Nutrient Trading in Lake Rotorua: Determining Net Nutrient Inputs

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Motu Working Paper 08-03
Motu Economic and Public Policy Research

April 2008

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Acknowledgements

This paper has been produced as background to a dialogue process (www.motu.org.nz/nutrient_trading) and is released publicly to facilitate discussion. We would like to thank Environment Bay of Plenty, the Ministry of Agriculture and Forestry, the Ministry for the Environment and the Foundation for Research Science and Technology through the programme 'Markets for Water Quality', for their financial support. We also appreciate feedback from members of the Nutrient Trading Study Group and in particular from Paul Dell and Rick Vallance, as well as from Uwe Morgenstern at GNS-Science and Suzie Greenhalgh at Landcare Research. Any opinions expressed are those of the authors and do not reflect the views of the funders or study group. The authors remain responsible for any errors and omissions.

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Abstract

Lake Rotorua is experiencing increasing nutrient-related water quality problems. This paper is one in a series that explores the idea of creating a nutrient trading system as part of the ongoing policy response to this problem.[1] Most of the current nutrient flows to the Lake come from non-point rural sources – measuring these emissions is challenging. We find that it is possible to monitor/model nutrient loss from a wide range of activities in the Rotorua catchment. The model OVERSEER combined with ROTAN and some other models for forestry, urban and geothermal activities and horticulture already exist. They are currently in a process of enhancement – a particular area of current weakness is knowledge of the groundwater lags from specific locations in the catchment. The land-based models need to be used in a specific form that relies on initialisation with verifiable data and uses easily collated and verified data on an annual basis. The form of the model should be fixed for each regulatory year to minimise uncertainty for landowners and regulators. The models need to be updated to reflect new science. The process for doing this needs to be strategic and credible (this will be discussed in a later paper on governance processes). Once changes are recommended they need to be implemented in a way that is perceived to be fair.

JEL classification
Q53, Q57, Q58

Keywords
Water quality; monitor, verify, report, model, emissions trading

[1] To see the other papers go to www.motu.org.nz/nutrient_trading

Contents

1 Introduction

Lake Rotorua is experiencing increasing nutrient-related water quality problems. This paper is one in a series that explores the idea of creating a nutrient trading system as part of the ongoing policy response to this problem. Lock and Kerr (2008) provide an overview of the prototype design. In the nutrient trading system prototype, a trading cap is first defined. This defines the total controllable nutrient flows that will be allowed to reach the lake in each time period (Kerr et al (2007)). 'Allowances' summing to the total cap are issued (through gift or sale) to nutrient sources. Each nutrient source must then determine its annual nutrient loss and surrender sufficient allowances to match this loss. If they do not have enough allowances they must buy them from other sources who have more than they need. Strict compliance measures will be used to ensure that all nutrient loss is matched by allowances and hence that the environmental goal is achieved. The advantage of the trading system is that nutrient sources have much greater flexibility in how the environmental goals are achieved. Those who are able to reduce at low cost have an incentive to reveal this and all sources have incentives to innovate and adopt new nutrient reduction and mitigation ideas. This flexibility and these incentives should significantly lower costs as well as maintaining farmers' control over their own land.

Most of the current nutrient flows to the Lake come from non-point rural sources – measuring these emissions is challenging. Partly for this reason (though primarily for political ones), nearly all nutrient trading systems outside of New Zealand have focused on point sources which are comparatively easy to monitor and brought in agricultural sources through voluntary opt-in programmes (The World Resources Institute (2007)). These opt-in programmes have generated methods to estimate the effects on nutrient flows of specific mitigation options but they do not attempt to model farm scale water quality impacts for a large group of actors. The exception is a manure trading system in the Netherlands where manure application is used as a proxy for water quality impacts. A simple proxy like this cannot be used when dealing with New Zealand livestock production where animals are primarily grass fed or with heterogeneous nutrient sources. This paper focuses on ways to address the problem of determining nutrient flows for regulatory purposes.

In a nutrient trading system we need to determine[2] net nutrient exports from each property to ensure that they are matched by the appropriate allowances for two reasons: first, to ensure that the cap is actually met and hence that the environmental goal is achieved; second, to make the system fair so that no one can benefit relative to others by non-compliance.[3] The approach used to determine allowance requirements needs to be seen to be consistent and effective.

The problem of estimating nutrient loss is not unique to a nutrient trading system. Any system that effectively regulates nutrient loss at a farm level needs tools to estimate that loss. In a nutrient trading system, however, the determination of nutrient loss is regular and comprehensive and measured nutrient loss has direct financial implications for private actors. The tools are more visible and hence more likely to attract public criticism or legal challenge. Also, monitored nutrient loss is explicitly compared across properties that are allowed to trade; environmental advocates might challenge trades if the tools are not publicly accepted. In contrast, under other forms of regulation, regulators often deal with farms one by one in a less transparent way and there is less pressure to formalise and standardise tools.

If trading is to have low transaction costs, and hence achieve the anticipated efficiency gains, compliance requirements must be certain; the model used must unambiguously determine the number of allowances required rather than being open to argument about the accuracy of any estimate. Because the model is explicitly used in compliance it must be based only on data that can be verified and audited if necessary.

Non-point source nutrient export rates vary in space and time, and nutrients come from a large number of properties. This makes them difficult or even impossible to measure and costly to estimate accurately. In many situations

[2] In this context 'determine' does not mean 'measure' which is impractical. It means using suitable proxies from which nutrient export can be calculated based on clearly defined regulatory rules.
[3] For discussion of the definition of 'allowances' for this market see Kerr et al (2007)

we have no alternative but to monitor proxies for nutrient export (viz., measurable variables that determine nutrient export). We then ‘model’ nutrient exports using the proxies (e.g., productivity, stock numbers, fertiliser usage) as input variables for the model(s). The challenge is to use the ‘best’ model possible in the circumstances.

This paper explores what ‘best’ model means for a trading system and describes the current technology for modelling so the reader can assess whether the current models are strong enough to support nutrient trading. Over time the models could be improved to increase the efficiency and equity of the system. The characteristics of a ‘good’ model are that it is:

- accurate: the model structure is well understood and scientifically credible and it is supported by the best current scientific information available;
- cheap to apply: it is based on relatively cheaply monitored inputs and is easy for landowners to use; and
- transparent: it is difficult to manipulate and perceived to be consistently applied.

Some of these may be in conflict with others and we need a framework in which to make tradeoffs between goals.

This paper will begin by presenting the components of an ‘ideal’ model; what we would use if we had no scientific limitations and an infinite budget. This is presented to provide a benchmark for comparison. We then discuss the efficiency, equity and legal implications of real systems for determining nutrient flows and other emissions for regulatory purposes and give some examples from existing trading systems.

The paper then describes the processes that need to be modelled and the current models available for the Lake Rotorua catchment. We discuss issues of monitoring and verification of basic property level data required as inputs to these models. We then explore how should we address aspects where there is significant scientific uncertainty and introduce issues relating to how to update the monitoring model as scientific information improves and as landowners demand the ability to monitor specific farming practices. We will also offer some thoughts on how to target research effort that directly aims to improve a nutrient trading system.

2 Determining nutrient loss

2.1 An 'Ideal' system for determining nutrient loss and real tradeoffs

What we would really like to know is the impact of net exports from each property on net inputs to the lake in each time period. The timing of the impact depends on groundwater lags; because of local geology, water, and hence nutrients, can take between 0 and 200 years to reach the lake depending on where it falls. The size of the ultimate effect on water quality depends on off-farm attenuation; not all nutrients that leave the land will reach the lake. If we could measure inputs to the lake directly and accurately, landowners would be rewarded for every action they take that affects the lake in proportion to the benefit they create by their efforts. In economic terms, the effects on the lake would be 'internalised'.[4]

The accuracy of the method used to determine nutrient loss has efficiency implications. The type of data reported to the regulator determines the land uses and practices that landowners can get credit or be penalised for changing and how much credit or penalty they get. Therefore, the model we use determines how well our effort to protect the lake is targeted. Accurate models (or responsive models that rapidly include new practices as they are discovered) also provide incentives over time to develop new nutrient reduction and mitigation practices and technologies whose real effects would be picked up by the model. Property owners will have financial incentives to adopt new practices and technologies

[4] Tietenberg (1996), Tietenberg (2006)

when they are available because they will lower their need for allowances and hence reduce their need to buy or enable them to sell allowances.[5]

An accurate model may be perceived to be more equitable. Nutrient sources will need to surrender the same number of allowances if they have the same environmental impact.

2.1.1 Why don't we determine nutrient loss accurately?

The first reason is simply that we can't. We are unable to directly measure nutrient flows because they mostly pass through groundwater, and we don't have scientific methodologies that can accurately estimate the implications of all actions at all times and in all places on lake water quality. Even if we did, we couldn't possibly collect enough data to apply these methodologies over all actions at all times in the catchment. Even if we attempted to get as close to perfection as is currently scientifically possible, it would be extremely expensive and we could more usefully spend the resources on improving lake quality directly.

Another reason to stop short of the highest level of accuracy we can achieve is that very complex models are non-transparent. Only a few people can understand them or verify the data that went into them. Thus it is hard to know if they are unbiased and applied consistently. This creates a risk of manipulation by a few unscrupulous players and makes the perception of inequity likely.

We need to compromise and use simpler more user-friendly models that require relatively few data inputs for each source. This will lower compliance costs for those who need to use the model (both nutrient sources and regulators) particularly by reducing costs of verification and audit. We should however strategically simplify models to reduce costs and improve transparency while minimizing the sacrifice in accuracy and hence efficiency and equity.

The exact form of the model we choose will change over time as technology develops, the value of nutrients changes and land use patterns and

[5] Kerr and Newell (2003) give empirical evidence that firms' adoption decisions respond to tradable permit markets.

drivers change. New scientific knowledge and technology may allow us to achieve a higher level of accuracy with no additional compliance cost; if allowances have a very high value, the efficiency loss from inaccuracy will rise and the trade-off between the value of accuracy and the cost of compliance will shift toward a greater weight on accuracy; if some land uses and practices rise in importance in the catchment, the damage from inaccuracy in models of their water quality impacts will also rise simply because they will contribute a greater share of nutrient losses; further investment to improve the accuracy of determination of their nutrient losses will be justified.

2.1.2 Quantifying pollutant discharges/emissions in other tradable permit markets

The use of proxies and models for the ultimate resource or pollutant of concern is normal in tradable permit markets. The US Acid Rain market that controls sulphur dioxide emissions from US electricity generators is the closest to an exception because they can monitor emissions of SO_2 directly and continuously. Even in this case however, the spatially variable impacts of the SO_2 are not taken into account so 'hot-spots' of pollution could occur (Ellerman et al (2000)).

In other cases the link between the proxies and the actual pollutant is arguably closer than it is with nutrients. In the New Zealand Emissions Trading system fossil fuel emissions will be monitored at the point of extraction and import of fossil fuels.[6] This misses the timing of CO_2 emissions and some subtleties of fuel use that affect emissions. Some fuel is wasted; it comes out as soot. Similarly a petrol tax, which has the same information requirements as a tradable permit market, is a blunt instrument that is sometimes used to address local air pollution.[7]

[6] Ministry for the Environment (2007) *The framework for a New Zealand Emissions Trading Scheme*, September. Accessed at http://www.climatechange.govt.nz/files/emissions-trading-scheme-complete.pdf on 16 January 2008.

[7] For modelling of the impacts of regulating petrol as a proxy for local air pollution see Fullerton and West (2002). For simulations of the effects of imperfect modelling of carbon sequestration in tropical forests on a potential avoided deforestation programme see Kerr et al (2005).

Within New Zealand, the New Zealand Individual Transferable Quota system for fisheries management aims to ensure the sustainability of fisheries (Lock and Leslie (2007)). Authorities cannot however monitor the impacts of fishing activity on stock sustainability directly so they monitor tonnes of fish caught. Sustainability depends on the tonnes of fish caught each year but also depends on their age, specific location, timing of catch, techniques used etc. Supplementary regulations address some of these things but not all.

The key difference between these systems and the modelling of nutrient loss is to do with perception. All of these systems use proxies for emissions and use models implicitly or explicitly to link those proxies to the environmental outcomes of concern. In each case, however, the participants in the system are regulated on the basis of something easily observable; fish, petrol, SO_2. It would be possible to do this for nutrients from livestock production systems and monitor only animal numbers but at a significant loss in terms of accuracy because management is important. We have to consider the trade-off between participants' perceived loss of certainty when we explicitly use a model in the monitoring process, and the increased flexibility and environmental certainty that a more complex model brings.

The treatment of agricultural emissions within the New Zealand Emissions Trading System presents the closest parallel to nutrient trading. One option is to use the model OVERSEER based on data at the farm scale. Many of the issues we are discussing here arise in that context (Kerr and Sweet (2008)) – this is the subject of intense engagement and research in 2008.

2.1.3 The legal status of modelling

Legislation and/or regulations need to reflect the fact that the use of proxies and models for the ultimate issue of concern is the only efficient and equitable approach. Otherwise the rules for monitoring and modelling nutrient loss – and hence how many allowances must be surrendered to match it - can be challenged case by case on the basis that the model used does not accurately reflect true emissions. If this happened too often it would make the system unworkable and would create bias toward those who are able to challenge the system. It does not matter if the models are imperfect so long as the models are the ‘best’ available, we understand and accept limitations of the models, monitoring data etc. and the models are used consistently and transparently.

Ideally, the participants in the trading system would be willing to accept the inaccuracies of the modelling system in exchange for the flexibility that an effective trading system offers. Then rather than challenging the system they can put their energy and resources that into trying to improve the models over time or simply into reducing nutrient flows. The issues within the New Zealand legal system are discussed in more detail in Rive et al (2008).

Terminology

‘**Attenuation**’ is the *permanent removal* from runoff, groundwater and/or stream flow of bioavailable N and P (viz., those that stimulate plant growth in the lake). Dissolved inorganic nutrients (DIN) (e.g., nitrate, phosphate) are readily taken up by plants. However, plant uptake does *not* represent permanent removal and is only temporary storage. At the end of the growing period, plants leach dissolved organic nutrient (DON) and die to form particulate organic nutrient or detritus (PON). Some bacteria and fungi derive energy by metabolising DON and PON. In the process they release DIN, which is then available to stimulate plant growth. P may become temporarily adsorbed onto sediment particles and/or form complexes with calcium, iron etc. These chemical processes are reversible and P may be released (e.g., from anoxic sediments in lake and stream beds).

The term ‘**nutrient cycle**’ describes these uptake/release processes. Cycling is less than 100% efficient and each time nutrient goes around the cycle, some fraction is ‘lost’ by being converted into non-available forms (viz., attenuated). Typically in large catchments (>100 km^2) the nutrient load measured at the catchment outlet is ~50% of the sum of the loads into the system (e.g., from farms, point sources, rain etc). The other 50% is ‘lost’ or ‘attenuated’.

For N the main mechanism of permanent removal is **‘denitrification’** (viz., conversion of nitrate to nitrogen gas). A small fraction of N in plant material (e.g., ligin) is mineralised so slowly that it can be considered permanently removed but it is difficult to estimate the fraction of plant material permanently removed. For P, permanent removal occurs principally through burial.

‘**Mitigation**’ describes the things that landowners can do to increase permanent removal on-farm. For N this includes enhancing riparian wetlands to maximise denitrification. It also includes enhancing grass buffer strips and wetlands to maximise trapping of sediment and particulate nutrient. However, trapped particulates may release nutrients (mineralisation) unless denitrification occurs or plants are harvested. In contrast **‘nutrient reduction’** is any change in behaviour that reduces the nutrient loss in the first case by either reducing application or increasing efficiency in its use in harvested products.

‘**Off-farm attenuation**’ occurs *after* water (and hence nutrients) has left the farm but before it enters the lake, for example in large natural wetlands, streams, and aquifers. ‘Off-farm mitigation’ could include ‘treating’ stream flow (e.g., alum dosing as is being trialled in the Utuhina, diversion of spring and/or stream flow into natural or constructed wetlands) or groundwater treatment to remove nutrients.

In our terminology ‘**export**’ = ‘**on-farm nutrient loss**’ minus ‘**on-farm attenuation**’.

3 Monitoring in practice

3.1 Available models of nutrient exports

To estimate net export from a property we need to model:

1. Nutrient generation and
2. on-farm attenuation.

Two models currently used to estimate nutrient generation from pastoral farmland are: AgResearch’s model OVERSEER and the United States Department of Agriculture model CREAMS. For pasture and cropping land the HortResearch model SPASMO can be used. These models predict ‘edge of field’ nutrient losses (viz., nutrient fluxes leaving the root zone in drainage (OVERSEER, SPASMO) or at the bottom of the hill slope in surface flow (CREAMS)).

Currently no single model estimates how much nutrient is permanently removed by on-farm mitigation measures such as riparian buffers, wetlands, ponds etc. This is the subject of ongoing research (e.g., NIWA is sub-contracted by AgResearch to develop nutrient attenuation modules for inclusion within the new version of OVERSEER).

These models require input data. Some of the required data for a given property needs to be estimated only once (e.g., slope, soil type etc). Other information varies with time (e.g., stock type and number, fertiliser use, productivity etc). A sub-set of these data needs to be monitored – other data can be set to default values. The data inputs we monitor for the model that determines the N losses from a property defines what landowners can get credit or be penalised for changing.

These models might not be used directly, in their current form, in the regulation. They might be too complex and involve too many variables. They could, however, be the basis of specific, simplified versions that would make up the 'regulatory model'. They might also need to be supplemented by other models for reduction and mitigation options that are not currently included but that Environment Bay of Plenty (EBOP), the Regional Council that has responsibility for water quality in Lake Rotorua, wants to include in the nutrient trading system. Here we focus on models relating to pastoral agriculture but these will need to be supplemented by models of forestry, urban emissions and horticulture.

3.1.1 OVERSEER

OVERSEER is a model developed by AgResearch that can be used to calculate annual average nutrient budgets for individual farms throughout New Zealand.[8] Its original aim was to help farmers optimise farm production. Almost coincidentally it calculates nutrient loss to the environment, and this aspect has made it attractive to regional councils.

It can be operated in two modes – simple and detailed. The former considers the whole farm as a single unit, while the latter sub-divides the farm into blocks. The data inputs for OVERSEER are extensive and include: farm type (e.g., sheep/beef), productivity (e.g., t/y milk solids for dairy), soil type, soil drainage class, slope, rainfall, stocking rate, dry matter production, fertiliser use, supplementary feed, area for effluent irrigation, and in future will include the area and 'condition factor' of: wetlands, riparian buffers zones, and fenced and unfenced streams and which blocks they are found in. Changes in any of these inputs affect nutrient loss.

Originally OVERSEER did not estimate how much nutrient is permanently removed by on-farm mitigation measures such as riparian buffers, wetlands, ponds etc. This led Environment Bay of Plenty to contract NIWA to develop the NPLAS model which is described below. Recently NIWA was sub-contracted by AgResearch to develop nutrient attenuation modules (filter strips,

[8] http://www.agresearch.co.nz/overseerweb/

natural and constructed wetlands) for inclusion within the new version of OVERSEER.

OVERSEER calculates exports of both nitrogen and phosphorus. Soil erosion is the main delivery mechanism for P from land use although direct deposition of dung by stock in streams, bank and bed erosion by stock, and point source inputs (e.g., industrial discharges to streams and surface runoff from saturated effluent irrigation blocks) are also important.

3.1.2 NPLAS

NPLAS (Nitrogen and Phosphorus Loading Assessment System) is a model developed by NIWA for EBOP. It takes predictions from the OVERSEER and CREAMS models of N and P generation, and adds the effects of ‘on-farm mitigation’ (e.g., wetlands & riparian buffer strips). Again it is an annual average model. The data inputs for NPLAS are similar to those for OVERSEER. NPLAS is likely to be superseded by the updated OVERSEER.

3.2 Modelling groundwater lags and attenuation

To link net exports to lake inputs we need to quantify groundwater lags and off-farm attenuation.

Because of groundwater lags, annual exports from different properties in a given year affect annual inputs to the lake in different years. For example in catchments where groundwater residence times are 15 and 70 years, exports this year will most strongly influence inputs in 15 and 70 years respectively. Because of ‘mixing’ within the aquifers, the annual export from a property will be ‘spread’ over several years and mingle with exports from earlier and later years.

Natural off-farm attenuation in the Rotorua catchment (viz., in the aquifers and streams) is believed to be minimal. However, this has not been confirmed. The potential exists to undertake ‘off-farm mitigation’ (e.g., the current alum dosing trial in the Utuhina Stream and earlier P-sock trials at Lake Rerewhakaaitu) and this could be included in the nutrient trading scheme (see box).

Crediting enhanced attenuation is a slightly unintuitive aspect of efficient monitoring and rewarding of changes in nutrient impacts. A landowner should need fewer lake-input-allowances to match nutrient exports if they will be attenuated en route to the lake, even if the attenuation occurs on someone else's land.

Suppose a wetland on property 2 will affect the inputs related to nutrient exports from property 1 (i.e. attenuate the exports) because the water flows through property 2's wetland. We want to provide appropriate incentives for property 2 to create/enhance the wetland. Some of the benefits of the wetland will accrue directly to property 2 because its own exports will be associated with lower lake inputs and the owner will need fewer allowances for the same activities. Some of the benefits will flow to property 1, however, because property 1's exports also will require fewer allowances. Requiring fewer allowances on property 1 is efficient because property 1's exports now result in fewer lake inputs so are less damaging.

One way for property 2 to capture more of the benefits of its investment is to negotiate with property 1 before creating/enhancing the wetland and get them to share part of the investment cost – perhaps in proportion to the nutrients that currently flow through it. Both properties receive a return on their investment through the trading system.

3.2.1 ROTAN

Quite a lot is known about the effectiveness of nutrient reduction and 'on farm' mitigation systems. We know less about how quickly nutrient travels from a property to the lake, whether it follows surface pathways (viz., streams) or sub-surface pathways (viz., shallow or deep groundwater) and the amount of attenuation that occurs after nutrient has left the property (e.g., in streams, wetlands, groundwater or riparian zones). For effective regulation we need to estimate when nutrients will affect water quality and how this varies depending on groundwater lags and attenuation.

Groundwater 'lags' are important at Rotorua and will need to be included in any nutrient-trading scheme. In the Lake Rotorua catchment, flows of nutrients through surface water that may have shorter lags are minimal. GNS-Science has conducted groundwater investigations in the Rotorua catchment that includes measuring groundwater age (using 'bomb' tritium and other tracers) and detailed finite-element modelling to determine groundwater catchment boundaries (viz., which springs are connected to which properties).[9]

Results from a number of studies have been used to develop the ROTAN (ROtorua and TAupo Nutrient) model. ROTAN is a daily time-step model that is being developed by NIWA in collaboration with GNS–Science and EBOP. It is being used to examine research questions including: the role of in-stream attenuation, the potential for riparian wetlands to attenuate nutrients, the effects of storm flows and groundwater lags and impacts of land use change in general. ROTAN addresses issues including the spatial location of farms and changes over time in land use and hence nutrient loss. It can be used to estimate uncontrollable flows of nutrient through groundwater that results from past land use as well as predicting the timing and extent of impacts of current land use. The inputs to ROTAN include: daily rainfall and evapotranspiration time series, land use and vegetation cover maps at regular intervals of time (e.g., every 5 years), detailed catchment topography (from a digital elevation model so that slopes and catchment areas can be calculated), the stream network, and aquifer boundaries, volumes and residence times. The data on aquifer boundaries and the lag times associated with different parts of those aquifers is the subject of current GNS-Science and NIWA research.

3.3 Modifying and combining models to create a system for determining nutrient flows

We propose that ROTAN, in a simplified form, could be linked to NPLAS, or OVERSEER and CREAMS, and SPASMO to create a modelling package that could be used to define inputs to the lake from each land parcel within a nutrient trading system. This would assist the design of a nutrient trading system by allowing us to simulate different design options to assess key tradeoffs empirically. If a trading system is adopted, this package, or a simplified version of it, could be used to determine net nutrient loss and lags between exports and inputs within the regulation. It would need to be usable by both nutrient sources and the regulator.

[9] For reports on groundwater in this catchment see http://www.envbop.govt.nz/Water/Lakes/Technical-Reports.asp.

For regulatory purposes, each property could be assumed to have one length of lag even though in reality there will be some distribution of lags. Kerr et al (2007) explains how this information can be incorporated in nutrient market design. As the groundwater lags increase, the uncertainty associated with them is also likely to increase. It may be sensible to define a period of time in which nutrients lost from the land are anticipated to reach the lake (of increasing range as the average lag increases) with properties in those zones rather than one specific year.

For a nutrient trading system it would be possible to include 'on farm' attenuation but it might be sensible to exclude 'off-farm attenuation', at least initially because their impacts are still highly uncertain. If and when 'in stream' attenuation and other forms of 'off-farm' mitigation (e.g., alum dosing or stream diversion into wetlands) can be quantified satisfactorily at Rotorua, they could be included in the nutrient trading model.

For non-land based activities such as sewage, storm water and geothermal activity, other existing models are needed to supplement the land-based models.

3.4 Monitoring and verification of model inputs.

We must have agreed standards for monitoring and modelling: verifying, and if necessary auditing, the quality of the monitored data, and verifying the modelling results. Only OVERSEER data will vary across the nutrient sources – groundwater lags and geophysical characteristics of properties will not vary across time so can be reported and verified once only or determined directly by EBOP from external datasets such as cadastral, soil, slope and precipitation maps and ROTAN for groundwater lags. Verifying modelling results is simple; each property simply submits its OVERSEER model input files each year and EBOP staff can rerun the model. Verifying and auditing input data may be more complex.

The variables that can be altered in OVERSEER can be divided into those that will be monitored annually for regulatory purposes and those that will have fixed (possibly farm-specific) default values after initialising the model with geophysical and fixed infrastructure (e.g. riparian boundaries and fenced wetlands) data for each farm.

Initialising the model for each property requires some farm specific measurements and will be relatively time intensive. This is necessary only once however. The 'benchmarking' process for Rule 11, an existing regulation that caps nutrient loss from each farm, is essentially creating these data while also establishing an estimate of current nutrient loss or 'benchmark'. It cannot be done by farmers alone – some external verification is required. If farmers want to use OVERSEER as a farm management tool, which they should in order to optimise their use of nutrient allowances, they may need assistance but use for compliance is simply a matter of data input.

Farmers have an incentive to initially exaggerate the data that will change from year to year, for example fertiliser use and stock numbers, if free allocation of allowances is done on the basis of the 'benchmarked' data. This means these data must be carefully verified. If allocation of allowances and subsequent determination of nutrient losses are based on the same initialisation of fixed parameters however, any errors in the farm specific, non-changing data in the initialisation (e.g. soil type and slope) will have only second-order effects on farmers' profitability. Hence there is a lower incentive to manipulate the data to provide high initial estimates of emissions. Initial exaggeration of nutrients could raise farmers' free allocation of allowances but it will also increase the number of allowances they need to surrender. In contrast, if free allocation is based on something other than benchmarked values (as is proposed in Kerr (2008)), certification of the initialisation will be more important because farmers will have an incentive to initialise to values that imply lower nutrient loss.

Once the model is initialised for each property, a number of variables will then be reported each year to generate actual nutrient loss numbers. OVERSEER allows a large number of such variable inputs including animal type and number, output, fertiliser application, supplementary feed and existence of a wetland. For regulation, only those that could be verified after the end of a year can be included easily. These will be those where financial records exist – for example purchase of fertiliser or supplements. Other values will have to have predetermined values, e.g. location of animals within the property during year. EBOP would randomly audit some nutrient sources' reported data to deter cheating.

EBOP and property owners might consider it worthwhile to include more complex nutrient reduction and mitigation options that require ongoing farm specific measurement or frequent data that cannot be verified at year end. These would need to be associated with a more intensive enforcement process that may require real time certification of some data. For example the timing of fertiliser application is important for nutrient loss; this cannot be confirmed by ex-post audit if the farmer applies fertiliser, however if the fertiliser company applies the fertiliser and keeps records they can certify the location and timing of fertiliser application. Data that cannot be verified ex post from paperwork might need to be reported more regularly and subject to random on-site inspections (of, for example, on which block of the farm animals are located).

Another way to improve the detection of non-compliance (i.e. reporting lower nutrient loss and surrendering fewer allowances than the model based on correct data would determine) is to make public the data files provided to EBOP. This way NGOs and others within the catchment can see each property's data and say if they believe the data are misleading based on their own observations. For example if a farmer claims a riparian boundary, his neighbour may know that it was burned or removed (or never planted). If these data were to be made public, valid confidentiality concerns of property owners would need to be considered and farmers would need to be consulted.

4 Uncertainty and updating/enhancing models

Two issues arise here: adding new nutrient nutrient reduction and mitigation options; and updating the science of land use and management practices that are already included.

4.1 Adding new nutrient reduction and mitigation options

When the cost of compliance is relatively high, landowners and others will demand the ability to monitor specific farming practices or other nutrient reduction and mitigation options that are not currently included in our set of models.

When considering whether to include options that are not in the model used to determine net nutrient loss we need to consider four key issues:

1. Scientific confidence in genuine reduction and the size of that reduction (and our ability to do new science to improve the reliability of the estimation);
2. our ability to collect data to verify a model that incorporates the new options (at reasonable cost);
3. the potential impact on nutrient loss across all properties; and
4. how much landowners or others will gain from their use (the value of reductions in terms of allowances net of the cost of achieving and reporting/verifying them summed over those who are likely to adopt). There is no point in incurring the cost of a more complex model if landowners will not take advantage of the new options and make considerable savings.

Landowners have expressed concern that there may be very long lags between identification of a new option and its recognition/inclusion in the regulatory system. We could potentially add pastoral farming options that are not in OVERSEER or CREAMS if either the creators of OVERSEER and CREAMS are not intending to add those options, or if they are excluding them because they consider the uncertainty to be too high for their purposes. In the model used to determine nutrient loss for regulatory purposes, it may be preferable to include an option but attribute low nutrient loss implications rather than exclude it altogether – i.e. the regulatory standard of certainty may be lower than the scientific modelling standard.

4.2 Updating science on nutrient loss from land use or mitigation options already included in model

Although we propose basing the monitoring system on OVERSEER and other models, it would not be necessary to update the monitoring model each time the underlying models are updated. Updating on a schedule driven by outsiders may create unwanted uncertainty within the regulatory system. However there does need to be a process to update the regulatory system as science evolves both to protect the lake and ensure that we are doing so in the most efficient way possible.

4.3 New research

New research will need to be funded. A governance body will need to determine research priorities and commission research. It will be possible to use research on related issues that is externally funded. For example the agricultural component of the New Zealand Emissions Trading System will require research to update OVERSEER that will be complementary to the needs of this system. Given that both systems may affect the same farmers, it would make sense to coordinate research programmes and also seek consistency between the models, and critically the exact form of required model input data, used for each system.

4.4 Altering allowance requirements for compliance when models are updated

When the model used to determine nutrient loss for regulatory purposes changes, properties and actions will be associated with different levels of nutrient loss. Will the ‘allowance requirements’ of landowners suddenly change with a new version of the model? Would this be efficient? Would it be fair?

A principle that could apply when the regulatory tool is upgraded is: no retrospective penalties should apply. The purpose of upgrading the regulatory tool is to alter the incentives for changing land use and management. Retrospective changes that change the cost burden when landowner behaviour has not changed lead to landowner uncertainty with no compensating benefit.

If the old tool is found to be systematically biased in terms of the environmental impact, this should be taken into account through an adjustment to the cap. This principle can be implemented by compensating nutrient sources for the impact of the model change on the allowances required to continue with current behaviour.

Example

In the following table (Table 1) the allowance requirement for each of the identical sheep/beef properties is estimated at 9kg per ha. Forestry has the lowest possible nutrient loss and hence requires no allowances at the start of the programme. If the regulatory tool were unmodified, the calculation of change in allowances required for a change in land use from sheep and beef farming to forestry (the lowest possible nutrient loss) would be straightforward – a ‘reward’ of 9kg allowances per ha.

Over time, however, the reward for a change from sheep/beef to forestry varies – through overestimation and then underestimation of nutrient loss from forestry by the tool. The reward is estimated at 9kg initially, then 5 (now 4kg are estimated from forestry) and 7 (2 from forestry) respectively for three time periods: phases 1, 2 and 3 respectively.

Table 1– Effect of changes to the regulatory model on allowances required for compliance

Regulatory tool updated at commencement of each Phase				
		Phase 1	Phase 2	Phase 3
		KgN/ha	KgN/ha	KgN/ha
	Sheep/Beef	9	9	9
	Forestry	0	4	2
	'Reward' for change	**9**	**5**	**7**

Taking the three identical sheep/beef farms and the variation in modelled nutrient loss from forestry (Table 1) we show what happens to the landowners. Compensation/recall is based on the land use in the period before the change in the regulatory model.

Table 2 Allowance requirements (AR), compensatory allowance allocations (CAA) and effects on net wealth of landowners as a result of the regulatory model changes

	Phase 1		Phase 2				Phase 3			
Property	AR ha	use	CAA ha	AR ha	use	Effect of model change on landowner	CAA ha	AR ha	Use	Effect on landowner
A	0	F	4	4	F	0	-2	2	F	0
B	9	S/B	0	4	F	0	-2	2	F	0
C	9	S/B	0	9	S/B	0	0	2	F	0
Conversion Incentive	9			5				7		

F=forest; S/B = sheep/beef

In phase 1 only property A converts to forestry. The conversion incentive is the difference between the allowance requirement in sheep/beef and that in forestry.

At the beginning of phase 2 the model changes. Property A faces a 4 unit higher allowance requirement for its existing land use and is compensated by being given 4 allowances per ha so they are not disadvantaged. Neither property B nor C is affected by the change based on their previous use so they are not compensated. They face a new efficient, conversion incentive of 5 and property B chooses to convert.

At the beginning of phase 3 the regulatory model changes to a lower nutrient loss for forestry. Property B and C now face lower allowance requirements for their existing use so to avoid windfall gains they are required to give up 2 allowances per ha. The incentive to convert to forestry is now 7, which is again efficient based on current knowledge.

This approach makes the incentives to change land use and management as accurate as possible at all points in time and minimises the risk landowners face. The only agents who face risk associated with the change in the regulatory tool are those who were planning to change land use before the tool adjustment and then find that the rewards have changed.

To maintain alignment between the cap and the environmental goal, the total cap needs to be reduced between phase 1 and 2 (and increased between phase 2 and 3). The reduction in cap required to keep the goal consistent for all vintages (for definition and discussion of vintages see Kerr et al (2007)) is the change in modelled nutrient loss from forestry times the area in forestry. This will also need to compensate for all historical emissions – this may lead to a reassessment of the environmental goal. Options for how to reduce the cap are discussed in a paper on cost sharing (Kerr (2008)).

5 Summary

It is possible to monitor/model nutrient loss from a wide range of activities in the Rotorua catchment. The models OVERSEER and CREAMS combined with ROTAN and some other models for forestry, urban and geothermal activities and horticulture (SPASMO) already exist. They are currently in a process of enhancement – a particular area of current weakness is knowledge of the groundwater lags from specific locations in the catchment.

The land based models need to be used in a specific form that relies on initialisation with verifiable data and uses easily collated and verified data on an annual basis. The form of the model should be fixed for each regulatory year to minimise uncertainty for landowners and regulators.

The models need to be updated to reflect new science. The process for doing this needs to be strategic and credible (this will be discussed in a later paper on governance processes). Once changes are recommended they need to be implemented in a way that is perceived to be fair.

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