilising OVERSEER farm model data:

- Store source data (farm questionnaires and support documents such as invoices) and build farm models as required. This approach is likely to be most applicable to specific catchments where a regional council has a very proactive role. This approach can require significant resources to build accurate farm models for all properties.
- Store only the outputs of a farm model supplied by a primary producer or their advisor. This approach has advantages from a privacy perspective but means the regional council is unable to utilise the data to assess the impacts of an OVERSEER version change or other plan change. In addition, output data alone do not enable a regional council to undertake any quality assurance checking of the farm system information.

- Store the farm model XML file in a council file system folder. This approach could provide granular access control (folders can be protected) but would not typically record accesses. This would simply be an electronic filing system with no efficient mechanism to manage or analyse the data.
- Store the farm model XML file in a document management system, along with the other supporting documents relating to a property or a resource consent. This can be a useful approach as long as the document management system supports the appropriate level of controls and logging. Catchment analysis or analysis of OVERSEER version changes must be accomplished in this case by identifying and checking each relevant farm model, a process that becomes complicated as the number of farms and files to be assessed grows. A document management system will not typically provide detailed search functions able to identify OVERSEER files with specific sets of parameters.
- Store the farm model in a dedicated database or in a separate table or structure in an existing database. This approach allows versioning and bulk selection and use of data, but may risk disconnecting the farm model from other supporting documents.

These techniques highlight the advantages and disadvantages of different approaches and a number of recommendations are made at the end of this section.

It is also important that there is a high level of backwards compatibility when a new OVERSEER version is released, so that an OVERSEER XML file created under a previous version of OVERSEER can be run successfully on a new version of OVERSEER. However, it is acknowledged that there could be technical challenges in achieving this e.g., for files that may have run successfully on a previous version but a new version identifies actual input errors. Additional measures will be required to appropriately address these types of issues.

Forward compatibility (the ability to run an XML file created or modified with a new version of OVERSEER using an old model) is not required. While full long-term backwards compatibility would be an ideal situation, it appears that a 4-year period would enable most regional council requirements to be met. The need to incorporate a significant new module or function may make full backwards compatibility difficult, but in most cases recoding data to a new format or prompting the user for additional information should allow an old file to be updated to the new format. If changes that break compatibility are needed, prior consultation should occur with regional councils to discuss measures needed to achieve effective backwards compatibility.

10.6 Privacy and security requirements and systems

In addition to the controlled document frameworks implied by the Local Government Official Information and Meetings Act, the Resource Management Act, and the Archives Act, use of farm information in OVERSEER farm models raises privacy and data control issues (under the Privacy Act and more broadly) for primary producers, advisors or consultants who have been involved in the preparation of farm models.

Regional councils and contractors or advisors will need to show that they have:

- an information security policy for the organisation (as documented in ISO 27001) that defines appropriate policies and controls for the type of data held and allows the organisation to audit or check that those policies and controls are implemented
- a mechanism to determine the identity of any person attempting to access farm model data (authentication) and to provide appropriate access controls (authorisation) for that person. Access controls might include denying access, allowing read access, or allowing modification

- a mechanism for logging all access to farm model data (including read access) to provide confidence that privacy requirements are being followed, and appropriate policy guidance for staff and contractors. A similar approach is used by banks, police and government service organisations to log access to individual accounts or case files.

In addition to the above, there are three principal areas of concern for farmers and advisors that should be addressed:

- Primary producers are concerned that information from other sources or even ad-hoc observations (e.g., of stock numbers on farm) might be incorporated into a farm model without their knowledge. Regional councils could address this by making farmers aware of their processes for monitoring, triggers, and response protocols.
- Advisors invest their reputation in developing OVERSEER farm models for their clients (farmers or regional councils). They are concerned that later unauthorised modifications to farm models might damage their reputation, or that they may be held responsible for inappropriate use of the farm models they have created.
  OVERSEER Limited and regional councils could address this by developing and implementing a publishing protocol that identified the purposes for which an advisor had created and released a farm model, and by implementing additional 'digital signing' so that later modifications could be identified and repudiated.
- Advisors invest their intellectual property in the process of collecting data and transforming this into a biologically feasible and accurate steady-state model of a farm system. Some advisors are concerned that a farm model might later be released by a regional council or a primary producer to a competing advisor or organisation, without recognition of their efforts. Regional councils could address this by ensuring they have appropriate controls for the use and redistribution of farm models. Advisors who are developing farm models for primary producers could address this by appropriate agreements and by utilising a publishing protocol such as that identified above to assert their authorship of the farm model.

10.7 Farm Data Code of Practice

In 2015 the Farm Data Code of Practice was created and endorsed by a number of industry organisations to provide leadership and increase transparency about the use of detailed farm data by organisations. The Farm Data Code of Practice encourages organisations to become accredited by having clear terms and conditions and supporting documents that tell primary producers their rights and responsibilities and how organisations will utilise and manage the data they collect, and by having policies that support those terms. A key focus of the Farm Data Code of Practice is to provide confidence around datasets that may not be covered by the Privacy Act, as these data pertain to a (farm) company or trust rather than a natural person.

The Farm Data Code of Practice is administered through an independent review panel, appointed by its shareholding organisations: Beef+Lamb New Zealand, Dairy Companies Association, DairyNZ, Federated Farmers, Meat Industry Association, Te Tumu Paeroa (The Maori Trustee), and the Veterinary Association.

Regional councils implementing the information security policy and controls described above would find it straightforward to achieve accreditation under the Farm Data Code of Practice, which would provide further assurance to farmers and advisors.

10.8 OVERSEER data and model interoperability

There are a large number of models used in agriculture, water quantity and water quality management (e.g., TRIM, CLUES, Farmax, Pasture Growth Forecaster, Mike 11, IrriCalc, S-map, etc.). The majority of these models operate either independently or have limited interoperability e.g., S-map and OVERSEER. Given the significance and importance of some common data sources, e.g., climate data, farm data, and soil information, there is a need to enable enhanced model interoperability to enhance the efficiency and consistency of modelling. There are significant potential benefits to regional councils if there is enhancement of interoperability between models that are relied on directly or indirectly by regional councils.

An example of the issues that can arise is regional plan and resource consent hearings being provided with evidence from expert witnesses using models that use different climate data and farm management data. Similarly, components of one model or dataset can be incorporated into another but over time models and datasets are developed and enhanced on different timeframes, which can result in older components remaining in other models. This can lead to inconsistencies in model outputs that can be significant e.g., the estimate of annual drainage from a water resource model may differ significantly from that of OVERSEER (possibly because of different climate datasets and/or soil information used in each model). In addition, currently, outputs from one model have to be manually entered or manipulated prior to use in another model e.g., outputs from OVERSEER used in catchment modelling, or data from Farmax used in OVERSEER. This may require additional adjustments to make the models somewhat consistent, which means that the original source of the data can become hard to trace.

Some work has been done on these issues (e.g., Snow et al., 2014; Elliott et al., 2014). Two overall conclusions of those studies are summarised here:

1 There is a need for technical advisory committees to provide advice on data standardisation including the potential for common datasets that could form the basis for a number of models e.g., Farmax and OVERSEER.

2 Enhanced interoperability of freshwater modelling has been demonstrated as possible. However, there are a number of significant technical, institutional and resourcing challenges that need to be addressed before significant improvement of model interoperability occurs.

From the perspective of endeavouring to enhance the accuracy, interoperability and efficiency of OVERSEER inputs, three key model inputs stand out: climate data, soil data and farm system data. Given the importance of these inputs to OVERSEER and other farm system modelling, there would be significant potential benefits in developing and enhancing model interoperability with e.g., common datasets that could be inputted to different models.

Where other datasets are utilised in OVERSEER farm models, it will become increasingly important to trace the source of these data. In some cases, this is possible by a policy (e.g., input protocols that specify a common source and use of climate data), but more generally it would be advantageous to include a reference to source data in the OVERSEER farm model XML file. OVERSEER should consider a simple linking or reference mechanism to enable documentation of data provenance and assist traceability of data from multiple sources.

10.9 Land subdivision

Land subdivision can create issues for OVERSEER data management and regional rules and resource consents with 'OVERSEER conditions'. These generally arise when a title is 'split' during a subdivision process and where a resource consent has been granted, it may not be clear how a land use consent property nutrient allowance should be 'split' between the resultant titles. Apportionment issues are best addressed on a case by case basis and data management systems need to be designed to enable splitting and transfer to new properties.

Recommendations – data management, security and quality assurance

1 Regional councils should:

(a) Store OVERSEER XML files using a method that enables file data to be extracted using an automated process, and that provides for access controls and logging e.g., in a controlled system (document management system or database) or in a dedicated database table or store machine-readable references to the document, which may be stored in a document management system.

(b) Include additional database information to track:

(i) the provenance (original source) and date of the farm model,

(ii) the OVERSEER version used to develop the farm model/outputs,

(iii) for audit reviewed OVERSEER XML files, the reviewer, date of review, OVERSEER version used, audit rating, and any review notes, and

(iv) for any modification to OVERSEER XML files (e.g., after an audit review or to ensure the farm model complies with required practices), the date, originator and purpose of the modification, as well as the OVERSEER version used.

(c) Consider automated extraction of key farm model data or calculated outputs (such as farm areas, stocking rates, N and P nutrient budgets) to a separate table or area to enable rapid reporting without needing to extract individual results from XML or recalculate (OVERSEER version and date of calculation would also need to be stored with the extracted data).

(d) Consider developing methods to export anonymised OVERSEER file data from the database via a secured process to support use for purposes such as auditing, catchment studies or sensitivity analyses.

(e) Ensure that an information security policy for the organisation defines appropriate policies and controls for the type of data held and allows the organisation to audit or check that those policies and controls are implemented, including mechanisms to determine the authentication or identity of people accessing farm model data along with their authorisation to access such data, and to record such data access.

(f) Once the above information security policy and controls are implemented, consider seeking accreditation under the Farm Data Code of Practice, which would provide further assurance to farmers and advisors regarding the rights and controls surrounding identifiable farm data.

(g) Implement processes to ensure that all parties who provide OVERSEER XML files as part of a regulatory requirement are advised of the processes and protocols used to manage that information.

(h) Consider collectively or individually creating datasets that contain information such as typical range of stocking rates or pasture grown (or consumed) for different soil types of land classes to be used as a quick check for OVERSEER file information.

(i) Develop criteria for apportioning nutrient loss allocations specified in resource consents, if needed as a consequence of property subdivision.

(j) Ensure that OVERSEER modelling undertaken to meet a regional plan or resource consent requirement in a location of particular significance, e.g., for estimating nutrient losses in a catchment with significant nutrient water quality issues with regional plan objectives and policies that require reductions in nutrient source loads, is audited against a comprehensive suite of factors, such as those detailed in Table 12. Only those model outputs that have a modelling audit rating of High or Medium should be accepted for a regulatory requirement. (Also see Section 11).

(k) Consider development of processes to provide detailed guidance for the OVERSEER file audit process outlined in Table 12 e.g., to ensure consistency between auditors.

2 OVERSEER Limited and users such as regional councils and advisors should consider development and implementation of a mechanism that allows the creator of an OVERSEER XML file to identify the purposes for which it was created and released, supported by 'digital signing' so that later modifications could be identified and repudiated.

3 OVERSEER Limited and regional councils should consider developing a simple linking or reference mechanism to assist traceability of data from multiple sources. This could be implemented within the nodes or sections in an OVERSEER XML file.

4 OVERSEER Limited should endeavour to maintain backwards compatibility for at least 4 years i.e., to ensure that OVERSEER XML files generated 4 years previously can still be successfully run on the current OVERSEER model. If the need for significant model improvement/enhancement means that this cannot be achieved, there should be prior consultation between OVERSEER LIMITED and regional councils to enable the development of a methodology to achieve backwards compatibility.

5 Regional councils and OVERSEER Limited should support initiatives to enhance the interoperability of models used in Resource Management Act processes that involve OVERSEER inputs or outputs.

11 Qualifications and auditing

11.1 Introduction

This section is written primarily for RMA practitioners involved in the development and implementation of plans and/or resource consents.

The purpose of this section is to outline the need for qualifications and experience in OVERSEER modelling and the recommended qualification requirements for those preparing and auditing OVERSEER files.

The importance of OVERSEER modelling estimates and the complexities involved in ensuring that inputs and associated assumptions are as accurate and realistic as possible means that only appropriately qualified and experienced practitioners should prepare or audit OVERSEER file information that is being used in a significant RMA regulatory or planning process. However, as in financial accounting, it is also critical that reliance is not placed solely on qualifications and experience. There is also a need to have transparent auditing processes available so that all involved in processes that rely on OVERSEER modelling can have an appropriately high level of confidence in the output results while appreciating the inherent uncertainties in OVERSEER modelling (see Section 7).

Box 16 Key messages – qualifications and auditing

1. OVERSEER modelling requires a detailed knowledge of the New Zealand farming system being modelled and a detailed understanding of OVERSEER. This is particularly significant for scenario modelling.
2. A high level of assurance about the fitness for purpose of an OVERSEER estimate of nutrient loss needs independent auditing by a person with significant knowledge of the modelled farming system and OVERSEER.
3. The use of OVERSEER requires an understanding of the functions and relationships of component parts of the model. This requires regular publication of the details of those functions and relationships.

11.2 Experience and understanding of New Zealand farm systems

OVERSEER is not a fully ‘self-adjusting model’ i.e., it does not automatically change all aspects of a farm system in response to inputs. For example, adding fertiliser or irrigation does not cause OVERSEER’s estimates of pasture production to increase. This is particularly important in the application of OVERSEER to scenario analyses. Therefore, it is critically important to have a detailed understanding of both how the model operates and the farming systems that it models.

Many of New Zealand's farm systems have become increasingly complex over the past 50 years and there are also many mixed farm systems. Many complex factors combine to explain why, for example, adjacent dairy farms may operate differently, and modelling those differences appropriately in OVERSEER requires detailed knowledge of both OVERSEER and dairy farming systems. Therefore, a fundamental requirement for appropriate OVERSEER modelling is a full understanding of relevant farm systems and what is required to operate and model a long-term biologically feasible farm system. Similarly, it is critical that those involved in the use of OVERSEER have a sufficient knowledge of the functions and relationships of component parts of the model.

11.3 Currently available qualifications relevant to OVERSEER

The key currently available qualifications are the following:

- Massey University Intermediate and Advanced Sustainable Nutrient Management
- The Nutrient Management Adviser Certification Programme.

Massey University describes the Intermediate Sustainable Nutrient Management Course:

To be up to the challenge, participants should have completed at least one tertiary level course in Soil Science or Land Resource Management or have significant practical or professional experience in production agriculture/horticulture or environmental science. You need a good understanding of farm systems; it should not be your first introduction to the concepts of nutrient cycling and you should have prior knowledge of the Overseer Nutrient Budgets software. You may need to confirm with us that your qualifications and experience are appropriate.

Two options have been developed:

- Pastoral agriculture - with a focus in the case studies predominantly on dairy systems, and

- Orchard and Arable - with case studies including tree, vine, vegetable and cropping systems.

Participants on the Intermediate SNM course must complete a short pre-course assignment, attend a three-day contact course and sit a two-hour examination on the final day.

Massey University describes the Advanced Sustainable Nutrient Management Course:

To enrol in this course, participants must have successfully completed the Intermediate SNM Course. [Note: An exemption may be granted if an applicant can demonstrate prior equivalent learning and/or an in-depth knowledge of sustainable agricultural practices and use of the Overseer Nutrient Budgets software. Please contact us if you think you may qualify for being exempt the Intermediate SNM course as a pre-requisite.]

Participants must complete four assignments over a five-month period, attend a three-day contact course and pass a two-hour examination. The assignments are case studies using the latest version of Overseer Nutrient Budgets software and include both pastoral and arable examples. These are intended to assist participants to develop nutrient management plans that meet production goals for actual farm enterprises whilst minimising the negative effects of nutrient losses on the environment.

The Fertiliser Association of New Zealand run the Nutrient Management Adviser Certification Programme and describe its purpose as:

… to build and uphold a transparent set of industry standards for nutrient management advisers to meet, so that they provide nationally consistent advice of the highest standard to farmers.

These courses and their related qualifications can progressively develop the knowledge to undertake OVERSEER modelling for a range of farming systems. However, expertise in modelling one type of farming system, e.g., dairying, is not a guarantee that a person would have an equivalent level of expertise in modelling another type of farming system e.g., complex arable cropping systems.

11.4 Auditing of OVERSEER modelling

As the potential significance of OVERSEER modelling increases for both freshwater quality objectives and potential consequences for land owners/managers, so too does the need for appropriate auditing with transparent criteria to ensure that there is an appropriate level of confidence in the output results (see Section 10 – Data provision and security).

If OVERSEER modelling results are only being used for information purposes or if the scale and significance of nutrient loss are trivial, there would generally not be a need for independent auditing. However, independent auditing against clear and transparent criteria is usually needed for more critical modelling where the results may have particularly significant implications for regional plan development, determining a regional plan activity status or resource consent compliance status of an activity (see Section 10).

When considering whether auditing is required and the qualifications and/or experience needed for auditing a file, the complexity of the farm system being modelled should be considered. For example, a relatively small existing farm with a recognised low nutrient loss per hectare (e.g., dryland sheep) in a large catchment is unlikely to require independent auditing, while a large farm undergoing a new significant farm system change (e.g., to irrigation) in a small catchment would likely require an experienced and qualified person (e.g., a Certified Nutrient Management Adviser) to be able to adequately audit an XML file.

Industry audited self-management systems are appropriate in many situations if there is an acceptable level of independence, transparency and reporting, and the auditors are suitably qualified and experienced. However, there are a number of significant quality assurance benefits that can be provided by independent auditing.

The recommended criteria for auditing OVERSEER modelling are set out in Table 12 in Section 10 of this report.

Recommendations – qualifications and auditing

1. The minimum qualification requirement for undertaking OVERSEER modelling should be a Massey University Certificate in Advanced Sustainable Nutrient Management, an equivalent qualification, or extensive experience in a specific farming system and detailed understanding of OVERSEER.
2. For OVERSEER modelling of particular significance, e.g., for estimating property nutrient losses in a catchment with significant nutrient water quality issues with regional plan objectives and policies that require reductions in nutrient source loads, independent auditing of modelling should be undertaken by a person with the minimum qualification specified above, against the factors and process outlined in Table 12.
3. The functions and relationships of component parts of the OVERSEER model need to be published and those publications updated regularly by OVERSEER Limited to ensure that they are understood by those involved in the use of OVERSEER.

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APPENDICES

Appendix 1

Relationship with other OVERSEER documents

The following is an outline of the key documents and sources of information available to assist in understanding OVERSEER and its application to water quality management issues:

Report or information source	Brief description
http://www.overseer.org.nz	Website for OVERSEER with direct or indirect references to a significant collection of technical reports that explain the development, operation, and many applications of OVERSEER. This includes many science papers that explain specific technical aspects of OVERSEER.
OVERSEER Best Practice Data Input Standards, (Usually updated with each version change)	The purpose of these best practice 'standards' is to reduce inconsistencies between different users operating OVERSEER. They do not prescribe input requirements, but have been adopted by many organisations as a key reference.
Technical Description of OVERSEER for Regional Councils, Watkins, N. & Selbie, D., 2015.	A brief description of how OVERSEER works, including descriptions of the different methods used to estimate N leaching and P run-off, limitations, assumptions and uncertainties in model outputs.
Stocktake of Regional Council Uses of OVERSEER, Arbuckle, C., 2015.	A summary of the different ways that regional councils currently use OVERSEER
Individual regional council guidance on input requirements or preferences, e.g. Waikato Regional Council and Environment Canterbury.	These documents usually specify some information requirements to ensure that OVERSEER modelling is consistent and meets specified standards.
OVERSEER: Answers to commonly asked questions, Wheeler D. and Shepherd M., 2013	Responses to a series of questions posed by a variety of users, compiled into the following categories: general, uncertainty issues, performance for different sectors and policy development and application.

Appendix 2

Project brief

Outputs

The required output is a document providing guidance on the use of OVERSEER by regional councils in a regulatory context. The document must draw out the policy implications of the information collated in the 'Stocktake of regional council uses of OVERSEER' and 'Technical description of OVERSEER for regional councils' reports. The project board is looking for real strength in the analysis of potential policy approaches and an equally strong understanding of what that means for implementation and compliance on the ground. The tone should be informative and guiding rather than prescriptive.

This work is highly significant as it will inform future council practice. It is therefore critical that the guidance developed is robust and credible. We expect the expertise of experienced planners and implementers will be called upon and why approaches have been recommended will be fully justified. Finally, the guidance must take account of the objectives of regional councils throughout, in particular the protection or improvement of water quality.

Details of the outputs that will be produced by the contractor are outlined in the proposal and quotation dated 1 December 2015.

Report Scope

The following areas have been identified as requiring guidance:

1 Principles

This section should outline any overarching principles that should be applied to the use of OVERSEER as a tool in a regulatory context. Specifically it must cover the need for a councils to have a clear Resource Management Act (RMA) planning rationale for why managing nutrient losses at the property scale (the scale at which OVERSEER functions) is appropriate in a particular catchment. Principles for the use of OVERSEER by councils must take account of:

- *The known modelling limitations, including any easing of those limitations through the adoption of recommendations in this guidance report.*
- *The need for supporting information e.g. the separate modelling of nutrient attenuation and (where relevant) groundwater lags.*
- *The potential implementation costs to councils and landowners.*
- *The need for councils to have considered alternatives to achieve the same/similar water quality objective(s). However, this section should not be an exploration of alternatives to OVERSEER-based regulation. Rather, the focus is on identifying the strengths and weaknesses of potential OVERSEER-based regulation which will need to be addressed in any accompanying Section 32 analysis and be used (as necessary) in relevant communication with stakeholders.*

2 Policy, Rules and Compliance

This section will form a substantial part of the guidance and should provide detailed guidance on the range of appropriate ways OVERSEER can be used in policy and rules by regional councils. Rather than being overly prescriptive, the guidance should provide an analysis of the advantages and disadvantages of various possible approaches under different conditions, taking into account that *councils are operating in varying circumstances.*

- *Potential policy pathways for the use of OVERSEER as a tool in regulating diffuse discharges, and the implications of different approaches.*
- *Potential rule frameworks that could incorporate OVERSEER generated information, and the implications and potential consequences of different frameworks.*
- *Model rule wording and/or model consent conditions.*
- *Compliance implications of different policy and rules frameworks.*
- *Pitfalls to be avoided.*
- *Data input requirements – how prescriptive councils should be.*
- *Requirements for receiving files from landowners (e.g. frequency).*
- *Qualification and certification requirements for those preparing and auditing OVERSEER files.*
- *Identification of appropriate security and file management requirements for councils.*
- *Advice on how OVERSEER can be used in conjunction with other software, tools and systems within policy frameworks:*
  - *Farm Environment Plans (e.g., the use of OVERSEER generated benchmarks to monitor the results of implemented farm plans)*
  - *Catchment or sub-catchment models*
  - *Tools with a spatial element such as Ballance's MitAgator and Ravensdown's Smart Maps.*

To inform this guidance, analysis will be needed of the policy implications of a number of recognised modelling limitations, including:

(a) Uncertainty

Uncertainty in the inputs and the modelled outputs of OVERSEER are broadly identified in the 'Technical Description of OVERSEER for regional councils' report. The guidance material should address how this affects the appropriateness of various approaches, what more could be done to understand uncertainty in OVERSEER, and how uncertainty can be managed.

(b) Version change management

Guidance should include:

- *Analysis of options to manage OVERSEER version changes within RMA rules.*
- *Analysis of options available to address issues arising from OVERSEER version changes (where OVERSEER is used to understand compliance with numeric discharge limits, at either a property or catchment scale). These issues may include impacts on activity status and land use change aspirations.*
- *Recommendations for OVERSEER owners, regional councils and all users on managing future version releases.*

(c) Input and output averaging methods

The guidance should include recommendations for developing optimal repeatable methods for averaging input and output data over time, where OVERSEER is used to assess compliance with or progress towards a numeric discharge limit. This should include how many individual years of results should be used to determine trends.

Appendix 3

Assumptions for principles of use of OVERSEER

Land use and water quality management assumptions

- The loss of N and P to water from agricultural (and urban) land use is contributing to significant water quality issues in many water bodies and estuaries in New Zealand.
- Soil type, climatic conditions, topography, land use and management practices can all impact on the magnitude of human-induced nutrient losses to water.
- Nitrogen and P have significantly different loss to water pathways. Nitrogen loss to water is predominantly via leaching while P loss to water is primarily via overland flow with soil /run-off, or shallow sub-surface drainage.
- Nutrient losses via overland flow are generally more visible than those lost direct to ground, and mitigation strategies for tackling losses via overland flow are generally more intuitive and easier to gauge success.
- Direct and reliable measurement of diffuse N and P loss from a farm is not generally feasible.
- Modelled or estimated nutrient losses can be useful in the management of diffuse nutrient loss from land.
- Information obtained from both modelling and measurements involves uncertainties.

Guidance for general use of models in environmental decision-making

The US EPA (2009) developed guidance for the effective development, evaluation, and use of models in environmental decision-making. These recommendations are summarised below:

- Sound science principles are used in model development.
- The model is supported by the quantity and quality of available data.
- Evaluation of the model is undertaken to assess how closely the model approximates the real system of interest and how well the model performs against a quality assurance objective.
- There is appropriately comprehensive documentation of all aspects of the model.
- There is effective communication between modellers, analysts, and those using the model.

Key OVERSEER limitations, assumptions and uncertainties

OVERSEER incorporates important limitations, assumptions and uncertainties that are outlined below (derived from Watkins & Selbie, 2015b):

Model scope

- The OVERSEER model boundary relevant to this report is the farm boundary and the root zone.

Limitations

- OVERSEER is not spatially explicit beyond the level of defined blocks.
- Not all management practices or activities that have an impact on nutrient losses are captured in the OVERSEER model.
- OVERSEER does not represent all farm systems in New Zealand.

- Components of OVERSEER have not been calibrated against measured data from every combination of farm systems and environment.

Key Assumptions

- OVERSEER assumes steady state conditions (i.e., inputs and site characteristics are in equilibrium with farm production).
- OVERSEER estimates annual average outputs assuming that the farm management and inputs are constant.
- OVERSEER assumes that the production did occur for the given inputs.
- OVERSEER assumes that certain practices or levels of practice are occurring e.g., fertiliser is spread evenly, dairy shed effluent ponds are sealed.
- OVERSEER assumes long-term average rainfall, PET and temperature and a specific rainfall pattern based on location. (Version 6.2.2 provides for monthly climate input for research purposes.)

Uncertainties

- Modelling uncertainty derives from:
  - imperfect input data
  - differences between users' input of data
  - variability in the representation of the actual farm system via data records
  - errors in input and boundary condition data, model structure, parameter values, observations used to calibrate or evaluate, errors of omissions, commensurability of modelled and observed variables and parameters
  - the unknown 'unknowns'.
- There is temporal and spatial variability in field measurement data used for sub-model calibration.
- Scientific knowledge has been used to add components and to extrapolate to circumstances where calibration data has not been collected. The uncertainty around the estimated losses is likely to increase in circumstances that are substantially different from those in the calibration range.

Version changes

- New versions of OVERSEER are usually released twice per year to improve estimates of nutrient losses, improve the ability to characterise farm systems, enhance the model user interface and associated reports, address software bugs/defects, etc.

Appendix 4

Guidance and pitfalls for specifying OVERSEER thresholds in resource consents

(Note: This material is not comprehensive and is solely intended to raise awareness of some possible resource consent condition examples and some potential pitfalls to consider.)

Required resource consent component	Explanation
A well-defined threshold	Need to specify with absolute certainty what the mandatory threshold(s) is (are). This will require a numerical or narrative quantitative specification with direct or indirect linkages to definitions contained within the resource consent. May also be useful to have an 'early warning' trigger threshold below this to ensure that appropriate action is taken to reduce the risk of breaching the threshold.

Some resource consent condition examples to consider and develop:

One approach:

The consent holder shall not exceed a Nitrogen Discharge Allowance (NDA) of a rolling three-year average (the mean value of the three most recent annual nitrogen loss estimates) of Z kilograms of nitrogen per hectare per year (as calculated using Version XYZ of OVERSEER) over the land area to which the consent relates.

Another approach that uses an early warning 'trigger':

(a) If the nitrogen loss calculation exceeds 0.9X kilograms of nitrogen per hectare per rolling three-year average, then a report shall be prepared by a suitably qualified person and provided to the ABC Regional Council, Attention: XYZ Manager within one month of provision of the information provided under condition (e). That report shall detail the measures that will be taken to ensure compliance with the threshold of X kilograms of nitrogen per hectare per rolling three-year average.

(b) The nitrogen loss calculation shall not exceed X kilograms of nitrogen per hectare per rolling three-year average.

General potential pitfalls:

- If the key resource consent condition requires a report to be submitted "that demonstrates losses meet" a threshold requirement rather than a condition that specifies the threshold requirement, then there may be some compliance/enforcement limitations because the focus of the condition is a report "that demonstrates" rather than a threshold. It is generally preferable to separate the threshold requirement from a requirement to provide information relevant to that requirement.
- A specific or wider policy is needed to ensure that there is a clear and transparent process for responding to any non-compliance with a threshold e.g., is there a documented 'tolerance' policy for trivial non-compliance? Have OVERSEER uncertainties been taken into account in developing the threshold, should they be built into resource consent conditions and/or a compliance/enforcement policy, etc.?
- A condition that states what should or must be done if a threshold is breached needs to be written very carefully with a clear understanding that this may limit enforcement options that would otherwise be available.

Required resource consent component	Explanation
A requirement to undertake OVERSEER modelling in accordance with appropriate standards and guidelines, e.g., the BPDIS (see Section 10), and in particularly sensitive situations, a requirement for independent auditing as outlined in Table 12.	Needs to be explicit that the consent holder has to ensure that OVERSEER modelling is undertaken in accordance with the BPDIS and other appropriate considerations (see Table 12). Some consent situations e.g., scale, significance and/or location, may not warrant independent auditing. The need for auditing will be related to rule wording including thresholds e.g., if set relatively high, auditing may be needed for all OVERSEER files; conversely, if set relatively low, may need to identify a threshold or policy for auditing.

A resource consent condition example to consider and develop:

OVERSEER modelling shall be undertaken by the consent holder to provide estimates of nutrient loss and shall be undertaken in accordance with conditions of this resource consent, the relevant OVERSEER Best Practice Input Standards, generally accepted good practice and shall be audited using the audit criteria and system outlined in Table XYZ, by a person independent of the person who undertook the original OVERSEER modelling.

General potential pitfalls:

- Leaving it implicit that the consent holder will ensure that modelling is undertaken, potentially leaves the task to be undertaken by the regional council.

Required resource consent component	Explanation
A defined period(s) of time over which the OVERSEER modelling must be undertaken.	This must be made clear and line up with any specific catchment limit requirements (see Section 8). Specifically, see the limitations with using one year's actual farm data.

A resource consent condition example to consider and develop:

"Nitrogen Loss" means the loss of nitrogen from the property towards water as estimated by OVERSEER output, averaged over the most recent 4-year 1 July to 30 June period and expressed in kg per hectare per annum.

General potential pitfalls:

- A condition that doesn't explicitly define the period over which the modelling should be undertaken is vulnerable to different interpretations, e.g., what does 'per year' mean, when does the year start, etc.?
- Specification of modelling to be undertaken for one 12-month period only has risks that the farm system management over those 12 months may not be consistent with OVERSEER's long-term climate data (e.g., rainfall) and lead to overestimates or underestimates of actual nutrient loss (see Section 8). In addition, OVERSEER has been designed to provide long-term annual average outputs and providing individual one-year annual estimates may not be consistent with those steady state assumptions.

See Section 8 for specific guidance on averaging time periods.

Required resource consent component	Explanation
An OVERSEER version management mechanism.	Essential to clarify how OVERSEER version changes will be managed.

Some resource consent condition examples to consider and develop:

"Benchmark Nutrient Discharge Allowance" means the Nitrogen Loss estimated using the current (at any given date) version of OVERSEER calculated using the information in the OVERSEER Input File XYZ prepared for the 2015/2016 season 1 July to 30 June, and dated 30 June 2016, including any necessary inconsequential modifications needed to run that file data on the current version of OVERSEER.

The consent holder shall not exceed a Nitrogen Discharge Allowance (NDA) of a rolling three-year average (the mean value of the three most recent annual nitrogen loss estimates) of Z kilograms of nitrogen per hectare per year (as calculated using OVERSEER Version XYZ) over the land area to which the consent relates.

General potential pitfalls:

See Section 6 for detailed guidance on version management.

Required resource consent component	Explanation
A minimum qualification requirement for the person undertaking the OVERSEER modelling, and if auditing is required, the minimum qualification for the person undertaking the auditing.	OVERSEER is a complex model that requires detailed knowledge of both how the model works and NZ farming systems. A minimum qualification is essential (see Sections 10 & 11).

A resource consent condition example to consider and develop:

The person undertaking OVERSEER modelling for the purpose of estimating nutrient loss and for that estimate to be compared with the requirements of condition X, shall have a minimum qualification of a Certificate of Completion in Advanced Sustainable Nutrient Management from Massey University or a qualification that is at least equivalent. Evidence of this shall be provided to the ABC Regional Council, Attention: XYZ Manager on request.

General potential pitfalls:

- Not including a qualification requirement for the person who undertakes the OVERSEER modelling can significantly reduce the confidence in the quality of OVERSEER estimates.
- Giving a council employee, including a Chief Executive, unfettered discretion to determine what qualifications are appropriate is inadvisable. That approach is generally accepted as ultra vires; see the QP website for more information. A reference to a specific qualification and an alternative 'equivalent qualification' is preferable. The power to make a determination on what constitutes an 'equivalent qualification' can be delegated to a senior technical officer. The courts could ultimately make a determination if required.

See Section 11 for more detailed information.

Required resource consent component	Explanation
A requirement to provide the OVERSEER XML file and supporting information by a specific date, on request, or if a specific event occurs.	It needs to be clear exactly what and when information must be provided to the regional council.

Some resource consent condition examples to consider and develop:

1 OVERSEER nutrient loss estimates undertaken in accordance with condition (3) shall be provided to the ABC Regional Council Attention: XYZ Manager, by 31 August each year.

2 The OVERSEER modelling undertaken for the purpose of estimating nutrient loss and assessing compliance with condition (2) shall be audited by a different and independent person than the person who undertook the original modelling, against the audit system detailed in Table XYZ. Only those OVERSEER file results with an overall audit rating of Medium or High shall be accepted by the ABC Regional Council as a nutrient loss estimate for the purposes of assessing compliance with Condition (2).

3 Detailed records shall be maintained of fertiliser application rates, location and crop type (including winter feed/forage crops), cultivation methods, stock units by reference to type and breed, and all other inputs to the OVERSEER, or an equivalent, nutrient budget model. A copy of these records shall be provided to the ABC Regional Council, Attention: XYZ Manager on request.

4 A copy of each OVERSEER XML file used to obtain nutrient loss estimates used to assess compliance with condition (2) shall be maintained and provided to the ABC Regional Council, Attention: XYZ Manager on request.

General potential pitfalls:

- Care is needed to ensure that XML files have not been changed since modelling was undertaken.
- Care is needed to not specify that information is provided after an event that the consent holder has control over. The date should be independent of actions of the consent holder.

See Section 10 for detailed guidance on information provision.

Required resource consent component	Explanation
Any circumstances that would trigger a requirement for a complementary FEP	An FEP or NMP can be useful to provide a comprehensive integrated plan of how nutrient loss thresholds will be achieved, and to provide information to support the OVERSEER nutrient loss estimates. An FEP can also address nutrient management and other contaminant issues that may not be covered by OVERSEER.

Some resource consent condition examples to consider and develop:

A nutrient management plan shall be prepared by a suitably qualified person in accordance with the minimum requirements specified below:

1 Property details:

- (a) Physical address.
- (b) Name of a contact person.
- (c) Description of ownership structure.
- (d) Legal description of the land and farm identifier as provided by Regional Council.
- (e) Name and contact details of the person responsible for managing the property/farming enterprise if different from above.

2 A map(s) or aerial photograph at a scale that clearly shows:

- (a) The boundaries of the property.
- (b) A block map for the property/farming enterprise.

3 A description of how each of the following management objectives, where relevant, will be met….

"Suitably qualified person" is a person with a minimum qualification of a Certificate of Completion in Advanced Sustainable Nutrient Management from Massey University or a qualification that is at least equivalent, and at least X years' professional experience in providing land/fertiliser management advice.

General potential pitfalls:

- Care is needed to ensure that the status and role of the FEP/NMP is very clear. For example, is its purpose to complement other 'primary' conditions, or is it the 'primary' condition? The condition(s) requirements need to be certain and enforceable.

Appendix 5

Assessing methods to generate nutrient source loads against methods and tools to manage uncertainty

		Methods to generate nutrient source loads				
Methods to manage uncertainty		**Generic or literature values**	**Anecdotal case studies**	**Representative farms (few)**	**Representative farms (many)**	**Actual farm budgets**
Uncertainty of methods						
Managing data inputs	Quality of data inputs	High	Moderate	Low	Low	Variable
	Expertise of modellers	Unknown	Unknown/ moderate	Low	Low	Unknown/ variable
	Representativeness of modelled information	High	High	Moderate	Low	Low
	Similarity of system to calibration dataset	Unknown/depends on catchment				
Uncertainty of methods						
Using OVERSEER outputs	Significance analyses and use of ranges	Not possible	Generally not possible	Possible	Possible	Possible but resource intensive
	Alternative sources of evidence	Possible	Possible	Possible	Possible	Possible
	Model outputs used in a relative sense	Possible	Possible	Possible	Possible	Possible
	Precautionary Principle - conservatism	Not possible	Generally not possible	Possible	Possible	Possible but resource intensive
	Precautionary Principle - adaptive management	Possible	Possible	Possible	Possible	Possible
	Shortened consent term	Not possible for use in consents - - lacks specificity			Mod-high uncertainty - lacks specificity needed for consent	Possible
	Resource consent review conditions					Possible
	FEP and OVERSEER used together					Possible
	On-going targeted monitoring and revision	NA	NA	NA	NA	NA
Can incorporate updates to OVERSEER?		No	Possible	Yes	Yes	Yes

Appendix 6

Summary of approaches used to address various implications of OVERSEER version changes

Approach	Explanation	Advantages	Disadvantages
Options primarily relevant to regional plan development and implementation. They may have broad or partial application to a version change issue. Some options can be combined.			
Lock in a specific OVERSEER version number for regional rules and/or resource consent applications, e.g., a rule may state "…estimated using OVERSEER version 6.X.Y"	A regional rule can state that a specific OVERSEER version be used to determine for example, compliance with a nutrient loss threshold or that a specific version be used for resource consent applications. For example, OVERSEER version 5.4.3 is specified as the version to use for the Lake Taupo catchment since new regional plan rules became fully operative in 2011.	Provides certainty for land owners/managers that actual rule thresholds and/or resource consent thresholds won't change. Provides user certainty if nutrient allocation trading is established as occurs in the Lake Taupo catchment. No need to respond to OVERSEER version changes. Plan provisions can allow for resource consent applications or applications to change resource consent conditions to use a subsequent version of OVERSEER.	Can make it difficult to take advantage of model enhancements/ improvements/new mitigation options in a new version. Obtaining access to an old version needs permission from the OVERSEER owners. If this approach became common, it could result in multiple versions in use in a region and/or around the country. Can result in a significant implementation workload for council and land owners/ managers.
Explicitly or implicitly specify the current/most recent version for regional rules and/or resource consent applications e.g., a rule may state "…estimated using OVERSEER."	This is currently included in a number of regional rules that state a nutrient loss threshold and individual property nutrient loss estimates are to be determined using the current version. If the version is not specified, the same approach is implicit, because at any one time only one version is generally available.	Can take advantage of model enhancements/ improvements/new mitigation options in a new version. Updated versions generally involve model improvements that reduce the uncertainty involved in overall catchment nutrient source loss estimates. If a new version includes additional mitigation options, these can be used to both better reflect existing practices and encourage their uptake.	Unless robust version change management strategies are implemented this can create uncertainty for land owners/managers because numerical threshold rule compliance status could change with each version. The extent of this issue would vary depending on the specific plan provisions. The use of different versions over time could result in different actual consented losses for equivalent activities if consented under different versions.

Approach	Explanation	Advantages	Disadvantages
Specify in the appropriate rule that when a new OVERSEER version change occurs that results in a change to a relevant nutrient loss threshold or property nutrient loss estimate, that would not affect the exercise of specific existing resource consents (S68(7) RMA)	This is a relatively common approach used in similar situations to provide certainty to parties who may be potentially affected by a new rule that relates to minimum standards of water quality.	Could enable new OVERSEER versions to be applied over time. Could provide certainty for specific resource consent holders.	Depending on the application of such a provision, this would create challenges in estimating consented source loads, and potential for anomalies in treatment of similar resource consent applications.
Development of a plan framework that avoids or minimises the consequences of OVERSEER version changes	For example, use of rules that don't rely on thresholds that require an OVERSEER estimate to determine compliance, and rely instead on specific policies that utilise OVERSEER. For example, use of a limited number of activity class rules that can prevent an activity changing from one activity class to another as a consequence of an OVERSEER version change e.g., instead of having rules that include all activity classes defined on the basis of OVERSEER estimates, having a limited number of activity classes not defined on the basis of OVERSEER estimates. This is the approach in the Bay of Plenty Regional Council Proposed Plan Change 10	Can prevent OVERSEER version changes causing any activity class changes. Can assist in developing regional rule requirements that are easy to understand and apply. A clear policy framework and/or updating mechanism can minimise any inequities that could otherwise arise between any consents granted before and after an OVERSEER version change.	May not provide the degree of flexibility that a full range of activity classes would provide. Would put significant reliance on the resource consent process and would need a very clear policy framework to ensure plan objectives are achieved and farming sectors treated equitably.

Approach	Explanation	Advantages	Disadvantages
Provision of a version updating method specified via plan provisions but sitting outside the plan e.g., on a website, to address the effects of an OVERSEER version change on threshold estimated losses.	Such systems are being proposed to provide a transparent system to endeavour to address the effects of an OVERSEER version change by specifying via plan provisions a methodology e.g., a calculator, reference file system, or 'data input transfer' system. The methodology allows nutrient loss estimates to be recalculated with new versions of OVERSEER without changing the plan provisions, classification or compliance status of a farm system.	Depending on the details of the rule wording and the updating system, can be an effective method to address the effect of a version change on the status of an activity. Provides certainty to landowners/ managers about compliance after OVERSEER version changes. Would not appear to require a plan change or a Schedule 1 Part 3 process.	Updating systems may still result in a change in the status of an activity because a version change may not affect the activity and the threshold 'symmetrically'. Input updating systems rely on the input structures of OVERSEER remaining constant and establishing protocols for dealing with any minor model changes that may create technical challenges for 'transferring' input data. There does not appear to be any specific case law on these 'external plan linked' updating systems.
Provide the ability for a council or a council Chief Executive to approve or certify alternative models to estimate property nutrient loss.	An alternative model for an unusual land use that is not modelled by OVERSEER could be certified against public specifications or criteria.	Certification against clearly defined criteria or specifications could be a robust route to provide for alternative models and/or new versions. A plan would need to include clear technical criteria or specifications that a model or new version would be assessed against by an appropriately qualified person. Would provide options where the use OVERSEER may not be appropriate.	Would require resources to establish robust criteria or specifications and a certification process.
Use OVERSEER information to develop readily understood narrative rule thresholds e.g., maximum hectares of irrigation, maximum area of specified land use on a specified soil type, specific good management practices, etc.	This allows for OVERSEER information to inform the process of developing appropriate thresholds, e.g., permitted activity thresholds, but without reliance on an OVERSEER estimate to determine activity status.	This could address OVERSEER version issues for those activity categories where it is used (e.g., permitted activity threshold). Enables easily understood rule thresholds.	This could result in a narrow focus on specific inputs and less of a focus on outputs and effects. Would limit land owner/manager flexibility May not treat all situations equitably e.g., it would be a challenge to ensure that all possible land uses are recognised with equivalent narrative thresholds.

Approach	Explanation	Advantages	Disadvantages
Options primarily relevant to resource consents (many resource consent applications would be made under provisions of a proposed or operative regional plan with OVERSEER related provisions, many will also be made in circumstances where there are few provisions specific to OVERSEER)			
Lock in a specific version number for any granted resource consent	As described above for regional plan approach. Assumes that ongoing access to an old version would be provided, or a resource consent change or review process would be used to update to a new OVERSEER version.	Similar advantages as described above for a regional plan. An additional advantage is that it is significantly more straightforward (at least for limited numbers of consent holders) to apply for a change to a resource consent condition to take account of enhancements to OVERSEER in a new version. Resource consent conditions could specify a process for responding to version changes.	Similar disadvantages as described above for a regional plan.
No version or current version specified.	Where a resource consent is granted that explicitly or implicitly requires the most current version of OVERSEER to be used to estimate nutrient loss to water.	Similar advantages as described above for a regional plan. More flexibility in a resource consent process than regional plan process for parties to agree conditions that provide for future versions to be used and an updating process (i.e., Augier Principle, see QP website for more information).	Challenges in assessing resource consent applications over time using different OVERSEER versions. Potential challenges in using data provided as part of a resource consent requirement to estimate catchment source loads and wider catchment modelling. Depending on the detailed conditions, could result in uncertainty for the consent holder and other parties about future compliance e.g., a new OVERSEER version could change the compliance status in relation to a specified threshold.

Approach	Explanation	Advantages	Disadvantages
Include a condition in a granted resource consent that provides for a version updating method that provides for a calculator, reference file system, or 'data input transfer' system to address the effects of an OVERSEER version change on threshold estimated losses.	As described above for regional plan approach.	Similar advantages as described above for a regional plan. More flexibility in a resource consent process than regional plan process for parties to agree conditions that provide for a version updating method (i.e., Augier Principle).	Similar disadvantages as described above for a regional plan.
Condition wording that requires an OVERSEER estimate to be undertaken within a specified time frame while a specified OVERSEER version is available.	This would require modelling to be undertaken within a specified period of time while an OVERSEER version is available and records maintained and/or provided to the regional council.	This could be used with a 'batch' of resource consent applications to ensure that estimates were all undertaken within a specific time frame while one version is available. Would not be affected by an OVERSEER version change and would provide certainty. Could be complemented by conditions providing for OVERSEER estimates to be undertaken at a later period. May be applicable where there is no need for ongoing nutrient loss estimates.	Unlikely to be feasible for large catchments with many land owners or on a region scale. Would require significant coordination with many parties to be feasible. May require an additional mechanism to enable ongoing certainty for compliance monitoring.
Use OVERSEER to develop readily understood resource consent condition thresholds that do not require an OVERSEER estimate to determine compliance e.g., maximum hectares of irrigation, or maximum area of specified land use on a specified soil type, specific good management practices, etc.	Develop narrative statements of land management that are consistent with estimated property nutrient loss targets designed to achieve estimated catchment limits. Instead of using OVERSEER numerical thresholds, these are translated into narrative land use thresholds.	This would partly address OVERSEER version issues. Enables easily understood resource consent condition thresholds.	Would limit land owner/manager flexibility. This would result in more of a focus on inputs rather than outputs. Any narrative resource consent conditions that referred to, e.g., 'good management practices', would need to define exactly what is required to ensure that such conditions are certain and enforceable.

Approach	Explanation	Advantages	Disadvantages
General wider potential options			
Modify the current OVERSEER version change frequency and/or content, and availability of earlier versions.	This could include limiting intermediate version changes to matters that don't affect nutrient loss estimates e.g., user interface improvements. This could include a possible longer-term version change cycle e.g., every two or three years, that could tie in with a review of a regional or catchment nutrient management plan. The OVERSEER owners have also, under certain situations, made specific version(s) available.	Less frequent version changes would enable version response systems to be more manageable.	Less frequent version changes would limit the ability to quickly incorporate model improvements/enhancements. Achieving agreement on an ideal version change frequency/content between all key stakeholders would be difficult to achieve.
Amend Schedule 1, Part 3 of the RMA to allow for more effective incorporation of a new OVERSEER version into a regional plan. Or provide some other route such as that used to update a National Environmental Standard.	This has been suggested (Arbuckle, 2015) to develop a quicker process than that currently required by Schedule 1 Part 3. For example, if a specific consultative process has been followed to incorporate a new version change. This may provide an opportunity to develop a methodology for other important environmental models used under the RMA, e.g., air contaminant dispersion models, river flow estimation models, groundwater resource estimation models, etc.	If practicable and acceptable, would enable new versions of OVERSEER to be incorporated into regional plans faster than could currently occur, while still providing for input on the implications of a new version.	There are likely to be reservations about developing a 'fast-track' system solely to manage OVERSEER version changes, because this may conflict with normal RMA consultation processes.

Appendix 7

Parliamentary Commissioner for the Environment (2018). Overseer and regulatory oversight: Models, uncertainty and cleaning up our waterways.

Overseer and regulatory oversight:

Models, uncertainty and cleaning up our waterways

December 2018

Parliamentary Commissioner for the Environment
Te Kaitiaki Taiao a Te Whare Pāremata

This report has been produced pursuant to subsections 16(1)(a) to (c) of the Environment Act 1986. The Parliamentary Commissioner for the Environment is an independent Officer of Parliament, with functions and powers set out in the Environment Act 1986. His role allows an opportunity to provide Members of Parliament with independent advice in their consideration of matters that may have impacts on the environment.

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December 2018

Parliamentary Commissioner for the Environment
Te Kaitiaki Taiao a Te Whare Pāremata

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1

Overview

How this review came about

A review of Overseer was one of a number of topics that my staff suggested to me when I took over my role. It struck me as a challenging but potentially useful mission. It was featuring in two major environmental policy debates and yet it was, for most people, a black box. It seemed useful to ask whether it merited either the confidence being placed in it by some or the scepticism expressed about it by others.

Shortly after I announced my decision to conduct a review of Overseer, I was exposed to two entirely different reactions in the same week. The first, from a person confident in the model's capabilities, was a warm endorsement of the idea. Overseer, he felt, needed support and could only benefit from independent scrutiny. The second was from someone equally enthusiastic to see Overseer being used but who drew the opposite conclusion – was it wise to ask too many questions when Overseer is "all we've got"?

How could two people who understood the model's value – and supported its use – come to such different conclusions about the merits of reviewing it? In the weeks that followed, I was consistently surprised by how many people had a view about something that is 'just' a model.

Perhaps I shouldn't have been surprised, given the wide settings in which it has been talked about. From the outset, it was designed to be accessible to farmers and the advisors they work with. More recently it has been drawn into two major environmental management debates.

Abroad, Overseer has been cited by officials as a tool that can provide assurance that New Zealand has the means to reckon with on-farm agricultural emissions. At home, it has increasingly featured in regional-level battles to turn the tide on nutrient pollution.

Here its reception has been, to put it mildly, mixed. Its use in regulation has caused significant disquiet in the farming community. Updated versions have in some cases thrown farmers' resource consent obligations into doubt. Councils have understandably been cautious about imposing nutrient limits on the basis of modelling results they cannot easily explain to those affected by them.

Verdicts on Overseer are not made in a vacuum. The confidence with which it is promoted or accepted is closely related to the purpose for which it is being enlisted, and the interests of the party affected. Whether it is 'good enough' for that purpose is not a scientific judgment. It depends on the use to which it is put.

Overseer's ability to assist in one debate (e.g. nutrient pollution and water quality) may shed light on its potential in another (e.g accounting for on-farm greenhouse gas emissions). However, as the uses are different, the answers to the question of whether Overseer is fit for purpose may also be different.

This is why I have focused my report on Overseer's use in a regulatory setting to assist with the management of diffuse nutrient pollution. The suitability of Overseer for estimating biological greenhouse gas emission of farms I will leave to others. However, the recommendations of this investigation touching on transparency and openness would certainly apply to any regulatory use of Overseer.

I do not pretend that this report makes for exciting reading. Models for most people are zones of algorithmic mystery. But those who use the model, or are affected by its use, need to know what it can and can't do, and how much confidence can be placed in its outputs.

Models, Overseer the model, and how it is currently being used

In writing this report, I felt the need to go right back to the beginning – both in terms of asking what purpose models serve, and what this particular model may be able to contribute to the management of diffuse nutrient loss on farms.

As chapter 2 explains, a model is a simplification and an approximation of reality. Models enable us to make sense of complex interactions and test different possible future outcomes. Indeed, this ability to help make informed decisions about the future is one of the greatest strengths and values of models. However, those simplifications that make a model possible are also a source of limitations. We can't ask a model to do more than it was designed to do.

Reference to Overseer's intended purpose is a leitmotif that runs through the entire report, particularly in view of the fact that it has been appropriated for multiple uses. Overseer was initially developed to help farmers make more efficient use of nutrients with the aim of boosting both productivity and profitability.

The company responsible for developing and maintaining Overseer – Overseer Ltd – still sees it very much as an on-farm management tool. The company's Strategic Plan 2015-2017 envisions making Overseer "the trusted on-farm strategic management tool for achieving optimal nutrient use for increased profitability and managing within environmental limits."

This investigation has not sought to contest Overseer's usefulness to farmers. But the very reference to 'environmental limits' in the company's strategic plan highlights an undeniable reality: the same information that is valuable to a farmer is equally valuable to a regulator. Whether it was an original part of Overseer's purpose or not, the same model that optimises nutrient use mechanically estimates nutrient loss from the root zone of a paddock.

Excessive nutrient loss is not only costly from a farming point of view. It is also costly from an environmental point of view. And it is regional councils that have to determine the 'environmental limits' the company refers to. It would be strange for a regional council trying to limit nutrient losses to water to ignore an estimate that farmers themselves are generating and, one assumes, have confidence in. Furthermore, it is an estimate that relates to a real working business unit, which is ultimately where policies and regulations have to be directed.

Beyond that, there are obvious advantages in having a model that can treat both production optimisation and pollution minimisation in a joined-up way. It avoids a battle between estimation tools and ensures that scarce resources are used to come up with the best possible account of how land uses and water quality are related to one another.

This investigation is about Overseer's fitness for purpose in a *regulatory* context. Can we be confident that its estimates of nutrient loss provide regional councils with a basis for making regulatory decisions, notwithstanding the simplifications and approximations that are inevitable in having recourse to models?

Regulators must be able to defend their decisions to their citizens. Furthermore, the Resource Management Act 1991 requires them to evaluate the costs and benefits of their proposed remedies. So they need to be sure that a key tool like Overseer can convincingly support the measures they propose.

It is in the nature of modelling that necessary simplifications and approximations will entail a certain level of uncertainty. Uncertainty is a recurring theme in this report. How significant is the uncertainty that surrounds Overseer's outputs? Does it undermine its use in determining limits to nutrient losses? Would recourse to completely different instruments that eliminate uncertainty be any more acceptable?

Whether the particular simplifications and approximations Overseer makes are acceptable will depend on how it is used. That acceptability will, crucially, depend on what's at stake – who carries the risks of decisions being taken on the basis of the model's outputs?

The same person can demand very different levels of assurance depending on how the model is being applied. For example farmers who use Overseer to make decisions on fertiliser applications will likely view the risks of any uncertainties as being acceptable, as they are fully in control of the commercial risk that is being run.

But the same farmer is likely to be much more demanding if those risks are imposed by a regional council in a way that could be used in a dispute about compliance. Few farmers today will argue with the need to be part of the national effort to clean up our fresh water. But they want to know that the analysis behind the measures they are being asked to take stands up to scrutiny.

My starting point is that nutrient pollution from a wide variety of agricultural and horticultural activities is a major contributor to degraded water quality in New Zealand, and that that degradation is socially and environmentally unacceptable. The question elected representatives at national and regional levels of government are grappling with is *how* they should limit that degradation and drive improvements where they are needed.

There are many regulatory interventions that could be promoted to bring the problem under control. For instance, quantitative limits could be attached to any number of inputs like fertiliser, or to livestock numbers themselves. The costs of any such regulations attaching to easily quantifiable inputs would not be shrouded in any uncertainty. But they would be very inflexible.

Farmers and their advisors have overwhelmingly stated a preference for effects-based measures rather than input controls. Focusing regulation on limiting environmental pressures leaves the land user with the maximum flexibility in choosing how to respond. As such, an effect-based regime is an incentive to innovate.

But because the environmental effect of one farm's diffuse nutrient pollution cannot be measured separately from the combined effects of all farms in a catchment, the regulator is forced to fall back on using nutrient leaving the property as a proxy for the environmental damage it will cause. And since that nutrient cannot be physically measured, paddock by paddock, farm by farm, the regulator is thrown back on having to estimate the loss – which is where Overseer is called into action.

Given the scale of the nutrient pollution challenge and the variability of farm types, management systems, soils, climates, and many other variables, expecting a single model to make sense of it all might seem heroic given the sheer complexity of the biophysical systems that are being addressed.

But this is the story of a long process of evolution and improvement. The Overseer model farmers and councils use today has its roots in developments launched in the 1980s. A great deal of public and private money has been invested in it, and it has become as near to being a household word as any model in rural New Zealand is ever likely to be. The model's functionality is described in some detail in chapter 3.

However, if Overseer is going to be able to command the confidence my enthusiastic interlocutor expressed at the outset, it has equally to be able to withstand the scrutiny of a more sceptical audience, namely those whose farms are being regulated. They are entitled to ask whether the model is fit for use in a regulatory setting. Its current use by regional councils is outlined in chapter 4. It is by no means being universally used to set nutrient limits, but those regions facing the most acute nutrient pollution problems have turned to it in different ways with differing degrees of conviction.

Some of the problems councils have encountered can be resolved through better policy design. But there are other limitations not within councils' power to resolve, and these have given rise to caution on the part of councils, and scepticism on the part of farmers.

What needs to happen if Overseer is to be confidently used in a regulatory context?

Chapter 5 is the heart of this report and tries to explain what is known about the model's engine, and the extent to which there are weaknesses that could compromise its performance. It assesses Overseer in the light of what might reasonably be regarded as best practice when using models in a regulatory setting. In the absence of any official guidance in New Zealand on how to determine whether models are of sufficient quality to support regulations, I drew heavily on advice provided by the United States Environmental Protection Agency.

Using that advice I have come to the conclusion that in some important respects, Overseer does not meet the levels of documentation and transparency that are desirable in a regulatory setting. Important issues remain to be clarified concerning the uncertainty that attaches to its outputs. All of these things are resolvable if there is a desire to do so.

That leads me to a fundamental question which I have addressed to the Government: does it *want* to see Overseer used by councils to help achieve policy goals and water quality outcomes? If the answer to that question is yes – and there are good reasons why that should be the answer – then a significant level of government commitment, guidance and support is required.

Critically, a number of key model evaluation and quality assurance steps are required. To this end, I have recommended that the owners of Overseer (AgResearch, the Ministry of Primary Industries and the Fertiliser Association of New Zealand) undertake a comprehensive and well-resourced evaluation of the model, which should embrace a peer review of the whole model, formal sensitivity and uncertainty analyses and provide public access to the 'engine' of the model.

This last step is proposed in the name of transparency. Transparency emerges from this investigation as a key issue that needs to be addressed if confidence in the model's use in a regulatory setting is to be cemented. The current proprietary nature of the intellectual property Overseer represents is a barrier to the sort of transparency that is needed.

Opening up the model in this way inevitably raises fundamental issues about the closed, proprietary nature of the model. The history of how the model came to be owned and curated is set out in chapter 6.

It is clear that none of the owners have invested resources in developing the model to make commercial profits or spin off a stand-alone business. Indeed, Overseer Ltd's constitution expressly prohibits the payment of dividends to shareholders, and requires income to be reinvested in the maintenance and improvement of Overseer and the business.

It is my conclusion that the proprietary nature of Overseer has been driven by the search for a sustainable funding model. If the model is to be opened up, there are implications for Overseer Ltd's ownership, governance, and resourcing that will need to be considered. I have recommended that the Minister of Primary Industries and Minister for the Environment consider how the model might be mandated, managed and resourced.

A review of resourcing should consider the extent to which Overseer can rely on subscriptions, and the relative contributions of public good research funding and regional council investment to further the model's development.

A full evaluation along the lines I propose would take time and could lead to significant changes in model outputs, in much the same way experienced with the shift from Overseer version 5 to version 6. For this reason, regional councils should take particular care to ensure plans are written in a way that can accommodate changes without disruption to farmers.

Much advice on how to achieve this is already available in the report by Freeman and others (2016).[1] But it could be valuably enhanced if the Ministry for the Environment, in consultation with regional council staff, scientists and planners, were to prepare guidance for council planners on the design of relevant plan provisions. This could take the form of non-statutory guidance, or a more formal regulatory tool such as a National Environmental Standard or Resource Management Act regulations.

More generally, I am recommending that the Minister for the Environment task his officials to develop guidance on the development, evaluation and application of environmental models in a regulatory setting. Overseer is by no means the only model being used by regulators. Models are essential tools and it is vital that when they are used, the wider community can be confident that development, maintenance and use meet appropriate standards.

[1] Freeman et al., 2016.

Beyond Overseer

For all the fascinating detail this investigation has traversed concerning Overseer and farm-based nutrient management, I am left with a keen sense that resolving nutrient pollution will have to commandeer a much wider array of tools.

While nutrient pollution originates in the paddock, Overseer only records its transport 60 centimetres below the surface – the so-called bottom of the root zone. The environmental consequences are measured at the level of the catchment, which can be thousands of square kilometres.

Chapter 7 explores the world beyond Overseer, the research and modelling tools being deployed there, and the need to augment them. I have concluded that the Minister for Science and Innovation, in consultation with the Minister for the Environment, should take a look at the ownership, use and development of the many models and databases that inform our understanding of catchments. Access to these models and databases, and future investment in them, should ensure that we give ourselves the best chance of realising the goal of protecting 'the life-supporting capacity of air, water, soil and ecosystems'.

The full text of my formal conclusions and recommendations can be found on page 117.

Simon Upton

Parliamentary Commissioner for the Environment

Tā te Kaikōmihana tirohanga whānui

Ko te pūtake o tēnei arotake

Ko te arotake i Overseer tētahi o ngā kaupapa i marohitia e aku kaimahi i taku urunga mai ki tētahi tūranga. Ki a au nei, he wero nui tēnei, engari he whakatakanga whai take pea. He mea whakaatu ki ngā taupatupatu kaupapa here taiao matua e rua, heoi anō, mō te nuinga o ngā tāngata, he kaupapa huna tēnei. Me pātai te pātai mēnā e tika ana te hunga e whakamanawa ana i tēnei mea, mēnā e tika ana rānei te hunga e whakaparau ana i tēnei mea.

I muri tata iho i taku tauākī i taku whakataunga ki te ārahi i te arotake i Overseer, i rangona e au ngā uruparenga rerekē rawa i te wiki kotahi. Ko te uruparenga tuatahi, i puta mai i te tangata i whakamanawa i te āheitanga o te tauira, i kaha tautoko i te whakaaro. Ki a ia, me tautoko a Overseer, ā, ka whaihua te whakatātare motuhake. Ko te uruparenga tuarua, i puta mai i te tangata ōrite tana whakamanawa i te whakamahi o Overseer, engari he tauaro tana whakataunga – he pūmahara rānei te patapatai mēnā ko Overseer "te mea anake kei a tātou"?

Kua pēhea ngā tāngata e rua nei e mārama ana ki te uara o te tauira – ā, i tautoko i tana whakamahi – e tauaro ai ngā whakataunga mō te painga o te arotake? I ngā wiki i muri iho, i ohorere tonu au i te tokomaha o ngā tāngata i whai whakaaro mō te mea nei, he tauira 'noa iho'.

Tērā pea, he tika kia kaua au e ohorere, nā te mea he tino whānui ngā wāhi i kōrerotia ai tēnei. Mai i te tīmatanga, i hoahoaina kia āhei ai ki ngā kaipāmu me ā rātou kaitohutohu. Ināia tata nei kua uru ki ngā taupatupatu whakahaere taiao matua e rua.

Ki tāwāhi, kua kōrerohia a Overseer e ngā āpiha hei taputapu e whakawhiwhi i te whakataurangi he tūturu te pūrongo i ngā putanga ahuwhenua ā-pāmu nō tēnei whenua. Ki te kāinga, kua piki te whakaatuhia o Overseer ki ngā pakanga ā-rohe ki te whakahuri i te tai o te parahanga taiora.

Ki konei, ko te whiwhinga, me pēnei te whakamāmā i te kōrero, he rerekē. Ko tana whakamahi i roto i te waeture kua whakaputa i te āwangawanga ki te hapori pāmu. Ko ngā whakaaturanga whakahou kua whakararu i ngā whakaaetanga rawa taiao o ētahi kaipāmu. He mārama te take kua tūpato ngā kaunihera ki te whakatūturu i ngā tepenga taiora, nā te āhua o te whakatauira kāore e taea e rātou te whakamārama ki te hunga e whakaaweawetia ana.

Ko ngā whakataunga e pā ana ki Overseer kāore i te whakatauhia ki te korekore. Ko te whakamanawa o te whakatairanga, o te whakaae rānei, e tino tūhonoa ana ki te take e whakamahia ana, me ngā whaipānga o te tangata i whakaaweawetia ai. Mēnā he 'pai noa iho' mō tēnā take, ehara i te whakawākanga pūtaiao. Me titiro ki te take e whakamahia ai.

Ko te āheitanga o Overseer ki te tautoko i tētahi taupatupatu (hei tauira, parahanga taiora me te kounga wai) ka whakamārama pea i tana māiatanga ki tētahi atu (hei tauira mō ngā putanga haurehu kati mahana ā-pāmu). Heoi anō, nā te mea he rerekē te whakamahi, ko te whakautu ki te pātai mēnā e tika ana a Overseer mō te aronga he rerekē pea.

Koinei te take kua arotahi taku arotake ki te whakamahi o Overseer ki te wāhi waeture kia āwhina ki te whakahaere o te parahanga taiora horahora. Ko te pai o Overseer hei whakatau tata i ngā putanga haurehu kati mahana koiora o ngā pāmu, ka waiho au ki ētahi atu tāngata. Heoi anō, ko ngā tūtohunga o tēnei uiuinga e pā ana ki te whakatīahotanga me te whakatuwheratanga ka pā mai ki te whakamahi ā-waeture o Overseer.

Kāore au e whakataruna ko tēnei pūrongo he mea whakaihiihi. Ki te nuinga o ngā tāngata ko ngā tauira he wāhi hātepe pōkīkī. Engari, mō te hunga e whakamahi ai i te tauira, e whakaaweawetia rānei i te whakamahi, me mōhio ki ngā mea e āhei ana, me ngā mea kāore e āhei ana, ā, me pēhea te whakamanawa ki ana putanga.

Simon Upton

Te Kaitiaki Taiao a Te Whare Pāremata

2

Models – uses, approaches and limitations

"Essentially, all models are wrong, but some are useful." (George Box)[2]

Aotearoa New Zealand has a major water quality problem associated with diffuse farm nutrient losses.[3] It is commonly said you cannot manage what you cannot measure. Being able to measure nutrient losses defines the scale of the problem and provides a benchmark against which we can measure progress. But those nutrient losses are very difficult to measure directly.

Farmers have always been interested in managing nutrients to maximise production and profitability. But managing nutrient flows to minimise unwanted environmental impacts as well requires far more information. This is because the questions being asked are no longer just about how nutrient flows end up in valuable productive output, but now also about how much nutrient is lost from a farm, where it comes from, and where it ends up.

To answer this, farmers need to be able to understand the complex interactions of a large number of factors. These include soil properties, rainfall and drainage, the requirements and uptake rates of nutrients by plants, the rate and feed requirements

[2] Box, 1979, p.2.

[3] Diffuse sources of nutrients include indirect discharges originating from a (relatively) large area. The other source of nutrients is "point sources", which discharge directly into a receiving waterbody at a discrete location (OECD, 2017, p. 17). For more information about nutrient sources and their contributions to water quality see PCE (2012) and OECD (2017).

of animals, and the redistribution of nutrients in the form of animal excreta. The interaction of all these factors poses a serious measurement problem.[4]

And even if it could be solved satisfactorily, knowing how much nutrient is lost to the environment wouldn't tell us what the environmental impact is likely to be. This is because nutrient loss from a single farm may travel, mix with losses from other properties and sources, and impact distant waterbodies. However, farm nutrient losses provide an indication of environmental stress exerted far away.[5]

Source: Richardprins

Figure 2.1 Bay of Plenty Regional Council has determined it must reduce the quantity of nitrogen and phosphorus entering Lake Rotorua to reach the water quality target set for the lake. In response, it has proposed rules to reduce nitrogen losses from farms, along with non-regulatory measures such as an incentives scheme and gorse programme.

In the absence of practical direct measurements, models of nutrient movement have been developed to quantitatively estimate losses from a variety of farm systems.[6]

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[4] For example, measurement techniques called lysimeters have been developed to quantify nutrient leaching losses from soil by capturing all the water leaving a defined area of soil, which can then be analysed for its nutrient concentrations. The area in question will be a small fraction of the paddock and is unlikely to capture all the physical processes going on at a paddock scale. For example, lateral spread of roots or lateral flow of water will not be captured. If these are important, the leaching measured will not represent the whole paddock. The results can be modelled to calculate the loss at the paddock scale depending on the urine patch coverage of a grazed pasture.

Lysimetry is useful for conducting component research to determine different treatment effects on nutrient leaching losses. However, lysimeter techniques are not well suited to on-farm monitoring of nutrient leaching in grazed pastures. Lysimeters are also expensive. A single 50 centimetre diameter and 70 centimetre deep lysimeter on a pastoral farm can cost around $5,000 to $10,000 (pers. comm., Keith Cameron and Hong Di, 2018).

A minimum of four replicate lysimeters may be required to measure the nitrogen losses of a particular treatment such as under a urine patch. The cost can become very high to measure paddock-scale leaching losses in situ because the random deposition of urine patches can require large number of lysimeters. The cost rapidly becomes prohibitive. And in any case, there can be significant variability of soil and drainage even within paddocks.

[5] Monaghan et al. (2007), for example.

[6] See Cichota and Snow (2009) for examples.

To do this, models integrate data and information from farm enterprises with scientific understanding of concepts and processes to develop a fuller picture of nutrient movement and losses.

The major benefit of modelling is that it can investigate and quantify nutrient losses in a relatively cost-effective manner, and can be tested and improved over time. Models can also be used to study and improve management practices (either directly or as part of a farm management plan).[7] Finally, the outputs from farm-level nutrient models can provide a basis from which the nutrient stress on receiving waterbodies can be investigated.

In New Zealand, OVERSEER® Nutrient Budgets (for simplicity referred to as Overseer throughout this report) is the model most widely used to estimate farm nutrient flows. However, before discussing Overseer in detail, it is important to understand what models are, how they vary and what they can tell us.

What is a model?

A *model* is a simplification or *approximation* of reality.[8] Models are frequently used in the physical, biological, economic, and social sciences to synthesise current knowledge, and can help to understand and explain the interaction of complex processes. Importantly they can be used to predict what may happen in the future.[9]

However, models should not be viewed as 'truth' generating machines.[10] Rather they are tools designed and developed for a specific task or purpose.

What to consider when developing a model?

Model development is influenced and constrained by a combination of:

- the intended purpose and use of the model
- model structure and approach
- the knowledge base available at the time of model development
- the availability and quality of input information
- assumptions and uncertainties.

Identifying and articulating these constraints is important for developing a model that is fit for purpose. Users also need confidence in the model's output and the extent to which it can be relied on.

[7] A farm management plan provides a farmer with a set of tailored management strategies to improve nutrient management and other aspects of the farm enterprise (e.g. erosion control, water efficiency, stock management, etc.). More specific farm environment plans (or other similarly named plans) can also be developed to target management practices to improve environmental outcomes. Farm plans in general are becoming a common requirement as part of the consenting process governed by regional councils.

[8] Models can come in many forms, the main two being conceptual and computational (or empirical) models. Conceptual models represent a hypothesis of the interaction of important factors and interactions in a system, whereas computational models use empirical and mathematical relationships to produce quantitative outputs. In this report we are largely concerned with, and discuss, computational models.

[9] For a general introduction of models and nutrient models in New Zealand, the reader is directed to Understanding the practice of water quality modelling (Anastasiadis et al., 2013), which can be found at www.pce.parliament.nz.

[10] Beck et al., 1997.

In particular, defining the purpose, scope, scale, and intended use of a model is of cardinal importance. These need to be considered throughout the model's development, use, and evaluation (i.e. the model's life cycle). This is to ensure that the model focuses on the objects of interest and does not include irrelevant details that can contribute unnecessarily to model *complexity* and *uncertainty* associated with its outputs.

Models can be quite simple. For example, a model to work out how large a population is might look like this:

Population this year = population last year + births – deaths

This model would explain some systems well, how many birds there are in an aviary for example. Indeed, for an aviary we do not really need a model, we can just count the birds directly. However, as situations become more complex and harder to measure, for instance when evaluating the bird population on an island, models become more valuable.

However, we may not be able to measure all processes in a system directly. For example, to know exactly how many births there were on an island, we would need to find and monitor every nest and see how many chicks hatched and survived. Similarly, we would need to monitor every adult bird to see if it survived, or died.

To simplify data collection we can gather information on births and deaths by sampling parts of the population and arrive at an estimate of how many birds there are on the island. But sampling part of the population will not be perfect, there will be more or less certainty about the sample results depending on the quality of the sampling technique.

Source: Dr James Newman

Figure 2.2 Counting the entire population of tītī (sooty shearwater) on an island is a difficult task. Sampling part of the population and using a model can make the task simpler, but will introduce uncertainty into population estimates.

To get even this far we have to make *assumptions.* For example, we assume that sampling *part* of the population is representative of the *whole* population, and we also assume that we have understood and captured all the processes that contribute to population size. For example, birds will not only be born or die, some will fly away from the island and others will move in and stay. We could expand our model to include additional *parameters* that capture these processes:

Population this year = population last year + births – deaths + immigration – emigration

We can carry on including more parameters into our model, and these may help us to better understand the factors that affect population size. However, more parameters mean more complexity and the need for more data. This may make the model less useful in other settings unless large amounts of new data can be gathered.

As model complexity increases, there is also often a need to introduce parameters that we do not have much information about. In our island example, we may not have any information about the contribution of immigration to the population. But there may be data on immigration rates for other populations. These could be used but they will add an element of uncertainty.

One of the major benefits of building such a model of bird population is the ability to use it to predict future population sizes. For example, scenarios, such as what might happen if the birth rate increased, or the immigration rate decreased, or indeed any combination of the parameters, can be tested.

Model uncertainty

Irrespective of how complex our population model is, our estimate of the population size will not be exactly right. If we have only counted some of the nests or monitored some of the birds, if we have included all important parameters, or if we have had to include assumptions about outward and inward migration, there will be *uncertainty* in the estimate. The term uncertainty is used to describe the lack of knowledge about the system being modelled. Uncertainty affects model development, implementation and its use.

In general, three categories of uncertainty are associated with model development:[11]

- natural variability – uncertainty associated with natural variations in the system that is investigated
- modelling uncertainty – does the *model framework* truly represent the current scientific understanding of the system being modelled, and do the *model inputs* accurately represent the real world (e.g. due to measurement error, input error, analytical imprecision, and limited sample size for model parameters)
- deep uncertainty – current unknowable factors of the system that contribute to uncertainty.

[11] MfE, 2016, p.6.

Discussions of uncertainty in this report are largely focused on model uncertainty, as this is the component that can largely be managed. However, this is situated in the wider context of natural variability and deep uncertainty.

Model developers, users (e.g. farmers) and decision makers (e.g. regional councils) that may require a model to be used want the level of uncertainty to be as low as possible – they want to know there is a good chance that an action will lead to the expected outcome. But uncertainty cannot be eliminated, so having a good understanding of the level of uncertainty is going to be almost as important as a model's output if it is to be confidently relied on. Understanding uncertainty, and being transparent about incomplete knowledge, is essential if policies or regulations based on models are to be credibly defended.[12] How much uncertainty is acceptable will depend on the risks being run and who will bear the consequences.

Simple and complex models

Model complexity is largely dictated by the trade-off between intended use, the resolution of all the elements that have been incorporated, the availability of representative datasets, and the form and function of the modelling approach used. There is no single defining factor that separates simple and complex models. Rather, there is a continuum of model complexity.

A useful analogy is to think about maps, how they are developed, and what they show.[13] At one end of the spectrum you may have a simple road map that has only one *intended* use – ensuring a person can get from point A to point B. At the other end there will be extremely detailed maps showing not only roads, but also power lines, buildings, vegetation, and topography (e.g. LINZ topo50 maps). Similarly, the intended use of a map will dictate the level of spatial detail. A large amount of detail may be needed but it may only need to cover a small area (e.g. a map used by maintenance contractors digging up roads and pavements in a busy city).

Given the range of uses and scales needed by different users, it is not practical for any one map to include all the information that would ever be needed to describe the world in all its detail. Similarly, no model can capture all of the complexity of biological and physical systems like a farm system.[14]

The simpler the model framework, the more likely it is that important factors and processes will not be well represented in model outputs. This can increase uncertainty in whether outputs are capturing relevant aspects of a system, and if it is at a scale that is useful or required. Conversely, simple models are more likely to be used by a wider range of audiences.

More complex models are required when we need to understand the structure and processes occurring in a system in more detail. For example, to model processes at

[12] MfE, 2016, p.19 and 28.

[13] Maps are in fact a type of model that translates the complex physical environment into understandable graphical representations.

[14] NRC, 2007, p.18.

finer scales, greater detail must be included in the model – increasing the amount of information required to develop and run the model.

However, increased model complexity also comes at a cost. As the number of processes and parameters increases, greater uncertainty is introduced in model outputs. This is because each process or parameter will have a level of uncertainty attached to it, which is then compounded through model calculations.[15]

Because uncertainty tends to increase at both ends of the scale – both as models become simpler or more complex – a middle ground needs to be reached to ensure that the model captures the required detail, but does not include unnecessary or poorly defined elements. The phrase often attributed to Albert Einstein summarises this point well:

> *"Everything should be made as simple as possible, but not simpler."*

Modelling approaches

To fill out this brief introduction to modelling, it is useful to understand something of the different modelling approaches that exist. Without being exhaustive, three broad distinctions in approach can be identified: empirical vs mechanistic, deterministic vs stochastic, and steady-state vs dynamic. Choosing between these different modelling approaches is not simple but will have important ramifications for how a model can be used.

Empirical vs mechanistic models

Empirical models rely on correlations that have been observed, either experimentally or in the field. They do not rely on complex scientific theories that may be difficult to model, or attempt to fully describe the real world implications of these correlations. They simply try to model the 'best fit' for available observations. However, to ensure the model is performing as intended, a large amount of data may be needed to accurately characterise the relationships. Extrapolation beyond the bounds of the sample dataset will also introduce increasing uncertainty.

Mechanistic models, by contrast, focus on simulating detailed processes (e.g. biological or physical) that explicitly describe system behaviour, with each model element having a corresponding real-world equivalent. Mechanistic models are appealing due to their close alignment with the system being modelled. However, they require more model elements – some of which may be poorly defined or unreliable.[16]

To highlight the difference, we can think about modelling the likelihood of a flipped coin coming up heads or tails. An empirical model can be developed by flipping a coin several times to generate the likelihood of the next coin flip. As the sample size

[15] For example, parameters may have greater uncertainty due to limited sample size in the original dataset used to develop the parameter, measurement error, limited scientific understanding, and so on (United States EPA, 2009, p.13).

[16] Recall the island bird population model described above, in which immigration and emigration were added to the model. Trying to accurately sample immigration and emigration is very difficult, introducing uncertainty into an estimate of population size using the model (i.e. increasing model input uncertainty). However, excluding these parameters may result in not accurately accounting for all important aspects of the island bird population (i.e. increasing model framework uncertainty).

increases, the modelled likelihood will tend towards 50 per cent for either result. In contrast, a mechanistic model could include parameters of the initial state (heads up or down), coin shape, angle and force of flipping, distance to the surface, air resistance, gravity, etc, to predict the result. The mechanistic model may be theoretically more accurate, but requires significantly more information to develop. On the other hand, the empirical model does not give any information explaining the physical reason for the different results – just the probability of either occurrence.

Deterministic vs stochastic models

Deterministic models use a specific combination of parameters and initial conditions to produce an output. The result is the same for every model run. This means that deterministic models are good at producing a single output value for a set of conditions. However, they do not take into account the effects of uncertainty and variability of model inputs when reporting results.

Stochastic (or *probabilistic*) models include variability in model inputs and parameters. Variability is a function of changing environmental conditions, averaging parameters and inputs over time and space, and random natural variability. The solution obtained is a function of variability, often represented as a probability distribution of model outputs.[17] The result may better represent output uncertainty, but requires more data for each input and parameter to generate results. Where limited data is available, uncertainties will be greater and reflected in the range of outputs the model produces.

An example of a deterministic model is a GPS navigation device that estimates the best route between two points based on distance and assuming an average travel speed. This is deterministic because the distance and speed are set prior to the model run, with the choice of route between the same points always the same.

In contrast, a stochastic model could take into account the probability of something like traffic congestion when selecting the preferred route. In this case, the variability of traffic conditions with respect to time of day is included in route selection. A different route may be selected based on the likelihood and magnitude of any congestion and the effect it has on total travel time.

Steady-state vs dynamic models

Steady-state (or *static*) models assume constant conditions. They can provide a snapshot of the systems at a given time, but often produce long-term or time-averaged outputs. Most variability is averaged out by targeting the predictions to large spatial areas and long time spans – allowing a simpler description of many combined processes. The relatively modest amount of input data makes this approach appealing. However, conditions or situations which deviate from the average might not be represented.

[17] United States EPA, 2009, p.47.

Dynamic models describe the change in a system over time. To do this the model 'remembers' model outputs at one point in time and uses this information to update the model as it iterates through a model run to predict estimates for the next time step. Because dynamic models often handle a large variety of processes, they require more input data and computer processing power. Dynamic models tend to be more complex than steady-state models, which limits the range of users who can run them.

A simple estimation of an island bird population, as described earlier in this chapter, is an example of a steady-state model, as each parameter represents a yearly total. However, the same model could be considered dynamic if it were used to predict population trends over, say, a 30-year period.[18] The predicted population is dependent on the previous year's total. Therefore, the model needs to use the previous year's modelled population to calculate the current year. The model output is not a single population number as in a steady-state model, but rather the predicted change in population over time.

Modelling farm nutrient losses

With the benefit of the preceding discussion, it is time now to ask how modelling can usefully help estimate farm nutrient losses. As no modelling approach is 'right' or 'wrong', the challenge lies in choosing and developing a model that is fit for the intended use.

To make tactical management decisions on the ground, a farmer might want a model to estimate and predict the rate of nutrient loss at a point on a farm at a daily or weekly timescale. Such a model would help identify the movement of nutrients throughout the entire farm system over a short time, allowing farmers to improve decision making to increase efficiency and minimise environmental impacts.

However, developing such a model that will work equally well on all New Zealand's farms would require prohibitively large amounts of data and likely be very complex. It would also need to be tailored in its construction on a farm-by-farm basis to ensure that individual farm characteristics are taken into account, requiring significant expertise.

Simplifications and assumptions are needed if a model is going to be able to estimate farm nutrient losses from a wide range of farm systems and for a variety of purposes. This is Overseer's ambition.[19] However, before we can assess how well it achieves that, we need to understand the basic design of the Overseer model, how it is set up, and what it does.

[18] Another example could be if the rates of change varied over time (for example, as a function of population or climate).

[19] Other models (such as Agricultural Production Systems sIMulator (APSIM) and Soil Plant Atmospheric System Model (SPASMO)) are also used in New Zealand. Their development and intended use often confines them to research and site-specific investigations.

Source: Taranaki Regional Council

Figure 2.3 Many dairy farms now dispose of their shed effluent by applying it to land, reducing the need for fertiliser. This is a management practice that can be modelled.

3

The Overseer model

This chapter builds on the broad modelling approaches outlined in the previous chapter, and goes further to show that Overseer is a largely empirical, deterministic, and steady-state model. It also outlines key assumptions and sources of uncertainty in Overseer.

This description of the Overseer model is presented in three sections. The first section outlines key design features of Overseer. The second section provides a high-level description of how Overseer generates its estimates of greenhouse gas emissions, and nitrogen and phosphorus losses. The final section provides examples of what Overseer can and cannot do, given the model's evolution, design principles, calibration, and uncertainties.

Overseer: scope, design principles and uncertainty

What Overseer does: the basics

Put simply, Overseer is a model that describes nutrient flows on farms (Figure 3.1). Overseer takes nutrients that are present or introduced to the farm, models how they are used by plants and animals on the farm, and then estimates how they leave the farm and in what form.

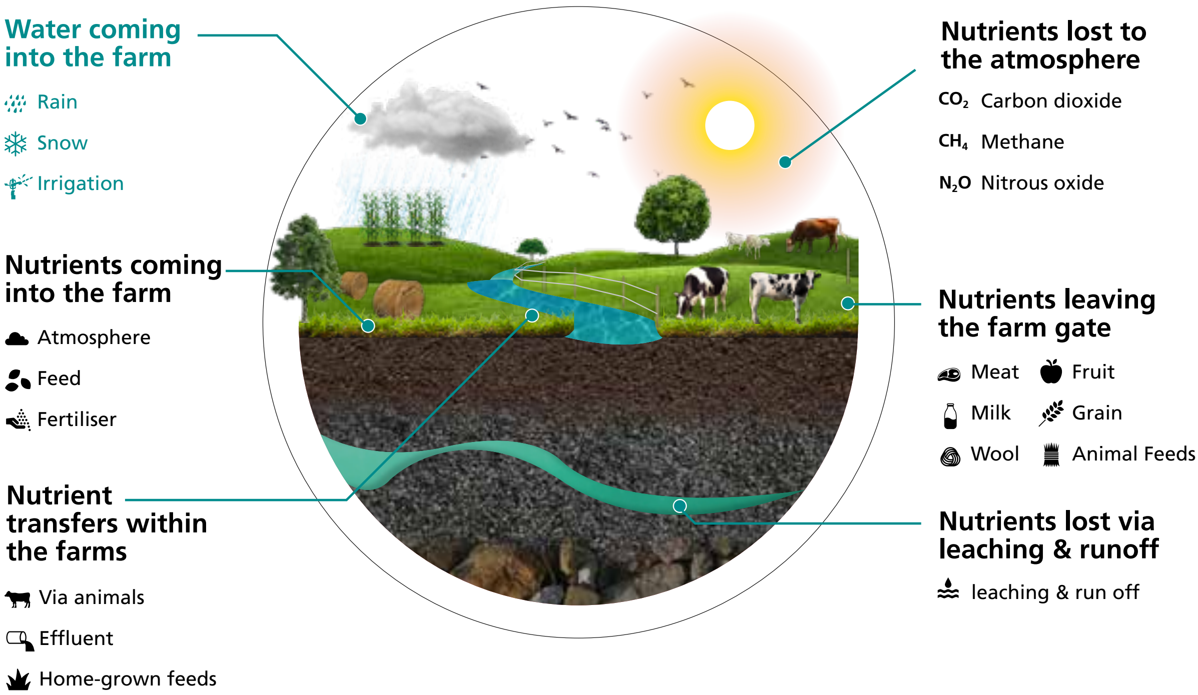

Figure 3.1 Nutrient flows on farms.

Some nutrients are already in the soil on the farm, and more nutrients are added as fertilisers and animal feed.

Nutrients end up in plants and animals, supporting their growth and the production of valuable products (such as crops, meat, milk, wool). Excess nutrients are excreted by animals as dung and urine, which are deposited on the soil or in farm structures, and are often reused on-farm as fertiliser.

Some nutrients leave the farm gate as farm products (e.g. meat, milk, crops, wool, and wine), while others are lost to the environment. How much is lost will depend on the local climate, management practices, and soil characteristics. Overseer estimates these nutrient losses from the farm, which includes gaseous emissions into the atmosphere, leaching through the soil, and run-off across the land surface.

Overseer estimates nutrient flows and provides a '*nutrient budget*' for seven nutrients: nitrogen, phosphorus, potassium, sulphur, calcium, magnesium, and sodium. It also estimates soil acidity for paddocks under pasture. Sediment and pathogens, such as *E. coli*, fall outside the model's scope.

By modelling nutrient flows, Overseer can provide a farmer with estimates of what nutrients are in deficit and could be supplemented through fertiliser to maintain plant growth and production. This was the job Overseer was originally designed to do: improve the efficiency of fertiliser applications.

To help manage fertiliser application, Overseer had to estimate how much nutrient was *not* being captured in productive outputs but, rather, was being lost to the environment. These modelled estimates of nutrient losses helped farmers minimise their fertiliser bills. But the same estimates became useful for farmers and others interested in environmental pressures due to the loss of excess nutrients.

Overseer cannot estimate the environmental impacts of these nutrient losses, because these often occur far beyond the farm boundary in distant receiving waterbodies. However, Overseer-derived nutrient losses provide a good starting point for estimating environmental impacts, since nutrient loss is a major stress on the receiving environment.

The Overseer model is offered as a web-based application.[20] The latest version, OverseerFM, models seven land uses (i.e. management block types), thereby enabling nutrient losses from diverse land uses within a single agricultural enterprise to be quantified.[21]

The modelled land uses are:

- pasture
- crop
- fruit
- trees and scrub
- fenced wetland
- riparian
- house.

[20] The latest software interface, termed OverseerFM, was released in June 2018. The older software interface is now referred to as the Overseer legacy version.

[21] OverseerFM website (https://fm.overseer.org.nz/). Accessed 3 October 2018.

It is worth noting that Overseer models pastoral land uses best (dairy systems in particular). The model outputs for the other land uses are more uncertain.[22] This is due to the greater geographic coverage and investment in understanding processes that control nutrient flows in pastoral systems. Much of the discussion below focuses on Overseer's modelling of pastoral farming.

Key modelling principles

In relation to the broad modelling approaches outlined in the previous chapter, the general approach used by Overseer is steady-state, largely empirical, and deterministic in nature. This combination of approaches is largely tied to a key design principle that goes back to the model's origins – namely, that input data needed to run the model is readily available for the farms being modelled.

The following section highlights how the modelling approaches and design principles affect Overseer's performance.

Steady-state

The steady-state nature of Overseer means that the model assumes average and constant management and site characteristics. This allows on-farm nutrient flows to be compared over time. However, Overseer is less useful for modelling situations when farm management is significantly changing, which happens, for example, when a land use is changing or intensifying.[23]

A secondary issue is climate variation. Farm management during a wet year is different from farm management during a dry year, which in turn is different from the long-term average climate that Overseer is based on. This means that farm inputs are not necessarily consistent with the long-term climate from either an annual or a monthly perspective.

[22] Wheeler and Shepherd, 2013, p.19.

[23] Overseer can be used to model two different farm systems (e.g. pre- and post-land use change). This modelling can be used to assess relative changes between the two farm systems.

Source: Rob Suisted/naturespic.com

Figure 3.2 The steady-state nature of Overseer means that the model assumes average and constant management and site characteristics. This makes Overseer less useful for modelling situations when farm management is significantly changing, for example, when a piece of land is converted from forestry to intensive dairy farming.

Farm inputs are consistent with production

The steady-state approach of Overseer is reflected in the principle that inputs are consistent with entered production.[24] The model assumes that entered production characteristics (e.g. crop yields or milk-solids production) can be achieved with the user-defined inputs, (e.g. management practices, and site characteristics).

Moreover, Overseer assumes that inputs are consistent with production irrespective of whether a farming system is viable or not. The ability to enter unrealistic inputs and create unrealistic farming operations is a clear drawback of this principle.[25]

[24]This is often referred to as inputs being in equilibrium with production. See Watkins and Selbie (2015, p. 29).

[25]Over time, there have been some efforts to allow users to manually check aspects of the viability of farm systems. For example, in Overseer version 6, estimated pasture production was reported, which users can use as a feasibility check. In addition, some sensibility testing is embedded into OverseerFM (e.g. for pastoral blocks), as the software provides a suggested range for production, and can also generate error messages. OverseerFM website (https://fm.overseer.org.nz/). Accessed 16 October 2018.

Further, if a user changes one input, the model does not automatically update other inputs (or production). This means users need enough knowledge of farm systems to make adjustments themselves to ensure a farm system is viable.

On the upside, this principle combined with the reliance on readily available input data has made the model more accessible to a wider audience, in comparison with more complex dynamic models.[26]

Semi-empirical nature of the model

Overseer is a largely empirical model, which has mechanistic components that have been fitted to match data that has been collected in the field. This means it relies on calibration – a process that fine-tunes its parameters using experimental data.

It is worth noting that variable amounts of research have contributed to the development of the different Overseer components. As a result, some parts of the model have been much better calibrated and tested than others. For example, pastoral blocks within Overseer are the most calibrated. In comparison, crop blocks in Overseer are based on a limited body of research, and not all crops grown by horticultural and arable enterprises are currently represented in the model.

It is not only the lack of calibration that limits the ability of Overseer to accurately represent cropping systems. It is also a consequence of the underlying steady-state modelling principle described above. Crops need to be rotated between different paddocks, meaning that block management frequently changes.

Furthermore, soil is cultivated and new crops are planted on a regular basis. This means that the decomposition of crop residues and nitrogen mineralisation are key processes in cropping systems. However, these processes are not well represented in Overseer, thereby introducing greater uncertainty into model outputs.[27]

Table 3.1 summarises the extent of calibration undertaken across the land uses modelled by Overseer.

[26] APSIM is an example of a complex dynamic model, often used for research purposes.

[27] See Khaembah and Brown (2016). This study recommended revisiting the way these processes are modelled in Overseer, however, to-date these recommendations have not been taken up.

Table 3.1. Calibration extent of Overseer.[28]

Source: Shepherd et al., 2015; Pers. comm. Richard McDowell, 2018.

Management block	Nitrogen calibration	Phosphorus calibration
Pastoral	Calibration (undertaken in 2012) used nutrient loss measurements from farmlet studies at eight locations. These were: Edendale, Southland (intensive beef); Tussock Creek, Southland (dairy); Kelso, Otago (dairy); Lincoln University Dairy Farm, Canterbury (dairy); Massey University Dairy Farm, Manawatū-Whanganui (dairy); Ruakura, Waikato (dairy); Scott Farm, Waikato (dairy); and Wharenui, Bay of Plenty (dairy). A recalibration exercise is currently underway.	Calibration (undertaken in 2005) used data from 23 sites: Canterbury (2), Otago (3), Southland (2), Manawatū (5), Northland (2), Waikato (4), West Coast (2), Wellington (1), Hawkes Bay (2).
Crop	Arable crops – very limited calibration (one Lincoln site).	Arable crops – none due to a lack of experimental sites. Forage crops – limited to 2 sites in Otago and 1 in Southland.
Fruit crop	None due to a lack of experimental sites.	None due to a lack of experimental sites.
Trees and scrub	None due to a lack of experimental sites.	None due to a lack of experimental sites.
Wetlands and riparian	Very limited calibration based on published studies.	Very limited calibration based on published studies.
House	Very limited calibration (based on one international study).	None.

[28]For pastoral blocks (nitrogen) – see Shepherd et al. (2015). A re-calibration exercise is currently underway – pers. comm., Mark Shepherd (2018). For pastoral blocks (phosphorus) – see McDowell et al. (2005) and Gray et al. (2016). For crop blocks (nitrogen) – see Shepherd et al. (2015). For forage crop blocks (phosphorus) – see McDowell (2006), McDowell and Houlbrouke (2009), and McDowell and Steven (2008). For wetlands and riparian blocks – see Rutherford and Wheeler (2011), Gray et al. (2016) and McDowell et al. (2008). For house blocks – see Wheeler et al. (2010a) for details.

Model scales

Temporal scale

In keeping with Overseer's steady-state approach, inputs are time-averaged and the model provides annual average outputs.[29]

Even though parts of the model operate at multiple time-steps (including daily and monthly) to better represent the processes, one of the key inputs – climate data – is supplied as a long-term (30 year) average.[30] This means that any extreme variations between years are smoothed out in the climate inputs. This can create a mismatch between annual farm management inputs and long-term climate inputs.[31]

Overseer has also been calibrated using long-term average data. For example, regarding nitrogen leaching, Watkins and Selbie note, "A research trial will likely produce different N leaching measurements in each year of a 5-year study… [However] the average N leaching is used (alongside other research trial data) to calibrate the model."[32]

Spatial scale

Overseer is not concerned with what is happening at any single point in space. Instead Overseer takes a whole block (and a whole farm) view. This concept allows Overseer to simplify the complexity of some farm processes to more easily estimate nutrient loss from blocks and the whole farm.

For example, soils and grazing stock management are often spatially variable and complex. Different soils often occur within the same paddock, sometimes metres apart. Moreover, even within the same soil types, specific soil properties can differ.

While the real-time management of stock on a farm is quite complex, Overseer's approach reduces the need to specify exactly where animals are grazing. The model assumes that the animals are grazing *somewhere* on the block. This implies that excreta returned is also *somewhere* on each block.

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[29] Wheeler et al., 2018.

[30] For example, to simplify inputs, annual rainfall data in OverseerFM is automatically retrieved – from the 30-year average climate database from the NIWA Virtual Climate Station Network – based on the user-supplied location (Overseer Legacy version also allows for manual entry of annual or monthly rainfall data). However, the majority of processes in Overseer (in particular the drainage and nitrogen leaching model) operate at monthly or daily time steps, requiring annual rainfall to be distributed between months and days (Wheeler et al., 2018).

[31] Of particular importance is the term over which farm input data is entered. The NIWA Virtual Climate Station Network data captures the long-term average of climate, meaning that any extreme variations between years are smoothed out. In contrast, production and farm management varies year to year. There is unknown uncertainty with comparing annual average climate with actual annual production and farm management data to calculate a 'year-end' nutrient budget.

When Overseer is used as a predictive tool, rather than calculating a year-end nutrient budget, it is suggested by Overseer that five years' worth of actual farm data is used to create a long-term management average, which is more in line with climate data (Willis, 2018, p.15).

[32] Watkins and Selbie, 2015, p.29.

Horizontally, the model stops at the farm boundary. In Overseer, a farm is divided into blocks, with blocks typically representing areas with similar physical characteristics and management practices (Figure 3.3).[33] While a block is spatial, it is not joined up to the blocks around it. In this way Overseer cannot be described as being spatially explicit in the normal sense of the words.[34] Also, Overseer does not require these blocks to be contiguous in nature, meaning that different farm elements can be spatially connected or not. A block could even be located in another catchment.

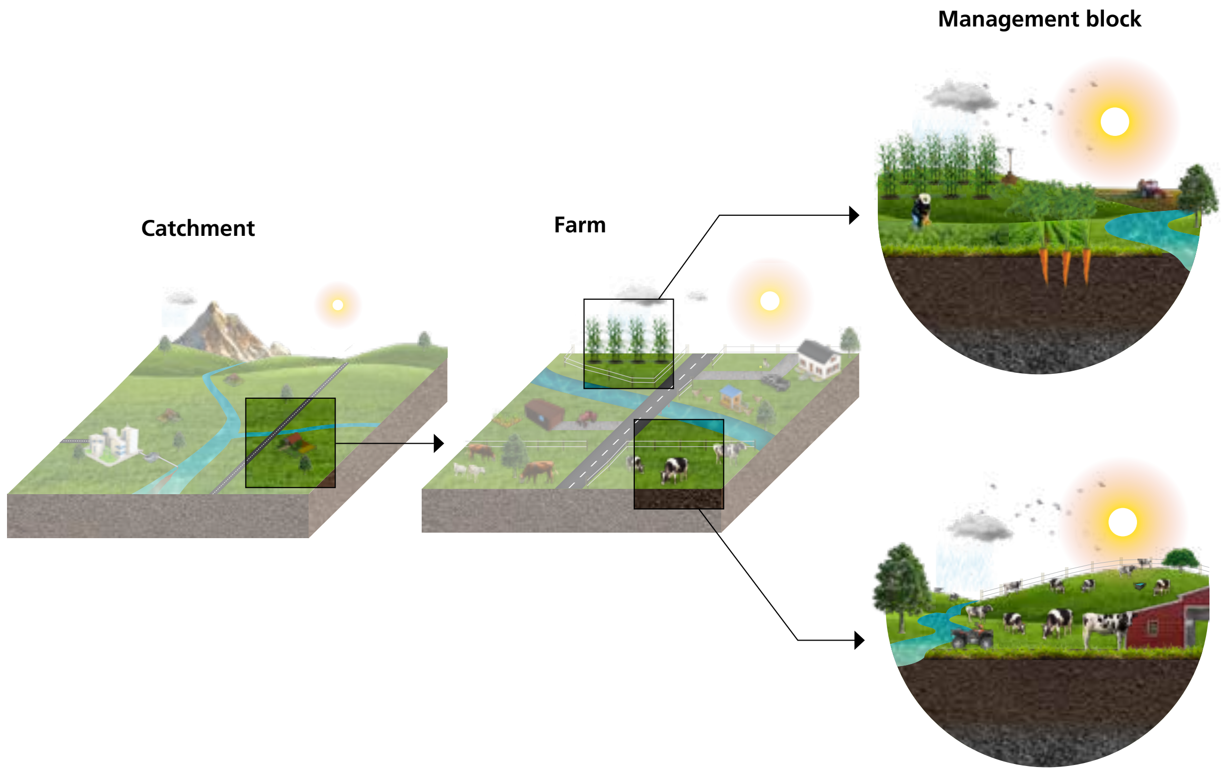


Figure 3.3 In Overseer, a farm is divided into blocks, with blocks typically representing areas with similar physical characteristics and management practices.

The way a farm is blocked can have an effect on the distribution of nutrients within the farm system and must therefore be carefully considered. For example, the ideal blocking of a farm to account for nitrogen losses may be different from that used for phosphorus losses, given the different relative importance of topography in influencing nitrogen and phosphorus loss.[35]

[33]But the sum of management blocks does not equal the farm. Overseer also accounts for nutrient transfers between blocks and farm structures such as a milking platform, feed pad, effluent pond, and lanes.

[34]However, some spatial variability can be modelled as a result of the way a user divides a farm into blocks. In addition, OverseerFM 'starts to be' spatially explicit, by allowing users to draw blocks on a mapping interface. These blocks 'know' which climate and soil data to load.

[35]McDowell, 2018.

One important consequence of Overseer not being strictly spatially explicit is that it has limited ability to identify critical source areas on a farm. Such areas can be significant contributors to nutrient losses from farms, especially for phosphorus. However, once identified, critical source areas can be modelled as separate blocks and managed accordingly.[36]

Vertically, Overseer does not consider the leaching of nitrogen beyond the bottom of the root zone (which for pasture is assumed to be 60 centimetres). This means that the model provides no information about nitrogen transport and transformations between the root zone on a farm and a receiving waterbody.

Overseer also estimates emissions to the atmosphere of the three main agricultural greenhouse gases (carbon dioxide, methane, and nitrous oxide).[37]

Assumptions

Assumptions are inevitable when developing a model. For example, all of the key modelling principles outlined above represent assumptions that have been made to simplify the farm system and make the model easier to use.[38] The combination of assumptions incorporated into the model play a significant role in what the outputs represent and how they can be used. For example, where there is limited or no data, Overseer is dependent on extrapolation beyond measured ranges and expert judgement.[39]

Similarly, several assumptions reflecting good farming management practices are incorporated into Overseer, and the model produces outputs accordingly.[40] These assumptions include the following:

- effluent is stored in sealed structures (i.e. sealed non-leaky ponds)
- dairy cows use laneways to move from the paddock to the milking shed
- fertiliser is applied according to Fertmark[41] and Spreadmark[42] Codes of Practice (i.e. evenly at the time and rate stated, without any poor management).

However, if good management practices are not followed, environmental losses will in reality likely be higher than those estimated by Overseer.

[36] Several spatially explicit models (e.g. MitAgator and Land Use Capability Indicator (LUCI)) have been recently developed that build on components or outputs of Overseer. For example, MitAgator allows critical source areas to be identified.

[37] These emissions are estimated by using emissions factors. See Wheeler et al. (2008).

[38] For example, assumptions include the use of long-term average climate data, spatial aggregation of soil data, that sample data sets used to develop relationships are representative, and that site characteristics are constant over time. In general, key assumptions built into Overseer have been publicly stated by model developers (e.g. Watkins and Selbie, 2015).

[39] This is a well-established practice where there is a lack of empirical data from model parameterisation.

[40] Overseer assumes some specific good management practices are used, because not all processes can be adequately captured due to the model's steady-state nature. 'Good management practices' have also been termed 'best management practices' by Wheeler (2018a, p.19).

[41] Fertmark website (http://fertqual.co.nz/understanding-the-marks/fertmark/).

[42] Spreadmark website (http://fertqual.co.nz/understanding-the-marks/spreadmark/).

By its nature, Overseer does not reflect day-to-day management. So it cannot capture any losses associated with a one-off incident such as an effluent spill. Nor can uneven fertiliser applications or applications too close to a stream be modelled in Overseer (even if a farmer has access to that data from GPS tracking).[43]

While Overseer incorporates several assumptions reflecting good farming management practices, it can still model some instances of 'bad practice'. For example, it is possible to model over-stocking, the application of phosphorus fertiliser when run-off is likely, over-irrigating and winter applications of nitrogen fertiliser, as well as over-application of fertiliser for the required level of production.

Uncertainty in Overseer

Principles such as steady-state and the long-term averaging of Overseer raise an obvious question: how closely does the model approximate a real farm? This is a critical question. Users need to know that they are actually applying the right amount of fertiliser to meet their production targets, while also meeting environmental management goals.

The question might appear to be simply one of comparing model results with measured data. But it is not. Models are simplifications of complex systems and uncertainty is inescapable. Answering this question involves understanding the uncertainties inherent in any model.[44]

As mentioned in chapter 2, there are two fundamental types of modelling uncertainty: uncertainty inherent in the model framework and uncertainty associated with model inputs.

A good example of *uncertainty inherent in the model framework* is Overseer's use of a 'typical' animal in a mob for its calculations of animal energy requirements.[45] The model assumes that using the mean characteristics of a mob to generate total energy requirements is the same as summing all individual animals in the mob. This approach creates uncertainty as not all animals are 'typical' – natural variability between animals is inevitable.

Poor record keeping is a direct source of *uncertainty associated with model inputs*. For example, a farmer might be unsure how much fertiliser or supplemented feed was used on the farm. An unreliable estimate of a key input increases uncertainty of the final outputs.

[43] Overseer model developers have given some consideration to including the option of modelling nutrient losses if good management practices are not followed (e.g. effluent ponds are not sealed), although no changes to the model to allow this have been included to-date (Wheeler, 2018a, p.20).

[44] United States EPA, 2009.

[45] The term 'mob' is used by Overseer (Wheeler, 2018b), and represents the collective total of an animal type on the farm.

A more fundamental source of uncertainty is the limited availability of experimental field data of measured nutrient losses that can be used to calibrate the model. As previously discussed, Overseer is a semi-empirical model and relies on data to 'tune' or calibrate its parameters. However, the datasets of nitrogen and phosphorus loss measurements are quite limited (Table 3.1). Depending on whether a farm of interest has similar (or different) combinations of soils, rainfall, climate, and farming systems compared with the ones used for calibration, uncertainty can be small or large.

Model uncertainty is unavoidable, especially when modelling complex biophysical processes such as nutrient losses from farm systems, and one of the goals of the modeller should be to assess and communicate that uncertainty when reporting any outputs. Uncertainty analysis is used to quantitatively estimate the likelihood that the estimated values represent the real world values.

A related analysis, called a sensitivity analysis, is also used to improve the model and is often carried out alongside an uncertainty analysis. Sensitivity analysis helps determine which elements or parameters contribute the most to variations in results. The two analyses are used to improve model development.

It is worth noting that in Overseer, different uncertainties are associated with different outputs. For example, uncertainty associated with greenhouse gas estimates may not be the same as for nitrogen loss estimates.

No formal uncertainty analysis of Overseer as a whole has ever been conducted. The significance of this is discussed in chapter 4. Uncertainty estimates, however, exist for some elements of the model.

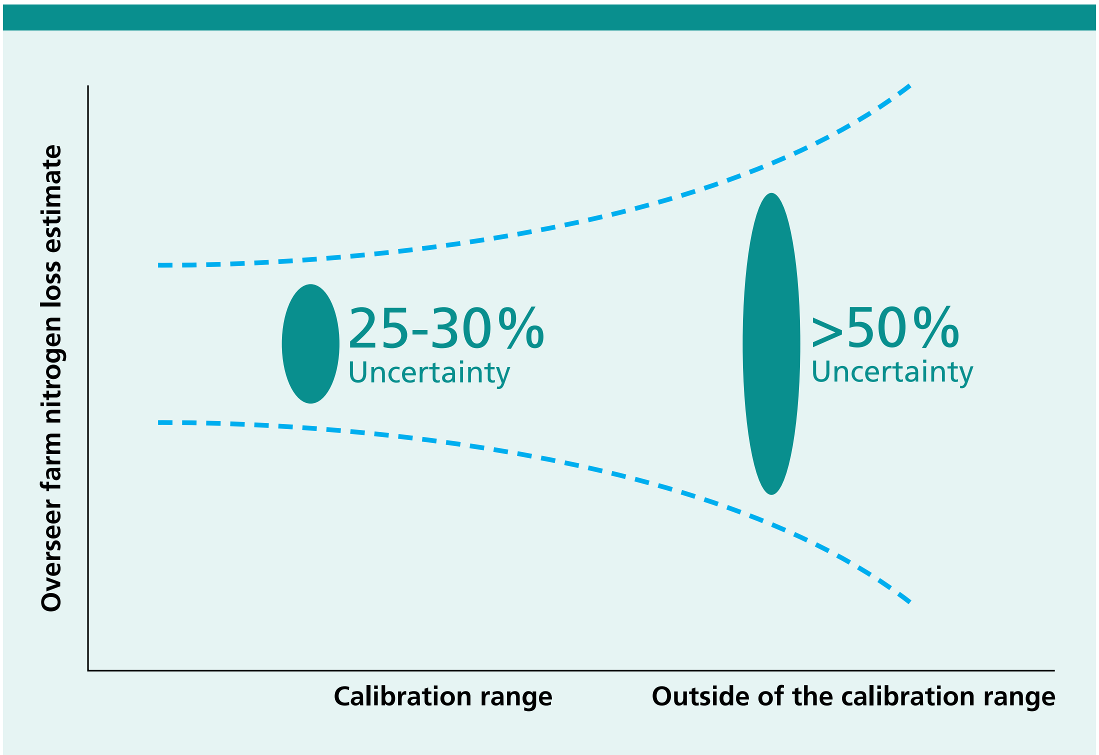
Uncertainty in nitrogen loss estimates

A simple uncertainty analysis for predicted nitrogen losses was undertaken in 2001 using an earlier version of Overseer (version 5).[46] This analysis (not publicly available, but widely quoted) indicated that the model uncertainty for predicted nitrogen losses (on farms that have characteristics similar to those from which field data has been gathered and used to calibrate the model) was about 25-30 per cent. Apparently, this estimate did not include errors associated with measurements, or uncertainty from data inputs, providing only part of the full picture of quantifying uncertainty.[47]

According to Overseer's developers, a similar uncertainty range is likely to apply to the model's predictions of nitrogen loss using the current version (version 6). This of course, only applies to farms 'within the calibration range' – in other words, farms that have characteristics similar to those from which field data has been gathered and used to calibrate the model (Figure 3.4).

[46] Ledgard and Waller, 2001.

[47] Watkins and Selbie 2015, p.32.



Source: Watkins and Selbie, 2015, with data from Wheeler, 2018a, p.10.

Figure 3.4 Schematic description of uncertainty associated with nitrogen loss estimates.

Table 3.1 highlights that the locations used for the 2012 calibration of pastoral blocks were primarily from the Waikato and Southland regions. The sites had a limited range of soils types, a limited band of rainfall (between 600 millimetres and 1200 millimetres), and a limited range of management practices.

If farms of interest have characteristics that differ from those used for calibration, higher levels of uncertainty can be expected. It has been suggested that uncertainty in these circumstances is likely to exceed 50 per cent, but could be much higher still.[48]

For example, in Canterbury, Overseer estimates of nitrogen leaching from dairy farms on light and poorly-drained soils could be anywhere from nearly 40 per cent below to 60 per cent above the actual leaching rate. A similar pattern was observed for sheep, beef, and deer enterprises.[49]

[48] Wheeler, 2018a, p.10.

[49] These uncertainties were derived by experts with good knowledge of Overseer. The experts used an uncertainty elicitation framework (Sheffield Elicitation Framework) to estimate uncertainties of modelled nitrogen losses for each soil and land use groups, in the three management areas in the Waimakariri zone. See Etheridge et al. (2018) for more details.

Talking about uncertainty ranges in percentage terms is somewhat abstract. The sheer scale of uncertainty becomes more tangible when translated into nitrogen load estimates. For example, for one of the management areas in the Waimakariri Zone, the experts were 90 per cent confident that the estimated nitrogen loads were somewhere between 399 tonnes N/year to 910 tonnes N/year.[50] This variation is significant by any standard, although not surprising given the variability in nitrogen leaching rates seen under field conditions.[51]

Higher uncertainty will also apply to cropping systems due to a lack of experimental sites used for calibration.

Very little sensitivity analysis has been conducted on Overseer. However, a simple sensitivity analysis of nitrogen loss estimated by Overseer version 5 was undertaken in 2006. [52] Drainage, animals, effluent management, fertiliser, crops, and imported feed were (qualitatively) identified as the key drivers of nitrogen loss in Overseer by a group of experts.[53]

Uncertainty in phosphorus loss estimates

With regard to phosphorus, loss estimates, uncertainty, and sensitivity analyses were conducted in 2015. The uncertainty analysis indicated that for the 32 measured losses of phosphorus from small plots to catchments, uncertainty was up to 30 per cent.[54]

A quantitative sensitivity analysis showed that estimated phosphorus losses were most sensitive to hydrological variables (e.g. rainfall or drainage class), followed by soil characteristics (e.g. slope and anion storage capacity), and then the type and rate of phosphorus applied.[55]

[50]In percentage terms, this 90% confidence interval translated into a range from -38% to +42% (Etheridge et al. 2018, p. 11).

[51]For example, one study found that measured N leaching varied by an order of magnitude (<10 to >100 kg N/ ha /year) over a 9-year study period because of variations in weather and farm management (Rutherford, 2018. p. 15).

[52]See Power et al. (2006) for details.

[53]This one-page summary was provided by Michael Keaney (Ballance Agri-Nutrients) and prepared with assistance from K. McCusker, I. Power, A. Roberts and D. Wheeler (Keaney, N.D.).

[54]Mean uncertainty was determined as the standard error of the relationship between modelled and measured estimates (Pers. comm., Richard McDowell, 2018).

[55]MitAgator, a spatial farm-scale tool, built using Overseer's core algorithms, was used for this exercise (McDowell et al., 2015a).

How Overseer generates its estimates

Overseer requires a wide range of inputs to be able to model farm nutrient loss and greenhouse gas emissions estimates (Figure 3.5).[56]

Information about farm management is a core model input. Farm management information falls into two categories – farm-level and block-level inputs. These tend to reflect the scale of decision making. For example, decisions on land use, stock policy and farm structures (e.g. milking platforms or effluent ponds) are typically made at the farm level, whereas decisions about fertiliser application, irrigation, the choice of crops, or grazing management practices are made at the block level.

Information about the natural characteristics of the farm (i.e. soils and climate data) is also required. Here Overseer draws on climate and soil data that New Zealand's research institutions have generated over many years. These are of varying comprehensiveness.[57,58]

[56] One of the model's original development goals was the requirement for the information to be readily available to farmers and farm consultants or, where absent, the availability of suitable defaults.

[57] As mentioned above, OverseerFM is able to draw on NIWA's Virtual Climate Station Network to retrieve rainfall data from the 30-year average climate database (Wheeler 2018c).

[58] Similarly, OverseerFM is able to retrieve soil information from S-map (a spatial soil database developed by Manaaki Whenua – Landcare Research). By supplying a block's coordinates to S-map, OverseerFM is able to identify soils present on that block. These soils are automatically loaded into OverseerFM, and the user can then select up to three soils per block. The leaching result for a block is a weighted average of losses from each soil.

However, S-map does not cover the entire country. As of October 2018 it only covered 34% of New Zealand or about 63% of the productive land. Where S-map is not available, users have to use legacy soil maps – like Fundamental Soil Layers – which come with coarser resolution and more uncertain soil properties.

Technically, soil siblings are supplied by S-map. New Zealand soils are grouped into categories at five levels: order, group, subgroup, family, and sibling. As evident from above, soil sibling is the most detailed unit. Soil siblings are selected based on soil physical properties, like soil depth, texture, and stoniness. Information on soil siblings is available from the New Zealand Soil Classification website (https://soils.landcareresearch.co.nz/describing-soils/nzsc/).

Fundamental Soil Layers supply information on soil orders. The New Zealand Soil Classification has 15 soil orders, which cover all of New Zealand. These soil orders are: allophanic, brown, gley, granular, melanic, organic, oxidic, pallic, podzols, pumice, recent, semiarid, ultic, anthropic, and raw soils. Information on soil layers is available from the New Zealand Soil Classification, soil order website (https://soils.landcareresearch.co.nz/describing-soils/nzsc/soil-order/).

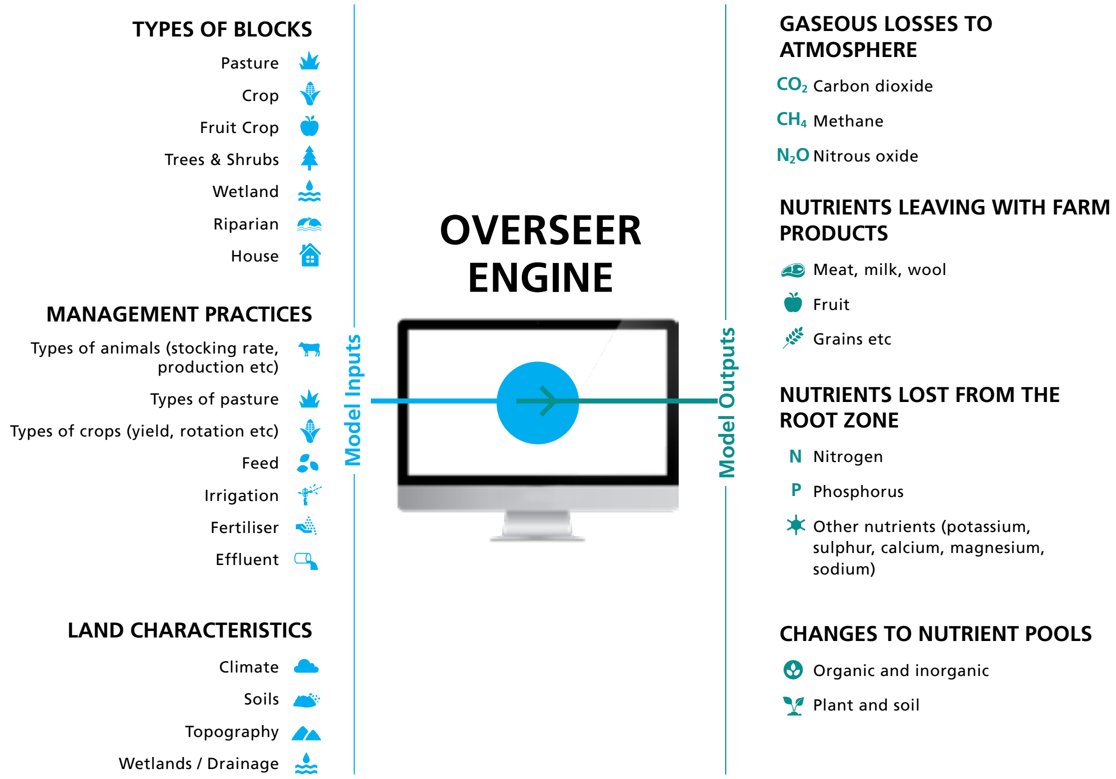


Figure 3.5 Conceptual diagram showing information required to set up Overseer (model inputs) and information generated by the model as a result (model outputs).

On the continuum between complex and simple models, Overseer sits somewhere in the middle.[59] This is largely due to complex interactions between relatively simple components. The 'engine' of the model (Figure 3.5) consists of over 30 sub-models (Table 3.2).

[59] Shepherd, et al., 2013, p.3.

Table 3.2. Sub-models in Overseer.

Source: Wheeler, 2018a.

Sub-model	Publicly available documentation[60]	Documentation not available publicly
Animal sub-model		
Animal model		Technical manual
Characteristics of animals	Technical manual	
Animal metabolisable energy requirements	Technical manual	
Intakes	Technical manual	
Subject-related sub-models		
Hydrology	Technical manual; Wheeler and Bright, 2015	
Climate	Technical manual	
Characteristics of soils	Technical manual	
Characteristics of fertilisers	Technical manual	
Characteristics of pasture	Technical manual	
Characteristics of crops	Chakwizira et al., 2011	Technical manual
Supplements	Technical manual	
Crop growth	Cichota et al., 2010	
DCD	Shepherd et al., 2012	
Wetland sub-model	Rutherford et al., 2008; Rutherford and Wheeler, 2011	
Riparian strip		
Specific enterprises		
Dairy goats	Carlson et al., 2011	
Outdoor pigs	Barugh et al., 2016, Wheeler et al. 2016	
Allocation procedures		
Supplement allocation	Technical manual	
Crop feeding		
Between-source and enterprise allocation		

[60] A list of publicly available technical manuals can be found on the Overseer website (https://www.overseer.org.nz/user-portal/science-model-information).

Distribution of farm data to block scale		Technical manual
Effluent and pad management	Wheeler et al., 2012	Technical manual
Farm distribution		
Specific block sub-models		
Pastoral		
Fodder crop		
Cut and carry	Wheeler et al., 2010b	
Riparian strips		
Wetlands	Rutherford et al., 2008; Rutherford and Wheeler, 2011	
House blocks	Wheeler et al., 2010a	
Tree blocks		
Nutrient models		
Crop-based nitrogen sub-model	Cichota et al., 2010; Wheeler et al., 2011a	Technical manual
Urine patch sub-model	Cichota et al., 2012	Technical manual
Phosphorus (P)	Metherell, 1994; Metherell et al., 1995; McDowell et al., 2005; McDowell et al., 2008	
Sulphur (S) and potassium (K)		
Cations (calcium, magnesium and sodium)	Carey and Metherell, 2002	
Acidity	de Klein et al., 1997	
Reporting		
Constructing a nutrient budget	Selbie et al., 2013	
Constructing reports and indices	Wheeler et al., 2011b	
Greenhouse gas reporting		
Carbon dioxide, embodied and other gaseous emissions	Technical manual	
Calculation of methane emissions	Technical manual	
Calculation of nitrous oxide emissions	Technical manual	
Greenhouse gas reporting	Wheeler et al., 2008; Wheeler et al., 2011c, Wheeler et al., 2013	

Nitrogen losses in Overseer

An estimate of nitrogen losses is the final combined result of many calculations made in almost all sub-models except those dedicated to other nutrients and greenhouse gases. As a result, the quality of all of these sub-models matters.[61]

The urine deposited by grazing animals (sheep, cattle and deer) is the primary source of nitrogen losses on pastoral farms. Urine patches contain high concentrations of nitrogen (up to the equivalent of one tonne of nitrogen per hectare), which are much greater than the capacity of pasture to take it up. As a result, excess nitrogen is prone to losses, especially via leaching through soil.

In order to estimate nitrogen losses from animal urine and dung, Overseer uses a calculation sequence which starts with an animal – how much nitrogen was taken in by the animal, how much was retained in the product, and how much was excreted.

Overseer estimates animal feed intake from the net energy requirements of an animal and the energy content of the feed. It uses the nitrogen content of the feed to estimate total nitrogen intake. Nitrogen intake is then partitioned between animal products (e.g. milk, meat) and excreta (urine and dung). Most of the excreted nitrogen ends up in urine. Nitrogen leaching from urine patches and non-urine sources (fertiliser and effluent are the main non-urine sources of nitrogen losses) is then modelled separately.

The last step in calculations involves scaling up all the losses to the block and farm level, as this is the scale for which Overseer produces nitrogen loss estimates.

In the absence of animals, nitrogen fertiliser (e.g. urea) becomes an important source of nitrogen losses. In this case, Overseer estimates nitrogen losses as the net difference between inputs (fertiliser, soil, biological fixation by clover) and removals (uptake by plants, denitrification). In general, Overseer assumes that plants are relatively efficient at taking up nitrogen when not overwhelmed with excessive amounts of nitrogen from urine, so nitrogen losses on enterprises without animals are generally lower.

Phosphorus losses in Overseer

Overseer uses a separate sub-model to estimate phosphorus losses. This sub-model was developed in 2005 and has remained largely unchanged since then.[62]

The main sources of phosphorus inputs within an agricultural system include soil itself, fertiliser, effluent, supplements, and excreted animal dung. Unlike nitrogen, the amount of phosphorus in animal urine is insignificant. Currently Overseer assumes that all phosphorus ends up in dung and none in urine.

[61] Not all sub-models have been documented. Even fewer have been peer-reviewed. Overseer model components that have been reviewed include: the use of soil parameters (Pollacco et al., 2014), greenhouse gas sub-models (Kelliher et al., 2015; de Klein et al., 2017), the metabolisable energy sub-model (Pacheco et al., 2016), the phosphorus loss sub-model (Gray et al., 2016), and the hydrology sub-model (this review was led by David Horne from Massey University, but it is not publicly available). However, the key sub-models for estimating nitrogen losses (e.g. urine patch and background nitrogen losses) have not been peer-reviewed.

[62] Some minor modifications have been made to the phosphorus model, including the addition of other farming systems (e.g. deer). See McDowell et al. (2005) for the original description of the phosphorus sub-model, and Gray et al. (2016) for the peer-review.

The phosphorus sub-model within Overseer is calibrated to phosphorus losses to second-order streams due to run-off. In this case run-off includes surface run-off and sub-surface (leaching) flows, but excludes deep drainage to groundwater or mass movement.[63]

Sitting behind the block- and farm-scale losses are estimates of different forms of phosphorus losses. These include incidental losses (recent soil phosphorus inputs with fertiliser, effluent, dung) and background losses from the soil (erosion or animal treading damage). The sum of both these losses is referred to as total phosphorus lost to water.[64]

One limitation of the phosphorus sub-model is that not all types of erosion are included. For example, the sub-model can account for sheet flow and some gully erosion.[65] However, it does not estimate phosphorus that is lost in sediment associated with mass movement due to more extreme events such as earthflows or landslides.[66] In some topographical settings, particularly in the hill country, this can be a major source of phosphorus in some years.

As mentioned above, Overseer does not 'know' where critical source areas are. Critical source areas are minor parts of a paddock, farm or catchment that account for major proportions of water quality contaminant loss. For example, stock camps established on hill slopes have high concentrations of phosphorus that may be lost via run-off. However, as these critical source areas remain unknown to the model, Overseer has limited ability to help with targeting them and making mitigation options more cost-effective. However, if trained, a user could identify obvious critical source areas and include them as a separate block.

[63] A first-order stream is a headwater, while a second-order stream results from the joining together of two first-order streams. While the model does not know where the second-order stream is, it is unlikely for a farm to be hydrologically isolated from a second-order stream.

[64] The phosphorus loss in run-off includes both dissolved phosphorus and particles of phosphorus attached to eroded soil.

[65] Sheet erosion is the uniform removal of soil in thin layers by the forces of raindrops and overland flow, and can cover large areas of sloping land.

[66] Gray et al., 2016, p.32.

Source: Peter Scott

Figure 3.6 Heavy rainfall can lead to mass landslides on exposed hillsides. As well as being a costly loss of productive soil, landslides can add significant amounts of sediment and phosphorus into waterbodies. Overseer cannot model the occurrence or impact of such erosion events.

Greenhouse gas emissions in Overseer

As mentioned earlier, Overseer also estimates gaseous emissions from farms: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), all of which are significant greenhouse gases.[67]

Within Overseer, the three greenhouse gases (GHG) are calculated using different approaches, accounting for differences in pathways and processes. Ten sources of greenhouse gas emissions are considered in Overseer.[68]

[67] Due to the increasing focus on greenhouse gasses (GHG) that has followed New Zealand's signing of the Paris Agreement and the development of the Zero Carbon Bill, several studies have been commissioned to investigate the underlying science used in Overseer when accounting for farm scale GHG losses (e.g. Kelliher et al. 2015; de Klein et al. 2017).

This work is in addition to the technical manual chapters (Wheeler, 2018d,e,f) and GHG reporting publications (Wheeler et al., 2008, 2011c, 2013) from Overseer that relate to GHGs. Furthermore, the potential role of Overseer in GHG reporting has been discussed by the Productivity Commission (New Zealand Productivity Commission, 2018) and the Prime Minister's Chief Science Advisor (Gluckman, 2018).

[68] The sources include seven animal sources (dairy, dairy replacements, sheep, beef, deer, dairy goats, and others) plus horticulture, cropping, and export (Wheeler, 2018d,e,f).

The majority of carbon dioxide emissions come from direct emissions (e.g. fertiliser) and embodied emissions (e.g. electricity use and fuel).[69] Methane and nitrous oxide emissions (with the exception of fertiliser N_2O emissions) are related to animal processes and by-products, which in turn are governed by the animal's energy requirements.

Methane emissions come largely from processes in the animal's rumen (enteric processes) and the breakdown of dung.[70]

Nitrous oxide is primarily produced as a by-product of soil nitrogen transformations from excreta (about 80-85 per cent) and fertiliser application. Nitrogen in urine and dung is estimated based on the nitrogen content of animal feed intake. The rate of nitrous oxide loss is then estimated using an emission factor for the different excreta. Emissions from fertilisers are calculated by multiplying the amount of nitrogen applied to a block by the emissions factor for fertiliser.

Overseer Legacy offers three different options for entering nitrous oxide emissions factors. They include: annual average emission factors, annual averages that are seasonally adjusted, and using farm-specific emission factors. Annual emission factors used by Overseer are largely the same as the New Zealand's Agricultural GHG Inventory model.[71]

While the ability to account for farm-specific factors for nitrous oxide has been noted by several authors as an important tool for accounting for on-farm GHG emissions, using farm-specific approaches can lead to erroneously high nitrous oxide emission estimates (compared to empirical observations and the use of annual average national emissions factors).[72] As a result, it has been recommended to use the annual emission factors option rather than the farm-specific approach.[73]

[69] Embodied emissions are estimated as the sum of energy required to produce a good or service.

[70] In Overseer, monthly dry matter intake is multiplied by a default enteric emission factor, with monthly values summed to produce an annual rate. The emissions factor varies based on the species of animal, and in the case of sheep by age. The default emissions factors used by Overseer are – by and large – the same as those used in the New Zealand's Agricultural GHG Inventory model, which have been generated from New Zealand-based studies. This research has also shown that the methane emission factor remains stable throughout the year and across locations. As a result, Overseer does not incorporate any seasonal variations in enteric methane emission factors. In addition, all feeds are currently assumed to have the same methane emission factor (Wheeler, 2018e).

[71] See Kelliher et al., 2015 for details. However, the use of farm specific emission factors is seen as desirable given that a primary driver of nitrous oxide emissions is thought to be soil water content (de Klein et al., 2017).

[72] See de Klein et al. (2017) for details.

[73] See de Klein et al. (2017) and Overseer Ltd. (2018a) Release notes for Overseer version 6.3.0. However, the ability to select the different input emissions factors for nitrous oxide does not appear to be currently present in the new interface (OverseerFM).

What Overseer can and cannot do

As a consequence of Overseer's purpose, design, history, evolution, and data availability Overseer CAN do the following:

- estimate farm (and block) nitrogen losses from the root zone and phosphorus losses to second-order streams
- estimate whole farm greenhouse gas emissions
- model seven nutrients (nitrogen, phosphorus, potassium, sulphur, calcium, magnesium, and sodium) and greenhouse gases (carbon dioxide, nitrous oxide, methane)
- estimate maintenance fertiliser requirements
- model most common farming practices and mitigations to reduce the environmental footprint (e.g. lowering stock numbers, decreasing fertiliser application, irrigation management, types of feed and supplements)
- model proposed changes in the farm system (e.g. introduction of mitigations), and estimate nutrient losses and greenhouse gas emissions as a result of those changes[74]
- model some instances of 'bad farming practice' (e.g. over-stocking, over-fertilising, over-irrigating and winter applications of nitrogen fertiliser, as well as over-application of fertiliser for the required level of production)
- model seven land uses or block types, with varying degrees of uncertainty.

By contrast, Overseer CANNOT:

- accurately model situations when farm management is changing, which happens, for example, when a land use has changed or intensified
- check if the inputs result in a farming operation that is realistic or not
- capture any variation in nutrient losses within a block
- capture patterns of nutrient losses at a shorter term (e.g. daily, weekly)
- be used to help make any day-to-day management decisions (e.g. when to irrigate)
- capture any losses associated with an incident (e.g. spill-over of effluent)
- model uneven fertiliser applications or applications too close to a stream
- model some novel farming practices and mitigations to reduce environmental footprint, such as urease inhibitors, pastures with plantain and chicory, use of dietary salt, and a full range of crops[75]

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[74]This option allows farmers and consultants to test possible scenarios.

[75]Wheeler 2018a, pp.18-19.

- produce accurate estimates outside calibration ranges
- provide the uncertainty associated with an estimate of nutrient loss or greenhouse gas emissions (e.g. Overseer does not provide a range of values within which an estimate could lie, or the level of confidence associated with the range)
- model sediment and pathogens (e.g. *E.coli*)
- model phosphorus lost with mass movement of sediment (i.e. slips and landslides) from large storms
- identify critical source areas on a farm (such as stock camps established on hill slopes) – unless these are modelled as separate blocks
- model impacts of the spatial layout of blocks or any spatial relationships between blocks
- provide information about what happens to nitrogen beyond the root zone (60 centimetres from the land's surface) or phosphorus beyond a second-order stream.

4

Overseer, regional councils and water quality

This chapter examines the way Overseer is being used by regional councils in support of policies designed to limit diffuse nutrient pollution.

It first examines the way Overseer is being used by regional councils in support of policies designed to limit diffuse nutrient pollution. It does not directly consider non-regulatory industry use of Overseer, except to acknowledge that such usage is widespread.[76]

It then turns to some of the key issues councils face if they elect to use Overseer in managing nutrient loss. This section draws on guidance provided to councils in two reports: *Using OVERSEER in regulation*, prepared by Freeman Environmental Ltd in 2016 ('the Freeman report'); and *Using Overseer in Water Management Planning*, prepared by Enfocus Ltd in 2018 ('the Enfocus report').[77]

This analysis is informed by the views of farmers, farming consultants, and regional council staff interviewed by the Parliamentary Commissioner for the Environment's (PCE) staff in the course of the investigation.

[76] For example, Overseer nutrient budgets are produced by Fonterra for its farms under the 'Supply Fonterra' Nitrogen Programme, which was launched in 2012.

[77] The Freeman report (Freeman et al., 2016) was commissioned by a number of regional councils, Ministry for the Environment, Ministry for Primary Industries and industry groups. The Enfocus report (Willis, 2018) was commissioned by Overseer Ltd.

Regional council use of Overseer

This section draws on a report commissioned by the PCE to examine the ways regional councils are currently using Overseer, and to ascertain what council staff see to be its advantages and disadvantages. The report is available in full on the PCE website.[78]

Reference to Overseer in regional council and unitary authority regional policy statements and resource management plans

Seven councils do not explicitly reference Overseer in their regional policy statements or resource management plans (Table 4.1, column 2). However, even where councils do not explicitly reference Overseer in these documents, they may still use it. For example, staff at Greater Wellington Regional Council consider Overseer to be a valuable tool for catchment modelling despite no reference to the tool in the council's policies and plans.[79]

Three councils include preparation of an Overseer nutrient budget as one of the requirements for permitted activity status for farming activities but impose no restriction on the amount of nitrogen leached (Table 4.1, column 3).

For example, under Environment Southland's Proposed Water and Land Plan, existing farming operations will be permitted activities provided the farmer prepares and implements a Farm Environmental Management Plan containing an Overseer nutrient budget and meets a number of other permitted activity standards.[80]

The Overseer nutrient budget component of the Farm Environment Plan is intended to encourage good farm practice and provide the council, and the community, with an information base on which to make policy decisions regarding nutrient management when the catchment-by-catchment limit setting process begins in Southland.[81] While the Farm Environment Plans are not subject to council approval, they must be provided to Environment Southland upon request.

Six councils go further than simply requiring preparation of an Overseer nutrient budget. These councils attach some regulatory consequence to the amount of nitrogen leached by a farm. In other words, they use Overseer as part of a framework that imposes *nitrogen loss limits*. Typically councils will require a retrospective 'performance' file displaying nitrogen loss rates based on actual farm data. Some councils also require a predictive Overseer file to show how a future nitrogen limit will be met (Table 4.1, column 4).[82]

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[78] The report, commissioned from The Catalyst Group, is based on findings from a desktop review of the resource management plans of all 16 regional councils and unitary authorities (with the exception of Chatham Islands) and phone interviews with 31 staff from these councils. See The Catalyst Group (2018) available at www.pce.parliament.nz.

[79] Pers. comm., Tony Faulkner, Greater Wellington Regional Council, 2018.

[80] Farms below 20 ha in size are exempt from the requirement to provide a Farm Environmental Management Plan containing an Overseer nutrient budget. Other permitted activity standards relate to the altitude of the activity and practices relating to intensive winter grazing. Proposed Southland Water and Land Plan, Rule 20.

[81] Hearing Report: Proposed Southland Water and Land Plan Prepared under Section 42A of the Resource Management Act 1991, April 2017. The Council intends developing a Plan Change for freshwater objectives, limits and targets in Southland (that includes all Freshwater Management Units) to be notified by 2022.

[82] Often plans allow for Overseer or an alternative approved model to be used.

In some cases, resource management plans contain activity status thresholds based on Overseer nitrogen loss estimates. For example, from June 2020 Hawke's Bay Regional Council will require farming properties in the Tukituki River catchment to obtain a resource consent should they exceed nitrogen leaching rates set out in the Regional Resource Management Plan.[83] The consent requirement will trigger a process for reducing nitrogen leaching from farms, through the implementation of progressively more stringent management practices.

In other cases, councils have avoided reliance on Overseer estimates for activity status, and have instead defined activity status with reference to the area used for specific activities. Environment Canterbury, for example, has used the area subject to irrigation and winter grazing to differentiate between permitted activities and those farming activities that require resource consents.[84] If a farm requires resource consent under these rules it will be subject to a nitrogen loss limit – and Overseer is used to monitor compliance – but the nitrogen loss limit is not the determinant of whether or not the farm requires resource consent.

The councils using Overseer as part of a framework imposing nitrogen loss limits (with the exception of Otago Regional Council) use Overseer in conjunction with farm plans that must be prepared as part of any application for a farming activity that needs a resource consent.

Implementation of the actions in these plans is then subject to monitoring and enforcement by councils. While the names used to describe these plans (e.g. farm environment plans, nutrient management plans etc.) and their specific requirements vary between councils, all need to be prepared by a certified person, and all must identify actions to reduce the risks of diffuse discharges of contaminants. The costs for most farm plans can be expected to fall within the range of $2,200 and $7,500.[85]

For example, Bay of Plenty Regional Council requires a Nutrient Management Plan (NMP) as a condition of consent for farms in the Lake Rotorua catchment as part of Plan Change 10. The NMP must spell out mitigation actions to provide a pathway from a property's nitrogen leaching start point to its long term 'Nitrogen Discharge Allocation' to be achieved by 2032. Overseer is used to model the pathway (i.e. establish that the actions proposed will achieve the long term reduction in nitrogen loss).[86]

[83]Hawke's Bay Regional Council, 2015. Hawke's Bay Regional Resource Management Plan. Rule TT1 – Production land use, p.191A.

[84]Environment Canterbury, 2016. Proposed Variation 5 to the Canterbury Land and Water Regional Plan. Rules 5.44A and 5.54A.

[85]Note that in this study preparing Farm Environment Plans (FEPs) for Fonterra farms was much quicker due to Fonterra already having existing farm maps and Overseer files for their shareholder farms (AgFirst Waikato, 2016).

[86]Section 42A Report for Proposed Plan Change 10: Lake Rotorua Nutrient Management. At the time of writing this plan change (Plan Change 10: Lake Rotorua Nutrient Management) was before the Environment Court.

Table 4.1 Use of Overseer in regional council and unitary authority regional policy statements and resource management plans

	Use of Overseer in regional policy statements or resource management plans		
Council	**No regulatory use of Overseer**	**Regulatory – permitted activity standard**	**Regulatory – nitrogen loss limits**
Auckland Council		■	
Bay of Plenty Regional Council			■
Environment Canterbury			■
Environment Southland		■	
Gisborne District Council		■	
Greater Wellington Regional Council	■		
Hawke's Bay Regional Council			■
Horizons Regional Council			■
Marlborough District Council	■		
Nelson City Council	■		
Northland Regional Council	■		
Otago Regional Council			■
Taranaki Regional Council	■		
Tasman District Council	■		
Waikato Regional Council			■
West Coast Regional Council	■		

Using Overseer to set nitrogen loss limits

Overseer is not only used in determining compliance with nitrogen limits (as described above) but is also used in *setting* nitrogen loss limits. This happens both at the level of the farm and catchment. These uses of Overseer are not always explicit in the regional policy statements or resource management plans themselves, so are discussed separately to the uses outlined in Table 4.1.

At the catchment scale, Overseer has been used as part of complex catchment-level modelling exercises. Overseer's role has been to estimate nitrogen losses from all the farms in a catchment while other models, accounting for nutrient transport and transformations, have been used to estimate the amount of nutrients finally entering receiving waterbodies. These catchment-scale modelling exercises have helped regional councils determine the scale of reduced nutrient leaching that will be needed to achieve desired water quality objectives.

One of the more sophisticated catchment-scale modelling exercises that has been undertaken concerns Lake Rotorua and the writing of Plan Change 10. Once an 'acceptable water quality' outcome for the lake was agreed, a target nitrogen load was determined. A catchment-scale model (which accounted for attenuation and groundwater time lags) was then used to determine the level of farm nitrogen losses consistent with achieving the target. Further discussion of catchment-scale issues is included in chapter 7.

Overseer plays a significant role in the setting of farm level nitrogen loss limits, also known as 'allocations'. Broadly speaking, the approaches taken to date have been based either on what have been loosely termed 'natural capital' approaches (Otago, Horizons and Hawke's Bay regional councils) or on approaches based, at least in part, on a farm's previous nitrogen losses, known as 'grandparenting' (Waikato and Bay of Plenty regional councils and Environment Canterbury).

In the Horizons region, Land Use Capability (LUC) classes were used as a proxy for natural capital, with a maximum nitrogen leaching limit ascribed to each of eight classes. The limits for each LUC class were developed using hypothetical reference farms, which were modelled using Overseer.[87]

In the Lake Rotorua catchment, the Bay of Plenty Regional Council used Overseer to model each farm's historic nitrogen losses from 2001–2004. In order to achieve the reduction in the total nitrogen load to the lake sought by the council, a standard percentage reduction for each property based on the type of land use (dairy or dry stock) was applied. A further adjustment was made, where necessary, to bring a property within a range for that sector (this enabled the council to require the higher nitrogen leaching properties to reduce more).

As the above examples illustrate, Overseer has been used by some councils as a tool to determine a property's leaching limit, but not to determine the approach taken to allocation. This is a decision made by councils, informed by political, social, economic and scientific considerations.

Overseer and phosphorus management

With respect to phosphorus, no council currently imposes phosphorus loss limits at the farm scale. However a number of councils require a nutrient budget that estimates phosphorus loss (in addition to nitrogen loss) as part of a farm plan. Council plans require Overseer, or an alternative approved model, to be used for this purpose.

[87] The Land Use Capability (LUC) classes date back to a 1950s classification of the productive potential of land, with most LUC/NZLRI (New Zealand Land Resource Inventory) mapping taking place in the 1970s and 1980s. A number of concerns have been voiced by scientists about LUC's fitness for the purpose of setting nitrogen limits. Main criticisms included: narrow focus on agricultural productivity (with the focus on arable cropping rather than pastoral land use), high variability of pastoral productivity within a LUC class, and limited correlation of LUC classes with nitrogen losses. See Lilburne et al. (2016) for details.

For example, in the Tukituki River catchment in Hawke's Bay, a Farm Environmental Management Plan (FEMP) must be prepared that contains a nutrient budget including phosphorus loss and nitrogen leaching rates for a farm. Farms in this catchment also need a specific Phosphorus Management Plan to be included in the FEMP. The plan identifies the inherent risks associated with phosphorus and sediment loss, the significance of those risks, and the management practices that will be implemented to avoid or reduce the risks.

Other methods to manage diffuse discharges

A variety of other mechanisms are used by councils to manage diffuse discharges alongside, or instead of, Overseer. Some of these mechanisms are voluntary, such as the riparian programmes utilised by the Taranaki Regional Council.[88] Others are regulatory, such as permitted activity standards that require stock exclusion from waterways, or standards for fertiliser use, irrigation, and effluent application to land.[89]

Issues with Overseer application

In addition to the survey commissioned for this investigation, in-depth interviews were conducted with council staff, users and experts. From that body of evidence four key application issues emerge:

- data input uncertainty
- version change
- the inability of Overseer to represent farm systems in particular regions
- uncertainty in a compliance setting.

This is not an exhaustive list. During the investigation, other concerns were raised by council staff that merit further attention.[90] While the discussion that follows is from a regulator's perspective, the issues in question are also issues for farmers and the wider community.

Issue 1: Data input uncertainty

As mentioned in chapters 2 and 3, uncertainty associated with inputs is a key type of model uncertainty. With Overseer, input uncertainty can occur in a number of ways.[91]

Inadvertent errors can occur when someone enters a different value than the one they intended while recording farm data or setting up Overseer files.

[88] However, Taranaki Regional Council is proposing to shift its riparian programme on the Taranaki ring plain from non-regulatory to regulatory. Taranaki Regional Council, 2015. Draft freshwater and land management plan for Taranaki. Rule 35(c) – Intensive pastoral farming p.66.

[89] The Catalyst Group, 2018, pp.21–23.

[90] For example, access to farm data in order to undertake catchment modelling to underpin plan development was a challenge for several councils. In some cases this data was held by industry organisations but not provided to the council e.g. because the data was not explicitly collected for that purpose. Other issues include dealing with sales (and new owners) and leased land.

[91] This list is based on the categorisation in the report by Enfocus (Willis, 2018).

Errors can also result from poor record keeping. For instance, a farmer might be unsure how much fertiliser or supplementary feed was used on the farm. An unreliable estimate of a key input increases uncertainty of the final outputs. Errors can also arise from simple misunderstandings or a lack of knowledge.

Uncertainties can also arise when users seek to 'work around' a problem because Overseer is not able to model a particular farm system. Workarounds are required in a range of circumstances, as outlined below.[92]

- Some crop types grown in New Zealand are not modelled in Overseer. These are generally specialist vegetables or high value non-herbage seed crops.
- Double-sowing of crops (two crops sown during the same month) is not modelled in Overseer. For example, to increase winter grazing potential, growers often sow forage crops and clover seeds concurrently. In Overseer only one crop management option per month is allowed.[93]
- Changes to paddock boundaries in the course of the year cannot be modelled in Overseer. Crops are often grown on small areas (e.g. 0.2 ha), with some variation throughout the year as space becomes available. However, Overseer is currently designed to model larger areas and even combine paddocks with common attributes and management into a single block.
- Uneven distribution of animals over a block that is being grazed cannot be modelled in Overseer. However, in reality forages and fodder crops are likely to be break fed. It can take five to eight weeks to break feed a crop like kale.

Source: pxhere.com

Figure 4.1 Overseer models a range of land uses. However, uncertainty can arise when Overseer cannot model a particular farm system (e.g. some crop types grown in New Zealand are not modelled in Overseer).

[92] Hume et al., 2015.

[93] It is anticipated that results from the 'Forages for Reduced Nitrate Leaching' project will enable enhanced forage crop options within Overseer.

As a consequence of these limitations, Overseer users have devised ways of representing farm systems in Overseer. Despite their best efforts there may still be significant (or at least unknown) differences between the actual farm and the farm as represented in Overseer. This can be problematic, especially if any workarounds are not explicit and are not applied consistently by different users.[94]

Interpretation differences are another source of input uncertainty. For example, wetlands can be set up as separate wetland blocks or be included in other blocks (e.g. pasture) with very different results for estimated nutrient loss.

Finally, it is possible to deliberately manipulate Overseer outputs. For example, indicating that soil moisture is monitored using special sensors and that irrigation is only applied when soil moisture falls below a trigger point, will produce a lower nitrogen loss number compared with visual assessments or no assessments at all.

Setting up management blocks in another catchment in order to reduce the average nutrient loss estimated by Overseer is another example of deliberate manipulation. While, on paper, nitrogen leaching will be reduced, in reality no on-the-ground change in farming practice has occurred.

This investigation has not been able to find any published data quantifying the frequency with which any of these sources of input uncertainty occur, nor of any attempt to quantify the resulting impact on model uncertainty. However, data input uncertainty was raised as a key disadvantage of Overseer by regional council staff. In discussions with farmers, farm consultants and regional councils, numerous anecdotes of deliberate manipulation were reported, as were instances of workarounds, and interpretation differences.

A number of resources and practices are available to help overcome these problems. Several of them are described below.

Overseer Best Practice Data Input Standards

Overseer Best Practice Data Input Standards were first developed in 2013 by a group of technical expert users and model developers. The latest data input standards are designed for Overseer version 6.3.0 and were published in March 2018 by Overseer Ltd. The standards aim to reduce inconsistencies between different users and provide guidance on data inputs that "consistently achieve the most meaningful results".[95]

Use of the standards should, in particular, reduce interpretation differences. For example, as outlined above, wetlands can be set up as separate blocks or be subsumed within other types of blocks. According to the standards, if a wetland area is retired from grazing, then this area should be accounted for as a riparian block. This is

[94] For example, Overseer Ltd publishes Frequently Asked Questions (FAQ) online which guide users on some 'workarounds' to known difficulties in selecting the most appropriate input parameters.

[95] Overseer Best Practice Data Input Standards. Overseer Version 6.3.0, March 2018.

because expert knowledge on types of wetlands is currently required to correctly set up a wetland block.[96]

The standards also provide useful advice on how to deal with some of the 'workaround challenges' described above. For example, if a particular crop is not represented in Overseer, the standards recommend choosing the most similar crop from the ones available.

The standards will not, however, in and of themselves reduce inadvertent errors, deliberate attempts to manipulate the final number, or improve record keeping. Further, in some instances, adherence to the standards may not provide the best representation of the farm. For example, the standards recommend the use of 'occasional pugging' for all soil types under dairy farms. However, not all dairy farms have the same level of pugging. Farm knowledge, user experience and training are vital to ensure accurate representation of a particular farm in Overseer.

As mentioned above, the standards aim to reduce inconsistencies between different users, and are useful to this end. For this reason they should be used by all those undertaking Overseer modelling when the results will be used to inform regulation. This is consistent with the recommendations of both the Freeman report and the Enfocus report.

Certification of farm advisors

As Overseer is a technical tool, it requires an operator who possesses a certain level of expertise to operate it in a way that minimises the various forms of input uncertainty described above. The Freeman report recommends, at a minimum, the possession of a Massey University Certificate in Advanced Sustainable Nutrient Management, an equivalent qualification, or extensive experience in a specific farming system and detailed understanding of Overseer. The Enfocus report recommends the Massey University Certificate in Advanced Sustainable Nutrient Management.

While the need for operators to possess appropriate qualifications seems generally accepted by regional councils, significant waiting periods have been reported in those regions where councils require farmers to prepare Overseer budgets for compliance purposes, highlighting a shortage of appropriately trained people.

Auditing of Overseer modelling

Where Overseer is used to set a farm nitrogen loss limit (for instance, one based on a farm's historical losses) or determine compliance with nitrogen limits, there are significant incentives for the deliberate manipulation of Overseer modelling results.

The Freeman report identifies situations in which regional councils should require the audit of Overseer modelling by a qualified person not involved in the initial

[96] However, it seems this issue is still not entirely resolved. The OverseerFM User Guide, which was published by Overseer Ltd since the latest standards, suggests that unfenced natural wetlands be entered using the Drainage/Wetlands tab. A photo guide produced by NIWA is accessible to users to help determine wetland type.

Overseer modelling exercise. Audit is recommended for determining resource consent compliance and in cases where the results may have particularly significant implications for regional plan development or determining a regional plan activity status. It provides a comprehensive list of factors that should be considered in an audit.[97]

To be able to audit Overseer files, councils and auditors need access to the necessary information. In most situations the full Overseer XML file (the file which sets out the full suite of input and output data) is required to provide an independent auditor with sufficient information to ensure the robustness of a nutrient loss estimate. For example, Environment Canterbury requires the suite of inputs that go into generating an Overseer estimate so it can check the validity of the nitrogen loss output and recreate these estimates from time to time in the most recent version.[98]

The auditor is likely to be 'off-site'. This means they will need a way of checking the input data using information from various sources such as annual taxation accounts showing opening and closing stock numbers, stock transactions or annual nutrient statements provided by the fertiliser company.

As noted in chapter 3, Overseer assumes that inputs are consistent with production irrespective of whether a farming system is viable or not, opening up the possibility of an operator entering unrealistic inputs and creating unrealistic farming operations.[99] The auditor needs to have the expertise to assess whether inputs and outputs are within the normal range for the farm system and location. The current shortage of qualified professionals outlined above is equally problematic for ensuring a robust audit system.

Secure receiving and storing of Overseer information

Councils need a secure way to store Overseer information and one that enables them to efficiently locate and uplift this data should it be needed in the future, such as for catchment modelling, auditing, or undertaking compliance activities.

Historically this would have required councils to build a secure system to collect and store the XML files used to generate Overseer estimates. However, in the new OverseerFM the centralised farm account replaces the XML files in the legacy product. Instead of providing an XML file to a council, the new software allows users to submit information to councils using the 'publication' button in the OverseerFM user interface. Overseer Ltd consider this will make sharing of information from farmer to council much more streamlined and improve councils' ability to audit Overseer files.

However, exactly what information regional councils will be able to extract, store and analyse remains unconfirmed. Several councils are concerned about the extent to

[97] Freeman et al., 2016, Table 12, pp.82–84.

[98] Pers. comm., Leo Fietje, Environment Canterbury, 2018.

[99] Over time, there have been some efforts to allow users to manually check aspects of the viability of farm systems. For example, in Overseer Version 6.0 estimated pasture production was reported, which users can use as a feasibility check. In addition, some sensibility testing is embedded into OverseerFM (e.g. for pastoral blocks) as the software provides a suggested range for production, and can also generate error messages. OverseerFM website (https://fm.overseer.org.nz/), accessed 16 November 2018.

which OverseerFM may affect their ability to recreate or audit Overseer files and the potential for a property owner to refuse to share information (e.g. if threatened with enforcement action). Affected regional councils are currently in negotiations with Overseer Ltd on this issue.[100]

The use of the best practice data input standards, certification, auditing and secure storage of Overseer files are practices generally accepted by regional councils.[101]

It should not, however, be assumed that implementing these practices is easy. There is a need for council staff to have a high degree of understanding of farm systems and expertise in Overseer to facilitate the auditing of Overseer results. Effective oversight of the process of receiving, auditing and storing Overseer files is likely to require significant staff time.[102]

Issue 2: Version change

Overseer is updated fairly regularly. Some of these changes are to the model user interface, or relate to fixing minor bugs or adding some functionality. These changes may or may not impact on nutrient loss estimates.

However, once a year, more significant changes are made to the computational 'engine' of the model with consequences for nutrient loss estimates. For example, a substantial upgrade of the irrigation sub-model occurred in 2015 which resulted in significant changes to nutrient loss estimates from irrigated land.[103] The ongoing process of updating soil information in the S-map soils database also affects the model's output.

The Freeman report states there are potentially very significant policy, regulatory and implementation resourcing implications flowing from Overseer version changes. Version change was also highlighted by council staff as a major problem. The impact on farmers of version changes is potentially significant, and was frequently raised by farmers and farming consultants as a key concern.

For example, the use of nitrogen loss rates as consent thresholds in plan rules has meant that, simply due to model changes, farms in some regions have suddenly become subject to different and generally tougher consent requirements.[104] This creates uncertainty with respect to regulatory obligations and undermines farmer confidence in the model.

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[100] Pers. comm., Waikato Regional Council and Environment Canterbury, 2018.

[101] For example, where Overseer is used in a limit setting context all regional councils require the development of an Overseer Nutrient Budget that is calculated by a suitably qualified or accredited farm advisor in accordance with Overseer Best Practice Input Standards.

[102] Pers. comm., Bay of Plenty Regional Council, 2018.

[103] OVERSEER® Release notes for version 6.2.0, April 2015.

[104] Freeman et al., 2016, p.50.

Source: Parliamentary Commissioner for the Environment archives

Figure 4.2 Farmers in the Manawatū-Whanganui region faced issues with Overseer version changes in 2012. Under Version 5.4 of Overseer, the council considered about 80 per cent of farmers in the region would be able to comply with nitrogen loss limits in the regional plan. Under Overseer Version 6, the council's position was that this figure was closer to 20 per cent, meaning that many more farmers would require a tougher resource consent to continue farming. Horizons Regional Council is still working through issues this version change caused for its regional plan.

That said, council staff also recognise the need for continuous and timely improvements to the model. Farmers also want improvements to Overseer that can better reflect their farm systems.

Some regional councils have responded as the pitfalls of particular planning approaches have become known. For example, nitrogen loss limits were used in the Canterbury Land and Water Regional Plan to define whether a farm's activity had permitted activity status. Farm nitrogen losses based on Overseer were revised upwards as a result of version updates. This resulted in many farms requiring resource consents despite no change in actual farming practices.

The council responded to this issue in a 2016 plan change. Instead of using Overseer estimates, it used the area under irrigation and winter grazing to differentiate between permitted activities and those farming activities that required resource consent. This approach (defining permitted activities using 'narrative' thresholds) avoided the issue of Overseer version changes in the regional plan.[105] However, the council still confronts the issue of Overseer version changes in its resource consent processes.

[105] Environment Canterbury, 2016, Proposed Variation 5 to the Canterbury Land and Water Regional Plan, Rules 5.44A and 5.54A.

Bay of Plenty Regional Council's approach to version changes (in Plan Change 10) is to use the latest version of Overseer and specify a method (referred to as the 'Reference File' method) to maintain the proportionality of a property's nitrogen allocation relative to the rest of the sector. The rationale is that the proportionality of the initial nitrogen allocation is sound and should therefore be maintained into the future, across multiple version changes.[106]

While there has been significant thinking about ways to address this challenge in recent years on the part of regional council staff, it is not clear that the issue of version changes can be considered 'solved' for any council using Overseer in a framework with nitrogen loss limits. Some of the approaches are yet to be tested, either in the Environment Court, or in on-the-ground implementation.

While the Freeman report states it is essential that councils clarify how Overseer version changes will be managed, and provides some useful ways to do this, it does not provide a recommended option, and in this sense may be of limited assistance to councils, particularly those preparing plans which refer to Overseer for the first time.

If there is to be more consistent and confident practice on the part of regional councils, central government will need to step forward and prescribe a best practice approach. Flexibility could be left to councils to depart from it on a case by case basis. With the release of OverseerFM and the move by Overseer Ltd to make the legacy version unavailable, the need for such advice is particularly urgent.

Issue 3: The inability of Overseer to represent farm systems in particular regions

As explained in chapter 3, Overseer is a largely empirical model. This means it relies on calibration – a process that fine-tunes its parameters using experimental data. Higher levels of uncertainty can be expected when Overseer is used to model farms with characteristics that differ significantly from those used for calibration purposes.

The locations used for the 2012 calibration of nitrogen losses from pastoral blocks were primarily from the Waikato and Southland regions. The sites covered a limited range of soil types, a limited band of rainfall (between 600 and 1200 millimetres), and a limited range of management practices. It follows, for example, that sites with high rainfall (>1400 millimetres) as well as those on shallow, free-draining soils (which are common in large parts of Canterbury) will have higher uncertainty. In addition, higher uncertainty will also apply to cropping systems, as the majority of the sites used for calibration were dairy farms.

Some regional councils with climatic conditions, soil conditions or farm systems which are not reflected in the calibration exercise have recognised the need to improve Overseer's calibration. Recognising that Overseer has not been calibrated for the high

[106] For a full description of the reference file methodology see the Statement of Evidence of Alistair Charles MacCormick on Behalf of the Bay of Plenty Regional Council in the matter of Lake Rotorua Nutrient Management – Proposed Plan Change 10 to the Bay of Plenty Regional Water and Land Plan, 17 January 2017.

rainfall conditions in Rotorua, the Bay of Plenty Regional Council initiated calibration trials on two dairy farms in the Lake Rotorua catchment with AgResearch. Project funding came from the council, DairyNZ and AgResearch.

Environment Canterbury has expressed concern about the lower level of confidence in Overseer's ability to model arable and horticultural systems compared to its ability to model intensive pastoral systems which have had a greater level of calibration.[107]

It is apparent that an inadequate range of calibration studies may significantly degrade the reliability of Overseer estimates in regions such as Marlborough, Tasman, West Coast, Gisborne, Taranaki and Northland. As soil information is one of the key inputs, areas with no S-map data will have less accurate results. Regions such as Northland, Taranaki, Gisborne and the West Coast have no or limited S-map coverage, and therefore the more generic 'Fundamental Soil Layer' option must be selected within Overseer.[108] This is a reason to give real priority to improved calibration trials and soil information to underpin regulator and farmer confidence.

Issue 4: Uncertainty of Overseer in a compliance setting

A key concern raised by council staff is that due to the uncertainty of Overseer's estimates, absolute outputs from Overseer could not be relied on for enforcement purposes. Enforcement refers to the broad range of actions taken by councils to respond to non-compliance with the Resource Management Act 1991 (RMA). These actions include negotiation, abatement notices, enforcement orders and, at the most serious end, prosecutions for offences under the RMA.

Prosecutions require that the elements of a criminal charge are proved beyond reasonable doubt. The concern is that Overseer cannot be used to prove non-compliance with a limit set in a resource consent – for example, proving that actual nitrogen leaching on a farm exceeds a given number of kgN/ha/yr. Councils relying on an Overseer derived estimate of nitrogen loss to trigger a requirement for resource consent face issues of a similar nature, albeit to a lower standard of proof.

We are not aware of any cases where a prosecution has been initiated in the Environment Court based on an Overseer estimate of nitrogen loss. In the absence of any case law, whether the model forms an adequate basis for prosecution remains a live issue for councils.[109]

However, the RMA provides a number of enforcement mechanisms designed to ensure compliance with the statutory regime that do not require councils to meet the evidential test required in a criminal prosecution.

[107] Pers. comm., Leo Fietje, Environment Canterbury, 2018.

[108] Manaaki Whenua Landcare Research advises that as at October 2018, national S-map coverage was 34%; LUC 1-4 63% but LUC 5-8 was <25%; Waikato 72%; Bay of Plenty 59%; Canterbury 46%. Soil-map and S-map online website (https://soils.landcareresearch.co.nz/soil-data/s-map-and-s-map-online/).

[109] The Catalyst Group, 2018, p.iv.

Some councils are satisfied that these other mechanisms (e.g. letters, abatement notices, enforcement orders) allow them to satisfactorily achieve compliance. For example, in one instance where a council received Overseer files which didn't match what it saw on the ground, it conducted formal interviews with the farm owner, farm manager and consultant. It emerged that some of the information was false and steps were put in place to rectify the situation.[110]

There are also ways to respond to Overseer's uncertainty in the design of planning provisions themselves.

First, there is the way councils design their 'compliance platform'. Bay of Plenty Regional Council's Plan Change 10 uses Nutrient Management Plans and the 'committed actions' set out in these Plans as the primary point of monitoring, and, if necessary, compliance, as opposed to the Overseer nitrogen loss estimate itself.

Second, expert opinion suggests there is a lower level of uncertainty when using models to describe relative differences, such as the increase or reduction of nitrogen leaching after a management change, rather than when providing the absolute values of leaching.[111]

This principle is applicable to Overseer's nitrogen loss estimates – the science and model construction mean Overseer's estimate of the degree of change between two systems on the same soil with the same climate will be less uncertain than the absolute value.[112]

Because of this, the Enfocus Report suggests Overseer in a regulatory context is probably best regarded as a tool for assessing the relative change in nitrogen leaching between different points in time, rather than a model that attempts to estimate nitrogen leaching in absolute terms. The Report states: "… Overseer will be very good at assessing whether a (say) ten percent reduction in N leaching has occurred on a particular property (given a series of practices) over a prescribed (say) five-year period."[113]

An example of a council using Overseer to assess the relative change in nitrogen losses from a farm is Plan Change 10. Bay of Plenty Regional Council requires each property to reduce nitrogen losses by a specific percentage by 2032. It does this through the use of reference files.

While the planning provisions of some councils have been developed with Overseer's uncertainty and compliance challenges in mind, overall the approach by councils varies significantly and this issue remains a key concern of council staff.

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[110] Pers. comm., Leo Fietje, Environnent Canterbury, 2018.

[111] Chicota and Snow, 2009, p.250.

[112] Statement of Evidence of David Mark Wheeler before the Board of Inquiry in the matter of the Tukituki Catchment Proposal, September 2013.

[113] Willis, 2018, p.16.

Conclusion

Some of the issues outlined above are partly within the power of regional councils to solve.

Councils are able to lessen the scope for deliberate manipulation of Overseer modelling through auditing Overseer files, and setting up robust systems to receive, store and retrieve them.

However, as this chapter notes, there is a need for council staff to have a high degree of knowledge of both Overseer and of farm systems in order to audit Overseer files. The shortage of qualified Overseer operators in the wider sector has been highlighted. This issue is even more pronounced among councils which, relative to industry, have few in-house qualified operators.

Planning provisions can be drafted in a way that reduces issues arising from Overseer's limitations, uncertainty and version changes, but the issue of version changes continues to pose a significant challenge to councils using Overseer in a framework with nitrogen loss limits.

If greater uniformity of practice and confidence in regulators is to be forthcoming, official guidance from central government setting out a best practice approach to managing version change and dealing with problems of model uncertainty in the design of planning provisions would be desirable.

The issue of some climatic conditions, soil conditions or farm systems not being reflected in the calibration studies for Overseer has led to some regional councils funding new calibration studies. However, these are multi-year, costly exercises that do not appear to be the subject of current strategic or prioritised investment.

Some issues associated with using Overseer in regulation are not within the power of regional councils to solve or improve – or councils may not have access to the information and resources required to address the issue.

Model uncertainty can only partly be addressed by councils. Councils have limited means of understanding where the most important sources of model uncertainty arise, or understanding the consequences of these sources of uncertainty on Overseer's outputs. Ultimately, this means Overseer's uncertainty cannot be fully acknowledged, quantified and carried through into risk analysis when councils are developing plans.

Furthermore, in the absence of an independent peer review of Overseer, councils have limited ability to reassure those they are seeking to regulate that the model is utilising the best available scientific information, and that it is incorporating it appropriately.

Understanding and addressing these issues requires a more fundamental look at the model itself. It requires an understanding of the scientific elements that should be assessed and the processes that should be followed, when judging whether a model can be used to support regulation making. That is what the next chapter deals with.

5 Assessing Overseer

This chapter has three main sections. The first section looks at how to judge a model's suitability for use in support of regulation. It notes that despite New Zealand's use of models in regulatory processes there is no official guidance to assist either regulators or those being regulated to make an informed judgment about whether a specific model is suitable and acceptable for use.

In the absence of New Zealand guidance, this section describes the United States Environmental Protection Agency's (EPA) framework for the evaluation of environmental models. This framework identifies scientific elements that should be assessed, and process steps that should be undertaken, when judging whether a model can be used to support regulation.

The second section assesses Overseer using the United States EPA's framework. It is not a formal, exhaustive evaluation. Rather, it provides a picture of the existence – or absence – of information that could help determine whether Overseer is of sufficient quality to serve as the basis for regulation making.

On the basis of this assessment, the third section poses the question of whether Overseer can be used in a regulatory context.

Judging a model's fitness to support regulation

The implementation of New Zealand's environmental policy drives the use of models in a range of domains. For example, the New Zealand Coastal Policy Statement 2010 requires coastal hazards risk, over at least 100 years, to be assessed.[114] Similarly, the National Policy Statement for Freshwater Management 2014 requires regional councils to establish and operate a freshwater quality accounting system, which records information on contaminant loads and sources.[115] In the air quality domain, the National Environmental Standard for Air Quality requires councils to determine the effect of a new air discharge application on ambient standards.[116]

Although not always explicitly stated, the above policy instruments necessitate the use of models in their implementation. Models are also commonly used to inform decision making throughout the consenting process under the Resource Management Act 1991 (RMA).[117] In this sense Overseer can be seen in context as one of many models used for environmental regulatory purposes in New Zealand.

If a model is to be used in a regulatory setting, everyone – regulators and regulated alike – need to have confidence that it is fit for purpose.[118] Despite New Zealand's use of models in environmental regulation, there is a lack of guidance on how to assess whether a specific model is acceptable for use. There is also no widely applicable guidance on what good practice looks like for those developing models for regulatory decision making.[119]

Fortunately, such guidance has been developed in other jurisdictions and in academic literature.[120] The United States National Research Council (NRC) 2007 report *Models in Environmental Regulatory Decision Making* and the United States EPA's 2009 report *Guidance on the Development, Evaluation, and Application of Environmental Models*

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[114]New Zealand Coastal Policy Statement, Policy 24.

[115]National Policy Statement for Freshwater Management (2014) – amended 2017, Policy CC1.

[116]Resource Management (National Environmental Standards for Air Quality) Regulations 2004.

[117]Özkundakci et al. (2018) provides an overview of model use and the legal challenges that have been raised against them within a New Zealand context.

[118]For example, Özkundakci et al. (2018, p.1) outline that modellers and decision makers need to have a clear understanding of the purpose of the model, ensure transparency in the modelling process, acknowledge and minimise limitations and ensure that relevant best practices guidelines are followed. However, what modelling best practice looks like is sometimes difficult to define, as differences between scientific best practice and regulatory best practice vary with environmental domains.

[119]However, some domain specific guidance is available on the application of modelling in implementing environmental policy. Examples include guidance related to the National Policy Statement for Freshwater Management (e.g. MfE, 2016), New Zealand Coastal Policy Statement (e.g. MfE, 2017) and Resource Management (National Environmental Standards for Air Quality) Regulations 2004 (e.g. MfE, 2004). In addition, as discussed in the previous chapter, Freeman et al. (2016) provides some non-statutory guidance for regional councils on the use of Overseer. However, this report does not address the issues of model development and evaluation.

[120]For example, Jakeman et al. (2006) outline ten steps in model development and discusses minimum standards for model development and reporting; Bennett et al. (2013) suggest a five-step procedure for evaluating the performance of environmental models, focusing on graphical and numerical methods; Tonitto et al. (2018) define a seven-step process for model selection and use; United States EPA (2009) provides guidance on the development, evaluation, and application of environmental models; and Queensland State Government's *Good Modelling Practice Principles* (Jakeman et al., 2018) sets out good water modelling practices and principles.

are particularly useful guidance documents.[121] In these documents the term 'model evaluation' is used to describe the process of generating information that helps determine whether a model and its analytical results are of sufficient quality to serve as the basis for a regulatory decision.

These publications provide a list of scientific elements that should be assessed, and process steps that should be undertaken, when evaluating a model. They are applicable across a wide spectrum of environmental models, reflecting the United States EPA's reliance on models in diverse settings – including atmospheric and indoor air models, groundwater and surface water models, exposure models, risk assessment models, and economic models.[122]

Furthermore, these publications have been developed specifically for models used to inform regulatory decisions. This is in recognition of the fact that evaluation of regulatory models must interrogate a model differently, and address a more complex set of trade-offs, than research or other models used in the public or private sector for non-regulatory purposes.[123] This issue is expanded on later in this chapter.

In the absence of a New Zealand specific framework for evaluation of environmental models, this report uses the United States EPA's evaluation framework to assess Overseer.

Elements of model evaluation

The United States EPA suggests twelve elements should be addressed in model evaluation. For this report, these elements have been grouped into four broad categories.

1. Is the model based on sound science?

- *Scientific basis*
- *Computational infrastructure*
- *Assumptions and limitations*
- *Peer review*

2. Is the model managed to ensure quality?

- *Quality assurance and quality control*
- *Data availability and quality*
- *Test cases*

[121] National Research Council (NRC), 2007 and United States EPA, 2009.

[122] For examples of environmental models used by the United States EPA, see NRC (2007) Appendix C.

[123] For example, the NRC (2007, p.2) states "Evaluation of regulatory models also must address a more complex set of trade-offs than evaluation of research models for the same class of models. Regulatory model evaluation must consider how accurately a particular model application represents the system of interest while being reproducible, transparent, and useful for the regulatory decision at hand. Meeting these needs may require different forms of peer review, uncertainty analysis, and extrapolation methods."

3. Does the model's behaviour approximate the real system being modelled (including the tools and procedures necessary to make this judgment)?

- *Sensitivity and uncertainty analysis*
- *Corroboration of model results with observations*
- *Benchmarking against other models*

4. Is the model appropriate for a specific regulatory application?

- *Model resolution*
- *Transparency*

Model evaluation based on these elements not only helps determine whether a model is of sufficient quality to serve as the basis for a decision. It also helps identify potential areas for model improvement.

Importantly, the United States EPA recommends that evaluation is conducted over the entire life cycle of the model, starting early in the process and continuing throughout model development and application.[124]

Tailoring model evaluation to the model's intended application

An evaluation of any model should be tailored to the task the model is being asked to perform. Because Overseer is used for a range of regulatory and non-regulatory applications, it is important to be very clear about the purpose for which the model is being used. Here are four different tasks a user might ask of the model.

- Task one: A farmer might use Overseer to optimise maintenance fertiliser requirements, to help maximise farm productivity and profitability.
- Task two: A farmer might use Overseer to explore ways to reduce a farm's environmental footprint, looking at how alternative farming practices affect the amount of nitrogen and phosphorus that leaves the farm. This use of Overseer might be required by a regional council in order for that farm to be considered a permitted activity, or could be undertaken voluntarily by a farmer.
- Task three: A researcher or regulator might use Overseer in a catchment modelling exercise to help determine the total nitrogen load reaching a waterbody (discussed more in chapter 7). This might ultimately inform limits set in a regional plan.
- Task four: Regulators might require the use of Overseer to estimate the amount of nitrogen that leaves a farm, for determining compliance with nitrogen limits.

[124]United States EPA, 2009, p.19.

The assessment of Overseer in this chapter is based on Overseer's use as described in task four. However, we consider trust and confidence in Overseer to also be important for the uses in task two and task three, and the questions posed throughout the evaluation process are applicable to these uses. This is because these uses may still broadly be considered 'regulatory'. For example, where Overseer is used for catchment modelling, its use might ultimately inform a regulation or a specific policy approach by a council.

Evaluating a model in a regulatory context differs from evaluating the same model for research or private purposes. There are more complex trade-offs with regulatory use. For example, if we take *transparency* from the United States EPA's list, one aim in a regulatory setting will likely be enabling regulators and regulated alike to understand, and develop confidence in, how the inputs are transformed into model results. This usually favours a simpler model, as it is easier to communicate how the model works, how outputs change as inputs are varied, and how predictions match observations.

Where the science requires a complex model (as is often the case), it is very difficult to communicate the model workings to affected parties. In such situations, *transparency* involves building trust with affected parties through clear communication of a model's uncertainty backed up by details of quality assurance tasks.

Two pressures compete with the desire for simplicity as an aid to transparency. First, there is the desire to 'improve the science' which usually increases the complexity of the model (often by introducing additional parameters), requires more detailed input data, makes quality assurance more challenging, and makes it increasingly difficult for the layperson to understand the modelling.

Second, there is the desire by affected parties to 'expand the scope' of the model so that it addresses issues not envisaged when the model was first developed. Such trade-offs are certainly relevant to an evaluation of the use of Overseer.

Regulatory models also require more scrutiny of their accuracy and robustness as the use and consequences of erroneous outputs can have significant and uneven impacts on individuals and the wider community. As a result, the processes of *uncertainty analysis, model corroboration*, and *model implementation* are important.

For example, in circumstances where the use of an environmental model is for the purpose of protecting public health or environmental health, there may be significant consequences for the public, or the environment at large, if the model's result is erroneous. This is not to say there are no consequences of a non-regulatory model producing an erroneous result, but the nature of the risk is likely to be different. Again, this is relevant to the level of detail that an evaluation of the regulatory use of Overseer requires.

Regulatory models must also be evaluated within the applicable legislative environment, and need to be sufficiently 'robust' to be defended from legal challenges. For example, when a plan is prepared under the RMA, regional councils must prepare a report which assesses the risk of acting or not acting if there is uncertain or insufficient information about the subject matter of the plan provisions.[125] The uncertainty associated with the use of Overseer in preparing plan provisions, and indeed the uncertainty of any alternative approaches, is relevant to such a report.

Assessing Overseer against the United States EPA guidance

The following section describes aspects of what is known and not known about Overseer, using the twelve elements suggested by the United States EPA as a series of questions.[126]

This review was unable to make a comprehensive evaluation of Overseer because some information is not available in the public domain (e.g. aspects of the science behind the model, model calibration, corroboration, and robustness). This review does, however, identify what information exists to help determine whether Overseer is of sufficient quality to serve as the basis for regulatory decision making, highlight information that appears to be lacking, and recommend future review, analysis, and testing activities.

1. Is the model based on sound science?

Scientific basis

Evaluation of the scientific basis of a model is one of the most important factors to consider in model evaluation, as it underpins the conceptual framework from which a model is developed. Evaluating the scientific basis of a model can take many forms, but one approach is to consider the 'scientific pedigree' of a model. This refers to the history and quality of scientific theories used within the modelling framework and can apply to the model as a whole, or to sub-models.[127]

For Overseer, although many of the underlying principles appear to be well grounded, there is no full, publicly available, comprehensive description of the scientific framework used by Overseer.[128] As a result, the scientific pedigree of the model as a whole is hard to assess.

A similar statement can also be made about the pedigree of the individual sub-model components, with some more easily assessed than others. For example, a sub-model for which the pedigree can be assessed with reasonable confidence is the metabolisable energy requirements of animals to calculate dry matter intake. The use of this approach is well accepted in the scientific community.[129] It also underpins New Zealand's Agricultural Greenhouse Gas Inventory.[130] By contrast, the limited publicly

[125] Resource Management Act 1991, s 32(2)(c).

[126] United States EPA, 2009, pp.33–34.

[127] NRC, 2007, p.71.

[128] However, the model's generalised conceptual framework is described on the Overseer website (https://www.overseer.org.nz/how-overseer-engine-works).

[129] Pacheco et al., 2016, p.1.

[130] For example, see Pacheco et al., 2016.

available documentation surrounding another sub-model, the urine patch component of the nitrogen leaching model, makes its pedigree difficult to discern.[131]

Given the evolving state and pedigree of the scientific underpinning of some model components, well documented reasoning for the inclusion and use of particular scientific theories is essential if users are to have confidence in Overseer.

Computational infrastructure

Computational infrastructure refers to the way phenomena are related through mathematical relationships to produce a numeric result in a model. The translation of scientific principles into mathematical relationships is an important aspect of model development.

An evaluation of this translation is needed to ensure the mathematical relationships are appropriate and the model's behaviour approximates the system being modelled.

For Overseer, information on many of the mathematical equations used can be found in the technical manual chapters which accompany the individual sub-models and are publicly available. But for some aspects of the model these chapters are withheld by Overseer Ltd (e.g. the urine patch and background sub-models).[132]

Some information can also be found in published journal articles and external reports written for Overseer. However, one thing that is sometimes missing from this documentation is information on the reason for equation and parameter choice where multiple options are available.[133]

No part of the Overseer source code has ever been publicly available.[134]

Without full access to the model structure, code and all supporting documentation, a comprehensive evaluation of the computational infrastructure of Overseer is not possible.

Assumptions and limitations

The important assumptions and limitations of a model, and the degree to which these are documented, are key pieces of evidence used to evaluate a model.[135]

The communication of Overseer's assumptions and limitations affects the level of understanding users have and, in turn, can significantly affect the way regulators approach the use of Overseer.

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[131] The Overseer website lists scientific papers, including some related to urine patch dynamics, but the related interactions within the full model are not described. Overseer scientific publications website (https://www.overseer.org.nz/science-papers).

[132] See chapter 3.

[133] See, for example, Pacheco et al., 2016, p.1.

[134] There is one instance of the code being made available under a non-disclosure agreement for external examination, (Pers. comm., Harry Clark, 2018).

[135] NRC, 2007; Özkundakci et al., 2018.

AgResearch has set out the key assumptions of Overseer in a useful document aimed at regional council staff.[136] While this provides a list of these assumptions, the scope of the document did not extend to describing just what these assumptions mean for the way regional councils should use the model.

This gap was targeted by two reports, the first by Freeman et al. in 2016 and a further report by Enfocus Ltd in 2018.[137] These reports provide information and advice to those using or considering using Overseer in the context of establishing freshwater objectives and limits under the National Policy Statement for Freshwater Management, and in resource consent processes.[138] In particular, Freeman et al. provides a useful table addressing the model's assumptions and limitations and what they mean for the use of Overseer in regulation.[139] The Enfocus report contains a broad discussion of similar issues in a more concise format.

These reports highlight that some of the fundamental assumptions made in the Overseer model affect its use in a regulatory setting. This emphasises the need for regulators to consider assumptions and limitations throughout a regulation making process. However, in the case of Overseer, this is made difficult by the limited available documentation and scrutiny that has historically been able to be applied to the underlying model.

Peer review

Peer review critically evaluates the adequacy and implementation of the scientific and technical components of a model. Such reviews should be undertaken by individuals who collectively have at least the same technical qualifications and experience as the model developers, but who are independent of those who performed the development work. However, consultation between developers and reviewers is likely to improve the review.[140]

Defining the purpose and scope of a peer review is very important, as the framing of the review will have implications for the selection of appropriate reviewers, types of recommendations and the aspects of the model that are investigated.

The peer review process is not unidirectional, with the response to recommendations by model developers being as important as the independent review that is undertaken. As a peer review process is intended to improve model functionality, a review by itself does not achieve this. Once a peer review is completed, any issues and recommendations raised by reviewers need to be discussed with model developers, a consensus reached and any agreed changes that need to be made (or not made) need to be documented. Documentation should take the form of an acknowledgement of

[136] Watkins and Selbie, 2015, pp.28–30.

[137] Freeman et al. (2016) was commissioned by a number of regional councils, Ministry for the Environment, Ministry for Primary Industries and industry groups. The Enfocus report (Willis, 2018) was commissioned by Overseer Ltd.

[138] Neither report examined the underlying model design. Rather, the reports considered how the model could be best used 'as is'.

[139] Table 1 in Freeman et al., 2016, pp.13–16.

[140] United States EPA, 2009, pp.23–24.

changes in release notes and a fuller explanation of changes in a published document of responses to reviewers' comments.

Several peer reviews of aspects of the Overseer model have been undertaken. Each review has focused on a specific sub-model, ranging from investigating the science available to support the use of the Overseer model conceptual framework to assessing the implementation of different components of the model.

Overseer model components that have been reviewed include: the use of soil parameters,[141] greenhouse gas sub-models,[142] the metabolisable energy sub-model,[143] the phosphorus loss sub-model,[144] and the hydrology sub-model.[145] Key themes raised by these reviews included the need to update the model to reflect the latest scientific understanding, the inclusion of new features, better documentation and increased transparency, the need for recalibration using expanded datasets, and the need to carry out uncertainty and sensitivity analyses.

Generally, the responses to recommendations and comments that have been made during the course of the peer reviews have not been documented (although some changes are noted in the release notes of model updates since Overseer Version 6.0). As a result, it is often unclear how and what review recommendations have been incorporated into the Overseer model.

The level of detail in the peer reviews of Overseer model components has varied. Difficulties in gaining access to aspects of Overseer that are not publicly available have been noted as a particular obstacle to generating a full picture of the model's functionality and implementation.

This has resulted in reviewers repeatedly highlighting the need for increased and improved documentation and transparency. This is often raised not only in the context of improving the ability of reviewers to assess the functionality of the Overseer model, but also to improve trust in modelling outcomes.[146]

The potential benefit of peer reviews to the quality of the model is apparent from those few that have been conducted. For example, in 2014 model developers worked with the S-map team at Manaaki Whenua Landcare Research to understand how soil properties and categories were used in Overseer. The resulting review identified a number of opportunities to improve the description of soil processes within Overseer.[147]

While reviews of the individual sub-models are important undertakings, a review of the entire model is needed to complement sub-model reviews. This whole-of-model peer review is particularly important in the case of Overseer, given its complexity,

[141] Pollacco et al., 2014.

[142] Kelliher et al., 2015; de Klein et al., 2017.

[143] Pacheco et al., 2016.

[144] Gray et al., 2016.

[145] This review was led by D. Horne from Massey University in 2014, but is not publicly available.

[146] Comments from individual reviews are presented in chapter 3.

[147] Pollacco et al., 2014.

the significant number of disciplines that interact within the model, and the range of different uses made of the model by different stakeholders (e.g. farmers and regulators). To date, such a whole model external review has not been undertaken.

2. Is the model managed to ensure quality?

Quality assurance and quality control

Quality assurance practices are designed to ensure that model implementation – and changes that are made to it – is robust, justified, and well documented. The level of quality assurance needed is dependent on model use and what model fitness-for-purpose looks like. Quality control, on the other hand, is designed to minimise the introduction of errors (e.g. coding errors) and ensure that the model is computationally fit for purpose. Both practices often include planning, documentation, assessment, and reporting of model functions and code development.

The implementation of quality assurance and quality control for the Overseer model was historically the responsibility of the model's scientific developers, AgResearch. Following the formation of Overseer Ltd, that company has taken over responsibility for quality assurance and quality control, with input from AgResearch.

For Overseer, quality assurance has largely taken the form of scientific developers ensuring that current scientific understanding has been included in the model and the commissioning of reports to investigate specific aspects of farm systems to be included in the future. Historically the inclusion (or not as the case may be) of elements into the model has fallen to a small number of developers, with the reason for changes to the model (beyond brief release notes) not always being made explicit.

Overseer Ltd is currently in the process of developing a science advisory panel to assess protocols and processes for the inclusion of new model elements and the revision of current elements.[148] An advisory group of this nature has the potential to provide more transparency about the model development process. However, good practice would be for any decisions made by Overseer Ltd (in response to recommendations from an advisory group) being made publicly available and open to scrutiny to ensure trust in the decision-making process. This is something that has been perceived to be lacking historically.

Since Overseer Version 6.0, communication of quality assurance practices has also taken the form of publishing release notes associated with version changes on the Overseer website. The release notes provide an outline and narrative of model and user interface changes. The level of detail in release notes may be acceptable if the intent is to communicate the types of changes that have been needed to ensure the model is functioning. But it will be insufficient to answer questions about exactly what changes have been made, and why, and how individual changes may cascade through the model operations.[149]

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[148] Pers. comm., Caroline Read, 2018.

[149] A comparison of the net effect of version changes on nutrient loss and greenhouse gas emissions has been reported in release notes since Overseer Version 6.2.1, by comparing model runs between the old and new versions using farm files held by AgResearch.

The release notes also encompass several elements of quality control, such as ensuring that the computational implementation of the model is fit for purpose. This includes information about descriptions of fixes to the code and dealing with known issues and errors. Other aspects of quality control (e.g. version control, user manual, information technology requirements for external parties such as S-map, and user issue reporting) are also documented and available in various locations.[150]

Ultimately, quality assurance and quality control processes must contribute to trust and confidence in any model. Consolidating information into a single accessible repository that describes the processes that are currently implemented to ensure quality assurance and control would be beneficial for Overseer users.

Data availability and quality

This element of the framework is focused on the availability and quality of data that can be used for both developing model input parameters and assessing model results.

The three main aspects are:

- data used as default and user-defined inputs to the model
- data used to estimate values of model parameters
- data used for model evaluation.

The availability of input data depends on the type of input. For example, soil data from Manaaki Whenua Landcare Research's S-map and climate data from NIWA's Virtual Climate Station Network are available as default input data from the original providers. However, Overseer also requires user-defined farm management data. This data can be unreliable and difficult to obtain.[151]

Data used for model development and parameterisation is not readily available for peer review and the way the data has been used is unclear. Several coefficients in the Overseer equations need to be calibrated using empirical data. However, only a limited number of studies have been conducted (e.g. lysimeter studies at a small number of predominantly dairying sites in both the North and South Island measuring nitrogen leaching but not covering all soil types and rainfall regimes).[152] While summary papers and research articles are often published at the end of experiments, actual datasets are often not. While Overseer developers have generally been able to access that data, the wider science community has not.[153]

[150] For example, aspects of quality control are described in Watkins and Selbie (2015) and on the Overseer website (https://www.overseer.org.nz/).

[151] However, Overseer Best Practice Input Standards advise users on appropriate input selection for user-defined data.

[152] Best modelling practice recognises that collecting new data is a challenge, and recommends that modellers should build relationships with researchers and those responsible for collection of additional data to determine how such new data can guide model development (NRC, 2007, p.72).

[153] For example, in order to calibrate Version 6 of Overseer in 2012, model developers have been able to access a range of farmlet datasets, including unpublished data from Manawatū and Lincoln University Dairy Farm (Shepherd et al., 2015).

Source: Parliamentary Commissioner for the Environment archives

Figure 5.1 Lysimeters have been developed to quantify nutrient leaching losses from soil by capturing all the water leaving a defined area of soil, which can then be analysed for its nutrient concentrations. This information can be used to improve Overseer model estimates.

Finally, a lack of available data has meant that a formal model evaluation hasn't been undertaken. Some informal or qualitative analyses (sensibility testing or expert judgment) seem to have been undertaken, but these have not been publicly documented. This is despite the fact that Overseer's developers envisaged that model evaluation would be ongoing.[154]

Test cases

Test cases help to determine whether the model software is working in a reliable and consistent way. This process involves a suite of software checks including the absence of 'bugs', stress testing and reasonableness checks.[155] The methods used and results obtained should be documented.

[154]Shepherd et al., 2015.

[155]NRC, 2007, p.74.

While test case comparisons are likely to have occurred at various stages of Overseer's development, the testing process followed by Overseer Ltd is generally not documented on the website or available in other materials.

Currently work is underway by Overseer Ltd to develop the software in a way that will allow the isolation of various components and sub-models of Overseer.[156] This will improve Overseer Ltd's ability to conduct test case comparisons on individual model components.

3. Does the model's behaviour approximate the real system being modelled?

Sensitivity and uncertainty analysis

Acceptance of model outputs, by the regulated and regulators alike, is ultimately dependent on confidence that the model represents the conditions that are being modelled.

Sensitivity analysis involves interrogating the model to determine how sensitive it is to changes in different elements and attributes.[157] Sensitivity analysis is normally undertaken by the model developer to help calibrate the model and quantify uncertainty, and also to guide further experimental and modelling work. It can also help users to understand the system being modelled and to build confidence in the model.

Uncertainty analysis builds on sensitivity analysis to quantify how natural variability, model framework uncertainty, and input uncertainty contribute to the likelihood that the model output truly reflects the real world (see chapter 2 and chapter 3 for more details).[158] Generally both analyses are undertaken in tandem.

Uncertainty and sensitivity analyses help parties make informed decisions and increase confidence that any decisions made using model outputs are appropriate. As such, these analyses are a critical aspect of model evaluation, both during the model's development and its use.[159] Within a regulatory context, failure to communicate and manage uncertainty in a meaningful way may also result in legal challenges.[160]

[156] Pers. comm., Caroline Read, 2018.

[157] Sensitivity analysis is typically carried out by running a model a number of times, incrementally changing inputs around a single defined value (local sensitivity analysis) or across the entire feasible range of input values (global sensitivity analysis), and comparing inputs against outputs to understand the relationship between the two. Variability can either be assessed using one-at-a-time (varying each input individually) or all-at-a-time (vary all input factors simultaneously) methods. In general all-at-a-time methods provide a better characterisation of the sensitivity of the input factors.

[158] There are different ways in which the estimate of uncertainty (i.e. the result from an uncertainty analysis) can be described. For example, uncertainty can be quantitatively described with mean and standard deviation, with a 95% confidence interval, risk probability (e.g. of exceedance) or qualitatively (e.g. level of confidence expressed as likelihood classes). The quantitative descriptions can be generated using approaches such as analytical (e.g. Taylors Series approximation and other mathematical techniques), simulation-based (Monte Carlo methods, importance sampling), Bayesian, and non-probabilistic methods (e.g. fuzzy, interval). Qualitative descriptions can be generated using expert judgment of likelihoods.

[159] NRC, 2007, pp.79-87.

[160] Özkundakci et al., 2018, p.60.

Formal uncertainty and sensitivity analyses have not to date been carried out for Overseer. This is despite numerous calls for these analyses.[161]

Available literature on Overseer provides users with some basic understanding of the sources of uncertainty, and some guidance on how to reduce the level of uncertainty of input data.[162] However, the absence of a formal uncertainty analysis for the whole model, or for component parts, is a significant shortcoming in the development of Overseer.

The justification for not undertaking a full uncertainty analysis has centred on the complexity of the Overseer model, the limited amount of data available for testing, and the difficulty of identifying and quantifying all sources of uncertainty in the model.[163] Limited studies focusing on parts of the model – often relying on expert judgment – have been carried out. However, the majority of these are outdated and some are not publicly available.[164]

No model will ever be perfect and there will always be uncertainty associated with results. But, without an uncertainty analysis for Overseer, it is difficult for regional council staff to engage with interested parties about the level of certainty that can be attached to modelled nitrogen losses. In the absence of an uncertainty analysis, Environment Canterbury has used collaborative expert judgment analysis to estimate uncertainty of Overseer-derived nitrogen losses.[165] This highlights the desire of users to have access to uncertainty analysis in some form to support their engagement with interested parties and make better-informed decisions on appropriate limits.

Undertaking sensitivity and uncertainty analyses would improve transparency and increase trust in the model. It would also help improve the model by identifying elements in need of further research or elements that do not contribute substantially to model outputs.

Corroboration of model results with observations

Corroboration involves comparing model results with data collected in the field or laboratory to assess the accuracy and improve the performance of the model.

The approach may be quantitative (e.g. using statistics to estimate how closely the model results match measurements made in the real system), or qualitative (e.g. using expert knowledge to obtain understanding about a system's behaviour). The former approach may be appropriate in data-rich situations, while the latter approach may be preferred where data is scarce.[166]

[161] For example, Polacco et al., 2014, Gray et al., 2016 and Freeman et al., 2016.

[162] For example, Shepherd et al, 2013; Watkins and Selbie, 2015; Overseer web page (https://www.overseer.org.nz/how-overseer-engine-works).

[163] Etheridge et al., 2018.

[164] For example, Ledgard and Waller (2001). The need to undertake an uncertainty analysis is on Overseer Ltd.'s radar, with an initial proposal in development (pers. comm., Caroline Read, 2018).

[165] Etheridge et al., 2018. This analysis was done for the Waimakariri Zone.

[166] United States EPA, 2009, p.65.

Sometimes, the term 'validation' is used to describe this process. 'Corroboration' is a better term as validation implies a claim of truth, and no model is ever *truly* validated.[167]

The previous chapter described another process in model development – 'calibration'. This is the process of adjusting model parameters so that the resulting predictions give the best possible fit to the observed data. The reason it is relevant to this section is that the model calibration step can be linked with a corroboration step where a portion of the observations are used to calibrate the model, and then the calibrated model is run and results compared with the other portion of data to corroborate the model. The key point here is that a different data set is used for each process.

A full corroboration of the model has never been undertaken.[168]

In respect to nitrogen leaching estimates, a calibration process took place in 2012 prior to the release of Overseer Version 6.0. A revised nitrogen pastoral grazing sub-model was calibrated against nitrogen leaching measurements.[169] During this process up to three parameters were adjusted to give reasonable agreement between modelled estimates and measurements from a limited set of data. Sensibility testing also took place. But this is not documented. A limited dataset of nitrogen leaching data meant there was insufficient data to both calibrate and formally corroborate the model.[170]

Work is currently underway to recalibrate several sub-models used to estimate nitrogen leaching (the hydrology, urine patch and background nitrogen sub-models).[171]

Ongoing corroboration of all model components in line with best practice would be valuable. In addition, the procedure followed and results generated should be well-documented and publicly available.

Benchmarking against other models

Benchmarking compares one model with other similar models.

Over the years, researchers have made several attempts to compare nitrogen loss estimates generated by Overseer with a more complex mechanistic model called an Agricultural Production Simulator (APSIM). For example, in 2015 researchers compared nitrogen leaching estimates generated by the two models from well-drained soils under a dairy farm. Both models produced plausible estimates (i.e. within the same order of magnitude). However, some disagreements between the models were identified.[172]

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[167] NRC, 2007, p.138.

[168] Shepherd et al. (2015, p.5) note the need to calibrate and evaluate various model components.

[169] The studies used for the 2012 calibration included (Shepherd et al., 2015): Ruakura dairy farm (Waikato, N rate and stocking rate trials); Scott Farm (Waikato, three farm systems and a range of soils types); Edendale (Southland, intensive beef, a range of N rates); Tussock Creek (Southland, duration of grazing and DCD (dicyandiamide)); Manawatū (effluent). Additionally, extra unpublished data was secured from Manawatū and Lincoln University Dairy Farm (covering Templeton and Eyre soils).

[170] Shepherd et al, 2015, p.2.

[171] Pers. comm., Caroline Read, 2018.

[172] Vibart et al., 2015.

A comprehensive effort to compare nitrogen loss estimates for crops derived from the same two models – Overseer and APSIM – was undertaken by Plant and Food scientists in 2016. The testing focused on Overseer's crop module and aimed to identify discrepancies occurring between Overseer and APSIM. However, the scientists couldn't interrogate the Overseer code – they could only compare whole model outputs. As a result, they couldn't identify the exact reasons for any discrepancies, and recommended further areas for investigation.[173]

Another example of benchmarking is the comparison of irrigation and drainage estimates from IrriCalc and a modified version of Overseer.[174] This comparison was undertaken in response to concerns about Overseer's irrigation sub-model. The authors compared average annual estimates of irrigation and drainage for a range of soils and climates, and irrigation management regimes produced by IrriCalc and a modified version of Overseer. The comparison highlighted general agreement between the estimates from the two models. It also highlighted some differences in the estimates of irrigation depth for variable irrigation management scenarios. Further investigation to understand the causes behind discrepancies was suggested.[175]

4. Is the model appropriate for a specific regulatory application?

Model resolution

Model resolution refers to the spatial or temporal scale at which the model operates. This is compared with the scale at which the model is going to be used.

Overseer operates at block and farm scales, and produces long-term annual average outputs. This spatial and temporal resolution stems from the model's original application – helping farmers identify maintenance fertiliser requirements for pastoral blocks on farms.

As a result, much of the temporal and some of the spatial variability is averaged within Overseer. This means that although input information for a specific year can be added, the rate of nutrient losses represents the long-term trend, not necessarily the rate for that particular year. Setting aside attenuation beyond the root zone, Overseer's long-term nutrient loss predictions are a better fit when the receiving body is also broadly sensitive to long-term impacts (e.g. aquifers and lakes). Conversely, rivers are more sensitive to fluctuations of nutrient inputs at shorter timescales, which Overseer does not predict.

[173]Khaembah and Brown, 2016. Some discussion to address the recommendations raised has occurred since (pers. comm., Caroline Read, 2018).

[174]IrriCalc is a web-based single-layer soil water balance model. It uses daily measurements or estimates of irrigation, rainfall, drainage, and actual evapotranspiration to calculate daily soil water content. The hydrology sub-model in Overseer is similar to IrriCalc in that it is also a single-layer soil water balance model that uses a daily soil water content calculation to estimate daily drainage. IrriCalc website (http://mycatchment.info/). For more discussion on the benchmarking exercise see Wheeler and Bright (2015).

[175]Wheeler and Bright, 2015.

In contrast a dynamic model (for example APSIM) can describe nutrient losses at finer spatial and temporal scales (a point in a paddock, and on a daily time step).

However, dynamic models are often developed to be site-specific, require large amounts of input data, and greater expertise is typically required to run them. These factors limit the use of dynamic models to the research environment primarily.

The resolution of Overseer is broadly in line with some of the regional council requirements and goals (e.g. property scale). However, Overseer's resolution is not consistent with the need to manage nutrient impacts at the catchment scale (e.g. the combined impact of nutrient losses from a number of properties and other sources within a catchment). Trade-offs and compromises will naturally need to be made between model resolution, regulatory needs and the resources needed to review, improve and implement Overseer.

Transparency

Transparency refers to the ability of scientists (e.g. peer reviewers), affected parties and members of the public to comprehend the essential workings of the model and understand the processes followed in developing, evaluating, and applying a model.

For models used in environmental regulatory decision-making, high standards of transparency are important for a range of reasons. Most fundamentally, those affected by regulations have a right to understand the basis on which the regulations were made.

Greater transparency also allows independent experts to offer a constructive critique of model components, and could also result in the model being improved by third parties.

Previous sections have highlighted a number of key pieces of information about Overseer that need to be documented and made publicly available (e.g. the crop based nitrogen sub-model and the urine patch sub-model). This information should cater for both lay users of the model (farmers, regulators, and the public) and scientists.

Regulators, farmers, and the wider public need a working understanding of the model – that is, what the model can and cannot do and the level of uncertainty associated with its estimates. As non-scientists, these users need documentation that is clear and well-presented. The documentation should openly convey the strengths and weaknesses of the model. The *Technical Description of OVERSEER for Regional Councils* provides a comprehensive resource on these matters for regulators, farmers, and the wider public.[176]

Scientists want more detailed information about a model's workings, particularly those peer reviewing a model, or using it for research purposes. For these purposes, documentation should state the underlying scientific principles, sources of data and equations used to build the model engine.

[176]Watkins and Selbie, 2015.

Overseer Ltd currently documents this information in its technical publications. To its credit, the majority of Overseer sub-models or components have been documented in the form of publicly available technical manual chapters. However, several issues remain.

- A small number of model components, including those relating to crop growth and some allocation procedures, are not documented at all. In some instances there is a limited write up in the form of a manuscript from a presentation at the annual Fertilizer and Lime Research Centre Workshop, but this does not provide the same level of detail as a technical manual would usually provide.
- Several components of the model, including the animal model, the crop-based nitrogen sub-model and the urine patch sub-model, are documented in a technical manual chapter but the chapter is not publicly available (see chapter 3). These technical manuals are intentionally withheld under the Overseer Intellectual Property (IP) Policy.
- Technical manual chapters are lacking important details, such as the reasons behind the choice of equations or omission of components, which could be critical. In a 2016 review of the metabolisable energy requirements sub-model, many of the recommendations relate to the need to provide a clearer rationale for the choice of equations.[177]

These issues mean scientists (e.g. catchment modellers) and users continue to be seriously limited in their ability to understand the workings of Overseer. Independent peer review is currently prevented for several components of the model where technical documentation is not available (including several components fundamental to estimating nitrogen loss) unless special access to Overseer documentation is negotiated.

Some scientific reviews will require greater detail about how the model works than the level of documentation currently available. Reviewers require a good scientific understanding of the processes being modelled. In addition, they need access to the source code to ensure that numerical algorithms have been correctly implemented in the software. Access to the code is also important for scientists hoping to improve the model (e.g. those wishing to conduct sensitivity analysis). However, the source code of Overseer is proprietary and Overseer Ltd is prevented from sharing it under the Overseer Ltd IP Policy.

There is only one instance where access to the source code has been provided to an external party. In this case, a small working group (including modellers, programmers and animal, soil, and system scientists) were granted permission to scrutinise the code, in order to review the choice and implementation of the equations for the animal sub-model and calculation of methane and nitrous oxide.[178] This work is being completed to standardise algorithms and equations between Overseer and the New Zealand Greenhouse Gas Inventory and allow Overseer to be used for farm-scale greenhouse gas reporting.[179] At the time of writing the resulting review was not yet published.

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[177] See Pacheco et al., 2016.

[178] Pers. comm., Harry Clark, 2018.

[179] de Klein et al., 2017, p.5.

Can Overseer be used in a regulatory context?

Overseer can provide farmers with valuable information when making judgments about farm management, and when working with fertiliser companies and farm consultants. However, using Overseer to estimate nitrogen loss to meet regulated limits changes the way its output is viewed – even if published guidance on how to use the model has been followed. The level of trust placed in modelled outputs is crucially dependent on what's at stake – who carries the risks of decisions being taken on the basis of the model's outputs? Farmers may be happy enough with the model as a decision support tool for farming purposes, but demand a much higher level of assurance when the consequences can be used to compel legal compliance.

Although Overseer has been accepted by the Environment Court for use by councils in regional plans to manage nitrogen losses, it has not been subject to the rigorous formal scrutiny necessary for regulators and regulated alike to have full confidence in its fitness for purpose.[180]

The assessment undertaken in the section above revealed that a significant amount of information that is needed to assess Overseer's fitness for purpose is lacking. A comprehensive and well-resourced evaluation of Overseer should be undertaken. Initiating this will inevitably require access to the 'engine' of the model, which in turn raises important questions about the proprietary nature of Overseer. These issues are discussed in the next chapter.

It would be tempting to conclude that Overseer should not be used in regulation until such an evaluation is carried out. However the decision to use a model is not based only on scientific criteria. Public values, economic, social and legal considerations also contribute to the decision.

The National Policy Statement for Freshwater Management effectively requires councils to manage diffuse discharges of nitrogen. Councils can specify practices that are known to be beneficial in terms of reduced nutrient losses, although this can still be a resource-hungry process. In some cases ensuring farms are following good management practices, through a monitored and enforced farm plan programme, will be sufficient.

Where nutrient loadings in a catchment are clearly beyond anything that is consistent with safeguarding the life-supporting capacity of receiving waterbodies, councils need to determine what reductions are required across the whole catchment, and to know that specific, quantifiable reductions can be achieved on each individual property. There is a need to have a tool capable of quantifying nitrogen lost from farms. Overseer can fulfil this task.

[180]For example, Overseer's use in managing nitrogen leaching from farming using Overseer-determined nitrogen discharge allowances for individual properties was first accepted by the Environment Court in its decision on Waikato Regional Council's Proposed Variation 5 to the Waikato Regional Plan. See *Carter Holt Harvey Ltd v Waikato Regional Council*, Environment Court, Auckland, A123/2008, 6 November 2008.

It appears from this investigation that most, if not all, of the regional councils currently using Overseer for determining compliance with nitrogen limits do so in this context – i.e. the severity of the nitrogen problem they face has led them to Overseer. Council staff acknowledge the tool is far from perfect, but blunter tools would be required if Overseer was not available.

This investigation has identified some important gaps and shortcomings in transparency, peer review, corroboration, uncertainty and sensitivity analyses, and the way the model has been documented. If Overseer is to continue to be used in a regulatory setting, these shortcomings need to be speedily addressed to provide confidence to the regulators and regulated alike. This is essential to building trust in its application and in the nutrient limits that are being set.

It should also be recalled that Overseer assumes good management practices are occurring on farms. To be able to have confidence in a regulatory framework using Overseer-derived nitrogen loss limits, regional councils must be satisfied that these practices are occurring. Regional councils therefore would do well to spend effort monitoring farms for compliance with these practices alongside any Overseer-based framework.

Source: Dr Mike Joy

Figure 5.2 Excess nutrients can promote unwanted algae and plant growth in streams and lakes, leading to low oxygen levels that affect fish like this kōaro (*Galaxias brevipinnis*) and other species. At extreme levels, nutrients can directly reduce the life-supporting capacity of waterways.

6

Ownership, governance and funding of Overseer

A history of ownership, governance and funding of Overseer

Overseer's roots date back to 1982 when the Ministry of Agriculture and Fisheries Fertiliser Advisory Service attempted to summarise all available fertiliser research and provide standardised advice on fertiliser application. The rationale for this advice was essentially economic.

The Ministry and the fertiliser industry's interest in understanding agriculture's impacts on freshwater and helping farmers to manage these impacts came later in the early-1990s. By then, publicly funded research on fertiliser application was in the hands of one of the new Crown Research Institutes, AgResearch Ltd ('AgResearch').

At the time, AgResearch was developing a model called "Outlook" – an econometric model that could calculate optimum fertiliser recommendations. The Ministry of Agriculture and Fisheries, along with the Fertiliser Association, wanted to develop a model that could help farmers, advisors, and industry staff understand nutrient balances better, both with respect to improved fertiliser use *and* to provide a better understanding of nutrient flows in an environmental context.

By combining the nutrient balance component from the Outlook model with the 'PKS Lime model' (a fertiliser decision support model that was also being developed at the time), AgResearch was able to provide a way forward. The resulting model became "Overseer" in 1999.

It was, from the outset, hampered by funding. The Ministry had only small amounts of funding to develop the model. However, the Fertiliser Association expressed an interest in contributing to the model's development. AgResearch offered in-kind contributions. From the Ministry's point of view, this provided both welcome resources and a continued collaboration with an organisation that had a ready network of farmers and farm advisors, and an organisation with research experience.

In the late 1990s, a Memorandum of Understanding (MoU) was drawn up between the Ministry of Agriculture and Forestry, the Fertiliser Association, and AgResearch establishing equal joint ownership of Overseer. The Ministry and the Fertiliser Association were to provide funds and AgResearch was to provide intellectual property. Total funding of approximately $100,000 per year was secured.

Overseer's use in a regulatory setting first arose in 2005 when the Waikato Regional Council notified Variation 5 of its regional plan relating to the Lake Taupō Catchment. This was a high-profile water quality challenge involving an iconic water body. The first more generalised recourse to Overseer was made by Horizons Regional Council in its *One Plan*, notified soon afterwards in 2007.

Source: Parliamentary Commissioner for the Environment archives

Figure 6.1 Lake Taupō in the central North Island is valued for its scenery, clean water and internationally renowned trout fishery. Concerns with increasing nitrogen loading in the lake, particularly from intensive farming nearby, led the Waikato Regional Council to impose a nitrogen cap for land users in the catchment. Farm-scale nitrogen losses and targets were calculated using Overseer, although a key part of the approach was the establishment by the National Government of a fund to help buy properties in the catchment and retire them from pastoral farming.

In the same year, the New Zealand Government decided to establish an emissions trading scheme for greenhouse gases. A tool that could estimate greenhouse gas emissions from a farm was needed and Overseer was the only readily available option. The importance of accurate estimations for New Zealand's international reporting obligations under the United Nations framework convention on climate change (UNFCCC) provided some urgency to the task of a significant upgrade of Overseer. A funding boost from the three owners in 2007 provided Overseer with $1.2 million per year for five years, its largest budget to date.

The owners recognised the need for a more formal ownership agreement to replace the MoU. That ownership agreement was signed in 2009. It confirmed the joint equal ownership of Overseer by the Ministry of Agriculture and Forestry, the Fertiliser Association, and AgResearch.

The essence of this ownership arrangement remains in place under an updated agreement signed in 2016. Today it is the Ministry for Primary Industries (MPI), the New Zealand Phosphate Company Ltd, and AgResearch that each own a one-third share in Overseer intellectual property.[181]

Within five years, it became clear that the growing demands on the model were outstripping the owners' capacity to develop the model to meet them. These demands included the requirements of regional councils, the need for wider stakeholder engagement, increased technical resourcing, and management systems to better control development of the model. In 2013, Overseer Management Services Ltd was established, with the appointment of a general manager to address these needs.

The owners also sought a new, financially sustainable structure for Overseer that would relieve the owners of the need to fund it indefinitely.[182] In 2015, various different resourcing options were explored. These included: leveraging funding as joint ventures with primary sector agencies, introducing a user charge, and MPI redirecting funding from other programmes. The possibility of funding from regional councils was investigated, but ultimately this came to nothing.[183]

The owners also concluded that Overseer's governance needed to evolve to introduce clear accountability, manage perceptions of conflicts of interest, and to limit their liability.[184] MPI, supported by AgResearch, initially favoured a discrete business unit within MPI. The Fertiliser Association did not support such an approach, preferring a limited liability company and the creation of a more commercially responsive management structure.[185]

[181] The New Zealand Phosphate Company Ltd became an owner following assignment of ownership by the Fertiliser Association of New Zealand in 2016.

[182] MPI, 2014, 2015a.

[183] MPI, 2014, 2015b,c.

[184] MPI, 2015d.

[185] MPI, 2015b.

Agreement on a new governance model was reached in 2016. A limited liability company would manage the day-to-day running and development of the model, while the owners would retain existing and new intellectual property. This new company was incorporated in 2016 and named 'Overseer Ltd'.

The owners granted Overseer Ltd an exclusive licence to Overseer's intellectual property. The company's mission is to procure science and technical input, grow revenue sources, market Overseer, liaise with stakeholders, and manage and improve Overseer's intellectual property, *inter alia*.[186] The three owners agreed to contribute financially or in-kind to Overseer Ltd for three years.[187]

Unlike the tripartite ownership of the intellectual property that Overseer represents, Overseer Ltd has just two shareholders, AgResearch and the New Zealand Phosphate Company Ltd. At the time of incorporation in 2016, Overseer Ltd's shares were held equally by the two shareholders.

The Crown restricts its shareholding in private companies. As a result, the Ministry for Primary Industries has no shareholding. However, it is granted all the rights and powers of shareholders under the shareholders agreement, such as the appointment of directors. Changes to the company constitution require the vote of the Ministry for Primary Industries appointed director, and shares in the company cannot be transferred to any other party unless there is written consent from MPI. The company constitution also prevents the payment of dividends to shareholders. Income is to be reinvested in the maintenance and improvement of Overseer and the business.[188]

At this point, it is useful to explain the business of each of the three intellectual property owners.

The New Zealand Phosphate Company is a limited liability company trading as The Fertiliser Association of New Zealand Incorporated. The Fertiliser Association is a trade association representing and owned in equal shares by the two major New Zealand manufacturers of superphosphate and nitrogen fertilisers – Ballance Agri-Nutrients Ltd and Ravensdown Ltd. Both companies are farmer-owned cooperatives.

AgResearch is a Crown Research Institute (CRI) established under the Crown Research Institutes Act 1992. This Act requires CRIs to undertake scientific research for the benefit of New Zealand.[189] AgResearch's research focus is primarily pasture-based animal production systems, the products derived from these systems, and the environmental performance of these systems.[190] AgResearch is a Crown Entity

[186]OVERSEER Ownership Agreement, clause 6, executed 29 March 2016.

[187]For the financial year ending June 2017, the Ministry for Primary Industries funded Overseer Ltd $1,000,000. The Fertiliser Association of New Zealand funded Overseer Ltd $937,500 and AgResearch Limited provided $500,000 of in-kind services to Overseer Ltd (Overseer Ltd, 2017).

[188]Shareholders' agreement relating to OVERSEER Limited, executed 29 March 2016, and Constitution of OVERSEER Limited under the Companies Act 1993.

[189]Crown Research Institutes Act 1992, section 5.

[190]AgResearch's core purpose is to "enhance the value, productivity and profitability of New Zealand's pastoral, agri-food and agri-technology sector value chains, to contribute to economic growth and beneficial environmental and social outcomes for New Zealand. AgResearch website (https://www.agresearch.co.nz/assets/Uploads/Statement-of-Core-Purpose.pdf), accessed 3 December 2018.

Company under the Crown Entities Act 2004, which means its ownership must remain 100 per cent with the Crown. It must also generate an adequate rate of return on shareholders' funds, and operate as a successful going concern.[191]

The Ministry for Primary Industries is a government ministry, employing over 2,500 people. MPI's work includes policy development and regulatory responsibilities across the dairy, forestry, horticulture, viticulture, meat and wool, and seafood sectors. MPI is part of the multi-agency Freshwater Taskforce, based within the Ministry for the Environment and charged with freshwater policy.

The Overseer board is responsible for the overall corporate governance of Overseer Ltd. The chief executive is responsible for the day-to-day management of the company and conduct of the business. There are currently nine in-house roles (chief executive, business development, customer services, product manager, two developers, tester, administrator, communications). A science manager role is being investigated.

Overseer Ltd's major focus since its incorporation has been to place Overseer on a financially sustainable basis without ongoing recourse to the owners to fund the maintenance and further development of the model, and to accelerate development of the model.

Overseer Ltd has, from the outset, sought to ensure Overseer achieves its vision as "the trusted on-farm strategic management tool for achieving optimal nutrient use for increased profitability and managing within environmental limits." Despite the growing demands of regional councils to use the tool, at no stage has Overseer Ltd's vision been to create a regulatory tool.[192]

Overseer Ltd's first business plan was approved by the shareholders and MPI in July 2017. The plan established a software-as-a-service business model, including a complete rebuild of the software, increasing customer support, and introducing charging. While the model has been available free of charge from its inception, the business plan proposed users would be charged to use the new software.

In early 2017 it became apparent that the business plan would not be successful without additional funding in the short term. New Zealand Phosphate Company Ltd and Overseer Ltd entered into a redeemable preference share (RPS) arrangement under which New Zealand Phosphate Company Ltd advanced funds to Overseer Ltd, subject to interest and an obligation on Overseer Ltd to redeem the RPS for cash (repaying the funds advanced) at the end of the specified period. If the funds advanced (plus accrued interest) are not repaid at the end of the period specified under the RPS arrangement, those redeemable preference shares will be converted to ordinary shares.[193]

[191] Crown Entities Act 2004, section 51.

[192] Overseer Ltd, 2015.

[193] Under the Redeemable Preference Shares Subscription Agreement between Overseer Limited and New Zealand Phosphate Company Limited, $550,000 had been paid by New Zealand Phosphate Company Limited at 30 June 2018 (Overseer Ltd, 2018b).

AgResearch Ltd has an option to subscribe for, in aggregate, up to half the number of fully-paid redeemable preference shares held by New Zealand Phosphate Company Ltd. AgResearch Ltd may exercise its option at any time prior to the redemption or conversion of New Zealand Phosphate Company Ltd's RPS. If AgResearch Ltd exercises its option to subscribe for the maximum number of RPS available to it, and both New Zealand Phosphate Company Ltd's RPS and AgResearch Ltd's RPS are converted to ordinary shares in Overseer Ltd, the proportion of ordinary shares held by each entity will remain unchanged.

The RPS are non-voting shares. As such, the issue of redeemable preference shares does not, on its face, change the governance of Overseer Ltd. The RPS arrangement entitles New Zealand Phosphate Company Ltd and AgResearch Ltd (if AgResearch Ltd exercises its option to subscribe for RPS) to a dividend, the result of which is that interest accrues on the funds advanced by each RPS holder to Overseer Ltd. Other than that dividend entitlement, the issue of RPS does not affect the requirement that profits are reinvested in the company.[194]

More recently still, the Government announced further funding of $1.25 million per year for four years to support improvements to Overseer.[195]

The new software, 'OverseerFM', was released on a free-of-charge basis in June 2018, but an annual subscription per farm account will apply from January 2019. The amount of the subscription has yet to be confirmed.

The transition to a software-as-a-service model has enabled a major change in the way Overseer is accessed. This means farm data is stored centrally within a farm account. Farmers can submit information to councils and other organisations using the "publication" function from their farm account.

It is anticipated that the central repository of farm data will be a significant time saver. Once a baseline farm analysis is set up within a farm account, it can be reused and amended without having to create a new analysis from scratch.[196]

The "user interface" – the part of the software people see and interact with – has been significantly overhauled with improved design and functionality. A report commissioned by Overseer Ltd to quantify the benefits of OverseerFM, estimated time savings of 25-50 per cent (between three to five hours) when generating a nutrient budget in OverseerFM compared to OVERSEER Nutrient Budgets version 6.3.0. A key factor in the time savings is the new mapping feature in OverseerFM.[197]

[194] Redeemable Preference Shares Subscription Agreement between Overseer Limited and New Zealand Phosphate Company Limited; and Redeemable Preference Shares Subscription Agreement between Overseer Limited and AgResearch Limited.

[195] Parker and O'Connor, 2018.

[196] Barber et al., 2018.

[197] Barber et al., 2018.

Aligning ownership, governance and funding with the model's purpose

Chapter 5 described why transparency is important for a model like Overseer that is used in a regulatory setting: those affected by regulations have a right to understand the basis on which the regulations are made. This reasoning is rooted not in science but good public process.

Beyond that, there is a utilitarian argument that greater transparency expands the number of scientists and developers who are able to critique the model, and in doing so contribute to its improvement.

Chapter 5 concluded that gaps in publicly available information mean that Overseer falls short of the transparency required in a regulatory setting. This is equally true for the use of Overseer to determine compliance with nitrogen loss limits as it is for any potential future regulatory use to estimate greenhouse gas emissions.

As the following section argues, making Overseer transparent to render it fit for regulatory use, is inseparable from issues of ownership, governance and funding. This chapter explores these issues and proposes an alternative way forward.

How the intellectual property in Overseer came to be proprietary

As a starting point, it is worth reiterating that Overseer is a proprietary model. A model is proprietary if any component that is a fundamental part of the model's structure or functionality is not available to the general public, or not available without charge.[198] There is a range of ways a model can be proprietary. Currently Overseer has a proprietary source code and some proprietary algorithms and technical manuals, but the user interface is available freely. In 2019, the model will also have a proprietary user interface.[199]

That Overseer today is a proprietary model is the end point of a long evolution that was not preordained from the model's early days. None of the Overseer owners have contributed on the basis that Overseer was valuable software that could earn its owners significant commercial returns. The prohibition in Overseer Ltd's constitution on the payment of dividends to shareholders, and the requirement that income is to be reinvested in the maintenance and improvement of Overseer and the business, are the evidence of that.

Overseer has evolved as it has largely in response to the way it has been funded. The owners did not set out to build a model for regulatory purposes. Consequently the Crown did not scope, then allocate, the investments needed to achieve that. Funds have been allocated by the Crown as pressures for nutrient or greenhouse gas emissions management pressed on the Government of the day.

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[198] NRC, 2007, p.111.

[199] OverseerFM is currently available to the user for free, but in 2019 users will be charged. There is an intention that a research version of the model will be available freely for non-commercial research. (Pers. comm., Caroline Read, 2018.)

The fertiliser industry's interest has been in helping farmers and their advisors to make efficient use of fertiliser, and, in a social and political climate that has increasingly questioned farming's environmental impact, also understand nutrient losses. Retaining a social licence to operate through being able to demonstrate responsible practices provided an important motivation to remain engaged.

While AgResearch has been the source of much of the scientific and technical knowledge needed to develop the model, it has never regarded Overseer as a flagship for technology transfer through commercialisation. It has made the best of whatever resources it has been able to lay its hands on to develop a tool that has been understood as simultaneously advancing the institute's core business of improving the productivity of pastoral systems, and addressing concerns about their environmental sustainability.

The current move to a business model in which both the source code (and some algorithms and technical manuals) *and* the user interface are proprietary appears to have been driven by a desire on the part of the owners to secure a solid funding basis. There is recognition by the owners, that to effectively resource the various development and evaluation activities sought for the tool, significantly more funding is required. The owners' concern is that making the intellectual property freely available could undermine the company's ability to generate the revenue it needs.

The need for secure funding going forward cannot be emphasised enough. Historically, it has been the most important factor limiting model improvements. Following the release of OverseerFM, Overseer Ltd has estimated it will need to generate $4 million per annum to continue to develop and maintain the tool.[200] When this is compared with the $1 million to $1.5 million per annum the tool was receiving up until recently, the scale of the underfunding of the tool becomes apparent.

Would greater transparency undermine the interests of Overseer's owners and the model's future?

The Draft Intellectual Property Policy prepared by Overseer Ltd sets out the approach the company takes to Overseer intellectual property (IP).[201] The policy requires Overseer Ltd to protect Overseer IP to maximise the benefits from the owner's investment in Overseer IP and minimise risks. One of the risks identified in the policy is the development of competitive models by a third party. A competitor model could undermine Overseer Ltd's revenue from user subscriptions and thereby place at risk the future development of the model.

As a consequence of the IP policy, several technical manual chapters have been intentionally withheld from public release. There are limited examples of technical manuals being released under non-disclosure agreements to allow external review.[202] No part of the source code has ever been publicly available. In one instance the code was released under non-disclosure agreements for external review (see Box 6.1).

[200] Pers. comm., Caroline Read, 2018.

[201] At the time of writing the IP Policy was in draft form, having been approved by the Board and awaiting approval of shareholders.

[202] For example the Animal Model technical manual chapter was shared in confidence to enable a 2016 review of the Metabolisable Energy Requirements Model (Pacheco et al., 2016).

Box 6.1 External review of the Overseer model code

In 2018, part of the Overseer source code was made available for external review under a non-disclosure agreement between Overseer Ltd and the reviewers. The review is focused on the choice and implementation of the equations for the animal sub-model and the calculation of methane and nitrous oxide emission estimates.

The foundations for this review were laid several years prior when the New Zealand Agricultural Greenhouse Gas Research Centre initiated a benchmarking exercise comparing greenhouse gas emission estimates by the New Zealand's Greenhouse Gas Inventory and Overseer models. Both models use the same underlying methodology.[203]

During this exercise, differences in estimates were found between the two models, attributed to Overseer's animal sub-model. However, as the researchers did not have access to Overseer's source code they could not be certain.[204] Further studies followed in subsequent years and differences in estimates persisted. An error in Overseer's source code was identified.[205]

This work provided the basis for facilitating access to the animal sub-model code for review in 2018. At the time of writing the resulting review is not yet published, but the results of this study are expected to inform changes to the Overseer source code.[206]

Greater transparency could be addressed at two levels – publication of the model's algorithms and making the model's software open source. The consequences of these no longer being treated as proprietary are considered in turn.

Publishing the model's algorithms – the set of mathematical steps or procedures used to build the model engine – would be an important element in improving Overseer's transparency.

Currently it is impossible for anyone outside the model development team to know how Overseer generates nitrogen loss estimates. Making the algorithms available would of course make them available to any competing model developer. If they were published, they could supposedly be replicated in another model.

It is difficult to know how likely this would be. Any competitor model would presumably have to be funded privately and, if it was to compete with the use of Overseer in a regulation-making context, would be subject to the same transparency expectations recommended in this report.

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[203] The underlying methodology for both models is based largely on the Australian feeding standards (CSIRO, 1990, 2007).

[204] Kelliher et al. 2015; Harry Clark, pers. comm., 2018.

[205] de Klein et al., 2017.

[206] Harry Clark, pers. comm., 2018.

Beyond the potential loss of revenue to Overseer Ltd, competing models would create a challenge for regulators. Councils would be required to store data across a range of model platforms, and the ability to integrate data (from, for example, farms in the same catchment using different models) could present a technical challenge.

The cost to farmers and industry if required to become proficient in using a new model, or several models at once for different purposes, is another consideration. There are also issues of quality control. In a world of multiple models, a regional council would need to ensure that not just one model, but multiple models were fit for their intended regulatory purpose. New Zealand is a small country with a small pool of modelling expertise, and focusing efforts on the development of one model to estimate diffuse nutrient losses may be a better use of these limited resources.

Beyond access to Overseer's algorithms, there is the question of the Overseer software source code – the programming language that tells the software how to function. Software can be associated with several licensing paradigms; the most important distinction is open source versus proprietary software. Generally speaking, software is open source if the source code is free to use, distribute, modify and study, and proprietary if the source code is kept secret.

The arguments for open-source software being used for environmental modelling in a regulatory context are essentially the same as those outlined earlier with respect to transparency. Open-source software facilitates those affected by a regulatory decision to understand the basis on which decisions are made. For this reason the United States Environmental Protection Agency has a preference for using non-proprietary software for environmental modelling.[207]

Open-source software also has the advantage of allowing third-party scientists and developers to freely critique and improve the model. While publishing the scientific basis of the model and the parameters, equations, and algorithms it uses would improve Overseer's transparency significantly, access to the source code is considered the gold standard for encouraging improvements to the models by the wider modelling community.

The Agricultural Production Systems sIMulator (APSIM) moved to an open-source platform in 2007 and remains open source for non-commercial use with its source code available on the web. The move to an open-source platform has encouraged developers outside the founding agencies to modify and enhance APSIM. In addition, the number of users and developers continues to grow, ensuring APSIM's longevity even after many of the foundation members have moved on.[208]

One of the concerns raised with open-source models, particularly those used for regulatory purposes, is a perceived lack of control over what is incorporated into the model. From conversations with modellers and model developers, it appears that this is

[207] United States EPA, 2009, p.31.

[208] Holzworth et al., 2018.

not an insurmountable challenge. The issue can be managed by an organisation acting as a gatekeeper to the official version of the model. That organisation maintains full control, having the ability to manage changes, and decide when an official release of a new version is desirable.

The groundwater model MODFLOW described in chapter 5 provides a case in point. Developed by the United States Geological Survey in 1984, the model's code is open source and the software can be used, copied, modified, and distributed without cost. The model is now used worldwide, including in a recent modelling exercise in the Ruamāhanga catchment.[209] The United States Geological Survey has a "core" MODFLOW version at any one time. This is the version that is under active development and is often the most widely used and most thoroughly tested.

What would be the implications of making Overseer open source? As a starting point, it would be a significant change in terms of the public perception of the model, although the ability to scrutinise the source code would be unlikely to be of significant use to the broader public and stakeholders. However, the model is likely to acquire greater legitimacy with stakeholders because of the potential that is created for accountability on the part of regulators. Stakeholders would be able to seek independent third-party advice on whether the model's assumptions and simplifications were sound. In addition, making the engine of the model transparent creates an opportunity for scrutiny by independent experts.

The new opportunity for independent experts (i.e. those outside the model development team) to modify and enhance Overseer, is perhaps the greatest benefit of an open-source approach. As experience suggests with APSIM, the move to an open-source platform enabled a wider community of developers to modify and improve the APSIM model. Overseer Ltd's decision to release the source code of the animal sub-model under a non-disclosure agreement for external review illustrates the potential for improvements to Overseer when external experts have access to the source code (Box 6.1).

The other significant benefit of an open-source approach would be an enhanced usefulness of the model for research purposes and catchment modelling relevant to regional plan preparation. The closed nature of the algorithms and code within Overseer poses challenges to incorporating it within an interoperable modelling framework, the general intention of which is to have models and data that are open and freely available where possible.[210]

An open-source Overseer would, however, create an additional management challenge. Increased transparency would be accompanied by a need to respond to questions, improvements and critique by stakeholders. Overseer's curators would need to have the resources and processes in place to do this.

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[209] Blyth et al., 2018.

[210] Sandy Elliott, pers. comm. May 2018.

What sort of ownership and funding model would be consistent with a model directed at achieving environmental improvements and one used for regulatory purposes?

Starting from the premise that maximum transparency is in the best interests of those subject to regulation, regulators themselves, and the research community on which they rely, a way needs to be found to support the maintenance and development of the model consistent with that premise.

A simple, blunt solution would be to require that when regional councils are seeking to manage nutrient losses in their plans, at least for pastoral farms, Overseer should be the only accepted model for this purpose. A national environmental standard or other regulation under the Resource Management Act 1991 could be used to mandate this. This would make official what has, in fact, been the approach of government throughout Overseer's development history.[211]

One concern with such an approach is that it would reduce the incentive for innovation. Central and regional levels of government would need to ensure that Overseer remained the subject of regular evaluation and improvement.[212] On the other hand, the very nature of an open-source model encourages third-party innovation and improvement.

Another concern is that managing diffuse nutrients requires more than just dealing with pastoral farms. Other land uses can have significant nutrient losses. New markets are opening up in response to consumer concerns about climate change and other environmental impacts of farming, to products such as alternative proteins and synthetic meats. Given that there is likely to be an increasing diversity of crops grown, the Government needs to consider developing other models for non-pastoral land uses.

Establishing Overseer as the official model for regulatory purposes for pastoral farms would at least secure whatever revenue can legitimately be derived from subscriptions. But the extent to which subscriptions can be relied on to raise revenue requires further examination. It seems reasonable that land users should meet part of the costs of the regulatory system needed to manage their diffuse pollution. This would also recognise the private commercial benefits to be gained through use of Overseer such as efficiencies in fertiliser use and, potentially, the benefit to trade on the environmental credentials of the model.

Meeting those costs is a more reasonable burden to shoulder when complete transparency about the Overseer model enables land users and their advisors to interrogate the reasonableness of any limits or other regulatory requirements that are imposed.

[211] From the memory of staff involved from the early development phase, the Ministry for Agriculture and Forestry made a conscious decision not to fund any other models that were being promulgated. Consequently the Ministry for Agriculture and Forestry, and then MPI, supported only Overseer as a decision support tool for greenhouse gas and nutrient loss management (pers. comm., Penny Nelson, Ministry for Primary Industries, 2018).

[212] Each of the elements of model evaluation set out in chapter 5 would need to be considered, and improvement and review activities identified and undertaken as a result. These include the soundness of the science underling the model, whether it is managed to ensure quality, the degree to which the model's behavior approximates the real system being modelled, and the appropriateness of the model for a specific regulatory application.

Source: pxhere.com

Figure 6.2 The majority of investment and development in Overseer has been focused on pastoral farming systems. However, as farms diversify in the face of changing consumer preferences and the impacts of climate change, it is an open question whether Overseer will be the best model for managing the environmental impacts of these new farming systems.

But even with greater transparency and all the gains that research-community access to the model could provide, it is doubtful whether subscriptions alone can provide the resourcing needed to support nutrient pollution management. This is because while the Overseer model itself requires approximately $4 million per annum to be maintained, far more significant sums are required to fund the underlying empirical research needed to corroborate and calibrate the model.

The limited extent of these investments has been outlined in chapters 3 and 5. Upgrading our understanding of soils and innovative farm management practices will undoubtedly benefit the Overseer model. But the benefits are much more widespread. This is classic public-good research that is legitimately part of the Crown's public-good science investment. And to the extent that regional granularity is required, it is research that should be co-funded by regional councils and their ratepayers.

Making Overseer an open-source model, and one that is officially supported by the Government as the model of choice for estimating nutrient losses to water for pastoral farms, firmly embeds Overseer's purpose as one of importance to 'New Zealand Inc'. While there are private commercial benefits to be gained from the use of Overseer on farms, the purpose of Overseer becomes directed at achieving environmental improvements on farms to help achieve environmental policy objectives.

Overseer's ownership and governance need to align with this purpose. The most immediate question is whether it would be consistent with the Fertiliser Association's current co-ownership of the intellectual property. The Fertiliser Association's significant contribution to Overseer over many years has kept the model afloat. Without its support we would not be where we are today. Opening up the model raises two questions: would it be fair to the Fertiliser Association (given its investments)? And would a clear public-good purpose be consistent with its continued ownership stake?

The answer to the first question depends on the extent to which a valuable asset is being devalued. This is not an assessment this review can make. Conversations with the Fertiliser Association suggest that the model's value to the fertiliser companies is rooted not so much in ownership as the link it enables them to maintain with farmers and farm advisors. An open-source model would not disrupt that. Neither would it prevent the companies developing value-added proprietary tools based on the Overseer model.

The second question comes down to this: is it appropriate for a trade association owned by the two major New Zealand manufacturers of superphosphate and nitrogen fertilisers – Ballance Agri-Nutrients Ltd and Ravensdown Ltd – to be part owners of an open-source model explicitly supported by the Government for use in managing diffuse discharges and maintained as a public-good instrument?

This is a question that should be directly addressed. If the answer is no, then it would be an option for the Government to buy the Fertiliser Association's ownership stake in the intellectual property. This would make the Overseer IP jointly owned by AgResearch and the Government. Given AgResearch's ultimate ownership by the Crown, and its statutory requirement to undertake research for the benefit of New Zealand, reaching agreement on open sourcing the model would be potentially more achievable.

Resolving the issue of intellectual property ownership is a separate matter from who develops and maintains the model. Since its incorporation in 2016, Overseer Ltd has developed significant in-house expertise in software development. Recently, model development has been brought "under one roof" by having software developers working full time in-house on Overseer. Overseer Ltd considers this will enable it to interrogate the implementation of the model and start to establish approaches for evaluation.

In the course of this investigation, it has become apparent that the company has built relationships with multiple stakeholders and has an in-depth understanding of the issues arising from the perspectives of councils, farmers, industry, and others.

A change in ownership would necessitate a fresh look at the governance of the Overseer model and whether a limited liability company remains the right vehicle to develop and maintain Overseer. If Overseer officially becomes the model of choice for regional councils seeking to implement property-level nitrogen limits in their plans, at least for pastoral farms, a regional council perspective on the governance board would make sense. Regardless of the specific governance arrangement arrived at, the existing expertise and institutional memory of staff at Overseer Ltd will be essential to retain going forward.

Beyond Overseer – understanding and modelling catchments

This chapter situates the use of Overseer in a broader catchment context. It has four sections.

The first section draws readers' attention to additional information needed to understand the impacts of excess nutrients on water quality. As mentioned earlier in this report, Overseer has been used as part of catchment-scale modelling exercises. Catchment-scale modelling and the steps involved are described in the second section of this chapter.

The third section talks about making better use of the information base we have, and provides examples of available datasets that can assist our understanding of nutrient transport across catchments. The final section makes a few concluding remarks.

Developing a better understanding of nutrient transport in catchments

For regional councils to be able to manage diffuse discharges as required by the National Policy Statement for Freshwater Management, they need a better understanding of sources and environmental impacts of excess nutrients on water quality. This goes beyond the scope of Overseer.

Overseer is designed to model nutrient inputs and losses from an individual farm. Losses of nitrogen are calculated where it leaves the root zone (60 centimetres below the paddock's surface) and for phosphorus, where it enters second-order streams. The environmental impacts of those losses, however, are felt at the level of catchments or sub-catchments.

Therefore, to understand the environmental impacts of excess nutrients on water quality, regional councils need to couple the farm-level estimates that Overseer generates with additional catchment-scale information.

In particular they need answers to these questions:

- How much of the nutrients leaving a farm actually makes it to a waterbody?
- What sort of waterbody do the nutrients end up in? How vulnerable is it?
- What other factors affect the impact the nutrients have, including contributions from other sources?

All of these factors need to be considered when thinking about how to manage nutrients to improve water quality. The following sections deal with each of these issues in turn.

From a farm to a waterbody

Excess nutrients from farms reach waterbodies through a number of pathways.[213] Being highly mobile in water, nitrogen tends to go with the flow – down into groundwater, laterally through soil closer to the surface, or travelling via surface water. Phosphorus, in comparison, is much less mobile and mainly enters waterways with soil and sediment, although losses into groundwater have been noted recently in a few cases.[214]

The speed and form in which nitrogen reaches water bodies varies. Nitrogen changes its chemical form depending on the surrounding conditions and these forms have different fates. Nitrogen may stay in the water as mobile nitrate and be temporarily stored (e.g. taken up by annual plants that generally grow prolifically in summer and die back in winter and decay). Or microbes may turn it into gaseous forms and permanently remove it from the water by a process called denitrification. Climate, topography, hydrology, soils, and underlying geology all play a role in determining which of these processes occurs.

Collectively, processes that reduce the amount of nitrogen as it travels from the root zone to a waterbody are known as *attenuation*.[215] Depending on the conditions, the amount of attenuation can be trivial or can significantly reduce the amount of nitrogen reaching waterbodies.[216]

For example, researchers at Massey University have shown that the rate of nitrogen attenuation varies between 30 per cent and 70 per cent across different sub-catchments in the Tararua Groundwater Management Zone (Figure 7.1).[217] Clearly, depending on where they are situated, the contribution of identical farms to water quality degradation will differ significantly.

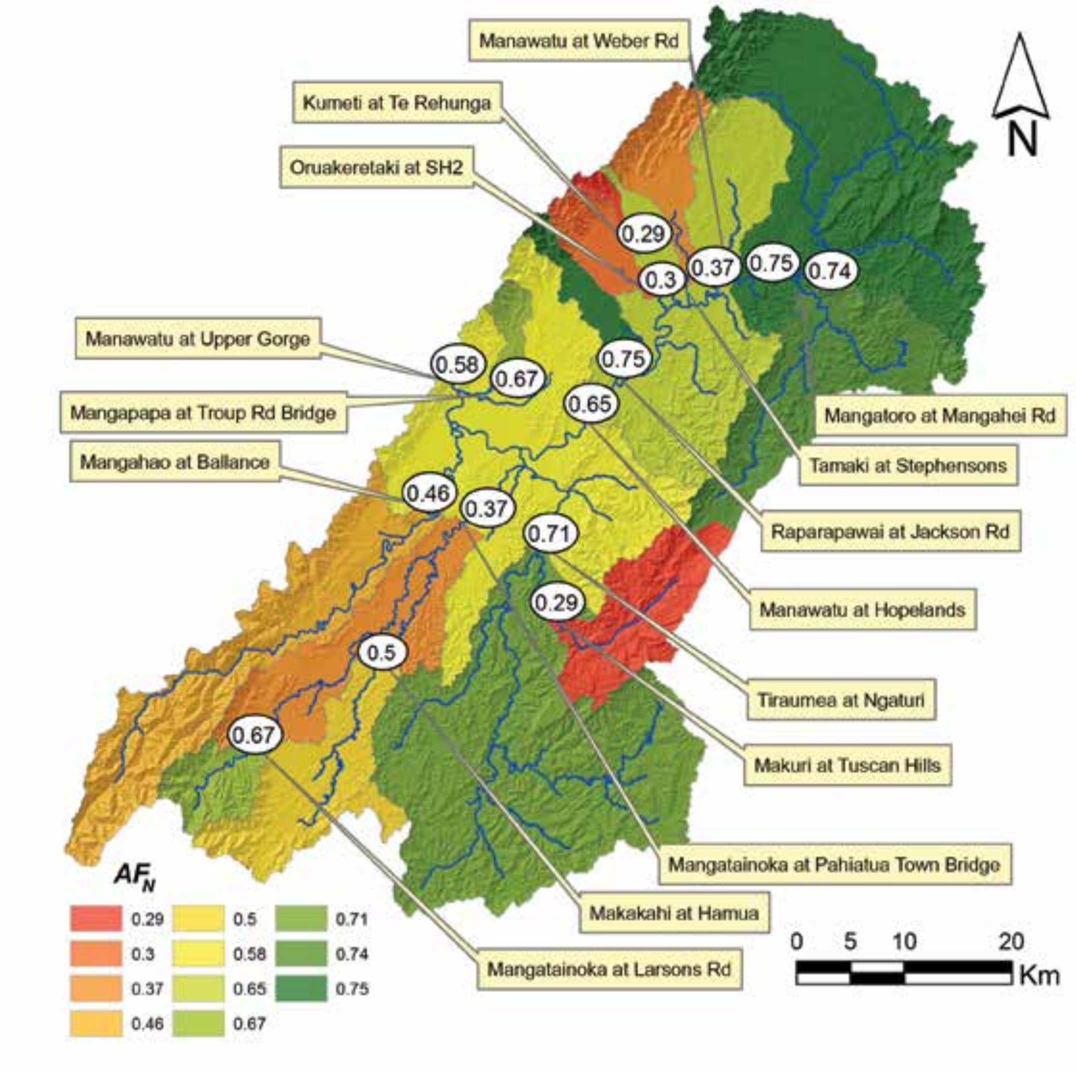
[213]Broadly speaking, more rainfall means more water is available to move contaminants both over the surface and down through the soil into groundwater. Topography (slope) determines the pathway water takes. The interconnectedness of the different soil and subsoil layers determines the ease and speed with which contaminants can travel from farm paddocks to rivers, lakes, and aquifers.

[214]McDowell et al., 2015b.

[215]*To attenuate* means to make something smaller, thinner, or weaker.

[216]Some phosphorus leaching into groundwater can also be attenuated. McDowell et al., 2015b.

[217]Elwan et al., 2015.



Source: Elwan et al., 2015

Figure 7.1 Variable nitrogen attenuation rates across the Tararua Groundwater Management Zone. AF_N stands for nitrogen attenuation factor, which is calculated as a loss of nitrogen between where it leaves the farm and where it affects a receiving waterbody.

The vulnerability of the receiving waterbody

The impact of nutrient pollution is significantly dependent on the natural characteristics of the waterbody where the nutrients end up.[218]

- Generally, lakes and estuaries are more vulnerable than rivers. Lakes and estuaries can act like sinks, accumulating pollutants that can in turn favour algal blooms and nuisance plant growths.
- How much water there is in a river or stream, how fast it moves, whether it is shallow or deep, shady or open, and the variability of its flow will all affect its vulnerability.
- Aquifers are, in effect, underground reservoirs that are fed by water soaking through the ground. How vulnerable an aquifer is to dissolved pollutants depends on how accessible it is to water from the surface (which depends on the subsoil), and how quickly water moves through the aquifer.

When different nutrients reach a waterbody is also important. For example, rivers and streams are usually most vulnerable to nutrients in summer. Algae and aquatic plants generally grow more prolifically in summer because lower rainfall results in higher temperatures, lower flows, fewer flushing flows, and higher concentrations of nutrients. There is also more sunlight in summer, resulting in more photosynthesis.

Source: Brian High

Figure 7.2 Algae and aquatic plants generally grow more prolifically in summer because lower rainfall results in higher temperatures, lower flows, fewer flushing flows, and higher concentrations of nutrients. There is also more sunlight in summer, resulting in more photosynthesis.

[218] PCE, 2013.

What other factors determine the impact nutrients have?

Nutrient concentrations themselves do not generally have negative impacts on the health of waterbodies, although nitrogen can be directly toxic to aquatic species and people at high concentrations.[219] Rather, high concentrations have indirect effects through the promotion of excess plant growth, which can lead to the smothering of habitat, dangerous oxygen depletion, and pH changes causing changes in the structure and functioning of freshwater communities.

However, these relationships are not always easy to predict.

For example, studies of the relationships between nutrients and algae show a fairly clear relationship in lakes, but weaker direct relationship in streams and rivers.[220] This is because lakes are more likely to provide the warm, stable conditions algae need to build up. In comparison, flow in streams and rivers can be highly variable. When a high flow or flood occurs, algae will be washed away and a new community will begin to establish itself until the next high flow occurs. Any analysis of the relationship between nutrients and algae in streams and rivers must therefore include information on flow levels.[221]

Similarly, modelling exercises found that while increasing nitrogen concentrations have negative impacts on stream invertebrate communities, the physical characteristics of the site and the amount of fine sediment had an even greater influence.[222]

This discussion has highlighted the complex relationship between nutrients entering the land and the effects that they can ultimately have. However, understanding nutrient sources is only one (albeit important) piece of the puzzle.

Modelling catchments

Understanding how nutrients travel through catchments requires a picture in three physical dimensions, plus a fourth: time. The water cycle is continually refurbishing flows across, through, and under the land on the way to lakes, aquifers, and, ultimately, the sea.

We cannot physically measure nutrient flows through catchments in such detail that we have a perfect understanding of what ends up where, and with what effects. Instead, we need to turn once again to models for help.

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[219] In recognition of this fact, standards have been set to limit nitrate concentrations in drinking water to protect human health, and for natural waterbodies to protect aquatic species. For human health see Table 2.2, Maximum acceptable values for inorganic determinands of health significance, in Drinking Water Standards for New Zealand 2005 (Revised 2008) on the Ministry of Health's website (https://www.health.govt.nz/system/files/documents/publications/drinking-water-standards-2008-jun14.pdf).

For waterbodies, see nitrate toxicity limits for rivers in Appendix 2 of the National Objectives Framework in the National Policy Statement for Freshwater Management 2014 (revised in 2017). Available from the Ministry for the Environment website (http://www.mfe.govt.nz/sites/default/files/media/Fresh%20water/nps-freshwater-ameneded-2017_0.pdf).

[220] For example, Smith et al., (2016) found a positive relationship between chlorophyll-a concentrations (as a measure of algal growth) and total nitrogen and total phosphorus in the surface water of Lake Rotorua between 2001 and 2015.

[221] Snelder et al., 2014.

[222] Clapcott and Goodwin, 2014.

Catchment-scale modelling exercises consist of three key steps:

1. quantifying the total loss of nutrients from all sources in a catchment
2. quantifying the nutrient load that reaches a waterbody
3. assessing the impact of nutrients on the waterbody.

Each of these is discussed in greater detail below.

Step one: quantifying total nutrient losses

Root zone nutrient losses from individual farms can be used to help determine the total amount of nutrients entering waterbodies in a catchment.[223]

The total agricultural diffuse nutrient losses can be estimated as the sum of modelled losses from individual farms in a catchment using actual Overseer farm files. A good example of this was the modelling exercise undertaken to inform a plan change to improve water quality in Lake Rotorua.[224] Detailed 'benchmarking' data for the majority of farms in the Rotorua catchment collected by the Bay of Plenty Regional Council formed the basis of such modelling.[225]

However, obtaining Overseer nutrient loss estimates for actual farms in a catchment can be challenging. Overseer may not be used by all farmers in a catchment of interest or Overseer data may not be available to regional councils due to privacy concerns.[226] In this case "proxies" – estimated nutrient losses for generic farms – can be used instead. The Waikato Regional Council used proxies to inform the Healthy Rivers/Wai Ora plan change due to a lack of actual farm-level data from Overseer.[227]

It is also important to quantify the contribution of nutrients from other sources within the catchment.[228] While the great majority of nitrogen entering waterways comes from livestock urine, and most phosphorus comes with soil and sediment, the contribution of nutrients from point sources can be significant at specific times and places.

For example, point sources of phosphorus from wastewater treatment plants in the Upper Manawatū River are very significant for a good portion of the year. About half

[223]Total amount of nutrients also includes diffuse nutrient losses from other non-agricultural land, urban areas, natural sources and point source discharges.

[224]At the time of writing this plan change (Plan Change 10: Lake Rotorua Nutrient Management) was before the Environment Court.

[225]See Rutherford, 2016, p.15 and Palliser et al., 2018.

[226]However, such farm data may be held by farming industry organisations (e.g. Fonterra and DairyNZ).

[227]Nutrient losses from diffuse sources were calculated as a function of land use and the source yields associated with these land uses. The source yields for pastoral and horticultural land uses in the Waikato and Waipā River catchments were derived from Overseer. However, report authors recommended that Overseer-derived diffuse source yields should be reassessed due to large uncertainties and model limitations (Semadeni-Davies et al., 2015).

[228]For example, contributions from point sources (septic tanks, geothermal inputs, and sewage) in the Rotorua catchment were also estimated and used in the catchment-scale modelling (Rutherford et al., 2009, pp. 31-32).

the phosphorus entering the river from spring to autumn comes from point sources. By contrast, in winter, higher rainfall washing in more sediment and manure reduces the share of point-source phosphorus to less than a quarter.[229]

Step two: quantifying nutrient load that reaches a waterbody

The second step is to quantify the nutrient load that reaches a waterbody. A number of catchment-scale models have been developed internationally for this purpose.

The term *catchment model* is a broad term that can include modelling of groundwater and surface water, erosion and sediment, nutrients and pathogens. Catchment-scale models come in all shapes and sizes, and can be designed to model changes over a range of timescales, from daily to long-term, multi-year averages.

For example, the Soil and Water Assessment Tool (SWAT) developed for the United States Department of Agriculture, Agricultural Research Services, is a catchment-scale model that attempts to quantify the impact of land management practices on river flow and water quality.[230] In New Zealand, SWAT has been used to model water, sediment, and nutrient fluxes in the Puarenga Stream catchment near Rotorua.[231,232]

While international models often come with extensive databases, local values are needed for the model to correctly reflect local conditions. A lack of local data for required parameters has proved to be a barrier to using international models in New Zealand catchments.[233] In addition, international models often come with a set resolution (i.e. the grid size), which might make modelling highly variable terrain challenging.[234]

As a result, several simplified hybrid models, which include mechanistic components that are empirically calibrated, have been developed. CLUES (see Box 1) and ROTAN are examples of New Zealand-developed hybrid models.

[229]Ledein et al., 2007, pp. 23-26.

[230]SWAT is a catchment-scale model used to simulate the quality and quantity of surface and groundwater, and predict the environmental impact of land use, land management practices, and climate change. The model uses topography, soil types, land use, climate/rainfall, crop and land management properties to generate water and contaminant flux, yield, and state for various spatial (hydrologic response unit, sub-catchment, reach, catchment) and temporal (daily, monthly, yearly) levels. SWAT website (https://swat.tamu.edu/).

[231]Me et al., 2015.

[232]Another example of a complex dynamic suite of models is an integrated hydrologic modelling system MIKE, developed by the Danish Hydrological Institute (DHI). MIKE SHE, which is one model in the suite, is an integrated model for groundwater, surface water, recharge, and evapotranspiration. The core of the model is based on a hydrological cycle, but it can quickly become rather complex due to links with other MIKE models and add-ons (e.g. rainfall run-off simulations, contaminant dispersion, and sediment transport). MIKE website (https://www.mikepoweredbydhi.com/).

[233]Tuo et al. (2015) compared five catchment-scale mechanistic models (including SWAT), and concluded that data availability was a crucial factor in evaluating model results and uncertainty in these models. Moreover, in many situations models were difficult or impossible to implement due to the limited available data.

In addition, NIWA used the selection criteria outlined by Tuo et al. (2015) and concluded that none of the available mechanistic models were well suited for application in catchments like Rotorua, Taupō and Tukituki where limited data is available for model calibration (Rutherford, 2018, p.24).

[234]For example, for application of the MIKE SHE model in the Selwyn catchment, a grid cell size of 1 km^2 was used, which meant small-scale variations could not be modelled even though they may have been important (Rutherford, 2018, p.27).

ROTAN was used as part of the aforementioned modelling exercise in the Lake Rotorua catchment. Firstly, Overseer was used to estimate nitrogen losses from farms in the catchment.[235] Secondly, ROTAN was used to model transport of these losses from within the catchment to the lake Rotorua. Three delivery pathways (quick flow, groundwater and stream flow) were conceptualised, and different attenuation and groundwater time-lags were taken into account.[236] The authors predicted nitrogen loads to Lake Rotorua, however, they found that uncertainty was lowest for total catchment loads, higher for loads from individual sub-catchments, and very high for individual farms.[237]

Box 7.1 Surface water modelling – Catchment Land Use for Environmental Sustainability model (CLUES)

Catchment Land Use for Environmental Sustainability model (or CLUES) is often used for catchment-scale water quality modelling in New Zealand. Developed by NIWA, this hybrid, steady-state model is an amalgamation of existing modelling and mapping procedures. CLUES provides mean annual loads and median concentrations of contaminants (nitrogen, phosphorus, sediment and *E. coli*). While the model is simple to set up and run, it does not capture day-to-day variations.

The components of CLUES include: a simplified version of Overseer, SPASMO, SPARROW and CLUES Estuary, as well as simple socio-economic indicators.[238]

- Overseer is used in a simplified way to estimate mean annual loads of nitrogen and phosphorus from pastoral land uses as a function of enterprise type, stocking rate, soil drainage class, rainfall and region. Overseer is run for each land use within each sub-catchment. While individual farms are not represented, different land uses are represented based on land cover and AgriBase information.[239]
- SPASMO is used to estimate nitrogen losses from horticultural and cropping land uses.[240]
- SPARROW is used to estimate *E. coli*, sediment, nitrogen and phosphorus from all other (i.e. non-agricultural) sources. In addition, SPARROW is used to estimate downstream transport of various contaminants. SPARROW estimates

[235] Nitrogen losses were estimated over a period from 1900 to 2015. The authors reported that uncertainty in nitrogen losses averaged ± 50%. This was due to changes in survey methods, reporting only at district scale, limited information about historic land use, and uncertainty in Overseer itself. See Palliser et al. (2018) for more details.

[236] See Rutherford et al., 2018 for more details.

[237] Rutherford, 2018, p. 27.

[238] Elliott et al., 2016

[239] AgriBase is a national spatial database which holds information on approximately 142,000 current New Zealand farms. It is administered by AsureQuality. AgriBase website (https://www.asurequality.com/our-solutions/agribase/).

[240] SPASMO (Soil Plant Atmosphere System MOdel) has been developed in New Zealand by Plant and Food Research. The model estimates the transport of water, microbes and solutes through soils by integrating variables such as climate, soil, plant water uptake, and other factors affecting environmental processes and plant production.

attenuation rates from observed in-stream concentrations of nutrients at monitoring sites in the catchment.[241]

- CLUES Estuary takes CLUES estimates of catchment loads of nitrogen and phosphorus, and represents how these are mixed in an estuary to determine estuarine water quality.

Since its development in 2006, CLUES has been used to estimate the loads of nutrients, sediment and *E. coli* in research studies, and to support catchment policy and planning. The model has been applied to assess potential impacts of land use change in single catchments (e.g. Upper Waikato River Catchment) as well as the entire country. It has also been applied to assess the efficacy of mitigation measures (e.g. stock exclusion and conservation planting) on sediment loads into Kaipara Harbour.[242]

Several aspects of CLUES' structure and functioning can affect the accuracy of the model:

- CLUES is a surface water model, which means it assumes all contaminants are transported via a network of streams and rivers, rather than via groundwater.
- For each sub-catchment, the proportion of the area within each of the 19 land use classes used in CLUES is specified. However, the precise location of the land use within the sub-catchment is not represented explicitly. This limits the spatial resolution of the model.
- The default land use dataset provided with CLUES is for the baseline year of 2008. Because New Zealand doesn't have a comprehensive, robust, land use dataset, up-to-date land use information is difficult to obtain. Currently, land use is inferred from land cover information (derived from the Land Cover Data Base, last updated in 2012) in combination with other often proprietary databases (like AgriBase).
- The simplified version of Overseer accepts a limited set of inputs (stocking density, pastoral enterprise type, rainfall, soil order, and topographic slope class) compared with the full detailed version. It has been suggested that assumptions within the simplified Overseer model may need to be re-examined as little sensitivity to stock rate intensification was observed.[243]

As the level of uncertainty of Overseer estimates is largely unquantified, it is difficult to conduct formal uncertainty analysis of the overall catchment-scale estimate. In addition, every time Overseer is significantly updated, other components of CLUES (namely SPARROW) need to be recalibrated to compensate for such changes. Uncertainty in Overseer and the implications for other model parameters remains of concern.

[241] SPARROW (SPAtially Referenced Regressions On Watershed attributes) has been developed by United States Geological Survey. The model estimates the amount of a contaminant transported from inland catchments to larger waterbodies by linking monitoring data with information on catchment characteristics and contaminant sources. The term 'watershed' is synonymous to 'catchment'.

[242] Elliott et al., 2016.

[243] Elliott et al., 2016.

Nutrient transport through different parts of the landscape is usually modelled using separate models. For example, CLUES (see Box 7.1) is used for modelling surface water (streams and rivers), and MODFLOW for modelling groundwater (see Box 7.2).

Box 7.2 Groundwater modelling – MODFLOW

Developed by the United States Geological Survey, MODFLOW is a dynamic model that simulates saturated groundwater flow. As the model's code is open source and free to use, the model is now used worldwide. A modular structure is the key feature of MODFLOW, which allows for new packages to be added and the model's scope to be expanded. While anyone with the necessary skills can write a customized component and suggest improvements to the model, the United States Geological Survey maintains official releases.

MODFLOW has several companion models, including:

- MODPATH – to track particle paths
- MT3DMS – to simulate contaminant transport in the saturated groundwater
- RT3D – to simulate chemical reactions
- UZF – to simulate unsaturated zone flow
- SRF – to simulate shallow and surface hydrologic processes.

Currently MODFLOW only models deep groundwater and does not model 'quick flow' (viz. overland flow and shallow interflow) in detail, and requires nitrogen losses in drainage to be specified (e.g. based on Overseer).

In New Zealand, MODFLOW is one of the models regularly used by GNS Science. For example, MODFLOW was one of the models used in a recent modelling exercise in the Ruamāhanga catchment.[244]

Integrating models across surface water and groundwater domains is a complex technical task, often requiring collaboration between modellers and organisations.[245] Several key water models used in New Zealand are not open source and are developed by different organisations.[246] These issues contribute to integration challenges.

An attempt to integrate various models has recently been made under the umbrella of the *Our Land and Water – Toitū te Whenua, Toiora te Wai – National Science Challenge*. A *model interoperability* project is aiming to construct a framework of nationally applicable open-source models that draw on national datasets. The

[244] Blyth et al., 2018.

[245] For example, an integrated catchment water quality model of the Ruamāhanga catchment was developed as collaboration between Greater Wellington Regional Council, Jacobs, GNS, NIWA, Waikato University and Aqualinc. It's envisaged that this model will help guide the freshwater limit setting required under the National Policy Statement for Freshwater Management.

[246] Examples of closed source models include: Overseer, CLUES, ROTAN.

modelling framework is envisaged to be suitable for integrated and spatial assessment of the economic, production, and environmental implications of land use and land use change at farm to catchment scales.[247] This builds on one of the recommendations arising from a catchment modelling workshop held almost a decade ago: namely the removal of intellectual property restrictions on data and models to facilitate both the uptake of models and collaboration in model development.[248]

Limitations of catchment-scale modelling

Catchment models are valuable tools. They allow land managers to understand and test relationships between land use practices, interventions, and environmental outcomes, and make better-informed decisions when proposing policies and rules.

However, catchment models, by their nature, also have to make a number of simplifying assumptions. For example, CLUES assumes all contaminants are transported via a network of streams and rivers – groundwater is out of the model's scope.

Models also make assumptions about attenuation rates. For example, a model might assume that attenuation of nitrogen is uniform across a sub-catchment. However, as we have seen from the Massey University research (Figure 7.1), the attenuation potential of land can be highly heterogeneous. Differences even metres apart can cause attenuation to differ significantly. Models can account for this by using measurements from within the catchment to provide estimates of attenuation rates.[249] However, the accuracy of these calibrations will depend on how many sites have been monitored – the greater the number of sites, the better and more finely scaled the estimates.[250]

It is important that any model assumptions and uncertainty are well communicated and factored into risk assessments and policy decisions, as they are present in all models.

There is an opportunity to improve catchment models by expanding current monitoring networks, investing in new field instruments, and striving for real-time, continuous water quality measurements. This approach could also facilitate adaptive management – adjusting policy targets and actions on the ground on the basis of the state and trends of receiving environments.

[247] Elliott et al., 2017., p.6.

[248] The 2009 workshop also recommended that guidelines on project conceptualisation, model selection and calibration should be developed (Fenton, 2009, p.16). However, almost a decade later, this recommendation is still outstanding.

[249] However, any measurements will also have a degree of uncertainty due to natural variability which will affect any estimated rates.

[250] It is often not only the number of sites that is an issue, but also the length of time that measurements have been collected.

Improvements can also be made by:

- better understanding and keeping a record of land use practices in the long-term (including historical knowledge). Such information can help identify and predict lag times in a catchment
- better understanding of spatial and temporal variability of surface water and groundwater interactions
- improving the resolution of land use information to make better use of datasets (e.g. matching decisions on land use practices with the resolution of weather forecasts).[251]

Step three: assessing the impact of nutrients on the waterway

Quantifying the quantity of contaminants that reach waterways is not enough in itself. It is influencing the quality of water that is the object of policy makers. They need an understanding of the impact excess nutrients have on a waterbody. The relative importance of addressing excess nutrients depends on the state of the waterbody, and the values the community wants to protect. In terms of the Resource Management Act, these values can be thought of in terms of a waterbody's life-supporting capacity.[252]

A catchment model would ideally be able to provide information on the impact of excessive nutrients on the life-supporting capacity of a waterbody. Currently, individual catchment models are limited in this regard – CLUES can provide estimates of the loads and concentrations of nutrients in waterbodies, but does not model resulting algal biomass or the effects on aquatic invertebrates. To model such outcomes, different and often more complicated models are required, or the results from a catchment model are fed into other models designed for such a purpose.

There are a number of models developed to describe the relationships between nutrients and other stressors, and water quality outcomes. These have been used to explain what drives particular outcomes, and predict where management actions may be effective. Examples of this approach include identification of the impacts of sediment on catchments in the Manawatū-Whanganui region, recent work looking at the impacts of nutrient concentrations and site characteristics on stream invertebrate communities, and modelling the impacts of nitrogen and phosphorus loads on ecosystem health in Lake Rotorua.[253]

[251] Pers. comm., Richard McDowell and Ken Taylor, 2018.

[252] Section 5 of the Resource Management Act 1991.

[253] For example, a model called SedNetNZ was used to assess the impact of the Sustainable Land Use Initiative in the Manawatū-Wanganui region on river sediment loads (Dymond et al., 2014).

Clapcott and Goodwin (2014) examined the cause-and-effect relationships between land cover and associated land-use impacts and the Macroinvertebrate Community Index.

For information ecosystem health in Lake Rotorua see Rutherford et al. (2009), Rutherford et al. (2011) and Rutherford (2016).

The models used to investigate these relationships often rely on data from a wide range of sites and sources. Therefore, while they may help identify key mechanisms or processes, they may be less useful for working out what interventions are required in a specific catchment or sub-catchment. However, such investigations can help to parameterise models such as CLUES for individual catchments, or can identify key management interventions – such as the need to specifically target erosion rates,[254] or increase shading through a streamside replanting programme.

Making better use of the information base we have

As is always the case with modelling, the physical information needed to calibrate catchment-scale models poses a challenge. But New Zealand does not start from a blank slate.

Decades of taxpayer and ratepayer investment have resulted in numerous datasets being generated that can assist our understanding of nutrient transport and transformations across catchments. Over the years, several attempts have been made to document the available resources.

In preparation for the State of the Environment reporting in 2012, Statistics New Zealand characterised environmental datasets and information across multiple domains. In collaboration with the Ministry for the Environment (MfE) and the Department of Conservation (DOC), data gaps were identified and *Environment Domain Plan 2013* was developed to fill those gaps.[255]

Building on this effort, recent State of the Environment reports have documented available indicators and datasets across domains alongside key information gaps. For example, *Our land 2018* and *Our fresh water 2017* provided useful stocktakes across land and water domains.[256]

Some of the gaps these reports reveal are significant. For example, it has been estimated we only understand the structure of about 30 per cent of the aquifers in New Zealand.[257] Soil databases are also patchy in scale, age and quality. As of October 2018, the S-map coverage of New Zealand was 34 per cent, although this is 63 per cent of productive

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[254] A recent report by Snelder (2018) produced for the Horizons Regional Council demonstrated strong statistical evidence of regional improvement in the water quality measures (*E. coli*, clarity, suspended sediment, turbidity) over the past decade in the Manawatū-Whanganui region. In addition, this analysis provided strong statistical evidence of water quality improvements associated with upgrading point source discharges throughout the region. Moreover, weak but statistically significant positive associations were observed between improving trends for all water quality variables and the proportion of catchment area involved in Sustainable Land Use Initiative (SLUI) farm plans.

The Sustainable Land Use Initiative was founded by the Horizons Regional Council in 2006 to limit the effects of large-scale hill erosion and prevent silt building up in rivers in the region. The focus of this voluntary initiative has been on completing whole-farm plans, which identify areas for erosion control on a farm-by-farm basis, and undertaking works on farms once the plans are complete. The SLUI programme is funded by central government, ratepayers, and landowners. For more information see Cooper and Roygard (2017).

[255] See Statistics New Zealand, 2012, and Statistics New Zealand, Ministry for the Environment, Department of Conservation, 2013.

[256] MfE and Stats NZ, 2017, 2018.

[257] Pers. comm., Chris Daughney, GNS, 2018.

land.[258] It is important that such gaps in data and understanding are prioritised and incrementally closed.[259] Without that, models will remain poorly calibrated, with higher levels of uncertainty in some settings.

Another stocktake of existing land and water models, alongside data sources to support modelling, was undertaken as part of the proposal for the development of an interoperable modelling system.[260]

A key finding of the stocktake exercises is that while numerous datasets exist, they are maintained by a variety of different organisations, and come in various states of comprehensiveness and age (Figure 7.3). Also, funding for their maintenance and development has not been driven by any clearly defined national objectives.

Furthermore, these datasets are not 'joined up' in the most useful way to gain a better understanding of nutrient transport across catchments. In a number of cases, the datasets are also not easily accessible due to proprietary ownership arrangements.[261] This is hard to justify given that taxpayers have funded the creation of these datasets in the name of public-good science.

[258]S-map coverage as of October 2018. (https://soils.landcareresearch.co.nz/soil-data/s-map-and-s-map-online/). In addition, while the older soil datasets (Fundamental Soil Layers) is non-proprietary, the newer, more detailed S-map is proprietary for commercial use.

[259]Recommendations to prioritise the data gaps identified in *Our land 2018*, and make an investment case to incrementally close them, have already been made to the Secretary for the Environment and the Government Statistician. See *Our land 2018* commentary available at www.pce.parliament.nz.

[260]Elliott et al., 2017, Tables 7-3 and 7-4, pp.42-49 and pp.56-64.

[261]For example, information on water features (e.g. stream networks) requires permission to access, as it is linked to river reaches and is part of the River Environment Classification provided by NIWA. Similarly, Virtual Climate Station Network administered by NIWA, is also proprietary. New Zealand also does not have a single, comprehensive, robust, nationally representative dataset that characterises land use, and how it is changing spatially and temporally. Current estimates are based on data from a variety of sources, including Land Cover Data Base (LCDB) and AgriBase (which provides some information on land use class and stocking rates. However, coverage is incomplete and the database is proprietary).

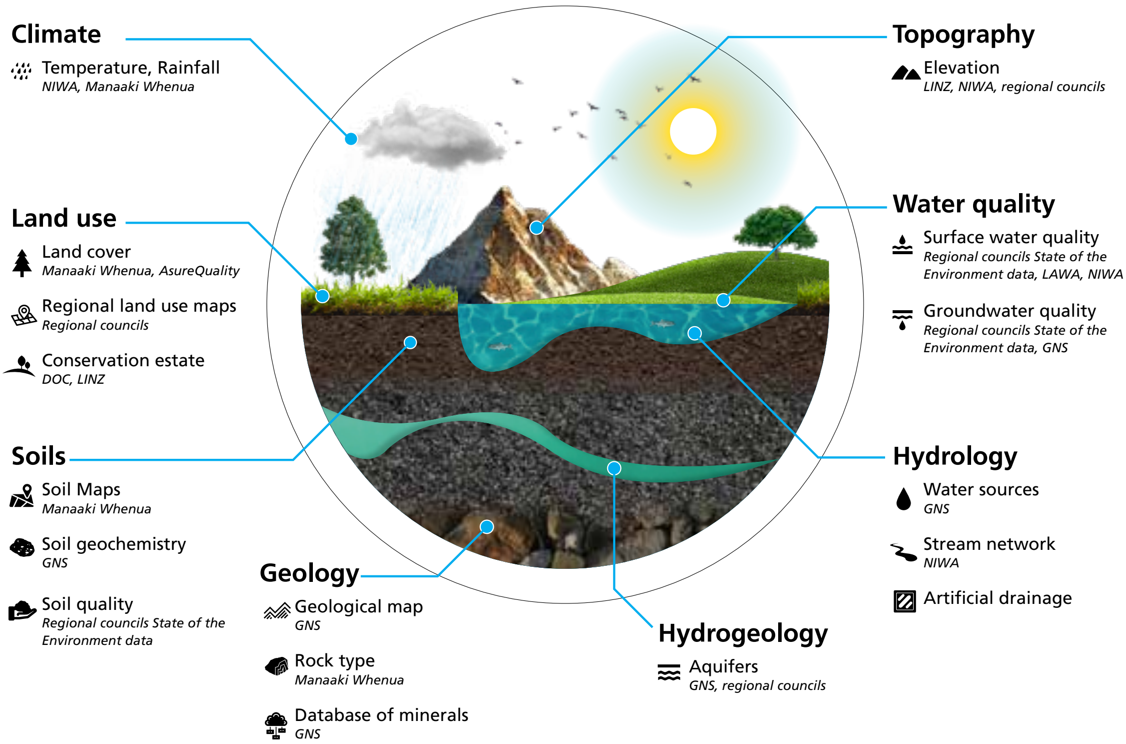

Figure 7.3 Existing datasets – and their curators – that can assist the understanding of nutrient transport across catchments.

It is important to collect new data and keep expanding existing datasets. However, it is equally important to advance our understanding by extracting extra value from existing information and data – for example, by joining up datasets across domains, rethinking existing conceptualisations and designing new ones (see Box 7.3). A comprehensive rethink of the public-good purpose of these datasets, their funding, and accessibility is overdue.

Box 7.3 Novel approaches

The *physiographic approach* is an example of a novel approach to mobilise existing datasets. The focus on water is a key feature of this approach – it is water rather than land that lies at the heart of this framework.

At its core, a physiographic approach involves systematically mapping the constituent biophysical characteristics of a landscape (like climate, topography, hydrology, soils, and underlying geology) to identify key processes that influence water quality. Importantly, land use with its nutrient pressure on water quality is not included as an inherent landscape property. As a result, the integrated classification system of physiographic units and zones can provide useful information about the vulnerability of the land. It can then be used predictively to help indicate appropriate land use and management.

The physiographic approach is still being developed, and initial trials have been conducted in Southland, and more recently Northland at a regional scale, and in the Waituna catchment on a catchment-scale.[262]

High-resolution catchment-scale mapping can lead to targeted actions to improve water quality (e.g. see the high-resolution physiographic maps for the Waituna catchment). However, they often need new data to be collected, and the quality and resolution of existing data will affect the spatial accuracy of the physiographic units.

Another novel approach is the *land use suitability approach* that attempts to build on existing models and datasets. It looks to develop an enhanced understanding of 'land suitability', by assessing the land in terms of both its productive potential and its environmental constraints.[263]

A land use suitability approach tries to assess a piece of land based on a combination of the following attributes:

- productive potential – the inherent capacity of a land parcel to deliver primary production
- risk to receiving environments – the inherent capacity of the land to attenuate contaminants on their way to receiving environments. How 'leaky' is a land parcel?
- constraints on receiving environments – given a particular limit or a water-quality objective, what is the maximum acceptable load of contaminants for a receiving environment? Is it already exceeded or not?

[262] Southland: Rissmann et al., 2016, Hughes et al., 2016; Northland: pers. comm. Clint Rissmann, 2018; Waituna: Rissmann et al., 2018. High-resolution physiographic units for the Waituna catchment can be found on the Land and Water Science website (https://www.landwaterscience.co.nz/living-water).

[263] McDowell et al., 2018.

This approach has also been recently trialled in Southland, where a few models (such as Overseer and SPARROW), as well as several datasets (such as land use information, soil maps, drainage, river environment classification, and physiographic zones), were combined and mapped to inform the three attributes mentioned above.[264] Like the physiographic approach, the quality and resolution of existing data and models will affect the spatial accuracy of the land use suitability approach.

Importantly, new conceptualisations like those described above could help match land use to inherent landscape features, inform targeted efforts to improve water quality, and minimise impacts of agricultural production on receiving environments.

Conclusions

Overseer estimates on their own are rarely enough to make decisions about managing water quality in a catchment. Additional information about the biophysical characteristics of the entire catchment is often required. This includes information on nutrients leaving farms as well as any other non-farming sources, and their transport and transformations on the way to distant receiving environments.

While the above task is beyond the scope of Overseer alone, the information the model can provide is a good, quantitative, starting point for understanding the stress that nutrient loss is imposing on the receiving environment. However, estimates produced by Overseer are only estimates, and will always be accompanied by some degree of uncertainty. Overseer estimates are not the only source of uncertainty though – catchment-scale modelling efforts bring further uncertainty.

Uncertainties in model estimates and complexities in the underlying science are not reasons for inaction. While the impact of nutrients on water quality can vary, it is clear that if nutrient loads increase significantly, so does the stress on water quality.[265] The state of water quality in many intensively farmed catchments is *prima facie* evidence of the need to reduce that stress. But to accurately quantify the likely environmental impact of reduced nutrient loss, and then link that to monitored water quality outcomes, requires a much better understanding of catchment-scale dynamics.

While nutrient transport and transformations through catchments is complex, a wide variety of datasets and models is available to help understand and manage catchments. Their coverage and management is fragmented. Depending on the locality, the contribution they can make to modelling and decision making will vary

[264] Pers. comm., Richard McDowell, 2018.

[265] PCE, 2013, p. 62.

significantly. Dataset coverage can also inject significantly different levels of uncertainty into both Overseer and catchment-scale models.

Large public investments have been made in both models and databases. The public-good nature of these investments suggests their accessibility should not be constrained by the ownership interests of the institutions that host them. This in turn demands a careful examination of the way their maintenance and future development is funded.

A joined-up view of catchment-scale environmental outcomes, and the goal of protecting 'the life-supporting capacity of air, water, soil and ecosystems', suggests that a collaborative approach to setting priorities and investing in these databases is required. This should embrace Crown Research Institutes, regional councils, and other science providers.

As with the estimates from Overseer itself, the outputs of catchment models can have significant on-the-ground consequences for farmers and other businesses. As a result, catchment-scale models must also meet the key criteria for use in regulatory settings. Given the range of catchment-modelling approaches that can be used, best practice guidance on when and how such models should be used in policy and plan making would be valuable.

8 Conclusions and recommendations

Conclusions

Overseer provides farmers with valuable information in making judgments about farm management. This is the purpose for which it was initially designed, and for which it has been managed and resourced.

But using Overseer's output is also useful to regional councils who are required, under the National Policy Statement for Freshwater Management, to do something about farm nutrient losses, which are seriously compromising water quality. The same model that optimises nutrient use for farmers, mechanically estimates nutrient loss from the root zone of a paddock.

Of course, there are plenty of practices councils can specify that are known to be beneficial in terms of reduced nutrient losses. And in some cases, ensuring that farms are following good management practices through monitored and enforced farm plans will be sufficient to achieve water quality outcomes.

But where nutrient loadings in a catchment are well beyond anything that is consistent with safeguarding the life-supporting capacity of receiving waterbodies, councils need to know that specific, quantifiable reductions are being achieved. There is a need for a tool capable of quantifying nutrients loss from farms.

It is scarcely surprising that some regional councils, grappling with unsustainably high nutrient leaching, have turned to Overseer, since it provides estimates of the very environmental pressure they are charged with managing.

But using the tool privately, and using it to estimate limits and enforce compliance are two very different things. Farmers may be happy enough with the model as a decision-support tool for farming purposes, but demand a much higher level of assurance when the consequences can be used to compel legal compliance. The level of trust placed in modelled outputs is crucially dependent on how those outputs are being used.

Although Overseer's farm and user-based focus make it attractive for use in regulatory decision making, it has not been subjected to the rigorous formal scrutiny that those who are being regulated might expect.

The assessment contained in this report has revealed that a significant amount of information needed to confirm Overseer's use in a regulatory setting is lacking. For this reason, a comprehensive and well-resourced evaluation of Overseer needs to be undertaken, if both councils and farmers are going to be able to feel confident that the model is fit for purpose. Initiating this will inevitably require access to the engine of the model, which in turn raises important questions about the proprietary nature of Overseer.

This conclusion raises an immediate question: what should happen in the meantime? As this report has described, Overseer currently underwrites a number of regulatory approaches that are either in force or in the process of being implemented. The approaches of some regional councils represent a considerable amount of 'learning by doing'.

It appears to me that most if not all the regional councils currently using Overseer to determine compliance with nitrogen limits do so because of the nature of the challenge they face. Overseer, in conjunction with catchment-scale modelling, provides a defensible quantitative basis for charting a pathway towards a lower environmental nutrient burden. And Overseer, by itself, provides a defensible basis for engaging land users on how they can, in a quantifiable way, reduce their share of that burden.

I should also observe that in these heavily over-allocated settings, if councils were to step back from trying to quantify limits, they would have to turn to much more aggressive input or land-use controls. I am not sure farmers would be any happier with that. They have consistently resisted input controls, such as limits to stocking rates, fertiliser application, cropping practices, and the amount of imported feed, on the basis that these sorts of regulations would be inflexible and stifle innovation on the farm.

Those concerns have and should continue to be taken seriously. Land-use controls will have a role in some situations, but trying to make an effects-based regime work, in which farming activity is limited by its environmental impact, is in my view worth the effort. After all, it focuses everyone on the issue we are trying to address: degraded water quality.

The best way forward is to speedily address important gaps and the shortcomings in transparency, peer review, corroboration, uncertainty and sensitivity analysis, and model documentation raised in this investigation. This will provide confidence both to regulators and farmers that uncertainties associated with the model are within acceptable bounds. This is essential to building trust in its application and in the nutrient limits being set.

It should also be recalled that Overseer assumes that good management practices are occurring on all farms. To have confidence in a regulatory framework using Overseer-derived nitrogen-loss limits, regional councils must be satisfied that these practices are occurring on all farms. Key instances where farms may not be compliant with these practices, based on our interviews, relate to storage and application of effluent on farms, and irrigation practices. Regional councils would therefore do well to ensure they are monitoring farms for compliance with these practices alongside any Overseer-based framework.

Recommendations

It is not enough for me to conclude that Overseer can be used in a regulatory context, subject to the matters I have identified as needing to be remedied. The Government itself has to decide if it wishes to see Overseer used to help manage water quality. All my detailed recommendations should follow from that.

While modelling nutrient loss using Overseer is just one tool in the water quality toolbox, if it is going to be used, it must be able to command a wide degree of confidence. Further, if modelling is going to be used to measure farm-level nutrient loss, then it should be used in a way that is nationally consistent. Only the Government can bring the parties together to ensure that best practices find their way into plans.

In making that high-level judgment, the Government can, in addition to this report, draw on a wide range of analyses, reviews, and guidance documents. But after a multi-decadal process of model development, and the elapse of more than ten years since Overseer was first used to set nitrogen discharge limits in Lake Taupō, it would be helpful if the Government were to clearly outline the regulatory uses of Overseer that are appropriate, and then establish steps to support that view.

1. I recommend that the Minister for the Environment and the Minister of Agriculture indicate if they wish to see Overseer used as a tool in the regulation of water quality and, if so, clearly identify what additional steps and actions may be required to support that use.

The recommendations that follow are made on the basis that Ministers are prepared to endorse Overseer's use in a regulatory context and direct officials accordingly.

The use of models in decision making and regulation calls for a higher level of scrutiny and transparency than is needed when using a model for research or non-regulatory purposes.

Currently there is a lack of guidance on the development, evaluation, and application of environmental models within the New Zealand environmental policy context. In its absence, this report used the elements of model evaluation developed by the United States EPA.[266]

The development of 'good' or 'best' practice environmental modelling guidance could go a long way to alerting model developers and users alike to the processes and requirements that need to be considered throughout model development, evaluation and application.[267]

2. I recommend that the Minister for the Environment task his officials to develop best practice guidance for the development, evaluation, and application of environmental models in regulation, drawing on international experience.

Given that the original development of Overseer did not envisage its current regulatory application, and that its use and ambitions have evolved organically over time, it is perhaps not surprising that more formal elements of model evaluation were neglected, at least in the early days.

That said, Overseer has been used to support regulation since 2005. If that is to continue, important gaps and shortcomings in transparency, peer review, corroboration, uncertainty and sensitivity analysis, and model documentation must now be addressed to provide confidence to councils and farmers.

[266] As noted in chapter 5, some domain-specific guidance is available on the application of modelling when implementing specific environmental policy, but there is a lack of guidance on the development and evaluation of environmental models for regulatory purposes.

[267] A distinction is often made between 'good' and 'best' modelling practices. The term 'good' is used to represent a general consensus, whereas the term 'best' is often used to represent a clear and common understanding of what modelling practices should look like. Ultimately the decision will be up to the authors of the guidance document.

3. I recommend that the Overseer owners and Overseer Limited ensure that a comprehensive and well-resourced evaluation of Overseer is undertaken. In particular:

(a) a whole-model peer review should be undertaken by technical experts independent of those who performed the development work.

A peer review of the whole Overseer model has never been carried out, nor have peer reviews of several key sub-models (such as the nitrogen leaching suite). Ongoing peer reviews are important for assurance that Overseer is of sufficient quality to serve as the basis for regulation making and to ensure the model's quality is maintained.

(b) a formal uncertainty and sensitivity analysis should be undertaken for the Overseer model.

Formal uncertainty and sensitivity analysis has not been carried out for Overseer. Understanding model uncertainty is important when models are used as the basis of policies and regulations. Quantifying and communicating uncertainty may not be an easy task for those managing Overseer, but it is necessary in some form to improve confidence and transparency in the model outputs.

Uncertainty analysis is also of importance when Overseer is used in interoperable modelling frameworks as part of catchment-modelling studies. Currently these studies are limited in their ability to understand Overseer's contribution to overall modelling uncertainty.

A better understanding of Overseer's uncertainty reduces the risk of discussions being derailed by how much modelled outputs diverge from the real world and will help focus thinking on how it can be most effectively used.

(c) In the interests of greater transparency, the following information should be documented and made publicly available:

- **the collated data used to calibrate and test the model**
- **the underlying scientific principles for all model components**
- **the algorithms, equations and parameters for all model components**
- **the source code.**

4. I recommend that Overseer owners make Overseer an open-source model.

An open-source model provides the transparency needed for Overseer to be used in regulation with greater legitimacy. Stakeholders would be able to seek independent third-party advice on whether the model's assumptions and simplifications were sound. In addition, making the engine of the model transparent creates an opportunity for scrutiny and improvement by independent experts.

An open-source approach is in conflict with the business model that has been adopted by Overseer Ltd. A way would need to be found for Overseer Ltd to support the ongoing maintenance and development of Overseer as an open-source model.

5. I recommend that the Minister of Agriculture and Minister for the Environment seek advice on ownership, governance and funding arrangements that would:

- **enable Overseer to be mandated as the 'official' model for estimating diffuse nutrient pollution for water management purposes where that is appropriate; and**
- **secure the ongoing resources to maintain and develop the model.**

6. To provide long-term funding stability, I recommend that the Minister of Agriculture and Minister for the Environment direct officials to conduct a strategic review of the:

- **resourcing needed to maintain and develop the model**
- **level of ongoing costs appropriately attributable to Overseer users in a regulatory setting**
- **level of public-good investment needed to build trust in the model through better corroboration and calibration using a greater number of sites throughout the country**
- **basis on which regional councils should contribute to regionally specific research to support use of the model.**

A comprehensive evaluation of Overseer and a move to making Overseer an open-source model would take time. In the meantime, regional councils have to work with the model under current arrangements. I have raised the need for guidance on managing version change and undertaking compliance in relation to Overseer estimates.

While these are key areas that need addressing, they are not exhaustive and there will be others. In all cases, regional councils need to ensure that plans are drafted in a way that can incorporate model-driven changes without disrupting farmers trying to comply with their obligations.

Official central government guidance should be provided to assist council planners to design plan provisions where councils have decided to use Overseer in regulation. This guidance should build on the Freeman report and the Enfocus report but could go further, setting out preferred approaches and, equally, those that are not recommended.[268]

The guidance should be accessible to planners without significant experience in using Overseer, and should be linked with other advice produced to support the implementation of water quality policies and objectives, including the National Policy Statement for Freshwater Management.[269]

7. To this end, I recommend that the Minister for the Environment direct officials, in consultation with regional council staff, scientists, and expert planners, to prepare guidance for councils designing plan provisions that use Overseer as part of a framework involving nitrogen-loss limits.

8. I further recommend that the Minister for the Environment direct officials to initiate a working group including representatives from each regional council and unitary authority, scientists, and Overseer Ltd to undertake a strategic review of:

- **those circumstances where regionally specific research is needed to support use of the model (e.g. field trials to be used in calibration or corroboration)**
- **the mechanisms to fund this research**
- **ways of ensuring that the outputs of this research are fit for purpose (e.g. the trial duration is long enough) and can be subsequently used in Overseer's modelling.**

[268] The Freeman report (Freeman et al., 2016) was commissioned by a number of regional councils, Ministry for the Environment, Ministry for Primary Industries and industry groups. The Enfocus report (Willis, 2018) was commissioned by Overseer Ltd.

[269] For example the guidance should augment the *Draft Guide to Limits under the National Policy Statement for Freshwater Management 2014 (as amended in 2017) (MfE 2018) and Draft Guide to Communicating and Managing Uncertainty When Implementing the National Policy Statement for Freshwater Management 2014.* (MfE 2016).

Overseer estimates on their own are rarely enough to make decisions about managing water quality in a catchment. Additional information about the biophysical characteristics of the entire catchment is required. In addition to nutrients leaving farms, this includes nutrients from non-farming sources, and their transport and transformations on the way to distant receiving environments.

While nutrient transport and transformations through catchments is complex, a wide variety of datasets and models is available to help understand and manage catchments. Their coverage and management is currently fragmented. Depending on the locality, the contribution they can make to modelling and decision making will vary significantly. Dataset coverage can also inject significantly different levels of uncertainty into both Overseer and catchment-scale models.

Large public investments have been made in these models and databases. The public-good nature of these investments suggests that their accessibility should not be constrained by the ownership interests of the institutions that host them. This in turn demands a careful examination of the way their maintenance and future development is funded.

9. I recommend that the Minister for Science and Innovation, in consultation with the Minister for the Environment, reviews the ownership, use, and development of the many models and databases that inform our understanding of catchment-scale dynamics, to ensure that water quality managers have access to the best possible understanding of nutrient transport and transformation.

10. I recommend that the Minister for Science and Innovation ensures that the Crown's ongoing investment in these models and databases is made in a joined-up way, with the express aim of contributing to the goal of protecting 'the life-supporting capacity of air, water, soil and ecosystems'.

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Appendix 8

Farm size estimate working

I used GIS to estimate farm sizes in the Healthy Rivers catchment using land title and ownership data. I removed urban areas and aggregated the remaining adjoining rural land parcels that had the same ownership and determined these to be individual farms (Figure 1, Figure 2). I removed all aggregated land parcels less than 2 ha.

I used the Land Cover Database files to estimate forestry and native bush cover (Figure 3) on each farm, and removed farms that had more than 90% forestry by area. By eliminating farms with >90% forestry, I removed about 180,000 ha from the analysis.

Est. Farm size (ha)	*Est. number of. farms*	*% of farms*	*Area (ha)*	*% of farmed area (ha)*
2-4.1	3,823	23%	11,278	1%
4.1-10	3,748	22%	23,306	3%
10-20	2,115	13%	30,955	4%
20-40	2,131	13%	60,643	7%
40+	5,031	30%	745,788	87%
Total	16,848	100%	871,970	100%

Figure 1: Example of aggregated land titles in common ownership to form farm boundary.

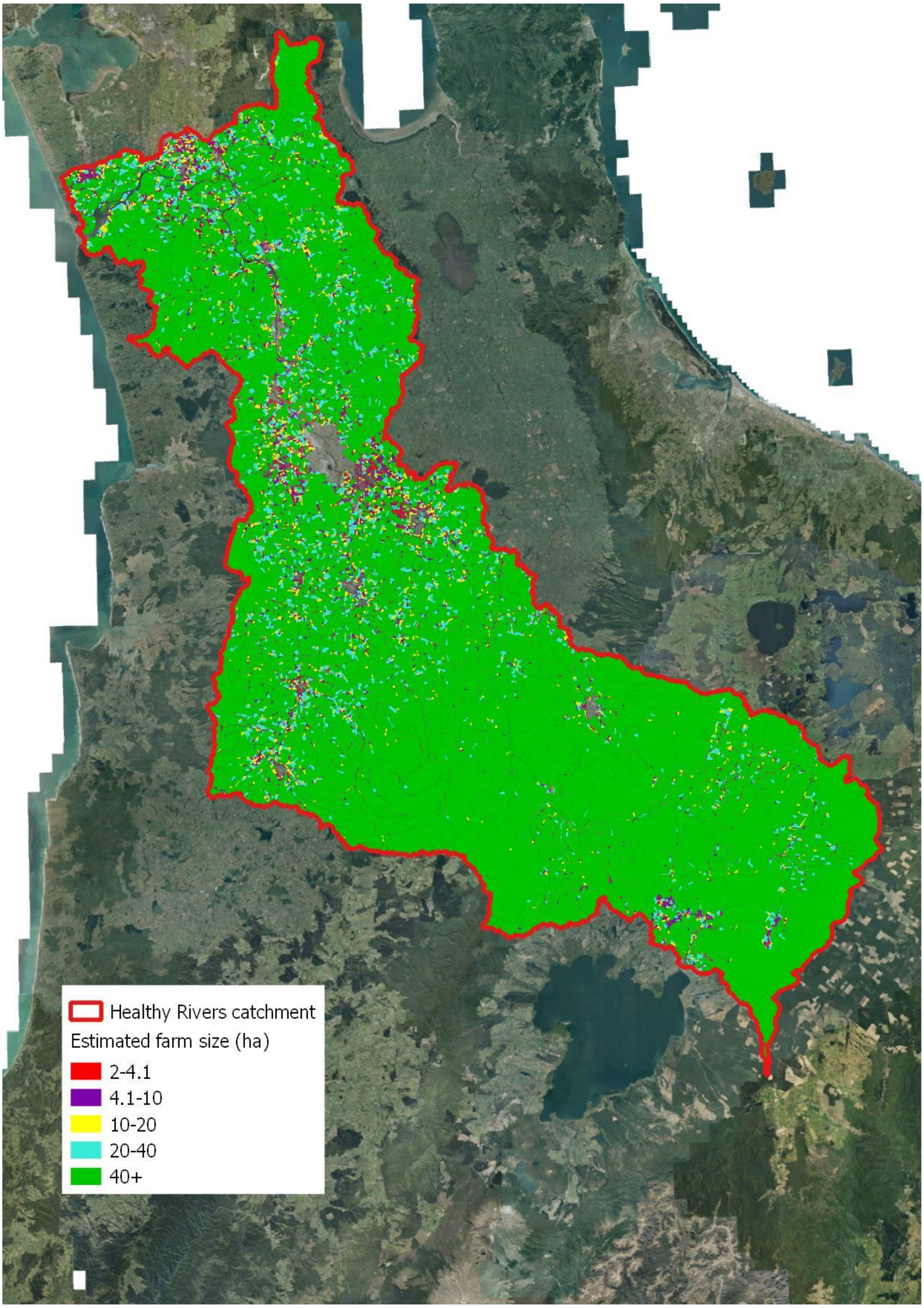

Figure 2: Estimated farm sizes in Healthy Rivers catchment.

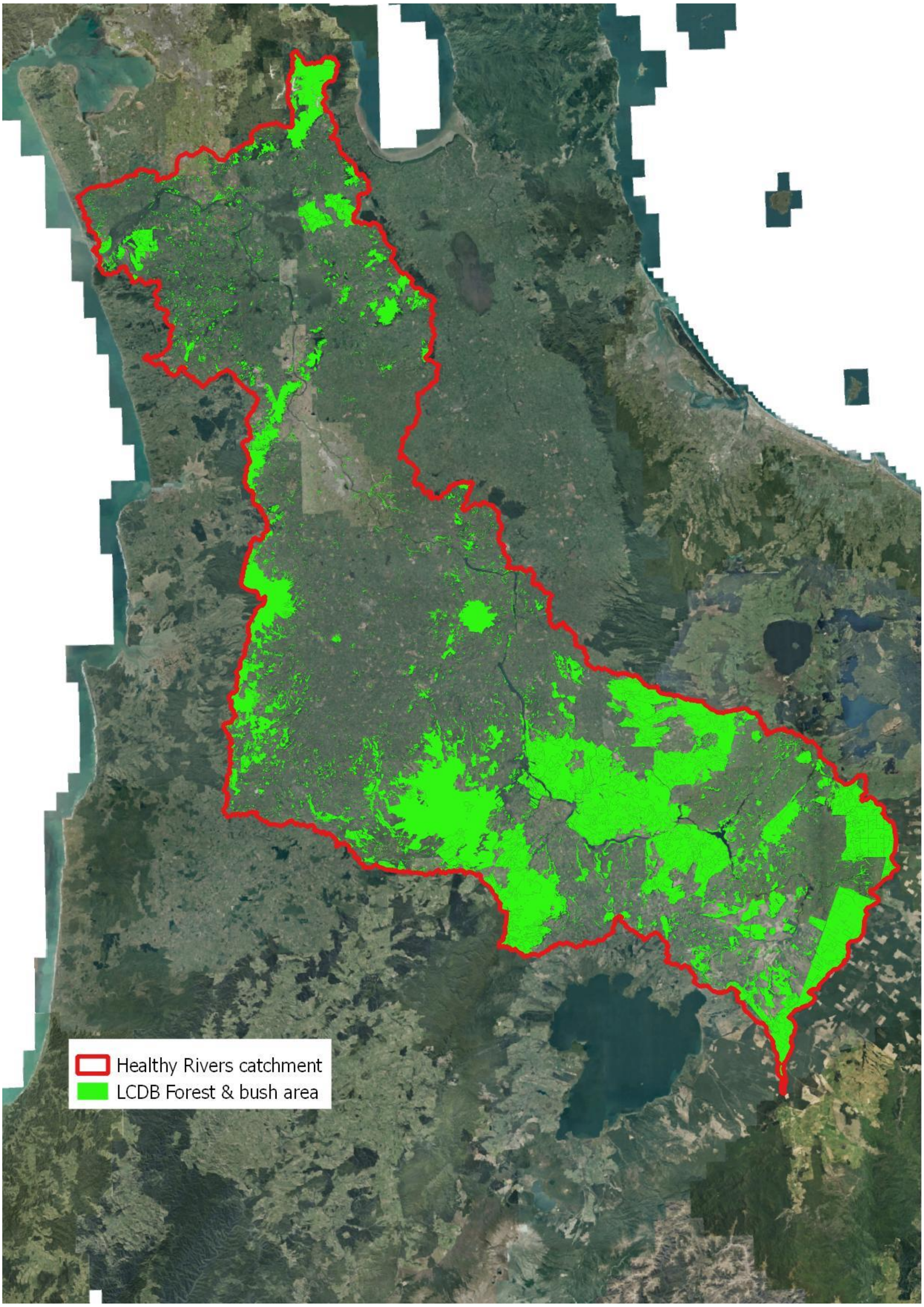

Figure 3: Forestry and native bush area taken from Land Cover Database.