

**Tradeable recharge credits in Coleambally  
Irrigation Area: Report 5**

**Field trial and farm case studies**

**September 2005**

**CSIRO & BDA Group**

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This paper is the fifth in a series from a two-year research program. The focus in this paper is on a field trial of alternative institutional frameworks using experimental economics techniques and on farm level case studies of the impact of alternative recharge management strategies on farm management strategies. Papers in this series are:

- *What are the issues?*
- *Economic impact of tradeable recharge credits and other net recharge abatement policies for the Coleambally Irrigation Area*
- *Designing experiments to test tradeable recharge credits in the Coleambally Irrigation Area*
- *Laboratory tests of alternative institutional frameworks*
- *Field trial and farm case studies*
- *Biophysical modelling for linking farms with regional net recharge targets*
- *Experiences, lessons and findings*

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## Executive summary

This report is part of a series detailing the outcomes of research into the exploration and development of tradeable recharge rights as a tool to manage irrigation induced salinity in the Coleambally Irrigation Area (CIA) in south western New South Wales (NSW). Tradeable recharge rights are a ‘cap-and-trade’ scheme. Under this type of policy instrument a limit or ‘cap’ is placed on the total allowable net recharge. Shares in the ‘cap’ are allocated to individual farmers who then must manage their enterprises within this cap or trade with others to enlarge their share.

Management of net recharge has a number of similarities with other environmental markets, where the actions of a group of individuals or businesses are degrading a common property resource such as a groundwater aquifer or waterway. Cap-and-trade schemes have proved both workable and efficient where the impacts have been of a point source nature. Over recent years, the CSIRO Division of Land & Water in Griffith has developed a state of the art farm level hydrological economic model, SWAGMAN Farm (Salt Water And Groundwater MANagement). The SWAGMAN Farm model has been calibrated to provide an accurate and repeatable framework for estimating paddock-scale, or effectively a point source recharge estimate, and thus a suitable method for recharge property rights. The use of the SWAGMAN Farm model at the farm scale underpins the research reported in this paper.

The focus in this report is on how CIA farmers relate to the tradeable net recharge approach. Two aspects of farmer reactions are described. First, farmer reactions to a simulation trial of a net recharge market are reported. The simulation trial was constructed using an experimental setting comprising a set of representative farms in the CIA. The simulation trial was intended to identify farmer responses to a potential net recharge trading environment. The simulation trial was limited by the range of responses available to participants. Hence, a set of farm case studies was undertaken as an additional check on whether actual farm management responses to a net recharge cap matched the modelled changes.

The experimental setting was constructed based on the application of the SWAGMAN model to a set of Coleambally farms. This context rich experimental setting was designed to test recharge trading concepts using simplified yet realistic simulations of farm decision making. The experimental setting was previously used in laboratory settings to test hypotheses about alternative recharge market parameters (see the fourth report from this series “*Laboratory tests of alternative institutional frameworks*”). The simulation (or field) trial in this report was designed to allow landholders to experience the concepts of net recharge trading in a structured setting that they were able to relate to their own farm management decision-making processes. The setting was designed to facilitate comparison with laboratory experiments, but formal testing was precluded by differences in context and method.

The results from the simulation trial are broadly consistent with the laboratory experiments. The key result is the similar proportional reduction in total recharge in response to the introduction of communication as a coordination mechanism. The observed aggregate crop loss in the Yanco simulation trial control was substantially less than the laboratory control. This is consistent with expectations as Coleambally’s irrigators are familiar with the recharge issues.

The simulation trial, although realistic, represented a simplified decision making environment compared to the full range of decisions and tradeoffs facing Coleambally irrigators. Hence, a case study analysis was developed to gather additional information and ground-proof likely individual farmer responses to recharge reduction targets and credit trading opportunities.

Three farm case studies were undertaken. All of the case study participants are knowledgeable on the concepts of net recharge management and tradeable recharge contracts as a policy tool to achieve sustainable recharge in an irrigation region. The case study participants all had practical experience in the water market and thus experience in trading a similarly stochastic resource.

The irrigators involved in the case studies indicated broadly consistent strategies in response to a binding requirement to reduce recharge. Summer crops (such as rice and maize) were replaced with lower recharge crops such as winter cereals and lucerne. Participants recognised that variability in abatement costs together with a recharge market could deliver increased flexibility to their farm management activities. However, the additional complexity and potential difficulty in gaining community acceptance of net recharge trading was recognised as a major impediment to adoption. Finally, the case study participants supported use of SWAGMAN as a tool in farm scale management of net recharge.

It is important to note that the case study farms responses may not be representative of all Coleambally irrigators. In particular, farmers may be reluctant to substitute lucerne for other crops due to increased labour intensity, farm infrastructure constraints and personal management tastes.

The findings from the simulation trial and case studies support the conclusions drawn from laboratory tests, economic modelling and instrument design undertaken and reported elsewhere in this project.

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## Abbreviations

CIA	Coleambally Irrigation Area
NSW	New South Wales
CICL	Coleambally Irrigation Cooperative Limited
SWAGMAN	Salt Water And Ground Water Management Model
dS/m	DeciSiemens per meter

# 1. Introduction

This report is part of a series detailing the outcomes of research into the exploration and development of tradeable recharge rights as a tool to manage irrigation induced salinity in the Coleambally Irrigation Area (CIA) in south western New South Wales (NSW). This project is a pilot under the National Market Based Instruments Pilots Program. In this report we present the results of a simulation trial of a recharge market, and the attitude and crop management response of three case study farms to tradeable recharge credits if implemented in the CIA.

Irrigation induced salinity, caused by net recharge beyond system capacities, is a well known problem in mature irrigation areas across Australia and the CIA is no exception. The consequences of salinity in irrigation areas include production losses, increased production costs, and damage to environmental and infrastructure assets in the region. A number of instruments have been adopted to address the threat that irrigation induced salinity poses to Coleambally and other communities including regulatory approaches (such as the rice area quota), improved management tools (such as the SWAGMAN Farm management tool), and incentive programs (such as those included in Land and Water Management Plans). Each of these actions has had some success in reducing the incidence of irrigation-induced salinity but none has been wholly successful. Hence, the focus in this study has been on the development of a tradeable recharge credit mechanism within the CIA.

Tradeable recharge rights are a ‘cap-and-trade’ scheme. Under this type of policy instrument a limit or ‘cap’ is placed on the total allowable net recharge. Shares in the ‘cap’ are allocated to individual farmers who then must manage their enterprises within this cap or trade with others to enlarge their share. Through the creation and trading of these rights, greater efficiency, effectiveness and flexibility can often be achieved relative to other policy instruments.

Other reports in this series describe: the necessary steps to design and implement a tradeable recharge scheme (*What are the issues?*); compare the benefits of a tradeable rights scheme against other policies (*Economic impact of tradeable recharge credits and other net recharge abatement policies for the Coleambally Irrigation Area*); experimentally test alternative market structures (*Laboratory tests of alternative institutional frameworks*); and, most importantly, the biophysical modelling process necessary to set the cap (*Biophysical modelling for linking farms with regional net recharge targets*).

The focus in this report is on how CIA farmers relate to the tradeable net recharge approach. Two aspects of farmer reactions are described. First, farmer reactions to a simulation trial of a net recharge market are reported. The simulation trial was constructed using a set of representative farms in the CIA and was intended to identify farmer responses to a potential net recharge trading environment. The simulation trial was limited by the range of responses available to participants. Hence, a set of farm case studies was undertaken as an additional check on whether actual farm management responses to a net recharge cap matched the modelled changes. A secondary aim of the case studies was to assess the willingness of farmers to engage in recharge trading.

The report is structured as follows. In the next section additional background material and context to the simulation trial and farm case studies is provided including a summary of the recharge problem and biophysical modelling basis. The simulation trial undertaken at Yanco Agricultural College is reported in the third section. Three farm case studies are described in section four. A brief set of conclusions and outstanding issues completes the paper.

## 2. Background and context

### 2.1 Net recharge and net recharge measurement

Prior to irrigation, the watertables in the CIA were around 20 metres below the surface (Khan *et al.*, 2004). However, due to recharge from inefficient irrigation practices, leaky channels and recharge from rainfall in fallow paddocks, an increasing proportion of the CIA has watertables within 2 metres of the soil surface (Coleambally Irrigation Co-operative Limited (CICL), 2003). Shallow watertables induce waterlogging and salinity, both of which damage crop production, infrastructure and the environment. Current policies relating to recharge management have not been sufficient in abating net recharge to a sustainable level. As a consequence it is likely that the area and severity of waterlogging and salinity will increase in the CIA if further action is not taken.

Net recharge is a diffuse source problem to which cap-and-trade approaches have had limited application. Critical to the use of tradeable rights instruments is a robust scientific knowledge base. For many diffuse source problems it is difficult to attribute impacts to sources. However, the circumstances of irrigation management and research support in the Coleambally Irrigation Area suggested that it was possible to accurately and cost-effectively estimate paddock-scale recharge, and to establish and enforce a tradeable net recharge rights scheme.

Over recent years, the CSIRO Division of Land & Water in Griffith has developed several modelling techniques to inform and aid recharge management in the region. At the regional scale Khan *et al.* (2004) have derived net recharge targets at the regional level and for 5 sub-regional levels (zones) using MODFLOW and APSIM. At the farm scale is a state of the art farm level hydrological economic model, SWAGMAN Farm (Salt Water And Groundwater MANagement). The SWAGMAN Farm model has been calibrated to provide an accurate and repeatable framework for estimating paddock-scale recharge, and thus a suitable method for recharge property rights.<sup>1</sup>

Khan *et al.* (2004) have estimated that the current level of recharge for the CIA is approximately 55,000 MI and the level of sustainable recharge is approximately 30,000 MI. If the sustainable level of recharge becomes the cap, approximately 25,000 MI of net recharge needs to be abated per year. Therefore, on average, each farm in the CIA has to abate approximate 45% of their current recharge which equates to approximately 0.28 MI/ha/year. However, due to the different groundwater

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<sup>1</sup> More information about the biophysical modeling is provided in the 6<sup>th</sup> research report from this series: *Biophysical Modelling for Linking Farms with Regional Net Recharge Targets*.

conditions throughout the CIA, the recharge abatement required in the northern area of CIA is lower than that required in the central and southern areas. The recharge management targets in the simulation trial, and the farm case studies, are broadly based on these targets. More restrictive alternatives are also discussed in the farm level case studies to account for potential variation in individual caps, and the potential for exceeding individual targets in order to sell net recharge credits.

## **2.2 Designing and testing a net recharge market**

Management of net recharge has a number of similarities with other environmental markets, where the actions of a group of individuals or businesses are degrading a common property resource such as waterway or groundwater aquifer. Cap-and-trade schemes have proved both workable and efficient where the impacts have been of a point source nature. That is, the source and nature of impacts are readily observable and measurable, such as pollution discharges from a chimney or drain.

The major focus in this project has been the design and evaluation of an equivalent cap-and-trade scheme for diffuse source net recharge. Six critical design issues have been identified within this process including: defining net recharge rights, setting the overall cap, practical application in a stochastic climatic environment, allocation of the cap amongst stakeholders, setting relevant administration and trading rules, and monitoring and enforcement requirements (including penalties).

A context rich experimental setting was constructed in order to test the implications of alternative approaches to solving the design issues. The experimental setting used simplified yet realistic simulations of farm decision making and consisted of a simulated catchment constructed from model farm data for the region. The simulated catchment comprised twelve model farms based on a representative sample of farms from the CIA, with sizes ranging from 200 to 335 hectares. The SWAGMAN Farm model was used to estimate levels of income and recharge for each model farm under alternative crop mix and farm management options. In the laboratory experiments, participants were told they were playing the role of a farmer, and the shared nature of the recharge problem was explained.

The experimental setting was used to pre-test a number of alternative market designs that were prioritised from a set identified in Ward (2004). Solutions to the most important potential impediments were embedded into the experimental design. The embedded impediments were viewed as critical to any proposed field application, and therefore a necessary base for testing the effectiveness of alternative solutions. For example, some form of property rights is essential to any market-based solution. Other contextual factors were designed into the experiment. For example, experimental settings were based on real farm data, in part to identify the importance of relatively small proportional changes to farm income on market efficiency.

The experimental economics approach is useful to highlight potential aspects of policy design which may reduce its effectiveness. The application of experimental results can minimise the need for costly trial and error in real world policy implementation (Ward 2005). More detail on the experimental economics can be found in the 3<sup>rd</sup> and 4<sup>th</sup> reports from this series (*Designing Experiments to test tradeable recharge credits in the Coleambally Irrigation Area* and *Laboratory Tests of Alternative Institutional Frameworks*).

A number of conclusions were drawn from the experiments (Ward 2005):

- 1) Recharge information at the paddock scale is necessary to achieve effective management, but is unlikely to be sufficient in itself;
- 2) Providing a forum for communication resulted in significant decreases in total recharge and crop loss, and increased incomes. This suggests that face to face communication facilitates the formation of robust social contracts and reinforces informal social norms of reciprocity. Such institutions are attractive because they are entirely voluntary, and involve very low transaction costs;
- 3) Introduction of a recharge market reduced crop loss and increased incomes;
- 4) Introduction of an individual penalty (rather than a group penalty) caused the most dramatic reduction in recharge. This is to be expected, as the individual penalty eliminates the incentive to free ride.<sup>2</sup> Combined with the market institution, this treatment delivered the highest gains from trade. However, as in all the market treatments, gains from trade were still significantly lower than predicted by economic theory.

The laboratory experiments demonstrated that communication, market exchange and individual non-compliance penalties are all effective institutions for reducing recharge in the simulated catchment when combined with information from the SWAGMAN model.

The subsequent simulation (or field) trial that is one of the foci in this report was designed as an extension process to aid in familiarising irrigators with net recharge trading concepts and frameworks. The main goal of the trial was for landholders to experience the concepts of net recharge trading in a structured setting that they were able to relate to their own farm management decision-making processes. The trial was also structured to facilitate comparison with earlier laboratory experiments. The results of the trial are discussed in Section 3.

## 2.3 Net recharge caps and farm management decisions

The creation of an irrigation recharge cap-and-trade framework would create a number of costs and benefits to irrigators through changes to agricultural production, and the local and wider community through protection of infrastructure, biodiversity and reduction in potential negative downstream impacts. In particular, the imposition of a farm scale cap would lead to farm management changes in order to comply with the cap. SWAGMAN Farm incorporates the economic and environmental tradeoffs in adopting different land and water management options, and can help to decide

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<sup>2</sup> Where one person benefits from another's actions without contributing they are said to 'free ride'. A 'free rider' in the net recharge context is an individual who does not reduce their recharge while others do so.

sustainable irrigation intensities. These tradeoffs were the basis for the construction of the experimental setting and economic modelling.

The simulation trial was only able to incorporate five generic responses to the imposition of an individual recharge cap. While these responses were informed by the SWAGMAN model (and verified via stakeholder consultation), feedback before and during the simulation trial indicated some concerns about the SWAGMAN tradeoffs. Hence, the project team considered it prudent to further test the nature of the tradeoffs landholders would make.

A case study analysis was developed to identify how individual farmers would respond if they had to reduce recharge on their respective farms. Reducing recharge can be achieved through land use changes (that is, replacing recharging crops with discharging or low recharging crops) or by subsurface drainage and disposal options. However, preliminary analysis has indicated that subsurface drainage options are much more expensive than land use changes and therefore they have not been considered in the case study farm analysis.

The aim of the farm case studies was to conduct a detailed assessment of the impacts of a net recharge cap-and-trade framework on actual farm management decisions. A series of structured questions were posed to farmers to elicit the changes they would make to their management in order to meet specific recharge abatement targets. Using the information about crop management changes, the opportunity cost of abatement was calculated and the farmers were asked at what prices they would buy or sell recharge credits and whether they would be likely to participate in a market. The farm case studies also provided an opportunity for feedback on the use of the SWAGMAN Farm model in the context of a cap-and-trade environment. The results of the case studies are reported in section four of this report.

### **3. Simulation trial**

At the beginning of 2005, CIA farmers were invited to participate in a simulated on-ground trial of a market exchange of tradeable recharge credits.<sup>3</sup> The architecture of the recharge market, the provision of farm management information and subsequent levels of recharge and the coordination mechanisms were informed by the results of the laboratory experiments. At the conclusion of the recharge credit trading session, salinity reduction benefits and the cost effectiveness of the trial were evaluated.

#### **3.1 Trial setting and structure**

##### *3.1.1 Setting*

The experimental simulation and recharge credit trading environment was field demonstrated at Yanco Agricultural College, Yanco, on the 10<sup>th</sup> and 11<sup>th</sup> of February, 2005. Access to the student computer laboratory was provided by the College, the timing of the demonstration contingent on student commitments, farmer work schedules and coordinated in consultation with the College Registrar and CIA.

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<sup>3</sup> The simulation trial was a proxy to the on-ground recharge credit trading trial originally proposed in the project agreement. Prevailing drought conditions in the CIA and the consequent lack of demand for recharge credits precluded a meaningful and reliable on-ground trial.

The simulation trial was intended as an extension and ground proofing process. It was structured to familiarise irrigators with the inter-dependent nature of excess groundwater recharge, to promote acceptance of the reliability of the SWAGMAN recharge model, and enable irrigators to explore and experiment with recharge market structures and outcomes. The demonstrations also play an important collaborative role in providing a forum for irrigator discussion, shared innovation, and information provision about recent developments in recharge management.

The informal nature of field demonstrations such as the simulation trial does not comply with the experimental design requirements of a controlled setting and precludes the collection of reliable experimental data. That is, to ensure reliable analysis of treatment effects, a robust experimental design aims to keep all salient factors constant except the variable (or treatment) of interest. Farmer participation in the field trial was contingent on the revelation of additional contextual data, crop mix management strategies, and recharge outcomes not provided to student participants. Hence, the treatment environments of the field and laboratory experiments are not consistent, precluding formal statistical comparison and analysis. Despite these differences we would expect broadly similar responses from the different settings. Therefore, performance criteria of the Coleambally MBI field workshop is therefore restricted to graphic comparison of recharge and crop loss values.

An important departure from earlier field demonstrations was the introduction of a performance payment scheme, as opposed to the more traditional sitting fee. Student payments and crop loss penalties were scaled by a factor of four to approximate commensurate sitting fees for farmer participation in the recharge management workshop. Empirical results presented by Smith (2002) indicate there are no significant differences in behavioural responses to scaled payments for similar experimental treatments.

### *3.1.2 Participants and structure*

Thirteen irrigators from the Coleambally district participated in the MBI workshop including three CIA staff who are also irrigators. Dr John Tisdell of Griffith University and the CRC for Catchment Hydrology, and Dr John Ward of CSIRO Land and Water administered and supervised the simulation trial. The trial reinforced the shared nature of the recharge problem, the theme of cooperative solutions, the market familiarisation objective, and importantly, the aim of irrigator involvement in developed solutions.

A SWAGMAN demonstration and tutorial preceded the experimental sessions, a response to recommendations from the August 2004 field demonstration and collaborative workshop.<sup>4</sup>

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<sup>4</sup> From the Coleambally Milestone Report 3, September 2004: Recommendations from the field demonstration of August, 2004: "Widespread consensus for a combined two day SWAGMAN/ Market trading workshop. The reliability of the SWAGMAN model was generally not perceived nor recognised by participating irrigators. Improved recognition and adoption of the model would be enhanced by the combined workshop. In order to coordinate with farm management schedules, the majority of participants agreed the best time for the workshop was February, 2005".

Twelve computers at Yanco were employed as terminals and re-routed to the Griffith University experimental economics server via the internet. Each terminal screen represented a discrete farm in the central sub-catchment of the CIA, with specific farm income, cropping management and recharge characteristics. The data and farm decision variables are identical to those employed for the student experiments and are detailed in Appendix 3.

A two day simulated recharge trading scheme was initially planned. The design of the trial relied on insights from the laboratory experiments. Planning for the trial intended to introduce farmers to the control, market, communication, and market plus individual non compliance penalty treatments over two days. Laboratory insights outlined in the sections above indicated these treatments yielded the best prospects for high levels of recharge reduction associated with high levels of player income.

Farmer commitments restricted the trial to a one day workshop, inclusive of the SWAGMAN tutorial.<sup>5</sup> The high degree of farmer support for recharge trading and the protocols of experimental simulation expressed at the August 2004 workshop differed substantially from the February 2005.<sup>6</sup> In contrast, the workshop revealed high levels of scepticism towards market exchange of recharge units and the reliability of data interpretation contingent on the simplified decision making environment. A dominant theme expressed by several farmer participants was the need for an increasingly interactive farm management process, offering a contextually richer and expanded decision set, inclusive of water trading, irrigation decisions, and more precise crop management. Whilst an aspiration of the experimental research, the provision of participant determined and interactive experimental decision sets is beyond the computational capacity and data analyses available.

A protracted negotiation period explaining the computational limitations and the guarantee of objective data interpretation reduced available workshop time and resulted in rescheduling and reduction in the number of proposed experimental treatments. Time constraints restricted the workshop to a single 10 period control and a 10 period communication treatment.

### **3.2 Yanco simulation trial outcomes**

The total recharge and crop loss results of the control and communication treatments observed at the MBI workshop are compared graphically with the laboratory experiments in Figures 1 and 2. More detailed results including a statistical summary are provided in Appendix 4.

The results from the simulation trial are broadly consistent with the laboratory experiments. The key result is the similar proportional reduction in total recharge observed for both the Yanco and laboratory experiments when communication is

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<sup>5</sup> Coleambally Irrigation Cooperative Limited did not support initial plans for a longer workshop or multiple workshops due to pressing farmer consultations relating to upcoming Land and Water Management Plan revisions.

<sup>6</sup> Note from the Milestone report 3 re farmer attitudes at the August workshop: "Overall the irrigators present enthusiastically participated in the recharge trading demonstration, recognising the immediate need for remedial, shared recharge management. Importantly the cohort of irrigators represented those affected by increasing catchment recharge and rising groundwater and those from high recharge areas of the catchment. The demonstration provided a forum for constructive and vigorous discussion of the shared nature of catchment recharge and highlighted the social dilemma facing constituents".

introduced as a coordination mechanism compared to the control (a reduction of 16% and 11% respectively).

The observed aggregate crop loss in the Yanco simulation trial control was substantially less than the laboratory control. This is consistent with expectations as Coleambally's irrigators are familiar with the recharge issues and, as revealed in the initial field trial, displayed a greater degree of social acceptance of the need for and commitment to improved recharge management. It is unclear whether this is a result of (either individually or in combination) previous exposure to SWAGMAN, protest bids, heightened risk aversion or poorly understood experimental instructions on the part of Yanco participants. Crop loss did decrease with the introduction of the communication treatment however.

Figure 1: Impact of treatment on simulated recharge

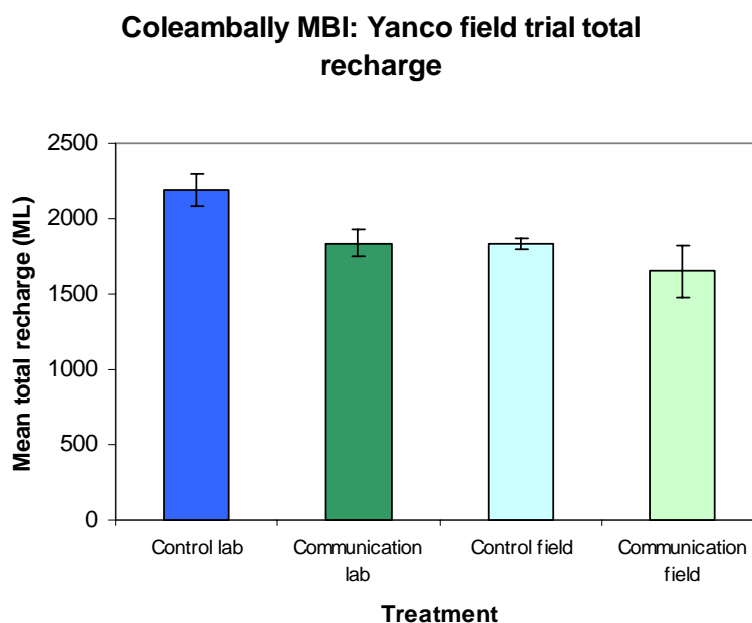
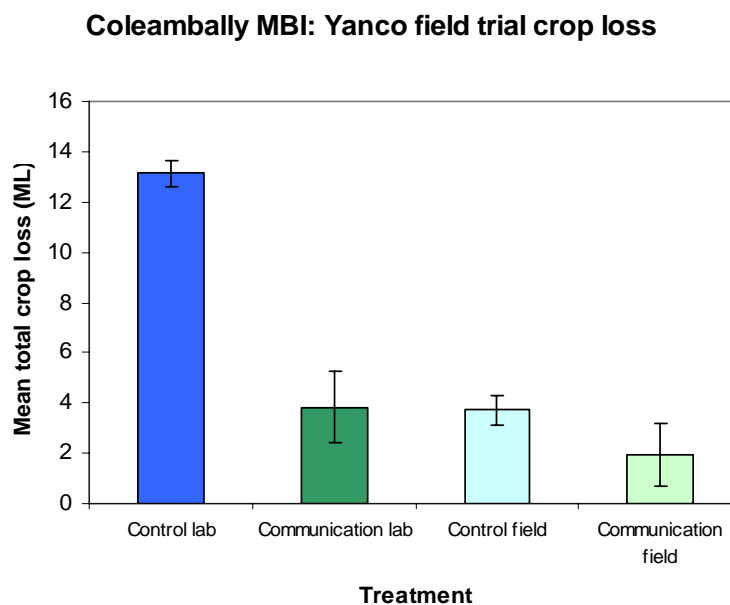


Figure 2: Impact of treatment on simulated crop loss



## 4. Farm case studies

### 4.1 Case study selection and structure

Three farm level case studies were conducted. The case study farms were selected on the basis that:

- The farmer had attended one of the experimental economics workshops so that they were familiar with the project and the concepts of both net recharge management and tradeable recharge credits;
- The farm was located in the southern half of the CIA where high watertables and associated problems are most prevalent and policy issues most pressing;
- The farmer was willing to be interviewed for approximately 3 hours; and
- There was substantial diversity between the farms selected.

The aim of the case studies was to determine farmer response in terms of land use change to meet specific recharge abatement targets on their respective farms. Using this information the opportunity cost of abatement was calculated and the farmers were asked at what prices the recharge credit would have to be for them to either buy or sell credits. This was achieved by following a questionnaire (shown in Appendix 1) and using the SWAGMAN Farm model to calculate net recharge and farm gross margins for the farmers' specified land use mix.

Each case study was structured around the following set of scenarios:

1. *Define base Scenario*: Calculate farm gross margin and net recharge for the farm's most likely crop mix assuming 80% allocation of total water entitlement (other modelling assumptions are summarised in Appendix 2).
2. *Recharge Abatement Scenario 1*: Calculate farm gross margin and net recharge for the farm's most likely crop mix to meet a net recharge target that is between 40% and 100% less than the net recharge calculated in the Base Scenario.
3. *Willingness to trade recharge* : Calculate the average abatement cost for Recharge Abatement Scenarios and using this information, discuss with the farmer if they would buy or sell recharge credits if the price of recharge credits was \$30/ML.<sup>7</sup>
4. *Recharge Credit Creation Scenario 2*: Calculate farm gross margin and net recharge for the farm's most likely crop mix to create recharge credits and discuss willingness to trade under this scenario.

A number of feedback questions were asked at the end of the session to gather additional insights into farm management decisions. Feedback questions included:

- The management issues that were considered when deciding on the crop mix to meet recharge targets (such as marketability of certain crops, expertise in growing certain crops, the ability or desire to own livestock); and

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<sup>7</sup> A recharge credit price of \$30 was selected based on modeled equilibrium prices of approximately \$38. See research report 3: 'Designing experiments to test tradeable recharge credits in the Coleambally Irrigation Area'.

- The farmer's experience in trading water, level of understanding of tradeable recharge credits as a policy tool to manage net recharge for the CIA, the farmer's attitude to the concept of tradeable recharge credits and what they think are the main advantages and disadvantages of such a policy (see questionnaire in Appendix 1).

## 4.2 Case study results

All farmers interviewed for the case studies had attended at least one of the experimental economics workshops. In these workshops the participants were given an overview of net recharge management, the concepts of tradeable net recharge credits, and flexibility of credit trading for net recharge management. All three farmers found the workshop informative and felt that it increased their understanding of net recharge management and tradeable recharge credits. However, one farmer said that the concept of tradeable recharge credits as a net recharge management tool probably raises more questions than it answers.

All farmers have participated in the water markets therefore have practical experience in trading a stochastic resource. All farmers have only bought water at this stage but would be prepared to sell water if water price exceeded the marginal benefit of using the water for agricultural production. All farmers calculated their marginal value of water before it was purchased. Given this experience, all farmers said they would be comfortable in trading net recharge credits.

### 4.2.1 *Farm A results*

Farm A has an area of 207 ha of which 173 ha is irrigable, with a water entitlement of 1,384 ML. The main soil types on the farm are red brown earths and transitional red brown earths with one small paddock of sandy loam.<sup>8</sup>

The owners of Farm A have removed rice production due to consistently high watertables causing salinity and waterlogging problems. The rice rotation has been replaced by lucerne and winter pastures for sheep with some winter crops (primarily as a break crop after the lucerne phase). Due to the low water allocations in the past three years, there has been enough water to produce the pasture required to carry sheep over summer. Therefore, store sheep are purchased, fattened on the pastures and sold off before summer. In higher allocation years, the farmer would consider maintaining a breeding flock over summer.

The farmer would run a crop rotation consisting of maize, lucerne hay (or intensive lamb fattening on lucerne pasture) and winter pasture under the base scenario (no recharge restrictions, 80% water allocation). This rotation was estimated to return a net income of \$102,579 and a net recharge level of 60 ML for the farm (Table 1).

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<sup>8</sup> For all farms it was assumed that groundwater outflow from the watertable was 0.25 ML/ha<sup>8</sup> and the watertable depth was 2 metres. Groundwater salinity is approximately 1.0 dS/m.

Given that the level of recharge for the farm is relatively low due to the high percentage of lucerne in the crop mix, the farmer was asked “what land use changes would be made if all recharge had to be abated?” as part of a new policy for the area. In response, maize was substituted with lucerne at an estimated cost of approximately \$17 per mega-litre of abated recharge (Table 1).

At a recharge credit market value of \$30/ML, the farmer indicated a willingness to substitute additional maize with lucerne and sell the recharge credits that would be created. For example, the farmer indicated a willingness to substitute a further 10 ha of maize with lucerne hay creating 52 recharge credits at an estimated abatement cost of \$19 per megalitre.

Table 1: Farm A land use response

	Base Scenario	Recharge Quota – 100% abatement	Recharge Credit Creation
Crop			
Maize (ha)	52	42	32
Lucerne hay (ha)	36	46	56
Winter pasture*	80	80	80
Fallow (ha)	23	23	23
Non arable (ha)	16	16	16
Total Area (ha)	207	207	207
Farm Gross Margin	\$100,479	\$100,538	\$100,596
Surplus Water Sales (@ \$30/ML)	\$2,100	\$1,050	
Net Income	\$102,579	\$101,588	\$100,596
Net Recharge (ML)	60	0	-52
Recharge Credits			52
Average Recharge Abatement Cost	n/a	\$17 /ML	\$19 /ML

\* Irrigation application for winter pasture was assumed to be 2 ML/ha.

The farmer believes that the main advantage of recharge trading is the potential for a significant positive impact for the CIA if the policy framework is kept simple and can be monitored accurately. However, the farmer believes that a recharge trading policy will be difficult to implement as he foresees that the policy will be complicated and therefore will be difficult to get community consensus. The farmer expressed particular concern that there would be complications in measuring and auditing recharge for each farm. The farmer believes the most appropriate deterrent for non-compliance by a farm not achieving a specific recharge target would be to restrict water supply in the following season. This is very similar to the penalty imposed on farmers who exceed their maximum rice area allowable in any one year.

The farmer believes that the SWAGMAN model is a useful education tool in determining land use options to manage net recharge for the farm. The model was a catalyst some years ago for the farmer in moving away from rice production due to the high recharging nature of the crop and its subsequent impact on the already high watertable.

#### 4.2.2 Farm B results

Farm B has an area of 320 ha of which 285 ha is irrigable, with a water entitlement of 1,598 ML. Approximately 80% of the farm consists of red brown earths and transitional red brown earths type soils with the remaining area being non-self mulching clays and sandy loams. The farm is a typical rice farm in the area incorporating a rotation comprising rice, winter cereals (including a cereal crop following rice in two thirds of the rice area), and pasture. Prior to the recent below average rainfall and low water allocations, the farm had a history of high watertables (less than 2 metres from the soil surface).

The farmer would run a crop rotation consisting of rice (maximum allowable area of 69 ha), wheat and barley under the base scenario (no recharge restrictions, 80% water allocation). Lucerne, dryland wheat and native pasture would be grown in the sandy loam areas. This rotation is estimated to return a net income of \$124,665 and a net recharge level of 85 ML for the farm (Table 2).

Under the scenario of zero abatement the farmer substituted rice with lucerne and wheat to achieve a zero net recharge outcome. The abatement cost to the farmer was estimated to approximately equal to \$153/ML of abated recharge (Table 2).

At a recharge credit market price of \$30/ML, the farmer would purchase recharge credits to maintain most or all of his rice area. As the abatement cost appeared high, some adjustments were made to crop areas to see if an alternative crop mix would meet the target of abating all recharge but at the same time reduce the cost of abatement. It was found that by substituting a smaller rice area with lucerne hay, the estimated cost of abatement could be lowered to approximately \$100/ML.

Table 2: Cropping response to recharge quota for Farm B.

	Base Scenario	Recharge Quota: 100% abatement	Recharge Credit Creation
Crop Area (ha)			
rice*	69	49	33
wheat	80	90	98
barley	40	40	40
barley after rice <sup>#</sup>	40	40	33
lucerne (agistment) <sup>^</sup>	10	20	35
dryland wheat	9	9	9
dryland pasture	31	31	31
fallow	26	26	26
non arable	15	15	15
Total Area (ha)	320	320	320
Farm Gross Margin	\$124,665	\$108,823	\$97,957
Surplus Water Sale (@ \$30/ML)	\$120	\$2,970	\$2,940
Net Income	\$124,785	\$111,793	\$100,897
Net Recharge (ML)	85	0	-78
Recharge Credits			78
Average Recharge Abatement Cost	n/a	\$153 /ML	\$140 /ML

\* Irrigation application for rice was assumed to be 12 ML/ha.

<sup>#</sup> Irrigation application for barley after rice was assumed to be 1 ML/ha.

<sup>^</sup> Gross margin for sheep agistment on lucerne is \$354 /ha.

For the final scenario, the farmer was asked to define a likely cropping mix that he would undertake to create recharge credits to sell in the market if the market price exceeded the abatement cost. In response, more rice area was substituted for lucerne hay and wheat to create 78 recharge credits for an estimated average abatement cost of \$140 /ML (last column in Table 2). In other words, the market price for recharge credits would have to exceed \$140 /ML before the farmer would consider creating recharge credits.

The farmer appreciates the recharge abating qualities of lucerne and would most likely graze the lucerne with agisted stock in preference to growing lucerne for hay. This is because the farmer is not particularly interested in looking after stock and the farmer believes that the market for lucerne hay is too volatile to consider entry.

The farmer believes that the main advantage of recharge trading as opposed to other regulatory measures is the potential for reducing cost of recharge abatement (via credit purchases). However, the farmer is aware that this will depend on the market for agricultural products. Also, any efficiency gains through reduced farmer abatement costs could be eroded if transaction costs are large. The farmer's main criticism of a recharge trading scheme is that he believes it will not be accepted by the majority of landholders in the CIA and could create division among the community if implemented. The farmer believes the most appropriate deterrent for non-compliance is a levy on excess recharge based on a sliding scale (that is, the greater the farm's excess recharge, the higher the levy per mega-litre).

The farmer believes that the SWAGMAN model is a useful education tool in determining land use options to manage net recharge for the farm.

#### 4.2.3 *Farm C results*

Farm C has an area of 223 ha of which 180 ha is irrigable, with a water entitlement of 1,224 ML. The farm mainly consists of a transitional red brown earth soil type and a small percentage of red brown earths. The farm is a typical rice farm with a crop rotation incorporating rice, winter cereals (including a wheat crop following rice), and pasture. Prior to the recent below average rainfall and low water allocations, the farm had a history of high watertables (less than 2 metres from the soil surface).

The farmer would run a crop rotation consisting of rice (maximum allowable area of 70 ha), wheat after rice and dryland pasture under the base scenario (no recharge restrictions, 80% water allocation). The rotation chosen by the farmer is dominated by rice because the farmer has an additional block of land that is primarily used for winter crops (which has not been considered within this analysis). The rotation is estimated to return a net income of \$94,757 and net recharge of 235 ML for the farm (Table 3).

The farmer was then given the task of choosing a crop mix under a net recharge policy requiring abatement of 40% of current net recharge. In response, 93 ML of net recharge was abated by substituting rice with lucerne and increasing the proportion of the rice area on which wheat was grown immediately following the rice crop. Recharge abatement on this farm was estimated to increase the net return for the farm equivalent to approximately \$11 /ML of abated recharge (Table 3). This is because the

net return for the new crop mix was greater than the net return of the crops that were substituted. This is an ideal situation where net recharge management has improved farm profitability as well as the environment.

Table 3: Cropping response to recharge quota for Farm C

	Base Scenario	Recharge Quota: 40% abatement	Recharge Quota: 57% abatement	Recharge Quota: 100% abatement
Crop Area (ha)				
rice*	70	56	50	35
wheat after rice <sup>#</sup>	35	56	50	35
lucerne hay		14	20	35
wheat				21
dryland pasture	86	65	71	65
fallow	25	25	25	25
non arable	7	7	7	7
Total Area (ha)	223	223	223	223
Farm Gross Margin	\$94,757	\$95,744	\$93,101	\$90,578
Surplus Water Sale (@ \$30/ML)			\$450	
Net Income	\$94,757	\$95,744	\$93,551	\$90,578
Net Recharge (ML)	235	142	100	0
Marginal abatement cost	n/a	-\$11 /ML	\$52 /ML	\$30 /ML

\* Irrigation application for rice was assumed to be 13.5 ML/ha.

<sup>#</sup> Irrigation application for wheat after rice was assumed to be 1 ML/ha.

Two additional recharge target scenarios were undertaken to determine the average abatement cost for different levels of recharge. For a recharge target equal to 57% of current net recharge, 6 ha of rice and wheat-after-rice area was substituted with lucerne hay and dryland pasture. This crop mix reduced modelled recharge by an additional 42 ML (column 4, Table 3). The average abatement cost was estimated to be \$52 /ML. The breakeven price for recharge credits decreased to an average of \$36 /ML under the farmers preferred crop mix when the recharge target was equal to abating all current net recharge.

The farmer was aware of the recharge abating qualities of lucerne and wheat-after-rice and used this as the main consideration when alternative crop mixes were needed to lower farm net recharge.

The farmer believes that the main advantage of recharge trading is the potential for more flexibility in crop choices to achieve recharge targets. The farmer's main criticism of a recharging trading scheme is that if the recharge credits are not available for sale then the trading scheme will fail. The farmer believes the most appropriate deterrent for non-compliance by a farm not achieving a specific recharge target would be to impose a cost on the farm greater than the value of the recharge credits. However, the system should be sufficiently flexible so that if recharge targets for a particular farm are not achieved in one year, the farmer has the option to make up the shortfall in the following year in addition to meeting the annual recharge target. Likewise, unused credits could be carried over into the following year.

As in previous case studies the SWAGMAN Farm model was believed to be a useful education tool in determining land use options to manage net recharge for the farm.

## 5. Discussion and conclusions

Current recharge management policies in the CIA have not been sufficient in abating net recharge to a sustainable level. As a consequence there is a significant risk that the area and severity of waterlogging and salinity will increase within the CIA if further action is not taken. In this report we describe the findings from a simulation trial of a recharge credit market, and the farm management response to differential recharge abatement requirements for three case study farms.

The results from the simulation trial are broadly consistent with the laboratory experiments previously undertaken in this project, although the simulation trial appears to outperform the laboratory setting. A similar reduction in total recharge was observed for both the Yanco and laboratory experiments when communication was introduced as a coordination mechanism. The observed aggregate crop loss in the Yanco simulation trial control was substantially less than the laboratory control. This is consistent with expectations as Coleambally irrigators are familiar in broad terms with recharge issues and can be expected to have a greater degree of social acceptance of the need to change management, as well as a commitment to change management through acceptance of existing land and water management plans.

In contrast to the prior field test of the experimental recharge trading environment, irrigator attitudes at the simulation trial revealed high levels of scepticism towards market exchange of recharge units and the reliability of data interpretation contingent on the simplified decision making environment. A dominant theme expressed by several farmer participants was the need for an increasingly interactive farm management process, offering a contextually richer and expanded decision set, inclusive of water trading, irrigation decisions and more precise crop management. Concern about the accuracy of the SWAGMAN model will need to be addressed by CICL should a decision be made to proceed with development of a recharge market. However, SWAGMAN offers a much richer conceptual environment for stakeholder engagement thus overcoming most farm scale concerns. This conclusion was supported by the farm case studies.

Three farm case studies were undertaken following the simulation trial in order to conduct a detailed assessment of the impacts of a net recharge cap-and-trade framework on actual farm management decisions. All of the case study participants are knowledgeable on the concepts of net recharge management and tradeable recharge contracts as a policy tool to achieve sustainable recharge in an irrigation region. The farmers had previously attended either the field test or simulation trials at Yanco and found these workshops informative and increased their understanding of net recharge management and tradeable net recharge contracts. The case study participants had also traded water, thus endowing them with practical experience in trading a resource. Given this experience, all farmers said they would be comfortable in trading net recharge credits.

General conclusions from the three farm case studies were:

- A consistent abatement strategy was to replace recharging summer crops (rice, maize) with discharging crops (lucerne, winter cereals). This was based on recognition that lucerne and cereal crops following rice have the greatest recharging abatement potential. All participants were comfortable in making this change if required to meet a recharge cap;
- All participants recognised the variability in abatement cost attributed to different crop mixes;
- All participants would consider crop management strategies to create recharge credits if the market value of credits was greater than the cost of abatement;
- All participants considered there to be significant advantages and disadvantages to tradeable recharge arrangements (for example increased flexibility in recharge abatement versus complexity of measurement of net recharge outcomes);
- Participants supported monetary penalties or reductions in water supply the following year for non-compliance with recharge requirements; and
- The participants indicated the SWAGMAN Farm model is a useful tool in determining farm scale net recharge management options.

It is important to note that although the case study farms opted to substitute lucerne for rice or maize to abate recharge this may not be the case on other farms. Farmers may be reluctant to grow lucerne because it is labour intensive, the farm lacks infrastructure for stock grazing (many farms have removed fencing), some farmers do not wish to manage livestock, or the difficulty and concerns about entering the hay market (including lack of machinery or contractors, and market volatility).

Overall, the simulation trial and case studies support the research undertaken in previous reports in this series. In particular, the simulation trial supports the conclusions drawn from laboratory experiments with respect to the importance of information in managing net recharge within the region. The farm case studies indicate changes to land use that are consistent with the SWAGMAN Farm model. Hence, the case study conclusions support the economic modelling which was based on economic optimisation using the SWAGMAN Farm model. Penalty suggestions from case study participants are also consistent with the attention to monitoring and enforcement issues in instrument design and the results of the imposition of individualised penalties within the laboratory experiments.

## References

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Ward, J. (2004) *Designing Experiments to test tradeable recharge credits in the Coleambally Irrigation Areas*, Tradeable recharge credits in Coleambally Irrigation Area 4<sup>th</sup> report, CSIRO.

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## Appendix 1: Questionnaire – Farm management change to recharge abatement policy

### Background

Name: \_\_\_\_\_

Farm No: \_\_\_\_\_

Farm Area: Irrigation \_\_\_\_\_ ha

Dryland \_\_\_\_\_ ha

Fallow \_\_\_\_\_ ha

Non-arable \_\_\_\_\_ ha

Maximum Water Entitlement (100% Allocation): \_\_\_\_\_ ML

Water Price: \$6.61 /ML

Soil Type: SMC \_\_\_\_\_ ha

NSMC \_\_\_\_\_ ha

RBE \_\_\_\_\_ ha

TRBE \_\_\_\_\_ ha

SAND \_\_\_\_\_ ha

Groundwater Salinity: \_\_\_\_\_ dS/m (derive from map)

Deep Leakage: \_\_\_\_\_ ML/ha/yr (derive from map)

Watertable depth: \_\_\_\_\_ m (derive from map)

### Scenarios:

	Allocation (%)	Water Market (\$/ML)	Recharge Reduction Quota (%)	Recharge Credit Value (\$/ML)
1	80	30	40	30
2	80	30	70	30
3	80	30	100	30

**Water Trading**

1. Have you traded in the water market?  Yes (Go to Q4)  No

2. If No, would you trade water if the water price was acceptable?

Yes (Go to Q4)  No

3. If No, why not?

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Go to Q6)

4. How do you determine your water purchase price?

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5. How do you determine your water selling price?

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**Recharge Credit Trading**

6. Are you familiar with the “Tradeable net recharge contracts in the CIA” project being conducted by CSIRO in conjunction with CICL?

Yes  No

7. Are you familiar with the concept of how a tradeable net recharge contract policy would operate in relation to net recharge management?

Yes  No

8. Have you attended any “recharge trading” workshops?

Yes  No

If Yes, did you find the workshop informative and increase your understanding of net recharge management and tradeable net recharge contracts?  Yes  No

**Conduct modelling exercise with SWAGMAN Farm**

**Scenario 1: Recharge quota imposed equal to 40% of current net recharge (base scenario)**

**Assumptions**

80% allocation,  
average crop returns,  
sell surplus water @ \$30/ML,

Crop	Gross Margin (\$/ha)	Business as Usual (Base Scenario)		Recharge Quota	
		Area (ha)	Gross Margin (\$)	Area (ha)	Gross Margin (\$)
Rice	1,026				
Maize	819				
Soybean	527				
Lucerne Hay	789				
Wheat	229				
Barley	188				
Canola	253				
Fababean	196				
Pasture	212				
Dryland Pasture	60				
Dryland Wheat	85				
Fallow					
Total Gross Margin		ha	\$	ha	\$
Water Sales	@ \$ /ML	ML	\$	ML	\$
Net Income			\$ <sub>(a)</sub>		\$ <sub>(b)</sub>
Net Recharge			ML <sup>(c)</sup>		ML <sup>(d)</sup>
AVG Recharge Abatement Cost				$\frac{(a-b)}{(c-d)}$	\$ /ML

Would you consider recharging even less than the above restriction quota, and sell the remaining recharge 'credit' for \$30/ML??  Yes  No

If No, at what price would the recharge credits need to be for you to consider

(a) abating recharge on your farm greater than the quota \$ \_\_\_\_\_ / ML

(b) abating all recharge \$ \_\_\_\_\_ /ML

**Scenario 2: Recharge Credit Creation: Recharge quota imposed equal to 70% of base scenario**

**Assumptions**

80% allocation,  
average crop returns,  
sell surplus water @ \$30/ML,  
recharge credit value @ \$\_\_\_\_\_/ML

Crop	Base Case	Strategy 1: Credit Creation	
	Gross Margin (\$/ha)	Area (ha)	Gross Margin (\$)
Rice	1,026		
Maize	819		
Soybean	527		
Lucerne Hay	789		
Wheat	229		
Barley	188		
Canola	253		
Fababean	196		
Pasture	212		
Dryland Pasture	60		
Dryland Wheat	85		
Fallow			
Total Gross Margin		ha	\$ <sup>(t)</sup>
Water Sales	@ \$ /ML	ML	\$ <sup>(g)</sup>
Recharge Credit Sales		ML	\$
Net Income	\$ <sup>(a)</sup>		\$ <sup>(w)</sup>
Net Recharge	ML <sup>(c)</sup>		ML <sup>(y)</sup>
AVG Recharge Abatement Cost		$\frac{(a-w)}{(c-y)}$	\$ /ML
Breakeven Value for Recharge Credit		$\frac{(a-f-g)}{(c-y)}$	\$ /ML

### Scenario 3: Total Recharge Abatement

#### Assumptions

80% allocation

average crop returns,

sell surplus water @ \$30/ML

recharge credit value @ \$\_\_\_\_\_/ML

Crop	Base Case	Strategy 2: Total Recharge Abatement	
	Gross Margin (\$/ha)	Area (ha)	Gross Margin (\$)
Rice	1,026		
Maize	819		
Soybean	527		
Lucerne Hay	789		
Wheat	229		
Barley	188		
Canola	253		
Fababean	196		
Pasture	212		
Dryland Pasture	60		
Dryland Wheat	85		
Fallow			
Total Gross Margin		ha	\$ <sup>(h)</sup>
Water Sales	@ \$ /ML	ML	\$ <sup>(i)</sup>
Recharge Credit Sales		ML	\$
Net Income	\$ <sup>(a)</sup>		\$ <sup>(x)</sup>
Net Recharge	ML <sup>(c)</sup>		ML <sup>(z)</sup>
AVG Recharge Abatement Cost		$\frac{(a-x)}{(c-z)}$	\$ /ML
Breakeven Value for Recharge Credit		$\frac{(a-h-i)}{(c-z)}$	\$ /ML

**Complete modelling exercise before answering these questions**

**Recharge Trading – continued**

9. Would you consider trading recharge credits?  Yes  No

If No, why not?

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10. What do you think are the main advantages of recharge trading as opposed to other regulatory measures as a net recharge management policy for CIA?

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11. What do you think are the main disadvantages of recharge trading as opposed to other regulatory measures as a net recharge management policy for CIA?

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12. What do you think would be an adequate penalty for farms that do not comply in meeting a recharge quota?

- Imposing a levy on water used in the irrigation season (approx. amount \$\_\_\_\_\_/ML)
- Restricting water supply in the following irrigation season (approx amount \_\_\_\_\_%)
- Imposing a fine (approx amount \$\_\_\_\_\_)
- No penalty but offer a reward scheme for compliance (eg lower water cost)
- Other

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13. Comment on the usefulness of the SWAGMAN Farm model as a tool to assist in developing land use management options to meet a recharge quota?

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*The CSIRO and CICL project team would like to thank you very much for your time and invaluable input into the “Tradeable net recharge contracts in the CIA” project.*

## Appendix 2: Crop water use and gross margin assumptions

### Crop Water Use (ML/ha)

	SMC	NSMC	TRBE	RBE	SAND
Rice	12.5	12.5	12.5	12.5	14.4
Maize	8.5	8.5	8.5	8.5	9.8
Soybean	8	8	8	8	9.2
Lucerne Hay	12	12	12	12	13.8
Wheat	2.5	2.5	2.5	2.5	2.9
Barley	2.2	2.2	2.2	2.2	2.5
Canola	3	3	3	3	3.5
Fababean	3.5	3.5	3.5	3.5	4
Pasture	3.5	3.5	3.5	3.5	4
Dryland Pasture	0	0	0	0	0
Dryland Wheat	0	0	0	0	0

### Crop Gross Margin (\$/ha)

	Price (\$/t)	Yield (t/ha)	Variable Costs* (\$/ha)	\$/ha*	\$/ha	\$/ML
Rice	207	9.5	730	1237	1026	82
Maize	180	10	838	962	819	96
Soybean	389	2.8	427	662	527	66
Lucerne Hay	150	15	1259	991	789	66
Wheat	130	5	379	271	229	92
Barley	140	4	335	225	188	85
Canola	318	2.7	555	304	253	84
Fababean	220	4	625	255	196	56
Pasture	30	12	89	271	212	61
Dryland Pasture	30	2	0	60	60	
Dryland Wheat	130	2.5	240	85	85	

\* water costs not included

### Water Price (\$/ML)

Water Price	6.61
Water Sale	30.00

### Appendix 3: Income, crop mix and recharge of 12 farms in the simulated catchment

						Crop Type (ha)											
Farm	Farm Crop Mix	Water Table rise (m)	Surplus water (MLs)	GM (\$)	recharge (MLs)	rice	maize	hay	lucerne	wheat	canola	wheat	dryland pasture	fallow	TOTAL (ha)	Total water use (MLs)	
1	1	max		106417	200	69	22			56		45	9	22	224	1158	
	2	0.3		104442	150	64	22	17				45	53	22	224	1162	
	3	0		100532	63	40	22	22		93		24		22	224	1172	
	4	-0.1		98382	34	33	22	22		112	12			22	224	1171	
	5	-0.25		95041	0	26	22	22	10	112	9			22	224	1078	
2	1	max		103965	228	69	20	3		48		40		20	200	1154	
	2	0.4	0	101180	160	56	20	13		66	0	25		20	200	1163	
	3	0.2	33	95333	104	57		11		52	60			20	200	1126	
	4	0	223	86041	44	39		10		71	60			20	200	946	
	5	-0.15	366	79071	0	25		10		85	60			20	200	813	
3	1	max		106706	180	69	22			59		45	6	22	223	1163	
	2	0		106363	170	69	22	4		39		45	22	22	223	1161	
	3	-0.3		104321	111.5	62	22	19				45	52	22	222	1159	
	4	-0.5		102584	62	50	22	22		46		45	15	22	222	1166	
	5	-0.758		98751	0	46	8	22		112		12		23	223	1164	
4	1	max		105687	246	69	22			57		44	5	22	219	1158	
	2	0.2		104165	201	66	22	15				44	49	22	218	1159	
	3	0		102562	155	58	22	22		7		44	43	22	218	1165	
	4	-0.325		96292	56	35	16	22	2	56	66			22	219	1158	
	5	-0.472	101	90073	0	57	22	21		20		44	32	22	218	1173	
5	1	0		119547	227	69	34			46		67	87	33	336	1232	
	2	-0.2		117472	166	63	34	16				67	122	33	335	1237	
	3	-0.3		116206	132	57	34	22				67	122	33	335	1237	
	4	-0.5		112048	31	25	34	19		167	7	50	0	33	335	1256	
	5	-0.571		109714	0	15	34	18		167	53	15		33	335	1262	
6	1	max		105396	220	69	22	9		15		44	37	22	218	1161	
	2	0.2		100901	148	61	11	13		67		44		22	218	1149	
	3	0		95038	97	56		11		99	26	4		22	218	1130	
	4	-0.2	152	86605	38.5	39		9		82	66			22	218	979	
	5	-0.4	274	80811	0	28		9		94	66			22	219	877	

						Crop Type (ha)										
Farm	Farm Crop Mix	Water Table rise (m)	Surplus water (Mls)	GM (\$)	recharge (Mls)	rice	maize	lucerne hay	lucerne	wheat	canola	dryland wheat	dryland pasture	fallow	TOTAL (ha)	Total water use (MLs)
7	1	max		106619	221	69	22			58		45	8	22	225	1163
	2	0		103107	123	55	22	22		19		45	38	22	224	1162
	3	-0.2		99874	68	42	22	22	5	65		45		22	224	1121
	4	-0.4		95983	24	43	12	22	12	69		45		22	225	1055
	5	-0.495		92897	0	46		22	15	35	40	44		22	224	1024
8	1	max		105619	229	69	22			56		44	5	22	218	1155
	2	0.2		104059	177	66	22	15				44	50	22	219	1159
	3	0		102116	124	55	22	22		22		44	31	22	218	1166
	4	-0.2		98931	72	43	22	22	5	60		44		22	218	1117
	5	-0.491		93251	0	35	12	22	12	109		7		22	219	1059
9	1	0.5		105332	221	69	21	2		54		42		21	209	1166
	2	0.15		103852	172.8	66	21	16				42	43	21	209	1163
	3	0		102753	141	61	21	21		2		42	41	21	209	1168
	4	-0.3		99129	75.5	46	21	21	6	52		42		21	209	1113
	5	-0.649	25	91729	0	25	21	21	12	46	63			21	209	1035
10	1	max		103751	244	69	21			49		43	11	21	214	1129
	2	0.2		102212	192	66	21	14				43	49	21	214	1139
	3	0		99218	131	47	21	14				19		21	214	1141
	4	-0.2	67	92102	56	48		11		69	64			21	213	1073
	5	-0.381	251	83143	0	30		11		88	64			21	214	904
11	1	max		97758	196	57	32					64	134	32	319	956
	2	0		97198	180	54	32	3				64	134	32	319	956
	3	-0.2		94881	113.5	43	32	15				64	133	32	319	968
	4	-0.4		92564	46.5	32	32	26				64	133	32	319	968
	5	-0.532		90740	0	21	32	32		28		64	110	32	319	978
12	1	max		105687	246	69	22			57		44	5	22	219	1158
	2	0.2		104165	201	66	22	15				44	49	22	218	1159
	3	0		102562	155	58	22	22		7		44	43	22	218	1165
	4	-0.325		96292	56	35	16	22	2	56	66			22	219	1158
	5	-0.472	101	90073	0	57	22	21		20		44	32	22	218	1173

## Appendix 4: Detailed statistical results from simulation trial

Figure A4.1: the value of total recharge of the control and communication treatments for the laboratory and field experiments

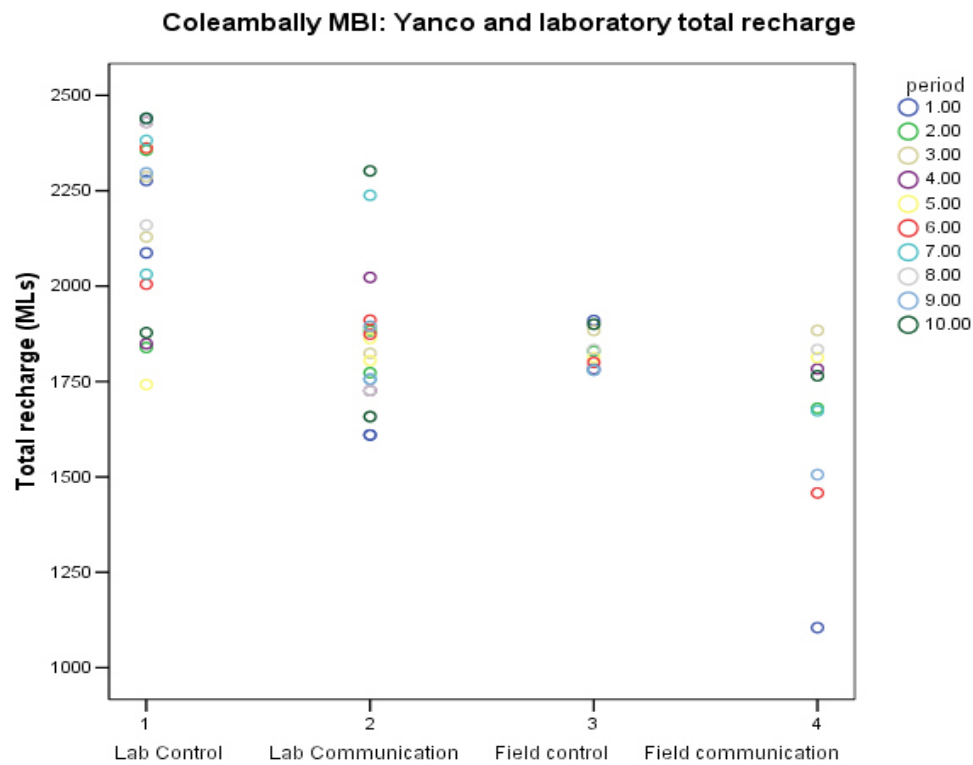


Figure A4.2: aggregate crop loss values comparing the control and communication treatments of the laboratory and field experiments

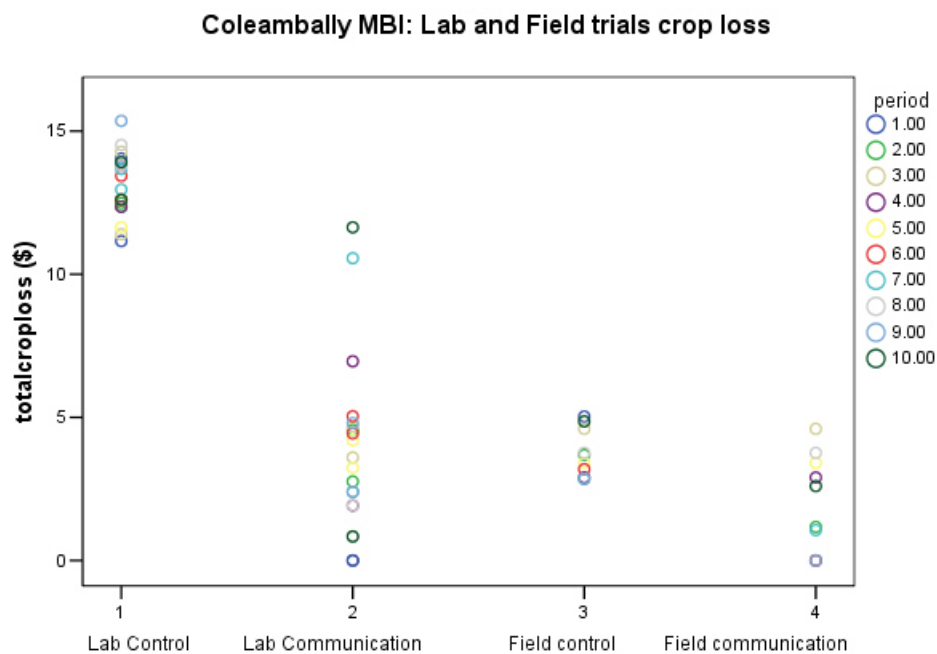


Table 4: Description of the mean and variance of total recharge and crop loss observed in the control and communication treatments in the laboratory and MBI workshop

<b>DESCRIPTIVES</b>								
<b>Total recharge</b>								
<b>95% Confidence Interval for Mean</b>								
	<b>N</b>	<b>Mean</b>	<b>Std. Deviation</b>	<b>Std. Error</b>	<b>Lower Bound</b>	<b>Upper Bound</b>	<b>Minimum</b>	<b>Maximum</b>
<b>Lab control</b>	20	2189.15	229.92751		2081.54	2296.745	1742.00	2440.00
<b>Lab comm'n</b>	20	1839.15	183.20948		1753.41	1924.89	1610.00	2302.00
<b>Field control</b>	10	1831.40	50.12252		1795.55	1867.26	1780.00	1910.00
<b>Field comm'n</b>	10	1650.10	236.20822		1481.12	1819.07	1105.00	1884.00
<b>Total</b>	60	1923.02	277.79266		1851.26	1994.78	1105.00	2440.00
<b>DESCRIPTIVES</b>								
<b>Crop loss</b>								
<b>95% Confidence Interval for Mean</b>								
	<b>N</b>	<b>Mean</b>	<b>Std. Deviation</b>	<b>Std. Error</b>	<b>Lower Bound</b>	<b>Upper Bound</b>	<b>Minimum</b>	<b>Maximum</b>
<b>Lab control</b>	20	13.1460	1.10427		12.6292	13.6628	11.16	15.36
<b>Lab comm'n</b>	20	3.8400	3.081380		2.3979	5.2821	.00	11.64
<b>Field control</b>	10	3.7140	0.84033		3.1129	4.3151	2.85	5.03
<b>Field comm'n</b>	10	1.9500	1.71798		0.7210	3.1790	.00	4.60
<b>Total</b>	60	6.6060	5.11786		5.2839	7.9281	.00	15.36