New Zealand Agricultural and
Resource Economics Society (Inc.)

Trading efficiency in water quality markets

Hugh McDonald, Marianna Kennedy and Simon Ngawhika with Suzi Kerr
Motu Economic and Public Policy Research

Paper presented at the 2010 NZARES Conference
Tahuna Conference Centre – Nelson, New Zealand. August 26-27, 2010.

Draft Copy – 14 September 2010

Trading efficiency in water quality markets

Hugh McDonald, Marianna Kennedy and Simon Ngawhika with Suzi Kerr

Draft – Comments welcome

Motu Economic and Public Policy Research

September 2010

Draft Copy – 14 September 2010

Author contact details
Hugh McDonald
Motu Economic and Public Policy Research
Hugh.McDonald@motu.org.nz

Acknowledgements
Paul Stacey of Connecticut Bureau of Water Protection and Land Reuse, Marion Peck of Lake Taupo Protection Trust, Justine Young and Natasha Hayward of Environment Waikato

Motu Economic and Public Policy Research

PO Box 24390
Wellington
New Zealand

Email	info@motu.org.nz
Telephone	+64 4 9394250
Website	www.motu.org.nz

 ISSN 1176-2667 (Print), ISSN 1177-9047 (Online).

Draft Copy – 14 September 2010

Abstract

A crucial factor in the success of any water quality trading market is its ability to cost-effectively reallocate nutrient allowances from initial holders to those users who find them most valuable; the market's trading efficiency. We explore causes of and solutions to trading inefficiency by assessing the impact on participant transaction costs and the tradeoffs that occur as a result of policy design decisions. Differing impacts of baseline-credit and cap-and-trade markets, the impact of trading rules and monitoring regimes are discussed in this endeavour. Possible solutions of increased information flows and regulatory certainty are also discussed. We then apply this framework to three existing water quality trading schemes; two from the US, and one from New Zealand. We use this experience to extract general recommendations for policy makers looking to maximise trading efficiency when designing future water quality trading markets.

JEL codes

Type codes

Keywords

Nutrient trading, trading efficiency, water quality markets, transaction costs

Draft Copy – 14 September 2010

Contents

Draft Copy – 14 September 2010

1. Introduction

Nutrient trading is a market mechanism to address nutrient loss that leads to water pollution. Nutrient markets are a 'command but not control' approach, in that they limit nutrient loss by creating fixed numbers of allowances which entitle their holders to release a defined amount of nutrients into waterways but do not explicitly define how reductions to meet these limits should be achieved. Sources of pollution can trade nutrient allowances to maximise profit in line with their individual costs of pollution control.

This review focuses on the process of trading allowances in nutrient trading markets. Efficient trading is a key component of a nutrient trading system, and occurs when a system minimises the costs of reallocating allowances from their initial users to the users who find them most valuable and hence allocates allowances in the most cost-effective way. Trading efficiency is distinct from overall system efficiency, which also depends on how efficiently environmental targets are set (are marginal costs equal to marginal benefits?).

Trading efficiency maximisation is of particular importance as it enables the benefits of market system to occur. If trading is inefficient and allowances cannot effectively move from their initial allocation to where they are most valued then the costs of pollution control will increase. Those who can most cheaply mitigate are only motivated to do so if they can easily and cheaply trade their resulting surplus allowances to those who cannot cheaply cut pollution. If this trading is constrained by poorly designed policies and high transaction costs, then the true benefits of a market system cannot be achieved.

Trading efficiency can be maximised through good policy design. Decisions over the scope of the nutrient trading scheme, the form that the scheme takes, the monitoring approach used and the acceptance or avoidance of transaction costs all have a significant impact on the level of trading efficiency that a scheme eventually attains. This paper attempts to examine exactly which policy options maximise this trading efficiency by examining the literature and assessing existing schemes. While some policy options and choices will be catchment specific, some will be generally applicable. When reviewing the literature we try to separate the idiosyncratic geographic features of particular case studies from differences arising from different policy choices to understand the general lessons for water quality markets and specifically the market we are developing for a New Zealand watershed[1].

---

[1] This paper is written as part of the Nutrient Trading and Water Quality research programme which is being run by Motu Economic and Public Policy Research in Wellington, New Zealand. The programme aims to design and simulate a prototype nutrient trading system for the Lake Rotorua catchment, in conjunction with a

Despite the clear importance of maximising trading efficiency in nutrient markets there is little attention paid to the issue in the design of nutrient trading schemes worldwide. Few existing or proposed nutrient trading schemes maximise trading efficiency; indeed, many seem to have been designed with very little thought at all of trading efficiency. Investigation of the literature and existing systems informs a framework which we use to assess three existing nutrient trading schemes in terms of their trading efficiency. These assessments, of the Lake Taupo trading system in New Zealand, the Pennsylvania Water Quality Trading System in the US and the Long Island Sound Nitrogen Trading Market in Connecticut, US, also help elucidate the importance of maximising trading efficiency but also the difficulties that arise in practice.

The review is set out as follows. It first introduces the problem of transaction costs, and the cost they place on trading efficiency. This is extended to examine the sources of these transactions costs and the trade-offs that can occur when attempting to maximise trading efficiency. The key dimensions of policy design that impact on trading efficiency are discussed in turn in section three; the scope of the scheme, the differences between baseline-credit and cap and trade schemes and the impact of this decision on monitoring and transaction costs are outlined in this endeavour. The paper then explores the impacts that policy choices over trading limitations can have on transaction costs and trading efficiency. General solutions to minimise transaction costs are discussed in section 5 under two headings: information flows and certainty. Existing scheme assessments are presented in section 6, and section 7 concludes.

2. Transaction costs

Trading efficiency can alternatively be defined as an absence of participant transaction costs. As a result, we can also think of maximising trading efficiency as minimising participant transaction costs. We define transaction costs as any cost faced by a participant associated with making a trade, in addition to the allowance price. There is wide variation in the definition of transaction costs throughout the literature (McCann et al, 2005). We use a narrow definition that focuses solely on the costs of trading that are faced by the participant in the market as a result of trading. Set up costs or compliance costs which are independent of the trading decision are not included as these will not affect trading efficiency, which is our focus. Our definition includes the costs of gathering information, bargaining, decision making, any excessive costs of trade approval, and in baseline and credit schemes, baseline setting and monitoring. For maximum gains from a trading system, transaction costs should be minimised as much as possible, while

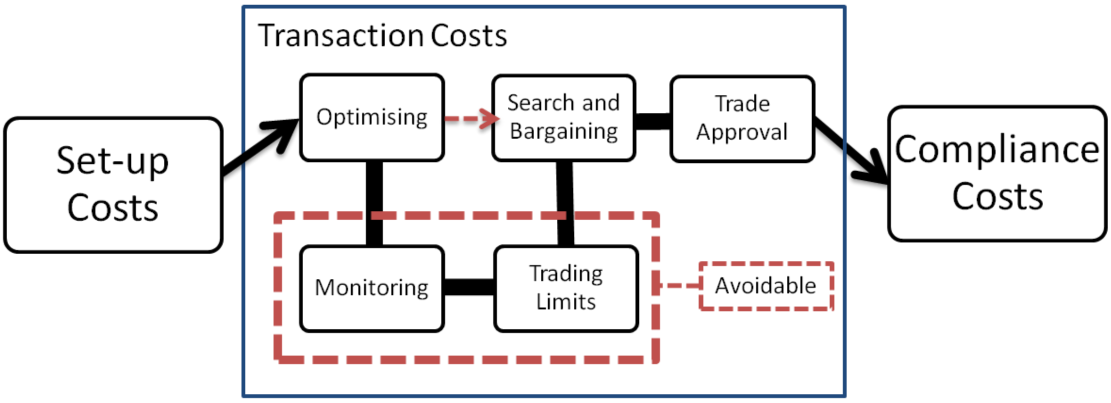
group of stakeholders and scientists with specialist knowledge of the region. An overview of the initial prototype design is published as Motu Working Paper 08-02 (Lock and Kerr, 2008).

ensuring environmental integrity: "The net gain from implementing a policy is the abatement cost savings minus the transaction costs; if the transaction costs are too high, they can offset all or a major part of the abatement cost gains from implementing the policy." (Tietenberg 2003: 484).

Transaction costs directly affect trading efficiency. High transaction costs lead to trading delays and allowance hoarding. Intuitively, at any level these transaction costs will discourage trading parties from transferring allowances to their most valuable uses. We have little empirical evidence of the impact of transaction costs on trading. Two studies address transaction costs directly. Kerr and Maré (1998) found that oil refineries were less likely to trade allowances if they faced high transaction costs during the US lead phase down. Gangadharan (2000) found that transaction costs in the Regional Clean Air Incentives Market (RECLAIM) were a significant factor explaining firms not participating in the trading system. This evidence supports our analysis that high transaction costs impact negatively on trading efficiency.

As a result, regulators should look to minimise costs at the time of trading, and maximise trading efficiency as much as possible, unless the transaction costs have a valid trade-off in improved environmental certainty, or, are unavoidable. Examining whether this is the case is most straightforward if we address the sources of transactions costs, and how these can be avoided, individually. These sources of reduced trading efficiency are set out in the central box of 1, and discussed further in the following section.

Figure 1 : Sources of Transaction Costs



2.1. Transaction cost sources

Optimising costs arise as the trading participant has to adapt their operations for the new regulation, and learn what the most profitable level of production and/or mitigation is for their land. These costs can be minimised by providing full information to participants on possibilities and mitigation options.

Monitoring costs occur as transaction costs if participants face the costs of measuring and monitoring at the time of making a trade. This will occur in any system where monitoring is carried out ex ante. Schemes can be designed such that monitoring is carried ex-post, an approach that transforms monitoring into a compliance cost, which has no impact on trading efficiency. This monitoring issue and the interactions between monitoring costs and nutrient trading market form are discussed in section 3.2.1.

Trading limits are any rules which restrict trading between participants or increase the cost of trading for traders. There are many examples of these sorts of transaction costs, and while some trading limits are justified on grounds of decreasing environmental uncertainty, many are not, and serve to reduce trading efficiency without a balancing positive environmental impact. Discussion of the various forms of trading limits and their impact on a trading systems trading efficiency are discussed in section 4.

Search and bargaining costs are the costs borne by traders when looking for other participants to trade with, and in negotiating an appropriate price for any nutrient allowances. These costs can be minimised by improving liquidity, information flows and through the use of central traders and online trading systems. These solutions, and international examples of their application, are discussed in section 5.

Any trades that are carried out must be approved and registered with the regulator to ensure that they are recognised come compliance time. If the participants face a cost when registering trades, then this too will be borne as a transactions cost and decrease trading efficiency, and will act to dissuade participants from trading. An example of this is present in the Lake Taupo nutrient trading scheme: to register trades both participants (buyer and seller) must complete a compliance process which will cost each between NZ$1000 -$3000 (Environment Waikato, 2009). Minimising the cost of registration through the use of online registration system and simplified compliance are discussed as part of section 5.1.

2.2. Trade-offs

The goal of minimising these transaction costs and maximising trading efficiency may seem like obvious ones but, as discussed in the introduction, existing nutrient trading schemes worldwide do not seem to have aimed for or achieved this. The likely reason for this is that there are significant costs in building a nutrient trading scheme that achieves high levels of trading efficiency. Generally the cost occurs as a financial or time expense of designing and running an efficient system. However, under particular circumstances these costs can also be faced as a decrease in the environmental certainty of the outcome. This particular case, and the trade-off it implies, is explored in the following section.

As will be explored, maximising trading efficiency generally requires that there are no restrictions on trading and that the system as a whole is as flexible as possible. While this approach ensures that allowances can cost effectively move from initial holders to those who value them the most, if there is any uncertainty or known differences in the relative impact of nutrient discharge cuts, this free trade can also lead to environmental uncertainty. This environmental uncertainty can occur if the actual impact of any nutrient discharges or reductions on the final environmental goal is not totally certain (as is often the case when including non-point sources in a trading scheme). If this is the case regulators cannot be sure that a decrease in discharges by one participant will totally offset an increase in discharges from another participant. As a result, any trading between these participants will increase environmental uncertainty.

While this environmental uncertainty might also occur under command and control type required reductions, it is likely to be a larger issue in a flexible trading scheme for a few reasons. There will be significant movement of discharges around the catchment under a trading scheme, with increases in some areas and decreases in others. There is also likely to be a higher number of mitigation methods under a flexible trading scheme, if these differing methods and spatial locations of mitigation have differing effects then the actual outcome of the scheme will be more uncertain than non-trading regulation. If a trading scheme is more successful in causing large shifts in nutrient discharge behaviour this too will magnify the uncertainty. Scientific understanding and modelling of nutrient discharges are based on status quo activities and discharge levels. Anything which causes large shifts away from this status quo level of activity will shift further away from accepted scientific understanding and will be associated with an increase in the uncertainty of the environmental outcome.

There is likely to be a cost to this uncertainty even if the likelihood of better or worse than expected environmental outcomes is equal. If the marginal damage of nutrient leakage into the lake is increasing with discharges, then this uncertainty will result in a lower expected level of social utility as uncertainty increases. This cost of uncertainty is shown in the left panel of Figure 2 below. A related issue is the actual state of the relationship between environmental risk and trading efficiency. If the relationship between the two is non-linear, for example if variability grows increasingly as trading efficiency increases, then a lower level of trading efficiency will be preferable relative to a situation where a linear relationship exists between the two. It is unclear what the likely relationship will be.

2.3. Formal Depiction of Trade-off

In a bid to decrease the cost of uncertainty regulators often introduce trading rules and increased monitoring and measuring at the time of trade. While this will decrease environmental uncertainty these regulations also act as transaction costs and decrease trading efficiency. This is clearly a balancing act – increasing the restrictions and costs of trading will decrease the benefits of trading. If this is taken too far, then no trade at all could be the result. Even small restrictions on trade will have a cost though. This trade-off is depicted visually in Figure 2.

Figure 2 shows the social benefit and cost of nutrient discharges into a lake. The marginal social cost of nutrients being discharged into the lake is given by the upwards sloping MD curve, indicating that this cost is increasing as nutrient discharges increase. The aggregated marginal value of discharging nutrients into the lake for landowners is given by the MV curve, which is decreasing as the level of nutrients discharged into the lake increase, indicating deceasing marginal returns to discharging. The equilibrium gives the optimal level of nutrient discharge, Q*. The MV line can also be thought of as a reverse of the marginal cost of reducing discharges. The first reductions of nutrients come cheaply, but as more reductions are made the marginal cost of the mitigation increases.

In the left hand diagram the MV line is drawn equal to MC*, where marginal costs are at their lowest, most efficient level. This occurs when only those who can most cheaply cut nutrient discharge do so. The only feasible policy that could achieve this efficient marginal cost outcome is a trading scheme with no trading restrictions; that is, one that is fully trading efficient. However, if there is uncertainty about the environmental impact of relative cuts and increases in nutrient discharges, then this free trading scheme will also be susceptible to uncertainty about the environmental outcome. This uncertainty is indicated by the band around Q*; the sum cost of this uncertainty is given by the shaded area[2].

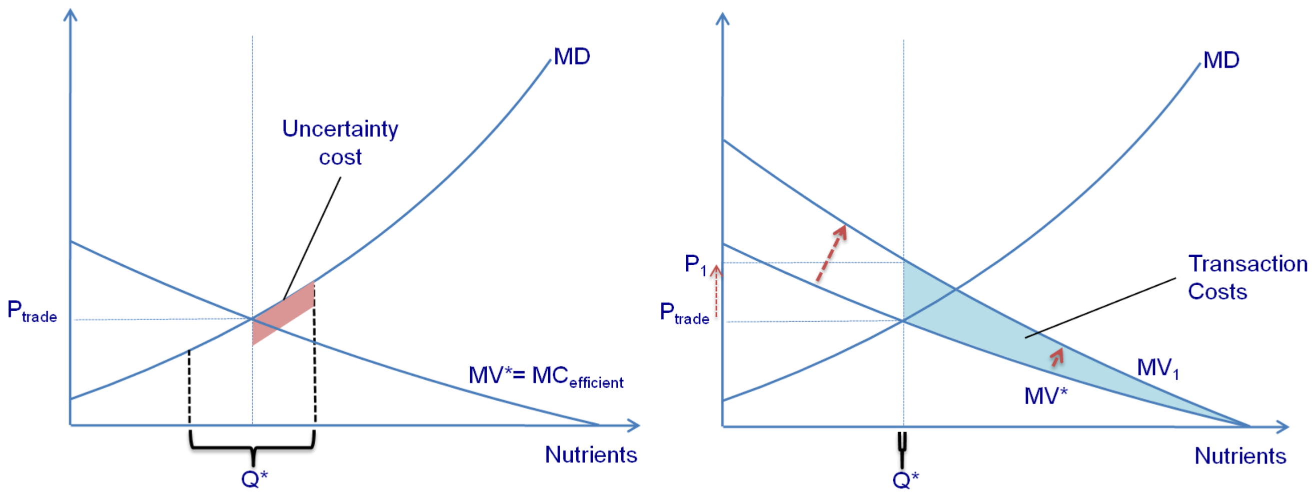
To avoid this uncertainty, regulators may look to restrict trading in some way, for example by limiting who can participate or by requiring extra monitoring and measuring[3]. This will have two effects, both of which are shown in the right hand diagram of Figure 2**Error! Reference source not found.**. The first effect will be an increase in environmental certainty, which is shown as a tightening of the uncertainty band around the goal level of discharge, Q*, which results in the disappearance of the cost of uncertainty. However, restricting trade in this way will also decrease the trading efficiency of the scheme, leading to higher costs of achieving

[2] This area is given by subtracting the economic cost if nutrient discharge levels were higher than expected, and fell at the high end of the uncertainty band, from the surplus that if nutrient discharges were lower than expected, and fell at the low end of the uncertainty band.

[3] These and other restrictions on trading are discussed in section 4 below.

any environmental goal. This is shown by a shift upwards of the marginal value line from MV* to MV_1: this MV line is no longer equal to efficient marginal cost as the trading restrictions mean that mitigation is no longer being carried out only by those who can most cheaply mitigate. The cost of this is shown by the increase in the price of the final unit of mitigation rising from P_{trade} to P_1, and also by the shaded area which represents the cost of the loss of trading efficiency in terms of transaction costs.

Figure 2: Trading Efficiency/Environmental Uncertainty



The trade-off between trading efficiency and environmental certainty is neatly captured in these two diagrams. The left diagram shows the case where loose trading rules and high trading flexibility allow trading to ensure that any mitigation is carried out by those who can do so most cheaply. This allows environmental goals to be reached at lowest possible cost. However, there may be an element of uncertainty as to what the actual environmental outcome of such a trading scheme may be. The right hand diagram demonstrates the costs that are borne when regulators look to restrict this environmental uncertainty through limits on the market. While this approach avoids the uncertainty over the environmental outcome, it comes with a higher cost of attaining any environmental goal; environmental certainty has been traded off for trading efficiency.

3. Key dimensions of policy design that affect trading efficiency

Minimising this trade-off between environmental certainty and trading efficiency, and minimising transactions costs more generally, depends largely on the design of the water trading policy. Good policy design can ensure clear information, flexibility and certainty for participants, which can help minimise the extent that these sources restrict trading efficiency. Policy design can also shift some of these costs out of the transaction costs sphere so that they occur as either set up or compliance costs. These costs will only affect trading efficiency if they occur at the time of the trade – if the costs are independent of the trading decision then there will be no obstacle to allowances moving from initial holdings to those were they are most valued.

The two most significant decisions in market design concern what sources to include; point sources, non-point sources or both, and what form the market should take; either a baseline and credit (offset) system or a cap and trade system. The relative merits of these choices and the impact that they have on transaction costs and trading efficiency are discussed first. These basic system design decisions fundamentally impact all sources of transaction costs, but particularly inform the effect that monitoring has on trading efficiency. This relationship is addressed in some depth.

Following these foundational market design decisions, the choice of whether and how to limit trading in a nutrient market has the next largest impact on trading efficiency. There are various motivations for these trading restrictions, and these are discussed along with international examples of their application.

Solutions to address the optimising, search and bargaining, and trade approval sources of transactions cost are discussed more generally. Ensuring that any trading system provides good, easily accessible information to participants and regulatory certainty will help to minimise these sources of transaction costs.

3.1. Scope: Point sources and non-point sources

A first concept central to this discussion is the distinction between point sources and non-point sources. Point sources (PS) discharge pollution at a specific location, for example the outflow pipe at a water treatment station. Non-point sources (NPS) pollute less directly, for example via diffuse run off from land. Water quality regulation has traditionally set limits only for pollution from PSs. NPSs are more challenging to regulate because NPS nutrient loss is difficult to measure and is subject to seasonal and weather-related variation (Stephenson and Bosch, 2003). As a result the inclusion of NPSs is likely to increase uncertainty about actual environmental impacts. There also tend to be a large number of relatively small non-point sources. They are often individually owned farms rather than large possibly public or regulated companies. Despite these issues the incorporation of NPSs of nutrient discharge is often crucial to achieve environmental aims, as NPSs often cause the majority of discharges[4]. This is also true

[4] Carpenter et al. (Carpenter et al, 1998) report that 82% of nitrogen and 84% of phosphorus entering USA waterways comes from non-point sources.

for our prototype New Zealand trading scheme; non-point sources are the primary origin of nutrients entering the lake.

3.2. Cap and trade and baseline and credit systems

There are two basic types of nutrient trading markets: cap-and- trade, and baseline-and-credit (or offset). The choice of scheme type has a large impact on the level of the trading efficiency of the system. To facilitate comparison we will assume that both types of market are set up with the same environmental goal. Cap and trade markets involve setting a comprehensive cap on the allowable discharge of a given nutrient over a catchment or watershed, and dividing this cap into individual, tradable allowances. These allowances are then distributed to market participants, and participants must obtain and remit an allowance for each unit of nutrients entering waterways from their property. Further trading rules can be written to ensure that the environmental goal is not compromised by trading. If nutrient reductions from non-point sources are expected to be cheaper than additional reductions from point sources, it is efficient to include non-point sources.

In a baseline and credit (offset) market not all sources of nutrient discharge are regulated. Baseline and credit systems involve some regulated participants facing a cap (individually or as a group with allowances allocated to individuals) in the same way as in a cap and trade system, but also include a voluntary component. Other sources outside this regulated group can opt into the system and participate in decreasing their nutrient discharges for credits. When these sources decide to participate, a baseline level of nutrient losses is set, generally by estimating nutrient leaching under best practice or business as usual. If this voluntary participant discharges less than its allotted baseline it can sell its surplus to the regulated cap and trade section of the system. When the system works as intended these voluntary reductions act as a substitute for nutrient reductions in the cap and trade segment of the scheme and the environmental goal is not affected. However, these systems do not always work as intended, and are particularly vulnerable to adverse selection.

If baselines are estimated accurately for all possible participants, then any participants that opt in will do so because they can profit from reducing nutrient losses at a low cost and then selling the accrued credits on the nutrient market. However, if there is asymmetric information such that regulators do not have the full information of possible participants, and as a result baselines are estimated with error, then there can be a second reason for sources to opt in. If sources are given an erroneously generous baseline, then these sources can choose to participate and collect credits for environmental savings without doing anything to reduce their runoff. The credits that they accrue from this participation are not perfect environmental substitutes for nutrient reductions by regulated sources, as no actual reductions have occurred. If instead a voluntary source is attributed an erroneously stringent baseline, then they will simply choose not to opt in; there will be no balancing out of the environmentally harmful credits. This is adverse selection. These spurious credits unintentionally increase the level of the cap, and as a result, if this is not controlled for, they will result in violation of the environmental goal.

The level of costs that are faced by participants at the time of trade is another significant problem with baseline and credit systems. Under a cap and trade scheme, the cost of measuring current discharges is faced by all participants as a set-up cost. However, participants in baseline-credit type schemes only face the costs of optimisation, baseline setting, and registration if they choose to trade and opt in to the system. As a result these costs are borne as transaction costs. If a discharge source in a baseline and credit system does not trade then they will not have to adapt in any way to the market regulation – they can avoid learning the new system, the costs of optimising their operations, and obviously any baseline setting, measuring, monitoring and registering costs that they would have to face if they opted into the system and traded. These costs provide a huge barrier to participating and trading in a baseline-credit system, and are costs that are do not need to be outweighed in a cap and trade system. These costs will greatly decrease the overall benefits of trading for optional participants, possibly to the extent that they decide not to participate even if they can provide low cost mitigation. These transaction costs significantly decrease the trading efficiency of a system.

The two systems each have benefits and costs. The advantages of cap and trade are more environmental certainty because of an explicit goal and compulsory participation, and greater efficiency because more sources are able to trade and mitigate emissions. The disadvantages are that determining an environmental goal (cap) and allocating permits to all sources can be politically difficult, and that monitoring all participants is a significant and costly undertaking. Baseline and credit systems are more easily and cheaply established at a small scale. The disadvantage of baseline and credit is that including fewer sources reduces market efficiency, as participants have fewer trading partners with consequently less variation in mitigation costs. The difficulty of accurately setting a baseline is another disadvantage of baseline and credit markets; these baselines are often set at 'business-as-usual discharges', which by definition are a counterfactual; estimating these wrongly will significantly affect the outcome of the policy. The transaction costs caused by baseline setting are another downside of these baseline-credit systems. Also, non-compulsory participation combined with inaccurate baselines introduces a risk of adverse selection, where participants can choose to participate and receive spurious credits without actually abating nutrient runoff. This was a reported outcome of voluntary participation in the US Acid Rain Program(Montero, 1999).

Clearly, a trade-off exists between the completeness and related efficiency gains of a cap and trade system, and the low relative administrative and political costs of the adverse-selection afflicted baseline and credit approach. Existing international examples are overwhelmingly baseline and credit systems, with our research only finding cap and trade systems in two instances[5], compared with the more than 55 baseline-credit systems we found worldwide (Selman et al, 2009). These systems also achieve different levels of trading efficiency and transactions costs, predominantly due to the different level of monitoring and measuring costs that each system requires.

3.2.1. Monitoring and enforcement

Any regulation (with or without trading) must specify how and when emitters are monitored, and whether emissions are 'monitored' in advance (ex-ante control) or once they have occurred (ex post monitoring). The method of determining emissions for regulatory compliance is critical for the environmental integrity of the system and also for the flexibility individual participants have in how they comply and their certainty about the effect of their actions on their compliance. Monitoring requirements can also have a large impact on the trading efficiency of any nutrient trading system.

Many water quality regulations require that non-point sources inform regulators as they make changes in management or production and assess the future environmental impacts of those changes before approving them. For example the Lake Taupo system (Environment Waikato, 2009) requires farmers to submit farm management plans for the coming year. Other systems monitor emissions ex-post based on actual behaviour. The choice of timing of monitoring partly determines which measures are available to be monitored: ex ante monitoring defines certain activities that will be undertaken such as a management plan – these activities are monitored throughout the year once the plan is established; ex post monitoring relies on data that can be verified after compliance and infers emissions from these data using a model.

These dimensions are summarised in

Table 1: Comprehensiveness of Monitoring

Table 1**Error! Reference source not found.**, where the arrow shows the direction of greater trading efficiency. Note that the level of monitoring is largely a factor of whether the

[5]The two cap and trade schemes are found at Lake Taupo, New Zealand and in Norway.

trading system is cap and trade or baseline and credit (offset). Cap and trade systems require participants to match their emissions and allowance holdings at the end of a compliance period, while baseline and credit systems are more likely to confirm that a trade meets its environmental target as part of the trading process itself.

Table 1: Comprehensiveness of Monitoring

	Comprehensiveness of monitoring		
Basis and timing of monitoring		**Sources monitored if they trade**	**All sources always monitored**
	Ex-ante – prescribed plan or activities	Ex-ante credit and baseline	Ex-ante cap and trade
	Ex-post – nutrient losses modelled based on verifiable information	Ex-post credit baseline (rare)	Ex-post cap and trade

Systems that require monitoring and approval of discharges and mitigation changes before every trade greatly increase transaction costs and decrease trading efficiency. These ex ante monitored systems place the cost of this monitoring only on those who trade, which will greatly decrease the benefits of trading, and as a result decrease the actual level of trade.

Systems that use models to estimate mitigation and discharges based on available data and precedents are able to achieve higher trading efficiency. These ex post systems require all participants in the scheme to report data to allow measurement and monitoring of discharges, and not just traders. This ensures that the cost of compliance is not faced as a transaction cost, and instead is faced independent of the decision to trade. This approach to monitoring and measuring can also be carried out more cheaply than ex ante monitoring schemes. Instead of requiring individual assessment of each trade, an ex post system generally uses models and data which is easy and cheap to collect and allows trades to occur based on pre-set rules and precedents, and monitors compliance after the trade has been completed. This decreases costs at the time of trade, which helps to maximise trading efficiency.

It should be noted that if little trade and participation from sources is expected, then an ex ante system with monitoring and measuring only for trading parties may be justified. The cost of setting up a full ex-post system may outweigh the benefits associated with its higher trading efficiency.

While the decision of what monitoring approach to take follows closely from the decision over the scope and form of the nutrient trading market, other policy choices are less clear cut. Decisions over the application and extent of trading limits vary widely across different systems. Some of this variation is due to differing local environmental circumstances, but much of the variation is due to idiosyncratic policy design. Motivations for these trading limits and the impact that they have on trading efficiency are explored win the next section, along with examples of their application in schemes around the world.

4. Trading limits

Trading limits and restrictions can be a significant source of transaction costs and trading inefficiency. However, well targeted trading restrictions and rules can also be an effective way to balance the trade-off between environmental certainty and trading. Trading rules are regulatory documents that define what constitutes an allowance, how allowances can be acquired, bought, sold, used, held, retired, reported, leased, etc. They also specify who may trade, with whom and how trades are exacted. Restrictions on trade will always decrease trading efficiency, and as a result should be avoided where possible. However, if this loss of efficiency is balanced by a counteracting increase in environmental certainty, then the restrictions may be justified. The use of uncertainty ratios is a commonly used trading restriction which falls into this category. However, there are a number of international examples of trading restrictions which do little to improve environmental certainty. These, along with the importance of considering the impact that trading rules will have on market liquidity and new technology innovation, are discussed in turn.

Trading rules specify under what circumstances allowances can be traded for emissions reductions in another time or place. These rules are political where allowances cannot be traded over regional council or national boundaries. They are environmental if the goal is to ensure that allowances have an 'equivalent' effect on water quality. Trading systems are usually set up under the assumption that the scheme alone will ensure that nutrient mitigation in one area is a perfect substitute for mitigation in another area. However, if regulators are not confident that this is the case, then additional rules or pre-approval of trade may be a sensible method to decrease any risk to the environment. Example of the types of rules that may be appropriate include restricting trading to between like sources, where like is defined by location within a watershed[6], or timing of nutrient arrival in the focal body of water[7]. However, the most common form of these environmentally motivated trading restrictions is as uncertainty ratios.

Uncertainty trading ratios can be found in many schemes internationally as a method to decrease the uncertainty about the actual environmental impact of trading, particularly in schemes which include NPSs. NPS discharge reductions are generally thought of as less certain than PS reductions, as their effectiveness depends on things such as the weather and storms (Selman et al, 2009). Uncertainty ratios are set such that for a NPS to get a credit equivalent to a one unit PS discharge reduction, the NPS would have to decrease their discharges by more than one unit. This approach is meant to work as a safety margin that ensures that even if NPS discharge reductions don't work as expected, water quality will not be negatively affected. While the use of uncertainty ratios may have some environmental benefit by ensuring that water quality is protected, they also impose clear costs on trading efficiency. The use of these uncertainty ratios provides a strong incentive to NPSs not to participate in any discharge trading system; any discharge reductions they make are worth significantly less than PS discharge reductions. This will work as a significant barrier to getting discharge allowances from the low cost abaters (presumed to be NPSs) to those who face high costs of abatement (presumed to be PSs), which by definition will negatively affect trading efficiency. However, if this is balanced by a significant decrease in the uncertainty of the environmental impact, then this may be justified.

International trading schemes offer many examples of these uncertainty ratios. In the Lake Dillon scheme in Colorado, USA, two units of discharge reduction by NPSs are required for any one unit increases in discharge by PSs(Woodward, 2003). The Pennsylvania, USA, Water Quality Trading Program places a 10% 'insurance' ratio on all trades to cover any mitigation that fails (Pennsylvania Department of Environmental Protection, 2006a). Uncertainty ratios are also present or proposed in many other schemes.

The use of uncertainty ratios is also preferable to other less certain mechanisms that are used to address this environmental uncertainty issue. Complicated and uncertain compliance systems, such as the approach used in the Lake Taupo scheme in New Zealand, may achieve environmental certainty but are associated with high levels of uncertainty for participants[8]. Under

[6] Such as in the Pennsylvania Water Quality Trading Program, which restricts trading to between sources in each of the two watersheds it encompasses.

[7] Such as in our proposed Lake Rotorua trading scheme, where allowances are appropriate for the year that nutrients will arrive at the lake (their 'vintage').

[8] In the Lake Taupo scheme both the buyer and the seller have to have any changes to their emissions individually assessed and approved before a trade can be carried out. This mechanism provides very little certainty for participants to plan ahead, is costly, and as a result significantly decreases trading efficiency.

such uncertain approaches participants may choose to mitigate more than is efficient and over-comply (buy additional allowances or not sell) to reduce risk.[9] This over compliance comes with a cost however, if the environmental certainty goal was pursued through a method which gave participants more certainty over their costs and obligations, such as the uncertainty ratios described above, then environmental certainty could be achieved at higher levels of production.

There are also many examples of trading rules and restrictions that limit trading but do not offer any related environmental certainty gains. In the Pennsylvania Water Quality Trading Scheme landowners can accrue nutrient credit s for decreasing nutrient discharges through the application of almost any methods, but they cannot receive credits for land use change. There was political concern in the lead up to the nutrient trading scheme that its introduction would result in farms stopping operations and selling or shifting to alternative land uses. A clause was written into the law to ensure that farmers would not get credits for such a mitigation method. In the Connecticut Long Island Sound Nitrogen Credit Exchange Program trades are only allowed between PS participants and the central exchange board. The board also sets the price of credits based on an assumed average mitigation cost. This approach results in no market clearing, and trading inefficiencies as a result. The restriction of participation to just PS participants is another trading rule which deceases trading efficiency, this limitation is present in at least 13 of the 57 existing, proposed or inactive trading schemes worldwide (Selman et al. 2009).

Trading system should also give participants the choice of whether or not to trade. While trading is expected to lower the cost of mitigation, in some cases nutrient discharges may be most cost effectively cut through onsite methods. Fang et al (2005) criticise the Minnesota system because it requires point sources to purchase allowances from non-point sources to comply – point sources are unable to meet their target through in-plant control methods. This restriction potentially forgoes more efficient nutrient reductions. It also retains a high level of control for regulators, negating the 'command but not control' philosophy of market-based instruments (Shabman and Stephenson, 2007). Proponents of nutrient trading argue that individuals and firms have the best information to make nutrient reduction decisions.

Local circumstances and political processes can also lead to trading rules. An example is the interaction between existing or parallel command-and-control regulations and any trading scheme. If the scheme is not carefully aligned with any existing regulation, trading efficiency can be significantly hindered. In Chesapeake Bay, Maryland, credits generated by trading cannot be used to comply with existing pollution control regulations, increasing polluters' compliance burden (King, 2005). Later regulations can also create issues. The Maryland administration approved a set of trading guidelines in 2003, but in 2004 introduced a $2.50 per month "flush tax". The effect of this tax has been to reduce demand for credits by wastewater facilities and reduce supply from agricultural participants – both sources receive subsidies to clean up pollution from income generated by the tax.

4.1. Liquidity and innovation impacts

The impact that trading limits have on market liquidity is another issue that should be considered when designing any trading restrictions. Market liquidity is essential in ensuring that search and bargaining costs are minimised. It should be relatively easy for a willing and able buyer to find allowances they can purchase, and vice versa.

To maximise this liquidity designers of nutrient trading systems should examine how much flexibility a region's hydrology can handle. For example, the period for which participants are able to bank credits might be restricted to the mean residence time of a water body. In Miami River, Idaho, participants may only purchase allowances generated upstream from their point of discharge (King and Kuch, 2003). This is important to distribute discharge across the water body, but means that buyers can only trade with a subset of potential sellers.

Allowing trading across more than one pollutant can significantly increase allowance liquidity. Stephenson and Bosch (2003) draw on emissions trading literature as an example and state that "cross pollutant trading could be a practical alternative in many watersheds." Our information for the Lake Rotorua catchment suggests that nitrogen and phosphorus need to be independently reduced. However, applying the same trading frameworks to both nutrients could streamline and simplify the trading process, and there will be cases where a single mitigation practice is shown to reduce both nutrients simultaneously.

Another issue that should be considered when introducing limitations and rules into a trading market is the impact this will have on the innovation and development of new technologies and mitigation methods. An often-cited benefit of environmental markets is that, unlike simple regulation, they can promote innovative responses to environmental problems. This can lead to nutrient reduction at lower cost. The design of a nutrient trading system needs to balance potential benefits from innovation with the need to ensure that innovative methods are beneficial to water quality. Shortle and Horan (2008) characterise lists of accepted abatement methods in US water trading systems as "defined more for [their] contribution to measurement than [their] contribution to cost-effective management." Trading efficiency increases as more pollution control options are approved, but only to the extent that the process of validating and monitoring new approaches does not create unrealistic transaction costs.

In summary, the role of regulatory agencies in a nutrient trading system will affect trading efficiency. For trades to take place efficiently, regulatory agencies should focus more on monitoring and enforcement than on directly controlling. Commanding 'what' happens but not 'how' it happens embodies the shift to second-generation 'command but not control' regulatory instruments. While concern of environmental uncertainty may motivate some trading restrictions, many trading restrictions will not result in an increase in environmental certainty. If these trading rules can be avoided, then trading efficiency can be maximised.

5. General policy responses

Trading efficiency is most affected by the big decisions: what sources to include, whether to use a baseline-credit or cap and trade market, and whether to restrict trading in any way. However, good policy in these areas alone will not be enough to ensure that any scheme is maximally trading efficient. To avoid all sources of transaction costs and the resulting costs to trading efficiency, policies must be developed to ensure that participants have easy access to full information, political and regulatory certainty, and are able to flexibly respond to the regulation. These requirements and examples of their application in existing schemes are discussed in the following sections.

5.1. Information flows

Trading efficiency is supported through traders having ready access to high quality information. The transaction costs caused by optimising and search and bargaining costs can be minimised by proving good information to participants. Market design can improve the types and quality of information available to those who require it.

Brokers and similar third parties make information gathering and decision making more efficient by accumulating knowledge of the trading framework and streamlining the trading process (Stavins, 1995). These organisations, in turn, require clear governing frameworks to ensure they are trusted and effective. Some markets have a single intermediary, known as a clearinghouse, which handles all allowance sales. The disadvantage of this approach is that there is no competition to encourage greater efficiency. Nevertheless, the World Resources Institute (WRI, 2007) lists as a success the implementation of a clearinghouse for the Great Miami River Water Quality Credit Trading Program in Ohio. The Miami River clearinghouse purchases allowances from agriculture and allocates them to 'investor' companies in proportion to their level of investment.

Online and automated trading facilities can also help to reduce optimising and search and bargaining transaction costs. Nutrient Net (www.nutrientnet.org), developed by the World Resources Institute, is a set of web-based tools to facilitate water quality trading. NutrientNet allows participants to connect with other possible traders, and to list credits for sale or bid on available credits. It also allows administrators and the public to access (confidentialised) trades and prices over time, and administrators to keep track of credits and compliance records. The system has been used for four trading programmes in the US (Selman et al, 2009), across five states. In addition to its benefit for buyers and sellers, NutrientNet assists administrators to track projects allowances and trades at minimal cost.

NutrientNet, and its New Zealand counterpart Overseer, also allow landowners to run relatively complicated nutrient models onsite and in their own time, which allows participants to more effectively and cheaply optimise their operations to changing market conditions. The New Zealand Overseer model has been built to compute nutrient budgets and leakages using data that can be reasonably easily obtained by farmers or consultants, whilst still giving thorough and dependable output. For example, the Overseer pastoral farming model uses data on a farm and block level, and computes outputs based on farming region, animal shelters and feed pads, effluent management, animal species and their management and stocking rate, supplements, nitrogen inhibitors and wetland areas, topography, climate, soil and pasture type, irrigation along with soil analysis and fertiliser inputs (AgResearch, 2009). The information that such models provide participants can greatly decrease optimisation costs and increase trading efficiency.

Information flows are also likely to change over time. A case study by Woodward (2003) investigating the first trade carried out in the Lake Dillon reservoir in Colorado, USA, suggests that over time participants have a better understanding of the system and also a greater knowledge of possible trading partners. Both of these factors work to reduce search and information costs and transaction costs as a whole, which increases trading efficiency of a system over time.

5.2. Certainty

Certainty in the context of a nutrient trading system refers to certainty in the definition of an allowance and its properties, and to certainty in the trading environment. The trading environment has regulatory, political and scientific elements. If uncertainty is present in any of these spheres then all sources of transactions costs are adversely affected. If there is uncertainty at any stage of trading then defensive, and trading inefficient behaviour, is likely to occur. For example, if participants expect future changes to regulation, but are unsure of what form these changes will take then they will struggle to optimise their operations and negotiation of appropriate prices for credits under this uncertainty will be difficult to resolve. They will be similarly averse to participating if uncertainties about trade approval and monitoring costs are present. This section explores these uncertainties and addresses how policy design can seek to avoid them.

Clearly defining an allowance and its properties is an important step for efficient trading. Measurements of nutrient losses may need to consider soil type, slope, microclimate, heavy rainfall events, groundwater lag times, nutrient attenuation rates and residence times. It is not practical to directly assess these factors for every trade on every property. Authorities can instead develop standardised estimation methodologies. Both buyers and sellers (or their representatives) use these methodologies to determine with certainty the nutrient loss they are responsible for. Online tools assist with this process. NutrientNet is one such tool; the Lake Taupo Trading Program (and Motu's prototype trading system for the Lake Rotorua catchment) uses Overseer, a nutrient budgeting model developed by AgResearch to estimate nitrogen and phosphorus loss from pastoral land (Selman et al, 2009). If participants can be certain in knowledge over the definition of an allowance then they can begin to mitigate and manage their nutrient runoff. Any uncertainty in this definition will increase costs in optimising operations and negotiating trades with fellow participants.

Regulatory uncertainty also impacts on trading efficiency. If participants anticipate regulatory changes they may avoid trading until these changes occur or are ruled out. Clear advance guidelines of regulations subject to change and how any changes will be applied can reduce this effect. For example, in the prototype system designed for Lake Rotorua we propose that any changes in the nutrient cap are borne by landowners, local government and central government according to a predetermined and well-publicised ratio (Kerr and Lock, 2009).

Uncertainty at a political level can have similar effects. Whether regulators, policy makers and politicians will remain interested in the nutrient trading system is a major concern for trading efficiency. Changes in political priorities could see politicians introducing new regulations or relaxing existing ones. Participants who anticipate these actions may choose to hoard or sell at a loss any allowances they hold. In Lake Rotorua, analyses suggest that a trading system cannot lead to a measurable improvement in lake water quality for a century due to groundwater lags. This is a very long time in political terms.

Draft Copy – 14 September 2010

A stakeholder process can help to generate political support. Selman et al (2009) advocate both education and ongoing dialogue with stakeholders to ensure a system is implemented smoothly. Their appendix lists educational resources for communicating relevant information to a range of stakeholder groups. As a practical resource, Motu's environmental trading game is designed to introduce the principles of nutrient trading to a non-technical audience[10].

Finally, the scientific information used to measure and address water pollution is subject to change, and provides another level of uncertainty for traders. New scientific information can be treated like any other potential change in regulation: uncertainty is avoided through clear specification of which elements may be subject to change and a declared mechanism for transferring liability (or unexpected gains) to allowance holders.

As a general rule, certainty in all of its spheres can be maximised by the inclusion of well developed processes for managing any future change. It is highly unlikely that any trading scheme will continue unchanged indefinitely, so planning for the almost certain future change is the most effective method to promote certainty within a system.

6. Existing Scheme Assessments

The above discussion informs a framework with which to assess existing nutrient trading schemes in terms of their trading efficiency. While these determinants of trading efficiency were discussed above in general terms, it is important to note that different water catchments will come with their own environmental, political and social conditions – what may work in one area may not be so successful elsewhere. With this in mind we review trading efficiency in three existing trading systems. Reviews of the Lake Taupo trading system in New Zealand, the Pennsylvania Water Quality Trading System in the US and the Long Island Sound Nitrogen Trading Market in Connecticut, US, follow. The assessment of these different systems helps to illustrate the different approaches possible, and to crystallise the conclusions reached above.

These systems were chosen for a few reasons. They represent a variety of different market types; Taupo is a strict cap and trade scheme, which is made up solely of non-point sources along with one additional large buyer. The Taupo scheme also highlights the difficulties that occur when introducing trading schemes into areas without prior experience of the trading approach and pre-existing legal frameworks. The Pennsylvania scheme is a baseline and credit scheme and operates over two watersheds and includes both non-point and point sources. It

---

[10] This can be found online at www.motu.org.nz/building-capacity/environmental_trading_game

provides an excellent example of the way trading rules are used to account for differences in nutrient mitigation across a scheme. The Connecticut system includes just point sources, and is an interesting example of trading scheme ideas applied outside of the traditional trading scheme setup of trades between participants.

Conclusions and policy recommendations follow the assessment of these three systems.

6.1. Lake Taupo Trading System

[Some facts: region, year of establishment, regulators, participants, relevant legislation etc]

The Lake Taupo nutrient trading scheme is based in the watershed surrounding Lake Taupo, in the centre of the North Island of New Zealand. Evidence of declining water quality was found up to and through the 1990s as a result of excess nitrogen in the lake, largely due to the intensification of farming in the area. As a response, in 2003 a cap and trade scheme was proposed for the watershed as a method to control excess nitrogen leakage(Environment Waikato, 2003). Following various legal challenges over the intervening years, the trading scheme and cap will become fully operative before the end of 2010, and will allow trading of allowances amongst approximately 150 non point source (NPSs)[11] farms and between these NPSs and an environmental fund.

The environmental goal for the scheme is to keep water quality in Lake Taupo at the level it was in 2001. Given the lags in nitrogen arriving in the lake, this has been translated as equivalent to a 20% decrease in nitrogen inputs on farms relative to 2001 levels, a decrease of 153 tonnes of nitrogen on an annual basis. This is to be achieved by 2018 (Lake Taupo Protection Trust, 2009). To achieve this goal a fund, the Lake Taupo Protection Trust, was created to pay for nitrogen runoff reductions from farms. This is to be achieved through the purchasing of nitrogen allowances, retiring farming land, supporting relevant research and otherwise encouraging land use change in any other method to reduce nitrogen runoff levels. The Trust will administer the fund, which was established with $81.5 million in 2007, with contributions coming from central government, Environment Waikato (EW), and the district council (45%, 33%, and 22% of the $81.5 million respectively)(Yerex, 2009).

Allowances were grand parented to farmers with the allowance level equal to the highest level of nutrient runoff 2001-2005. A quantity of allowances (equal to 14 tonnes per year) have been kept to allocate to those who were not farming during the benchmark years to allow for the

[11] Personal communication with Natasha Hayward, On Farm programme manager, Environment Waikato.

development of underdeveloped farms, particularly for local Maori[12] (Environment Waikato, 2010).

The trading system is operated by the regional council, Environment Waikato, but has to operate under and within New Zealand's national environmental legislation, principally the Resource Management Act (RMA). As a result, the actual trading of allowances between farmers is quite complex. Once landowners have found another participant to trade with they must then draft a contract with quantity, price and time of trade information, and then finally prepare new nitrogen management plans and apply for new consents for these from the local regulators, a process which is expensive for farmers (Environment Waikato, 2010). Sale of allowances to the Lake Taupo Protection Trust is more straightforward, if only because they clearly wish to purchase allowances and as a result transaction costs are smaller. The Lake Taupo Protection Trust had purchased 6 properties and retired their nutrient allowances, and also purchased nutrient allowances off one land owner (who changed land use to forestry) by July 2009, for a reduction in nitrogen leaching that sums to more than 20 tonnes annually (Kneebone, 2009). While the scheme is not yet fully operational, there have been a small number of trades carried out between farmers.[13]

6.1.1. System Wide Elements

Are there incentives to participate in the system? Does the system complement existing regulation?

Participation is compulsory for all farms with leaching activities above a very low level (exclusions are given for forestry, existing golf courses and farms with very low stock and fertiliser rates). Any new sources are obliged to buy or lease nitrogen allowances before they can begin activities which would result in nitrogen leaching.

The system has to work within New Zealand's national environmental legislation, the Resource Management Act (RMA). Environment Waikato's approach to dealing with this has greatly complicated the scheme; any trade has to be followed up with a new consent application and acceptance by all parties involved in the trade. Also, enforcement ability is limited; the Resource Management Act has set penalties that can be levied, often these are very low and may potentially not be high enough to convince farmers to abide with the schemes regulations. Environment Waikato believes that there may be a small group of resistant farmers, but through

[12] These can only be acquired free only at very low levels, 2kgs per hectare – which will allow only a very low level of development without the purchase of more allowances. e.g. 0.55 dairy cows per hectare (Environment Waikato, 2007).

[13] Personal communication with Natasha Hayward, On Farm programme manager, Environment Waikato.

monitoring, education, and if necessary, escalating penalties, these landowners will be lead to participate in the scheme.[14]

Environment Waikato's interpretation of the RMA is not the only possible reading; we have advice that indicates that an ex-post system without consent changes would be workable under the RMA. This would have significantly higher trade efficiency (Rive et al, 2008).

What are the relevant geophysical elements of the watershed/trading area? How does the system design respond to these elements?

There are significant and variable lags in nutrient runoff leaching through to groundwater and on into the lake. These lags vary by the location of the nutrient application(Morgenstern, 2008). However, the trading scheme does not take account of this time dependency due to there being no model available to accurately take these lags into account. The lake does have a high percentage of nutrients that reach the lake through surface water (i.e. with no time lags).

6.1.2. Flexibility

[of pollutants] How many pollutants are covered under the scheme?

Just one; nitrogen, although phosphorus discharge are also a problem.

[of administrative compliance] Is there banking or borrowing?

Banking and borrowing were avoided when the policy was first written up as it was seen as an added, unnecessary complication.[15] Farming groups have requested that the cap be applied on a three year average, as opposed to strictly every year, but EW have declined this request as they believe that the cap has been set at such a level as to allow flexibility without these changes.[16]

[of environmental compliance] Does the policy recognise lots of different ways to decrease discharges? And is it easy to introduce new recognised methods?

Discharges are modelled using the Overseer program[17]; any mitigating or reducing activities that can be measured in Overseer will be recognised in the system. This includes fertiliser application, stocking rate, cultivation methods and type, supplementary feed, effluent management (e.g. system type, feedpads), and new technologies (nitrogen inhibitors, wintering

---

[14] Ibid.

[15] Personal communication with Justine Young, Senior Policy Analyst, Environment Waikato.

[16] Following a recent Environment Court decision, the nutrient cap has been set at the farms highest level of leaching between the years 2001-2005. Early monitoring indicates that at most farmers' current operating intensity, this cap is not binding, with leaching levels often 10% below this benchmark. (Personal communication with Natasha Hayward, On Farm programme manager, Environment Waikato).

[17] Overseer is a nutrient budget modeling tool developed by AgResearch, New Zealand.

off)(Environment Waikato, 2007). Alternative mitigation methods can also be credited, but this has to be carried out through a non-compliant consent process; a method which would be more expensive and uncertain for the farmer.

[of trading] Can you trade with anyone?

Trading can be carried out between the NPS farms, or with the Lake Taupo Protection Trust.

6.1.3. Transaction Costs

Are transaction costs (costs of gathering information, bargaining, trade approval, monitoring, enforcement; also transparency) minimised?

EW has set up a basic central notice board where sale and purchase offers for nitrogen can be listed. This should help decrease searching and bargaining costs. Farmers also have the option of trading with the Lake Protection Trust, which will decrease these search costs for farmers looking to sell, but not those looking to buy.

Due to the RMA, trading of allowances has to be carried out through a consent process, which is time consuming and expensive; Environment Waikato estimates that to update a consent (as both parties have to do to complete a nitrogen allowance trade) will cost $1000-$3000 (Environment Waikato, 2009). This is a significant cost that will only be borne by participants if they trade[18]. It would be much cheaper for participants if a more streamlined process was developed with changes confirmed by regulators but not requiring such a stringent consent process.

Monitoring costs are paid by farmers; this will come out of the annual consent holders' fee. Due to the compulsory nature of the scheme these costs are not associated with trading; these are not transaction costs. Enforcement is carried out under the RMA; if farmers do not meet their consents (i.e. don't meet their agreed Nitrogen Management Plan) then this is enforced through provisions in the RMA. This is independent of trading.

6.1.4. Participant Certainty

[scientific] Are the allowances and their relative 'environmental' worth clearly defined? Are potential changes clearly signalled?

---

[18] There is a much smaller 'consent holder' fee of approximately $400 paid by all farmers holding consents, regardless of whether they trade (Environment Waikato, 2009).

Each allowance allows the holder to discharge one kg of nutrients annually, where discharges are given by Overseer. This annual time period refers to when the nutrients leak from the farmer's property, not to when they arrive in the lake.

The Overseer model is updated reasonably frequently; if it changes, then the new allowance allocation will be calculated using this new version, and any changes in consents will be calculated using this new version of Overseer (Environment Waikato, 2007). This may have an effect if new versions of the program give significantly different discharge results; however, this has not been found to be problem. To date, changes in versions have had negligible effects on estimates, and there is acceptance that the benefits of using the most recent version outweigh this small risk.[19]

[regulatory] Is the regulation stable? Are any future changes well signposted?

A process for reviewing the scheme in terms of environmental success and workability for users has been agreed following discussion and legal appeals between EW and stakeholders. This agreement brings much certainty to how future changes will be implemented.

[political] Is there general political support for the trading scheme? Strong stakeholder support?

Yes. Achieving the nitrogen cuts by purchasing nitrogen allowances off farmers, or purchasing and retiring land, both through the Lake Taupo Protection Trust has resulted in the costs of the policy being shared between farmers, local and district council, and the central government, which seems fair and equitable (Kerr and Lock, 2009).

The Lake Taupo Protection Trust has been successful in making significant cuts to future nitrogen leaching within cost goals (Kneebone, 2009). Farmer's fundamentally support protecting water quality in the lake, and as farmers begin to get used to the idea of the trading scheme, acceptance has increased.[20]

There has been no political support for revisiting this issue; it also appears stable at the political level.[21]

6.2. Long Island Sound Nitrogen Trading Market, CONN USA

[Some facts: region, year of establishment, regulators, participants, relevant legislation etc]

The Long Island Sound Nitrogen Trading Market is based in Connecticut, USA. The scheme was set up and has run since 2002 following decreased water quality and increased

---

19 Personal communication with Natasha Hayward, On Farm programme manager, Environment Waikato.
20 Ibid.
21 Personal communication with Justine Young, Senior Policy Analyst, Environment Waikato.

hypoxia in the Long Island Sound and the introduction of a Total Maximum Daily Load (TMDL)[22] in the Long Island Sound (LIS) in 2001. The program includes only point source (PS) dischargers; 79 municipal owned sewerage plants.

The environmental goal is set by the TMDL which is set by the US Environmental Protection Agency. The TMDL must be met by 2009, with a stricter one to be met by 2014; if the goal is not met the state will face hefty fines. To reach these federal limits the Connecticut Department of Environmental Protection has set yearly general permit limits which decrease annually towards the 2009 and 2014 goals.

PS allocations of allowances follow the tightening environmental goal. PSs were all initially allocated credits based on discharge volume (from a 1997-99 baseline) at an average level (across all point sources) of nitrogen enrichment. Each year, each PS's allocation falls proportionately with the goal. If the PSs discharge more than their allocation they have to purchase additional credits through the Nitrogen Credit Exchange (NCE), a so called 'clearinghouse', which is overseen by the Nitrogen Credit Advisory Board (NCAB). The NCAB sets the credit price at the end of each year and buys and sells at that price. The board sets the price equal to the average observed mitigation cost – that is they obtain information on costs of mitigation from all the PSs and calculate the total level of equalized nitrogen discharges decreased, and so set the price at this average mitigation cost[23]. Credits are not limited to the cap; indeed the 'market' has not balanced once. In the first three years of the scheme the PSs reduced total discharges below the annual goal, and received a net payout, but in the 4 years 2005-2008 the PSs had to buy credits from NCAB (implying that the overall annual discharge goal was not met)(Connecticut Department of Environmental Protection, 2010). This could not occur under a true tradable permit market where each credit purchased would be matched by one sold and the goal (cap) would have to be met and if it wasn't going to be then the price of credits would be

---

[22] A TMDL is the primary regulatory method that US and state EPAs use to set the maximum pollution limits for water discharges.

[23] The 'market' price is set using the following formula by the ECAB board (Connecticut Department of Environmental Protection, 2009)

"The value of an equalized credit = Capital Costs + Operational Costs / Total amount of equalized nitrogen reduced from project facilities"

Where "Capital Costs" were established by the Board as the annual amount spent by municipalities on nitrogen removal projects (this does not include grants). "Operational costs" were estimated by means of a survey sent to all Project Facilities. Department staff reviewed all survey data for consistency and reasonableness. The reduction in equalized pounds of nitrogen was calculated by subtracting the actual end-of-pipe pounds of nitrogen discharged by each of the Project Facilities from the "baseline" loading (level of discharge that would've occurred with no additional treatment since 1997-99). This was then adjusted using equalization factors and summed to calculate state-wide equalized reductions.

bid up to a point where it would be most profitable to attenuate discharges. However, the PS's have only limited options for decreasing their discharges. While they can make adjustments to increase the efficiency of nitrogen removal of existing technology, as they did in the early years of the scheme, the majority of funding for upgrades comes principally from state and federal grants; if these are slow in coming through it seems unreasonable to punish individual municipalities. While this is clearly not a market in the traditional sense, it does provide some environmental improvement (the cap will be binding on the state in 2009 and 2014) but keeps costs for PSs low by giving time for transition to occur.

As the focus of the scheme is increasing water quality in the Long Island Sound, all PS discharges and reductions are adjusted so each use of a credit has an equal effect on water quality in the sound. To achieve this there are 23 different transmission coefficients for the different areas, computed by combining a river delivery factor and a LIS delivery factor (i.e. to the edge of the sound).

6.2.1. System Wide Elements

Are there incentives to participate in the system? Does the system complement existing regulation?

Participation is compulsory for PSs.

The Nitrogen Credit Exchange program was motivated by the Clean Water Act and its requirement for cleaner water than is currently in Long Island Sound. They work together well – the USA EPA encourages and helps to fund nutrient trading programs.

What are the relevant geophysical elements of the watershed/trading area? How does the system design respond to these elements?

The use of delivery coefficients to equivalise discharges and reductions across the watershed matches the geophysical elements of the watershed well. This approach will aid achievement of the goal without restricting where future development takes place.

6.2.2. Flexibility

[of pollutants] How many pollutants are covered under the scheme?

One; nitrogen.

[of administrative compliance] Is there banking or borrowing?

There is no banking or borrowing in the system. This is possibly due to the focus on flows, rather than stocks, of nitrogen. The state is obliged to meet the TMDL which is a measure of flows into the sound not the total stock in the sound; banking and borrowing would make meeting this time dependent goal difficult.

[of environmental compliance] Does the policy recognise lots of different ways to decrease discharges? And is it easy to introduce new recognised methods?

Yes. A decrease in discharge is measured by monitoring – doesn't have to be upgrades; as mentioned above, in the first few years of the program a lot of discharges were cut through more efficient application of nitrogen removal techniques (Rocque, 2003). That is, it is very flexible in allowing new methods.

[of trading] Can you trade with anyone?

The only explicit trading is between individual PSs and the NCE; implicitly this is trade between the PSs. No trade is allowed with non point sources (NPSs); the definition of the goal and hence total credit allocations in the trading system assumes that NPS discharges will be reduced by 10% over the time period through alternative regulation.

6.2.3. Transaction Costs

Are transaction costs (costs of gathering information, bargaining, trade approval, monitoring, enforcement; also transparency) minimised?

The PSs are given an estimate of what the credit price will be by NCAB in October of the applicable year, based on the first 8 months of the year's data. They are then given a final value in March of the following year and have to settle their accounts.

As a result there are very low transaction costs for the PSs involved - the cost of trade approval and information gathering is borne by the state. There are no bargaining or search costs.

As inclusion in the scheme is non-voluntary, monitoring costs are independent of transactions. Monitoring has been performed by PSs in the sound area since at least 1993, it is not expected that any cheating will occur(Connecticut Department of Environmental Protection and New York Department of Environmental Protection, 2000).

Trade enforcement costs don't apply – the penalty for not meeting any goals is in the form of extra credits you have to buy from ECAB. There have been no issues with PSs not complying.

6.2.4. Certainty

[scientific] Are the allowances and their relative 'environmental' worth clearly defined? Are potential changes clearly signalled?

Emissions are clearly defined – they are measured at the PS outfall. This is then combined with the known transfer coefficients to get transferable credits.

The price/value of credits is not known until the end of the year. If the advance estimate is poor the market is inefficient and will not exactly meet the goal. However, as the credit price is set at the average mitigation price (which is decided by the NCE, who also provide the advance estimate) it is expected that the estimate will be based reasonably good information, and the actual price will not differ too much from the estimate.

[regulatory] Is the regulation stable? Are any future changes well signposted?

The discharge limits and transfer coefficients for each PS are set out in the Nitrogen General permit, which includes limits for each year in the next five year period, and an end goal for 2014. It is not expected that TMDL or the transfer coefficients will need changing[24], but if they do, this will be passed on to the individual PSs. To help ensure that changes are not necessary, the discharge limits have been set so that the TMDL will be met comfortably, this helps decrease the likelihood that changes will need to be made. There is a cost to this regulatory certainty though, overachieving the environmental goal will be associated with increased costs.

[political] Is there general political support for the trading scheme? Strong stakeholder support?

Yes. The scheme is well established, with 7 annual trading rounds completed and over 15.5 million credits exchanged with a value of about $45 million US. The sewage treatment plants like it because it saves them money over individual permit requirements, and the environmental groups are supportive because the scheme has already achieved cuts equal to more than 80% of those required to meet the final 2014 goal[25].

6.3. Pennsylvania Water Quality Trading Program, PENN USA

[Some facts: region, year of establishment, regulators, participants, relevant legislation etc]

The Pennsylvania Water Quality Trading Program is based in Pennsylvania, USA. It was introduced to reduce nitrogen, phosphorus and sediment run off into Chesapeake Bay. Pennsylvania State is a member of the Chesapeake Bay Program, an association of states which aims to coordinate the improvement of water quality within the Bay, among other goals.

---

24 Personal communication with Paul Stacey, Bureau of Water Protection and Land Reuse, CONN.

25 Ibid.

Following the signing of a renewed agreement in 2000, Pennsylvania moved to meet new nutrient standards set for 2010. This is intended to be achieved through a few channels; one of them being this nutrient trading system. The trading system allows trading between and amongst point sources (PSs) and non-point sources (NPSs).

The environmental goal for the system is to achieve a cap which is set allowing for a 10% increase in industrial discharges (from 2002 levels) and a decrease in average level sewage discharge levels to 6 mg/l for nitrogen and 0.8 mg/l for phosphorus, at projected 2010 flow(Pennsylvania Department of Environmental Protection, 2006b). The trading system is a voluntary baseline and credit system and has been established to decrease the cost for large nutrient dischargers in meeting their more stringent new water quality requirements. The system accrues credits to those who decrease their nutrient discharges below a baseline, and allows these credits to be sold to nutrient emitters who can use these allowances in lieu of reducing their own nutrient emissions. Typically these credits are generated by NPSs such as farms who introduce techniques and technologies to reduce their nutrient runoff below what is required[26] (Pennsylvania Department of Environmental Protection, 2009b). These credits are then purchased by PSs such as sewage plants or large industrial dischargers.

Credits are traded through a market or through bilateral trades. An online trading system using the World Resource Institute's NutrientNet website has been set up, although this does not appear to have had much use to date (Selman et al, 2009). Supply of credits has also been encouraged through a program run by the Pennsylvania Environmental Protection Agency (PA EPA), where they have encouraged districts to facilitate farmers carrying out nutrient saving activities on the promise that the PA EPA will act as an intermediary and purchase the credits and hold onto them to on sell when there is demand. By 2009 this had generated reductions of over 87000 pounds per year of nutrient runoff(Pennsylvania Department of Environmental Protection, 2009b).

As the focus of this trading scheme is on improving nutrient levels in Chesapeake Bay, the system incorporates trading ratios which adjust all discharges and reductions so that each use of a credit has an equal effect on bay water quality. These ratios compensate for any attenuation of nutrients over the journey from discharge point to the bay(Pennsylvania Department of Environmental Protection, 2009a). On top of these ratios, a reserve ratio of 10% is also applied as insurance against any credit generating activities that fail.

---

[26] Examples of techniques include stream bank fencing, rotational grazing and no-till farming.

One final restriction is that trading can only occur between sources within the same watershed (two watersheds are included in the Pennsylvania scheme; the Susquehanna and Potomac watersheds); this is to ensure that both of these watersheds too are protected by the trading scheme, and not just the bay. A final restriction is that credits cannot be generated by retiring farmland. There appears to be concern that this policy would accelerate the loss of productive farmland. Even if this is economically efficient, this is barred under the scheme(Pennsylvania Department of Environmental Protection, 2006a).

6.3.1. System Wide Elements

Are there incentives to participate in the system? Does the system complement existing regulation?

PSs and NPSs can only participate in the trading system if they have already applied some basic threshold level of nutrient reduction. PSs can only accrue credits for reductions below concentration limits set through National Pollution Discharge Elimination System (NPDES) by the US EPA. PSs can trade to achieve these limits.

NPSs can only accrue credits if they have an approved plan and one of three technologies/mitigation activities in place. These prerequisites are not eligible for credits.

The system was set up to assist existing regulation (NPDESs), and complements these well.

What are the relevant geophysical elements of the watershed/trading area? How does the system design respond to these elements?

Nutrient losses in the Susquehanna and Potomac River watersheds do not affect the other's water quality. As a result, sources can only trade within their own watershed, at any scale (stream to total). Delivery Ratios compensate for a nutrient or sediment's travel in water and will be applied to point and non-point sources. The ratio varies depending on the distance of the source from the mainstem of the Chesapeake Bay. The Edge of Segment (EOS) Ratio is a factor that is unique to each watershed model segment that has been determined by the Chesapeake Bay Watershed Model in order to estimate the EOS load for individual non-point sources within a watershed segment (differs for conventional till, conservation till, hay and pasture). The regulators also apply an insurance ratio of 10% to cover transactions that are ultimately unsuccessful.

Credits can only be traded like for like; that is, nitrogen credits can only be used to meet nitrogen reduction requirements, and not phosphorus requirements.

6.3.2. Flexibility

[of pollutants] How many pollutants are covered under the scheme?

Nitrogen, phosphorus and sediments, each traded separately.

[of administrative compliance] Is there banking or borrowing?

No. Credits must be surrendered in the year they are generated.

[of environmental compliance] Does the policy recognise lots of different ways to decrease discharges? And is it easy to introduce new recognised methods?

All activities must be certified before credits can be generated. The Department has pre-approved calculation methodologies for use by persons seeking approval of credits. The Department will also consider other calculation approaches, although the proposal review time may take longer.

However, credits cannot be accrued for converting productive farmland to other uses.

[of trading] Can you trade with anyone?

Yes, but only within each watershed. PSs, NPSs and any third parties (e.g. brokers) are eligible.

6.3.3. Transaction Costs

Are transaction costs (costs of gathering information, bargaining, trade approval, monitoring, enforcement; also transparency) minimised?

The cost of gathering information is low due to the use of NutrientNet as an online trading system; this allows easy investigation of market prices and options. It also lowers the cost of bargaining, as this can all be carried out online through a bidding mechanism.

The trading process includes phases of certification (proposal approval), verification and registration. Traders have the option of using Nutrient Net to calculate credits, post credits for sale and trade credits. However, the PA EPA has indicated that all trades must be reviewed and approved before they can be used to meet permit limits.

In an attempt to decrease the costs of this trade approval, the PA EPA has outlined acceptable contract terms for traders, and a model contract will eventually be available online.

Monitoring NPS nutrient reductions is not plausible, instead, the department estimates the nutrient savings that will occur as a result of the change in activities or technologies, and verifies that these changes have happened. This will clearly be cheaper than monitoring, but may be less certain.

Enforcement costs for participants may be quite high. Those who purchase the credits are responsible for enforcing the terms of their credit purchasing agreement, although the department will take action if NPSs or third parties wilfully fail the contract terms. Exceptions also exist if reductions fail due to unforeseen events. Despite these exceptions, this risk is a real additional cost of trading.

6.3.4. Certainty

[scientific] Are the allowances and their relative 'environmental' worth clearly defined? Are potential changes clearly signalled?

Environmental worth of credits is clearly defined; one allowance is equal to one pound of reduction of the particular nutrient leaching per year.

These three existing nutrient trading schemes serve to illustrate the importance of local characteristics to the design of a trading scheme. However, they also demonstrate that there are general similarities across successful systems, which can be applied regardless of the local circumstances to increase the trading efficiency of a scheme. These lessons are discussed in the conclusion below.

7. Conclusion

Maximising trading efficiency should be a key consideration when designing a nutrient trading market. Minimising the cost of reallocating allowances from their initial holders to those who find them most valuable is essential in creating an efficient system. However, there are many different possible obstructions in achieving this trading efficiency, and combined with differences between catchment areas, it is very difficult to conclude on a universally optimal approach. An approach that may be effective and efficient for the prototype trading system that we are designing for a New Zealand watershed may not be effective in an overseas regulatory, political or physical environment, and vice versa. Despite these caveats, the discussion above does suggest four general guidelines that should be followed when designing a nutrient trading system in order to promote trading efficiency.

Firstly, trading schemes should be designed with trading efficiency in mind from the very beginning. Consideration of the scope of the trading scheme and the choice of scheme type should be informed by an understanding of the tradeoffs involved in any decisions. While cap and trade schemes face larger set up costs, the inherently higher levels of trading efficiency that they can achieve and their avoidance of adverse selection mean that these set up costs are often outweighed by long term savings and gains.

Secondly, a similar understanding of the costs should be applied when considering the introduction of trading limitations. While trading rules and requirements may increase the environmental certainty of a scheme, this should be balanced by a consideration of the decrease in trading efficiency they also inevitable cause. Any restrictions on trading will make it more difficult for allowances to move from their initial allocation to where they are most valued, and will increase the cost of reaching environmental goals as a result.

Thirdly, transaction costs will decrease, and trading efficiency increase, as trading markets are made more transparent, flexible and more certain. For the market to work effectively it needs to be simple for sellers and buyers to find each other, and to help to keep bargaining costs low, historical prices should be readily available. This improvement in information available for participants can be achieved with very little cost, and can make a sizeable impact on the overall efficiency of the scheme. Online automated trading systems such as NutrientNet are an attractive mechanism to achieve this.

Finally, regulation should be stable with clear and well understood and accepted rules, and the regulation should be written with the goal of controlling the environmental outcome, but not how it is reached. Regulation that relies on systems and rules, and that monitors and enforces these rather than relying on individual approval of every transaction will help to achieve this. Stability of the regulation can be enhanced through general political acceptance, which can be achieved more easily if stakeholders are involved and consulted throughout the policy development and introduction. To avoid efficiency losses from uncertainty, any changes to regulation as a result of new scientific information or political will should be well sign-posted. At the same time, the policy should be flexible to new methods of leakage mitigation or reduction. This will clearly be a balancing act.

If these guidelines can be followed, then trading efficiency should be maximised. It will be up to policy makers to weigh up these increases in trading efficiency against any related increases in environmental uncertainty. It will depend on local circumstances and opinions as to what extent this trade-off is worth making.

References

AgResearch. 2009. "An Introduction to the OVERSEER Nutrient Budgets Model (Version 5.4)," . Available online at http://www.agresearch.co.nz/overseerweb/files/introduction-to-overseer.pdf.

Carpenter, S. R.; N. F. Caraco; D. L. Correll; R. W. Howarth; A. N. Sharpley and V. H. Smith. 1998. "Nonpoint Pollution of Surface Waters With Phosphorus and Nitrogen", *Ecological Applications,* 8:3, pp. 559-68.

Connecticut Department of Environmental Protection. 2009. "Report of the Nitrogen Credit Advisory Board, 2008," . Available online at http://www.ct.gov/dep/lib/dep/water/lis_water_quality/nitrogen_control_program/nitrogen_report_2008.pdf.

Connecticut Department of Environmental Protection. 2010. "Connecticut's Nitrogen Credit Exchange - An Incentive Based Water Quality Trading Program," . Available online at http://ct.gov/dep/lib/dep/water/lis_water_quality/nitrogen_control_program/water_quality_trading_summary_2010.pdf.

Connecticut Department of Environmental Protection and New York Department of Environmental Protection. 2000. "A Total Maximum Daily Load Analysis to Achieve Water Quality Standards for Dissolved Oxygen in Long Island Sound," . Available online at http://www.ct.gov/dep/lib/dep/water/lis_water_quality/nitrogen_control_program/tmdl.pdf.

Environment Waikato. 2003. "Protecting Lake Taupo: A Long Term Partnership," . Available online at http://www.ew.govt.nz/PageFiles/7058/strategy.PDF.

Environment Waikato. 2007. "Proposed Waikato Regional Plan Variation 5 - Lake Taupo Catchment (Appeals Version)," *Environment Waikato Policy Series 2007/24*.

Environment Waikato. 2009. "Nitrogen Management in the Lake Taupo Catchment," . Available online at http://www.ew.govt.nz/PageFiles/183/Taupo%20Revised%20Guide%20to%20FarmingAUG09.pdf.PDF.

Environment Waikato. 2010. "Nitrogen Sourcing and Trading in the Lake Taupo Catchment," . Available online at http://www.ew.govt.nz/PageFiles/15237/Nitrogen%20trading%20in%20the%20Lake%20Taupo%20catchment.pdf.

Fang, Feng; William. Easter and Patrick Brezonik. 2005. "Point-Nonpoint Source Water Quality Trading: a Case Study in the Minnesota River Basin", *Journal of the American Water Resources Association (JAWRA),* 41:3, pp. 645-58.

Gangadharan, Lata. 2000. "Transaction Costs in Pollution Markets: An Empirical Study", *Land Economics,* 76:4, pp. 601-14.

Kerr, Suzi and Kelly Lock. 2009. "Nutrient Trading in Lake Rotorua: Cost Sharing and Allowance Allocation," *Motu Working Paper 09-09*. Available online at http://www.motu.org.nz/publications/working-papers.

Kerr, Suzi and David C. Maré. 1998. "Transaction Costs and Tradeable Permit Markets: The United States Lead Phasedown," University of Maryland at College Park, New Zealand Department of Labour.

King, Dennis. 2005. "Crunch Time for Water Quality Trading", *Choices the magazine of food, farm, and resource issues,* 20:1, pp. 71-6.

King, Dennis and Peter Kuch. 2003. "Will Nutrient Credit Trading Ever Work? An Assessment of Supply and Demand Problems and Institutional Obstacles", *Environmental Law Review,* 33, pp. 10352-68.

Kneebone, John T. 2009. "Lake Taupo Protection Trust - Chairman's Report, 2009," Lake Taupo Protection Trust. Available online at http://www.laketaupoprotectiontrust.org.nz/file/chairmans-report-for-the-year-ended-30-june-09.pdf.

Lake Taupo Protection Trust. 2009. "Statement of Intent : 2009 - 2010," . Available online at http://www.laketaupoprotectiontrust.org.nz/page/5-Home.

Lock, Kelly and Suzi Kerr. 2008. "Nutrient Trading in Lake Rotorua: Overview of a Prototype System," *Motu Working Paper 08-02*.

McCann, Laura; Bonnie G. Colby; K. W. Easter; Alexander Kasterine and K. V. Kuperan. 2005. "Transaction Cost Measurement for Evaluating Environmental Policies", *Ecological Economics,* 52, pp. 527-42.

Montero, Juan-Pablo. 1999. "Voluntary Compliance With Market-Based Environmental Policy: Evidence From the U.S. Acid Rain Program", *The Journal of Political Economy,* 107:5, pp. 998-1033.

Morgenstern, Uwe. 2008. "Lake Taupo Catchment Groundwater Age Distribution and Implications for Future Land-Use Impacts," Environment Waikato. Available online at http://www.ew.govt.nz/PageFiles/5598/tr0749.pdf.

Pennsylvania Department of Environmental Protection. 2006a. "Trading of Nutrient and Sediment Reduction Credits - Appendix A: Nutrient Trading Criteria Specific for the Chesapeake Bay Watershed," Pennsylvania, USA. Available online at http://www.dep.state.pa.us/river/Nutrient%20Trading%20Documents/Additions%2012-29-2006/Final%20APPENDIX%20A%20_12-28_.pdf.

Pennsylvania Department of Environmental Protection. 2006b. "Trading of Nutrient and Sediment Reduction Credits - Attachment 1: Point Source Alloaction Strategy," Pennsylvania, USA. Available online at http://www.dep.state.pa.us/river/Nutrient%20Trading%20Documents/Additions%2012-29-2006/Final%20Attachment%201%20_12-28_.pdf.

Pennsylvania Department of Environmental Protection. 2009a. "Final Trading of Nutrient Adn Sediment Reduction Credits - Policy and Guidelines," . Available online at http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-48501/01%20392-0900-001.pdf.

Pennsylvania Department of Environmental Protection. 2009b. "Nutrient Trading in the Chesapeake Bay : Pennsylvania Conservation Districts Flyer," Pennsylvania, USA.

Rive, Vernon; Barclay Rogers and Cameron Law. 2008. "Nutrient Trading in Lake Rotorua: Overview Legal Advice," . Available online at http://www.motu.org.nz/Rotorua_Prototype.

Rocque, Arthur J Jr. 2003. "Report of the Nitrogen Credit Advisory Board, 2003," . Available online at http://www.ct.gov/dep/lib/dep/water/lis_water_quality/nitrogen_control_program/annrpt.pdf.

Selman, Mindy; Suzie Greenhalgh; Evan Branosky; Cy Jones and Jenny Guiling. 2009. "An Overview of Water Quality Trading," World Resources Institute, Washington, DC.

Shabman, Leonard and Kurt Stephenson. 2007. "Achieving Nutrient Water Quality Goals: Bringing Market-Like Principles to Water Quality Management.", *Journal of the American Water Resources Association (JAWRA),* 43:4.

Shortle, James S. and Richard D. Horan. 2008. "The Economics of Water Quality Trading", *International Review of Environmental and Resource Economics,* 2, pp. 101-33.

Stavins, Robert. 1995. "Transaction Costs and Tradeable Permits", *Journal of Environmental Economics and Management,* 29, pp. 133-48.

Stephenson, Kurt and Darrell Bosch. 2003. "Nonpoint Source and Carbon Sequestration Credit Trading: What Can the Two Learn From Each Other?," Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Montreal Canada, July 27-30, 2003.

Woodward, Richard T. 2003. "Lessons About Effluent Trading From a Single Trade", *Review of Agricultural Economics,* 25:1, pp. 235-45.

World Resources Institute. 2007. "An Overview of Water Quality Trading - Appendix C: Water Quality Trading Programs Interviewed," World Resources Institute, Washington, DC.

Yerex, Sue. 2009. "Protecting Lake Taupo - The Strategy and the Lessons," . Available online at http://www.ew.govt.nz/PageFiles/7058/ProtectingLakeTaupopublication.pdf.