45th Annual Conference of the Australian Agricultural and Resource Economics Society
Adelaide, South Australia, 22-25 January 2001

MEETING THE MDBC CAP IN THE BARWON-DARLING RIVER[1]

Cordina, D[2], Brill, T[3] and Crean, J[2]

Reform to the Australian water industry has received considerable attention in recent years. This can be partly attributed to growing community concerns about environmental degradation, increasing competition from extractive water users and greater focus by governments on micro-economic reform. One of the key reforms shared across a number of States is the implementation of the Murray-Darling Basin Commission's Cap on irrigation diversions.

In recent years, the Cap for the Barwon-Darling River has been exceeded and there is pressure on the NSW Government to address the situation. The purpose of this paper is to review some of the issues associated with Cap implementation in the Barwon-Darling River and to discuss the methodology being used to assess the farm level economic impacts of alternative options proposed to achieve Cap. The paper provides an overview of alternative approaches to achieve Cap, the development of representative farm models to assess agricultural effects and a description of some preliminary results of our analysis.

Key words: Water reforms, MDBC Cap, Barwon-Darling River

[1] The views expressed in this paper are those of the authors and not necessarily those of NSW Agriculture.
[2] Economist, NSW Agriculture, Orange
[3] Resource Management Officer, NSW Agriculture, Dubbo

1. Introduction

Historically, the allocation of water for irrigation purposes was based on priorities of State development, rather than on economic efficiency or sustainability criteria. Such priorities included encouraging closer settlement of irrigation areas, broadening the agricultural base and furthering regional development. The negative consequences of pursuing these priorities have become more evident in the 1990's with widespread evidence that the health of many river systems across Australia were in significant decline as a result of increased extractions and river regulation.

These issues are common to the Murray-Darling Basin which covers most of inland south-eastern Australia and includes much of the country's best agricultural land. The use of the Basin's water resources for irrigation has underpinned further agricultural development particularly in the western portion of the Basin. Since the 1950's, water diversions from the Basin's water ways have steadily increased resulting in significant changes to river flows.

Concerns about further increases in irrigation diversions, a deterioration in the riverine environment and the erosion of security of water supply to existing irrigators, led to a decision by the Murray Darling Basin Ministerial Council to place an interim cap on diversions in 1995. This was later confirmed as a permanent Cap in 1997. The Ministerial Council defined the Cap as the volume of water that would have been diverted under 1993-94 levels of development. For NSW and Victoria, the Cap in any year is the volume of water that would have been used with the infrastructure (dams, channels, pumps, developed irrigation areas) and management regimes that existed in 1993-94, assuming similar climatic and hydrologic conditions to those experienced in the year in question.

The Cap, while not officially linked to the broader COAG water reform framework, was introduced around the same time and is consistent with its principles in respect to the need to re-balance instream and consumptive water uses. The Cap applies to all rivers within the Basin and individual States are responsible for its implementation. In recent years, NSW has been called to account for possible breaches of the Cap in the Barwon-Darling catchment. Initial estimates by the MDBC's Independent Audit Group suggest that the Barwon-Darling was approximately 11per cent over the estimated MDB Cap in the 1998/99 season (IAG, 1999).

In NSW, water management committees (WMC's) were set up in all river valleys as part of the Government's community based approach to water management. An important task for the Barwon-Darling River Management Committee (BDRMC) is to develop a diversion regime that is consistent with Cap objectives. In this respect, the focus of the Committee is on the cost-effectiveness of options rather than cost-benefit analysis given that a higher level decision on the significance of the Basin scale environmental benefits has already been taken. Hence, BDRMC's main objective in relation to Cap is to develop long-term management strategies to achieve Cap whilst minimising the economic impacts of limiting diversions to Cap levels.

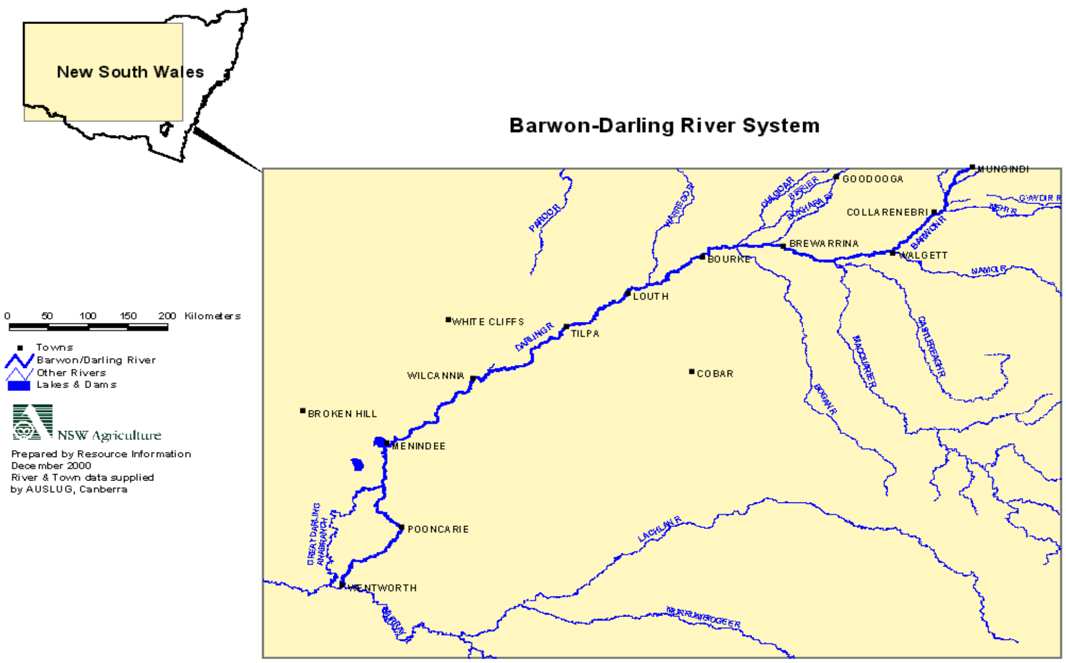
The objective of this paper is to outline some of the issues requiring consideration in developing an approach to Cap implementation in the Barwon-Darling River. The paper reviews some of the progress made by BDRMC in this area, discusses some of the equity and efficiency issues inherent in cap implementation strategies, outlines the methodology used and discusses some preliminary results on the nature of agricultural trade-offs involved.

2. The Barwon-Darling Region

2.1 Overview

The Barwon-Darling River is located in the north-west of NSW (Figure 1). The Barwon River begins at Mungindi on the NSW/Queensland border and flows south-westerly through Walgett and Brewarrina to the confluence of the Bogan and Culgoa Rivers, east of Bourke, where it feeds the Darling River. The Darling River flows through the township of Bourke then across the NSW outback before flowing into the Menindee Lakes, after which it flows into the Murray River at Wentworth[4].

Figure 1: The Barwon-Darling River



2.2 Irrigated agriculture

The Barwon-Darling region experiences the lowest and most unreliable rainfall for any irrigation region in New South Wales (CMWG, 1999). This, combined with high evaporation rates, makes soil moisture a major limiting factor for plant growth and hence for productive dryland agriculture in the region. In recent decades, irrigation has been introduced to overcome the soil moisture deficiency and in return has become a major contributor to the total value of agricultural production in the region.

Traditionally, land use in the catchment has been dominated by grazing activities with some areas of dryland cropping in the north-eastern parts of the catchment. This has changed over the last 15 years with the rapid expansion of irrigation. There are 216 irrigation licenses

[4] The Lower Darling River (below Minindee lakes) is regulated by the lakes and currently has a separate Cap to the rest of the Barwon-Darling River (pers. comm. Sheridan Maher, DLWC).

issued on the unregulated river, irrigating almost 26,000 hectares in the 1999/2000 season. The predominant irrigation activity in the Barwon-Darling catchment is cotton production based mainly on flood/furrow systems.

Despite the rapid growth in diversions in recent years, overall diversions are still well below licensed volumes. The volume of irrigation diversions in 1998-99 was in the order of 250GL compared to the total volume of A, B and C class licences[5] in the system of around 520 GL. The number of sleeper (totally inactive) and dozer (partially active) licences on the river suggest that there is significant potential for further development in the absence of controls. This is a different situation to most regulated river systems in NSW where a large proportion of development has already occurred.

Being an unregulated river, flows in the Barwon-Darling are both irregular and unpredictable. Irrigation farms have responded to these conditions through significant investments in high capacity pumps to access irregular flows, and on-farm storages to store water to improve the reliability of water supplies during the irrigation season.

2.3 Environmental issues

A number of local river health issues, relating to the sharing of water between instream and consumptive uses, have arisen in the Barwon-Darling in recent years. Changes to the general level of river flows have resulted from increased extractions and irrigation development on tributaries, whilst low flows have been influenced by the local irrigation industry.

Declines in river health are the result of a number of factors, but changed river flows are considered to be important contributors to such declines. The Department of Land and Water Conservation (1998) listed the following environmental impacts associated with changed river flows in the Barwon-Darling:

- Greater frequency of blue-green algal blooms,
- Riverbank instability and slumping and changes in channel form,
- Reduced fish breeding and migration opportunities,
- Decreased wetland inundation, and
- Impacts on natural processes, including the decline in food production to support fish and bird populations.

While local river health issues are important, Basin wide issues provide the major impetus for limiting irrigation diversions in the Barwon-Darling system. These issues are based largely on the significant changes in river flows in the Basin and the potential for this trend to continue in the future. For example, in the lower reaches of the River Murray, median annual flows from the Basin to the sea are only 21 per cent of those that would have occurred prior to development (MDBC, 1999). Reductions in flows have most notably affected small to medium size flood events. This has led to the lower reaches of the Murray now experiencing drought-like flows in over 60 per cent of years compared with 5 per cent of years under natural conditions.

[5] These licences involve different levels of supply security with access allowed only when river flows reach certain levels (Environmental Thresholds). The security of licences declines as you move from ‘A’ to ‘B’ to ‘C’ class licences as access under each category requires progressively higher river flows (which occur less frequently) to exist before pumping is permitted.

According to the MDBC (1999), reductions in flow have been associated with a range of river health problems in the Murray-Darling Basin including:

- Contractions in the area of wetlands:
- Declines in native fish numbers in response to a reduction in flow triggers for spawning;
- Rising salinity levels; and
- Increase in the frequency of algal blooms

Action to address these issues through Cap implementation has been judged at a political level to be in the community's interest. Support for the Cap on economic grounds would require that the basin and local scale economic benefits associated with addressing these environmental issues exceed the costs, principally in the form of impacts on consumptive users. The discussion and analysis of management options in later sections of the paper does not specifically address this issue. Rather, it acknowledges the Cap as a given and looks at the cost effectiveness of different options, in terms of the on-farm effects of different strategies, to achieve it.

3. Cap Management Options

3.1 Community involvement and river management planning

Increasingly, Government responses to natural resource management problems have focused on regional or community based approaches[6]. Such a move represents a significant shift from the traditional 'top-down' approaches to problem solving to so called 'bottom up' approaches which are characterised by community involvement in the development and implementation of solutions to local problems.

The advantages offered by community-based approaches to natural resource management issues have been commented on by a number of authors. Crean, Pagan and Curthoys (1999) summarised the rationale underpinning the move to more community-based approaches as:

- the failure of traditional 'top-down' approaches to prevent on-going land and water degradation;
- the complexity and regional nature of many natural resource management problems;
- the importance of addressing the social and economic aspects of resource management problems in addition to technical aspects;
- the importance of 'community ownership' of problems in adopting possible solutions;
- increasing community expectations for greater involvement in decision making; and from an economic perspective
- strengthening of collective property rights and the reduction in information failures which may be possible under more community based approaches.

[6] Community based approaches are referred to in a generic sense. In reality, there is a continuum of institutional structures rather than clear dividing lines between government and community. Our focus is on those approaches which encompass more genuine attempts at involving stakeholders in natural resource management decisions.

The NSW Government is articulating the water reforms as a government and community partnership in managing the State's water resources. Key to the community's involvement in water reform is the establishment of community based Water Management Committees (WMCs). DLWC (1998) states:

> 'Water Management Committees, representative of a wide range of stakeholders, are the cornerstone of determining future management arrangements for sharing water and addressing other environmental and sustainable production issues. Participation in water management is built around the empowerment of WMCs to deal with issues, influence overall operational policy development and take responsibility for developing various approaches for local interpretation and delivery of Statewide principles'.

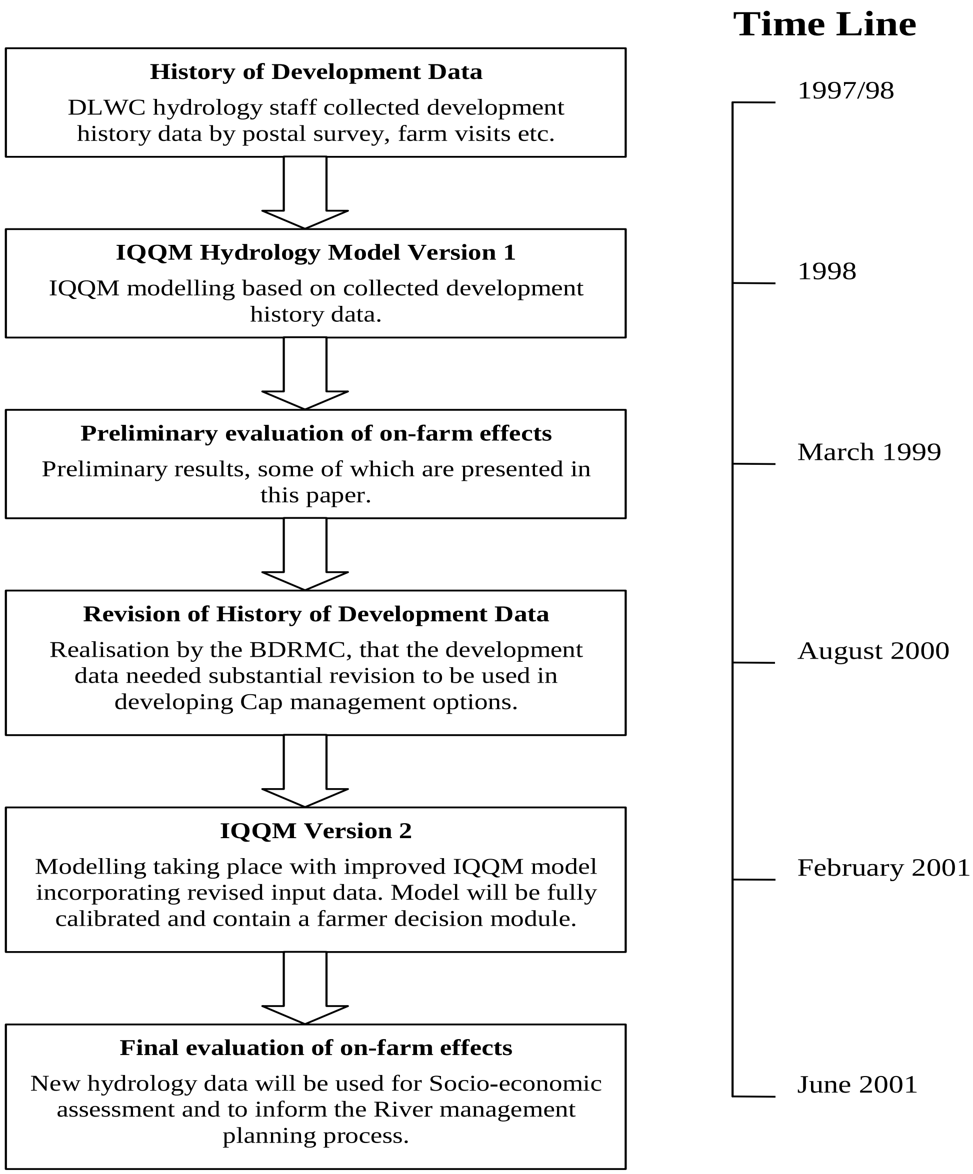
The Barwon Darling River Management Committee (BDRMC) was set up as part of the Government's community based approach to water management planning. The committee comprises a wide range of representatives, both from Government agencies and other stakeholder interests such as irrigator and environmental groups. The representation of key stakeholders on the committee is designed to ensure that the decisions of the committee reflect the interests of those living in the catchment. Together, the committee must determine options to manage a range of sensitive and contentious issues associated with water management.

The implementation of the MDBC Cap has been a key focus of BDRMC's activities since its formation in 1998. The significant implications that Cap compliance could have for the catchment has placed emphasis on ensuring the accuracy of hydrology modeling and associated data inputs. This has centred around activities to accurately identifying the extent to which Cap has been breached, the development of cap management strategies and consideration of the socio-economic effects of required change.

Figure 2 shows a summary of the key developments in the analysis of Cap management options as a major input into the development of a river management plan for the Barwon-Darling. An initial hydrology model (Barwon Darling IQQM Version 1) was developed by DLWC in 1998 based on development history data collected by its hydrology staff. In March 1999, IQQM results were incorporated into NSW Agriculture's representative farm models, from which a preliminary evaluation of on-farm impacts were obtained (some of these results have been used as an example in this paper to demonstrate the application of the methodology used).

A number of problems were found with the intial hydrology model prompting further research into irrigation development history data and refinement of the IQQ Model. A project to accurately define the level of development, and cropping histories was commenced in September 1999. This project used a combination of satellite image analysis and irrigator interviews to determine the irrigation development levels for each of the past 13 years. The project was completed in August 2000. The revised development history data is currently being used by DLWC to create an improved version of IQQM. The new model will also be fully calibrated and include a farmer decision module. Completion of the revised model is expected around late February 2001, after which further evaluation of the on-farm impacts of Cap management will be undertaken.

Figure 2: Collection of Data and Modeling Process for the Barwon-Darling Cap



Detailed data was collected by the History of Development project (Brill, forthcoming). This data showed that substantial development associated with irrigation had taken place between the late 80's and the late 90's. Significant expansion in on-farm water storage capacity occurred, however much of this was to assure supply of water to existing crops rather than to expand the area of crop grown. There was also an increase in the area developed for irrigation. Some of this translates to additional crop area while some is developed as rotation land. There has been a significant increase in the area of permanent horticultural crops grown, however, this still represents only a small portion of the total crop area.

The description of the above process would tend to indicate that involving the community in water management planning can significantly lengthen the time involved in implementing change. However, additional costs inherent in the process are likely to be more than offset by the additional rigour that community involvement has brought to the supporting analyses undertaken. In the absence of community involvement it is highly unlikely that the accuracy of hydrology modeling and the model input data would have been significantly reviewed. The consequences of which would have resulted in the use of a questionable, and possibly more restrictive, Cap target with resulting negative impacts on the irrigation industry. Certainly the management options which may have been implemented would not have been accepted by the local communities without the community based planning process which allowed their participation in the development of solutions.

3.2 Options proposed to meet Cap

Given some of the background provided above, it is clear that there remains considerable uncertainty about the long-term average Cap for the Barwon-Darling. Consequently, there is also uncertainty about the amount by which recent diversions exceed Cap and the required options to achieve it.

The options outlined in this section are based on the work of the Cap Management Working Group (CMWG) undertaken in 1999. The Working Group was established by the BDRMC to advise the Committee on Cap management options to assess and the selection criteria that should be used in assessing these options. In recognising the need to have an estimate of Cap, as a basis for the development of Cap management strategies, BDRMC agreed that a Cap figure of around 200,000 ML was reasonable (CMWG, 1999). The modeling undertaken at the time suggested that diversions in 1998-99 could be around 30 per cent above this.

On the basis of the projected changes to meet Cap, the Working Group identified the following five Cap management strategies:

i) Real time management

Real time management involves matching diversions with those that would have occurred with 1993/94 levels of development through the management of diversions for each flow event.

ii) Environmental Thresholds

This strategy involves increasing Environmental Thresholds to reduce diversions by reducing the frequency of pumping and the number of pumping days. The CMWG (1999) stated that these "thresholds would need to be continuously raised to ensure Cap compliance over the long term."

iii) Event sharing and agreed ratios

This option places limits on the proportion of daily flow that can be extracted above the 60th percentile flow. There are existing restrictions below the 60th percentile (low flow rules). DLWC modeling determined that flows above the 60th percentile would need to be shared equally between irrigators and the environment for the entire Barwon-Darling River to achieve the Cap.

iv) Quota Reduction

The quota reduction option aims to achieve Cap by reducing the maximum diversion volumes on licences to Cap levels. It was suggested that this strategy would improve the long-term security of water supply to existing users.

v) Hybrid Strategy

The Hybrid strategy arose from suggestions that the Cap management options which involved quota reductions and restrictions on the proportion of flows that could be diverted (Environmental Thresholds) could be combined to meet Cap and provide environmental improvements in addition to those already provided by the low flow rules. That is, this option is a "hybrid" of the Quota Reduction option and placing restrictions on the proportion of individual flow event that could be diverted.

For the purposes of this paper, only the environmental thresholds, quota reduction and hybrid strategies were evaluated. The CMWG ruled out the real time management and event sharing options on the grounds that they were considered not technically feasible or at best, very difficult to implement.

3.3 Efficiency and Equity issues

There are both efficiency and equity issues implicit in any decision to modify existing property rights under a particular Cap management option. Both these issues are essentially linked to differing views about the nature of property rights. According to Randall (1987, pg 157), 'property rights specify the proper relationships among people with respect to the use of things and penalties for violating those proper relationships'. When property rights are deficient, the full costs and benefits of using a resource are not met by those accessing the resource.

In the case of water, uncertainty about the nature of property rights can result in under investment and overall reductions in the level of returns generated from available water resources. Hence, uncertainty about property rights can reduce overall economic efficiency. Different Cap management options will rate differently according to this criteria. For example, the Environmental Thresholds strategy continually raises pumping thresholds without clarifying the share of resources between licence holders. This option would also create problems in establishing a trading market which would allow the transfer of water resources from low to high value uses. In contrast, the Quota Reduction strategy clarifies individual property rights and provides the basis for an effective trading market which would facilitate an efficient use of available water resources.

Property right conflicts can also involve concerns about equity relating to the sharing of water resources amongst licence holders. Equity can take on a number of dimensions, but common to water re-allocation problems is the provision of water to active versus inactive licence holders. Differential treatment favouring active water users is sometimes justified in terms of the level of investment that active water users have sunk into existing developments and the contribution that these active irrigators make to regional income and employment. Inactive irrigators argue that the water asset they hold has a value and their decision not to activate it within a given time period is irrelevant. Recognition of inactive licences, particular in areas like the Barwon-Darling where considerable inactive entitlement exist, will involve considerable reductions in the reliability of irrigation supplies for normal water users. Cap management options are likely to have differential impact on users according to activation levels. For example, the quota reduction strategy is likely to involve a major wealth transfer from holders of active to inactive licences if all licences are treated equally. Notions of what is fair and reasonable is largely contingent on the individual circumstances of irrigators.

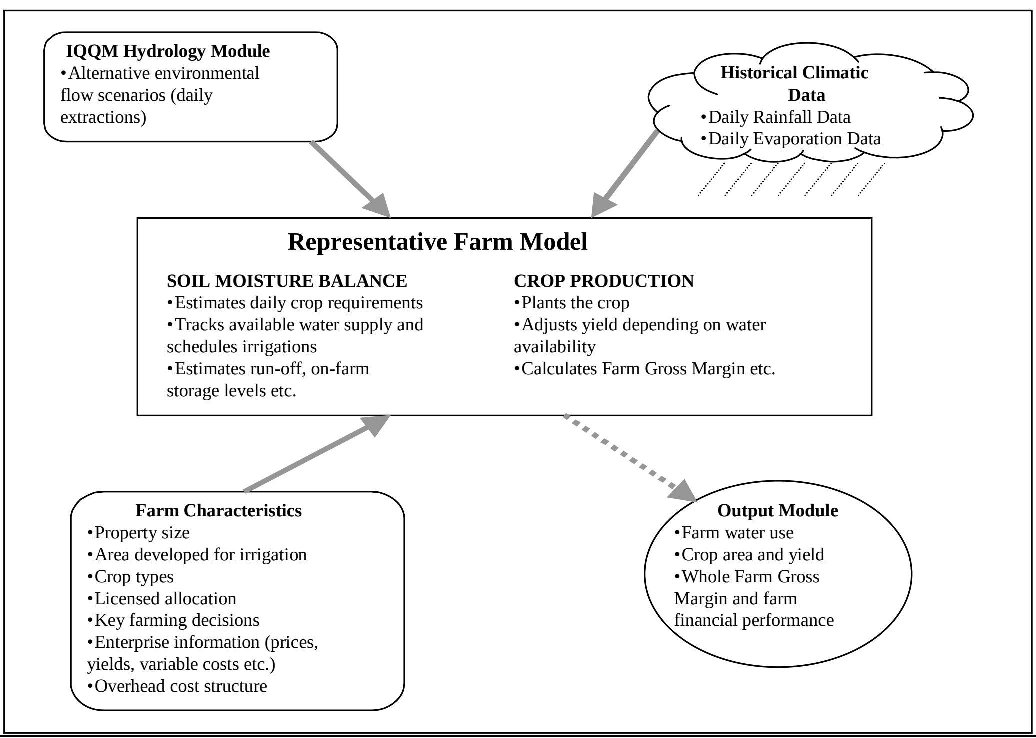
4. Methodology

4.1 Overview

A representative farm modeling approach is adopted in this study to assess the on-farm impacts of Cap management strategies in the Barwon-Darling. The modeling system is simulation based and allows tests to be undertaken on the sensitivity of a farming system to changes in various aspects of the system, such as water allocations. An advantage of simulation based models is the ability to simultaneously incorporate many variable factors such as climate, hydrology data, crop yields, income, costs, and risk. A limitation of this approach is that models developed are not well suited to complex decision problems involving determining optimum enterprise combinations with multiple resource constraints.

The methodology adopted in this study uses a combination of hydrology simulation modeling and farm level budgeting. The hydrology simulation component represents the variability in river flows and climatic conditions in the region and was considered important in the context of evaluating a climatically adjusted Cap. Farm level budgeting is used to capture differences in the physical and financial characteristics of irrigation farms along the Barwon and Darling rivers. These differences can have a major influence on the magnitude of farm level impacts of alternative cap management options. The disaggregation of agriculture within a catchment to a series of representative farms allows some consideration of the distributional consequences of water management options. This can be important given that Water Management Committee decisions are commonly based not only on the economic efficiency of options but also whether changes are considered to be “fair and reasonable”, incorporating notions of equity between water users (Carter, Crean and Young, 2000). The structure of the Barwon-Darling modeling system is shown in Figure 3 and its major components are discussed in the following two sections.

Figure 3: Modeling System



4.2 Hydrology simulation, climatic and farm characteristics inputs

4.2.1 Integrated Quantity-Quality Model (IQQM)

An important feature of the representative farm models is that they are designed to interact with hydrology data from IQQM which has been developed by the DLWC. IQQM is a generic, hydrological simulation model developed to provide hydrologic advice for water management options. The model simulates the Barwon-Darling River system with respect to water quantity behaviour on a daily basis. IQQM is specifically effective in investigating short term issues such as changes in flows or other parameters such as environmental flows (Black et al., 1995).

IQQM for the Barwon-Darling system is constructed around the physical characteristics of the river and the associated irrigation industry incorporating storage and pump locations, farm sizes and locations, normal irrigated areas, pump capacities, tributary inflows, effluent streams and returns, floodplain detention and flow limits (Black et al. 1995). The model for the Barwon-Darling is unique in that it involves simulations being undertaken on a farm scale, rather than a sub regional scale as is carried out in most other catchments. This is related to the relatively small number of farms, the high level of extractions on some of the large farms and differing infrastructure capacities.

The incorporation of such hydrology data is important in understanding how the impacts of environmental flow rules or Cap management options can vary across a range of different climatic years. Increased variability in returns arising from the introduction of environmental flow rules or Cap management options can also affect farm viability as well as absolute decreases in average water availability. The key hydrology data used in the representative farm modeling is simulated daily water extractions.

4.2.2 Climatic module

The Barwon-Darling River extends over a large area with significant differences in both rainfall and evaporation and hence irrigation demands. Rainfall is also highly variable between irrigation seasons creating variations in crop water demands from one season to another. To capture variability in crop water demands in both temporal and spatial scales, daily rainfall and evaporation data for different areas of the catchment were used. This data used in the simulation period is from historical records over the last 30 years, consistent with simulations under IQQM.

4.2.3 Farm characteristics

The key features of the representative farms are based on development and cropping information collected by DLWC hydrology staff in the early development of IQQM. The data was sorted based on predominant crop, farm location (river reach) and area of crop usually grown to determine groups of farms that were relatively homogenous. These groups were then re-labelled as representative farms. Hydrology data for each of the individual farms that made up the representative farms were obtained from IQQM. These were then averaged across each of the component farms to give the input hydrology data for the representative farms.

Five different farms were identified, however, only three of these were used in this assessment. These included two on the Barwon River with areas developed for irrigation of 315 and 120 hectares and the areas actually irrigated were 220 and 85 hectares, respectively. The remaining representative farm used is on the Darling River in the Bourke region, which has a developed area of 2,700 hectares with actual irrigated area of 1,900 hectares.

Large on-farm storages with large surface area are characteristic of farms in all reaches of the Barwon-Darling River. On-farm storages are typically large as they need to store adequate water to irrigate the crop for the whole season. These large surface areas are associated with high evaporation rates and irrigators incorporate an estimate of these losses into their farm planning decisions at the commencement of each irrigation season. The representative farms include an on-farm storage capacity and representation of evaporation and seepage losses. The key physical farm characteristics of each of the three representative farms used in this assessment are summarised in Table 1.

Farms on the Barwon River, upstream of Brewarrina, generally irrigate Upland cotton only, while irrigators in the Bourke region (on the Darling River) normally grow a proportion of PIMA cotton (estimated to be around 20 per cent). In a typical year, 70-80 per cent of developed land is sown to cotton. For all representative farms, approximately 30 per cent of developed land is sown to wheat each year as a rotational crop (to dry out the soil profile), of which, only a proportion is harvested.

Key enterprise details are based on information provided in NSW Agriculture's Farm Budget Handbooks[7] with the exception of yields which were based on a yield response function (described in the following section) and crop prices which are based on three year averages (1997-98 to 1999-2000). Information on the overhead cost structure of farms was also collated based on the 1996-97 irrigation survey, however, low sample numbers with resulting high standard errors prohibited its use in this situation. Consequently, impacts of on-farm performance were only assessed in terms of whole farm gross margin.

Table 1: Summary of representative farm physical characteristics

	Farm 1 Walgett - Macquarie Small	**Farm 2 Mungindi - Walgett Small**	**Farm 3 Bourke Large**
Maximum Area Developed (Ha)	315	120	2,700
Area Usually Cropped (Ha)	220	85	1,900
Quota (ML)	2,800	2,100	26,000
On-Farm Storage Capacity (ML)	1,900	1,200	20,000
Licence Class	B and C	B	B

[7] Scott, F. (1998) *Farm Budget Handbook, Northern NSW – Summer Crops*. NSW Agriculture.

4.3 Representative farm model

As outlined in Figure 3, the representative farm model has two major components, the soil moisture balance and crop production sections. These are described below.

4.3.1 Soil moisture balance

The model uses a daily water balance approach to determine daily crop water requirements, irrigation water availability in storage, water use by the crop and crop yield. The daily soil water balance permits relatively accurate estimations of rainfall recharge and runoff, irrigation application, and critical water deficits.

Daily soil water balance calculations determine the recharge achieved from individual rainfall events. The water balance allows refill of the soil profile by rainfall to saturation, after which, any additional rainfall runs off and is returned via the tail water return system to on-farm storages. The soil water balance also schedules irrigations once the soil profile reaches the refill point and thus requires the application of water to ensure the crop does not suffer depressed production. If the available water is insufficient to completely refill the soil profile, the model evenly applies the available water to the total crop, provided the amount is above the minimum irrigation threshold set for the farm. The model also keeps a daily account of on-farm storage levels. Included in these calculations are daily extractions, evaporation and seepage losses, water use for irrigation, and tailwater return.

4.3.2 Crop production

The crop production section of the model plants the crop, tracks yield according to a yield response function and calculates enterprise returns with resulting variable costs which are contingent upon yield and water application.

The model’s decision on area to be planted under cotton is based on the volume of water held in on-farm storage at the beginning of the irrigation season (end of August). The volume in storage is divided by the number of megalitres per hectare the grower likes to be certain they have at the time of planting. This can vary between 2 and 10 ML/hectare depending on the individual growers attitude to risk, but typically is around 6 to 8 ML/hectare. An individual grower’s attitude to risk will vary between seasons depending on their own personal experience. The model does not attempt to modify attitudes to risk (planting decisions) between years within a 30 year analysis run, however the decision rule can be changed to test the sensitivity of outcomes to this issue.

Other factors such as river flows expected, amount of moisture in the soil profile, amount of rainfall expected and cotton price will also directly influence the planting decision. These factors are not taken into account in this model. Overall, the amount of water in on-farm storage is considered to be the most important factor in the planting decision.

There are several factors which determine the crop yield for a particular year. Initially the model determines the amount of water transpired by the crop in that year and applies a yield equation to determine what is referred to as 'potential yield' in the model. The yield equation is derived from simulated cotton crop growth and yield (using the CSIRO, OZCOT model) under a range of water availabilities on the Barwon Darling River. The results from these simulations were regressed (transpiration vs yield) to determine a generic yield response equation. Yields are then adjusted according to any water deficits, and the time in which they occurred, during the year. The resulting yield is lastly adjusted for pests and nutrition losses to determine the final yield achieved in each year.

Enterprise returns are calculated on the basis of the areas grown, the yield achieved, average crop prices and variable costs. The variable costs are added in three components. Those costs that vary with area of crop grown (such as cultivation, or spraying); those costs that vary directly with water extractions and usage; and those costs which vary directly with yield. Enterprise returns are aggregated into a whole farm gross margin which is used as a measure of farm profitability. Lack of suitable data on the overhead cost structure of irrigation farms prohibited more detailed consideration of the impact of cap management options on other indicators of farm performance.

5. Preliminary Results

This section presents results of three Cap management strategies – environmental thresholds, quota reduction and hybrid strategies. The results are provided for illustrative purposes and are intended to show the application of the representative farm modeling approach adopted. All scenarios are compared against the Base Case, which includes a set of Low Flow Rules previously implemented in the Barwon-Darling River system. The preliminary results for the three farms are shown in Table 2, while effects on-farm profitability are shown graphically in Figure 4.

Farm 1

Farm 1 normally irrigates around 220 hectares of cotton using B and C class licences totalling 2,800 megalitres. The farm is characterised by a high level of activation and has a small on-farm storage (1,900 megalitres), relative to the area normally planted.

The results show small reductions in extractions as a result of the three Cap management options, with the largest falls occurring under a Quota Reduction strategy. The total area planted shows little change for the Hybrid strategy, a slight change under the Environmental Thresholds strategy and a considerable reduction under the Quota Reduction strategy.

Reductions in extractions and crop areas are reflected in whole farm gross margin. Farm 1 faces the largest reduction in farm gross margin under the Quota Reduction strategy of 35 per cent due to its high level of quota activation. The Hybrid and Environmental Thresholds strategies show smaller decreases in farm gross margin, 14 per cent and 13 per cent respectively. This in part relates to the farm's capacity to access sufficient water at individual flow events. All of the options have some influence on water use efficiency. Farm 1 is designed with the infrastructure to crop a typical area of 220 Ha. If lesser areas are planted, the efficiency of water use will be reduced with current infrastructure. This is due to the storage area being fixed and therefore incurring the same evaporation as it would when a larger area is grown.

The Cap management options also have an impact on the variability of farm gross margin, which may have implications for farm viability. This is evident through the coefficient of variation[8], which shows that the largest variability in farm gross margin is associated with the Quota Reduction strategy. This relates to Farm 1 utilising a high proportion of its quota, whilst also having an ability to extract water rapidly when available, helping mitigate variability effects associated with the other two strategies.

Table 2: Preliminary Results for Representative Farms

		406 Base Case (includes Low Flow Rules)	499 Quota Reduction	383 Environmental Thresholds	802 Hybrid
Farm 1					
Total Area Planted (Ha)		198	156	183	191
Extractions (ML)		2003	1753	1937	1893
Cotton Yield - Upland (Bales/Ha)		6.53	5.31	5.88	5.85
Farm Gross Margin	Mean	$290,135	$187,401	$253,332	$250,053
$	Standard Deviation	$136,301	$159,133	$147,202	$145,314
	Co-eff of Variation	0.47	0.85	0.58	0.58
Farm 2					
Total Area Planted (Ha)		83	81	78	n.a.
Extractions (ML)		967	960	928	n.a.
Cotton Yield - Upland (Bales/Ha)		5.53	5.37	5.16	n.a.
Farm Gross Margin	Mean	$90,618	$84,379	$76,292	n.a.
$	Standard Deviation	$48,433	$49,870	$58,887	n.a.
	Co-eff of Variation	0.53	0.59	0.77	n.a.
Farm 3					
Total Area Planted (Ha)		1559	1295	1493	1543
Extractions (ML)		18519	16996	17943	18168
Cotton Yield - Upland (Bales/Ha)		7.25	6.87	7.14	7.15
Farm Gross Margin	Mean	$3,625,000	$2,784,000	$3,389,000	$3,433,000
$	Standard Deviation	$2,296,000	$2,050,000	$2,291,000	$2,310,000
	Co-eff of Variation	0.63	0.74	0.68	0.67

Farm 2

Farm 2 is located in the upper reaches of the Barwon River. It has a small irrigation area of around 85 hectares with a quota volume of 2,100 megalitres. The farm has a relatively low level of activation.

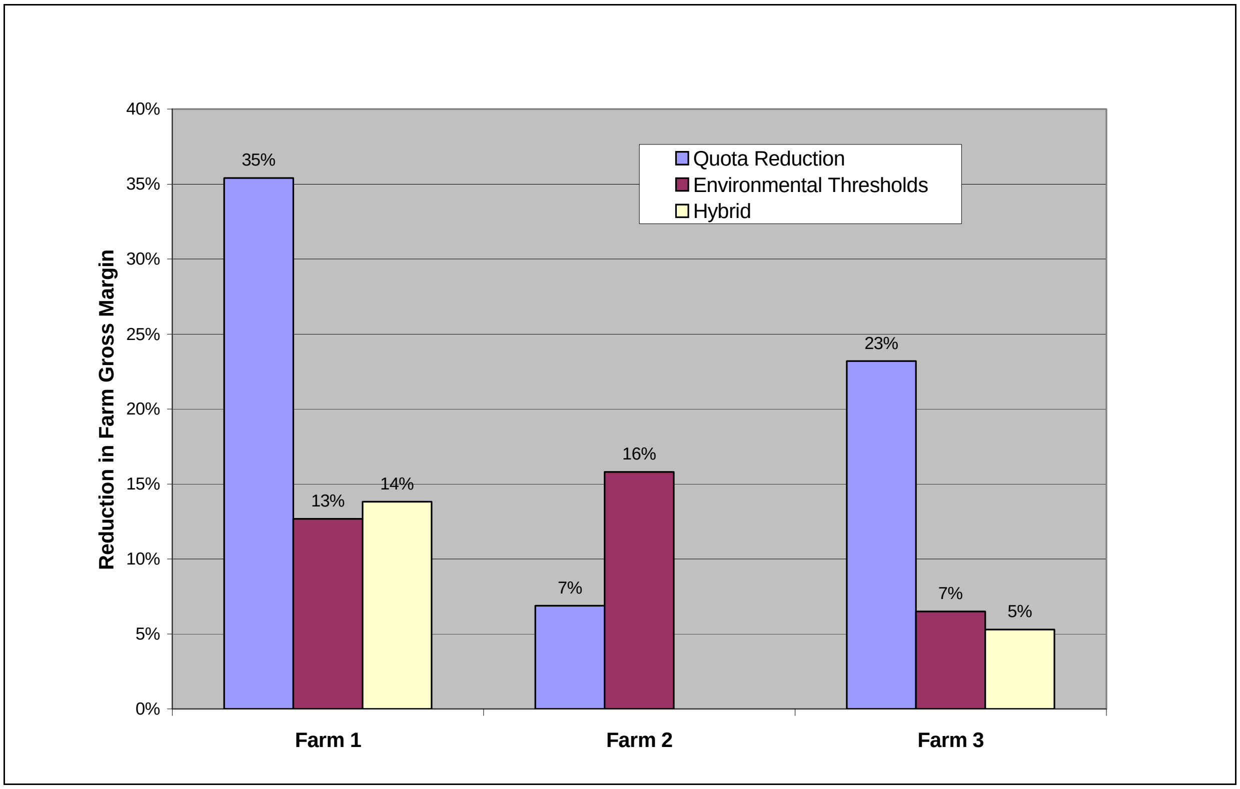
The preliminary results for Farm 2 show that the Quota Reduction and Environmental Thresholds strategies incur small reductions in extractions compared to the Base Case. The results for the Hybrid strategy are not presented, following the discovery of hydrology problems for that option. The larger area planted under the Quota Reduction strategy reflects Farm 2's abundance of quota relative to the area developed. The Environmental Thresholds

[8] The Coefficient of Variation is a measure of variability. It expresses the standard deviation as a proportion of the mean.

strategy showed the lowest area planted, which is likely to be a reflection of its inability to access sufficient water during periodic flow events.

The Environmental Thresholds strategy reduced the whole farm gross margin of Farm 2 significantly more than the Quota Reduction strategy. This again relates to irrigation infrastructure capacity and initial quota size. Farm 2 is not significantly constrained by water availability with respect to any of the Cap management options. However, Farm 2 has less capacity to extract periodic flows, causing greater variability under the Environmental Thresholds strategy.

Figure 4: Summary of Farm Gross Margin for Representative Farms



Farm 3

The third farm is representative of a large farm on the Darling River around Bourke. Farm 3 is characterised by the irrigation of large crop areas (1,900 hectares) and has a large quota of 26,000 megalitres. This farm has an on-farm storage capacity of 20,000 megalitres, made up of four separate storages.

The analysis of the strategies for Farm 3 shows a similar trend to Farm 1. That is, Quota Reduction has a much greater impact on all parameters than the Hybrid and Environmental Thresholds strategies. The results show that for all Cap management options, there are reductions in extractions compared to the Base Case. While the total area planted for each scenario falls under each scenario, the Quota Reduction strategy shows the largest reduction. Water use and yield for the Quota Reduction strategy is slightly less than in all other Cap management options, indicating a more significant water constraint.

As is the case with Farm 1, the Environmental Thresholds and Hybrid strategies show the smallest declines in farm gross margin for Farm 3 (7 and 5 per cent from the Base Case respectively), while the Quota Reduction strategy incurs farm gross margin losses of 23 per cent. This strategy also creates greater variability in irrigation returns compared to other strategies.

The effect that lower extractions have on farm gross margin is less than that of other farms. This partly relates to the greater level of flexibility that larger farms can have in managing multiple storages to minimise evaporation losses. That is, this larger farm can strategically manage its water storages to reduce the total surface area of water in storage throughout the season. This can be a significant advantage in areas like the Barwon-Darling, which experiences high evaporation rates. Larger farms also have an advantage in the rate at which they can extract supplies in periods of limited access, a factor mainly attributed to their pumping capacity. This reduces the impacts of options like Environmental Thresholds and Hybrid strategies, where such time limits are a feature.

6. Summary and conclusions

The declining health of river systems in the MDB has received much attention in recent years. In response, the MDBMC imposed an interim cap on diversions in 1995 to halt environmental impacts associated with changed river flows and the effect that further growth in diversions may have on the security of existing irrigators. In recent years, NSW has been asked to account for a possible breach of Cap in the Barwon-Darling catchment. The issue of achieving Cap in the Barwon-Darling has been made more difficult by considerable growth in development since 1994.

The implementation of the MDBC Cap has been approached through the NSW Government’s community based approach to water management. Experience in the Barwon-Darling suggests that Community based approaches can place additional demands on agency resources and can lengthen the time taken to reach decisions. However, experience also suggests that community involvement has added greater scrutiny of analysis which will ultimately result in the adoption of more appropriate options. These options also have a greater level of public support, attributed to community involvement in the process, and consequently may be less costly to implement in the longer term.

The paper outlined the adoption of a representative farm modeling approach to the evaluation of the farm level impacts of Cap management options. The representative farm models interact with hydrology and historical climatic data and incorporate physical farm characteristics to mimic the production constraints faced by farms similar to those assessed. The modeling work reported in this paper is based on early hydrology data which is in the process of being significantly revised. While the nominal results provided should be treated as indicative only, it is possible to draw some conclusions from the results in terms of the way in which farms of varying physical characteristics are affected by Cap management options.

The preliminary results show that the impacts of Cap management options vary significantly between farms. The level of activation and the irrigation infrastructure of the farm have a major influence on the effects of Cap management options. Irrigation infrastructure has significant bearing on the farm’s ability to cope with the changes in water availability and pumping restrictions. For example, larger farms have greater ability to soften the impact of reduced water availability than smaller farms due to greater flexibility in on-farm storage management to minimise evaporation losses. It is also possible that large farms have greater access to capital with which they can increase the capacity of infrastructure to adjust to the Cap. The differing characteristics of the irrigation enterprise and the level of activation also affected how Cap management strategies affected the variability of farm incomes. A key finding in this study was that reduced water availability has the tendency to increase the variability in all parameters reported, especially farm gross margin. The risks faced by irrigators from lower and more variable water supplies places the onus on irrigators to assess a range of strategic and tactical options.

Given these findings, it is likely that water trading will play a significant role in mitigating the effects that Cap management options. Depending on the rules, trading arrangements can provide significant flexibility to individuals in responding to future lower water availability. In fact, there is evidence of the irrigation industry already using water trading to adjust to Cap. Further refinement of trading rules may be required after a final decision is made in respect to Cap management in the Barwon-Darling.

Finally, the preliminary evaluation presented in this paper demonstrates that the Barwon-Darling Representative Farm Model has a capacity to reveal the differential impacts of Cap management options. Further refinement of hydrology data will enable this model to become a useful tool in advising the BDRMC of the nature of agricultural trade-offs in the water management planning process.

References

Carter, A., Crean, J. and Young, R. (2000), *Assessing the On-Farm Impacts of Groundwater Re-allocation Policies in the Namoi Valley*, Paper presented to the 44th Annual Conference of the Australian Agricultural and Resource Economics Society, Sydney, Australia, 22-25 January 2000.

CMWG (1999), *Achieving the Murray-Darling Basin Cap on Diversions in the Barwon and Darling Rivers*, Cap Management Working Group – Draft report to the Barwon-Darling River Management Committee, August 1999.

Crean, J., Pagan, P. and Curthoys, C. (1999), *Some Observations on the Nature of Government Intervention in Natural Resource Management,* Paper presented to the 43rd Annual Conference of the Australian Agricultural and Resource Economics Society, Christchurch, New Zealand, 20-22 January 1999.

DLWC (1998), *Barwon-Darling Environmental Flow Rules for 1998/99,* Department of Land and Water Conservation, Sydney, April 1998.

Independent Audit Group (1999) *Review of Cap Implementation 1998/99*. Murray-Darling Basin Ministerial Council, Canberra.

MDBC (1999) *The Cap: providing security for water users and sustainable rivers*. Murray-Darling Basin Commission, Canberra.

MDBC (2000) *Water Audit Monitoring Report 1998/99: Report of the Murray-Darling Basin Commission on the Cap on Diversions.* Murray-Darling Basin Commission, Canberra.

Randall, A. (1987). *Resource Economics: An Economic Approach to Natural Resource and Environmental Policy*, Second Ed., Wiley.

Scott, F. (1998a) Summer Irrigated Cropping for Northern NSW. *Farm Budget Handbook* NSW Agriculture, Tamworth.

Scott, F. (1998b) Winter Irrigated Cropping for Northern NSW. *Farm Budget Handbook*. NSW Agriculture, Tamworth.