Markets and water quality

Motu Economic and Public Policy Research

Project outline (for 4 year project)

August 2007

This project focuses on the development of a creative new institution: a nutrient trading programme that will help manage water quality issues in a long term, robust way. The design and evaluation life-cycle of any market-based instrument involves four main components: setting environmental/resource use targets; design and ex-ante comparison of market-based instruments to achieve targets; design, operation and evaluation of governance and consensus building processes; and evaluation of actual programmes and pilot projects. Motu's Market-Based Instrument Policy Research programme (http://www.motu.org.nz/research/index.php?pid=46), within which this work is embedded, is designed to cover all of these components across different environmental and resource issues. This proposal focuses on the components that are central to water quality management and will draw on and complement the broader research programme. Two closely linked objectives are proposed: market design under uncertainty; and integrated land use and water quality modelling; complemented by an active programme to incorporate the technical knowledge into specific policy processes.

Our team combines New Zealand and international experts in theoretical and empirical economics, surface, groundwater and freshwater-ecosystem modelling, integrated model building, law, and the political science of facilitation and technical communication. The key New Zealand collaborators are Motu, NIWA, GNS - Science, the Institute for the Study of Competition and Regulation at Victoria University and Global Learning with legal input from Chapman Tripp and Matthew Palmer at the New Zealand Law Institute. AgResearch has agreed to provide nutrient leaching rate estimates as required.

1.1 Background

The intensity of land use in New Zealand is growing rapidly accompanied by an increasing use of fertiliser and demand for water. For example, between 1994 and 2002 the number of dairy cows increased 34% (and the value of exports rose from 3459m to 7490m). This was accompanied by rapid intensification - milk solid production increased more than 34% per hectare and fertiliser use is growing almost exponentially. These are positive indicators of New Zealand's strong agriculture-led growth.

We are realising, however, that past uses of land and water may not be sustainable in the future and may be producing irreversible quality changes in water resources, which will adversely affect their future use. 90% of streams in intensively farmed catchments (e.g., in the Waikato) have moderate to high levels of nitrogen. Lake Taupo is showing early signs of enrichment (e.g., blue-green algal blooms in 2003, more severe de-oxygenation of the bottom waters, Gibbs 2006) and the Rotorua lakes are suffering from more frequent occurrences of hazardous and unsightly algal blooms (Hamilton 2006). In the Taupo and Rotorua catchments stream nitrate concentrations have increased significantly in recent years (Vant 2002, Rutherford 2003) as a result of land use intensification. This changing water quality threatens our tourism industry, which accounted for 15.8% of export earnings in 1995, 3.4% of GDP directly and 4.6% indirectly. Does one part of our economy have to be sacrificed to protect another? Not if we manage our water resources well.

Water quality is difficult to manage well because of spatial and temporal variations in land use and farming practice (e.g., stocking rate, fertiliser use, use of feed pads and supplementary feed, effluent disposal etc) and the complexity of processes that determine nutrient runoff generation and the flow pathways that transport nutrients into ground and surface water. A major scientific challenge is to integrate the effects of several land use practices within a catchment and to estimate the combined effects on the receiving waters. Catchment models are a valuable tool, although uncertainties are often large (e.g., associated with input data such as land use statistics; delivery pathways including groundwater flow; and nutrient transformations including permanent or temporary removal of nutrient). Especially important are (1) long, uncertain and variable time lags in groundwater flows (e.g., on the Canterbury Plains and the Central Volcanic Plateau); (2) so called 'nutrient attenuation' (e.g., the permanent loss of nitrate by denitrification, and the temporary uptake of inorganic nutrient by plants and its conversion into organic forms that may be less readily available in the receiving waters); and (3) large, potentially mobile stores of lake-bed nutrients. Additional problems are posed by the complexity of spatial and temporal tradeoffs among economic objectives.

Current regulatory approaches are struggling to deal with these problems. In Lake Taupo, an $80m programme is attempting to reduce nutrient loads by 20% but with no guarantee of success particularly in the long term. In

Rotorua, the current Programme of Action is expected to cost $200m in direct costs alone (excluding on-farm costs). Farmers claim they are suffering ‘death by slow strangulation’ under current approaches. Nutrient trading programmes could play a significant role in addressing these complex issues in some major catchments if they are designed well. They enable stakeholders to seek solutions within a defined framework designed to achieve clearly defined outcomes. This allows stakeholders to come up with innovative and economically efficient solutions. It also ensures that stakeholders ‘buy into’ the process of finding solutions to environmental problems in a way that may not happen through the imposition of rigid regulations. This comes at the expense of time spent on building the trading system, educating participants about its use, and potentially more complex compliance monitoring. This project aims to quantify the potential costs and benefits of a nutrient trading system relative to less flexible regulation and give insights into how best to design such a system, using Rotorua as an example. The lessons learned will help management in this catchment and will also be applied nationally.

1.2 Research programme

Objective 1. Market design under uncertainty.

This objective will build directly on the team’s previous work for MAF/MFE (Bennett et al. 2005; Kerr et al 2006) and address each key nutrient trading design question using New Zealand and international experience in market design, theory, and previous research.

The first key issue is that policy makers need to set nutrient caps that are understood and accepted by stakeholders in conditions of extreme economic and scientific uncertainty. For Lake Rotorua, the long term water quality target has recently been set as ‘…lake water quality as it was in the mid-1960s before the widespread occurrence of phytoplankton blooms etc…’ (EBoP 2006a) which equates to a Trophic Lake Index (Burns et al. 1999) value of 4.2. The total catchment nutrient load in the 1960s has been estimated (Rutherford et al., 1989) and adopted as the nutrient application target to be implemented through caps reducing over time. Rule 11 freezes most nutrient applications at current levels but further reduction is needed. Stakeholders (notably the farming community) feel that the nutrient cap has been imposed without an analysis of likely economic and social impacts, and without considering a range of alternatives.

We will review the international literature on non-market valuation of water quality, and the costs of irreversible damage and analyse how this literature can be applied in New Zealand. We will assess the effects of perceptions of water quality on tourism and on the value of our ‘clean green’ image through exports. This will build on previous work in Rotorua (Nimmo Bell 2004a & b) and valuation work under the FRST project - Valuing Biodiversity.

Our science work will concentrate on nutrient loads driven by land-based activities because these determine lake water quality in the long term and are controllable through a nutrient trading system. We will use existing research on the relationships between nutrient loads and lake water quality, particularly drawing on David Hamilton's research in the OBI - Restoring Freshwater Ecosystems and Resurrecting Indigenous Lake Biodiversity. We will use our simulation models (described below) to provide a quantitative relationship (with associated uncertainty) between nutrient caps applied to land-based activities and nutrient loads to Lake Rotorua in the short (10 years), medium (20 years) and long term (equilibrium) taking into account groundwater lags and attenuation. We will also explore the potential role of activities to reduce 'internal' loads in terms of both effectiveness in improving lake quality and cost, particularly in the short term. Together with the assessment of the value of water quality, these will provide insight into the potential benefits of controlling nutrient loss from land-based activities.

It is clearly impractical to achieve drastic reductions in catchment nutrient load overnight. Our simulation modelling described below will give some evidence of the likely costs of given policies and alternative trajectories of load reduction, and the uncertainty associated with those cost estimates. These estimates of benefit and cost trajectories under different paths of caps are critical inputs to decision-making.

The second key issue is how to adjust nutrient caps over time as economic conditions, societal preferences and scientific information evolve. We will explore international experience and use political theory to design legally enforceable property rights, 'allowances', and governance systems that allow caps (the sum of all allowances) to be changed over time in response to new scientific or economic information. Having robust systems that can smoothly adapt minimises political costs and minimises the uncertainty economic actors face. With properly defined allowances, economic actors can use market processes to protect themselves from uncertainty when they are making long term investments. The New Zealand ITQ system in fisheries offers one critical case for comparison. In the fisheries, quotas are defined in such a way that targets can be changed without the need to reallocate property rights and a governance system has been established to handle new information. The quota definition works well and has avoided problems that have arisen in other market instruments such as the US Acid Rain program where adjusting the targets threatens the integrity of the system as a whole. The NZ fisheries governance system does not currently work as well, so understanding its shortcomings and how other countries have been more successful will be useful beyond our immediate objective of designing of robust nutrient trading markets.

Third, once the cap is set in terms of total allowable nutrient loads, nutrient generation assessment and monitoring systems need to be established. The definition of allowances requires choice of a regulatory framework to translate observable indicators (such as number of cows, location of farm, whether farm has a feeding pad...) into nutrient loads. For Lake Rotorua, the current monitoring rules in Rule 11 provide a basis for this using the models Overseer and NPLAS to predict annual nutrient loss from farms using input data supplied by the landowner about stocking rates, fertiliser use, production etc. The key management challenges arise because of uncertainty, in this case our inability to cheaply and accurately measure the nutrient load on Lake Rotorua and our need to predict it with imperfect models and data. Here we will use theory relating to the value of information to provide a clear framework for evaluating potential changes to the regulatory framework The values of more accurate frameworks are: incentives to use resources efficiently; and considerations of equity - that benefits are linked to those who create them.

The value of information will tend to reduce as we get closer to perfect accuracy and may vary significantly depending on the type of information added. These values will be contrasted with the costs of collecting more information which include compliance costs of private agents, administration costs for regulators and the cost of loss of transparency which increases the risk of non-compliance. We can use our simulation modelling (discussed below) to quantify the economic and environmental value of improved (or reduced) accuracy in specific policy scenarios. These analyses will give valuable guidance to policy makers to help them make decisions about which dimensions of monitoring to emphasise (e.g. spatial differences vs. temporal differences) and to funders to help target research into monitoring. The assessment and monitoring system is needed for a system that does not involve trading; it will also be used to define trading rules – e.g. how a reduction in nitrogen loss from one land use in one part of the catchment can be used to allow an increase in nitrogen loss, possibly from a different land use in a different part of the catchment, without affecting lake quality in any time frame. The larger are the changes in land use and management, the more uncertain are the effects on lake quality. Trading is likely to induce greater changes in behaviour than a more rigid regulatory system and hence may introduce more uncertainty in environmental outcomes. Current and proposed policies often use trading ratios (a one unit reduction here translates to less or more than a one unit increase there) and ‘discount’ for uncertainty, reducing the value of the unit traded. This approach does not have a sound economic basis. No systematic research has previously explored the optimal way to address this type of uncertainty.

Fourth, the rights and obligations of individual agents must be defined. At one extreme, some agents may not be fully included in the regulatory system – e.g. the Taupo programme has exempted small life-style properties. Many programmes also involve voluntary ‘opt in’ for small agents or groups with low impacts. These special approaches may make sense in a static sense but can create perverse incentives. We will explore these both in theory and through simulations. The definition of rights and obligations has distributional implications which this programme does not aim to address. Combined with the definition of the allowances and the monitoring regime, it also has implications for how risk and uncertainty are allocated across agents. Different agents have different abilities to handle risk efficiently. Market institutions such as insurance and financial options are critical to how easily risk can be addressed efficiently. We will explore the appropriate market design drawing on experience in electricity markets as well as other environmental markets.

Finally the trading mechanisms must be designed. A key market design issue is how to avoid problems of market power so that no agent can influence the nutrient price or control access to nutrient allowances. We will apply the lessons from telecommunications, electricity and many other fields to nutrient trading markets. We will explore also how nutrient markets will interact with other markets – such as a market for greenhouse gas credits – to ensure that the nutrient trading market does not lead to perverse consequences in other markets, and maximises the benefits from the market interactions. Whenever we are considering market design we will be cognisant of the importance of transactions costs that can have dramatic effects on the gains that will eventuate in a real market. With modern IT, these costs are not the traditional ones associated with finding prices and trading partners but costs may arise if property rights are poorly defined or the legal processes required for trade are unclear or complex. Within NZ, a critical issue is how trading legally interacts with the Resource Management Act.

Objective 1 will generate direct advice for policy makers on nutrient trading design. It will also provide a clear framework for formulating questions and implementing policy design scenarios in the integrated model developed in Objective 2 as described below.

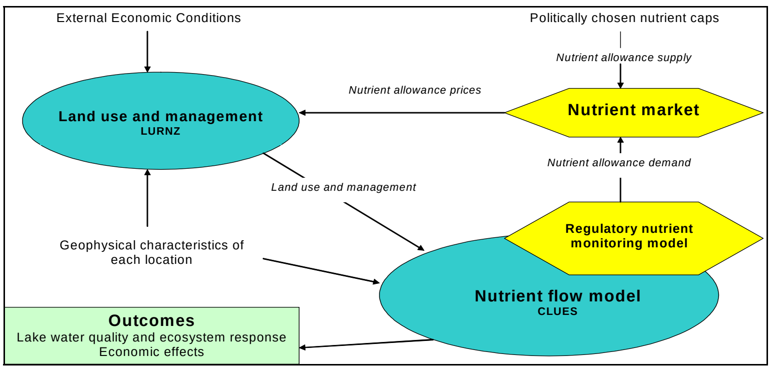
Objective 2: Integrated land use and water simulation modelling.
Objective 2 will generate three outcomes:

1. a simple integrated simulation model of nutrient trading systems, called N-TRADER;
2. a portfolio of alternative trading policy/regulation frameworks; and
3. a quantitative analysis and comparison of these alternatives.

The focus of this objective will be to adapt the existing LURNZ and CLUES models and demonstrate a new, integrated model N-TRADER (Figure 1). The N-TRADER model will then be used to analyse several different trading policies and regulation frameworks, and see whether and how they alter economic and environmental outcomes. For example, we could compare nutrient trading with and without allowance for attenuation, and see whether it alters farmer's behaviour and income, or nutrient outcomes for the lake. By exploring a number of alternatives, in collaboration with stakeholders, suitable trading policy/regulation frameworks for Rotorua and elsewhere in New Zealand can be identified.

The Land Use in Rural New Zealand (LURNZ) model takes predictions of exogenous economic and geophysical conditions and predicts land use and intensity over time and space. LURNZ results will be combined with the suite of natural science models CLUES (which incorporates OVERSEER, ENSUS, SPASMO and SPARROW) to predict nutrient loads. Together LURNZ and CLUES can predict nutrient loads and economic outcomes over time, together with uncertainty bands, but alone they cannot model policy. To create N-TRADER, the two 'nutrient policy' hexagons (shown in Figure 1) will be added to the linked LURNZ-CLUES model, enabling predictions to be made of nutrient loss for specified regulatory policies and trading. 'Policy scenario' outcomes can then be compared with a 'reference' case to evaluate the economic and water quality implications of specific policy decisions. The 'policy' is defined in terms of (1) a nutrient cap, which sets allowance supply, and (2) a regulatory model, which defines how land use and management is translated into landowners' demand for allowances. A simple market translates these into nutrient prices.

Figure 1. Outline of the proposed N-TRADER simulation model



The economic actors implicit in LURNZ respond to the prices of nutrients and to uncertainty in their prices and change their land use and management. By varying the nutrient ‘price’ we can trace out a cost curve for different levels of nutrient control. We can explore the extent to which these costs are sensitive to the time path of nutrient control (and hence prices) and to the use of different regulatory monitoring models. The former provides critical information for comparison of economic and environmental effects when setting nutrient caps.

Trading is ideally designed to lower economic costs but to have no direct impact on nutrient loads. Ideally allowances would be defined in terms of nutrients reaching the lake in a specific time frame. In reality, however, because of the costs and practicality of monitoring, and the need to have markets that operate relatively smoothly to reduce transaction costs and market power, trading rules can never fully mimic the complexity of the science involved. For example, permanent attenuation of nutrients before they reach the lake has important implications for the regulatory model and trading rules. If the regulator knows that 50% of N is attenuated between the head of the catchment and the lake, then the regulatory model could be built so that an allowance of 2 tN/y at the head of the catchment can be traded for an allowance of 1 tN/y close to the lake, and *vice versa*. The project will determine how uncertainties in nutrient generation, attenuation and the way the market operates create environmental risk. Spatial and temporal limits on trading protect the environment from uncertainty but sometimes at high economic cost. Similarly, not all farm management practices can be incorporated in the regulatory model simply because there are so many; their exclusion will have costs by reducing flexibility so inclusion/exclusion decisions should be taken carefully and with input from landowners. We will focus on modelling land use but will also evaluate a few key management options such as stocking rates, timing of fertiliser application and use of EcoN. We will endeavour to find policies that make optimal tradeoffs between environmental certainty, economic benefit and administrative feasibility.

Another common policy compromise is to exclude, or make voluntary participation by, ‘small’ landowners – we can simulate the likely effects of this when the policy maker faces uncertainty about small players’ intentions but the small players have perfect information about themselves. By combining N-TRADER with the existing model, LURNZ-Climate (Kerr and Hendy, 2004, Hendy and Kerr, 2006, Hendy et al., 2006a&b, Sin et al., 2005), we can explore the effects of a policy aimed at climate change mitigation on water demand and quality in a given catchment, and vice versa.

Knowing land use and intensity, the CLUES model predicts nutrient loss from land, nutrient attenuation and hence nutrient loads from the catchment. CLUES is the result of work led by NIWA in collaboration with Lincoln Ventures, Harris Consulting, AgResearch, HortResearch and Landcare Research, and funded by a CDRP grant from FRST to the Ministry of Agriculture and Forestry. CLUES currently predicts annual average loads of nitrogen and phosphorus at sub-catchment scale (~10 km^2) over the entire country (Woods et al. 2006). For this project it will need to be extended: (1) the spatial scale needs to be reduced from the current ~10 km^2 to individual farms; (2) a groundwater component (scoped but not implemented) needs to be added; and (3) on-farm mitigation measures need to be modelled in more detail. Much of this work is already planned with funding from PASTURE21. This project will accelerate CLUES development and enable it to address economic and trading issues.

Three 'complex' models will furnish information for use within N-TRADER: ROTAN, FEMWATER and DYRESM-CAEDYM. ROTAN is a GIS-based catchment model developed by NIWA that operates at time steps of days-years and models the different pathways by which water and nutrients travel from land to the lake. FEMWATER is a detailed groundwater model developed by GNS – Science that helps identify whether specific land areas contribute water and nutrients to deep, old aquifers (slow response to land use change), or shallow, young aquifers (rapid response). DYRESM-CAEDYM is a lake hydrodynamic-water quality model developed by Waikato University that can predict the response of lake water quality (including internal loads) to reductions in catchment nutrient load. These models are too unwieldy to include within N-TRADER, but their 'emergent properties' will be used to adapt CLUES to Rotorua, and their results used for calibration and testing.

The current version (version2) of Land use in Rural New Zealand (LURNZ) (version1 is described in Hendy et al. 2006a) is a GIS-based model for New Zealand at a spatial resolution of 25ha developed jointly by Motu, Landcare and others. The drivers of four key land uses (dairy; forestry; sheep/beef; scrub) are based on econometric estimates at a territorial authority level. Finer land use, other land uses and land use intensity are modelled using expert-driven rules and calibrated to available data. Dynamic simulations are initialised on the CLUES-CDRP map produced by MAF. Uncertainty is explicitly modelled. To apply this model to water quality analysis, we need to go to a finer spatial scale within the Lake Rotorua catchment. We will do this using spatial econometrics to analyse 30m resolution satellite data (see 'detailed methodology'). We will also enhance our 'land use intensity' modelling (Hendy and Kerr 2006) using a combination of stocking rate maps from Landcare Research, MAF farm monitoring data for dairy, Meat and Wool Innovation for sheep and beef, NEFD data for forestry, EBoP data on existing management practices in the Lake Rotorua catchment, and drawing on previous work in the MAF/MFE-sponsored CDRP-funded CLUES project. Preliminary work on this is currently being funded by MAF. This connection between economic costs, and land use and management will enable us to model land use and management responses to nutrient prices.

1.3 Outcomes from the project

As a result of the first two years of research we will have proposed a preliminary design for a nutrient trading system for Lake Rotorua, including detailed assessment of some legal, nutrient reporting and modelling, and governance issues as well as exploration of non-market values of water quality, will have adapted our existing model of land use drivers to the Lake Rotorua catchment, and will have created a strong methodological and empirical basis for more detailed modelling of land management and fine scale land use decision making. We will have created a nutrient sub-model for Lake Rotorua drawing on existing models and will have a clear strategy for new modelling and experimental work to refine this sub-model. This project will create a prototype for an integrated decision making mechanism for an issue of key economic and environmental importance for New Zealand's future.

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