Enhancement of the Water Market Reform Process: A Socioeconomic Analysis of Guidelines and Procedures for Trading in Mature Water Markets

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1 EXECUTIVE SUMMARY

The immediate implications of the research for water policy at a national and catchment level is (a) the need to develop strategies to overcome social and cultural barriers to trade and option of water reform, (b) the apparent willingness of farmers to account for and possibly accept a reduction in allocations to restore environmental flows, and (c) that providing information and environments for farmers to self govern aggregate extraction levels to assist in restoring environmental flow regimes will be effective has been demonstrated under controlled conditions. These issues were explored and highlighted in the review of the literature on water reform, the survey of irrigator and community attitudes to water reform and the results of the water market experiments.

A significant output of this project was the development of *MWater*. *MWater* is a computer package that provides a means of evaluating the economic theory and associated policy options underpinning water reform in a controlled laboratory environment. Under controlled conditions participants manage a stylized model farm and water allocation given a set of water trading operating rules governed by policy. While the environment is artificial, the salience is real because participants are paid according to their farm's performance. Using experimental methods in concert with traditional economic econometric and optimization modeling is seen as the future of resource economic policy evaluation.

Recognition of experimental economics as at the cutting edge of science is exemplified by fact that the person responsible for developing experimental methods in economics, Dr Vernon Smith, was awarded the Nobel Prize in 2002 for his contribution. This research has put Australia on the map as one of only two places in the world where water market experiments are actively conducted. Following a series of industry workshops demonstrating *MWater*, industry and State department interest in using *MWater* and experimental methods generally beyond the life of this project is gaining momentum.

2 INTRODUCTION

The success of the Council of Australian Government Governments (COAG) and National Competition Policy allocation and trading water reforms depends on appropriate institutional and legal structures and equally important acceptance by the community, which at the end of the day will by their actions operationalise the reforms by establishing trading environments and developing regional guidelines for accounting for environmental flows which are socially acceptable.

This report outlines a background to water reform issues, specifically water trading and accounting for environmental flows, and methodologies undertaken to evaluate attitudes towards and behavioural reactions to a variety of institutional and market structures are presented. The catchment and national implications of the results of this study are discussed, concluding with a series of national and catchment policy recommendations on trade.

2.1 Background Issues

As part of water management reform water markets and the role of water authorities are evolving in Australia as in other parts of the world. This research gave some insights into the social and cultural issues as yet largely unaddressed in water policy reform. The research explored farmers' resistance to trade, farmer and community attitudes concerning who should be allowed to trade, the role of the water authority in the marketplace, what role farmers see themselves and others playing in water markets and perceived blockages to trade. The findings of the research suggest that optimal market-based redistribution of water may not occur unless the social and cultural attitudes to trade are duly considered.

Using a case study approach, this research explored farmer responses to the introduction of water markets in three catchments across the eastern seaboard of Australia. Water markets, and the role of water authorities, are evolving - creating opportunities for empowering farmers to make decisions affecting the structure of water markets and the rate of adoption of market oriented practices. Easter *et al*. (1998) and Greig (1998) suggest that the inclusion and participation of stakeholders and water users predicates the successful implementation of a market reform agenda. In eliciting stakeholder attitudes to water markets, this study is therefore timely and relevant to that debate.

Australia's water management strategies have, in the past, failed to capture the multiplicity of water benefits, including the value of ecosystem functions, and to respond to changing social attitudes and objectives of improving instream values and water quality (Musgrave 2000, Pigram 1993). Greig (1998), Paterson (1987) and Randall (1981) note that in addition to the over-allocation of water diversions, resulting in environmental degradation and unrelated agency benefits and costs, water management has been characterized by a net transfer of public wealth to the domain of farmers who irrigate. As a result of changes in cropping practices and increased agricultural diversity over the past 20 years, original allocations of water no longer correspond to demand. Institutional failure, across most jurisdictional constituencies, to manage water as an economic good is now understood to be the primary causal agent of water usage associated problems in Australia (Davidson 1969, Musgrave 1996, Paterson 1987, Pigram 1993, 1999; Randall 1981).

In 1993 the Council of Australian Government (COAG) introduced a raft of water reforms to address these issues. The reforms were aimed at altering the historic links between land ownership and water allocations, thus facilitating the establishment of tradable water rights. COAG reforms incorporated recognition of legitimate environmental uses of water and the need to take full account of the cost of extractive uses of water. A market-based solution to the mis-allocation of water was promoted throughout Australian and international water sectors and has gained widespread government acceptance (Hartman and Seastone 1970; Randall 1981, Saleth and Dinar 1999). The success of these reform objectives, especially water trading to promote efficient use of water, depends upon voluntary participation by water users. If the water users are not willing or able to accept the reforms, the reform objectives will not be fully realized.

Based on market theory, water markets have been established to redistribute water entitlements to their most efficient use. From an institutional perspective, whether water markets will redistribute water and result in the efficiency and equity objectives of the reform agenda depends in part on the structure, conduct and performance of water markets. From a sociological perspective, how well the market will achieve government expectations depends in part on farmers' perceptions and attitudes to water trading in general and their perceptions of the structure and conduct of the market. To date, the nexus between establishing institutional structures for water trading and social acceptance of trade has not been fully explored.

2.1.1 Social acceptance of water trading

Since the initial development of surface water in Australia, settlers saw no distinction between owning irrigable land and access to water. The right of access to water that has evolved in Australia, known as the non-priority permit system, defines water entitlements as a volume per hectare of land, or a volume according to the type of crop grown on the land. The institutional nexus between land and water has been translated into a long history of farmers associating their water entitlements to their land. The historic link between land and water significantly attenuated[1] farmers' rights to water in Australia and, in concert with the statutory impediments to water transfers, were seen as a source of substantial institutional obstruction to the redistribution of water to alternative uses (Dudley and Musgrave 1988, Pigram 1993, Sturgess and Wright 1993). Defining water entitlements in solely volumetric terms is relatively recent in Australia. Throughout the late 1990s and early 2000 State governments introduced legislation to improve the definition of water entitlements as chattels and establish more formalized institutional structures for water trading.

State governments, and their water authorities, believe that establishment of appropriate legislative frameworks for trade will be effective in stimulating trade, and that trading will redistribute water to its most efficient use. Whereas the effective operation of water markets is primarily conditional on the recognition of the relative scarcity of water, the establishment of a regulatory framework for market specification and the enforcement of property rights and contractual regimes[2], it also requires social acceptance of the need and benefits of tradeable water entitlements.

The suspicion and tentativeness towards market determined water transfers have been noted by several international authors and highlighted by Tregarthen (1983) in an essay entitled "Water in Colorado: fear and loathing of the marketplace". Bjornlund and Mckay (1996, 1999a, b) note that a similar apprehension exists in irrigation communities in South Australia, although amidst a growing acceptance of market-based transfers. Consequently markets are thin, immature and erratic. Crase *et al*. (2000), observe a similar situation in New South

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[1] The nexus between land and water precluded the exclusive sale, or transfer of water only. That is water could not be treated as an independent chattel and traded as such.

[2] Grief (1997) and Cooter (1997) both argue that neo-classical theory does not imply the prerequisite existence of a formalised legal system for water right contracting and jurisdictional enforcement. Whilst not necessarily costless, and often typified by asymmetric information, informal water markets, based on social ties, personal trust and compliance with social norms are common.

Wales (NSW) irrigation communities. In both cases, the financial hardship of the most desperate entitlement holders is identified as a primary incentive for sellers of water allocations. Randall (1981) postulates that market apprehension by farmers may be related to a perceived decline in rural communities as a result of changes in water allocations. In addition, Randall (1981) identifies the threat of monopoly or foreign ownership, a perceived loss of subsidies and the eventual closure of water channels (as a result of regional market transfers) as sources likely to impede market acceptance.

Gaffney (1997), in a study of water markets in the United States, identified four impediments to functioning water markets. These included a lack of seller motivation and market distortions exacerbated by hoarding behavior; licensees withholding entitlements for fear of creating a public perception of surplus entitlements; institutional inconsistencies in the treatment of groundwater and differential levels and transparency of subsidies and the divesting of public property to the private sector, to enhance market activity and encourage rent seeking behavior.

In addition to geographic and infrastructure constraints, Bauer (1997) identifies three obstacles in the development of water markets in Chile and an explanation of market thinness. These include legal and administrative restrictions resulting from the failure to identify and quantify unused or non-activated entitlements (that is sleeper licenses[3]) and ill-defined rights; the cultural and psychological attitudes regarding the importance of irrigation as a symbol of national endeavour, willpower and overcoming hardship and finally an ingrained scepticism of market processes. Bjornlund and McKay (1996), Crase and Jackson (1998) and Samaranayaka *et al*. (1997) suggest a similar reticence of Australian farmers to enter water markets, including ambiguous market price signals, eliciting a view that markets do not adequately reflect the value of water. Sellers represent those that are the weaker and more desperate water users.

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[3] Sleeper licenses are those entitlements that have not been activated. Crase *et. al*. (2000) note that the activation of sleeper licenses may compromise the preservation of rights embodied in existing active entitlements. Alaouze and Whelan (1996) and Brennan and Scoccimarro (1999) state that the activation of sleeper licenses and increased farm storage may result in a potential increase in total diversions in the Murray Darling Basin.

2.1.2 *Stakeholder Apprehension Towards Water Markets*

There exists an inherent and ongoing aversion to the application of economic instruments to correct for poorly allocated natural resources, inclusive of water. Turner and Opschoor (1994) and Verbruggen (1994) note that whilst seemingly embracing general market theory, corporate and government stakeholders appear to have a preference for regulatory standards rather than economic instruments. The reasons for this preference can be summarised as a fear of erosion of international competitive advantage through additional charges, a proven predictability of standards, more corporate control of decision making outcomes and bureaucratic inertia. Opschoor and Vos (1989) found 85 examples of economic instruments in OECD countries from 1980 to 1987. Eighty per cent of these were for financing purposes, in the form of charges or subsidies, not as incentives of behavioural change. An OECD update in 1994 (Verbruggen 1994) indicated a modest increase of 20 economic instruments in that period. Despite the wide discourse on economic instruments, this limited application reflects the extent of bureaucratic inertia, the intransigence of regulatory instruments and a reticence to translate the abstract into reality. According to Colby (1995), institutions and policy makers have tended to cautiously explore the implementation of water markets, generally when the level of impacts and inefficiencies arising from their absence become unacceptable. The suspicion and tentativeness towards market determined water transfers has been noted by several international authors and highlighted by Tregarthen (1983) in an essay entitled “Water in Colorado: fear and loathing of the marketplace”. Bjornlund and McKay (1995), note that a similar apprehension exists for irrigation communities in South Australia, albeit amidst a growing acceptance of market based transfers (Bjornlund and McKay 1999b), which has resulted in markets that are thin, immature and erratic. Crase *et al.* (2000), observe a similar outcome for the motivation for permanent water transfers in NSW irrigation communities. In both cases, the financial hardship of the most desperate entitlement holders is identified as a primary incentive for sellers of water allocations. Randall (1981) postulates that market apprehension by irrigators may be correlated with perceived declines in less favoured rural communities, a loss of subsidies, the eventual closure of channels with only residual irrigators remaining and the threat of foreign or monopoly ownership. Gaffney (1997) in a study of permanent water markets in the United States, identifies the following impediments to functioning permanent water markets:

1. a lack of seller motivation and market distortions exacerbated by hoarding behaviour. Crase and Jackson (1998) found 2 per cent of irrigators ($n>200$) in the Murray Land

and Water Management Plan area, were prepared to sell their water entitlement independent of their land. Samaranayaka *et al.* (1997) observed 5 per cent of irrigators (n=43) in the Murrumbidgee Irrigation Area trading in permanent rights;

2. licensees withholding entitlements for fear of creating a public perception of surplus entitlements;
3. institutional inconsistencies in the treatment of groundwater and differential levels and transparency of subsidies; and
4. the divesting of public property to the private sector, to enhance market activity, encourages rent seeking behaviour.

Bauer (1997) identifies four obstacles in the development of water markets in Chile and an explanation of market thinness:

1. geographic and infrastructure constraints, including the difficulty and cost of inter basin movements;
2. legal and administrative restrictions and failures including the failure to identify and quantify unused or non-activated entitlements (that is sleeper licenses) and ill-defined rights;
3. cultural and psychological attitudes regarding the importance of irrigation as a symbol of national endeavour, willpower and overcoming hardship in concert with an ingrained skepticism of market processes. Results from the research of Bjornland and McKay (1995) Crase and Jackson (1998) and Samaranayaka *et al.* (1997) suggest a similar reticence of Australian irrigators to enter permanent water markets; and
4. ambiguous market price signals, eliciting a view that markets do not adequately reflect the value of water. Sellers represent those that are the weaker and more desperate water users. The latter is in accord with the results of Bjornlund and McKay (1995), identifying financially vulnerable irrigators and those with salinity problems as the most likely to sell water, often at a discounted price.

Crase *et al.* (2000) identify a likely correlation of potential under-investment in high value water using enterprises and the small number of market transactions in permanent water in NSW. The transfer of water from low value uses to high value uses, and the associated economic efficiency increase, is viewed as a primary benefi t of water markets. The thinness of permanent water markets and lack of market support by irrigators is seen as potentially a source of market destabilisation and an impediment to the reform process (Bjornlund and McKay 1995, 1999b; Crase *et al.* 2000). Crase *et al.* (2000) identify the following obstacles to the formation of effective and functioning water markets trading in permanent entitlements in NSW as:

1. ill-defined property rights;
2. an inherently unstable and unreliable hydrology, which is currently not reflected in the price of entitlements;
3. geographical obstacles to some inter-regional transfers;
4. high transaction costs;
5. delays in obtaining price information from agents and the associated administrative encumbrance;
6. an intrinsic cultural reticence and skepticism of water markets, associated with hoarding behaviour for speculative gain and to offset uncertainty (Crase *et al.* 2000 p. 319).

Easter *et al.* (1998b) notes that water authority or agency reticence may be correlated with a concern of potential litigation and compensation claims due to a failure to fulfill more stringently specified contracts of supply and transmission. The diminution of centralized decisions, relevant to allocations and diversions, as markets appropriate the bureaucratic domain are also seen as an obstacle to market implementation. Pigram (1999) lists a number of possible reasons, originally proposed by Thobani (1997) and reiterated by Easter *et al.* (1998a p. 15), which summaries the stakeholder "reluctance to adopt markets as a suitable instrument for water resources management." They are:

1. cultural or religious objections to the notion that acquisition of water should be traded in a market;
2. equity and monopoly concerns regarding the acquisition of water rights by large organizations and exclusion of the poor from access to water;
3. concern that small scale operators will sell their rights cheaply, in times of duress, and lose their livelihood;
4. fears that water transfers will damage the environment, cause aquifer depletion and degradation of river systems;
5. fears of change and loss of public sector control over sovereign water resources;
6. need for new legal regulatory and institutional frameworks;
7. difficulty in defining, measuring and enforcing water rights;
8. changes needed to infrastructure and delivery systems;
9. difficulties in establishing or strengthening public and private institutions to facilitate a properly functioning water market; and

10. challenge of convincing governments that the potential benefits from trading water in a market are sufficient to offset the costs of establishing tradeable water rights.

The controls and management of water resources rests predominately in the public domain, administered by statutory authorities and government enterprises. The management, planning and modelling of water resources has relied on, or implicitly assumed, a centrally regulated system. Governments are striving to improve on past water management regimes, which have almost ubiquitously failed to account for and reflect the actual scarcity value of water. The institutional recognition of the increasing relative scarcity of water, manifested as enforced allocation limits, has resulted in the emergence and wider acceptance of the notion of water as an economic resource.

Strategies to offset supply constraints on future economic growth include a more technically efficient application of existing supplies in conjunction with the transfer of low value water uses to higher value uses. Constrained by physical, ecological, environmental and social thresholds, ensuring the mobility of water to facilitate higher valued uses is fundamental to the water allocation decision-making process. Managing agencies have embraced market structures and processes as the most effective means to facilitate structural change to higher valued uses, without increasing available water supplies.

A market based solution, conditional on relative scarcity and reliant on transferable, enforceable and fully specified property rights, vested in the individual and negotiated independently of land are cornerstones in the reform strategy. Efficient market solutions are predicated on the satisfaction of the conditions of rational behaviour, sufficient buyers and sellers, complete symmetric information and fully specified property rights.

In addition to proposed efficiency gains, tradeable water rights confer the benefits of ongoing incentives to conserve water, improved entitlement tenure and security, an inducement to impose the full opportunity cost of water and a more flexible agricultural system, responsive to changes in crop prices, climatic variables and opportunities to diversify. Tradeable water rights are also proposed as a means of ensuring environmental flows.

The interdependencies of water outputs and uses may preclude the unambiguous, comprehensive assignment of property rights to water, and as a corollary the determination of partial benefits and costs. This is particularly relevant for the determination of in-stream and riparian ecosystem and environmental values. The strategy deployed to comply with the directive of ecological sustainability will influence the specified property right regime for environmental flows and their role in market processes. In concert with the essential nature of water and the heterogeneous demands placed on it, standardised, immediate and anonymous market transactions are in most cases, undesirable and improbable. The perceived inability of markets to account for the ubiquity and magnitude of externalities and non-market factors has resulted in the proposed augmentation of market structures. Proposed adaptive blends of regulatory, economic and suasive instruments remains iterative and unresolved.

Mindful of the potential limits of water markets, commentators note that the reliance on a singular metric of economic efficiency may not provide the necessary analytical scope to enable comprehensive decisions by policy makers. The evaluation of instrument and water market effectiveness relies on a composite index of the value specific measures of equity, compatibility, efficiency, efficacy, flexibility, uncertainty, security, full cost accounting and risk.

Generally, Australian water markets are characterised as thin and immature and associated with erratic prices. Exposure to water trading has resulted to a reduction in community apprehension and increased trading. Trading in temporary water accounts for approximately 95 per cent of the traded volume.

This study of water management in Australia, combined with the results of extensive surveying of irrigator and rural community attitudes to water reform, provides a sound and informed basis for developing potential water trading rules and procedures to enhancement of the water market reform process.

3 METHODOLOGY

The methodology involved a series of stages:

Stage 1.

Stage 1 of the project involved a review current literature on water reform in Australia, including the new water agenda, the evolution of water management in Australia; an overview of National Competition Policy, water reform implementation and the economic characteristics of water markets. This provided a knowledge base for developing a detailed survey of irrigator and community attitudes to water reform.

Stage 2.

Based on the knowledge acquired in stage 1, stage 2 of the project involved the construction and implementation of a survey of irrigators and rural communities attitudes to water reform. The review of literature suggested that the main issues restricting effective implementation of water reform included the development of water markets included resistance to trade, farmer and community attitudes concerning who should be allowed to trade, the role of the water authority in the marketplace, what role farmers see themselves and others playing in water markets and perceived blockages to trade. These issues became the areas of exploration in the survey.

The survey instrument consisted of a combination of dichotomous choice, constant sum and open answer questions. The questions are grouped into seven sections each dealing with a specific aspect of water reform:

1. Water reform general
2. Temporary water trading
3. Permanent water trading
4. Impacts and future of water trading
5. The role of the water authority in water markets
6. Environmental concerns
7. Demographic information

The allocation and provision of diverted surface water in the Murrumbidgee catchment is regulated and administered by various water providers. The Department of Land and Water Conservation (NSW) regulates the system and supplies water to irrigators along the main river system. Private irrigation corporations have bulk water entitlements, provided by the Department of Land and Water Conservation, to extract water and supply water to irrigators (in their capacity as corporate shareholders) within their companies. The method of water allocation, the proprietary constitution and the rules of trade differ between water management authorities and providers. To account for the differences between water managing agencies, which potentially affect the trading of water entitlements and to minimise sampling error, irrigators were stratified according to the water provider.

The three largest water providers; the Department of Land and Water Conservation Murrumbidgee Irrigation Pty. Ltd. and Coleambally Irrigation Pty. Ltd. were approached to supply the names of irrigators within their jurisdiction or constituency. The Department of

Land and Water Conservation provided a list of irrigators from which we selected a random sample. Murrumbidgee Irrigation Pty. Ltd. provided a randomly sampled list of high security and general security irrigators and Coleambally Irrigation Pty. Ltd. mailed surveys to shareholder irrigators on our behalf. The collective information provided by the managing authorities constituted the research sampling frame.

A total of 1,000 questionnaires were administered to irrigators. A total of 261 valid irrigator responses, received from respondents within the boundaries of the three water managing authorities, is used in the following analyses. The number of responses from the Department of Land and Water Conservation, Murrumbidgee Irrigation Pty. Ltd., Coleambally Irrigation Pty. Ltd. And others were 104, 101, 49 and 7 respectively.

A stratified random sample has been drawn from the community of the Murrumbidgee catchment. Towns were used as sub-stratums and community members were randomly drawn from the 1996 electoral roles. In total, a sample of 1,000 community members was drawn. The survey was administered using a modified version of Dillman's (1978) Total Design Method. The surveys were sent with an attached letter and offer of a copy of the final. A toll free phone number was established to allow respondents to contact the researcher interstate without cost. Two weeks following the initial postage a reminder postcard was sent to all possible respondents thanking them if they had replied and encouraging response. A second mail out was replaced with the opportunity for respondents to use the toll free phone number to acquire another copy. Responding surveys were coded and stored in an Access database. Data analysis was conducted using SPSS and SAS and involved a combination of parametric and non-parametric tests as appropriate.

Stage 3.

Stage 3 of the project involved further exploration of issues raised by the review of the literature and surveys in an experimental economics setting. Experimental economics provides a way to examine policy options under laboratory conditions and compare predicted outcomes with direct observations of economic behaviour. Experimental economics yields a formalized, replicable approach to rapidly assess alternate policy directives, typically expressed as market outcomes, prior to catchment-wide implementation (Dinar *et al*. 1998). The methodology provides a relatively inexpensive means of institutional analysis coupled with substantially reduced time horizons. Well-designed experiments allow for the evaluation of participant willingness to exchange, the stability of diverse institutional structures across an array of market conditions, the efficacy of policy directives and highlights potential detrimental outcomes, which may compromise a water reform process. The application of experimental results can provide water authorities and decision-makers with sufficiently robust information to circumvent or mitigate the consequences of inappropriate policy commitments, minimising the time for trial and error and associated social expense.

Plott and Porter (1996) highlighted an additional advantage of evaluating and developing economic policies using experimental methods. Plott and Porter (1996) argued that designing an experiment requires specification of the details of a policy and the economic environment the policy is designed for. Accordingly, this process raises questions that might never be asked until the policy is actually implemented.

"The very act of creating an experiment means that issues of timing, systems for gathering and reporting information, methods for resolving conflicts and uncertainties, and other institutional details that give policy life are specified in operational (as opposed to abstract) terms" (Plott and Porter, 1996, p. 237).

Roth (1995) argued that policy experiments are generally motivated by the type of policy question that interests regulatory agencies and the experimental environment is typically designed to resemble those aspects of the naturally occurring environment that are the policy target. This enables economists to utilise the scientific method in formulating policy advice, especially when existing theories are inadequate.

Researchers including Dinar *et al*. (1998) and Murphy *et al*. (2000) have used experimental water markets to explore the policy implications of water trade in the western United States. Murphy *et al*. (2000) emphasized the importance of experimental methods in allowing the smooth adoption of proposed institutional changes. Experimental water markets can be used to examine new market institutions, policy reforms, and even simulate environmental conditions such as periods of high rainfall or drought.

Based on the theoretical research in experimental economics, this research examined applied economic policy, which requires more realistic simulations of economic environments that depend closely on policies developed to account for the social, economic and biophysical complexities of water as a common pool resource.

Undergraduate students at Griffith University, Brisbane were recruited to role-play farmers. To promote participation each participant was given $10 plus their farm's income to spend at the University Bookshop. On arrival they were given instructions and randomly allocated one of the farms.

Three series of experiments were developed:

3.1 Experimental Series A.

3.1.1 Research Questions

What type of auction structure should be used to sell new entitlements arising from redefining groundwater entitlements or new water management schemes such as the water allocation management plan?
How do experimental results compare to those generated from optimization economic models?

Markets for irrigation water entitlements are evolving in Australia as a result of a national water reform agenda. To date, these markets have been thin and localized at a regional level. As they evolve and become commonplace it is expected that water authorities will hold English call auctions to sell new water entitlements as they become available and develop call auctions to allow surface water irrigators to trade their water entitlements on a temporary basis. National water markets are being explored with English call markets and sealed-bid call auctions the most likely auction structures. These English and sealed bid markets were conducted on paper and provided the researchers with their first experiences with operating an economic experiment.

3.1.2 Research Design

Series A.1

A series of experiments were conducted to explore the Pareto optimal and price behavior of English and Dutch oral auctions and single first-price sealed-bid and second-price sealed-bid auctions between 12 farm types.
As a result of water reforms and management, additional water may become available for extractive purposes. Examples include possible additional water arising from the re-definition

of groundwater in the Goulburn-Broken and the implementation of a water allocation management plan (WAMPS) in the Fitzroy Catchment. For demonstrative purposes, a water authority auction of 7000 megalitres (ML) of water is used to establish the initial experimental procedures. An oral English auction structure was used such that bids are made on a per unit (ML) basis. The winning bidder was allowed to purchase up to the maximum available. Remaining water was then allocated to the next auction until all the water was sold. The stated objective of the auction was to maximize the water authority's return from the water.

The study of English, Dutch and Price auctions is not new (Vickrey 1961, Boulding, 1948 and Cassady, 1967). Vickrey (1961) argued that under assumptions of linear utility, homogeneous expectations, and rectangular distribution of individual valuations the mean price of Dutch and English auctions are equal[4] and the variance of English auction prices are greater than the variance of the Dutch auction prices[5]. Over time Vickrey's hypothesis has developed into what has become known as the Revenue-Equivalence Theorem (see Davis and Holt, 1993, Kagel, 1995, Milgrom, 1989, and Riley and Samuelson, 1981). The theorem extends Vickrey's hypothesis to include first-price and Dutch auction equivalence under expected utility maximization, Nash behavior and private value, and second-price and English equivalence under expected utility maximization and private values.

There have been many studies of Vickrey's hypothesis and the Revenue-Equivalence Theorem. The general findings are that the theory needs to be adjusted to take account of alternative risk strategies. Frahnm and Schrader (1970) found support for Vickrey's hypothesis of greater variance in English multiple unit markets compared to Dutch markets and inconclusive evidence of equality of price means in paired comparisons. Coppinger *et al.*, (1980) found that first-price bids significantly exceeded risk-neutral levels. Numerous subsequent studies including Cox *et al.* (1988), Riley and Samuelson (1981), and Holt (1980) have supported these findings. Coppinger *et al.*, (1980) found support for the hypothesis that the English and Dutch auctions have equal mean prices but unequal variances in single unit commodity markets.

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[4] Equal to m=N-1/N+1 where N is the number of bidders and values are drawn from a rectangular density on the interval [0,1].

[5] $V_d = \dfrac{(N-1)^2}{N(N+1)^2(N+2)}$ and $V_e = \dfrac{2(N-1)}{N(N+1)^2(N+2)}$

Five English and ten Dutch auction sessions were conducted to explore equivalence between Dutch and English auctions, and the level of rent seeking achievable by the water authority arising from the auction. One first-price and one second-price auction were held for points of comparison. In order to establish a degree of parallelism representative farms were developed from available farm data[6]. Based on the data it was assumed that farmers using water in the case study region (a) on average grow two crops, (b) have water requirements ranging from 50ML to 1500ML per year, and (c) have a marginal crop value for water of between A$40/ML and A$160/ML. Based on these assumptions, 12 farms were generated by randomly allocating water requirements and values.

Series A.2

The irrigator survey findings suggest that the main blockages to trade (a) farmers view their water entitlements as an integral part of a farm and not for sale and (b) there is a general lack of understanding of how equilibrium prices are determined in sealed-bid call auctions (Tisdell, *et al.,* 2000 a, b, c). The results of the survey suggest that as a result of these blockages sale of water will be restricted to surplus water and the purchase of water to minimizing uncertainty surrounding rainfall. The purpose of these experiments is to explore whether these behavioural characteristics are expressed in water market experiments.

Three sealed-bid call auction experiments were conducted. Each experiment consisted of 12 monthly trade periods. Single crop representative farms were developed and given water allocation on the basis of meeting average water requirements. The twelve farms consisted of 2x6 representative farm types growing sorghum, rye grass, soybeans, lucerne, barley and cotton. Monthly crop water requirements were generated using standardised crop factors, and regional soil condition and epan evaporation rates. Water allocations were determined on the basis of the type of crop and size of property such that it met average water requirements.

In the experiments each player was given an allocation of water that could be draw from the water authority. Players could buy or sell water in the water market. There was one trading period each month. During each month it may have rained which altered the amount of water the players needed to use that month. At the start of each experiment players were given the historical median monthly rainfall and crop water requirements for each month of the year for their farm. Each month the market would be declared open for three minutes. During that time

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[6] For a discussion of parallelism see Friedman and Sunder (1994)

players who wished to trade could lodge a bid to buy or sell water. The bid included the bid price and quantity of water.

At the close of trade players were told the actual level of rainfall for their farm. Rainfall data was generated randomly given the mean and variance of rainfall records for the region of each farm and a coefficient of variation of 0.2. Players then needed to determine how much water they wished to use on their crops. Each crop had a minimum and maximum water requirement each month[7]. If a player failed to have sufficient water available to meet the minimum crop requirement the crop failed. If a player's crop failed they could still offer the balance of their water allocation for sale in the market to earn money.

Once all the water usage data was collected the equilibrium price was announced and updated water and income tables were distributed outlining the individual trade results, water usage and farm income and water balances.

3.2 Experimental Series B.

3.2.1 Research Questions

Given the uncertainty of rainfall under what conditions will farmers coordinate actions to reduce the level of environmental damage caused by water extraction?
Faced with a socialized environmental cost, will farmers attempt to free ride and as a result increase the environmental cost to all?

3.2.2 Experimental Design

Following a review of experimental design literature and discussions at review meetings the following experimental design was used. Literature on public good and common pool resource experiments collectively suggest that participants will vary their use of or contribution to such goods as a result of institutions which provide levels of per capita return, information or opportunities for participants to communicate. This research contributed to this body of knowledge through a series of experiments exploring the impact of sequential heterogeneous resource targets, individual extraction information and uncertain endowments

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[7] Early versions had high minimum crop requirements that induced risk adverse behavior and bankruptcies. Water allocations and minimum crop requirements were adjusted to balance induced risk adverse behaviour while maintaining parallelism with cropping practices.

on players' strategies[8]. Farmers with an allocation to extract water from a river in order to grow an irrigated crop, for example, face such an environment. In the experiments aggregate extraction of water from a river beyond an environmental threshold result in an environmental cost to society, which is shared equally.

Water is an imperfect public good as there are private rights to extract yet, due to the interdependence of supply, suffers from common pool resource problems, such as declining riverine ecosystems as a result of changes to river flow regimes. There is a wealth of literature applying experimental methods to water issues such as water trading (Dinar *et al*., 1998; Murphy, 1999, Murphy *et al*. 2000), groundwater management (Brown, 1974; Gisser, 1983; and Gardner *et al*., 1997), environmental uncertainty (Budescu, *et al*., 1995; van Dijk *et al*., 1999) and water quality and nonconsumptive water uses (Willett and Sharda, 1997; Lord and Kenney, 1995). To date, few studies have explored in detail the common pool and public good nature of surface water extraction decisions through time and the role information and communication may play in that decision process.

Fouraker and Siegel (1963) were among the first to recognize information as an important determinant of players actions in public good experiments. Experimental evidence that the provision of information increases cooperation in common pool resource or public good experiments, however, is not conclusive. Palfray and Rosenthal (1991) suggested that asymmetric payoffs and common knowledge produces lower contributions to public goods. Sell and Wilson (1991) found that providing individual information significantly increased contribution to a public good. Ledyard (1995), having reviewed the literature on information effects in public good experiments, concluded that complete information leads to less contribution to the public good compared to no information in heterogeneous environments.

Research to date has largely focused on the impact of uncertain information on people's behavior and attitudes to risk. Brown and Stewart (1999), for example, concluded that faced with uncertain information, risk-preferring individuals are more likely to cooperate than risk-averse individuals. Budescu *et al*., (1995) found that in public good experiments, uncertainty will induce players to further their own interests at the expense of the collective interest. Farmers deciding on how to manage their farm on a monthly basis also face uncertain rainfall conditions. This uncertainty adds an additional dimension to their decision frame and complicates their extraction choice. The assumption is that including uncertainty of rainfall

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[8] Exploring communication treatments were beyond the scope of this study.

will reduce the level of cooperation in the provision of environmental flow targets and result in increased aggregate extraction levels. Debate on the effect of uncertainty imbedded in sequential heterogeneous decision frames, such as in this research, where players face uncertain rainfall supply, has yet to be fully explored.

This research extends the body of knowledge through series of experiments exploring the impact of introducing (a) sequential heterogeneous extraction targets, (b) uncertain endowments and (c) individual extraction information. Extraction of water from rivers and streams beyond an environmental threshold results in an environmental cost to society, which is shared equally.

The following sections outlines the experimental design and procedures used. Two sets of computer-assisted experiments were conducted using a 2x2 4-player design.

Series B.1

The first series of experiments were designed to test whether the structure of the farms and environmental targets led to outcomes consistent with notion that the level of accordance with the environmental target would increase as the marginal per capita cost of exceeding the environmental extraction limit increases. Isaac, *et al.,* (1984) established the notion of a marginal per capita return (MPCR) to contributions to public goods. The same notion in the form of a marginal per capita cost (MPCC) is used here to measure the relative cost of extracting from the common pool resource. Isaac, *et al.,* (1984) found that the level of contribution to a public good increased in accordance to the level of MPCR. The hypothesis of this work is that as the level of the MPCC increases, aggregate extraction will fall in accordance with the environmental target. This is explored in (a) one-shot decisions experiments where the players decide the total amount of water to be used during the session and (b) multiple decision experiments were the players face heterogeneous crop watering targets throughout the year and decide water usage on a month-by-month basis.

Two levels of decision criteria (annual and monthly) and two levels of MPCC (0.375 and 0.75) were employed in a block design. A secondary hypothesis that increasing the level of complexity, by introducing monthly heterogeneous interdependent decision criteria, reduces the level of accordance with environmental targets was also tested. Eight (8) rounds of computer assisted one-shot experiments and five (5) rounds of multiple decision experiments were conducted for each level of MPCC.

Annual decision (one-shot) experiments

In the first series of experiments, players were told that the marginal environmental cost of extracting water above the environmental target was $150 (MPCC =0.375) and $300 (MPCC = 0.75) depending on the experiment, and that the total cost would be shared equally between the four players. The experiment involved 10 one-shot repeated computer assisted experiments[9]. The payoff to player *i* in this series of experiment was estimated by:

$$P_i = 10 + \frac{\sum_{j=1}^{10}(100x_{ij} - cp(\sum_{i=1}^{k} x_{ij} - 1670.4))}{5000} \text{ Provided } \sum_{i=1}^{k}(x_{ij} - 1670.4) > 0$$

where P_i is the payoff to player *i*

x_{ij} is the volume of water used by player *i* in session *j*

cp environmental cost ($150 or $300).

During each round the players were given two minutes to decide how much water they wished to extract that year. They then entered the amount into the appropriate box on a sheet provided and returned it to the experimenter. The extraction amounts were entered and total extraction and distribution of the environmental cost calculated. Updated sheets were then distributed to the players. These sheets included their individual extraction, individual farm income, aggregate extraction, extraction levy and final farm income and trader income for that period and a record at date (see Appendix A).

[9] Since these experiments were conducted a network version of the software has been developed.

Within season decision experiments

The second series of experiments involved each player making decisions on a monthly basis throughout a water year. Each player was given an instruction sheet that was read aloud by the experimenter. Procedural questions were answered. In addition to the information above, each player was provided with the same monthly irrigation schedule for the crop (see Appendix A). They were told that their crop could survive with 80% of its maximum water needs in any month. A decision to reduce the water usage in a month within the 80% range, while reducing the crop's yield and so their income, did not reduce the area of irrigated land and so restrict their water usage options in subsequent months. Water use below the 80% threshold resulted in the area of irrigated land being reduced. The payoff to player *i* in this experiment was estimated by:

$$P_i = 10 + \frac{\sum_{j=1}^{12}(100x_{ij} - cp(\sum_{i=1}^{k} x_{ij} - env_j))}{5000} \text{ Provided } \left(\sum_{i=1}^{k} x_{ij} - env_j\right) > 0$$

where P_i is the payoff to player i

x_{ij} is the volume of water used by player i in month j

env_j is the environmental target for month j

cp environmental cost ($150 or $300).

In the multiple decision experiments water usage in one-month impacts on the available supply in subsequent months. The crop's watering schedule varies between months according to its water requirements. The hypothesis is that complexity in the form of volatility in demand between months reduces the ability of players to coordinate and so the level of accordance with the environmental target.

In summary, the question of whether players whose decision frame is annual are more or less likely to free ride than players who make decisions on a month-to-month basis during a season is an important one. It is assumed that as the decision frame becomes more complex players are more likely to ignore the environmental cost and pursue their optimal water use targets. This being the case, decision makers may need to develop strategies to encourage extractors to focus on the environmental consequences of seasonal farm decision frameworks rather than month-by-month decisions.

Series B.2

The second series of experiments extended the 0.75 MPCC experiments to explore the impact of rainfall with and without information given monthly decision criteria[i10]. The hypotheses unpinning the second series of experiments were that (a) introducing uncertain endowments[11] through rainfall variability will reduce cooperation and lead to higher levels of aggregate extraction, and (b) releasing individual information[12], with and without rainfall will reduce aggregate extraction levels in accordance with environmental targets. Table 1 gives a detailed breakdown the experimental designs used in the research.

Table 1 Experimental design for the two series of experiments

Series B.1 Experimental Design

Annual		Monthly	
0.375	0.75	0.375	0.75
8 experiments	8 experiments	5 experiments	5 experiments
10 rounds each	10 rounds each	12 months each	12 months each

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[10] Communication and heterogeneity will be explored in a latter series of experiments.

[11] . This is not to be confused with heterogeneous endowments, as every player was made aware that they had the same farm and would receive the same rainfall as the other players.

[12] Ledyard (1995), having reviewed the literature on information effects in public good experiments, concluded that complete information leads to less contribution to the public good compared to no information in heterogeneous environments.

Series B.2 Experimental Design

	No rainfall	Rainfall
Information	5 experiments/ 12 months	5 experiments/ 12 months
No Information	5 experiments/ 12 months	5 experiments/ 12 months

In total 104 and 80 students from across the population of Griffith University were recruited to participate in the two series of experiments. There were four players in each experiment and a total of 46 experiments were conducted. Players were told that they were farmers who have exactly the same farm characteristics - an allocation of 522 ML of water, a marginal value of water of $100, and earn income by using the water entitlement to irrigate the crop. Further, that the government determined that aggregate water use needed to be reduced by 20% to meet an environmental extraction target[13], and that water usage beyond that target creates environmental costs to the group, which was shared equally by all. The income from growing the crop less any environmental costs amounted to farm income that in turn was converted to player's income.

Eight participants attended each experimental session. In order to generate a level of anonymity the players were told they were in a group of four but not the composition of their group.

3.3 Experimental Series C.

3.3.1 Research Questions

Given heterogeneous farms, how will the level of accordance be influenced by:-

1. The provision of aggregate information;
2. Discussion forums; and

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[13] This gave the players environmental certainty. In reality it is recognized that the levels of extraction and associated costs are largely uncertain. van Dijk *et al.,* (1999) conducted a series of experiments exploring the consequences of environmental uncertainty. It is likely, however that policy instrument employed by the Australian government will involve fixed targets and associated costs.

3. Disclosure of individual extraction information providing an opportunity for group sanctions.

In environments where there is:-

1. No trade in water entitlements;
2. A closed call auction structure; and
3. An open call auction structure.

The research questions and hypotheses explored were concerned with the common pool nature of riverine environments. Research by Ostrom *et al*. (1990) and Ostrom (1998), *inter alia*, suggests that common pool resources can be effectively managed if there are information and communication options available to those using the resource. Options for sanctions imposed on those who default on a group strategy are also possible and may reinforce co-operative strategies (Ostrom *et al*. 1992, Posner and Rasmusen 1999). The experimental design therefore took into account information (both individual and aggregate) and communication, blocked by market structure.

In the experiments participants acted as farmers extracting water from a river system to grow an irrigated crop. The experimental treatments comprised of three incremental sets of information levels presented to the participants. The first treatment tested for behavioural changes of participants when presented with real time data of aggregate abstractions compared to the natural flow regime of the experimental setting. The provision of information has been found to have a significant impact on the provision of public goods and the management of common pool resources. The notion is that simultaneously informing the group of monthly natural flows, monthly aggregate extractions and the associated environmental levy will encourage participants to coordinate extraction to reduce subsequent environmental costs.

The second treatment explored the effect of group communication and the development and implementation of voluntary, cooperative social contracts to reconcile the difference between natural flows and aggregate abstractions. In this context the traders were given time to discuss the nature of the levy prior to commencement of the experiment. Players were given the option of either equal proportional changes or individually determined changes in monthly extraction volumes. Both experimental groups decided by consensus to implement voluntary individual changes in monthly extraction levels. Individual behavioural responses were expressed experimentally as monthly aggregate extraction volumes. Each month, participants voluntary committed to water extraction targets prior to the announcement of their actual monthly farm specific rainfall; thereby internalising the risk of rainfall variability on the individual participants. The research hypothesis predicts that monthly discussion sessions will reduce the environmental cost of aggregate extractions.

Finally, the disclosure of individual extraction levels as a form of sanction, therefore reinforcing agreed aggregate extraction targets, will facilitate further reductions in the level of the environmental cost. In other words, the hypothesis is that the treatment introducing identifiably of contract defaulters and the possibility of verbal peer sanctions, will reduce the level of environmental costs.

Each treatment was blocked to take account of the impact of trade and auction structures. Market theory would suggest that increasing market knowledge during an open-call trading period would increase the level of trade and market efficiency. An open call auction is one in which the bids to buy and sell are publicly available as they are lodged. The working hypothesis is that the introduction of a closed-call auction will result in higher levels of economic efficiency compared to no-trade, and an open-call auction will result in further increases compared to a closed-call auction.

3.3.2 Experimental Design

A complete block design was used with the four common pool resource treatments and three market structures (including a no trade structure). The experimental design is presented in Table 2. Two groups of twelve traders were involved in simultaneously replicated experiments. Each group traded for one year for each treatment and block combination – a total of twelve years of trading, each year taking approximately two hours. An experimental session simulated a whole year of monthly trading in the water markets. In aggregate a total of 24 years of water trade and extraction was simulated during the experiments.

Field experiments of each of the key treatments were also conducted with farmers at Yanco Agricultural College. Farmers were only paid a turn-up fee and bottles of win were awarded to the best players on the day. While the situation necessitated a different payment vehicle, no statistical differences between students and farmers were found.

Table 2 Experimental design

Treatments	No information	Aggregate Information	Aggregate Information and Discussion	Aggregate Information, Discussion and Sanctions
No trade	2 sessions	2 sessions	2 sessions	2 sessions
Closed call	2 sessions	2 sessions	2 sessions	2 sessions
Open call	2 sessions	2 sessions	2 sessions	2 sessions

Note: sessions were run concurrently and represent 12 monthly trading periods.

4 THE *MWATER* MARKET ENVIRONMENT

The experimental environment involved players acting as irrigators with options concerning the management of a model farm inclusive of options for trading water. Participants accessed treatment-specific instructions by logging on to the experimental web-site, scrolling through a Power-Point™ slide series and following the prescribed screen prompts. The slideshow presentations varied according to the treatment combination in each session, with slides added for each successive treatment. Participants accessed a computer network link at the end of the instruction slides that allowed them to log on to the experiment session. The experimental sessions were conducted using an experimental water-trading program known as *MWater*. Through the *MWater* package participants viewed their general farm characteristics including their water allocation and crop water requirements. The package also allowed them to trade in an open or closed market environment, view their updated water usage and income tables, and information on extraction levels according to the treatment requirements of the experiment.

Participants were not allowed to talk to each other except in experimental sessions where communication was specified by the treatment. Participants were provided with a calculator if requested and were also able to use a spreadsheet to perform farm specific calculations.

Development of the *MWater* package was a significant undertaking well beyond the scope of the original project. A long series of experiments were used solely to assist in the development of *MWater* and software development was extensive. The first version of *MWater* used 25 VBA macros to generate (a) monthly rainfall information for each farm for each month, (b) record and process buy and sell bids, (c) determine supply and demand schedules and equilibrium prices and quantities and (d) produce monthly farm income and water accounts for each farm.

The current version uses over 100 Macros, links to web-based databases, and graphical and interactive web-based environments. It can be used on intranet and internet environments linking with Oracle and firebird databases and with pocket PC wireless environments. This allows for it to be used in large computer centres, small network systems and in regional areas with the use of pocket computers. In effect an *MWater* environment can be generated with a supercomputer within large databases such as Oracle, down to stand alone systems run in extremely isolated areas and regional towns with no computer facilities. The principle has been to develop as flexible a system as possible to allow for a range of field experiment environments. Development and testing of the Beta version of the software took 14 months. The development of the software is on-going and modified to the research issue explored. The development was conducted largely using external funding sources.

4.1 Farm Characteristics

Each of the twelve participants was provided with a unique set of model farm characteristics that governed the value of water used on their farm, the volume (megalitres (ML))[14] of allocated water for the year, farm specific historic median rainfall, and maximum and minimum water requirements for the farm specific crop in each month[15]. Information was provided both as yearly totals and as monthly figures. The totals, such as the size of each farm's remaining water allocation was updated monthly as water was applied to the farm's crop and as water was bought or sold. Table 3 displays typical information about each model farm's characteristics that is provided to the participants from the start of the water year. All values except for the 'Marginal value of water' are updated monthly.

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[14] 1 Megalitres equals approximately 1.23 acre-feet of water.

[15] Information on the individual farm characteristics is not reported in order to maintain the integrity of the data for future experiments. Further information on the farm characteristics can be obtained from the authors.

Table 3 Typical Farm Characteristics

Water supply available 960 ML	Historic usable rainfall to end of year 498 ML
Estimated max water needs to end of year 1275 ML	Estimated min water needs to end of year 1020 ML
Marginal value of water $97	Traders income total $10

Table 4 is an example of a water use table displaying water requirements for each month. Actual rainfall is provided before each irrigator decides how much water to use from their allocation in that month. Allocated and Total Water Use is displayed for all previous months.

Table 4 A Typical Water Use Table

Month	Historic Median Rainfall	Maximum Water Usage	Actual Rainfall	Allocated Water Used	Total Water Use	Minimum Crop Water Requirements	Qty sold	Qty bought
OCT	52	214	49	148	197	171		200
NOV	36	198	38			158		
DEC	48	186				149		
JAN	46	169				135		
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
SEP	0	0				0		

4.2 Crop Loss

Players faced uncertainty of rainfall and possible crop loss. ‘Crop loss’ refers to any lost potential income caused by irrigating less than the minimum crop water requirements. If monthly minimum water requirements were met the whole crop was maintained. However, if total water use was less than the minimum crop water requirements in any month then the area of crop was proportionally reduced. The potential income from the irrigated land left fallow was lost for the whole year. New minimum and maximum water requirements were then provided for the rest of the year. Rainfall was also reduced accordingly.

4.3 Income Calculations

Participants received a A$10 turn up payment plus the traders’ income earned during each experiment. The monthly farm income equalled total water usage times their marginal value of water, less crop loss, plus the income from the sale of water less the cost of water bought. Through a series of exchange rates farm incomes were converted to traders’ income in order to account for differences in farm sizes and characteristics. Table 5 displays a typical farm income table, including the values for market clearance prices and farm and trader's income.

Table 5 Typical Farm Income Table

Month	Total water usage	Monthly income from crop	Crop Loss	Equilibrium Price	Cost of water bought	Income from sale of water	Total monthly income	Trader's Income
OCT	197	19109	0	60	12000		7109	7.12
NOV								
DEC								
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
SEP								

With increasing community involvement and empowerment of self-regulation as a mechanism for implementing water policy it is necessary to explore the level of accordance with group agreements and the impact of supplying environmental information. The nature of the damage caused to riverine ecosystems is a social cost borne by all in the community. In the experiments this is measured by the value of the environmental levy.

4.4 Environmental Levy

In the experiments an environmental levy was introduced to create an experimental environment in which an individual's payoff depended both on their own actions and the actions of all other members of their group. The experimental river system consists solely of the twelve players' farms. The important environmental attribute of the system is located upstream of the farms. The flow upstream is completely dependent on the monthly aggregate extractive demand of the players. Consistent with the utilisation of a common pool resource, an individual player's final payment was comprised of the proceeds from their farm income (*viz*. farm and trading activities) less their proportional share of the costs of a change in riverine environmental services.

A change in environmental services is measured as a change in natural flows resulting from the extraction of irrigation water. The monthly volume of natural flows reflects the experimental catchment's historic median environmental flows, illustrated in Figure 1. The imposed environmental levy creates a system of incentives in the experiment consistent with the interdependency imposed by environmental externalities.

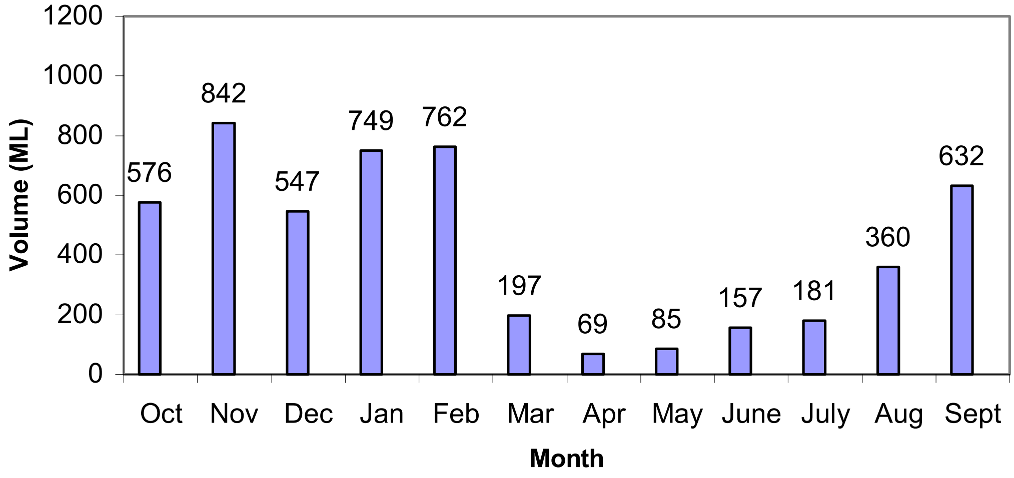

Figure 1 *Historic Median Environmental Flows*

The levy was one trader dollar per 100,000 units, calculated as the squared difference between aggregate extraction and historical median environmental flows as shown in Figure 2.

$$\text{Environmental levy} = \frac{\sum_{t=1}^{12}(AggExtraction_t - Naturalflow_t)^2}{100{,}000} \qquad (1)$$

The value of the environmental levy reflects increasing marginal environmental damages as the divergence between natural flows and extraction increases (Figure 2). This means that each additional ML of allocated water used by any individual farmer had a proportionally greater environmental cost.

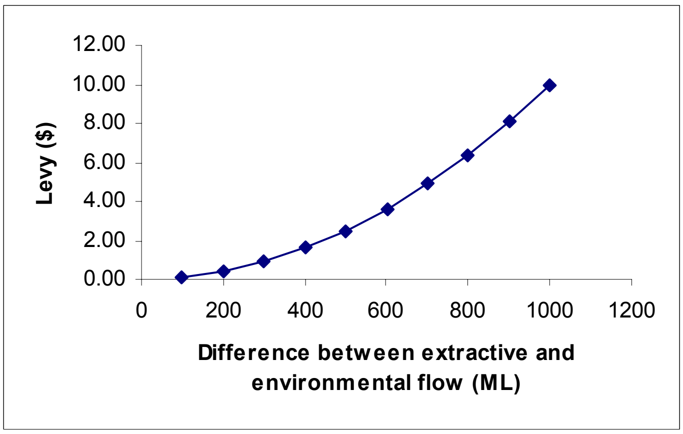

Figure 2 The Calculated Value of the Experimental Environmental Levy

5 RESULTS AND IMPLICATIONS

The research results and implications for national and catchment water policy are outlined below. More comprehensive summaries of the research findings can be found in the technical reports.

5.1 Literature Review

The review of the literature found that water management in Australia has changed considerably with time, and particularly over the last twenty to thirty years. When making decisions concerning water supply, water authorities now need to consider not just hydrological and system constraints, but also the social, environmental and regional economic consequences of their decisions. COAG reforms have brought with them questions of economic efficiency and equity in managing a public good, not just better management of water supply systems. This project aimed to assist in the development of new water policies and in particular the development of trading rules and procedures for water trading.

To understand and develop sound policy it is first necessary to understand the background to water management in Australia. For most of the first two hundred years of European settlement, water resource policies, like those relating to other resources, were focused on exploitation to promote economic and demographic growth, and employment generation. The role of the water authority was to engineer dams and supply systems to capture and promote the use of available water, rather than plan or implement national or state economic or social policies.

The relevant legislative arrangements in Australia date from 1886 and established the principle that streams were State property administered by State controlled water agencies. A system of administrative allocation of rights to water was also instituted, managed by public water authorities in each State.

On the basis of these institutional arrangements, State governments became developers of water supply infrastructure such as dams, and developers and owners of large-scale urban and rural supply schemes (including irrigation). In the 1980s water management in Australia began to consider broader objectives. No longer do water authorities look solely to the construction of bigger dams to solve water issues; rather, they examine options of improving the allocation of existing water entitlements in conjunction with environmental and social policy objectives. Their objective is seen as promoting efficiency and equity of water allocation while protecting the environment.

By 1990, water authorities were compelled to address issues and policies related to the management of water resources in a mature water economy. The incremental cost of water supply was sharply increasing. As most of the available and economic water resources had been exploited, and the cheap dam sites used, the opportunity cost of capital for water resource development had risen to historically high levels; an ageing infrastructure was contributing to increased operation and maintenance costs, and increased pressure for expenditure on replacement was increasing. Further, the demand for water resources was increasing in scale and diversity, particularly demand for environmental objectives, and concern for improved quality of supply. Conflict was growing, both between potential uses, and between the old developmental objectives and the newer economic and environmental objectives, but being played out within institutional settings geared to resource expansion rather than the optimal allocation of a scarce resource.

Finally, awareness was growing of the severity of environmental degradation, its irreversibility in some cases, and the consequences including declining quality of the resource. The water authorities are now involved in managing these conflicting demands on the use and distribution of water within a period of institutional reform – be they economic, environmental or social.

Meeting the broadening and changing role of water management in Australia will be among the greatest challenge facing water authorities in the future.

Australia is relatively well endowed with accessible fresh water resources, despite being characterised by substantial temporal and spatial variance of rainfall and groundwater stores. The magnitude of divertible and developed water resources is greater than in most countries. Further development is unlikely in high use catchments such as the Murray-Darling Basin; a function of previous over-allocation and interdependent environmental constraints. The irrigation sector uses approximately 70 per cent of the total water consumed, and accounts for 95 per cent of the observed increase in consumption. 63 per cent of that increase is attributed to irrigated pasture. Water use for the urban, mining, manufacturing, energy and service sectors accounts for 22 per cent of total water use and per capita use is relatively stable or declining. Declining per capita and absolute consumption by households has been observed for major capital cities. The balance of total water consumption is attributed to the sewerage and drainage sector. The urban and service sector contributed 90 per cent of total water revenue. The combined rural and irrigated agricultural sectors contributed 5 per cent of water revenues and consumed 80 per cent of total water supplies (AATSE 1999, ABS 2000, SOEAC 1996[16]).

Several commentators broadly classify the history of European initiated water resource development into at least two phases (for example Mulligan & Pigram 1989, Musgrave 1996, Smith 1998, Watson 1990 among others). The first one hundred years of European settlement was typified by the ad hoc and opportunistic development of water resources. Survival, food and shelter took precedence over any long-term national planning and development strategy and precluded any pioneering environmental consciousness.

Water resource policies since the Victorian *Irrigation Act* of 1886 (initiated by Deakin) to the late 1980's, like those relating to other natural resources, were focused on exploitation to promote economic and demographic growth and employment generation. Specific to water, the drought proofing of the nation was entrained in an ethos of national development, vigorously pursued and enacted. Private riparian rights were subordinate to those of the State, and administered according to a doctrine of "non-priority riparian rights". On the basis of these institutional and policy dictates, State governments became extensively involved in the water industry as developers of water supply infrastructure such as dams, and developers and owners of large-scale urban and rural supply schemes. The period of extensive and prolonged water diversion came to a relatively abrupt halt in the 1980s.

The following quotation by Mulligan and Pigram (1990) succinctly portrays the prevailing attitudes during the transition phase.

> Decades of steady growth, both economic and demographic, have, in a relatively short time, come to an end. The former emphasis on developing new sources of water supply has given way to encouraging more efficient management of existing supplies …unquestioned endorsement of water development programs can no longer be assumed…. In the harsher economic climate of the 1980s are the financial constraints resulting from intensified competition for funds between water resources development and other priorities for public works and services. These factors, in turn, make more

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[16] Australian Academy of Technological Sciences and Engineering, Australian Bureau of Statistics and the State of the Environment Advisory Council respectively.

> urgent the adoption of more appropriate financing and pricing policies, and more efficient management practices by water administrative bodies. Community attitudes to water are also changing. Environmental constraints are becoming increasingly effective in inhibiting water resources development and an active and vocal segment of public opinion…wants to participate in decisions affecting the physical and social environment (Mulligan and Pigram 1990 p. 1-2).

The confluence of the over-allocation of water, the spread of irrigation-based agriculture and a lack of financial conservation incentives culminated in a situation of severe environmental degradation, unrelated institutional revenues and costs and an agricultural sector supported by extensive subsidization. The combination of events galvanized forces to provide the necessary impetus for the substantial reform of water management.

The national goals of water management have been shaped and conditioned by a number of policy agreements, ratified by the Federal and State Governments. These in turn have been directed by a number of international conventions and treaties. Much of the impetus for water reform has come from the twin focal points of ecologically sustainable development and a national agenda of micro economic reform and prescribed economic efficiency. Both are viewed as cardinal objectives and often couched in at times conflicting ideological terms.

The extent to which economic and environmental objectives dovetail (as asserted in current Federal and State government policies), or whether there remain tensions between them, is a recurring theme.

The controls and management of water resources rests predominately in the public domain, administered by statutory authorities and government enterprises. The management, planning and modelling of water resources has relied on, or implicitly assumed, a centrally regulated system. Governments are striving to improve on past water management regimes, which have almost ubiquitously failed to account for and reflect the actual scarcity value of water.

The institutional recognition of the increasing relative scarcity of water, manifested as enforced allocation limits, has resulted in the emergence and wider acceptance of the notion of water as an economic resource.

Strategies to offset supply constraints on future economic growth include a more technically efficient application of existing supplies in conjunction with the transfer of low value water uses to higher value uses. Constrained by physical, ecological, environmental and social thresholds, ensuring the mobility of water to facilitate higher valued uses is fundamental to the water allocation decision-making process. Managing agencies have embraced market structures and processes as the most effective means to facilitate structural change to higher valued uses, without increasing available water supplies.

A market based solution, conditional on relative scarcity and reliant on transferable, enforceable and fully specified property rights, vested in the individual and negotiated independently of land are cornerstones in the reform strategy. Efficient market solutions are predicated on the satisfaction of the conditions of rational behaviour, sufficient buyers and sellers, complete symmetric information and fully specified property rights.

In addition to proposed efficiency gains, tradeable water rights confer the benefits of ongoing incentives to conserve water, improved entitlement tenure and security, an inducement to impose the full opportunity cost of water and a more flexible agricultural system, responsive to changes in crop prices, climatic variables and opportunities to diversify. Tradeable water rights are also proposed as a means of ensuring environmental flows.

The interdependencies of water outputs and uses may preclude the unambiguous, comprehensive assignment of property rights to water, and as a corollary the determination of partial benefits and costs. This is particularly relevant for the determination of in-steam and riparian ecosystem and environmental values. The strategy deployed to comply with the directive of ecological sustainability will influence the specified property right regime for environmental flows and their role in market processes. In concert with the essential nature of water and the heterogeneous demands placed on it, standardised, immediate and anonymous market transactions are in most cases, undesirable and improbable. The perceived inability of markets to account for the ubiquity and magnitude of externalities and non-market factors has resulted in the proposed augmentation of market structures. Proposed adaptive blends of regulatory, economic and suasive instruments remains iterative and unresolved.

Mindful of the potential limits of water markets, commentators note that the reliance on a singular metric of economic efficiency may not provide the necessary analytical scope to enable comprehensive decisions by policy makers. The evaluation of instrument and water market effectiveness relies on a composite index of the value specific measures of equity, compatibility, efficiency, efficacy, flexibility, uncertainty, security, full cost accounting and risk.

Generally, Australian water markets are characterised as thin and immature and associated with erratic prices. Exposure to water trading has resulted to a reduction in community apprehension and increased trading. Trading in temporary water accounts for approximately 95 per cent of the traded volume.

This review of water management in Australia, combined with the results of extensive surveying of irrigator and rural community attitudes to water reform, provides an sound and informed basis for developing potential water trading rules and procedures in the next phase of the project.

Fundamental problems of centralised management, co-ordination and allocation are confounded by the multiple and heterogeneous production outputs of water which are simultaneously produced and physically interdependent. These include both consumptive and non-consumptive uses, are inter-sectoral, constitute market and non-market values, include extensive public good values and are characterised by a high likelihood of external effects. As a corollary, the interdependencies of water outputs and uses preclude the unequivocal application of property rights common to most factors of production.

Murphy *et al*. (1999) note that centrally managed systems are typified by slow reaction times to intensified competition between disparate water users and increasingly stringent environmental objectives. Proposals for substantial institutional change to large scale water systems are hampered by the process of adaptation, the actual and potential irreversibility of decisions and bureaucratic inertia. The result renders the process of institutional reform as cautious, protracted and costly to society (Murphy *et al*., 1999).

Current literature based insights indicate experimental economics yields a formalised, replicable approach to assess alternate policy directives, expressed as market outcomes, prior to implementation.

The issues revealed by survey analysis highlighted the need for the experimentation to explore the perceived blockages to trade raised by irrigators, in particular levels of market information and knowledge, environmental flow objectives and market performance. In addition to the empirical inputs, the development of phase two has been informed by international literature.

There exists an extensive body of literature[17], both in the international sphere (for example Easter *et al*., 1998, Dinar, 2000) and that specific to Australia (*inter alia* Crase *et al*., 2000, Musgrave, 2000, Pigram, 1993, 1999; Randall, 1981), advocating the development of voluntary water markets to facilitate structural change to higher valued uses without increasing available supplies. The realisation of the perceived reform benefits are contingent on the existence of an effective competitive water market, in turn reliant on a suite of tradeable, enforceable and specified water entitlements.

Murphy *et al*., (2000) note that despite the well prescribed advantages of water markets, economic theory offers little regarding the effect on water allocations and outcomes of alternate market structures and institutions. For example, whilst not necessarily costless, and often typified by asymmetric information, informal water markets, based on social ties, personal trust and compliance with social norms are common, particularly in India and Pakistan (Cooter, 1997, Grief, 1997 and Bromley, 2000). To date there are no *a priori* prescriptions of alternate market institutions and auction systems, calibrated to catchment specifications, facilitating the successful translation of the abstract to an operational reality. The outcome for water authorities may be the hasty adoption and implementation of potentially inappropriate market structures and procedures, often to satisfy policy imperatives, or a furtherance of the postponement and prevarication in initiating the reform process. That is, any adverse consequences or the sub-optimal performance of a poorly designed reform agenda may remain undetected for long time periods, "possibly eroding the potential benefits and exacerbating the problem that the change was originally intended to resolve, and negating the opportunity for further innovation" (Murphy *et al*., 2000 p. 4).

Research in experimental economics indicates that trading rules and procedures governing market operations can substantially influence market outcomes and the realized gains of trade (Cox *et al*., 1991b, Vickery, 1961). Experimental economics yields a formalised, replicable approach to rapidly assess alternate policy directives, expressed as market outcomes, prior to catchment-wide implementation. The methodology provides an inexpensive means of institutional analysis coupled with substantially reduced time horizons. Well designed experiments allow for the evaluation of participant willingness to exchange, the stability of diverse institutional structures across an array of market conditions, the efficacy of policy directives and highlights potential detrimental outcomes which may compromise the reform process (Easter *et al*., 1998, Murphy *et al*., 2000). The application of experimental results can provide water authorities and decision-makers with sufficiently robust information to

[17] See Tisdell *et al*. (2000) for a detailed reference list.

circumvent or mitigate the consequences of inappropriate policy commitments, minimising the time for trial and error and associated social expense.

Latter sections of this report detail the development of the laboratory based water market experiments, founded in part on respondent attitudes to the series of research surveys and informed by literature based insights.

The survey of irrigators and community members in the Murrumbidgee found that there is general agreement among the irrigators and community members that water reform is necessary, that rights to water should be separated from rights to land, and such rights should be traded independently (a full report of the finding is reported in Tisdell *et al*, 2001a). While irrigator respondents believe that sleeper licenses should not be extinguished, the community at large feel they should. Irrigators also disagree with setting water aside for environmental use, while the community at large agrees with the notion. Irrigators are uncertain whether the reform process will lead to more secure water entitlements or higher reliability of supply. Involvement in the reform process has been seen as very poor. Approximately half of irrigators stated the CAP has impacted on them, while a small number of the community believe their business has been impacted. In prioritizing COAG reform objectives, ensuring a fair and just distribution of water is overall perceived as more important than maximising farm income, meeting natural flow requirements, or accounting for local town and community requirements. The number of buyers and sellers in part is determined by who has a right to trade. There is general agreement that the rights to trade should be open to irrigators and local towns and communities. There is support for restricting trade within channel systems when necessary to maintain infrastructure, when transactions impact on other water users, environmental flow objectives, and the economic viability of local towns and communities.

There is similar widespread support for restricting trade when the conditions of trade or the resulting distribution of water is deemed unjust, and where a company enters the market solely as a speculator. In the temporary market, the role of the temporary market is to realize the opportunity cost of water on a season-by-season basis, and allow for surplus water and within season tradeoffs to be made. There is strong interest in selling surplus water. However, few sellers stated that they made trade decisions on the basis of the opportunity cost of water, and few are prepared to consider changing farm practices and using the market to maximize their return from their water. Buyers tend to purchase water to meet end of season waterings and overall shortfalls in water allocations.

Overall, irrigators see traders in the future buying water: (a) prior to making a cropping decision; (b) should water become short; or (c) to acquire more secure water supplies. Selling will continue to be dominated by the sale of surplus water. Irrigators voiced concerns about the actions and roles of the water authorities and irrigation companies, and their impact on trade. The main blockages to trade, both perceived and actual, include a lack of information from their regulator on of how markets operate and market information.

Finally, the respondents see water markets playing a significant role in irrigated agriculture in the future, and will lead to an increase in overall farm income. A full report of the survey results can be found in Tisdell *et al*, (2001b).

5.2 Experimental Series A.

5.2.1 English oral auctions

The results of the English auctions are presented in Table 7. The equilibrium price in the first session was higher than the following sessions, which had equal prices ($F=24.853$, $p<0.05$). Following the initial experiment market efficiency stabilized at 0.85, suggesting limited learning and group strategies to minimize rent seeking by the water authority.

Table 6 Farm Characteristics of Players in Dutch, English and Price Auctions

Farm	Crop	Water requirement (ML)	Marginal value of water (A$/ML)
1	A	50	45
	B	300	105
2	A	1000	50
	B	50	110
3	A	1500	55
	B	300	115
4	A	500	60
	B	150	120
5	A	150	65
	B	1500	125
6	A	1500	70
	B	1000	130
7	A	300	75
	B	500	135
8	A	150	80
	B	500	140
9	A	500	85
	B	1500	145
10	A	300	90
	B	1000	150
11	A	1000	95
	B	150	155
12	A	50	100
	B	50	160

Table 7 Rent Seeking and Efficiency in English Water Auctions

Session No.	CS	No of bids	Mean Bid	Mean Qty	Rent Capture
Optimal	943250				1.0000
1	905860	14	129.79	500.0[b]	0.9604
2	804650	16	115.13[a]	437.5[b]	0.8531
3	808160	17	116.12[a]	411.7[b]	0.8568
4	799950	14	113.57[a]	500.0[b]	0.8481
5	807320	25	115.24[a]	280.0[b]	0.8559

Note: Mean values superscripted with the same letter are not statistically different.

The elasticity of demand for water, however, did decline through successive experiments; the number of bids and demand increased which may well hide learning and strategic behavior. Figure 3 shows the elasticity of demand falling and demand increasing through successive sessions, suggesting that possible realization of strategic behavior being masked by increased demand.

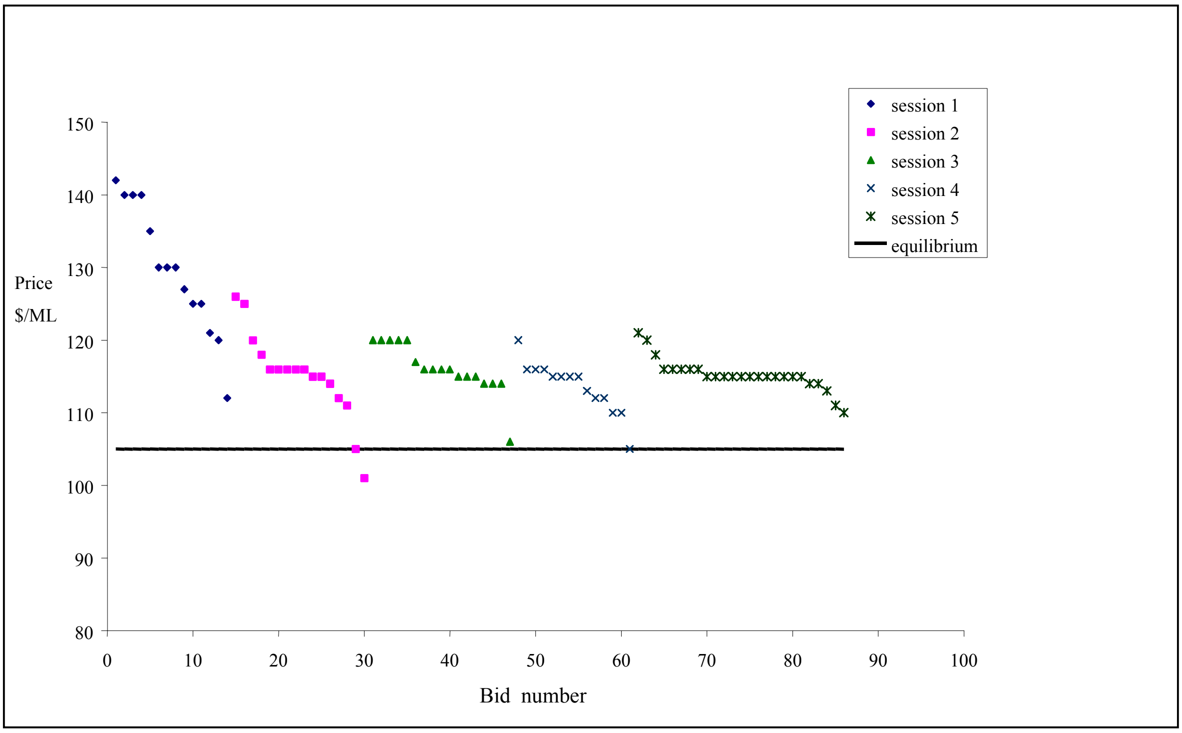


Figure 3 English Auction bids through time

5.2.2 Dutch oral auctions

A different cohort of 12 students with the same farm characteristics was used to run ten oral Dutch auctions. The auctions were conducted with a starting point of $200, with decreasing intervals of $5[18]. A buyer stopped the auctioneer by raising his or her land and could then purchase up to the remaining volume of water at that price. The auction then continued until all the water was sold or the price reached zero. In contrast to the English auction that approached equilibrium from above, the Dutch auction sessions (as shown in Figure 4) approached the equilibrium from below.

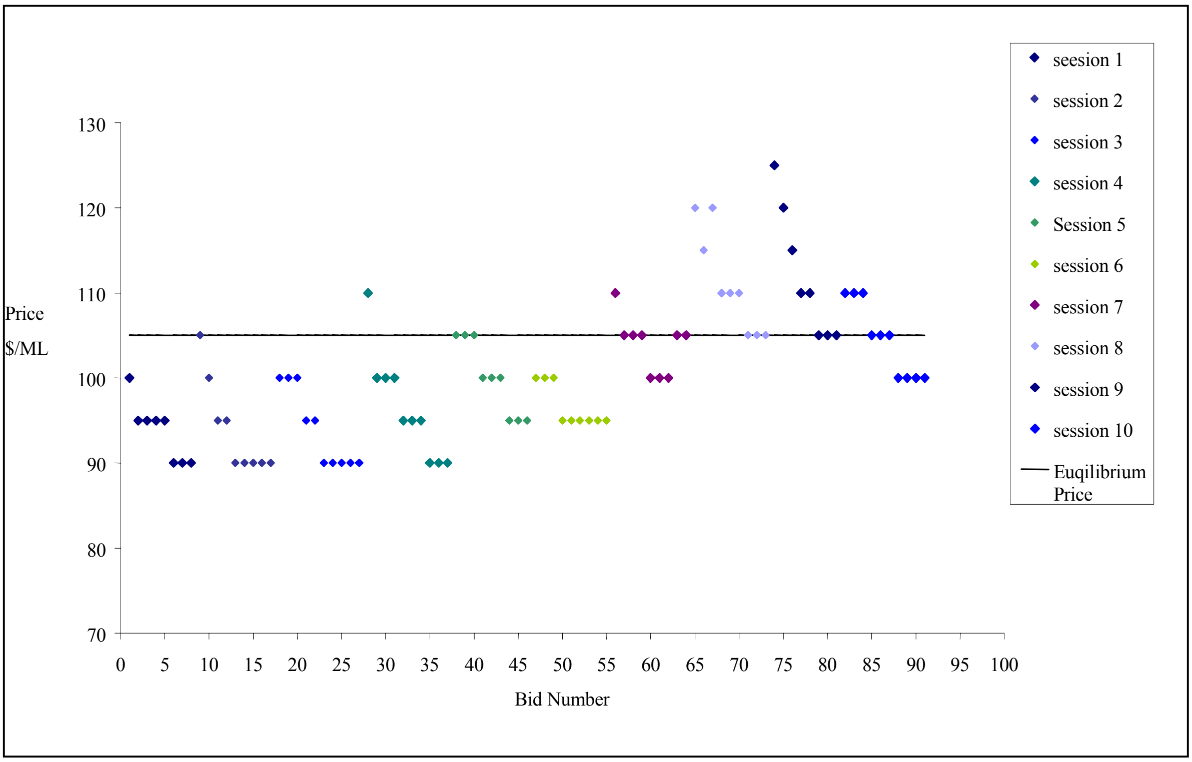


Figure 4 Dutch auction bids through time

Table 8 presents the level of rent capture, and mean bid and quantity for each Dutch auction session. In contrast to the results from the English auction experiments and learning, the level of rent capture increased through successive Dutch auction sessions, finally declining in the final session. The results suggest that while the Dutch prices are below competitive

[18] The procedure was followed consistently in order to minimize technical differences between Dutch auctions (for discussion see Cox *et al*. (1991)).

equilibrium (CE) prices rose through successive auctions resulting in increased rent capture. Once the trade price exceeded $130/ML prices fell in the final session.

Table 8 Results of Ten Dutch Auctions

Session No.	CS	No of Bids	Mean Bid	Mean Qty	Rent Capture
Optimal	943250				1.0000
1	661000	8	93.75	875	0.7008
2	655250	9	93.89	777	0.6947
3	657250	10	94.00	700	0.6968
4	665650	10	96.50	700	0.7057
5	697250	9	100.00	777	0.7392
6	675750	9	96.67	777	0.7164
7	725500	9	103.89	777	0.7691
8	762750	8	111.11	777	0.8086
9	782500	9	111.88	875	0.8296
10	731250	10	104.50	700	0.7752

5.2.3 First-price and second-price auctions

One shot first-price and second-price seal bid auctions were conducted at the start of the English and Dutch auctions for prints of comparison. The second price sealed bid captured more rent than the first price sealed bid in two one shot experiments. Further replicates of price auctions in the next phase will explore this further.

Table 9 Results of First-price and Second-price Auctions

Session No.	CS	No of Bids	Mean Bid	Mean Qty	Rent Capture
Optimal	943250				1.0000
First-price	742400	9	107.11	777.78	0.7871
Second-price	797400	9	113.33	777.78	0.8454

5.2.4 Comparison of first-price, second-price, English and Dutch auctions

In contrast to the revenue-equivalence theorem, the mean English auction pooled price exceeds the Dutch auction pooled price (t = 4.625, p<0.000) and the pooled price variances are equal (F = 0.293, p>0.05). The results of the first run of the English auction experiments and Dutch auction experiments, and one shot first and second price bids are not consistent with the revenue-equivalence theorem. The English auction appears to have produced the most risk adverse behaviour followed by the sealed-bid auctions then the Dutch auction.

Figure 5 shows graphically the different levels of rent capture between the four auction structures.

There are various possible explanations for the differences. One possible explanation for these findings lie in the distribution of the players' values and quantities. In these experiments the distribution of values is not rectangular, rather randomly determined within a range of possible values. Similarly the quantities demanded were not evenly spaced but randomly assigned within a range which may have resulted in differences in mean prices but equality of variances. A second possible explanation is that the behavioral characteristics of the student cohorts may have differed. Separate cohorts of students were used in the English and Dutch experiments. The experiments were conducted on different days and students self allocated to one or other of the experiments according to class and work commitments. They were unaware of the nature of the experiments and so did not self allocate according to their interest in one or other of the auction types. The students have similar levels of experimental experience, are enrolled in similar sources and are at the same level of undergraduate study.

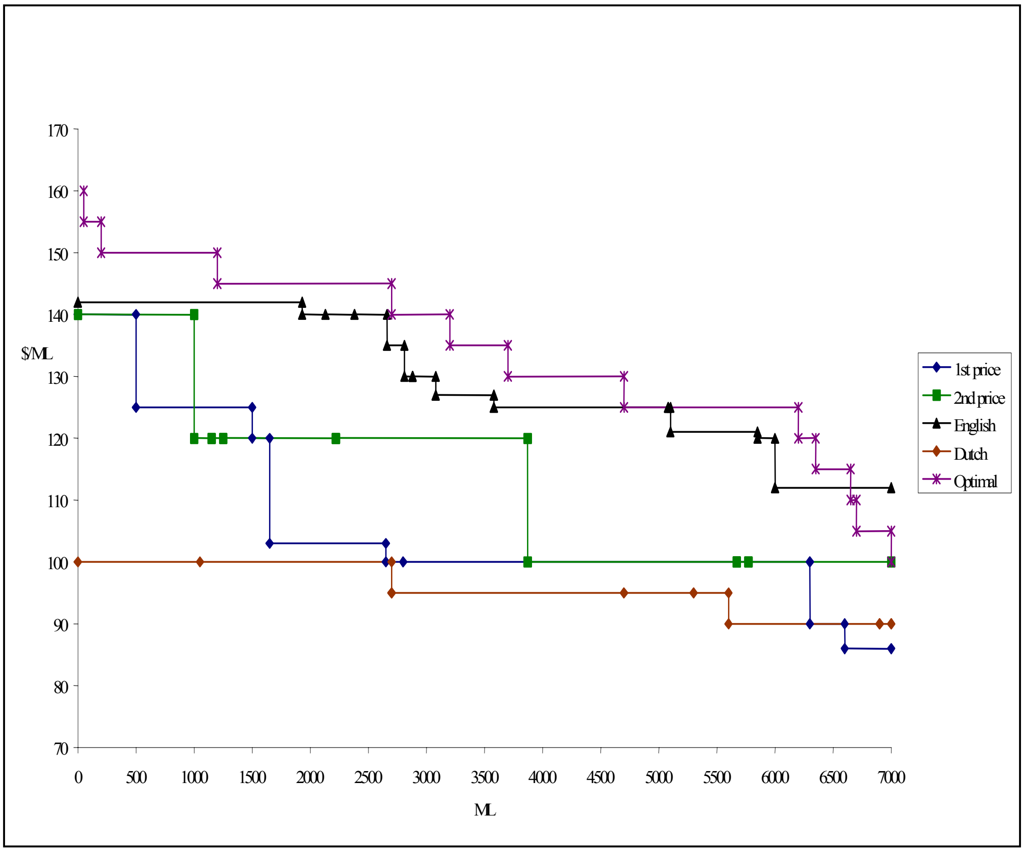


Figure 5 Comparison of auction structures

A third possibility is that the students became engrossed in outbidding each other in the English auction. This, however, was not apparent in the learning experiments. A final explanation arises from each player having two crops, one with a marginal value above equilibrium and one below. In the English auctions the group strategy was to bid for water for the most profitable crop. This behaviour differed from the players' behaviour observed in the Dutch auction. In Dutch auctions the price began below equilibrium implying that the traders were prepared to risk other traders and allow the price to fall within the lower value crop values. Further exploration with crossover design experiments may shed more light on this issue. The cause of the differences remains unanswered.

In summary, comparing the three auction structures, the English and second-price sealed-bid auction experiments showed the lowest rates of convergence to equilibrium and so the highest level of rent captured by the Water Authority. The Dutch auction experiments showed high rates of convergence to equilibrium and lowest rates of rent capture.

5.2.5 Results of the sealed-bid call auctions

Introduction of water markets is the cornerstone of Australian water policy to redistribute water to its most efficient use and maximize aggregate farm income. For this to occur there needs to be a level of certainty in water markets and realization of relative marginal values of water between extractive users. The experiments did not produce a major redistribution of water according to relative marginal values of water that the Government is hoping for. Rainfall and the risk associated with it played a major role in temporary water market experiments. The market redistributed surplus water to those with perceived or actual risk of water shortages. As a result of the risk and uncertainties associated with rainfall, no stable monthly equilibrium prices were produced. Each month supply and demand schedules shifted according to expected and actual rainfall.

To explore this further four metrics were used to evaluate the outcomes of the call auction experiments, (1) the equilibrium prices and quantities through time, (2) the level and distribution of aggregate farm income through time, and (3) the impact of trade on river flow regimes and (4) the impact of equilibrium price knowledge on trader behavior.

5.2.6 Equilibrium prices through time

Figure 6 shows monthly equilibrium prices through the three years of the experimentation. It was expected that the market would show a cyclical pattern through each year reflecting the crop requirements and seasonal conditions. In year 1 experiments equilibrium prices remained stable with two four month price steps. In years 2 and 3 a more cyclical pattern began to form with prices increasing during the summer months and then decreasing as the season closes.

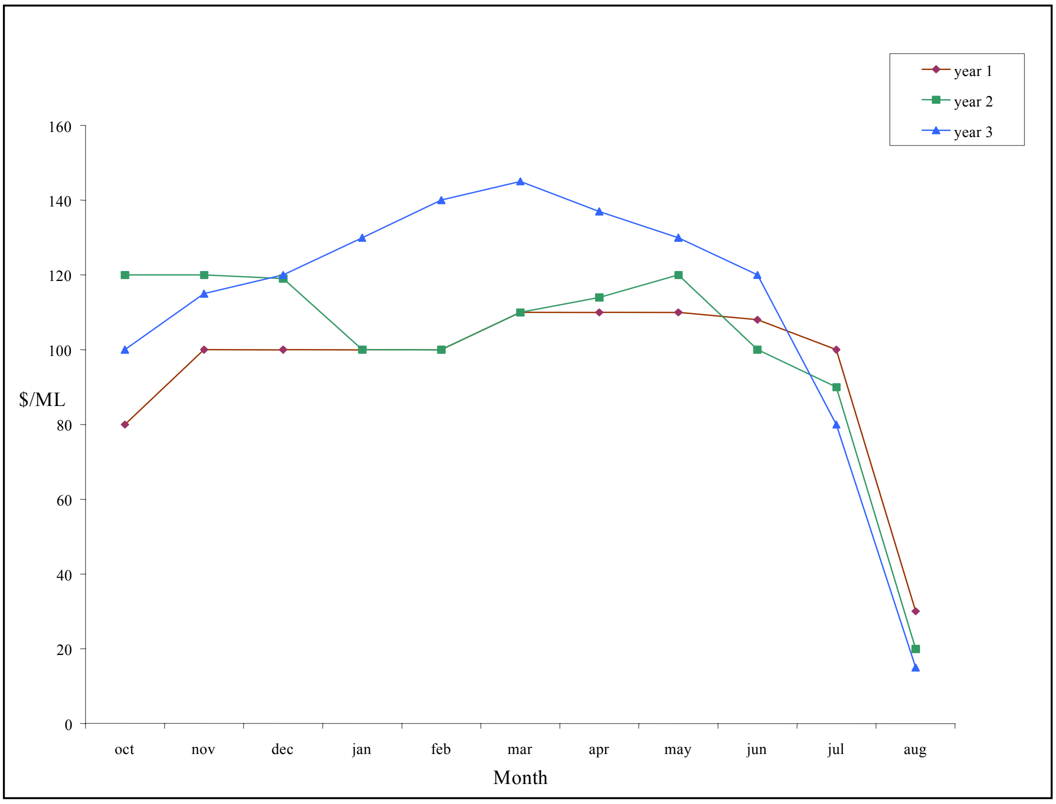


Figure 6 Equilibrium price through time

5.2.7 Water use efficiency

Water use efficiency is often modeled on the assumption of known water usage requirements. A typical optimization is to:

(1) Maximising $\sum_{k=1}^{3}\sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{q=1}^{12} GM_{kijq}x_{kijq}$

subject to

$\sum_{i=1}^{n}\sum_{q=1}^{12} w_{kijq}x_{kijq} \le a_{kj}$ for all k and j Water constraints

$\sum_{i=1}^{n}\sum_{q=1}^{12} x_{kijq} \le l_{kj}$ for all k and j Land constraints

where

GM_{kijq} is the gross margin in zone *k* for crop *i* on farm *j* in month *q*.

x_{kijq} is the area of irrigated land planted in zone *k* with crop *i* on farm *j* in month *q*.

a_{jk} is the allocation of water in zone *k* to farm *j*.

l_{kj} is the total area of irrigable land in zone *k* on farm *j*.

w_{kijq} is the water requirement in zone *k* of crop *i* on farm *j* in month *q*.

When water entitlements are tradeable the farmers are no longer constrained by their individual water allocation but theoretically by the aggregate supply of water. Extractive demand for water with trade was estimated by:

(2) Maximising $\sum_{k=1}^{3}\sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{q=1}^{12} GM_{kijq}x_{kijq}$

Subject to:

$\sum_{k=1}^{3}\sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{q=1}^{12} w_{kijq}x_{kijq} \le \sum_{k=1}^{3}\sum_{j=1}^{m} a_{kj}$ Water constraint

$\sum_{k=1}^{3}\sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{q=1}^{12} x_{kijq} \le \sum_{k=1}^{3}\sum_{j=1}^{m} l_{kj}$ Land constraint

Source: Tisdell (2001)

Using these models the estimated aggregate income pre-trade and post trade is $700,310 and $744,575 respectively. As shown in Table 10 and Figure 7 none of the three years of experimental trades produced an aggregate income beyond the modeled pre-trade aggregate income.

There are a number of possible explanations for this result. First, pre-trade optimization models treat rainfall as an endogenous variable within the calculation of monthly crop water requirements. This result suggests that post trade aggregate income under uncertainty of rainfall is less than pre-trade aggregate income with rainfall certainty. The implication is that trade is allowing farmers to offset part of the risk and uncertainty of rainfall but not beyond.

Second, a significant contributor to the demise of the experimentally derived aggregate farm income was crop failure. Crop failure arose as a result of some players (farmers) choosing a strategy of optimally watering their crops in the early months with the unrealized expectation that they will be able to purchase water in the market. This explanation will be explored further in experiments involving actual farmers in focus catchments.

Finally, for traders with low value crops it is rational for them to trade their water entitlement and not irrigate a crop. The results of the irrigator surveys found limited realization and/or adoption of this strategy. It was also not realized in the experiments. In the case of the student experiments this option may arise after further years of trading experience. In the actual market years of experience will need to be coupled with a mindset shift from being a farmer to one of water trader for this strategy to occur.

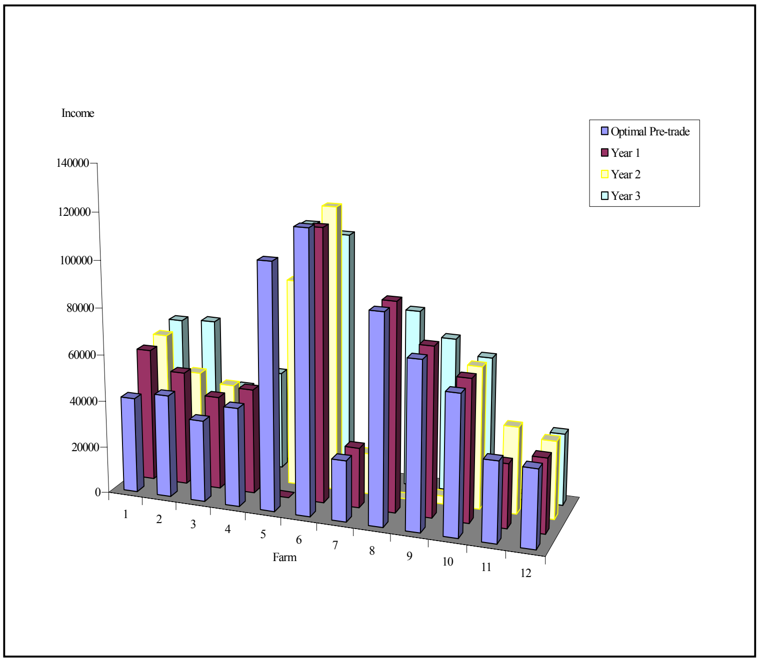


Figure 7 Water use efficiency

The increasing marginal value of water during a season has not been fully realized in the experiments or in actual water markets in Australia. The marginal value of water is calculated from gross margins that are based on the decision to grow or not grow a crop for its duration. Decisions to abandon a crop once it is planted and watered in order to sell water has a high marginal value. Assume a crop uses one ML each month. If a required ML of water is sold in month two the area of land requiring that water will fail and the prior watering is wasted. In other words the sale price has to account for the water used prior.

Table 10 Farm Incomes – Pre-trade Optimal and Experimental Outcomes

Farm	Pre-trade	Year 1	Year 2	Year 3
1	40979	57118	59195	61659
2	43947	48946	44117	62674
3	34974	40066	40292	34412
4	42312	45120	35950	42644
5	104916	0	88924	109441
6	119598	116291	121408	106302
7	26042	25748	17658	2800
8	88979	89031	0	76527
9	71474	72292	3470	66224
10	59690	60789	60753	59760
11	34250	27435	37215	137
12	33150	31870	33234	30840
TOTAL	700310	614706	542216	653420
Mean	58359	51226	45185	54452
St.Dev	31049	31062	34401	34644

5.2.8 Environmental flow impacts

The third aspect of trading considered is its impact on environmental flow regimes. The monthly water usage by each player following each year's trade is compared with the natural flow regime using a mean squared difference (MSD). This was estimated by:

(3) Minimising $$MSD = \frac{\sum_{q=1}^{12}\left[\sum_{k=1}^{3}\sum_{i=1}^{n}\sum_{j=1}^{m}(w_{kijq}x_{kijq}) + e_q - h_q\right]^2}{12}$$

subject to:

$$\sum_{q=1}^{12}\left[\sum_{k=1}^{3}\sum_{i=1}^{n}\sum_{j=1}^{m}(w_{kijq}x_{kijq})+e_q\right]\leq\sum_{k=1}^{3}\sum_{j=1}^{m}a_{kj}$$

where

e_q release of water for environmental use in month *m*.

h*q* natural flow of water in month *m*.

Source: Tisdell (2001)

A graphical representation of the natural flow regime and flows resulting from the three years of experiments is presented in Figure 8. The mean squared differences from environmental flow levels are presented in Table 11.

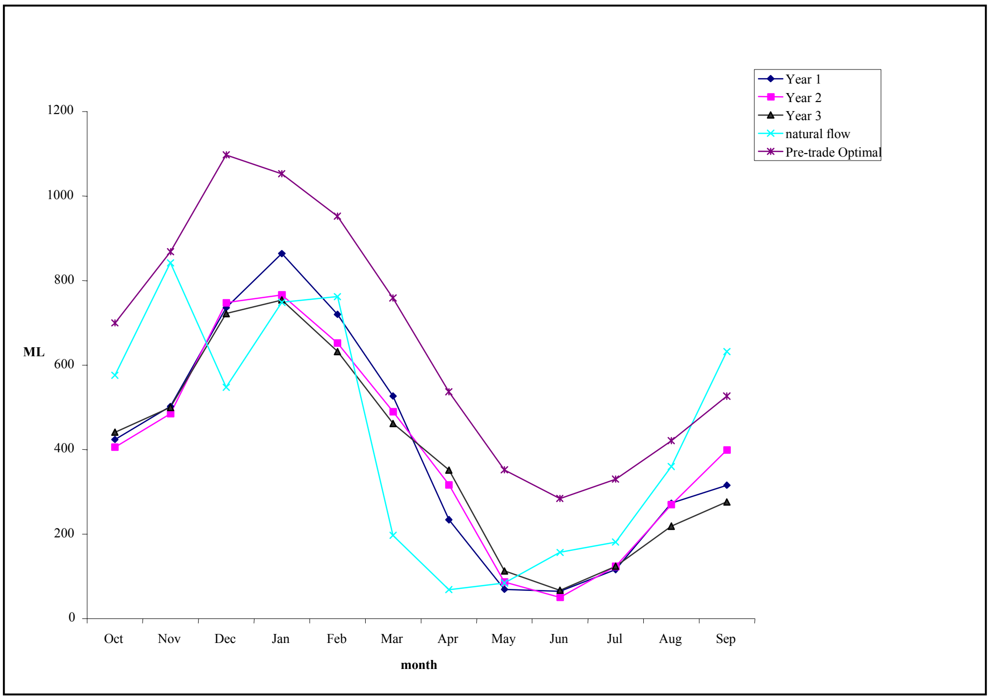


Figure 8 Flow regimes

As a result of the resistance to trade, the experimental trades did not significantly impact on environmental flows. The flow regimes while increasing use in the summer months and reducing the flow in the winter months did not change the flow regime as the optimization modelling would suggest.

Table 11 Post Trade Flow Variations

Trade Year	MSD

1	37,137
2	36,094
3	40,966
Average	38,066

Equilibrium price knowledge and trader behavior

The trading results for the three years are shown in Appendix B. The results suggest that through each year the relative number of buyers and sellers vary. In the early months of the water year the ratio of buyers to sellers approaches equality. As the market progresses the number of sellers diminishes as the summer crop requirements take affect. Once the summer growing season finishes demand decreased and supply increased. Market price in the first year remained stable.

This first series of experiments will provide a benchmark to explore the impact of market information on the strategic behavior of traders. In this series of experiments the equilibrium price of each monthly trading period was announced at the end of each session. No information on the number of traders or relatively of bids was released. As a result traders were not in the position to act strategically to shortfalls in demand or supply or relative market power. Within this series of experiments it is possible to test the hypothesis that the equilibrium price in period t (p_t) is a determinant of the average supply price (p_{ast+1}) and average demand price (p_{adt+1}) without confounding strategic behavior. In other words $p_{adt+1} = f(p_t)$ and $p_{ast+1} = f(p_t)$ expressed through an increase in minimum bid prices, an increase in demand or a decrease in supply.

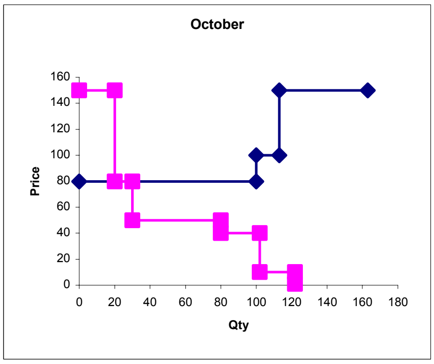
Table 12 presents the findings of the study. In year one, while the coefficient of equilibrium price variable is significant ($P<0.05$), the sign of the coefficient is not logical. The coefficient of equilibrium price variable in the average sell price model is also not significant. In years 2 and 3 the equilibrium price is significant in both models suggesting that both supply and demand are responding to the price information from the previous period. As the equilibrium price increases so the supply and demand bids increase. In year 3, while the lagged equilibrium price was significant the model overall was not, suggesting that further variables need to be explored.

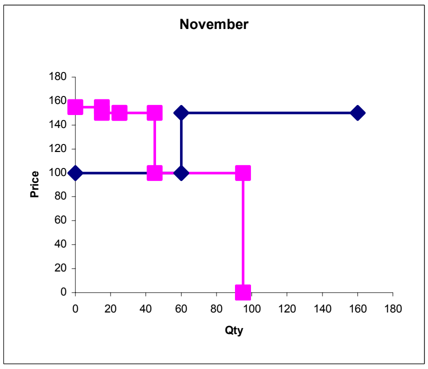
Table 12 Average Buy and Sell Price Models

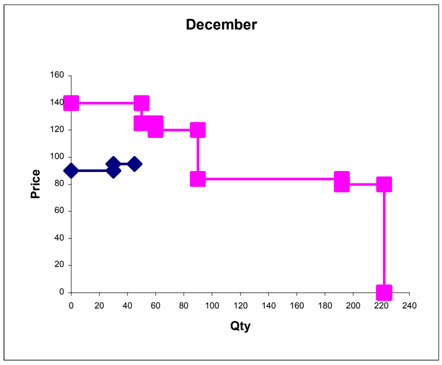
Dependent	Year	Constant	Coefficient	R^2	F	p
Average Buy price	1	202.306 (35.275)	-0.933 (0.345)	0.477	7.307	0.027
	2	-42.176 (28.753)	1.313 (0.262)	0.728	25.138	0.001
	3	70.020 (22.704)	0.324 (0.128)	0.189	3.094	0.117
Average sell price	1	175.993 (45.638)	-0.578 (0.447)	0.173	1.675	0.232
	2	-78.257 (1.675)	1.675 (0.462)	0.622	13.144	0.007
	3	-54.880 (30.894)	1.331 (0.251)	0.779	28.150	0.001

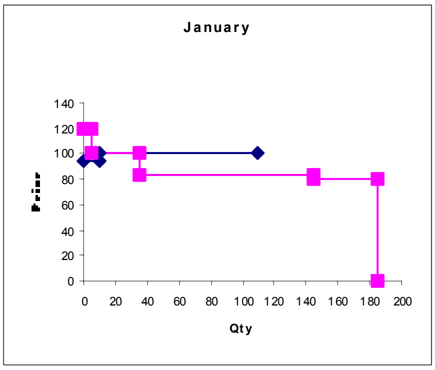
This document reported the findings of a series of preliminary water markets experiments in Australia. The government, through a national reform agenda is anticipating water markets to redistribute water to its most efficient use. The results of surveys of focus catchment irrigators suggest that trading water may be restricted to redistributing surface water and offsetting rainfall uncertainty. The results of the preliminary water experiments support those findings. Other blockages to trade include a lack of market information and knowledge of the workings of sealed bid markets. Further research will explore the impact of improved information and knowledge on water market performance.

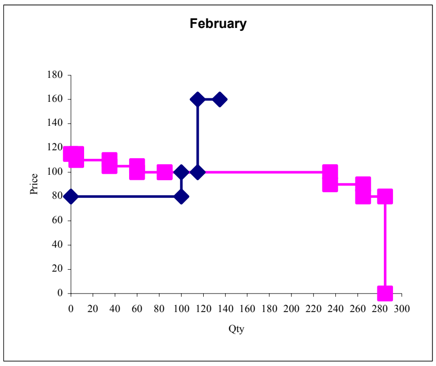
Year 1 Call Auction Market results

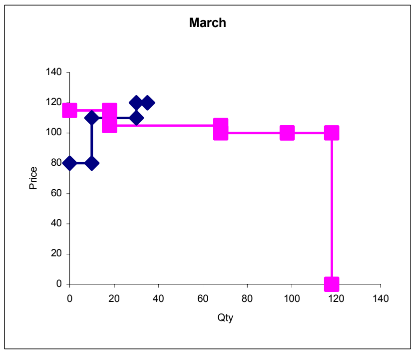


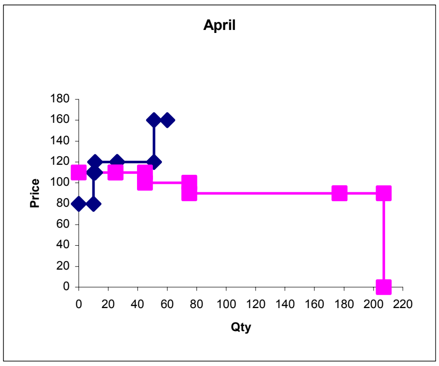


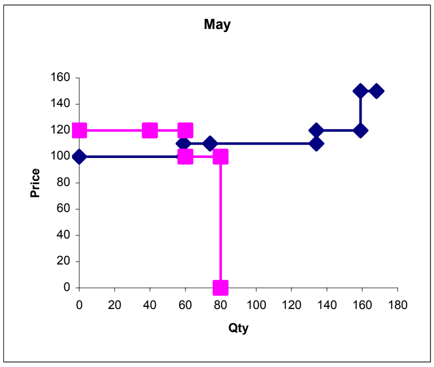


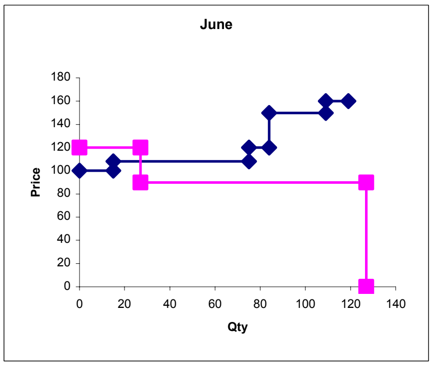


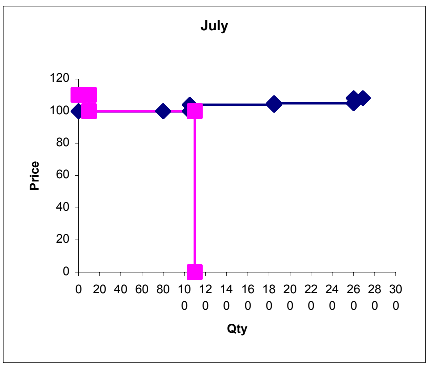


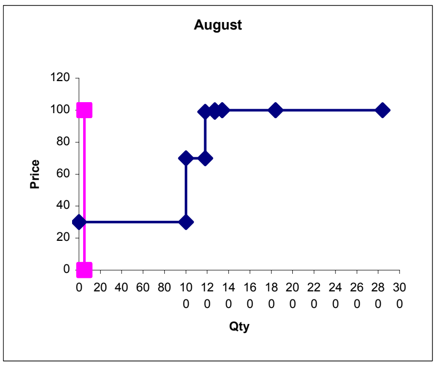




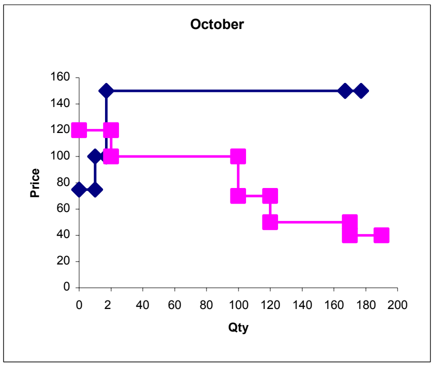


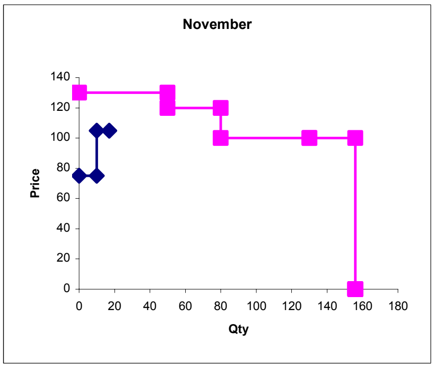


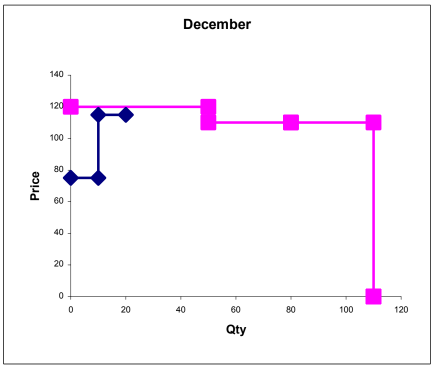


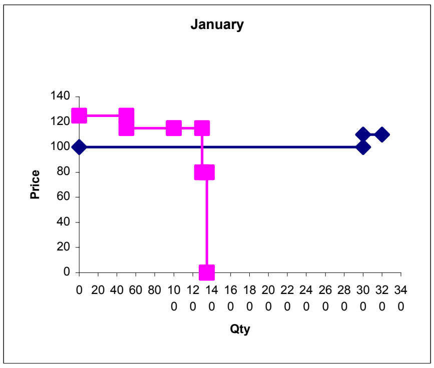


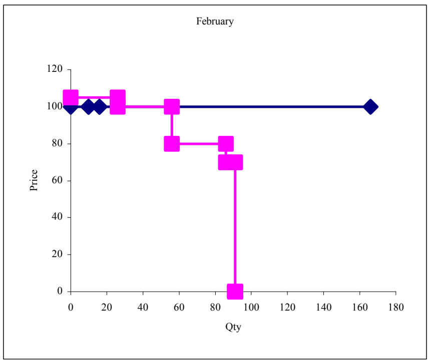
Year 2 Call Auction Market results

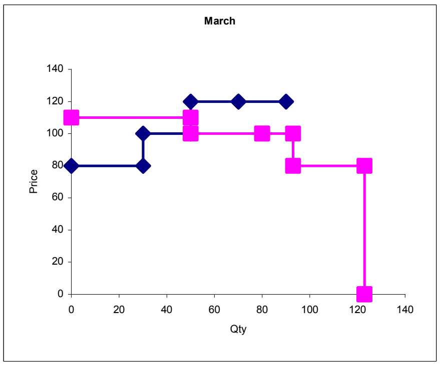


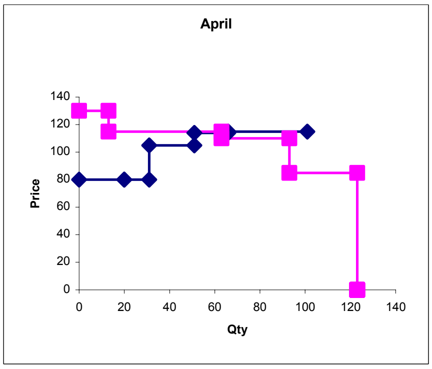


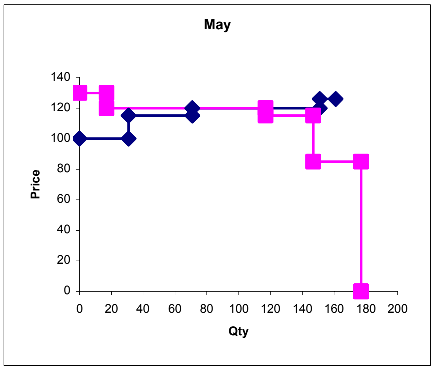


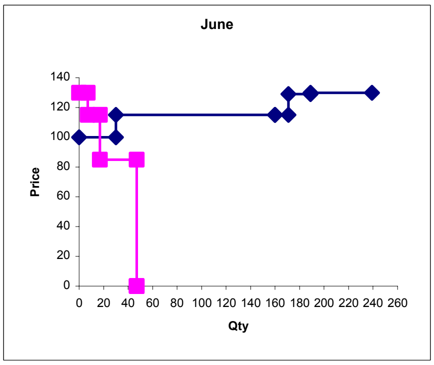


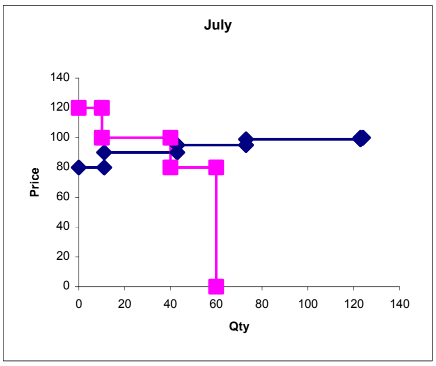


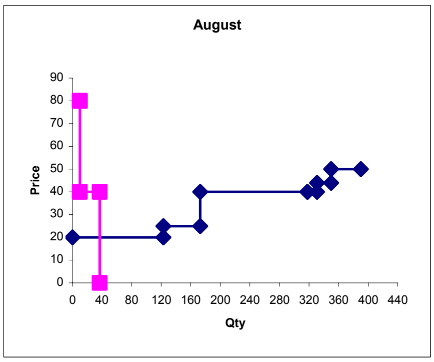












5.3 Experimental Series B.

5.3.1 Accordance with public good theory

The first series of experiments was designed to test whether the structure of the farms and environmental targets led to outcomes consistent with public good theory, namely that the level of accordance with environmental target increases as the marginal per capita cost of exceeding the environmental extraction limits increases. Tables 2 and 3 present the extraction levels of each of the four players over the 10 rounds of the repeated on-shot experiments. Table 13 presents the analysis of variance of aggregate extraction rates. The original work in the field of public goods and common pool resource experiments by Isaac *et al*., (1984) found that increasing the MPCR from 0.3 to 0.75 increased the level of contribution in public good experiments. Consistent with their findings, this study found that increasing the MPCC from 0.375 to 0.75 in the common pool environment significantly improved accordance with the resource extraction target ($p<0.01$). Mean aggregate extraction levels decreasing from 1920ML to 1762ML respectively.

Isaac, *et al.*, (1985) suggest that repetition may result in decreased cooperation in public good experiments. Figure 9 shows slight variation in the levels of extraction through the ten rounds but no definitive trends at either levels of MPCC. These experiments also found no change in the level of cooperation through rounds.

Table 13. Yearly Water Decisions with MPCC 0.375

Year									Average	Efficiency
	1	2	3	4	5	6	7	8		
1	1774	1784	1785	1879	1873	1983	1983	2088	1894	0.9069
2	1879	1791	1756	2056	1879	1878	1985	1983	1901	0.9104
3	1985	1984	1776	1951	1983	1983	1984	1983	1954	0.9356
4	1752	1734	1797	2056	1856	2044	1904	2088	1904	0.9118
5	1731	1792	1790	1941	1796	2066	1909	2016	1880	0.9004
6	1702	1772	1786	1889	1869	1983	1982	2066	1881	0.9010
7	1786	1878	1779	1899	1952	2088	1981	2088	1931	0.9250
8	1754	1856	1884	2088	1983	2088	1977	2088	1965	0.9410
9	1681	1831	1779	2018	1983	2088	1983	2088	1931	0.9250
10	1786	1878	1884	1984	1984	2088	1984	2088	1960	0.9385

Table 14. Yearly Water Decisions with MPCC 0.75

Year	Session								Average	Efficiency
	1	2	3	4	5	6	7	8		
1	1669	1671	1668	1807	1726	1724	1668.00	1774	1713	0.8206
2	1701	1671	1668	1739	1841	1724	1668.00	1809	1728	0.8274
3	1662	1672	1668	1842	1739	1800	1668.00	1835	1736	0.8313
4	1711	1669	1668	1834	1756	1796	1668.00	1825	1741	0.8338
5	1651	1670	1668	1869	1771	1924	1668.00	1902	1765	0.8455
6	1671	1777	1668	1994	1773	2014	1668.00	1891	1807	0.8654
7	1671	1751	1668	1714	1773	1809	1668.00	1879	1742	0.8341
8	1691	1756	1668	1773	1878	1869	1668.00	1995	1787	0.8560
9	1784	1796	1668	1781	1749	1869	1668.00	2051	1796	0.8600
10	1836	1878	1668	1776	1764	1891	1773.00	1883	1809	0.8662

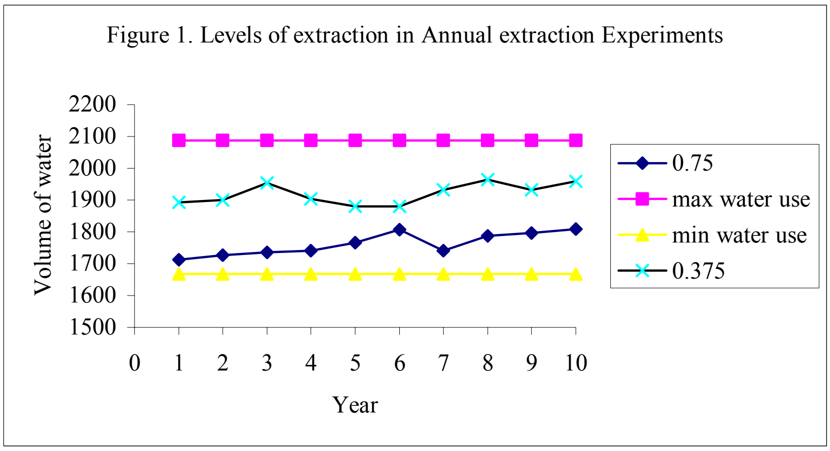
Table 15. Analysis of Variance: One-Shot Experiments

Tests of Between-Subjects Effects

Dependent Variable: AGGWATER

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1158509.869[a]	19	60974.204	5.156	.000
Intercept	542391743	1	542391743.3	45860.581	.000
MP	994929.306	1	994929.306	84.124	.000
ROUND	102935.931	9	11437.326	.967	.470
MP * ROUND	60644.631	9	6738.292	.570	.820
Error	1655775.875	140	11826.971		
Total	545206029	160			
Corrected Total	2814285.744	159			

a. R Squared = .412 (Adjusted R Squared = .332)



Given these results it was decided to explore whether these results hold when the player faced a series of monthly heterogeneous decisions on water usage according to the crop's monthly water demand, rather than a single decision for the whole water year. Tables 5 and 6 present the extraction levels of each of the four players given monthly water extraction targets. Table 17 presents the analysis of variance of efficiency measured in terms of percentage maximum extraction. Efficiency, rather than aggregate extraction was used due to the heterogeneous monthly targets. Analysis of variance therefore required asin transformation.

In both the MPCC trials there was a statistically significant trend to not meet the extraction target ($p < 0.01$). The analysis of the two levels of MPCC blocked by months presented in Table 18 suggest that consistent with the one-shot experiments, there was a significantly lower level of extraction as a result of increasing the MPCC in the monthly decision experiments ($p<0.01$). The level of extraction also increased over time. As shown in Figure 9 the rate of increase was greater in experiments where the MPCC was 0.375 compared to those where the MPCC was 0.75.

Table 16. Monthly water decisions with MPCC 0.375 No rainfall

	Session					Average	Max	Min	Efficiency
Month	1	2	3	4	5				
Oct	199	211	203	209	223	209	244	195	0.8566
Nov	212	237	217	224	234	225	256	205	0.8781
Dec	234	235	248	258	257	246	284	227	0.8676
Jan	248	260	263	275	268	263	300	240	0.8760
Feb	181	187	194	199	194	191	216	173	0.8843
Mar	176	176	175	186	182	179	200	160	0.8950
Apr	136	142	135	141	143	139	156	125	0.8936
May	56	62	62	67	66	63	72	58	0.8694
Jun	26	28	30	28	28	28	32	26	0.8750
Jul	58	59	57	59	60	59	64	51	0.9156
Aug	93	96	96	99	97	96	104	83	0.9250
Sep	148	147	144	155	152	149	160	128	0.9325

Table 17. Monthly Water decisions with MPCC 0.75 No rainfall

	Session					Average	Max	Min	Efficiency
Month	1	2	3	4	5				
Oct	202	211	214	208	208	209	244	195	0.85492
Nov	215	234	220	214	217	220	256	205	0.85938
Dec	229	250	243	236	243	240	284	227	0.84577
Jan	249	266	270	247	260	258	300	240	0.86133
Feb	198	178	190	179	186	186	216	173	0.86204
Mar	176	179	175	164	175	174	200	160	0.86900
Apr	144	135	135	129	139	136	156	125	0.87436
May	66	67	64	59	64	64	72	58	0.88889
Jun	28	29	26	27	28	28	32	26	0.86250
Jul	61	57	55	53	52	56	64	51	0.86875
Aug	89	95	89	84	94	90	104	83	0.86731
Sep	136	147	144	136	144	141	160	128	0.88375

Table 18. Analysis of variance: Multiple decision experiments

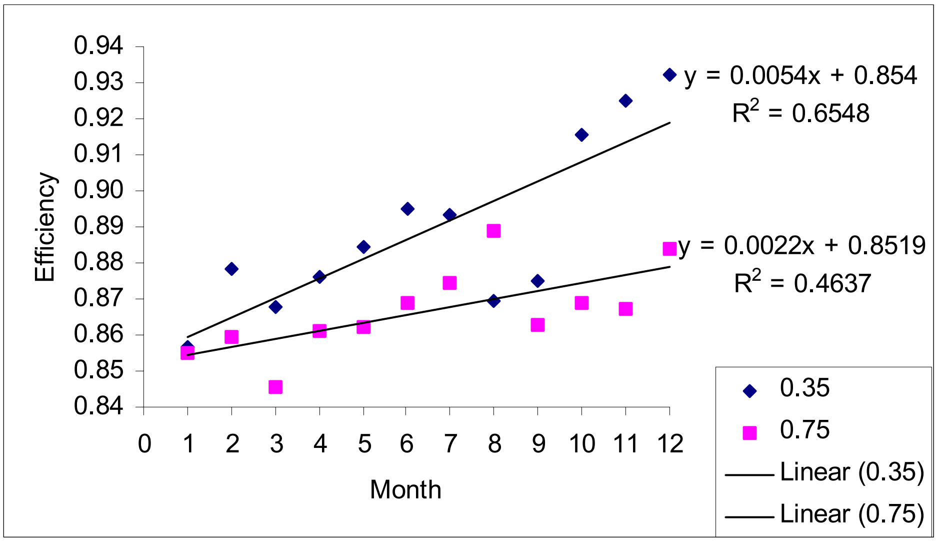
Tests of Between-Subjects Effects

Dependent Variable: MONTHWTR

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	663094.192[a]	23	28830.182	679.623	.000
Intercept	2774608.408	1	2774608.408	65406.740	.000
MONTHMP	414.408	1	414.408	9.769	.002
MONTH	662474.092	11	60224.917	1419.701	.000
MONTHMP * MONTH	205.692	11	18.699	.441	.934
Error	4072.400	96	42.421		
Total	3441775.000	120			
Corrected Total	667166.592	119			

a. R Squared = .994 (Adjusted R Squared = .992)

Figure 9. Relative efficiency of MPCC



5.3.2 Accordance with environmental targets

The second series of experiments explored the impact of rainfall and information on accordance with monthly environmental targets. The analysis of variance is presented in Table 19. The analysis showed (a) no significant interaction between the months, information and rainfall, (b) interaction between information and rainfall and (c) significant difference in the provision of information and (d) significant differences as a result of introducing rainfall. Table 20 shows the mean asin levels for rainfall and information.

Consistent with the findings of Budescu *et al*., (1995) that uncertainty will induce players to further their own interests at the expense of the collective interest in public good experiments, aggregate extraction increased as a result of introducing rainfall and the associated uncertainty of endowments. Farmers deciding on how to manage their farm on a monthly basis face uncertain rainfall conditions. This rainfall uncertainty reduced the level of cooperation in the provision of environmental flow targets.

The second major determinant is the level of information. Experimental evidence that the provision of information increases cooperation in common pool resource or public good experiments appears inconclusive in public good research. Ledyard (1995), having reviewed the literature on information effects in public good experiments, concluded that complete information leads to less contribution to the public good compared to no information in heterogeneous environments. In this series of common pool experiments, providing information on the extraction of the other players led to a significant reduction in the level of accordance with environmental targets.

Table 19.Analysis of variance: month, information and rainfall

Tests of Between-Subjects Effects

Dependent Variable: ASIN

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.596[a]	47	3.395E-02	2.013	.001
Intercept	288.626	1	288.626	17113.965	.000
MONTH	.393	11	3.575E-02	2.120	.021
INFO	.237	1	.237	14.025	.000
RAIN	.216	1	.216	12.819	.000
MONTH * INFO	7.041E-02	11	6.401E-03	.380	.963
MONTH * RAIN	.139	11	1.259E-02	.747	.693
INFO * RAIN	.493	1	.493	29.237	.000
MONTH * INFO * RAIN	4.774E-02	11	4.340E-03	.257	.992
Error	3.238	192	1.686E-02		
Total	293.459	240			
Corrected Total	4.834	239			

a. R Squared = .330 (Adjusted R Squared = .166)

Figure 10. Monthly extraction levels given rainfall

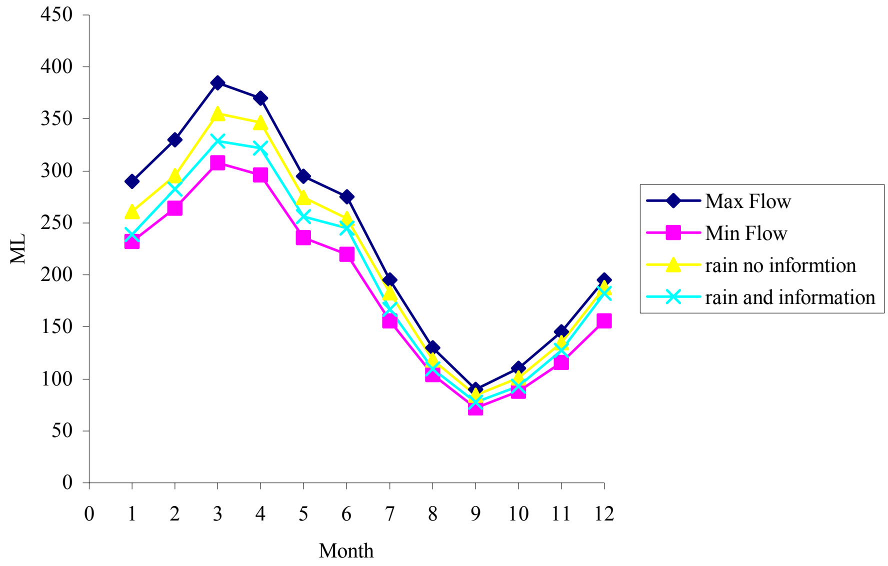
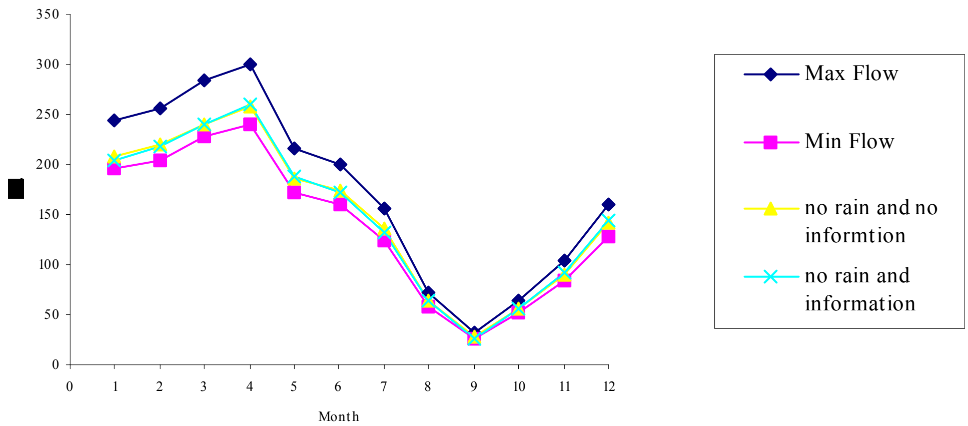


Figure 11. Monthly extraction levels without rainfall



Rainfall and information significantly interacts. Given information, rainfall made no significant difference in accordance with the monthly environmental targets. Without information, rainfall resulted in a reduction in accordance with the monthly environmental targets. Overall, the level of extraction was lower with information than without information.

Given no rainfall information, the experimentation found no significant difference in extraction as a result of providing information. Given rainfall, there is a significant difference in average extraction between information and no information ($p<0.01$).

Table 20 Asin average for Rainfall and Information

	Rainfall	No rainfall	Total
Information	1.0499 [a]	1.0806 [ab]	1.0652
No Information	1.2034	1.0527 [b]	1.1280
Total	1.1266	1.0666	

Note: means with the same symbol are not significantly different.

In summary, when faced with uncertainty of endowments, information improves cooperation in accordance with environmental targets. If the uncertainty of endowments as a result of rainfall can be minimized, information is not effective in reducing in accordance with environmental targets. Players appear to free ride less when presented with more complex farm information. When given monthly watering schedules, players appeared to move towards cooperation, even with low MPCC.

Public good experimental research has well established the impact of increasing the marginal per capita return to contributions to such goods. As a starting point, this research demonstrated that the principle also applies to common pool resource experiments in terms of a marginal per capita cost of extraction of the resource. Specifically, increasing the marginal per capita cost in repeated one-shot situations improved accordance with environmental targets. When presented with a series of heterogeneous targets, however, increasing the marginal per capita cost did not significantly increase accordance with environmental targets.

When faced with uncertainty of endowments, information improves cooperation in accordance with environmental targets. If the uncertainty of endowments as a result of rainfall can be minimized, information doe not affect the level of accordance with environmental targets. Players appear to free ride less when presented with more complex farm information. Evidence that when given monthly watering schedules players appear to move towards cooperation, even with low MPCC.

Areas of further research include the impact of communication; heterogeneous farm types, irrigation schedules and values and environmental targets, and the consequences of introducing trade in water entitlements. Kahneman *et al.* (1986), Kollock (1998), Ledyard

(1995) and Ostrom (1992) have found that communication significantly increases cooperation in public good experiments. Catchments have within them heterogeneous farm types, irrigation schedules and values and environmental targets. While not wishing to replicate reality capturing the salient features of the catchments will be important to gain industry credibility. Trade in water entitlements has been shown to potentially have a significant impact on flow regimes in river systems in Australia (Tisdell, 2001). Incorporating the confounding impact of such markets will be the challenge ahead.

5.4 Experimental Series C

This section reports the findings of the research[19]. It commences with an analysis of the level of accordance with environmental targets, measured by the environmental levy, as a result of each of the treatments. The findings are supported and supplemented by a graphical analysis of monthly extraction and environmental targets. A generally reviewed wisdom notes that the implications of laboratory findings should be interpreted cautiously beyond the specific institutional setting of the experiment.

5.4.1 The impact of the provision of information, discussion forums and sanctions on meeting environmental targets

It is expected that the level of environmental damage caused by water extraction will increase as a result of trade and decline with information, discussion and individual extraction disclosure. Table 21 presents the combined results of the two years of experiments.

In all cases, the level of environmental damage reflected in the value of the environmental levy is less without trade compared to open and closed call markets. Without trade the level of environmental damage declined with the provision of aggregate extraction information from \$5.48 to \$5.03. Coordinating individual actions to converge with environmental targets is difficult without a means of communication. Allowing the traders to communicate improved coordination of actions resulting in a further decline in the environmental levy to \$2.71. Releasing individual extraction levels compared to their agreed extraction levels was detrimental and resulted in an increase in the environmental levy from \$2.71 with discussion to \$3.30 with individual disclosure.

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[19] These results are preliminary only and should not be quoted without permission of Dr John Tisdell, Project Leader. A full statistical analysis of the results is scheduled during 2003.

Introducing a closed call market produced more adverse environmental consequences. Compared to no trade the average levy increased from \$4.13 to \$6.98. The provision of aggregate information in the closed call experiments reduced the environmental levy, while allowing discussion increased the levy. Disclosure of individual information reduced the levy, but not below aggregate information levels. Closed call markets by their nature provide less market information to participants and thus should have a less adverse environmental impact than an open call market. This was found to be the case only in markets where aggregate environmental information was provided. In contrast to the results of the no trade market experiments, provision of individual information in the open call experiments increased accordance with environmental extraction targets and thus reduced the level of environmental damage. Without trade the lowest environmental damage resulted from discussion between the players with aggregate extraction information. With trade an open call with discussion and individual extraction information led to the lowest level of environmental damage.

In these experiments the introduction of trade increased environmental damage.

Disclosure of only the impact of aggregate extraction on riverine environments was found to be counter-productive to achieving environmental extraction targets in open call market experiments. The environmental damage was maximised with this treatment.

Environmental damage was minimised by providing aggregate environmental information with a forum for group discussion and agreement in a no trade experimental environment.

Table 21 The value of the environmental levy

	No Information (\$)	Aggregate Information (\$)	Aggregate Information and discussion (\$)	Individual information and discussion (\$)	Average
No Trade	5.48	5.03	2.71	3.30	4.13
Closed Call	7.62	6.28	7.44	6.59	6.98
Open Call	5.75	8.80	4.52	4.44	5.88
Average	6.28	6.70	4.89	4.78	

5.4.2 The impact of the provision of information, discussion forums and sanctions on aggregate traders' income

Traders' incomes were calibrated to ensure equal potential income and used to compare the impact of the various treatments and auction structures. Table 22 presents the average traders' income for each treatment/block combination. Consistently the average traders' income without trade was lower than with trade. Introducing aggregate extraction and environmental information increased average traders' income in a closed call market compared to their no trade position, but not in the open market compared to a closed call market. A possible explanation for this may be that trade was seen as part of the cause of the environmental cost and this hampered open call trading. Once discussion was allowed it was transparent that the level of extraction, rather than the market, was the primary determinant of the environmental levy and the stigma of the open market was removed.

In these experiments average traders' income increased with trade in all cases.

Introducing aggregate extraction and environmental information increased average traders' income in trade experiments compared to no trade experiments.

Maximum average traders' income was achieved by providing information on aggregate extraction, environmental targets and a forum for discussion in an open call market.

Disclosure of individual information compared to aggregate information with discussion led to lower average traders' income in all cases.

Providing aggregate information and discussion produced higher average traders income compared to no information or aggregate information alone in all cases.

Table 22 Trader's income

	No Information ($)	Aggregate Information ($)	Aggregate Information and discussion ($)	Individual information and discussion ($)	Average ($)
No Trade	38.10	39.55	43.20	42.88	40.94
Closed Call	40.71	44.26	47.25	46.17	44.59
Open Call	45.24	43.22	49.67	47.59	46.43
Average	41.35	42.34	46.71	45.55	43.99

5.4.3 Ratio of income and environmental levies

Trade-offs between maximising extractive income and riverine environmental flow regimes is common. One metric to measure that trade-off is the income per unit of environmental damage. Table 23 presents that ratio for each treatment/block combination.

Table 23 Ratios of Aggregate Income and Environmental levies

	No Information	Aggregate Information	Aggregate Information and discussion	Individual information and discussion
No Trade	6.96	7.87	15.92	13.00
Closed Call	5.34	7.05	6.35	7.01
Open Call	7.87	4.91	11.00	10.72

Providing aggregate information and a forum for discussion without trade maximised the return per unit of environmental damage.

Compared to aggregate information and discussion, providing individual information provided lower returns per unit of environmental damage and therefore counter productive in all cases.

Table 24 Ranking of the Income and Environmental Ratios

Treatment	Market type	Income	Levy	Ratio
Aggregate information and discussion	No trade	43.20	2.71	15.92
Individual information and discussion	No trade	42.88	3.30	13.00
Aggregate information and discussion	Open Call	49.67	4.52	11.00
Individual information and discussion	Open Call	47.59	4.44	10.72
Aggregate Information	No trade	39.55	5.03	7.87
No information	Open Call	45.24	5.75	7.87
Aggregate Information	Closed Call	44.26	6.28	7.05
Individual information and discussion	Closed Call	46.17	6.59	7.01
No information	No trade	38.10	5.48	6.96
Aggregate information and discussion	Closed Call	47.25	7.44	6.35
No information	Closed Call	40.71	7.62	5.34
Aggregate Information	Open Call	43.22	8.80	4.91

5.4.4 Environmental agreements and accordance

During the discussion period participants were able to form agreements on aggregate extraction. Information on their aggregate agreement and aggregate extraction was provided. In the final series of experiments individual agreement and extraction variations were provided. The level of accordance reported in Table 25 is based on the inverse sum squared-difference between the monthly aggregate agreement and aggregate extraction. The level of accordance with the agreement was greatest in closed call, aggregate information and discussion experiments. Provision of aggregate information lead to higher levels of accordance in closed call experiments compared to open call experiments. In contrast, open call experiments produced higher levels of accordance in experiments where individual extractions were disclosed. Disclosure of individual accordance with agreements improved the level of accordance in the no trade and open call experiments but not in the closed call experiments.

Table 25 Level of accordance with agreements[1]

	Aggregate information and discussion	Individual information and discussion
No trade	0.0165	0.0241
Closed	0.0148	0.0100
Open	0.0057	0.0133

[1] Accordance measure= $\frac{1}{\sum_{t=1}^{12}(aggAgree_t - aggExtract_t)^2}$

The highest level of level of accordance was observed in no trade experiments with aggregate information and discussion.

The lowest level of level of accordance was observed in an open call environment with aggregate information and discussion.

6 CATCHMENT AND NATIONAL WATER POLICY RECOMMENDATIONS

The research raised the following catchment and national policy recommendations. They arise from an extensive review of the literature, surveys of irrigators and community members and a series of laboratory and field experiments. The recommendations also provide a platform for further research.

A. **Establish a further series of tranche payments, paid to State authorities demonstrating that their water market structures have led to increased water use efficiency and account for the externalities arising from trade**.
Review of the literature on water management in Australia shows few incentives for State water authorities to demonstrate effective water market results. Incentive schemes focus on establishing the legal structure for water markets but provides limited measure or incentive to operationalise or measure water market performance.

B. **Develop a series of strategies to address stakeholder apprehension towards water markets.**

The survey results suggest that apprehension to trading water is a significant barrier to trade and remains largely undressed. Survey results suggest that the opportunity cost of growing a crop is not realized in the market. A significant number of farmers responding to the survey view water as an integral part of their farm and not for sale or were philosophically opposed to trade. Farmers surveyed are largely selling surplus water and not willing to change farming practices to realize the full returns from water trading. They saw selling only surplus water as their strategy for the foreseeable future. This is a cultural and institutional problem that needs to be readdressed

C. **Establish information forums to assist farmers in understanding how markets operate in respect to market price determination and how to develop trader strategies**.

Survey and experimental results suggest that farmers have limited knowledge of how markets operate and are keen to acquire more information. A large number of farmers attending the *Mwater* demonstrations did not understand how the market price is determined and were very keen to have this explained. It was evident that once they understood how the market operates they were able to better manage their allocation and trade decisions.

D. **Give water authorities powers to restrict trades which results in social and environmental externalities.**

The survey of irrigators suggested that water authorities should be able to intervene in trades that may impact on other entitlements; the viability of local towns and community; and environmental flow objectives, are not just or equitable. Accounting for these externalities is important to achieve an economic optimal result from trade. Despite realizing the social costs of extraction participants in the experiments followed self-interest strategies and suffered the tragedy of the commons.

E. **Revise policy expectations as a result of sub-optimal outcomes.**

Experimental results suggests that the rate of market convergence is likely to be slow as a result of the market apprehension, uncertainty of rainfall and limited market information. Most field markets are unlikely to achieve optimal outcomes within the first 8-10 years.

F. **Increase the availability of market information.**

A major limitation achieving market efficiency is market information. Beyond the formal exchanges of Victoria, farmers have limited market information. Survey and experimental results (reflected in open as apposed to closed call auction structures) suggest that a lack of trade information is a major inhibitor to achieving market efficient outcomes. Even the release of market prices has been shown to significantly improve market efficiency.

G. **Establish more formal market exchanges.**

While some state and regional water authorities have set in place the legal requirements for trade, they have failed to establish any formal market structures. In such circumstances farmers establish bilateral trade agreements often with little or no market knowledge. Experimentally such bilateral trade environments have been shown to perform very poorly and rarely result in competitive market prices. Simply establishing markets without a formal exchange will not achieve market efficient outcomes. Markets require some form of structure in which market information, such as buy and sell bids, is transparent. Formal, centralized exchanges such as *watermove* should be promoted.

H. **Actively involve irrigator and irrigator groups in managing aggregate extraction in order to better meet environmental flow objectives.**

Survey and experimental results suggest that including the establishment of forums for irrigators to self-manage aggregate extraction levels as part of a suit of policy instruments to manage flow regimes may be effective. To be effective such forums require environmental flow information and necessary aggregate information. Providing a bulk entitlement to the environment may be necessary but not sufficient to effectively manage the tradeoffs between extractive and environmental water use. Trade in water entitlements limits the effectiveness of joint coordination of this nature.

7 CONCLUSION

This project has developed options for water policy based on an extensive review of the literature and an extensive survey of irrigator and community opinion, and developed a model for experimentally evaluating alternative resource management policy options. Experimental economics yields a formalised, replicable approach to rapidly assess alternate policy directives, typically expressed as market outcomes, prior to catchment-wide implementation Dinar *et al*. (1998). The methodology provides a relatively inexpensive means of institutional analysis coupled with substantially reduced time horizons.

This research examines applied economic policy, which requires more realistic simulations of economic environments that depend closely on policies developed to account for the social, economic and biophysical complexities of water as a common pool resource. To enable this complex analysis to occur this project has developed a number of methodical systems, inclusive of extensive survey design and analysis to experimental economics. This systemic approach has culminated in the research questions explored, providing empirical analysis of the issues arising from the review of water management in Australia and the extensive survey of attitudes to water allocation and trading. Promoting application of this technique through the communication and adoption plan has been completed with a series of very successful workshops with State and Federal leaders.

Experimental economics is becoming the leading tool in economic theory and policy analysis. Further exploration of permanent, intersectoral and interstate trade using such techniques is warranted.