The Australian Water Project

Volume 1

Crisis and opportunity: Lessons of Australian water reform

DRAFT DISCUSSION PAPER NOVEMBER 2011

A COLLABORATION BY:

ceda
committee for economic development of australia

VE RI TAS
HARVARD

Uniwater

WITH SUPPORT FROM:

MWH
BUILDING A BETTER WORLD

State Government Victoria
Department of Sustainability and Environment

The Australian Water Project

Volume 1

Crisis and opportunity: Lessons of Australian water reform

DRAFT DISCUSSION PAPER NOVEMBER 2011

By Australian Water Project editors
Professor John Langford AM and Professor John Briscoe
with support from
Nathan Taylor, Chief Economist, CEDA

A COLLABORATION BY:

ceda
committee for economic development of australia

HARVARD

Uniwater

WITH SUPPORT FROM:

MWH
BUILDING A BETTER WORLD

State Government Victoria
Department of Sustainability and Environment

About this publication
Australian Water Project

ISBN: 0 85801 278 2

The views expressed in this document are those of the authors, and should not be attributed to CEDA. CEDA's objective in publishing this collection is to encourage constructive debate and discussion on matters of national economic importance. Persons who rely upon the material published do so at their own risk.

Designed by Robyn Zwar Graphic Design
Photography by iStockphoto

About CEDA
CEDA – the Committee for Economic Development of Australia – is a national, independent, member-based organisation providing thought leadership and policy perspectives on the economic and social issues affecting Australia.

We achieve this through a rigorous and evidence-based research agenda, and forums and events that deliver lively debate and critical perspectives.

CEDA's expanding membership includes more than 900 of Australia's leading businesses and organisations, and leaders from a wide cross-section of industries and academia. It allows us to reach major decision makers across the private and public sectors.

CEDA is an independent not-for-profit organisation, founded in 1960 by leading Australian economist Sir Douglas Copland. Our funding comes from membership fees, events, research grants and sponsorship.

CEDA – the Committee for Economic Development of Australia
Level 13, 440 Collins Street
Melbourne 3000 Australia
Telephone: +61 3 9662 3544
Fax: +61 3 9663 7271
Email: info@ceda.com.au
Web: ceda.com.au

committee for economic development of australia

Contents

Foreword 4

Introduction 6

Section 1: Water markets, agricultural productivity and innovation 11

1.1 Editors' overview 12

1.2 Water markets: A national perspective Will Fargher and Chris Olszak 16

1.3 Regional imperatives for change Rob Rendell 30

1.4 Technological innovation and irrigation modernisation David Aughton and Iven Mareels 48

1.5 Water markets: A downstream perspective Mike Young 64

1.6 The politics of water Neil Byron 70

Section 2: Maintaining healthy ecosystems: rebalancing water shares 77

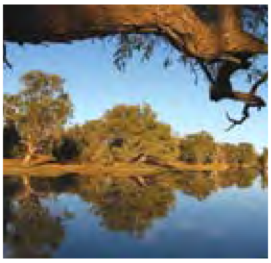
2.1 Editors' overview 78

2.2 The Living Murray Initiative Gary Jones and Ann Milligan 80

2.3 The economic impact of the buy-back program Glyn Wittwer and Peter Dixon 92

2.4 Critiquing the Water Act (2007) John Briscoe 102

2.5 Managing the Lower Lakes Dominic Skinner 108



Section 3: Managing risk: city water supplies 119

3.1 Editors' overview 120

3.2 The risks of urban water management Ross Young 122

3.3 Whole of water life cycle innovations Rob Skinner 128

3.4 A national perspective on urban water Erin Cini and Will Fargher 136

Section 4: Emerging developments 147

4.1 Editors' overview 148

4.2 Emerging food security challenges Julian Alston and Phil Pardey 150

4.3 Creating smart water supply chains Iven Mareels 160

Foreword

It is with great pleasure that CEDA presents Volume I of the *Australian Water Project – Crisis and opportunity: Lessons of Australian water reform*.

This discussion paper is the first of two volumes to be produced as part of the *Australian Water Project*, a joint collaboration between CEDA, Harvard University and Uniwater (a joint venture between the University of Melbourne and Monash University).

A key objective of CEDA's research and policy work is to examine the critical issues facing Australia's economy. Few are as fundamental as water. Access to clean fresh water is vital to the survival and success of any community and its economy.

This discussion paper draws together expert analysis of environmental, economic, agricultural and technological water management issues.

While Australia is a world leader in water management, the prolonged drought of the last two decades tested the resilience of our water resources and polices.The drought may have broken, but with predictions of increased climate variability and extreme weather due to climate change, it is important that we continue to review how we manage this precious resource.

The *Australian Water Project* provides an opportunity to examine the lessons of the extreme drought and how we can do things better in the future.

CEDA hopes this paper, and a series of workshops to be held in early 2012 across Australia, will prompt discussion and debate on this important issue. This will help identify and inform a series of priorities and recommendations for future reform to be included in Volume II.

I would like to thank editors Professor John Langford and Professor John Briscoe and all the contributing authors for their work on this project. I would also like to thank Nathan Taylor, CEDA's Chief Economist, for his project management of this report.

In addition, I would like to thank sponsors MWH, the Department of Sustainability and Environment (Victoria) and the Yulgibar Foundation who ensure CEDA can undertake important projects such as this.

I hope this paper provides a valuable resource to help guide future water reform in Australia and internationally.

Professor the Hon. Stephen Martin
Chief Executive
CEDA

Foreword

Everywhere I go – around the country, the region, and the world - there is always one issue that everyone wants to talk about: water.

Whether it is scarcity, abundance treatment, recycling, disposal, or competition, it is all about securing our future. No issue is more important than the sustainability of our water supplies.

Climate change, population growth, and urbanisation all add to the dilemma of how to secure our future. Australia is facing the same challenges as the rest of the world, though in some cases more transparently.

Our present decision frameworks are dominated by single-issue thinking and tension between competing demands. Nowhere has this been more apparent than in the recent stop-start efforts in developing a Basin Plan for the Murray-Darling system.

Competition for water between consumptive users, environment and other needs has divided governments, communities and families.

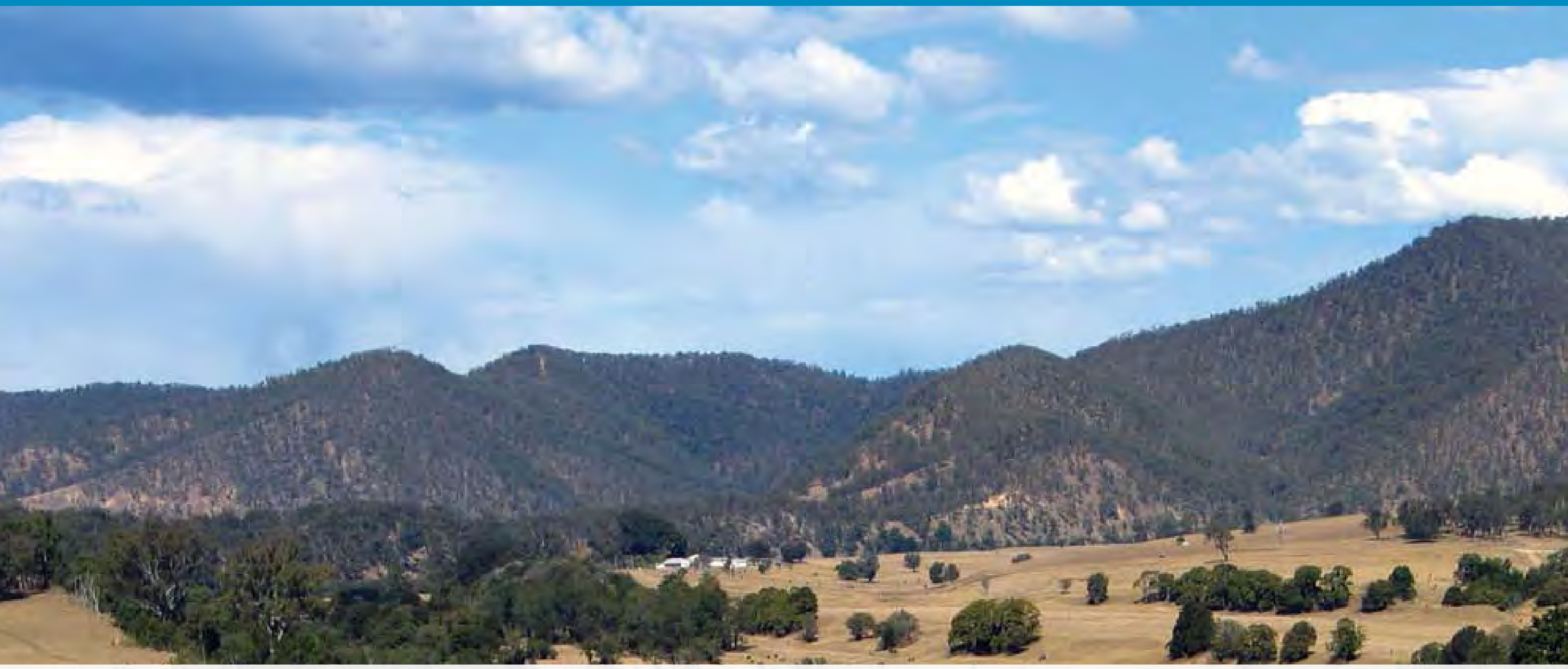
Our political landscape and decision frameworks are all framed at making one-off, unrelated decisions. We are not good at complexity or achieving multiple, positive outcomes. The current debate around food security, energy security, and sustainable communities as they relate to water and the resource sector is typical of our inability to have policy that crosses boundaries.

I am pleased to say that this study, the *Australian Water Project* is the first serious attempt to gather views and approaches that cross the boundaries of academia, government, industry and community.

CEDA is to be commended for assembling the range of contributors that it has and the initiative of undertaking such a complex task.

I feel that this is the first really balanced look at the issues we are facing and, rather than concentrating on the negatives, looking at the opportunities that are presenting themselves to us to secure not only our water future, but our collective wellbeing.

Peter Williams
Managing Director, Australia
MWH



Introduction

By Australian Water Project editors

Professor John Langford AM and Professor John Briscoe

with support from

Nathan Taylor, Chief Economist, CEDA

Professor John Langford is a leader in urban and rural water management reform and received an Order of Australia in 2005. He's currently the Director of UniWater, a joint initiative of the best minds in water research from the University of Melbourne and Monash University. John has worked as an engineer, water resource manager and research manager in the water industry. In 2004 he was selected by Engineers Australia as among the 100 most influential engineers in Australia. Among his many distinguishing career highlights John was the managing director of the Rural Water Corporation, Victoria's state-wide irrigation and rural water authority and the inaugural director of the Melbourne Water Research Centre.

John Briscoe is the Professor of the Practice of Environmental Health, HSPH Gordon McKay Professor of the Practice of Environmental Engineering, SEAS Department of Environmental Health at Harvard University. Briscoe has served on the Water Science and Technology Board of the National Academy of Sciences and was a founding member of the major global water partnerships, including the World Water Council, the Global Water Partnership, and the World Commission on Dams. He currently serves on the Global Agenda Council of the World Economic Forum; is a member of the Council of Distinguished Water Professionals of the International Water Association; and will be the first Natural Resource Fellow of the Council on Foreign Relations. He has published extensively in economic, finance, environmental, health and engineering journals. Recently he authored Water Sector Strategy, India's Water Economy: Bracing for a Turbulent Future, and Pakistan's Water Economy: Running Dry.

I love a sunburnt country,
A land of sweeping plains,
Of ragged mountain ranges,
Of droughts and flooding rains.

Excerpt from *My Country* by Dorothea Mackellar

Australia's climate is one of the most variable in the world and the historical record since European settlement has been punctuated by severe droughts and floods. Australia's uncertain climate is both a threat and an opportunity. While frequent droughts and floods cause great hardship to communities, they stimulate adaptation and generate the political will for reform. Australia's recognised management skills in adapting to an uncertain climate, and record of innovative water reform is due in no small measure to its uncertain climate.

The recent extended drought from the mid 1990s to 2009 has been the worst in recorded history for the vital catchments of the Murray-Darling Basin, and several of the capital cities. This drought has provided a "stress test" for Australia's water reforms and there are many valuable lessons to be learnt from hard experience. The international water community looks to Australia as an exemplar of water reform and is keen to learn from this experience. While there are many success stories of water management throughout this difficult period, a rigorous examination of the outcomes of the recent drought is also required to avoid the risk of repeating costly mistakes in water policy and management.

The Committee for the Economic Development of Australia (CEDA) initiated the Australian Water Project with Uniwater (a joint venture between the University of Melbourne and Monash University), and Harvard University to explore water reform in Australia. The outcome of this collaboration will be realised in two research volumes, this being the first.

Volume 1: Crisis and opportunity: Lessons of Australian water reform

This initial volume entitled *Crisis and Opportunity: Lessons in Australian water reform* contains the views of a range of water experts reviewing the historical context of Australia's water reforms and examining their consequences. It provides a critical independent review of the performance of the Australian reforms under the stress test of the recent drought.

Volume 1 is now a "draft for discussion" paper. A series of workshops will be held in Adelaide, Sydney, Brisbane, and Melbourne during the early part of 2012 to engage water policy experts, including the authors, CEDA's Water Panel and CEDA Trustees. These workshops will be focused on the reform agenda identified by the contributors to the discussion paper and will be incorporated into the final version by the editorial team.

To date a total of 14 contributions have been received which are organised into the following sections:

Section 1: Water markets, agricultural productivity, and innovation

Section 1 examines the performance of water trading and its capacity to alleviate the worst elements of the drought. To successfully allow water markets to operate considerable reform must be undertaken in water planning, pricing and infrastructure provision. Based on the contributions received, the editors have the following observations and questions to further discussion:

- Historically irrigation development has been driven by social policies of attempting regional settlement via investment in dams and associated irrigation infrastructure.

1. Should investment in irrigation in the 21st Century be led by the needs of Australian and international food markets having regard to the whole supply chain from the market back to the farm, and judged on its economic merits, or continue to be driven by public investment in irrigation infrastructure?

- Planning institutions for future water reform and infrastructure investment buckled under the stress of the recent drought.

2. What are the characteristics of planning institutions for Australia's increasingly uncertain climate?

- Markets for water are becoming increasingly sophisticated.

3. Are the arrangements for governance and regulation, including access to market information adequate for the future?

Section 2: Maintaining healthy ecosystems: rebalancing water shares

Section 2 examines how Australia has successfully achieved a balance between environmental and regional interests in the past. These lessons are particularly relevant given the evidence of further environmental damage in important catchments following the recent drought. Based on the contributions received, the editors have the following observations and questions to further discussion:

- Implementation of the *Water Act (2007)* is surrounded by controversy.

4. What are the steps and investments necessary to support adaptive management to progressively achieve rebalancing of irrigation and environmental water allocations in the context of the *Water Act (2007)*?

- Water buy-backs have the potential to facilitate restructuring of irrigation areas, for example by shifting water away from degraded land or land that is very expensive to service.

5. What is the scope for refocusing the water buy-back program to support restructuring of irrigation in marginal farming areas and in regions suffering environmental damage from salinity and poor drainage or flooding?

Section 3: Managing risk: city water supplies

The unprecedented nature of the drought drove an evolution in urban water management. The drought highlighted the lack of resilience in urban water supplies while the $30 billion invested in water supply augmentation fundamentally reshaped the industry. Based on the contributions received, the editors suggest the following observations and questions for discussion:

- In order to manage the risk of uncertain water supplies Australia's major cities have diversified their sources of supply including investment in desalination as insurance against an uncertain climate.

6. How should these complex portfolios of water supplies be best managed in the future?

- Diversification of water sources including more local or decentralised sources increases the complexity of planning. In addition; the increasing interactions between water supply sewerage and storm water requires a whole water system lifecycle analysis.

7. How can the economic costs of water service provision be assigned on a whole of life basis taking into account total system impacts including energy use, green house emissions, materials and embedded energy, together with the costs associated with the higher level of transactions in the whole system lifecycle approach?

- A number of Australian cities, including Melbourne would have run out of water if demand had not been managed by restrictions or setting consumption targets.

8. What are the lessons for managing water demands more equitably during the critical periods during future droughts?

Section 4: Emerging developments

Since the successful increases in agricultural productivity in the mid part of last century there has been global complacency about food production, resulting in a worldwide slowdown in agricultural productivity. This slowdown is occurring while climate change and increasing prosperity in the developing world is placing increasing strains on food security. Based on the contributions received, the editors suggest the following issues need to be resolved to ensure continued agricultural productivity growth:

- Evidence demonstrates a connection between declining growth in agricultural productivity and a decline in agricultural research.

9. How could revitalised funding and improved institutional and evidence based oversight of agricultural research and development reverse the declining growth in agricultural productivity?

- Water pricing is a highly contentious issue.

10. How would appropriate pricing of the water lifecycle create the necessary economic imperative for further innovation in water supply for both irrigation and cities?

This discussion paper is not exhaustive. The editors are also interested in what other issues need to be covered in order to have a comprehensive reform agenda for Australia. Any such issues will be addressed via additional contributions in the next volume of the report.

The intention is for the findings of this volume to serve as a valuable resource for an international audience considering water reform.

Volume 2: Directions for future water reform in Australia

Preparation of Volume 1, together with the workshops and discussions, will inform the work of Volume 2 which will explore future directions for water reform in Australia, scheduled for release in 2012.

Editorial Team

The editorial team includes Professor John Langford of Uniwater and Professor John Briscoe of Harvard with the support of Nathan Taylor (CEDA Chief Economist). The CEDA Research and Policy Advisory Council and CEDA's former National Director of Research and Policy, Dr Michael Porter, were responsible for initiating the project.

Acknowledgements

The Australian Water Project could not have been undertaken without the support of MWH, the Victorian Department of Sustainability and Environment and the Yulgibar Foundation.

Section 1.0

Water markets, agricultural productivity and innovation

1.1 Editors' overview

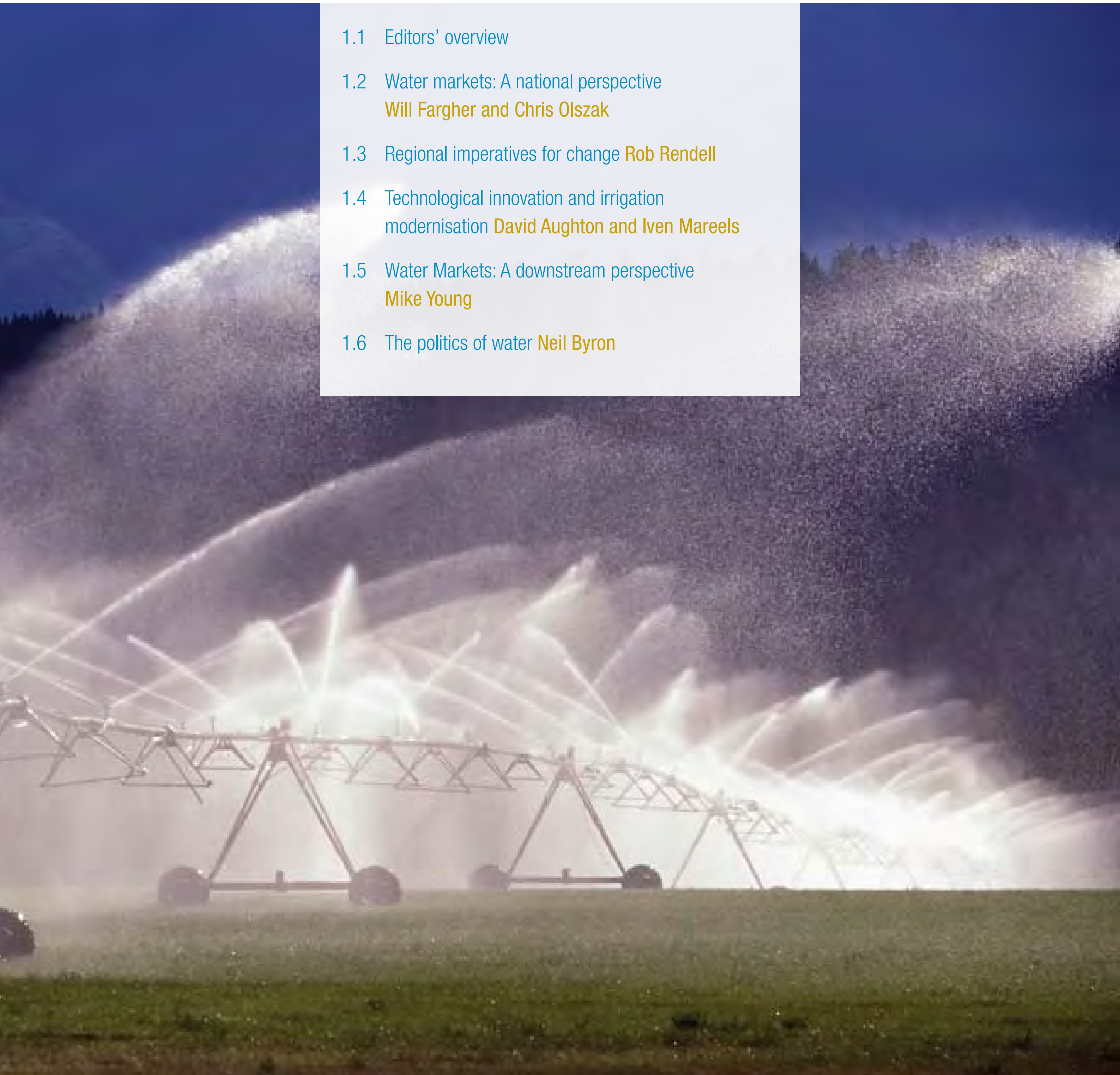
1.2 Water markets: A national perspective
Will Fargher and Chris Olszak

1.3 Regional imperatives for change **Rob Rendell**

1.4 Technological innovation and irrigation modernisation **David Aughton and Iven Mareels**

1.5 Water Markets: A downstream perspective
Mike Young

1.6 The politics of water **Neil Byron**



1.1

Editors' overview

Water and food are inextricably linked. More than 70 per cent of the world's water resources harvested by humans are applied to irrigation and food production. Growing populations, increasing wealth in the rapidly developing countries of Asia with consequent dietary changes, and use of food crops for biofuels combined with declining growth in agricultural productivity have the potential to impact on food supplies, prices and security.

The recent extended drought, the worst in recorded history, and combined with the need to address the historical over allocation of water in the southern Murray-Darling Basin will result in a water constrained future. In these changing circumstances, agricultural water productivity in particular will be crucial to continued success. Furthermore, the changing global context may provide Australia's innovative farm sector with significant food and knowledge based export opportunities.

In the words of Professor John Briscoe of Harvard University:

> *"Australia's water management policies enabled it to do something that no other country could conceivably have managed – in a large irrigated economy (the Murray-Darling Basin) a 70 per cent reduction in water availability had very little aggregate economic impact. This represents an achievement of global significance as human communities across the world respond to a changing climate."*

Examining the role of water markets, and how they affected the agricultural sector, will indicate reforms to ensure Australia remains a world leader in water management.

About the contributors

- Will Fargher and Chris Olszak describe the performance of water markets supporting agricultural productivity under critically low water allocations, at the river basin scale;
- Rob Rendell provides an overview of the implications of water markets at a farm and regional scale, as both a management opportunity for farmers, and as a facilitator of industry restructuring;
- Mike Young discusses the performance of water markets from the perspective of downstream interests; and
- David Aughton and Iven Mareels detail the opportunities created by the modernisation of irrigation infrastructure both in distribution networks and on farm; and
- Neil Byron discusses the politics and economics of water.

Discussion

The replacement of centrally planned water allocation to farmers with a market has been crucial in managing water under extremely low water allocations during the recent drought. Had water remained legally tied to land it would have been locked up in small inadequate allocations spread thinly across the entire irrigation community.

By revealing the economic opportunity cost of water, the market empowered irrigators to manage the limited allocations available. Trading encouraged irrigators to innovate, provided income when crops failed, helped maintain permanent plantings and facilitated necessary structural change in irrigation industries. Trading allowed water users, rather than governments, to make complex decisions about who should use water, where, and for what.

Modelling indicates that water trading increased Australia's gross domestic product by $220 million in 2008-09 to the benefit of the States in the southern Murray-Darling Basin. During the critical period of the drought between 2005-06 and 2008-09 the ABS estimates that gross value of irrigated agricultural production dropped by only 29 per cent, from $5.5 to $4.3 billion while water availability dropped by 53 per cent.

Water markets have been successful in allowing new, more economically productive irrigation enterprises to get established in a situation of constrained water resources. Additionally the water markets have facilitated industry restructuring supporting dignified exits from the industry, and removal of water allocated to less productive and/or land too expensive to supply. Importantly water trading has exposed the opportunity cost of water, giving irrigators a better measure of its value and driving innovative farming practices.

Not all has been plain sailing. While it is easy to be wise in hindsight there are some hard lessons that are valuable for those contemplating introduction of a water market or its extension to other river systems.

By the mid 1990s a consensus was reached that the demand for irrigation water had reached unsustainable levels relative to the available water resource and a cap was placed limiting future diversions.

The introduction of water trading into a system characterised by over-allocation of the water resource has resulted in unintended consequences. In hindsight it may have been better to address the questions of over-allocation before breaking the bond between land and water to create a water market.

While downstream interests have been a major beneficiary of water trading, they have also suffered from some unintended consequences. The drought has stimulated investment in water efficiency both in the water delivery systems and on farm. Improving water efficiency combined with water markets has allowed the efficiency savings to be used to support growth in either existing or new enterprises. In the past a proportion of these inefficiencies flowed downstream and was used to support downstream irrigation and environmental needs. In addition, the cap introduced in 1995 only applied to surface water diversions stimulating a boom in groundwater pumping, with the potential to further reduce downstream flows when the groundwater is connected to the river. Accurate measurement and accounting for all water sources, and the management of surface and groundwater as a combined resource is vital.

Limited availability of water has focused attention on water efficiency both in the channel networks supplying irrigation water, and in water productivity on farms. Investment in water efficiency per se has not always been a major driver of on farm investment.

Labour savings that allow irrigators to manage larger enterprises and reduce unit cost has historically been the principal driver of investment, with water efficiency a by product. Innovation combining modernisation of irrigation infrastructure in channel systems and on farms is capable of delivering an increase in water efficiency (from the diversion point into the channel system to the crop) from the current 40 to 50 per cent to between 70 and 80 per cent.

Australia is a leader in developing smart operating systems based on control system engineering and automation both for channel systems, and on farm irrigation. Substantial investments are now being made in modernising irrigation infrastructure, for example the $2 billion investment in the Northern Victoria Irrigation Renewal Program (NVIRP).

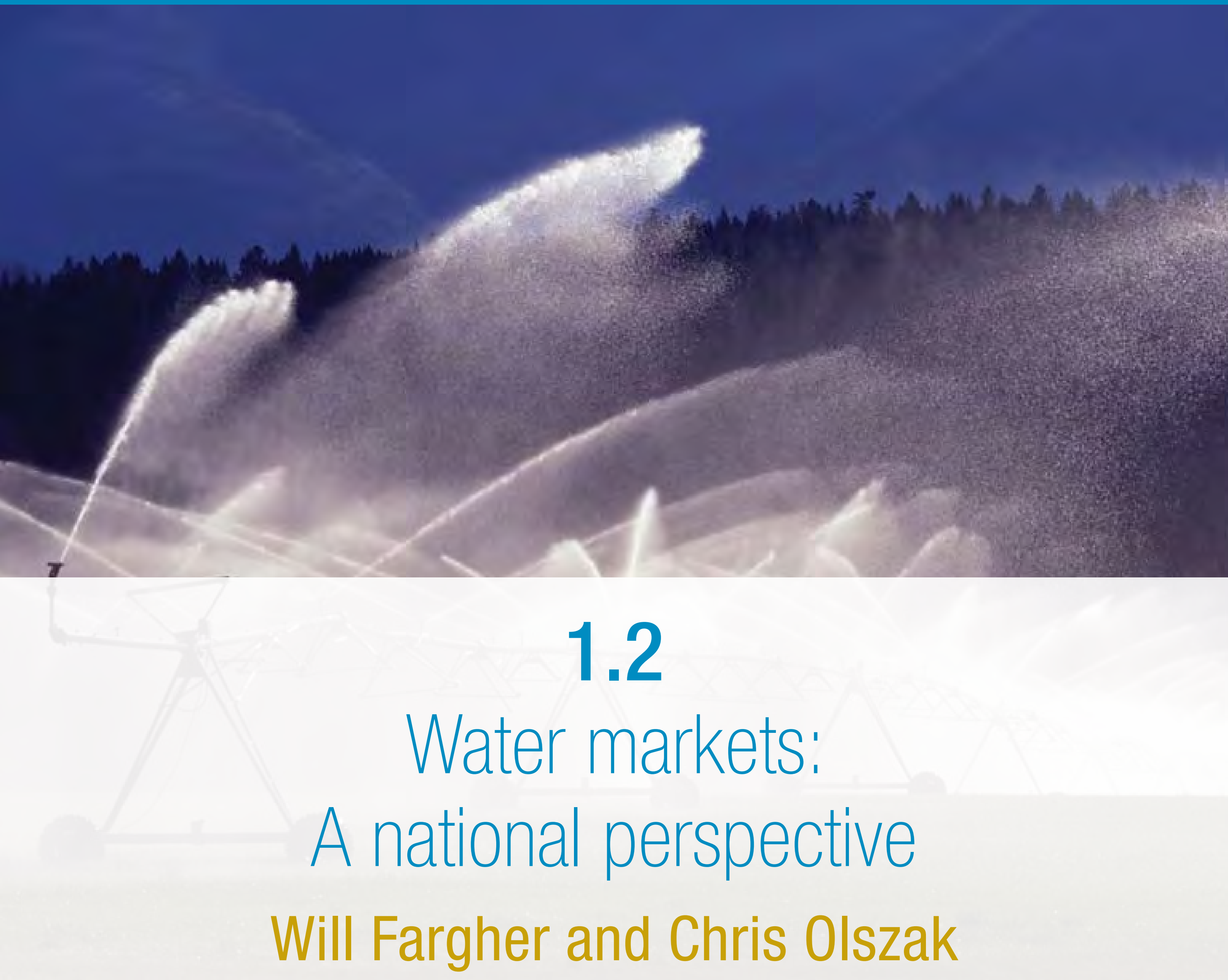
The poor level of service provided to irrigators by outdated manual operating procedures has limited the opportunities available to irrigators to improve their water productivity. The modern operating systems can supply effectively water on demand, higher flows while maintaining consistent water levels in the channels, which when combined with on farm automation can increase the overall water efficiency from 50 to 80 per cent. However, without meaningful pricing reform these public investments will worsen the capacity of irrigation schemes to cover the economic cost of supplying water.

Investment in irrigation has historically been driven by building infrastructure underpinned by strong social policy inclinations. Build a dam and make the deserts bloom. Such investments paid little regard to the markets for the commodities produced by irrigation or all the other factors along the supply chain necessary to supply those markets. In order to gain the full value from the investments in modernisation and the opportunities provided by better services to the irrigators, thought should be given to commodity markets, and the potential to gain more value from these investments.

There are fundamental shifts occurring in commodity markets as a result of rapid development in the emerging economies of Asia, and the currently unsustainable water management practices in India and China. These trends will create new opportunities for Australia's irrigation resources.

A review of these potential market opportunities and the range of initiatives that would be necessary to take up these opportunities would be a useful contribution to the current debate. The next generation of investments, whether modernisation of existing irrigation systems or building new systems should be led by commodity markets rather than driven by building irrigation infrastructure.

Planning and funding investment in irrigation systems, and other water related investment for that matter, are vexed questions. A case could be made that Australia's water planning systems were not up to the stress of the recent extended drought. However, it is questionable whether it is possible to untangle the economics and the politics of water without water trading as a mechanism to realise the opportunity value of water. Greater public transparency in decision making, with clearly defined property rights and water markets revealing the opportunity costs of decisions, can be developed through strong public institutions. This can ensure that the full economic consequences of political decisions are made clear.



1.2

Water markets: A national perspective

Will Fargher and Chris Olszak

Will Fargher, General Manager of the Water Markets and Efficiency Group, is responsible for analysis and reporting of water reform matters involving urban water, water industry performance and pricing, water trading, rural water use and structural adjustment. Will has been working on water policy and management at the Australian state and federal level for the past nine years. He is a Churchill Fellow, and holds bachelor degrees in economics and arts, an honours degree in geography and master of environmental science.

Chris Olszak is an economist based in Frontier's Melbourne office. Through over 10 years of professional experience he has gained extensive knowledge of water and natural resource policy settings across Australia. His key skills are in policy development and analysis, property rights and resource allocation systems, economic evaluation, water pricing and economic regulation, and institutional design and analysis. Much of his recent work has been for the National Water Commission where he has contributed to major public reports furthering water market and urban water reform in Australia.

Introduction

Since the first tentative but far-reaching steps in the 1980s and 1990s towards capping surface water diversions and permitting the more flexible reallocation of water between irrigators, the ability to trade water has emerged as a central part of water management in Australia.

From the mid 1990s water markets have expanded considerably and market activity has grown exponentially, particularly in the southern Murray-Darling Basin (MDB). Through this period water trading became entrenched as a key instrument in managing water scarcity, particularly in dealing with the severe and prolonged reduction in water availability through the millennium drought.

The rationale for the introduction of water trading was to enable the more efficient use of scarce and valuable water resources. Water markets allow water users, rather than governments, to make complex decisions about who should use water, where, and for what. Water markets allow water to be reallocated between uses, and give water users the flexibility to respond to changes in their operating environment, including seasonal conditions and water availability. Market prices provide a signal for users to consider the opportunity cost of their water-use decisions and make decisions in their own best interests. Market regulation and the specification of water property rights can help manage the potential third-party and environmental impacts of water trading.

Over the past decade, drought and changes in agricultural commodities markets have put this theory to the test. The aim of this paper is to examine the extent to which the theoretical benefits of water markets in the southern MDB were observed in practice. The focus of the paper is on the agricultural sector, although benefits to regional and urban communities and the environment are mentioned. While market price signals have contributed to improvements in technical water use efficiency, the paper focuses on the allocative and dynamic efficiency benefits observed in the southern MDB.

This paper demonstrates that water trading has proved to be a major success in supporting agricultural productivity; helping irrigators respond to seasonal conditions and manage risk; promoting more sophisticated farm management practices; providing irrigators with income when crops failed; underpinning the expansion of some industries and maintenance of permanent plantings; enabling irrigators to reduce debt levels and restructure their businesses; and facilitating structural change in irrigation industries.

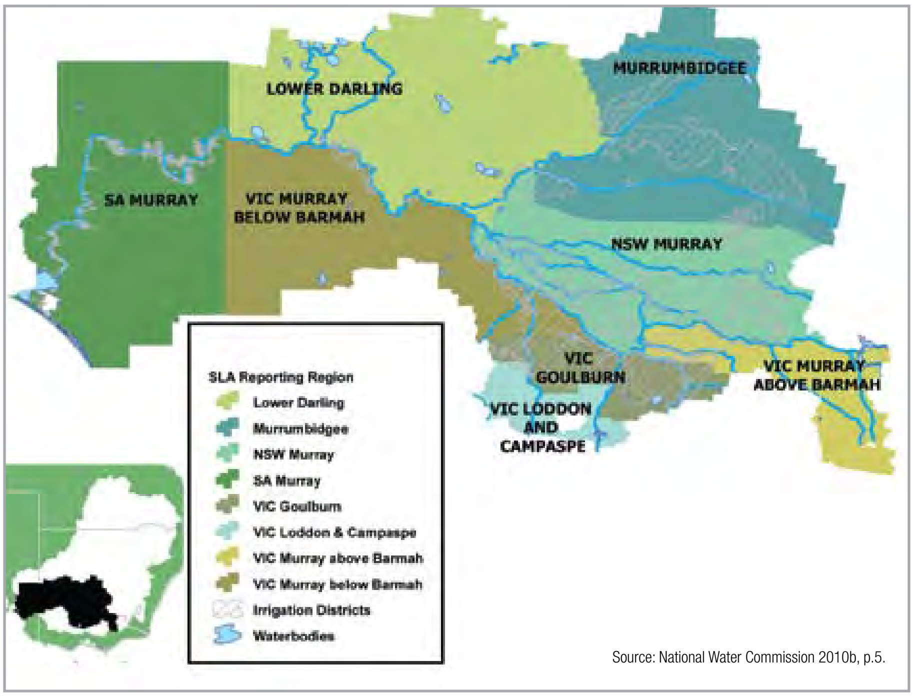
While the drought has had a significant economic and social impact on the irrigated agricultural sector, the ability to trade water means that remaining irrigation businesses are in much better shape than they otherwise would be. Experience has shown that water markets provide an autonomous mechanism for maintaining productive capacity in the agricultural sector.

Background

The nature of water access entitlements and water trading

The general approach adopted in Australia is that water rights are specified as entitlements to a proportion of the total pool of water available each year. Therefore, the exact volume can change from year to year reflecting Australia's highly variable annual rainfall and runoff conditions.[1] The states and major water systems have different types

FIGURE 1
CONNECTED REGIONS IN THE SOUTHERN MURRAY-DARLING BASIN



Source: National Water Commission 2010b, p.5.

of entitlements. NSW and Victoria have high and lower reliability water access entitlements which provide different volumes of allocated water under particular seasonal conditions.

There are two main types of rights to access water which are traded in Australian water markets:

- Water access entitlements: the perpetual or ongoing entitlement to exclusive access to a share of water from a specified consumptive pool; and
- Water allocations: the specific volume of water allocated to water access entitlements in a given season.

Subject to rules and regulations, water users can either choose to: use the water allocated to their entitlements; buy additional water allocations; sell part or all of their allocation; buy or sell entitlements; and/or lease entitlements. In some water systems, and under some circumstances, users can also choose to carry-over water, which means that they do not use it, but instead leave it in storage for use or trade in the following year.

Once water becomes scarce and aggregate caps are in place, water markets represent an individually-based approach to allocating water rights. The alternatives to water markets are that governments determine how water should be assigned to competing users under varying conditions or that users cooperate to make these decisions. The development of water markets in Australia reflects broader policy trends in agriculture which focus on providing individuals and firms with control over their production and risk management decisions.

The scope of water trading

Across Australia, there are water markets in different water systems and different segments within these markets, which have developed at varying speeds and to different degrees.

Market activity is mostly concentrated in the MDB – Australia's largest irrigated agriculture area[2]:

- The southern connected MDB which is operated as a connected resource comprising 13 distinct water trading zones including the Murray (in SA, Victoria and NSW), Murrumbidgee, Kiewa, Ovens, Goulburn, Campaspe, Loddon, Avoca and Lower Darling river catchments, (see Figure 1); and
- The northern MDB including the upper Darling, Macquarie-Bogan, Castlereagh, Namoi, Border Rivers, Moonie, Condamine-Balonne, Paroo and Warrego river catchments, characterised by unregulated rivers or rivers controlled by single storages.

Water trading has expanded rapidly in the southern MDB over the past decade of drought and trading in both water allocations and entitlements is now possible over large distances and both intrastate and interstate (see Figure 1).

The growth of water markets in the southern MDB is at least partially a result of the unique underlying characteristics of the water resources and industry mix. In particular, the large interconnected water systems, extremely variable inflows, and diverse mix of agricultural industries (with different water demands) make it conducive to water trading (see National Water Commission 2010a).

An overview of water trading activity

Over 90 per cent of water trading activity occurs in the southern MDB. The volume of water allocation trade and entitlement trade has grown significantly since its introduction, with three notable step change increases in trading activity.

The first significant increase was in 1994–95 (see Figure 2). This was the first year that there was a significant drop in seasonal water availability since the introduction of water trading.

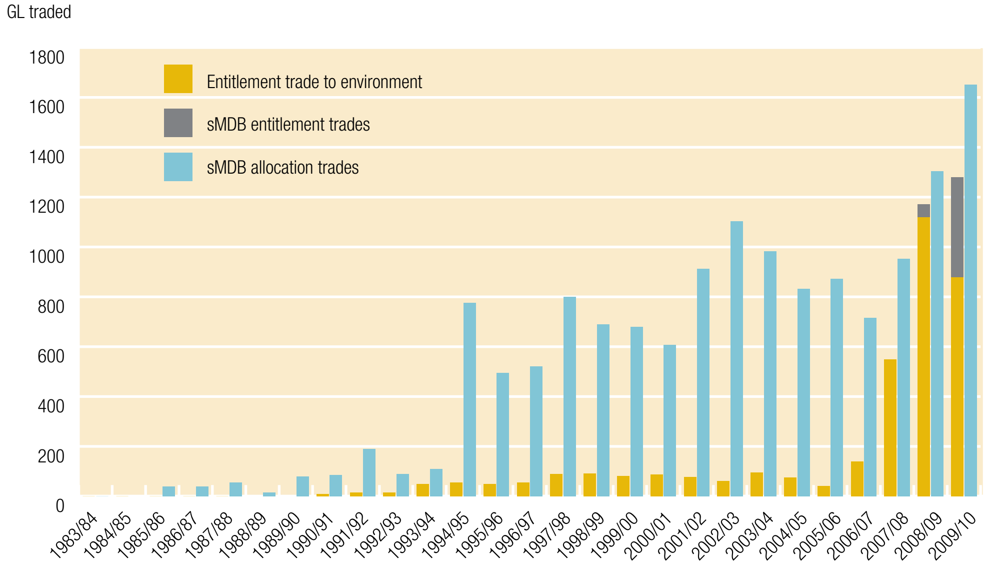
The second boost to water trading occurred in 2002–03. The severe drought conditions in that year prompted a step change increase in the proportion of water allocations that were traded from around seven per cent to almost 15 per cent (see Figure 3).

The third increase in water trading activity occurred in 2007–08, following very dry seasonal conditions in 2006–07 across most of the MDB. These dry conditions persisted in the southern MDB in 2007–08 and 2008–09, in some regions the driest on record, and the proportion of total water allocated that was traded more than doubled again to 41 per cent. These higher levels of allocation trading activity were maintained despite improved water availability conditions in 2009–10 (see Figure 2 and Figure 3).

Allocation trade has traditionally accounted for the majority of water trade in the southern MDB by volume. However, total entitlement trade volumes increased substantially from 2007–08. Though entitlement trading included government purchases of entitlements for the environment, in 2008–09 and even more so in 2009–10, much of the observed increase is attributable to entitlement trading between irrigators (see Figure 2).

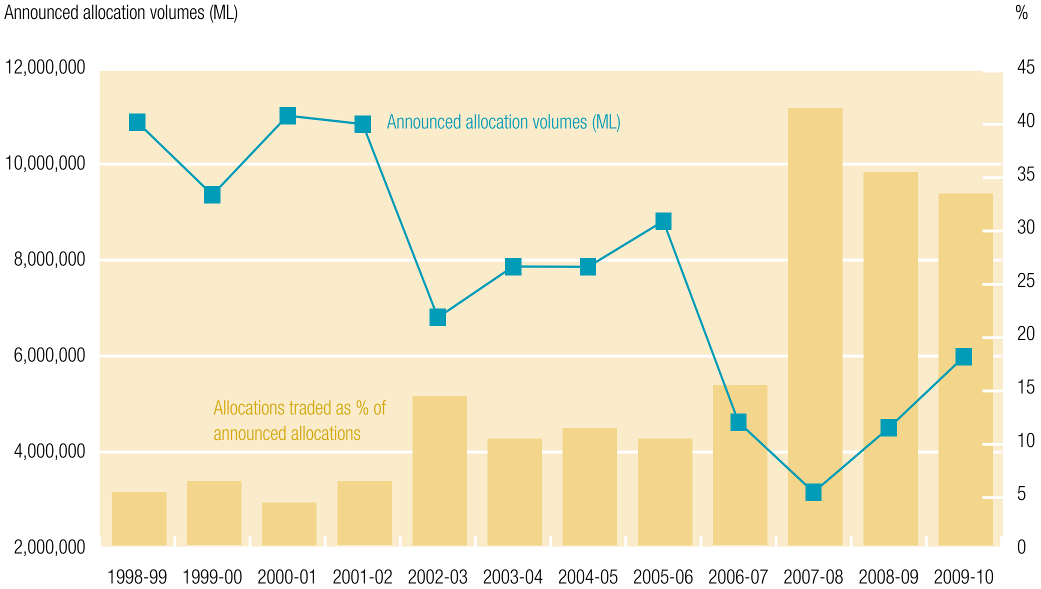
There is clear evidence showing that water market price signals adjust to seasonal conditions. Figure 4 demonstrates the strong and inverse relationship between the availability of water and prices for allocation trades. Allocation prices peaked in early 2007–08 on the back of concerns that extremely low allocations in 2006–07 may be repeated. In contrast, 2009–10 was characterised by substantially lower prices given the improved water availability situation. Prices decreased steadily over that season as water availability increased further.

FIGURE 2
VOLUME OF ALLOCATIONS AND ENTITLEMENT TRADE IN THE SOUTHERN MDB (1983–84 TO 2009–10)



Source: National Water Commission 2010b

FIGURE 3
WATER ALLOCATION SALES AS A PERCENTAGE OF WATER ALLOCATED IN THE SOUTHERN MURRAY-DARLING BASIN (1998–99 TO 2009–10)

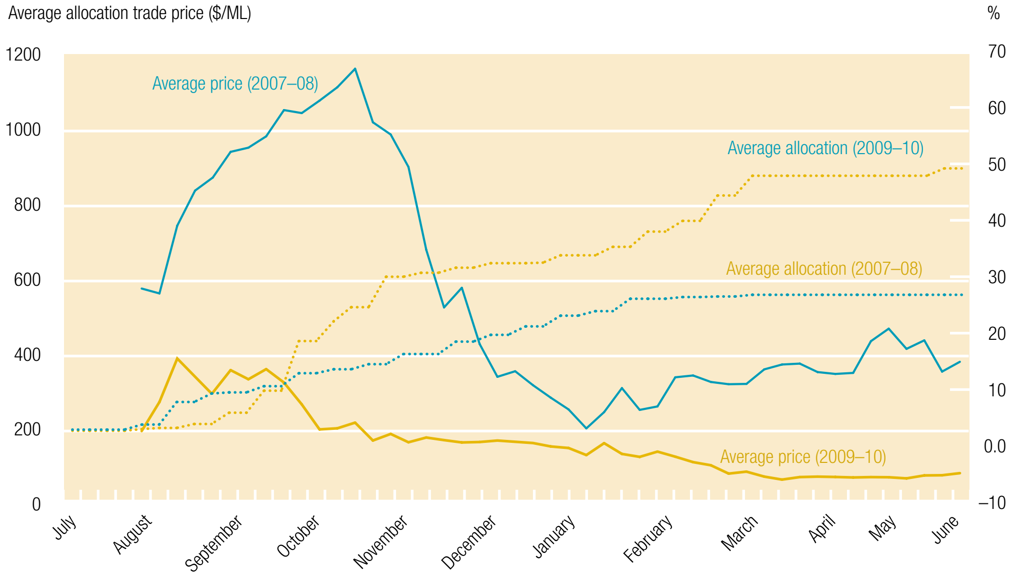


Source: National Water Commission 2010b

While seasonal variations in water availability and short and long-term changes in the fortunes of different agricultural activities were major drivers of the volumes and prices of water trades, the willingness of irrigators to participate in the market increased significantly over this period. This reflects growing acceptance of water trading, a greater understanding of how the market operates, and that more and more irrigators have developed farm management strategies that involve the use of water trading (NWC 2010a). Growing adoption of water trading can also be attributed to improvements in the functioning of the water market that have reduced transaction costs to buyers and sellers, increased tradeability, and increased the confidence of buyers and sellers in the market mechanisms.

FIGURE 4

AVERAGE WATER ALLOCATION AND AVERAGE ALLOCATION PRICE IN THE SOUTHERN MDB (2007–08 AND 2009–10)



Source: National Water Commission 2010b

Results

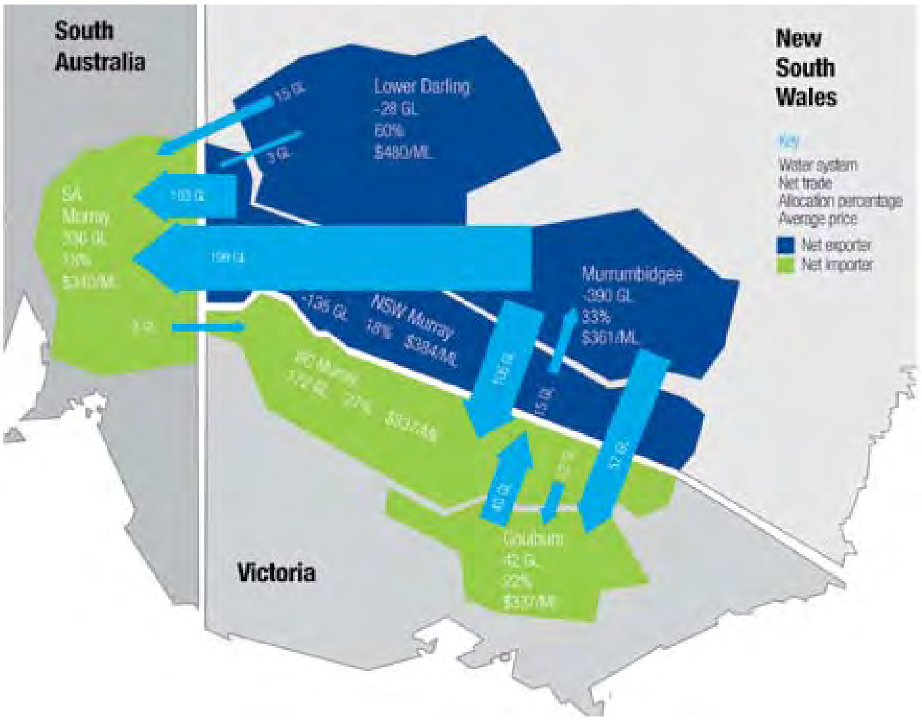
There is strong evidence that the expected benefits of water trading have eventuated in practice. At an aggregate level, economic modelling of the irrigation sector undertaken for the National Water Commission (NWC) estimated that water trading maintained production and productive capacity in the southern MDB during the drought. Overall, the modelling indicated that water trading increased Australia's gross domestic product by $220 million in 2008–09. The same modelling found that all states benefited from trading—New South Wales by an estimated $79 million, South Australia by $16 million and Victoria by $271 million in 2008–09 (NWC 2010a).

While, according to the Australian Bureau of Statistics (ABS), water available for use dropped by 53 per cent between 2005–06 and 2008–09, experimental ABS estimates of the Gross Value of Irrigated Agricultural Production (GVIAP) show that GVIAP only dropped by 29 per cent over the same period (from $5.5 to $4.3 billion). While broadly indicative of the allocative efficiency benefits brought about through the movement of water particularly to high-value horticultural enterprises, there are a number of acknowledged problems with GVIAP as a measure of the productivity of water. In particular, GVIAP does not consider price movements over the period; and does not recognise the fact that many dairy farmers substituted water for other inputs (see below).

Partly in response to this knowledge gap, the NWC continues to undertake a number of projects to understand the patterns and benefits of water trading in more detail. For example, preliminary data from the Commission's water trading supplement to the ABARES irrigation survey[3] shows that 43 per cent of surveyed irrigation farms across the southern MDB traded water allocations in the three years to 2010–11. An estimated 47 per cent of horticulture farms, 32 per cent of broadacre (rice and cotton) farms and 40 per cent of dairy farms traded water allocations over this period. The majority of irrigators indicated they found the process of trading temporary water allocations to be easy (89 per cent), reliable (84 per cent) and affordable (72 per cent).

FIGURE 5

INTER-REGIONAL WATER ALLOCATION TRADE IN THE SOUTHERN MDB IN 2008–09



Source: NWC (2011b)
Note: the movement of water to South Australia includes significant purchases for urban water users in Adelaide.

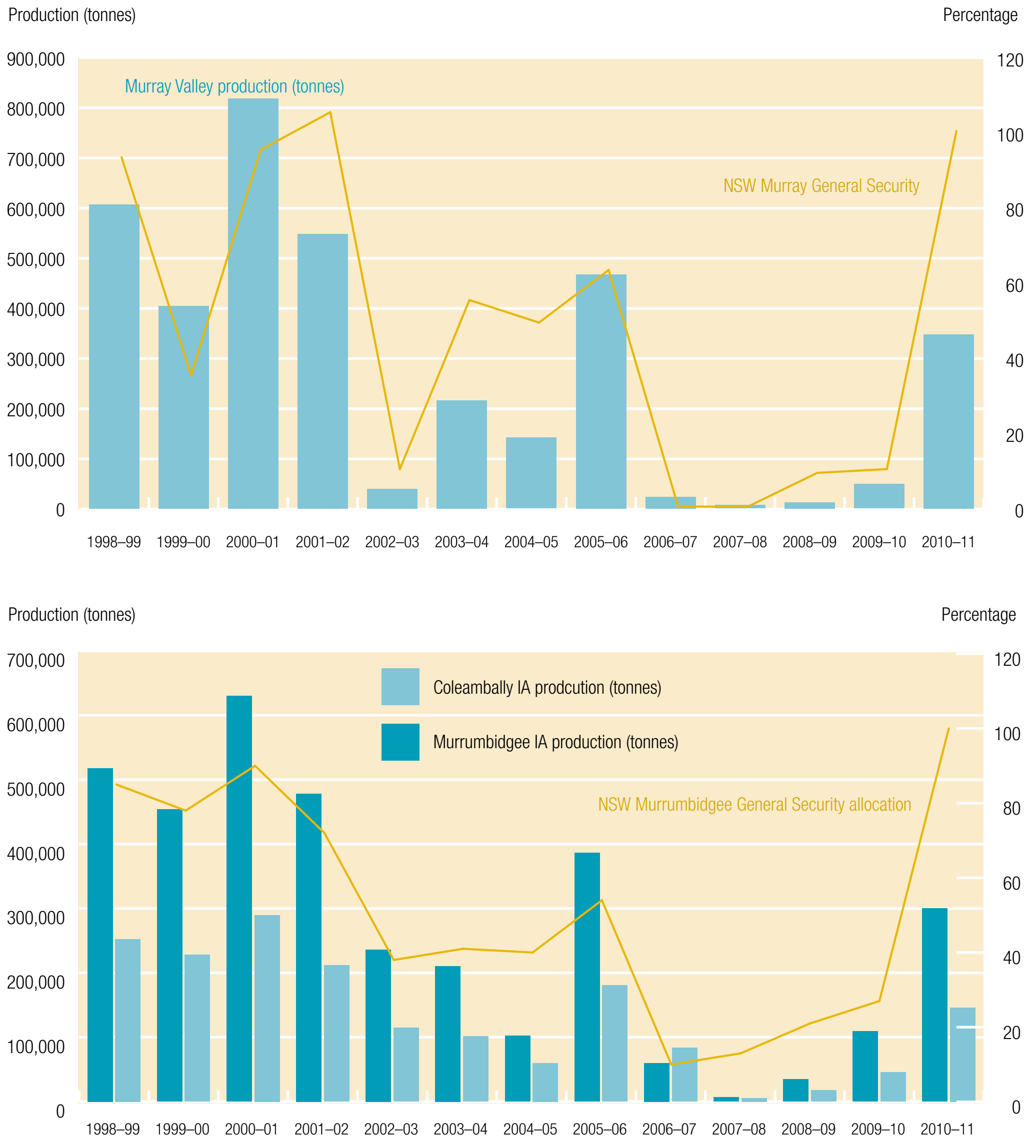
Fifteen per cent of surveyed irrigators traded water access entitlements in the three years to 2010–11, including 11 per cent of horticulture farms, 11 per cent of broadacre farms and 17 per cent of dairy farms. Around two-thirds of the irrigators that had traded water access entitlements had sold their entitlements, with most indicating the main reason for selling was to generate cash (69 per cent). The most common use of the proceeds from selling water access entitlements was to pay off debt (59 per cent). For those farms that traded permanent water access entitlements, 44 per cent stated that they sold to the Australian Government, while 20 per cent stated that they sold to another environmental purchase program. Around one-quarter of irrigators that sold entitlements were planning to cease irrigation, while a further 38 per cent had bought temporary water allocations since selling their permanent water access entitlements. Most irrigators felt the ability to trade water entitlements had helped their farm business (91 per cent).

At an individual producer and industry level, water trading has been vital for the rice, dairy and horticulture industries in the southern MDB during the drought. These key industries are geographically concentrated, with rice primarily located in the New South Wales Murray and Murrumbidgee area, dairy predominantly in the Victorian Goulburn-Murray Irrigation District and horticulture in South Australia and the Victorian Sunraysia region. In drought years, a clear pattern of water movement associated with inter-regional allocation trading has emerged. As shown in Figure 5 in 2008–09, water generally moves downstream to horticulture in Sunraysia and South Australia predominantly from rice growers in New South Wales.

This pattern of trade is indicative of significant allocative efficiency gains as limited water resources moved from those producers with flexible irrigation demands to those with inflexible demands including long-lived perennial horticultural assets. The movement of water was complemented by a compensating flow of payments in the other direction which helped maintain the viability of individual farm businesses.

FIGURE 6

RIVERINA RICE PRODUCTION AND END-OF SEASON ALLOCATIONS TO NSW GENERAL SECURITY WATER ENTITLEMENTS – MURRAY AND MURRUMBIDGEE (1998–99 TO 2010–11)



Source: The Rice Marketing Board for the State of New South Wales and New South Wales Waterinfo

Rice

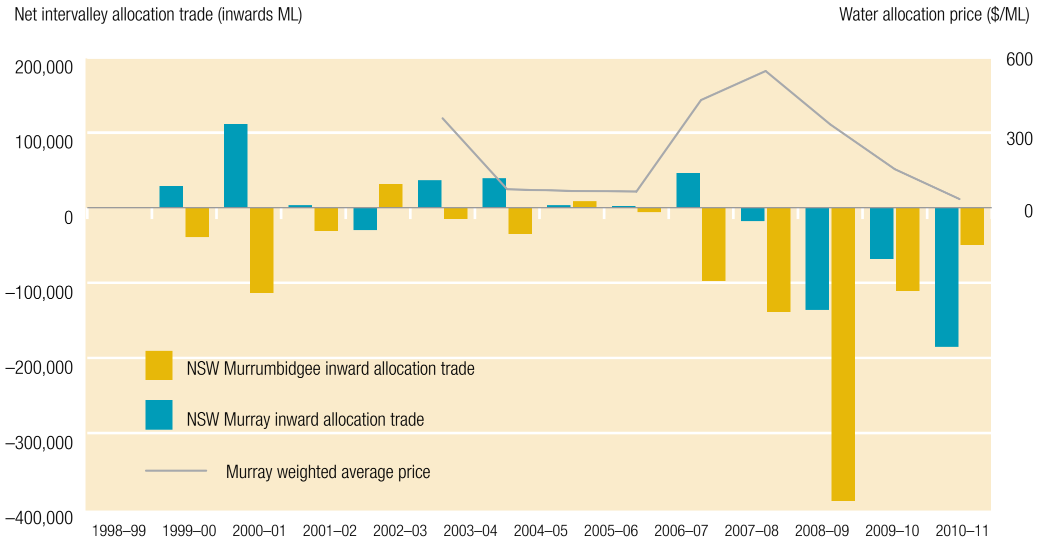
Rice production in Australia is concentrated in the Riverina area of the MDB, along the Murray and Murrumbidgee Rivers in New South Wales. The rice industry is highly vertically-integrated with about 1500 farms supplying the grower-owned company, Sunrice, which undertakes the vast majority of the storage, milling, processing and marketing of Australian rice.

Rice is an annual crop so it only needs water if the crop is planted. Rice growers can produce when water is relatively abundant and sell water on the market to provide them with additional income when water is scarce. The flexibility of rice production is well suited to the annual variability in water availability in the MDB and complimented by the flexibility of water markets.

Most rice growers hold New South Wales General Security Entitlements in the Murray or Murrumbidgee systems. As shown in Figure 6 and Figure 7, rice production and water trading is extremely dependent on allocations against these two entitlement types

FIGURE 7

OUTWARD WATER ALLOCATION SALES AND WATER ALLOCATION PRICES (1998–99 TO 2010–11)



Source: Watermove and MDBA Water Audit Monitoring reports

and the price of water allocations. Rice growers make decisions early in the irrigation season about how much rice to grow based on initial water allocation announcements, the expected price of water, and the price on offer for rice. In some years this may involve selling their water rather than using it to grow rice. But when water is plentiful, rice production expands.

Rice production peaked in 2000–01 when 2499 farmers in the NSW Riverina grew a record 1.74 million tonnes of rice (see Figure 6). However, the prolonged drought had a massive impact on rice production from 2002–03 onwards. Figure 6 shows that production fell even more significantly in the four years from 2006–07 to 2009–10. In 2007–08, a mere 38 farmers produced just 19,000 tonnes of rice in the Riverina. Despite the fact that rice prices increased to encourage production, drought induced low water availability and high water prices made it unviable to grow a crop.

Water trading has been vital to help rice growers respond to seasonal conditions and provide them with much needed income. Trading in seasonal water allocations in particular has proved essential for rice growers. As the price for water allocations rose above the threshold determined by individual rice growers as viable for use in rice production, they tended to sell allocations. During the drought years, rice growers could make more money, with less risk, by selling their water.

This was observed in the Murrumbidgee when:

- In 2007–08 a net volume of 139,096ML was traded out, the mean water price was $495/ML the expected gross margin for rice was $150/ML; and
- In 2008–09 when 390,000ML was traded out, the mean water price was $375/ML while the expected gross margin for rice was $260/ML (Sources: MDBA WAM reports, NWC Australian water markets reports, NSW DPI farm budgets).

Despite the limited allocations available to sell, rice growers particularly benefited from the high water allocation prices on offer in 2007–08 and 2008–09 (see Figure 7). Figure 7 shows the strong correlation between the price of water allocations and the volume of water allocations traded out of rice-growing regions (especially the Murrumbidgee). Even though prices for rice were up at this time, it still made financial sense for rice growers to sell their limited water allocations and cease rice production.

For many, water sales were their only source of income for four dry years from 2006–07. Trade helped these irrigators survive and they are now able to respond to improved conditions. Improved water availability in the Murray and Murrumbidgee systems, combined with low water prices, means rice growers are once again using the water allocated to their entitlements and bought allocations to expand production. Rice production is back online in the Riverina, rebounding to approximately 800,000 tonnes in 2010–11 and once again making a significant contribution to Australian agricultural exports and rural economies.

Dairy

Australia's major export-oriented irrigated dairy industry is located in northern Victoria and southern New South Wales. According to Dairy Australia, the estimated value of farm gate production in the region in 2009–10 was $610 million, there are 14 dairy factories including milk processing, milk collection plants and dairy product manufacturing in the region (Murray Dairy 2011).

Water is a key input in irrigated dairy production and the drought over the last decade has had a big impact. However, irrigated dairying can be thought of as a semi-interruptible production process. There are opportunities for dairy irrigators to avoid using water to grow fodder. Instead they can purchase fodder, move cattle elsewhere, and vary their herd size. Dairy farmers can also switch between annual and perennial pastures based on their exposure to water availability risk. Therefore, water use and trading decisions for dairy farmers are more complex than for irrigators in other industries.

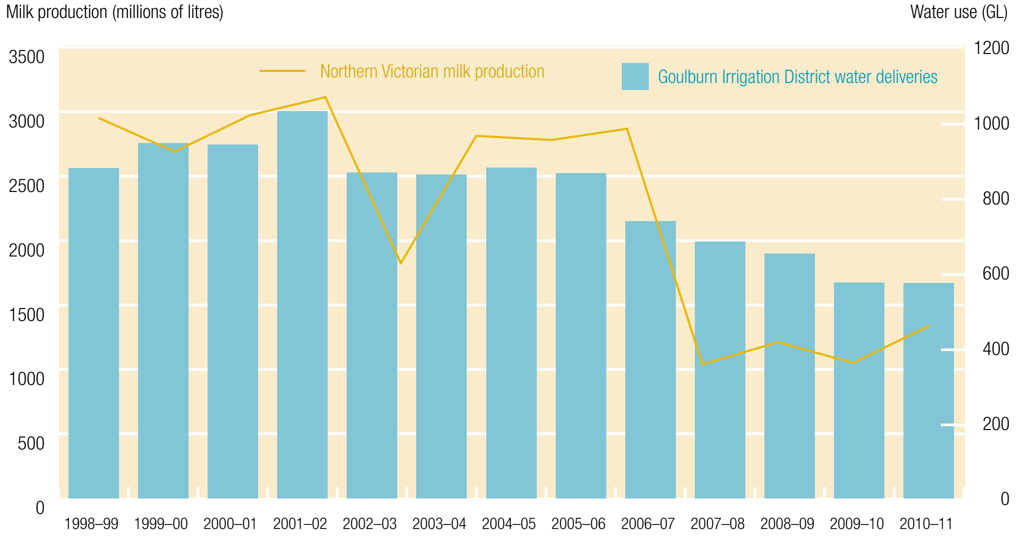
Given the substitutability of irrigated pasture and purchased fodder as feed sources, the water trading behaviour of dairy producers depends on water allocation prices and prevailing fodder prices (as well as milk prices). Most dairy farmers now understand the price in the water allocation market where they should move from buying more water to selling water. This breakeven point depends on the prevailing price of alternative feed sources and the milk price. In 2007–08 when allocations in the Murray system dropped dramatically, and horticulturalists purchased large volumes of water, the decision to sell allocations was straightforward. The high prices for water provided much needed income which could be used to purchase feed and maintain production.

Figure 8 shows that the proportionate reduction in milk production in northern Victoria was much less than the reduction in water availability (in the Goulburn system). This was primarily due to the potential to sell remaining water allocations at a high price and instead purchase fodder.

Water allocation trading has proved to be central to the decision making of dairy farmers, helping them increase or maintain production, maintain herd size, and generate additional income. The ability to trade water provides flexibility to determine the best mix of inputs at any point in time. Forty-three per cent of surveyed dairy farmers in the southern MDB traded water allocations in the three years to 2010–11.

Water entitlement trading has also enabled the dairy industry to respond to the prolonged drought, long-term adjustment pressures, and fluctuating market fortunes. ABARES irrigator survey results from 2006–07 to 2008–09 indicate that, on average, dairy farmers in the MDB had negative farm business profit and very low or negative rates of return on their assets during the drought. The ability to trade entitlements separately from land means that irrigators in financial trouble did not necessarily have to sell their farm and water assets; many chose to sell their water, lease out their land and remain on the property. Furthermore, the opportunity to sell water entitlements to the Australian Government's water recovery buy-back program has had a significant impact on the dairy industry. Many have seen the buy-back program as an opportunity

FIGURE 8
NORTHERN VICTORIAN DAIRY PRODUCTION AND WATER USE IN THE VICTORIAN GOULBURN IRRIGATION DISTRICT (1998–99 TO 2009–10)



Sources: Dairy Australia and Goulburn-Murray Water annual reports.

to reduce debt and change their farming strategy. These remaining irrigators have generally become more dependent on annual purchases of water allocations and carryover. Most have converted to annual pastures which are more flexible. In this way, allocation and entitlement trade are used as part of a combined strategy.

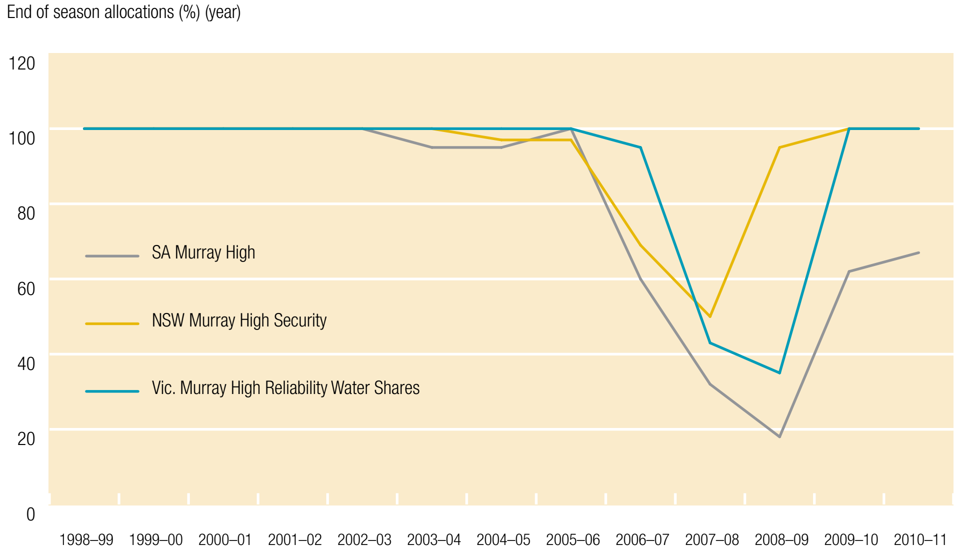
Horticulture

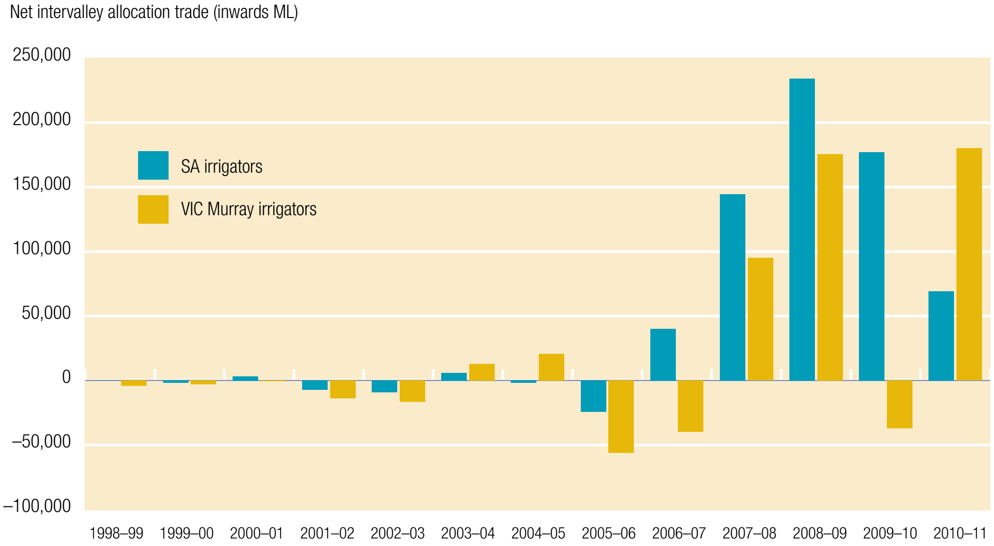
There has been a significant expansion of horticulture in the southern MDB over the last decade, particularly in wine grapes, almonds and olives in the Victorian Sunraysia, NSW Riverina and SA Riverland. For example, Australia's almond industry is one of Australia's fasting growing horticultural sectors. As new plantings mature, the current farm gate value of almond production of $250 million per year is expected to increase to $600 million by 2016. Wine grapes also developed rapidly in the early to mid 2000s but a glut in the wine market has led to a significant restructuring of the industry.

Water trading has played a key role in the horticultural industry, particularly in the Victorian Sunraysia and South Australian Riverland regions. Access to irrigation water is essential, and with a cap on total water use in place in the MDB, the ability to purchase water underpinned the new development on greenfields sites. The horticultural industry could not have developed in the MDB over the past decade without water markets.

During the investment phase, horticulturalists preferred to purchase high reliability entitlements. Unlike annual crops like rice, the water requirements of almond trees and wine grape vines are relatively fixed. Unlike dairy production where farmers can buy in fodder to substitute for irrigated pasture, there are no alternatives to watering via irrigation. The purchase of high reliability entitlements provides a means of managing the risk of needing to purchase allocations at high prices in dry years to meet all their water requirements. Farm managers have purchased entitlements progressively in accordance with development plans and increasing water requirements as trees and vines mature. Without an active water market, including the ability to trade water access entitlements, the development of the almond and wine grape industry could not have occurred in the same manner.

FIGURE 9
ALLOCATIONS AVAILABLE TO MURRAY HIGH RELIABILITY WATER ENTITLEMENTS AND NET ALLOCATION PURCHASES IN THE VICTORIAN MURRAY SYSTEM





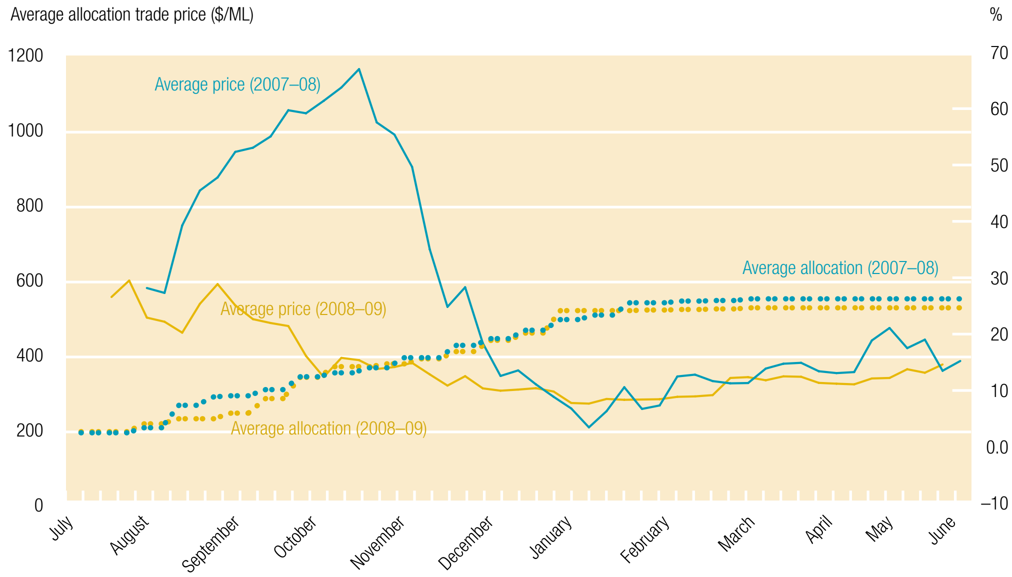
Source: South Australian, Victorian and New South Wales Governments, MDBA Water Audit Monitoring reports. Note: South Australian figures exclude water purchases for urban water use.

Most of the entitlements acquired during the horticultural development phase were purchased from dairy farmers in the Victorian Goulburn Murray Irrigation District. Importantly, entitlement purchases by horticulturalists provided these sellers with a return on their water assets as they made adjustment decisions.

Despite these investments in entitlements, water allocation trading played a critical role in ensuring that horticulturalists could survive the severe drought, particularly in 2007–08 and 2008–09 when seasonal allocations dropped below 100 per cent. To make up for the shortfall, horticulturalists had to enter the market and buy allocations (Figure 9).

In the recent survey implemented by ABARES, 63 per cent of horticulture farms in the Murray region traded water allocations in the three years to 2010–11. Purchases of additional water allocations kept almond trees and vines alive and helped maintain production. Without the water market, it is likely that many trees and vines would have died.

FIGURE 10
WATER ALLOCATION PRICES IN MURRAY (ZONE 7)



Source: National Water Commission 2011

In the rush to secure their water supplies in the dry commencement of 2007–08, many horticulturalists entered the market at the start of the season and contributed to the very high prices observed in the first months of the 2007–08 water year (Figure 10). Although water scarcity was just as acute in 2008–09, the extremely high prices observed in 2007–08 were not repeated, partially due to almond and other horticulturalist learning from the previous season and spreading water purchases more widely across the season.

Two of the original drivers of the development of water markets in the MDB were to enable new development within a system with overall caps on water use, and to allow water to move to where it is most needed in response to seasonal water availability. The horticultural industry illustrates that these goals are being met. With wine grape growers now subjected to low commodity prices and a wine glut, the sale of water entitlements, particularly to the Australian Government buy-back program is helping adjustment in the sector.

Brief overview of results in other theme areas

In addition to enhancing agricultural productivity, water markets have made a significant contribution to other themes explored in this volume:

- Managing risks for urban water supplies: Water security in cities and towns has been enhanced where it is possible to access the water market. For example, SA Water purchased large volumes of allocations at the peak of the drought to meet demand and limit the impact of water restrictions in Adelaide. In other areas, policy barriers to rural-urban water trading are likely to contribute to inefficient supply augmentation and sourcing decisions;
- Healthy ecosystems: As found by the Productivity Commission and others, the Australian Government buy-back program represents a cost-effective means of acquiring water for the environment and transitioning the irrigation sector to more sustainable levels of extraction. Water recovery through buy-back is a far more

cost-effective than through off-farm irrigation infrastructure projects. Over 1000GL of water entitlements have already been purchased in the MDB; and

- Regional economies: Sustainable irrigation communities need sustainable irrigators. Water trading has helped many irrigators survive the drought and this has flow on benefits for industries and regional communities. Structural adjustment is an ongoing process in the irrigation sector, and it is resulting in change in some localised communities. Water trading is not the underlying cause of this adjustment, but merely a tool for enabling individuals to respond to changing needs. Moreover, the key lesson of the international success of the Australian agricultural sector is that structural adjustment needs to occur to maximise the beneficial use of scarce resources in response to changing market, policy and environmental conditions. Distributional and equity objectives are best met through the welfare system and other targeted measures, rather than by constraining use of the water market.

Conclusion

The water market has grown into a multi-billion dollar institution. The existence of water markets makes for a more resilient and responsive irrigation sector which is better placed to adapt to drought and other pressures for change. Over the past decade water trading has been vital to irrigation industries; through this period of severe and prolonged drought water trading has:

- Helped irrigators respond to seasonal conditions and manage risk;
- Promoted more sophisticated farm management;
- Underpinned the expansion of the horticulture industry;
- Helped maintain permanent plantings;
- Provided irrigators with income;
- Enabled irrigators to reduce debt levels and restructure their businesses; and
- Facilitated structural change in industries and communities.

The value of these benefits in the southern MDB ran into the hundreds of millions of dollars per annum during the drought and represents a major success in water policy reform. Irrigators learnt quickly during the drought and now employ very sophisticated water trading strategies. Many irrigators are highly reliant on the water market. More broadly, benefits for individual irrigators have translated into benefits for regional communities, regions and Australia as a whole.

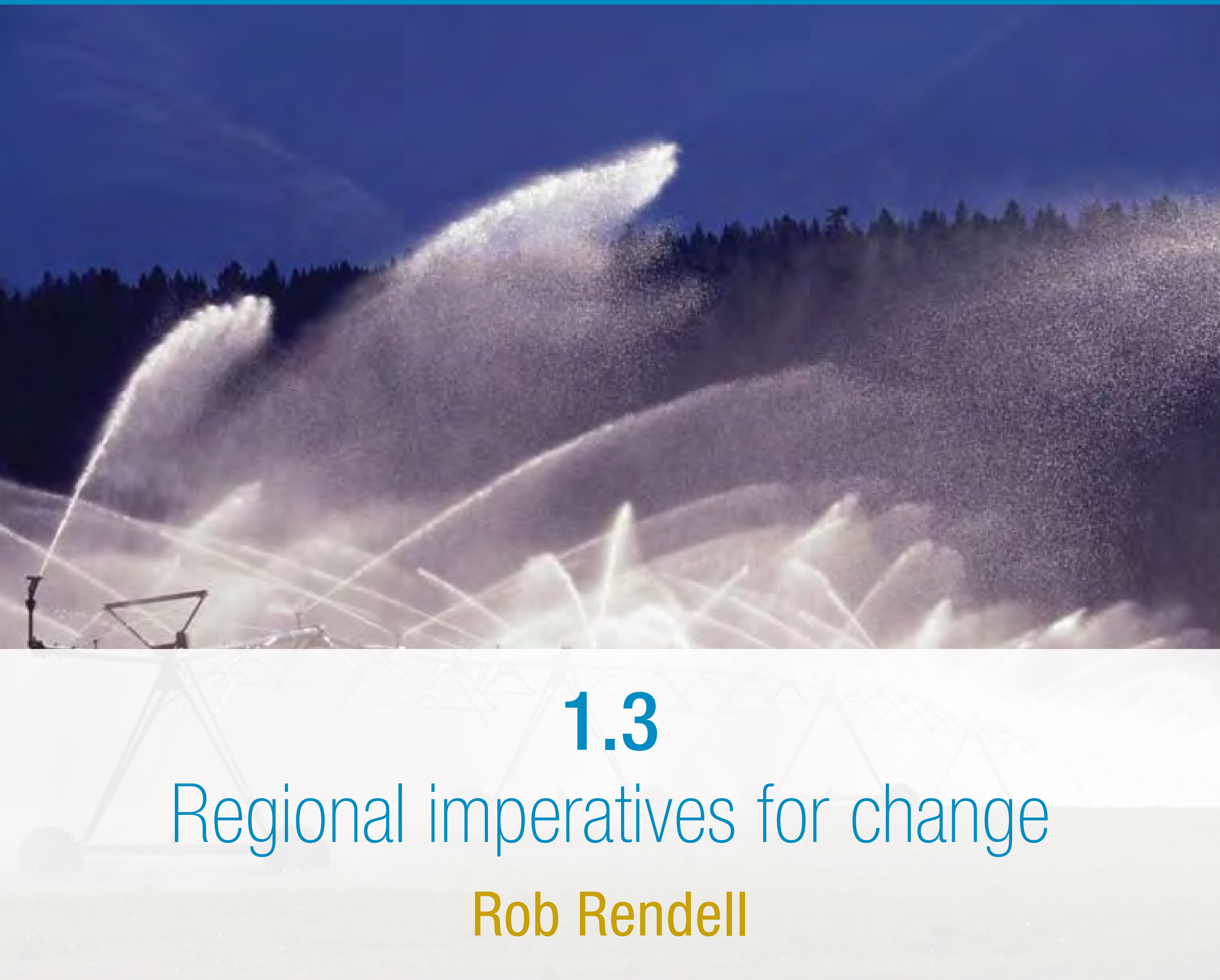
In our view, it is inconceivable that alternatives to water markets such as centrally-determined systems of water provision to competing users would have enabled the flexible movement and reallocation of water that has occurred during the drought. Water markets have resulted in a more resilient and responsive irrigation sector which is better placed to adapt to drought and other pressures for change.

Endnotes

1 For example, a water right (or water access entitlement) of 10 megalitres (ML) is not guaranteed to provide 10ML each year. The 10ML will only be available when there is an allocation of 100 per cent. For example, when resource availability is 80 per cent, the entitlement would only yield 8ML that year, and so on.

2 In 2009–10, the MDB accounted for just over half of Australia's total irrigated area and about 37 per cent of Australia's irrigating agricultural businesses (ABS 2011).

3 The ABARES irrigation survey is designed to collect information from broadacre (including rice and cotton), dairy and horticulture irrigation farms within the major irrigation regions in the MDB. The full results of the supplementary survey will be released in early 2012 as part of an updated assessment of the impacts of water trading in the southern MDB.



1.3

Regional imperatives for change

Rob Rendell

Rob Rendell has more than 35 years experience in irrigation, groundwater drainage, salinity management, project management, extension, reclaimed water re-use, practical irrigation farming and farm management, agricultural industry benchmarking and sustainability indicators. He is recognised as a leader in the water sector.

He has been an innovator in many areas starting with irrigated sunflower production on his family farm in the 70s and then being involved in the development of laser grading in the late 70s. In the 80s Rob was a key part of the salinity management planning process which evolved to catchment planning and more recently water infrastructure planning.

He developed much of the agricultural industry benchmarking systems in dryland, tomatoes, rice, dairy etc that evolved in the 90s. Along with this he was part of the FM500 farm management discussion group.

He has also led the development of policy guidelines and practical approaches to the use of land-based systems for the application of reclaimed water. These projects have covered every type of irrigation system and every type of irrigated agriculture. The projects have included over 30 sites throughout Victoria and recently New Zealand.

More recently he has been part of developing processes for managing over-allocated groundwater resources.

His largest project ($2 billion) has been the Northern Victorian Food Bowl project, where he played a role as the "architect" of the scheme.

A. Evolution: abundance to scarcity

The history of water reform in the southern connected Basin is characterised by a series of stages with highly differential drivers.

One unifying factor in the history of changes in water use for irrigation is the primacy of cost control and automation to reduce labour inputs in determining investment decisions. The aim has been to increase the scale of production to match international cost competition.

1. Early days

Each of the regions within the Southern Basin started as separate entities with their own storages or dams built over time from 1900. The history of major dam construction in the southern Basin spans 60 years, from when the Hume Dam was first started in 1919 to the completion of Dartmouth Dam in 1979. Large scale irrigation in NSW commenced with the establishment of the Murrumbidgee Irrigation Area in 1912 which diverted water from the Murrumbidgee River near Narrandera.

Initially each region had a separately constituted irrigation district such as Murrumbidgee Irrigation district, the Goulburn Murray Irrigation district, Sunraysia in NSW and Victoria and the Riverland districts.

Many of the districts were the product of explicit social policy with a commitment to resettle soldiers returning from the two great wars. In practice this policy was often disastrous in terms of establishing viable farming enterprises.

> *More than 10,000 returned soldiers took up blocks between 1918 and 1939, with most of the irrigation blocks being near Maffra and in the Goulburn Valley. Many settlers found that the block was too small or too infertile to sustain a living and many did not have the capital to make improvements. They found themselves in a spiral of ever increasing debt. By 1939, 60 per cent of soldier settlers had walked off their land.*[1]

An equivalent distribution after World War II saw larger blocks and more careful selection criteria.

2. 1950s–1970s

This period saw the major growth of irrigation infrastructure and supply systems. Dam building was prevalent and development was the primary objective. Water was abundant. This formed the background for most of the farm development and irrigation system construction that is in use today. The assumption during this period was that if there was pressure for more development then another dam and irrigation district were created. The Campaspe irrigation district was one of the last such districts completed in the 1970s on the back of the water available from Lake Eppalock that was completed in 1961.

The Snowy Mountains Scheme was a classic example of the mind-set with a desire to use water to generate production and promote social development. The scheme involved the construction of 16 major dams, 225 kilometres of tunnels, pipelines and aqueducts to transfer 2100GL a year from the Snowy and other rivers to support irrigated agriculture in the Murrumbidgee and Murray Rivers as well as to generate hydro-electricity. It was constructed between 1949 and 1974 and at its height employed 100,000 people from 30 different countries.

The water made available from the scheme also justified the setting up of the Coleambally Irrigation District in 1968. Indeed the period between 1955 and 1975 saw the steepest expansion in diversions from the Basin.

There was generally a significant time lag between the storage being built, the full entitlements being allocated and farm development.

The significant feature is that the granting of an entitlement was generally free with the intention of promoting the development of irrigated production. This contrasts strongly with the current scenario where the imposition of a cap on diversions and the development of water trading have created significant value in the water entitlement as a separate valued asset.

3. Salinity concerns: 1980s and 1990s

A major concern in the 1980s and 1990s was of the risks of increased salinity from raised watertables driven by increased accessions from irrigation. This concern created a focus on irrigation locations and controls. As ABARE reported in 1996:

> *Increasing areas are being affected by high groundwater and salinity in the irrigation areas of Victoria and New South Wales. To address these issues salinity and land and water management plans have been, and are continuing to be, developed. The plans are aimed at addressing waterlogging and associated salinity problems through improved resource management. While government funding is provided to the plans, they are essentially community driven projects. Since the first salinity management plan was developed in Victoria in 1983, the plans have evolved to incorporate more refined data, different methods of addressing salinity and waterlogging issues, and improved modelling procedures.*[2]

These plans, starting in the mid 1980s, were an early precursor of changes in the culture of irrigation from one based on expansion and growth into one focussed on controls and generating greater production from an increasingly managed resource.

Four factors were highly influential in the development of concerns around salinity:

- The Murray River was the main source of supply for Adelaide. The salinity in the Murray was seen to increase costs and risks for this supply;
- The floods of 1972, 1973 and 1974 and the wet years since World War II increased the level of groundwater tables dramatically, bringing salt closer to the surface;
- The period of water abundance led to risks from poor irrigation practice; and
- The low cost of state-provided infrastructure for surface water meant that groundwater was not generally accessed.

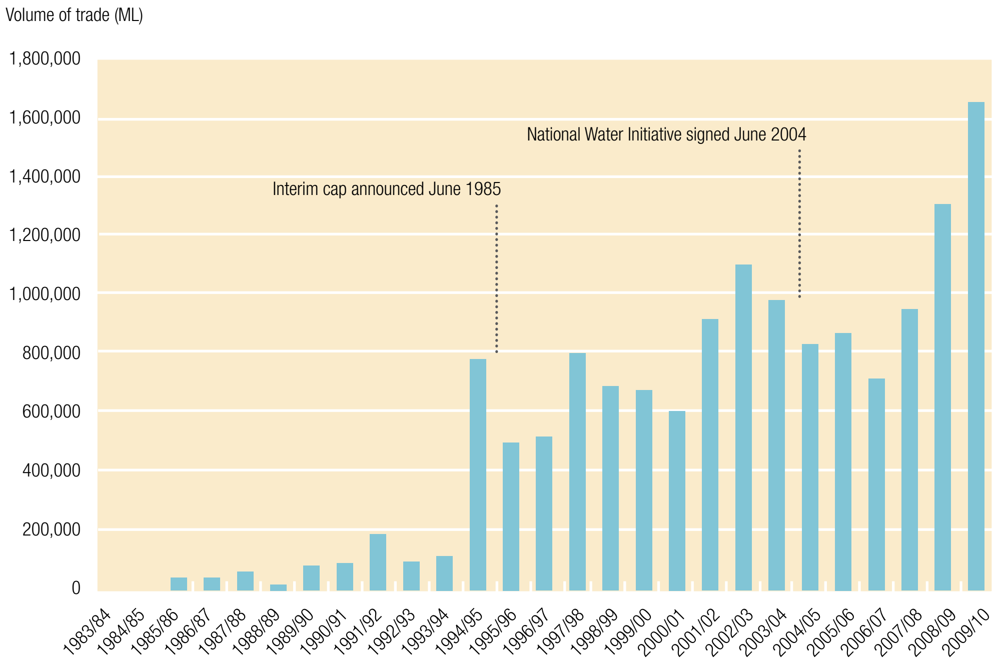
In hindsight, concerns about salinity have been addressed very largely by changed rainfall patterns, combined with the cap on diversions and water trading.

4. Constraints on growth: mid 1990s cap and trading

A cap on diversions from the Murray-Darling Basin river system was introduced by the Ministerial Council in June 1995 in response to an audit of water use across the Basin. This cap was confirmed as permanent with effect from 1 July 1997. The objective of the cap was summarised in the report from the independent audit group:

> *The introduction of the cap was seen as an essential first step in establishing management systems to achieve healthy rivers and sustainable consumptive uses. In other words, the Council determined that a balance needed to be struck between the significant economic and social benefits that have been obtained from the*

FIGURE 1
VOLUME OF WATER TRADE IN SOUTHERN BASIN 1983–84 TO 2009–10[4]



> *development of the Basin's water resources on the one hand, and the environmental uses of water in the rivers on the other.*[3]

The introduction of the Murray-Darling Basin Cap led to a number of important changes.

As long as new, additional entitlements were still being issued the property rights of existing holders were subject to continuous erosion. Placing a finite limit on diversions across the Basin, enhanced the property rights of existing holders. It also created the incentives for water markets and trade, as access to new water for growth was now constrained. In order for that trade to be effective, there was also a need for greater clarity on the terms and conditions of the relevant entitlements codifying security and access rights.

In the absence of the cap, there would have been increasing erosion of the security of supply for existing entitlement holders as the volume of entitlements issued continued to increase and the scale of irrigation demand expanded. This would have led to a downward spiral in the allocation available against each entitlement.

Water trade had existed from the early 1980s, although largely on an informal basis and often tied to the sale of land. This had provided a useful mechanism to allow the reconfiguration of existing properties and change of enterprise type, eg from mixed farming to dairying. However, as long as new entitlements were being issued and dams being built the water asset had little value. The imposition of the cap created a market for a scarce resource and provided the basis for defined property rights and trading.

The impact of the MDB cap on diversions can be seen in the record of water trading. The total volume of temporary allocations traded in the southern basin never exceeded 200,000ML/yr in the period up to 1993/94. By contrast, since the announcement of the Cap the volume of trade has rarely dipped below 800,000ML/yr. Clearly in more recent years the level of trade has been strongly influenced by the drought. It is worth noting that the data prior to 2007/08 does not include temporary trades within the larger NSW irrigation corporations.

The development of water trading provided a powerful mechanism to help promote continued development and expansion of irrigated production from a constrained resource:

- It provided an opportunity for irrigators running mixed farms on poorer soils to realise a capital value and exit the industry;
- It enabled dairy and horticulture to supplement their access to water in years of low allocations to maintain production;
- It provided a route for mixed farms to service and support the dairy sector either through access to water or through production of fodder crops for feeding systems;
- It allowed rice farmers to choose between growing rice or to realise the value of their allocations depending on the relative price of rice and or water in the temporary market; and
- It enabled the growth of higher value horticultural sectors through the permanent transfer of entitlement from older established areas to newer greenfield sites in Sunraysia and around Griffith.

The introduction of water trading means that the separate districts across the southern Basin now operate effectively as a single coordinated body.

5. Water security and production equilibrium

Irrigation in the southern Basin is strongly influenced by the high variability of rainfall and river flow from year to year. Different strategies have been adopted by different sectors and states based on the relative reliability of the water entitlement:

- Horticulture with high security water developed on the best available soil lands in four areas: Griffith/Leeton; Sunraysia (both sides of the river) and Riverland (and to a lesser extent in the Goulburn Valley);
- Dairy developed in northern Victoria where the security was mixed with a combination of a medium reliability water right backed by regular access to a lower reliability “sales” product;
- Southern NSW with its heavier soils adopted a rice enterprise which suited a lower security supply (but greater average yield); and
- Considerable volumes of lower reliability water was made available to traditional mixed farming (grazing/winter cropping) to supplement production.

Water trade from 1994 helped facilitate a shift in production within and between sectors and locations over time resulting in a new equilibrium based around different water products and different sectors:

- High security entitlement: is now mainly held by horticulture as this provides the risk management required for permanent plantings and long-term contracts for high value produce;
- Medium security: is mainly held by dairy with the ability to access additional water as required through the temporary market, or the ability to replace it with bought in fodder where necessary; and
- Low security: is mainly held by annual crops such as rice with opportunistic annual decisions on the area planted.

This evolution of the “equilibrium” was demonstrated in the recent drought where in the extreme drought only horticulture was able to afford to access the small amounts of water available and dairy survived by purchasing grain and fodder from dryland production. In the five or so dry years horticulture was unaffected but dairy had reduced volumes and rice had almost no production.

The different states have also adopted highly differential policies regarding entitlements and allocations. Victoria has traditionally been conservative in its allocations policy holding back sufficient storages to guarantee a full allocation in the following season before distributing "sales" water. This is effectively a socialised management of reliability needed to support sectors with a need for high reliability. By contrast, NSW has tended to promote an annual allocation model whereby the maximum available volume has been allocated each year. This is suited to annual cropping where the area planted reflects the volume of water available in that season.

6. Water trade – current developments

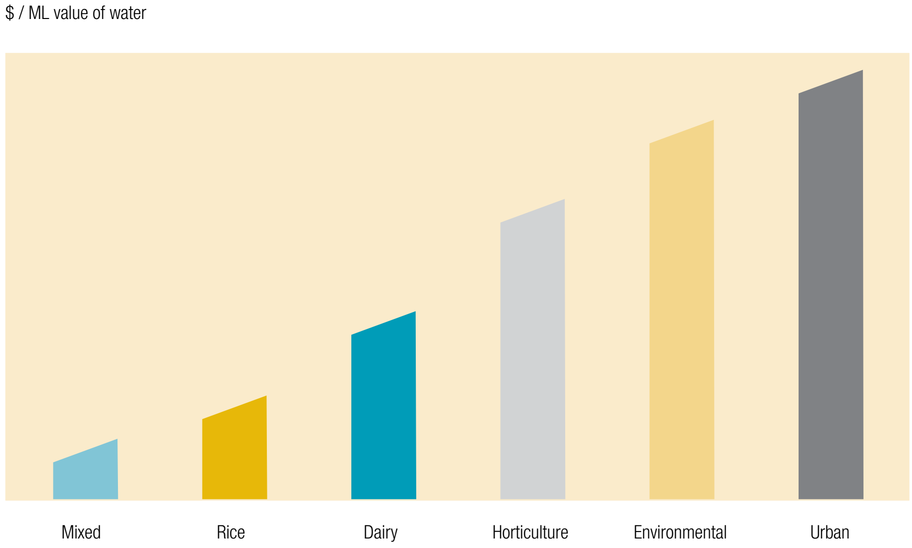
As noted above, water trade has facilitated major adjustments within and between sectors:

- Water was originally tied to land. Unbundling has separated out the constituent elements allowing water to be valued as a separate asset;
- Water trade has then created commercial imperatives to drive the allocation and use of that asset to higher values;
- Socialised allocation decisions around access to water in any season are now under pressure with a move to "privatise" risk management through greater rights of access to personal carry-over decisions; and
- Buy-back has exposed the new equilibrium and the correlation between the size of the demand and value in water markets.

It is important to understand the relationship between the scale of water trade, different sectors and the value of entitlements. Figure 2 provides a graphical representation of the key factors. It shows:

- Different sectors hold or sell water at different trigger points;
- There is differential production efficiency within each sector;
- As the Commonwealth Environmental Water Holdings has increased, buy-back demand has shifted further to the right on the graph;

FIGURE 2
WATER TRADE, SECTORAL IMPACT AND EFFECTIVE VALUE



- As this occurs, the sectors affected have changed and so the effective market value has increased to match the relevant spectrum of willingness-to-sell; and
- While the size of the buy-back was relatively small, it mainly affected annual cropping sectors with lower willingness to sell and consequential market value. As the aggregate volume sought has increased this has shifted the impact to sectors with higher values.

There are several lessons from this graph:

- Water moves to the most productive enterprise. This sees trade between sectors. The scale of the rice and dairy sectors has now squeezed out most other lower value sectors such as mixed farming;
- Water moves to the more efficient enterprises within each sector (this is shown by the slope at the head of each block). There are substantial differences in efficiency between farmers within sectors so water moves from low to high efficiency farmers within the sector;
- The price of water increases as it gets scarcer. This drives more efficient practices;
- The price of water is set by the sector that is selling, so horticulture buys water at the return available from dairying. As you move up the chain, the price goes up and the activities for water saving are encouraged further;
- The security of the entitlement matters. This drives an equilibrium, with different sectors holding the type of entitlement that matches their respective needs, for example horticulture holds high security entitlements while rice can operate with low security; and
- Increasing the value of water as you move up the chain provides a mechanism to promote restructuring and adjustment. This encourages lower value and less efficient enterprises to sell and gives them a decent exit strategy.

B. Cost control drives water use

The most profound drivers regarding water use in irrigation are commercial and seek to increase profit by increasing scale and reducing labour costs.

1. Drivers of change

Historically water was abundant and cheap. As a result, there was no incentive to reduce water use. On the contrary, the incentive was to increase the size of the property and the volume of water used, as the greater the total volume of water used the bigger the business and the greater the profit per business owner.

The primary driver of changed water-use has been the desire to control costs and expand the scale of production. Most irrigation farming businesses traditionally employ a minimum level of labour (normally only one-two units per business or use contract labour pickers etc). The owner/occupier would normally manage all irrigation activities themself as a high risk activity with major potential to impact on production and yields. Thus the historical imperatives are:

- Adopt simple systems that can require low skill levels;
- Limit labour requirements to minimise costs and reduce risks;
- Automate and mechanise to remove tasks that rely on the owner and allow expansion in scale; and
- Maximise total water usage to maximise production.

There are two practical implications of these imperatives:

- Automation; and
- Labour reduction to reduce costs and allow expansion.

Both of these elements result in water use savings. However, the primary driver is to drive down costs, enhance productivity and improve the quality of life for the property owner/occupier. The aim is to maximise the area a property holder can manage and minimise the amount of time required to manage the irrigation activities.

2. History of change

Early irrigation properties comprised of paddocks with large numbers of small bays constructed to match the contours. These small, irregularly shaped bays required a large number of hours to manage and limited the area that a single farmer could manage single-handed. This placed high demands on irrigation farmers and limited the productive capacity of properties.

The period from the 1970s has seen a succession of initiatives across sectors to maximise productivity and reduce costs and labour inputs. There are a number of key examples:

- **Laser levelling** allowed the construction of a smaller number of larger bays within the same area. This area could be irrigated with greater precision with a smaller number of bay controls, outlets and syphons etc. This allowed a larger area to be cultivated by a single property owner within the same overall aggregate time. That drove down unit costs and also enhanced the quality of life. It also freed up time so that the business could be expanded by using more water;
- **Automation** in horticulture was driven by a recognition that higher levels of mechanisation would allow a far larger area to be cultivated with lower unit costs. This imperative drove both mechanisation of pruning and picking and also automation of water delivery, with a move from flood/furrow to low level sprays and then drip. This also reflected limitations in labour availability. In the case of viticulture this automation also involved a happy coincidence between lower watering levels and the quality of the product, as the introduction of regulated deficit irrigation and partial rootzone drying led to improved colour and taste;
- **High-flow flood:** in dairy a move to high flow irrigation systems and automated controls has been driven by a desire to expand the scale of a property without an equivalent increase in labour costs. This allows the sector to win economies of scale and match international competition on costs of production; and
- **Drip tape:** in processing tomatoes this same drive to automation has seen the transformation of the industry from a large number of family farms with low levels of capitalisation to a small number of highly efficient automated producers employing fully automated production and watering techniques based on buried drip-tape with full fertigation.

In each case, the drive for automation and mechanisation has led to higher returns which have also resulted in a reduction in the unit volume of water applied per unit of production. However, the water savings are a secondary outcome from the primary drivers of cost, productivity, quality, labour inputs and quality of life. The sections below explore these drivers in more depth in their application to the central irrigated sectors.

2.1 Horticulture

Early horticultural development was based around flood and furrow irrigation technology. This required high levels of labour which constrained the scale and productivity of properties.

Initial developments in irrigation were, therefore, driven primarily by the demands for automation to reduce labour costs and expand the area that could be managed at reasonable cost to allow the sectors to match international commodity prices. This process saw the introduction of pressurised overhead sprinklers as the preferred technology on lighter soils. This change was led by viticulture and vegetable growing and followed less by the citrus sector or pome in the Goulburn Valley where the heavy soils were well suited to flood/furrow.

Later developments saw the introduction of automation in watering systems to ensure greater controls through micro-drip and drip-tape. Once again automation and control were the primary drivers to allow greater control over production and quality both in viticulture and stone fruits.

The introduction of water trade saw considerable expansion in horticulture which was able to buy water off all other users and establish new greenfield sites with optimal lay-out and controls.

The area of permanent plantings increased significantly between 1996/97 and 2000/01 (with a 78 per cent increase in fruit and nut trees and 77 per cent increase in grapes – mostly wine grapes). This expansion continued from 2001 to 2009 especially in Sunraysia where the area under irrigation expanded by around 75 per cent from 1997 to 2009 and now supports an estimated 64,000 ha of perennial horticulture. Most of this growth was outside the older soldier settlement schemes with their small blocks and ageing infrastructure. There was also growth in the Murrumbidgee wine sector during the 1990s. This growth was underpinned by the removal of planning controls that allowed vine plantings on larger blocks outside the older established horticultural areas.

There was also a 45 per cent increase in the area planted to high value annual crops (especially vegetables) between 1996/97 and 2001/02, with major increases in the larger growing regions. The area and value of vegetable crops grown in the Murray and Murrumbidgee valleys totalled 17,503ha in 2000/01, with a production value of $337 million, with half of this production in the Murrumbidgee.

The recent drought saw a variety of strategies to maintain production in the face of a combination of low allocation seasons and low commodity prices in wine grapes. Some producers bought allocation at high cost to maintain production, some dried off lower productivity plantings, some maintained the area on a reduced irrigation rate. This can be effective in the short-term in minimising demand but is not a sustainable practice as irrigation rates are now less than required to ensure a leaching fraction. The risk is that this will lead to a build of salinity within the root-zone undermining the productive capacity of the soil into the future.

In all sectors water trading has provided a mechanism to protect the longer-term viability of the business, albeit at a financial cost.

2.2 Dairy

The dairy sector in the Southern Basin was historically based on flood irrigation of perennial pastures with direct grazing. This was a simple system with three key aspects:

- Flood irrigation: this is a low capital cost approach with poor water use efficiency,

Processing tomatoes – case study

The processing tomato sector is a good case-study of the changes that have occurred in irrigated horticulture and the continuing pressures to reduce costs and increase productivity.[5] The primary limits to the competitiveness of the Australian sector have been scale and yield. The driver for the adoption of drip tape watering has been to match international benchmarks for yield and scale.

The number of independent growers has fallen sharply over the last 20 years from a figure above 100 in the early 1990s, to the current figure of around 20. Total production has remained broadly constant over that same time period indicating an increase in production per grower.

Figure 1: Number of growers

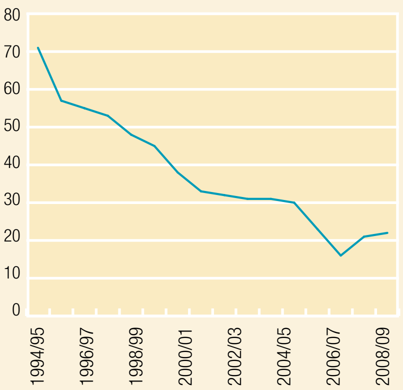
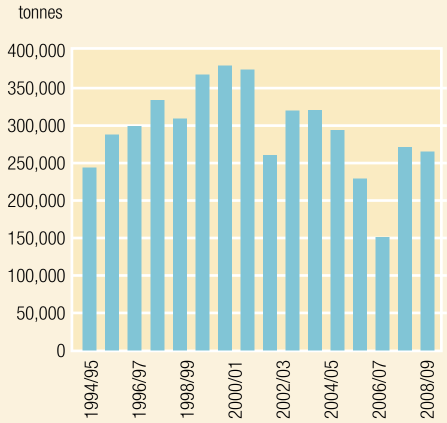


Figure 2: Total production (tonnes)



That increase in production is partly due to an increase in the scale of production, with the average property growing in size from 70 hectares to over 90 hectares, and also partly due to an increase in productivity, in terms of the yield per hectare (Figure 3).

One of the factors that has helped that increase in productivity has been the adoption of improved watering practices such as drip tape irrigation. That allows far greater controls over water and nutrient application and reduces unit labour costs. The adoption rate across the industry has climbed from less than 50 per cent of growers to over 80 per cent, over the last 10 years, with now near universal adoption in Victoria.

Drip improves yields but its major advantage is that it increases the scale of production that is easily managed. Businesses grew from an average annual production of 3000 tonnes in 1994–95 to 12,000 tonnes in 2009–10, a four-fold increase.

Figure 3: Soluble solids/ha (tonnes)

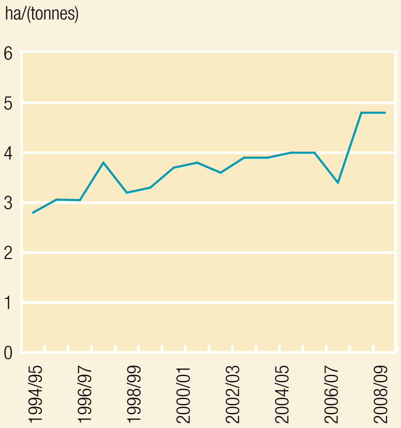
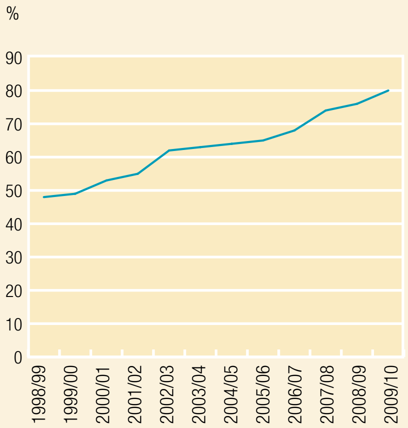


Figure 4: Percent under drip irrigation



but when converted to laser graded layouts had the advantage that the labour cost input are relatively low;

- A perennial pasture: this typically involves a mix of species, none of which are very efficient at converting water into dry matter but it means that cows can graze all year round with little labour input; and
- Direct grazing: this is a simple low cost system with low labour minimum equipment but direct grazing is inefficient at utilising dry matter.

This is a low cost, low risk technology when serviced by large-scale irrigation delivery systems. The characteristics of the perennial pastures allowed considerable leeway in irrigation deliveries between days and in terms of levels of service related to flow rates and consistency. In northern Victoria, dairy farmers were accustomed to receiving an average annual allocation that was a multiple of their entitlement.

Initial controls over irrigation involved the laser levelling of paddocks and the construction of larger bays to minimise labour costs and time and allow the expansion of herd sizes. This reduced the unit costs of a sector that was increasingly export driven and therefore exposed to international cost competition. There was limited automation of controls, with most irrigations still manual in operation from delivery systems through Dethridge wheels to bay operation. Most growth in the sector was through amalgamation with neighbouring properties to achieve greater economies of scale.

Historically, dairy farming has been more profitable than the mixed cropping and rice sectors. The growth of the dairy sector has come at the expense of mixed farming enterprises, as dairy has bought up water from this sector. Mixed farming enterprises also provide services to the dairy sector in the form of feed and agistment for young stock and dry cows. However, dairy itself has also been a net seller of water to horticulture in years of low allocations when water market prices are high, as they have been able to replace water for perennial pastures with bought-in feeds. This has been a season-by-season decision which is influenced by:

- The price of allocations on the water markets;
- The milk price;
- The cost of feed substitutes; and
- The level of individual farm water use efficiency.

The recent drought sequence has led to a significant change in the feeding systems commonly adopted across the dairy sector. In the past, farms were able to rely on fully irrigated perennial pastures, which typically comprised 60 to 70 per cent of the farm's total feed requirements. During the last 10 years there has been a move away from perennial pasture to more flexible feeding systems based on cut and carry, with an increase in production on-farm of annual crops, lucerne and annual pastures.

The change in the home-grown feed base has coincided with an increase in the level of bought-in feed. Even though the fodder grown on farm has shown increased productivity (in tonnes/ML), total home feed production has still declined due to the lack of water. The increased reliance on bought-in feeds and the changed home-grown fodder base has increased the complexity of the farming systems.

The change has also been driven by the need to meet highly competitive world milk prices. The only route to this is to increase size to win economies of scale and so reduce unit costs of production. A move to cut and carry rather than perennial pasture also helps achieve this objective.

Dairy has therefore seen a transformation driven largely by a need to match international milk prices but strongly influenced by the increasing constraints on water availability. The drought and further constraints in water allocations have seen the sector respond in a range of different ways based around different water products and levels of capital intensity.

Water trade has seen a segmentation of the sector into three different groupings:

- **High intensity:** At one end of the spectrum there is a high capital intensity sector holding high security entitlement. This segment has invested in high-tech drip tape to grow high value fodder crops such as lucerne and maize to feed large scale dairy herds through cut and carry and automated feeding systems. Both crops are about twice as efficient in dry matter production than traditional perennial pasture. This is a higher risk, higher return segment;
- **Medium intensity:** in the middle of the spectrum are properties holding mainly medium security entitlements. Here the strategy is to invest in 'high-flow' flood irrigation to maximise production from a constrained resource. This approach requires modernisation of the delivery system and automation of on-farm irrigation systems, but delivers reduced labour costs; and
- **Low intensity**: at the other end of the spectrum are smaller properties with lower stocking levels and lower capital intensity that rely on opportunistic watering of perennial pastures when allocations are available.

2.3 Rice

Rice was first grown in Australia in 1914 when 200 acres near Swan Hill was used as a demonstration site. The first commercial rice crop was grown in 1924 in the Murrumbidgee Irrigation Area around Leeton and Griffith.

The initial expansion of irrigated rice production was through conversion of the crop mix within existing mixed farms. The speed of adoption increased as the volume of entitlements expanded and the supporting infrastructure (such as rice mills) in the region became established. The speed of adoption was also promoted by deregulation of the previously very regulated industry which had previously seen formally defined rice quota areas. The abolition of this plus the decline in wool prices led to a rapid expansion of the area planted to rice.

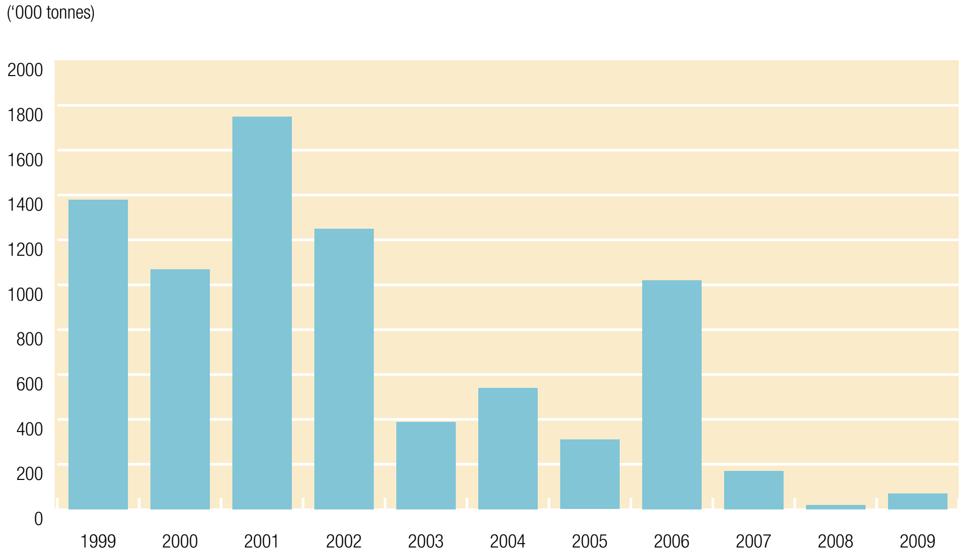
Laser levelling of bays was introduced to increase the area that could be watered within the same total labour costs. Laser levelling resulted in greater control over the flow of water on and off the paddock. This reduced the time and water required to irrigate the crop, leading to greater productivity.

Concerns about the risks of irrigation induced salinity led to the introduction of greater controls over where and how irrigated rice could be grown to minimise risks of groundwater rise. This led to soil testing and specification of best practice irrigation within land and water management plans. The controls were documented, for example, in Murray Irrigation's *Rice Growing Policy* which required two main controls:

- *Firstly, rice can only be grown on a paddock that has been tested and approved by Murray Irrigation as suitable for rice growing; and*
- *Secondly, a maximum rice crop water use figure is calculated each year based on the Rice Environment Policy Advisory Group (REPAG) agreed method of calculation, taking into account seasonal rainfall, evaporation and the crop water use requirement. In 2005/06 the average volume of water used for rice production was 12.2ML/ha.*[6]

As an annual crop, the area of rice planted and harvested varies between seasons, depending on the relative allocation that season of General Security Entitlement in southern NSW. Most rice growers operate mixed cropping properties, often growing a winter wheat crop on the residual moisture available in the rice bay:

TABLE 1
TOTAL ANNUAL RICE PRODUCTION ('000 TONNES)



Source: Rice Growers Association

> *"I am getting two crops from the same water because I utilise the moisture remaining in the soil from the rice."*[7]

The recent drought sequence has had a profound effect on overall rice production. The primary response has been to plant less rice. As a result, rice production has declined dramatically since 2002/03 with a reduction from a pre-drought peak close to 1.8 million tonnes in 2001 to a low point in 2008 of less than 50,000 tonnes.

As a result, many rice growers have seen a dramatic reduction in their on-farm revenue with a consequential severe reduction in off-farm processing capacity. Most of the rice mills in southern NSW were closed or moth-balled and most rice growers had to rely on dryland agriculture and diversification into a range of wider crops.

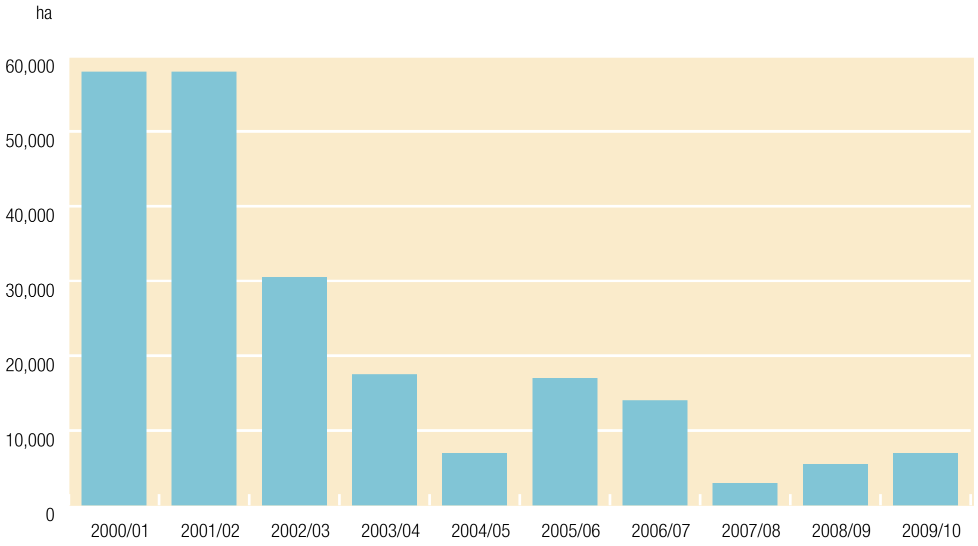
Water trading in the rice sector was initially limited and constrained to within the major irrigation corporations. However, rice growers have become increasingly opportunistic with growers deciding whether to grow or sell depending on allocations and market conditions. The level of rice production tends to decline at a greater rate than the respective decline in water availability. That is, a 40 per cent reduction in water availability will generally see a reduction of rice production by 60 per cent. This response is due to:

- Farmers responding to high annual water prices by deciding to sell their allocated water rather than grow rice;
- Low allocations early in the season creating uncertainty about seasonal water supplies at rice sowing time in October; and
- Available water being used to irrigate winter crops sown the previous autumn.

Rice growers are implementing a range of other approaches to maintain production in the face of constrained water allocations:

- Direct drilling or combine sowing of rice seed enables rice bays to be filled later in the growing season, therefore promoting greater water use efficiency; and
- Shorter season rice varieties (e.g. YRM 69) which require substantially less water to grow.

FIGURE 3
COTTON PLANTING IN THE MACQUARIE



2.4 Cotton

Cotton has been grown in Queensland on rain-fed properties since the nineteenth century, but the real growth in the sector depended on the development of the irrigation sector and was prompted by the construction of dams in northern and central inland New South Wales in the 1960s and 70s. Industry growth was slow at first, but accelerated through the 1980s, with governments encouraging the uptake of water licences and the subsequent development of land and infrastructure for irrigation.

As an annual crop, the area of cotton planted in any year is highly dependent on the level of the annual allocation. Cotton is part of a mixed rotation with other annual crops including sorghum and wheat, so in drier years, farmers rely more on dryland crops. Figure 3 shows the highly variable area planted by year in the Macquarie between 2000/01 and 2009/10 reflecting the low levels of allocation since 2002/03. The base level of production is sustained by groundwater entitlements.

The cotton industry relies on flood-furrow irrigation with syphons from a head channel into multiple furrows. There has been considerable research into opportunities to introduce lateral moves and/or drip tape, but without certainty of supply it is not commercially viable to make the necessary investment:

> *"If you don't have some level of water security, you don't want to spend $3,000 a hectare on machinery that may sit in the paddock."*

Over the last five years the main investments have been by irrigators with good access to groundwater which has been less affected by variations in allocations than for surface water diversions. The drought has driven the need to find smarter ways to grow more with less but, once again the major drivers have been production and labour costs as much as water use efficiency.

TABLE 2
SECTOR RESPONSES TO INCREASING SCARCITY

STAGE	HORTICULTURE	DAIRY	ANNUAL CROPS
			Rice and cotton
Early expansion	Flood/furrow	Flood of perennial pasture for direct grazing	Early expansion within mixed farms
Initial controls	Pressurised overhead sprinklers Linear move	Laser levelling Irrigation scheduling	Laser levelling to reduce costs
Later controls	Minisprinklers/microjets Drip / tape Automated moisture monitoring	Greater controls within bays Some centre pivot for high value sites	Established best practice controls/use soil suitability testing to minimise salinity risks
Water trade	Water trade allowed expansion with purchase from all other users allowing development onto greenfield sites	Water trade expansion by purchase from lower values and through amalgamation of properties	Opportunistic use of market to sell water or grow
Drivers	Driven by needs for automation of harvest to increase scale and off-set labour costs Reducing time to focus on other aspects of business/ lifestyle MIS enhanced this in orchard crops	Reducing labour costs and increasing scale	Maximising revenue minimising risks
Current	Drip tape and automated fertigation where it suits the farming system Micro-irrigation and overhead sprinklers for particular crops and soil types	Portfolio of products: **High security:** Drip tape for lucerne/maize Cut and carry for feedlots **Medium security:** Fast flow border check Annual pastures **Low security:** Opportunistic watering for pasture/crops	New varieties with lower water requirements and direct sowing to allow later watering

C. Supply distribution

1. The need for change

Most supply distribution systems were established during the 1950s to 1970s. They were based on the farm sizes and technology of the time to match the demand characteristics of mainly small scale dairy and mixed farming properties.

Pressure to win greater economies of scale has led to a significant increase in farm sizes. Murray Irrigation reports an effective doubling of the average property size since privatisation in 1995, either through purchase and amalgamation or through leasing. The irrigation systems in the GMID were designed around providing a supply outlet at the property boundary for a 70 cow dairy herd, where a 500 cow herd is now standard practice.

As a result, the long-standing irrigation supply systems are increasingly out-dated and incapable of meeting the current and future demands of irrigation customers:

- There is a considerable surplus of irrigation infrastructure (small scale channels, regulators and outlets) which impedes property amalgamation and production and drives up costs;
- Ordering times are long and delivery reliability is uncertain;
- Water losses are high at a time when allocations are increasingly constrained;
- Flow rates are erratic and channel levels uneven;
- Outlets are small scale and incapable of delivering the high flow rates required; and
- Outlets are manually operated and cannot be integrated into an automated irrigation system on-farm.

As a result, irrigation properties are constrained in their ability to operate best practice irrigation systems on-farm as they cannot guarantee the consistent high-flows and tight irrigation schedules to match the requirements of best practice on-farm watering requirements.

At the same time water trade has driven a flight of water from these older, large established public schemes into smaller private systems. This flight has had two effects:

- It made the existing infrastructure less cost competitive. This gave an impetus to reconfiguration to reduce costs; and
- It forced the systems to look at modernising to provide the equivalent levels of service as are available from private systems, such as on-demand service.

On the other hand, trade has placed a significant value on water savings and so created an off-setting benefit to justify investment in modernisation which is now much more cost effective.

Dairy and mixed farming have put pressure on system managers to modernise their systems to meet changed demand patterns, while horticulture has generally sought to establish new greenfield sites to create the scale they desire and to reduce risks by regaining control of core irrigation functions and decisions.

2. Conflicting objectives

There is a constant tension between the need to protect past investment in assets and the desire to promote flexibility to respond to changing circumstances.

The major aim in the 1980s and 1990s was to push up water charges to ensure adequate revenue to maintain longer-term infrastructure condition and so to protect prior capital investment.

The major aim in the 2000s was to promote greater change and allow water trade to move to higher values, even at the risk of stranding sunk assets.

The challenge is to develop an optimal rationalisation and modernisation strategy to ensure that the system is configured to match future demand requirements in the face of significant on-going change. Termination fees provide a measure of revenue certainty to cover fixed costs. However, they do not protect the business from the risk of the “swiss cheese effect” where supply systems become increasingly unviable because of the patchwork of non-serviced properties within the network. In particular, they make it very difficult to develop an optimal rationalisation plan.

3. Different approaches adopted

Different irrigation business operators have adopted different responses to this demand for change and the challenge of reconfiguration. The approaches reflect characteristics of the history of the original investment and the major irrigated sectors involved.

3.1 GMID and NVIRP

The supply infrastructure of the GMID was constructed to meet the characteristics of the dairy sector in the 1930s to 1950s when a 70 cow herd was a standard production unit. Channels were sized to provide a single outlet at the farmgate for each individual property connected to the system. Larger dairy enterprises now manage herds with 700 cows and seek an irrigation service that meets their current and future production requirements.

The Northern Victoria Irrigation Renewal Project is implementing a fundamental restructure of the supply system with:

- Retrenchment of the public supply system to the major supply channels comprising only 50 per cent of the prior supply footprint;
- Modernisation of those major channels to form a water super highway as a backbone, with automated integrated controls to deliver near on-demand supply;
- Retrenchment of all spur channels with consequential reduction in future costs and water losses; and
- Creation of new individual farm connections to the backbone via modern high flow outlets and meters that can be integrated into an automated on-farm irrigation system.

The new system will deliver:

- Close to on-demand supply;
- A consistent channel level and so constant flow;
- Automated and integrated channel controls to ensure swift adjustment to changing demands; and
- A high flow outlet that can be integrated with on-farm watering systems.

This will then support and promote investment on-farm in best practice irrigation technology to generate productivity gains. These drivers for productivity have also generated greater water use efficiency and water savings as a by-product. So NVIRP is scheduled to recover 425GL that were previously lost through conveyance losses as well as supporting greater water use efficiency on-farm.

3.2 Murray Irrigation Limited (MIL)

The design of the irrigation infrastructure at Murray irrigation was based on larger farm areas as it was focussed on supplying broadacre annual crops rather than permanent horticultural plantings. There is, therefore, less opportunity to make structural changes at a whole of company level to reduce costs and enhance levels of service as in the GMID. The only effective way to reduce costs is to close an entire district.

This approach has been proposed by a group of irrigators who have recently suggested a coordinated closure of part of the MIL in the Wakool district.

3.3 Murrumbidgee Irrigation (MIA)

MIA has traditionally run a hybrid system with both smaller-scale horticultural zones and larger-scale broad-acre cropping. The fact that the MIA was a early pioneer means that most of the original lot sizes were very small. This is also true of the traditional blocks around Mildura in the Victorian Sunraysia. The irrigation infrastructure and plot sizes makes reform and reconfiguration particularly difficult.

The last 20 years have seen significant expansion of horticulture into the broadacre areas at the periphery of the system to achieve greater economies of scale. However, this creates risks of supply security if the smaller-scale inner irrigation districts see reduced demand.

MIA is currently implementing an *Integrated Horticulture Supply* (IHS) program to refurbish 230km of open channels with a piped, pressurised system for improved levels of service and greater water use efficiency. However, it is still formulating a wider scale modernisation program to match levels of service and supply to customers needs and willingness to pay.

3.4 Coleambally Irrigation (CIA)

Coleambally Irrigation was the last irrigation district to be developed in NSW. It has the advantage that it was relatively late in development so the farm sizes and supply infrastructure are closer to current production needs.

The supply system is now gravity fed, solar powered, and incorporates state-of-the-art metering and flow regulation technologies providing for automated water ordering and accounting.

It has little opportunity to further reduce its system footprint or operating costs. It is constrained by the low value of its major crops and its reliance on annual crops.

References

1 www.nre.vic.gov.au/virtualexhibition/settle/index.htm

2 ABARE (1996), Land and water management plans in the Murray Valley – Assessment of the critical economic and farm management assumptions

3 Murray-Darling Basin Ministerial Council (1996), Setting the Cap, Report of the Independent Audit Group, page vi.

4 NWC (2011), Australian Water Markets: trends and drivers 2007–08 to 2009–10, figure 3.2, page 26.

5 Australian Processing Tomato Research Council (2010) Journal article, Vol 31, September, page 7.

6 Murray Irrigation Limited (2007), Rice Growing Policy

7 Hyder Consulting (2010), Rice Industry Case Study, from Strengthening Basin Communities study for local councils.

8 Cotton Australia: Case study – Water Efficiency in the Macquarie – Rob Tuck, Narromine, NSW www.cottonaustralia.com.au/library/casestudies/view.aspx?id=1

1.4

Technological innovation and irrigation modernisation

David Aughton and Iven Mareels

David Aughton is a director of Australian-based water technology company Rubicon Water, Together with Iven Mareels, David led the development of Rubicon's Total Channel Control automation system as a cost effective way of improving the efficiency of open channel irrigation supply systems.

Iven Mareels is the Dean of The Melbourne School of Engineering. He is a Fellow of the Academy of Technological Sciences and Engineering, Australia (ATSE), a Fellow of the Institute of Electrical and Electronics Engineers (FIEEE, USA), a member of the Society for Industrial and Applied Mathematics (SIAM), a Fellow of the Institute of Engineers Australia (FIEAust). He is a Foreign Member of the Royal Flemish Belgian Academy of Sciences and Humanities. He is registered in Australia as a Corporate Professional Engineer and he is a member of the Engineering Executives chapter of Engineers Australia.

Iven Mareels is a Professor of Electrical and Electronic Engineering, who has published widely. Since 1998 he has worked with Rubicon Water, and David Aughton in particular, on the development of irrigation channel automation. In 2008 he received a Clunies Ross Medal from the ATSE for his work on the systems engineering for irrigation systems.

Overview

This chapter discusses the opportunity for water efficiency savings and increased food production from the modernisation of irrigation infrastructure. We will highlight the recent technology developments and their current wide scale application within the Australian irrigation industry.

The agricultural irrigation industry

Irrigation is the provision of water to plants to complement or supplement rain-fed sources of water. As water is one of the basic ingredients necessary for plant growth, irrigation is typically employed where other necessary ingredients such as favourable soils and sunlight are plentiful, but low or unreliable rainfalls mean a lack of water would limit plant growth.

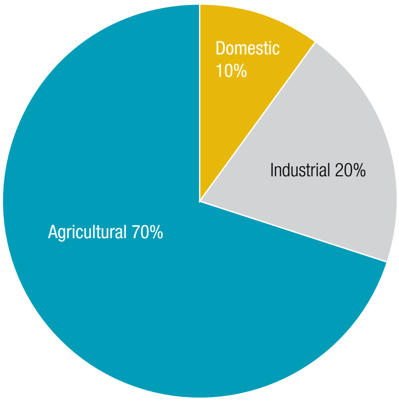
The challenge for the irrigation industry is the efficient and timely transport of the water from its source to the plant – both off-farm and on-farm.

As shown in Figures 1 and 2, the agricultural irrigation industry is the dominant consumer of Australia's and the world's water, accounting for approximately 70 per cent of total global freshwater use.

Irrigated agriculture is substantially more productive than rain-fed agriculture, with irrigated land producing significantly higher crop yields than rain-fed land. For example, as shown below in Figure 3, irrigated land represents 20 per cent of the world's cultivated land, but 40 per cent of global food production and 46 per cent of the world's agricultural economic output.[3]

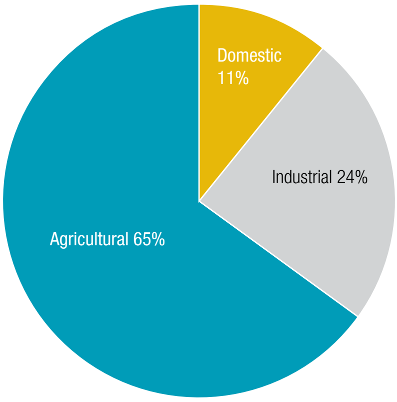
In addition to increasing crop yields, by facilitating crop growth in areas where low or unreliable rainfall would naturally be a limiting factor, irrigation substantially increases the amount of land that can be productively used for agriculture.

FIGURE 1
COMPETING TOTAL FRESHWATER USE – GLOBAL



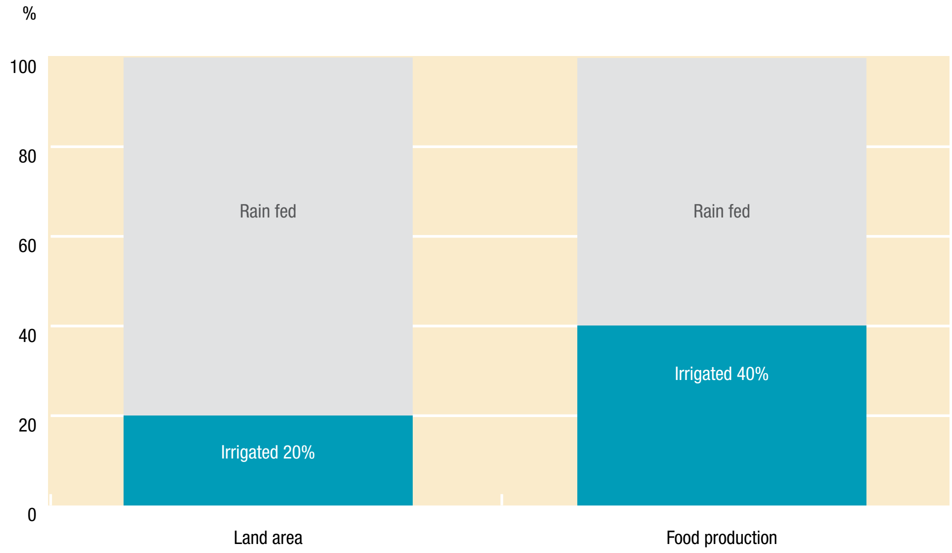
Source: United Nations Educational, Scientific and Cultural Organization (UNESCO)[1]

FIGURE 2
COMPETING TOTAL FRESHWATER USE – AUSTRALIA



Source: Australian Bureau of Statistics[2]

FIGURE 3
RAIN-FED VERSUS IRRIGATED LAND – PRODUCTIVITY COMPARISON



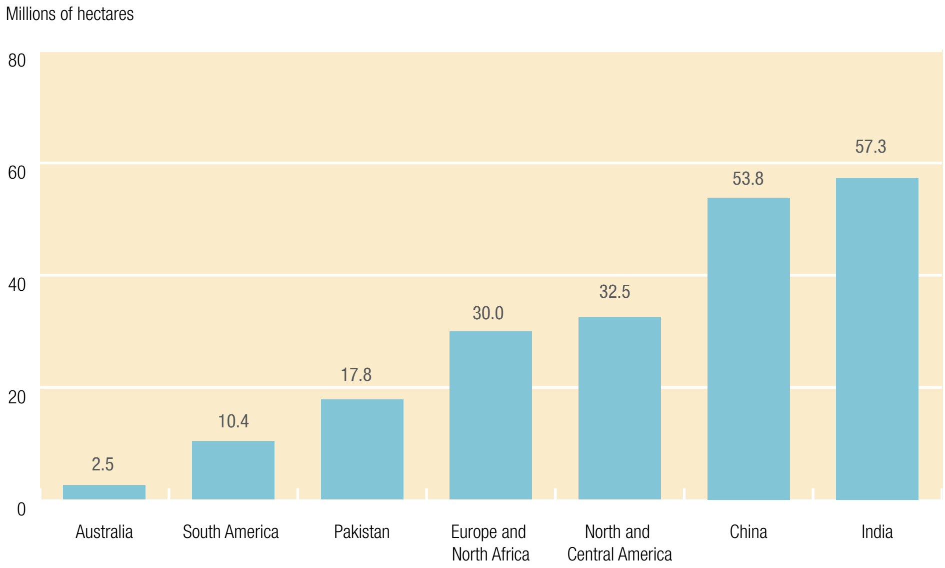
Source: United Nations Educational, Scientific and Cultural Organization (UNESCO)[4]

Irrigation supply systems

In 2007 there were approximately 287 million hectares under irrigation globally, up from 210 million hectares in 1980.[5] Figure 4 shows a number of major global irrigation regions including India with approximately 57 million hectares, China with approximately 54 million hectares and North and Central America with approximately 33 million hectares. Australia currently has approximately 2.5 million hectares under irrigation.

The two main sources of irrigation water are surface water, being water that flows over or is stored on the ground surface, from rivers, streams, lakes, dams, reservoirs or other sources (surface water); and ground water, being the reserve of water that is located beneath the earth's surface in aquifers (ground water).

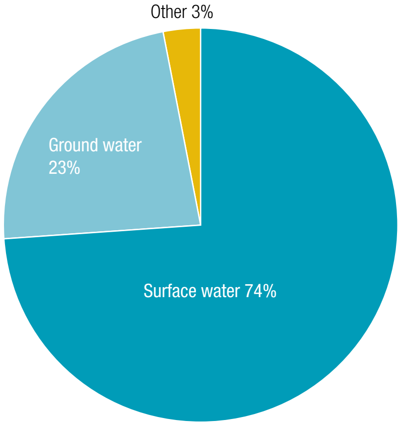
FIGURE 4
IRRIGATED LAND BY REGION



Source: United Nations Food and Agriculture Organization[6].

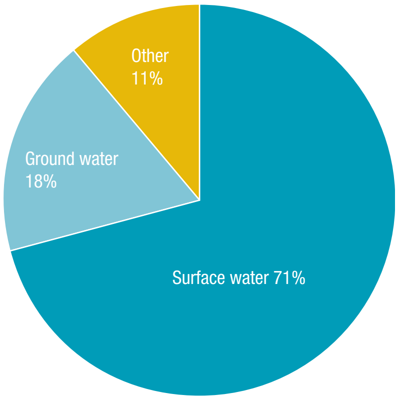
Note: Includes irrigated land supplied by both surface water and ground water sources.

FIGURE 5
SOURCE OF IRRIGATED WATER – AUSTRALIA



Source: Australian Bureau of Statistics.[7]

FIGURE 6
SOURCE OF IRRIGATED WATER – GLOBAL



Source: United Nations Food and Agriculture Organization as cited in United Nations World Water Development Report 3[8].

In Australia, 74 per cent of water used in irrigation is taken from surface water sources as shown in Figure 5, with the majority of the remainder supplied by ground water. Globally, surface water is also the primary source of water used in irrigation, as shown in Figure 6.

Surface water for irrigation has historically been diverted from naturally occurring rivers. Naturally occurring rivers are limited as a source of irrigation water due to geographical proximity and the natural flow of the river.

Historically, proximity to a river has been overcome by building a supply network to transfer water to the farm, commonly constructed with channels or pipes (typically referred to as an off-farm reticulation scheme). The reliability of the supply for these schemes is often achieved through the construction of large dams upstream in the water catchment.

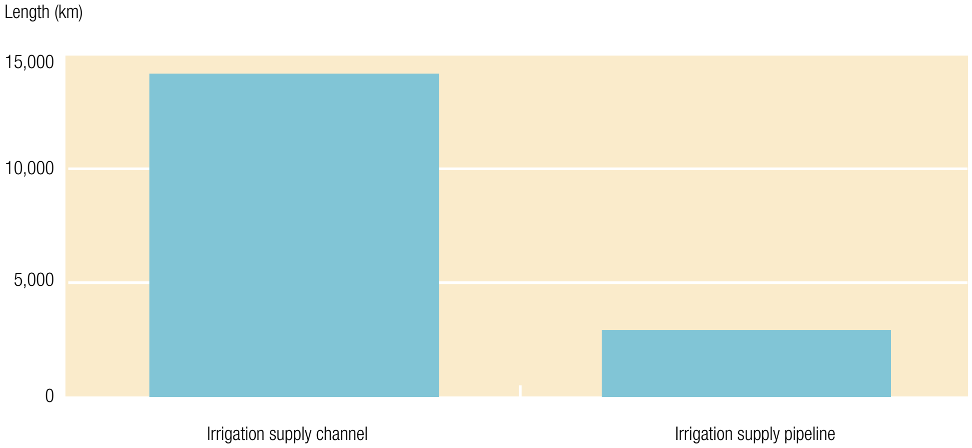
Ground water tends to be accessed through bores, either on farms or within close proximity to farms. As a result there is generally no need for large-scale off-farm water transportation infrastructure where ground water is used for irrigation. However, accessing ground water generally incurs significant ongoing costs in pumping water to the surface.

Traditional manually operated channel systems provide a supply service that is rigid and inflexible. The supply often suffers from fluctuating flow rates and the timing of deliveries does not necessarily correspond to plant requirements.

By comparison, farms that can access irrigation water from a ground water supply or pump directly from a river have been able to benefit from largely an “on-demand” supply. The greater flexibility afforded from an “on-demand” supply ensures water can be applied efficiently and in a timely manner that in turn leads to improved yields.

FIGURE 7

IRRIGATION RETICULATION BY TYPE – AUSTRALIA



Source: Australian Government National Water Commission[9].
Note: Irrigation supply services only, drainage not shown.

Off-farm water supply

Off-farm water supply systems facilitate the transfer of surface water from its source or storage facilities to the farm, normally via a combination of natural water courses, open channels and pipes. The use of natural water courses in irrigation systems is limited by naturally occurring locations. Figure 7 shows Australian off-farm water supply infrastructure.

Channels

Channel irrigation systems consist of a network of channels delivering water from source to farm. Most large Australian systems divert water by gravity from rivers, although pumps are used at some locations.

As shown in Figure 7, channels are the most common form of water carriers used within irrigation systems in Australia. The majority of large-scale reticulation networks around the world are channel based because they are the most cost effective means of transporting large volumes of water used for irrigation.

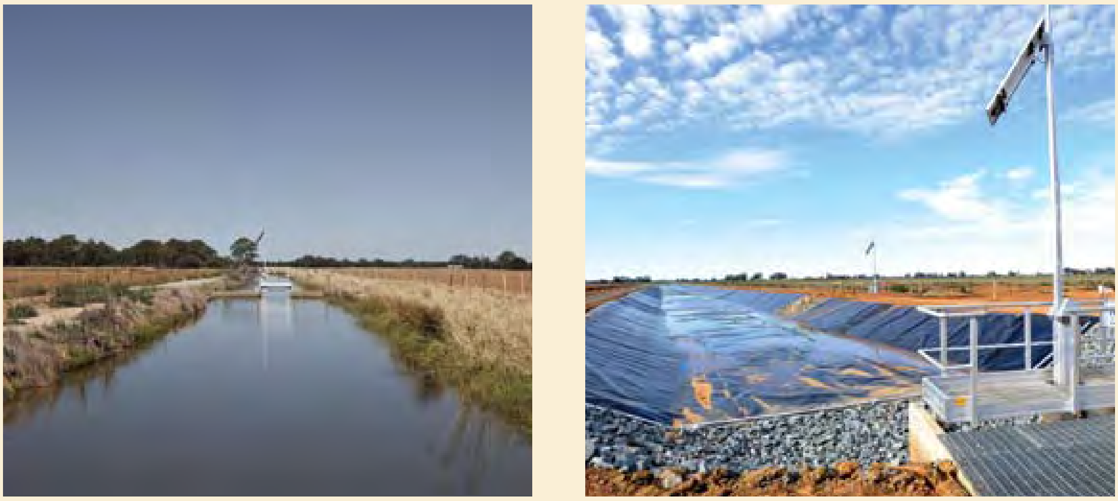
Channels used in irrigation systems may be built of excavated soil (unlined) or constructed with a form of barrier to decrease water leakage and seepage from the irrigation channel (lined).

A range of channel irrigation system infrastructure is shown below in Figure 8.

A proportion of the water that enters an irrigation channel is not assigned to customers due to inaccurate metering and water losses through outfalls, evaporation, leakage and seepage.

The proportion of water that is unaccounted for or lost in the distribution of water from storage to the farm gate varies depending on a number of characteristics, such as soil type, channel condition and the volume of water transported. In Australia, the average distribution efficiency of unmodernised open channel systems is approximately 70 per cent, leaving 30 per cent of the water that enters these systems either unaccounted for or lost.[10]

FIGURE 8
CHANNEL IRRIGATION SYSTEM INFRASTRUCTURE



Unlined channel

Lined channel

Manual regulating control structures

Automated control structure

Unaccounted for and lost water may be attributable to:

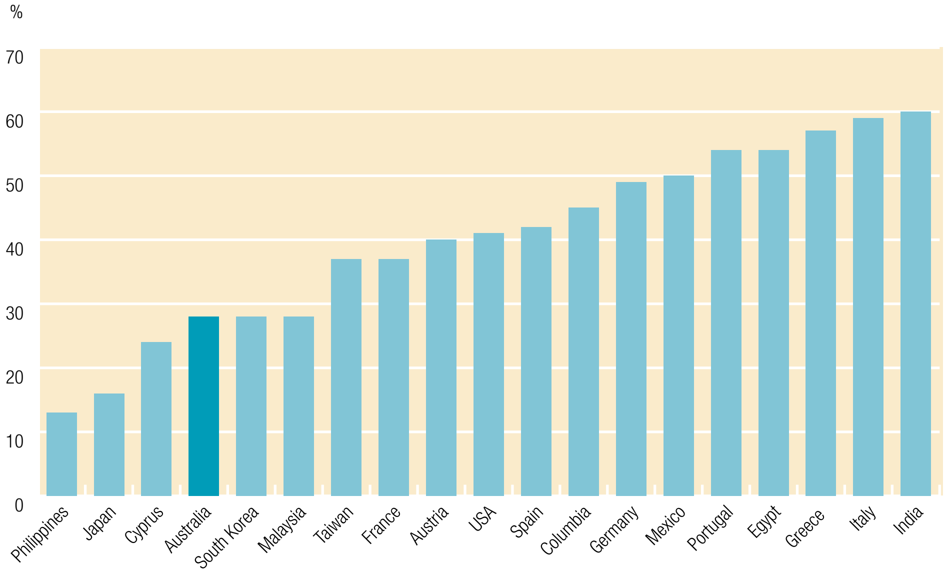
- Outfalls or operational spills, which occur where mismatches between supply and demand, largely as a result of manual operation;
- Leakage and seepage through the banks or bed of the channel;
- Inaccurate metering; and
- Evaporation and other losses.

Recent analysis of channel supply systems in Australia is showing the majority of unaccounted for and lost water has been attributable to outfalls, leakage and seepage and inaccurate metering.[11]

A substantial number of channel irrigation systems globally employ antiquated delivery systems and management practices, which result in significant unaccounted for and lost water as discussed above. The average distribution losses observed in a range of countries, including Australia, is shown in Figure 9.

FIGURE 9

AVERAGE DISTRIBUTION LOSSES (PER CENT) IN IRRIGATION WATER SUPPLY SCHEMES IN VARIOUS COUNTRIES



Source: International Institute for Land Reclamation and Improvement (1990) as cited by Land & Water Australia.[12]

Pipelines

As with channel irrigation systems, a proportion of the water that enters pipeline irrigation systems is unaccounted for due to inaccurate metering and leakage. However, piped irrigation systems avoid seepage and evaporation. Relative to channel systems, pipeline systems generally have higher installation costs and higher operating costs due to the ongoing requirement to pump water in many of these systems.

As a commodity, water is relatively heavy, making pumping large volumes an energy and cost intensive exercise. While not all pipelines are pressurised, decreasing pipe pressure increases the required pipe diameter to provide equivalent flows, which increases installation costs. As a result, large gravity-fed irrigation pipeline systems are rarely cost competitive with channel systems.

Compared to a fully lined irrigation channel, the major advantage of piped irrigation carriers is the elimination of evaporation losses (although these have been shown to be relatively small in Australia[13]). There are also benefits of a pressurised pipeline system where the end users use pressurised irrigation systems, as the need for pumping by end users is reduced, and where the system runs through urban areas and channels may pose a safety or contamination risk.

Metering systems

Metering systems are used by rural water authorities to account for on-farm water usage and charge end users appropriately. The metering unit sits at the intersection of on-farm and off-farm irrigation systems.

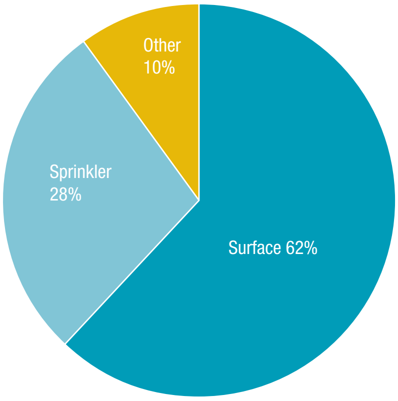
Inaccurate metering is a significant issue for managers of irrigation systems globally, with many irrigation systems having either no or largely antiquated and inaccurate metering technology. Without accurate metering technology, it is difficult to efficiently allocate and distribute water.

FIGURE 10
ALTERNATIVE METERING SOLUTIONS

Dethridge meter

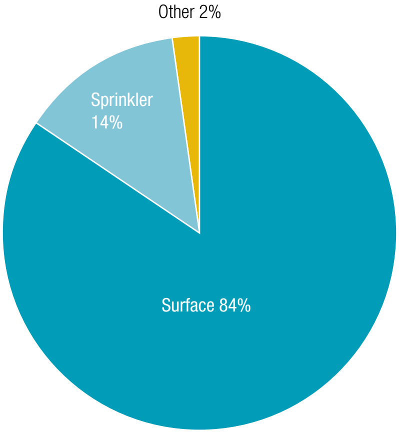
Automated integrated metering (Rubicon SlipMeter™)

FIGURE 11
AREA OF IRRIGATED FARMLAND BY TYPE – AUSTRALIA



Source: Australian Bureau of Statistics.[15]

FIGURE 12
AREA OF IRRIGATED FARMLAND BY TYPE – GLOBAL



Source: United Nations Food and Agriculture Organization.[16]

The majority of meters in Australia are Dethridge wheel meters. The Dethridge wheel meter (illustrated in Figure 10) was invented in Australia in 1910, and has remained largely unchanged for nearly 100 years.

As a result of outdated design and decreasing performance in-field, these meters are often inaccurate and are unlikely to comply with the draft Australian National Metering Standards. In Australia, as recently as 2005/06, it was estimated that approximately 70 per cent of installed meters were Dethridge wheels.[14]

As irrigation systems globally are modernised, there is likely to be an increasing requirement for accurate, integrated metering technology. The integration of on-farm and off-farm operations are likely to present considerable benefits to the irrigation industry as smart meters are doing in the broader utility industries. The benefits come from better matching the off-farm supply to the on-farm demand. Meters can now be linked to on-farm automation systems and adjust flows requested by these systems.

In addition to providing more accurate metering, modern metering systems such as pipe meters (acoustic and magnetic) and the SlipMeter™ are a necessary component in operation of a modernised off-farm and on-farm system. Modern irrigation meters need to be capable of accurately measuring both low and high flows to accommodate varying agricultural enterprises. The meters also need to measure flows through conduits with large cross-sectional area in order to keep head loss to a minimum for gravity supply networks. Flow control is also a necessary attribute of an automated delivery system.

On-farm water supply

On-farm water supply involves the direct application of water to crops and the monitoring and control of on-farm conditions, such as soil moisture. The two primary methods of on-farm irrigation are surface irrigation, which involves moving water over land by gravity in order to moisten the soil, and pressurised irrigation, which is made up of sprinkler irrigation and micro-irrigation.

The suitability of each irrigation technique depends on a number of factors including the type of crop being farmed. For example, surface irrigation is well suited to field crops (such as pasture, corn, cotton, rice and wheat), sugarcane and vegetables. Similarly, sprinklers are commonly used to irrigate field crops, especially where the land is undulating and not suited to surface irrigation.

However, they require substantially higher capital and ongoing energy costs. Micro-irrigation is particularly attractive in arid regions where water is lost through rapid evaporation. Micro-irrigation is typically the most expensive irrigation method and is often used to irrigate high value crops such as vineyards and orchards.

As a result of being the incumbent technique and due to the substantial cost advantages in installation and ongoing operation, surface irrigation is the dominant method of on-farm agricultural irrigation used in Australia and globally, representing 84 per cent of all irrigated land, as shown in Figure 12.

Table 1 summarises the application efficiencies of the different types of irrigation practices adopted in Australia. Given the existing investment in surface irrigation (such as laser grading) by Australian farmers, the move to precision surface irrigation is gaining strong acceptance. Precision surface irrigation is achieving application efficiencies close to that of sprinkler and micro irrigation with considerably less investment.

TABLE 1
ON-FARM MODERNISATION ALTERNATIVES TO TRADITIONAL SURFACE IRRIGATION

System	Application Efficiency	Water applied (ML/ha)	Water savings (ML/ha)	Energy use (MJ/ha)	Increase in energy use (MJ/ha)
Traditional surface	55%	7.3	–	9700	–
Sprinkler	90%	4.4	2.9	17,000	7300
Micro	95%	4.2	3.1	16,000	6300
Precision surface	85%	4.7	2.6	9700	0

Source: Khatri & Smith.[17]

Precision surface irrigation involves the application of water at much higher flows than those used in traditional flood irrigation ensuring the irrigation is completed in a much shorter timeframe. This new method of irrigation requires flows onto bays/furrows being controlled at the desired rate and the ability to accurately predict when to shut-off the irrigation to avoid under or over irrigation. The method achieves improved infiltration control and higher yields.

Modern irrigation supply systems – the alternatives

The options available to divert water from a supply source and deliver that water to agricultural farming land are summarised in Table 2.

Pipeline systems, whether gravity or pressurised, generally only become viable for those parts of a delivery system where flow capacities are low and subsequently where the costs can begin to approach those of a modernised channel system. The majority of irrigation delivery systems in Australia were constructed early last century when pipeline systems were less affordable than now. Channel systems, therefore, are

TABLE 2
OFF-FARM MODERNISATION ALTERNATIVES

Distribution system	Capital cost	Operating cost	Distribution efficiency	Responsiveness (on-demand supply)	Overall relative cost-performance rating
Gravity channel (manual)	Low	Low	Very Low	Very Low	Low
Gravity channel (automated)	Medium	Low	High	High	Very High
Gravity pipeline	Very High	Low	Very High	High	Medium
Pressurised pipeline	Very High	Very High	Very High	High	Low

the dominant means of transporting and delivering irrigation water in Australia prior to modernisation.

The irrigation modernisation challenge, therefore, is to convert and upgrade the existing base of ageing and manually operated channel systems so that they can:

- Deliver a flexible “on-demand” supply service;
- Incur minimal distribution losses;
- Accurately account for all water transported via the supply network; and
- Minimise operating costs.

In Australia, the recent investment in modernised infrastructure has largely been in the automation of existing channel infrastructure. There have only been a small number of channels converted to pipelines by comparison.

Modernising irrigation channel systems

The modernisation we discuss is being implemented in the Food Bowl of Australia, where the award winning Northern Victorian Irrigation Renewal Project is creating an autonomously operating water distribution channel system. This autonomous operation is achieved through installing automated, networked control structures linked through a radio-based internet: essentially an information and communication infrastructure overlay on top of the existing 6000km of open channel network infrastructure.

In an automated water distribution system all the otherwise manually operated water control structures in the channels are replaced by motorised gates that also measure flow and water levels – upstream and downstream of the structure (see Figure 8). All these are linked to one another through a radio-based internet data communication system. The examples of such control structures (FlumeGateTM) illustrated in Figure 8 are solar powered.

The software operating these structures enables each structure to work independently using only local data (stand-alone autonomous mode), or in a networked fashion using data sharing with other control gates and meters in the network (networked autonomous mode), or in a manual override mode, where either a locally present operator (using the local console) or a remote operator (using the internet link) can command the actuation.

Software and hardware can be remotely diagnosed and any software upgrades are performed over the radio-internet. Any significant metering or actuation event is logged, and may be monitored and communicated across the radio-internet. A great many diagnostic events describing the health of the structure's hardware and software are also logged, enabling such functionality as preventive maintenance, or fail safe operational modes.

Some of the significant operational differences between a manually operated system and an autonomously operating motorised system are described next.

In most irrigation districts, manually operated control structures are adjusted once a day, in some cases even only once a week. In such channels the water flow can only be regulated in relatively large and demand insensitive steps. Water demand is met through a scheduling regime, but at best a "steady state" operational mode can be pursued. Typical water demand is ordered with a significant lead time, to allow for the schedule to be constructed, and communicated to the operators. Moreover relatively large variations in water levels along the channels have to be tolerated (as a consequence of variations in demand).

One operational consequence is that channels are operated with a relatively large "free board", but with the objective of most gravity channels being to maintain minimum supply levels to branch channels or farms, then spills inevitably occur. Operator experience is of critical importance to achieve acceptable performance in these manually operated networks.

In the automated system the control structures (at least in autonomous mode) will react to changes in water levels and flows along the channel (due to demand variations, rain events, structure failures) and adjust their local conditions whenever a significant event occurs.

Operational experience across a wide variety of channel systems in networked autonomous mode indicates that typical structures will adjust themselves a few hundred times a day. These structures act on water supply information (which is derived from the instantaneous water demand) as well as variations in water levels (water height is an indicator of available potential energy, which is the main quality of service indicator for a gravity fed irrigation system).

As a consequence water order lead times can be significantly reduced. Experience indicates that in most automated channel systems a lead time of a few hours suffices. The system can react almost instantaneously to rain events. Importantly water levels can be tightly regulated, improving quality of service compared to manually operated systems, and providing for increased flow by exploiting the ability to operate with a reduced "free board". As a consequence the channels can be operated under higher water flow conditions, which may be used to mitigate the consequences of otherwise minor flood events.

At the core of the autonomous system is the decision software and computer power, the "brain" of the autonomous system. The computer power and software is distributed along the entire system, with each control structure working as a local agent in combination with others, under the supervision of the main computer node at the headquarters. This "brain" interprets the data from the control structures as well as the onto-farm metering information in the light of a mathematical model of the entire channel's dynamic behaviour to decide what action to take next.

Given demand information (accepted order information) and the present state of the channel system, the software decides how the entire channel system has to be set up in order to meet the demand. This is called the “feed forward” action. The feed forward action determines the majority of the control structures movements. However tempting, feed forward action can never determine all of the action to be taken by the control structures.

Feed forward action clearly relies on predicting what is going to happen on the channels in the near future. This prediction can never be totally precise. Indeed the demand information is never totally accurate (even when it is metered, there is at least a metering error). Moreover there are aspects of the channels’ behaviour that are not or cannot be captured by a model.

For example a simple model will not account for the seasonal variation in seepage from the channel, nor describe the daily variations in evaporation or the effect of wind on the water flow in the channel. No model could possibly predict localised leaks because of channel lining failure, or the failure in a control structure. All of this necessitates that next to the feed forward action, there is feedback action to correct for any deviation between the desired, predicted state in the channel and the actual state in the channel which is inferred from the measurements. Together feed forward and feedback action determine the autonomous behaviour of the entire channel system.

From an information theory point of view the main difference between the manually operated, even automated system and an autonomous system is the amount of information that is passed through the system. In a manually operated system the information is counted in bits per day, in an autonomous system it is of the order of bits per second. This goes a long way to explain the difference in operational performance.

A systems engineering description of the principles underpinning an autonomous open channel system are described in *Systems Engineering for Irrigation Systems: Successes and Challenges, Annual Reviews in Control*[18], and a control theoretic exposition is provided in *Control of large-scale irrigation networks Proceedings of the IEEE*[19] .

An additional critical component of an automated channel control system is demand management. Irrigation orders are processed on-line (web or interactive voice response) to ensure the hydraulic capacity of the network will not be exceeded and therefore cause possible instability. The demand management system reschedules on-line any orders for which there is no available hydraulic capacity, although less than five per cent of orders typically need to be rescheduled.

Modern irrigation supply systems – the benefits

The key objectives in modernising an irrigation supply system are:

- To facilitate increased agricultural production; and
- To use less water.

Table 3 provides a summary of some recent projects in Australia that are using channel automation.

TABLE 3
AUSTRALIAN CHANNEL AUTOMATION PROJECTS

Irrigation District/Project	Irrigation area (ha)	Length of channel (km)	Irrigation entitlement (ML)	No. of regulating structures	No. of customer meters	Project completion status	Distribution efficiency achieved
Food Bowl Modernisation Project (Goulburn-Murray Irrigation District)[a]	596,000	6054	1,600,000	6450	20,868	50%	Incomplete
Shepparton Irrigation Area	51,000	662	1,70,000	941	2808	95%	90%[20] (2010/11)
Coleambally Irrigation Area	95,000	516	500,000	338	761	100%	90%[21] (2005/06)
Macalister Irrigation District	55,000	592	140,000	1 310	2 200	15%	Incomplete

[a] Note: Includes Shepparton Irrigation Area

Source: Australian Irrigation Water Providers Benchmarking Report for 2005/200622 and National Performance Report 2008–200923 Rural water service providers

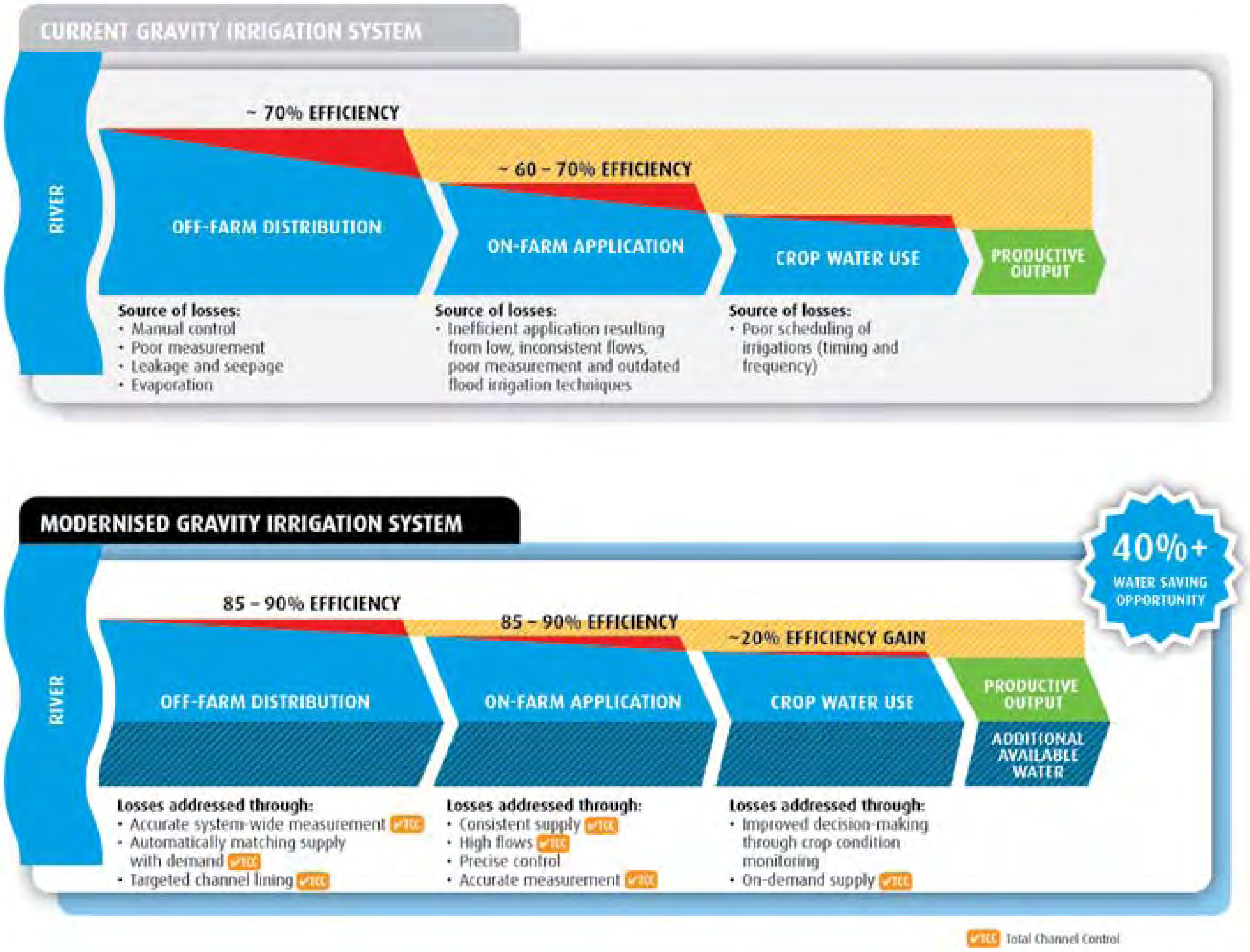
Figure 13 provides a "river to plant" summary of gravity irrigation supply system before and after modernisation using channel automation. The resulting aggregated efficiency improvement from both off-farm and on-farm investments can exceed 40 per cent.

Efficiency improvements are achieved in the three key elements of supplying the plant with the necessary water for desired productive output.

- **Off-farm water distribution efficiency:** In Australia the automation of channel supply systems are resulting in efficiencies of between 85 and 90 per cent *(see Table 3)*. Improvements have come from reduction in outfalls, accurate metering and reduced leakage and seepage.
- **On-farm application efficiency:** Application efficiencies on-farm of 85 to 90 per cent are now being widely targeted using modern irrigation techniques – micro, sprinkler or precision surface *(see Table 1).*
- **On-farm water use efficiency:** Improved scheduling techniques with more timely irrigations are not only resulting in improved yields but also reductions in the frequency of irrigations and volume of water used. Water use efficiency improvements of the order of 20 per cent are being achieved. A case study combining on-demand channel scheduling and improved on-farm automation reports even higher efficiency gains *Automation of on-farm irrigation: Horticultural case study, Agricontrol*[24]. There

is a strong interrelationship between the benefits from on-farm and off-farm. Many of the improvements on-farm are predicated on the level of service delivered by the off-farm supply system. Examples of these are the ability to deliver higher and reliable flows for precision surface irrigation, and on-demand supply allowing farmers to better respond to crop needs and achieve improved water use efficiency.

FIGURE 13
EFFICIENCY IMPROVEMENTS FROM IRRIGATION SYSTEM MODERNISATION



Endnotes

1 World Water Assessment Programme 2009, The United Nations World Water Development Report 3: Water in a Changing World, UNESCO, Paris and London, p.99

2 Australian Bureau of Statistics 2004, Water Account Australia 2004–05, cat no. 4610.0, ABS, Canberra, p. 72, accessed at http://www.ausstats.abs.gov.au/ausstats/subscriber.nsf/0/3494F63DFEE158BFCA257233001CE732/$File/46100_2004–05.pdf, 20 September 2011

3 Rabobank and The World Resources Institute 2008, Watering Scarcity: Private Investment Opportunities in Agricultural Water Use, p.15

4 World Water Assessment Programme 2009, The United Nations World Water Development Report 3: Water in a Changing World, UNESCO, Paris and London, p.108

5 FAO Aquatsat Database, United Nations Food and Agriculture Organisation, accessed at www.fao.org/nr/aquastat, 28 February 2010

6 FAO Aquatsat Database, United Nations Food and Agriculture Organisation, accessed at www.fao.org/nr/aquastat, 28 February 2010

7 Australian Bureau of Statistics 2004, Water Account Australia 2004–05, cat no. 4610.0, ABS, Canberra, p.72, accessed at http://www.ausstats.abs.gov.au/ausstats/subscriber.nsf/0/3494F63DFEE158BFCA257233001CE732/$File/46100_2004–05.pdf, 28 February 2010

8 World Water Assessment Programme 2009, The United Nations World Water Development Report 3: Water in a Changing World, UNESCO, Paris and London, p.100

9 National Water Commission 2009, National Performance Report 2007–08: Rural Water Service Providers, NWC, Canberra, p.p. 11, 19, 25, 53, 64, 70, 79, 88, 108, 125, 145, 162, 172

10 Murray-Darling Basin Commission 2006, Recovering Water for the Environment – The Shepparton Irrigation Area Total Channel Control Project Pre-feasibility Assessment, publication no. 13/06, MDBC, Canberra

11 Department of Sustainability and Environment 2010, Audit of Water Savings: Shepparton and Central Goulburn 1–4, Victorian Government, DSE, Melbourne, p.iii

12 Land & Water Australia 2003, Improving Water-use Efficiency in Irrigation Conveyance Systems: A Study of Investment Strategies, Land & Water Australia, Canberra, p.15

13 Sinclair Knight Merz 2000, Water savings in Irrigation Distribution Systems, Victoria, p. 76

14 Australian National Committee on Irrigation and Drainage 2007, Australian Irrigation Water Providers Benchmarking Report for 2005/2006, ANCID, Tasmania, p.15

15 Australian Bureau of Statistics 2004, Water Account Australia 2004–05, cat no. 4610.0, ABS, Canberra, p.72, accessed at http://www.ausstats.abs.gov.au/ausstats/subscriber.nsf/0/3494F63DFEE158BFCA257233001CE732/$File/46100_2004–05.pdf, 28 February 2010

16 FAO Aquatsat Database, United Nations Food and Agriculture Organisation, accessed at www.fao.org/nr/aquastat, 28 February 2010

17 Khatri, K.L. & Smith, R. 2011, Surface Irrigation for Energy and Water Efficiency, paper presented to Irrigation Australia Conference, Tasmania, 22–25 August 2011.

18 Iven Mareels, Erik Weyer, Su Ki Ooi, Michael Cantoni, Yuping Li, Girish Nair; Systems Engineering for Irrigation Systems: Successes and Challenges, Annual Reviews in Control, Vol 29, 191–204

19 M. Cantoni, E. Weyer, Y. Li, S.K. Ooi, I. Mareels and M. Ryan, Control of large-scale irrigation networks Proceedings of the IEEE, Special Issue on the Technology of Networked Control Systems (eds. J. Bailliuel and P. Antsaklis), Volume 95, Issue 1, Jan. 2007 Page(s):75 – 91

20 Goulburn-Murray Water 2011, Annual Report 2010–2011, Victoria, p.24

21 Department of the Environment and Water Resources 2007, Innovation in Irrigation, DEWR Canberra, p.6

22 Australian National Committee on Irrigation and Drainage 2007, Australian Irrigation Water Providers Benchmarking Report for 2005–2006, ANCID, Tasmania, p.p. 25, 31, 46

23 National Water Commission 2009, National Performance Report 2008–2009: Rural Water Service Providers, NWC, Canberra, p.p. 15, 86, 89, 176 Ooi, Su Ki; Cooley, Nicola; Mareels, Iven; Dunn, Greg; Dassanayake, Kithsiri; Saleem, Khusro; Automation of on-farm irrigation: Horticultural case study, Agricontrol, Volume # 3 | Part# 1, doi 10.3182/20101206-3-JP-3009.00045 ISBN: 978-3-902661-90-6

1.5

Water markets: A downstream perspective

Mike Young

Mike Young is the Founding Executive Director of the University of Adelaide's Environment Institute, holds a Research Chair in Water Economics and Management at the University of Adelaide, is a fellow of the Academy of Social Sciences in Australia, and is a Distinguished Fellow of the Australian Agricultural and Resource Economics Society.

A Member of the Wentworth Group of Concerned Scientists, in 2006, Mike Young was awarded Australia's premiere water research prize – the Land and Water Australia Eureka Award for Water Research. The award recognises the significant contribution of his research with Jim McColl to the introduction of improved water entitlement, allocation and trading systems.

Prior to joining the University of Adelaide, Mike spent 30 years with CSIRO where he established their Policy and Economic Research Unit with offices in Adelaide, Canberra and Perth. In 2003, Mike was awarded a Centenary Medal "for outstanding service through environmental economics". In 2009, he was named South Australian of the Year in the Environment Category.

A downstream perspective

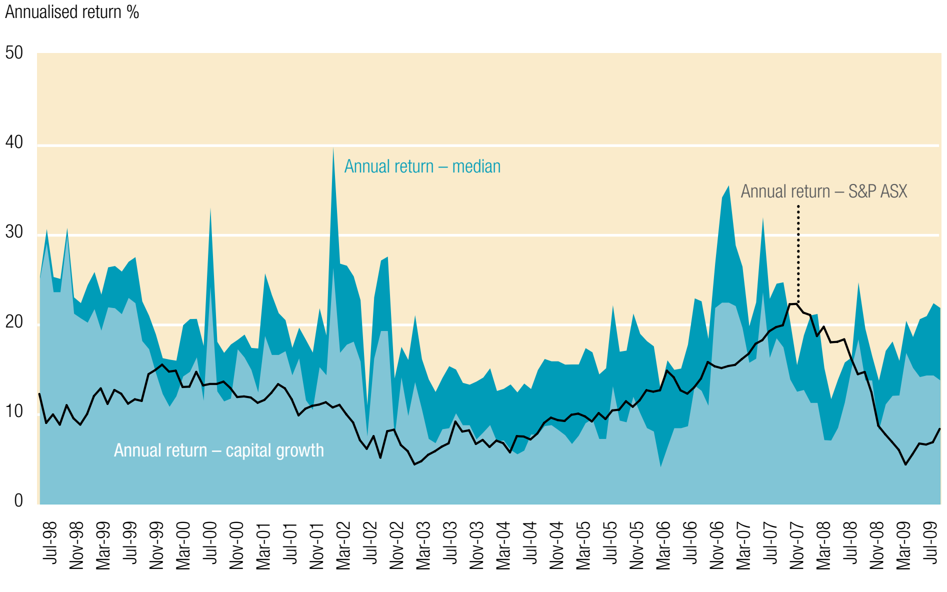
From a downstream perspective, two aspects dominate the mind of a water user. The first perspective is one of an important opportunity to trade water with upstream irrigators in ways that are of mutual benefit. The second perspective is one that looks at the broader suite of water reforms necessary to enable the full benefits of water trading to be realised. This second, broader perspective reveals a significant downside to the Australian water trading experience that could have been avoided. In fact, one can argue from a downstream perspective that the introduction of trading has stimulated an array of investments and actions that should never have been allowed to happen – the costs to the nation where too great. Australia got the water reform sequence wrong.

From the first perspective, the introduction of water trading has resulted in a significant increase in the value of water entitlements, enabled a rapid expansion in the area irrigated and helped irrigators avoid many of the worst impacts of the long-dry (drought) that occurred between 2002/03 and 2009/10. As shown in Figure 1, the internal rate of return from holding water entitlements has exceeded the rate of return from holding shares and has usually been well in excess of 12 per cent per annum. There was a net trade of water into South Australia and a significant increase in water use efficiency associated with a major investment in new plantations of grapes and almonds. From this perspective, the benefits of water trading look good – trading produced a significant increase in irrigator wealth.

A second dimension from this first perspective is recognition of the important role that markets played during the long dry between 2003 and 2009. During this period allocations were insufficient to keep all valuable permanent plantings in production. Trading allowed water allocations to be purchased from irrigators in NSW and Victoria who

FIGURE 1

ANNUAL RETURNS FROM SELLING ALLOCATIONS AND CAPITAL GROWTH IN THE VALUE OF A WATER ENTITLEMENT COMPARED WITH AN INDEX OF THE VALUE OF SHARES IN THE AUSTRALIAN STOCK EXCHANGE (S&P ASX), GOULBURN MURRAY SYSTEM, MURRAY-DARLING BASIN.



Source: Bjornlund and Rossini (2007).

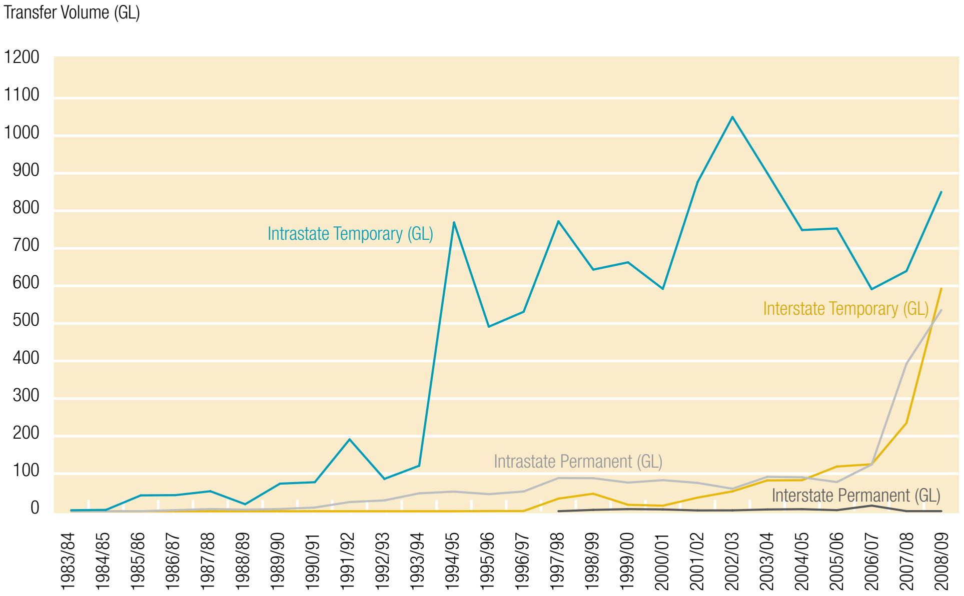
Box 1
An overview of the sequence of water reforms in the Murray-Darling Basin

1994	Introduction of an interim cap on diversions
1994	National Competition Policy requires states to introduce policies that require full cost pricing, the introduction of water trading in rural areas and arrangements that allow water entitlements to be held by legal entities that do not hold an interest in land
1996	Within-state trading allowed
1998	A two year pilot interstate water trading trial commenced between NSW, Victoria and SA but limited to areas close to the SA border
2000	Review of interstate water trading results in a decision to expand trading to cover most surface water use in the connected Southern Connected River Murray System
2002	Various proposals made for the reduction of water use in the Basin by reducing allocations by as much as 1500GL which eventually resulted in a decision to take a first step towards solving the “problem” by returning 500GL to the environment over the next five years
2004	National Water Initiative introduced
2007–8	Commonwealth Government passes a Water Act that attempts to transfer responsibility to the Commonwealth for development of a water use plan for the Murray-Darling Basin and the resolution of over allocation problems in this system. Subsequent negotiations between the Commonwealth and State Governments eventually resulted in a decision to establish an independent, expertise based Murray-Darling Basin Authority coupled with arrangements that gave State Ministers and officials a larger say in the development of the Basin Plan
2010	A guide to the Basin Plan released

could either decide not to grow an annual crop and/or irrigate pasture. Without the opportunity to buy this water many more perennial plantations would have had to be abandoned. Even so, in the peak of the long dry it was decided to allow salinity levels at the bottom of the river to rise to such an extent that irrigators, while still issued an allocation, could not use this water as it was too saline. Once again the role of the market was important, while these downstream irrigators were not able to use the water allocated to them, they were able to sell them to upstream irrigators who could use this water before it became too saline.

These apparent benefits, however, hide an important oversight. The second downstream perspective is much less positive. Trading has the potential to introduce massive benefits to irrigation communities and to individuals but only if they are surrounded by a suite of institutional arrangements that prevent the system from trading into trouble. When trading was introduced to the Southern Connected Murray-Darling System, this suite of institutional arrangements were lacking and, at the time of writing, are still lacking. The second downstream perspective stresses the importance of establishing robust water accounting arrangements and allocation arrangements. When these arrangements are not in place both trading can make the nation as a whole and many individual irrigators worse off.

FIGURE 2
DEVELOPMENT OF MURRAY-DARLING BASIN WATER ENTITLEMENT TRANSFERS



Source: Young (2010).

The sequence of reforms is important to understand (see Box 1). In the Murray-Darling Basin, these reforms began in the late 1980s with a series of negotiations that introduced a cap on diversions in 1994. This “cap”, as it was called, was acknowledged as an interim cap and was expected to prevent an increase in water use. If the cap had been introduced without the introduction of trading the volume of water used in the Basin would have remained the same. In 1994, however, as part of a National Competition Policy, state governments were required to allow water entitlements to be held separately from land titles and traded. The result was a dramatic increase in the volume of trading (see Figure 2).

Trading stimulated widespread investment in technologies designed to improve water use efficiency. These investments, however, significantly reduced return flows and, also, in the use of ground water that previously flowed unused into the river (Young and McColl 2003; Young 2010). There was also a significant increase in the capture of overland flows that previously flowed to the river. In short, the introduction of water trading worsened the extent of the Basin’s over-allocation problem that was identified when the cap was introduced. In retrospect, the cap should have been a cap on *nett use* rather than a cap on diversions which allowed those who improved irrigation efficiency to expand water use (Young 2010).

In the five years immediately after the introduction of water trading, use of water increased by 29 per cent. The area irrigated increased by 22 per cent (Bryan and Marvanek 2004) and nearly all of this new area involved the establishment of new vineyards and orchards. None of the water allocation plans, however, made any allowance for this increase in water use. Allocations continued as if no increase in water use had occurred. As a result, late in 2002 the River Murray stopped flowing and in November 2003 dredges had to be put into the mouth of the River to keep it open.

Officials were aware of these problems but were unable to find a politically acceptable way to manage the adverse effects of these processes on the health of the river. By 2002, it had been estimated that, at least, 1500GL of cap equivalent would be needed to restore health to the Basin and estimates of the economic and social impacts of securing this and other amounts of water for the environment where being made (See for example Young *et al*. 2002). While the increasing environmental costs of not fixing the Basin's over-allocation problems were appreciated, governments found difficulty in agreeing what to do. Ultimately, it was decided that a Living Murray program would be implemented as a first step towards solving the over allocation problem. Under this program, it was decided that 500GL of water would be secured for the environment over the four years between 2004 and 2009. This amount was, however, insufficient to cover the losses being caused by the expansion of irrigation and investment in new technology (Young and McColl 2003).

Net progress was negative and, in 2007, the Commonwealth Government decided to step in and introduced a new Commonwealth Water Act coupled with a commitment to purchase $3.1 billion of water entitlements and invest a further $5.8 billion in improving the efficiency of irrigation on the condition that half of the savings were returned to the river. Progress still proved difficult and in 2010 the Murray-Darling Basin Authority in a guide to the development of a new plan for the Basin estimated that entitlements in the entire Basin had to be reduced by over 3000GL (MDBA 2010). While the benefits of trading were apparent it was becoming increasingly clear that the costs of not fixing the Basin's over allocation problems before introducing water trading were rising. A problem that could have been fixed in 1994 – at little cost to taxpayers – had evolved into a problem that would cost over $8.9 billion of tax revenue to fix. As there are only 15,120 irrigators in the Murray-Darling Basin (ABS 2011), this is equivalent to over $588,000 per irrigator.

From a downstream irrigator perspective there are two other downsides to the claimed positive experience associated with the introduction of water trading. The first of these relates to the impact of the government's decision to invest in water savings on the condition that half of the savings would be returned to irrigators. In downstream South Australia, there were no channel systems to upgrade and, hence, the use of taxpayer's money to subsidise investment in another part of the Basin works to the disadvantage of already efficient downstream irrigators competing in a competitive water market. At the end of the day, even if the over-allocation problem is solved, it is not clear that those who had borrowed heavily to install state-of-the-art irrigation technology will be able to compete with their subsidised upstream competitors. Time will tell.

The last adverse downstream perspective offered, draws attention to the need to enable optimisation of inter-temporal water use as water trading is introduced. Before trading was freed up by the National Competition Policy reforms, most irrigators did not use all the water allocated to them and what they did not use was left in dams for use in subsequent years. Allocation policies understood this. When water trading was introduced, however, the new policy signal given to irrigators was that if you could not profitably use any water allocated to you, you should sell it to someone who could. Irrigators responded accordingly and water that would have previously been left in dams was sold. As a result, too much water was used and dam storages ran down too quickly. So much so that Brennan (2007) estimates that the apparent benefits of water trading were less than the cost of the increased drought-like impact of trading on the amount of water available for use in subsequent years. In retrospect, the golden rule, now realised by all Australian governments, is that if water trading is introduced, it must be possible for irrigators to decide that the optimal strategy is to carry forward water from one year to the next – especially when water supplies are low. As soon as officials appreciated the importance of allowing the carry forward of water from one season to another allocation policies where changed but this was not before the damage was done (Young 2010).

In summary, the downstream perspective of the experience with the introduction of water markets is mixed. Trading produced an increase in the value of water entitlements and wealth and stimulated a large amount of investment in new technology. Many businesses and communities benefited – at least in the short term. The resultant processes, however, significantly worsened over-allocation problems that are proving expensive to fix and while they remain unfixed are causing significant environmental problems at the bottom of the river. In retrospect the downstream perspective is one that recommends early attention to water accounting and allocation arrangements so that all the theoretical benefits of trading can be realised.

References

Australian Bureau of Statistics (2011) Water Use on Australian Farms, 2009–10. Canberra.

Bjornlund, H. and Rossini, P. (2007). An Analysis of the returns from an investment in water entitlements in Australia. *Pacific Rim Property Research Journal* 13(3):344-360.

Brennan, Donna (2007) Missing markets for storage and their implications for spatial water markets. Paper presented to AARES Conference, Queenstown, NZ, 14th February 2007.

Bryan, B. and Marvanek, S. (2004) Quantifying and valuing land use change for Integrated Catchment Management evaluation in the Murray-Darling Basin 1996/97 – 2000/01. Stage 2 Report to the Murray-Darling Basin Commission. CSIRO Land and Water.

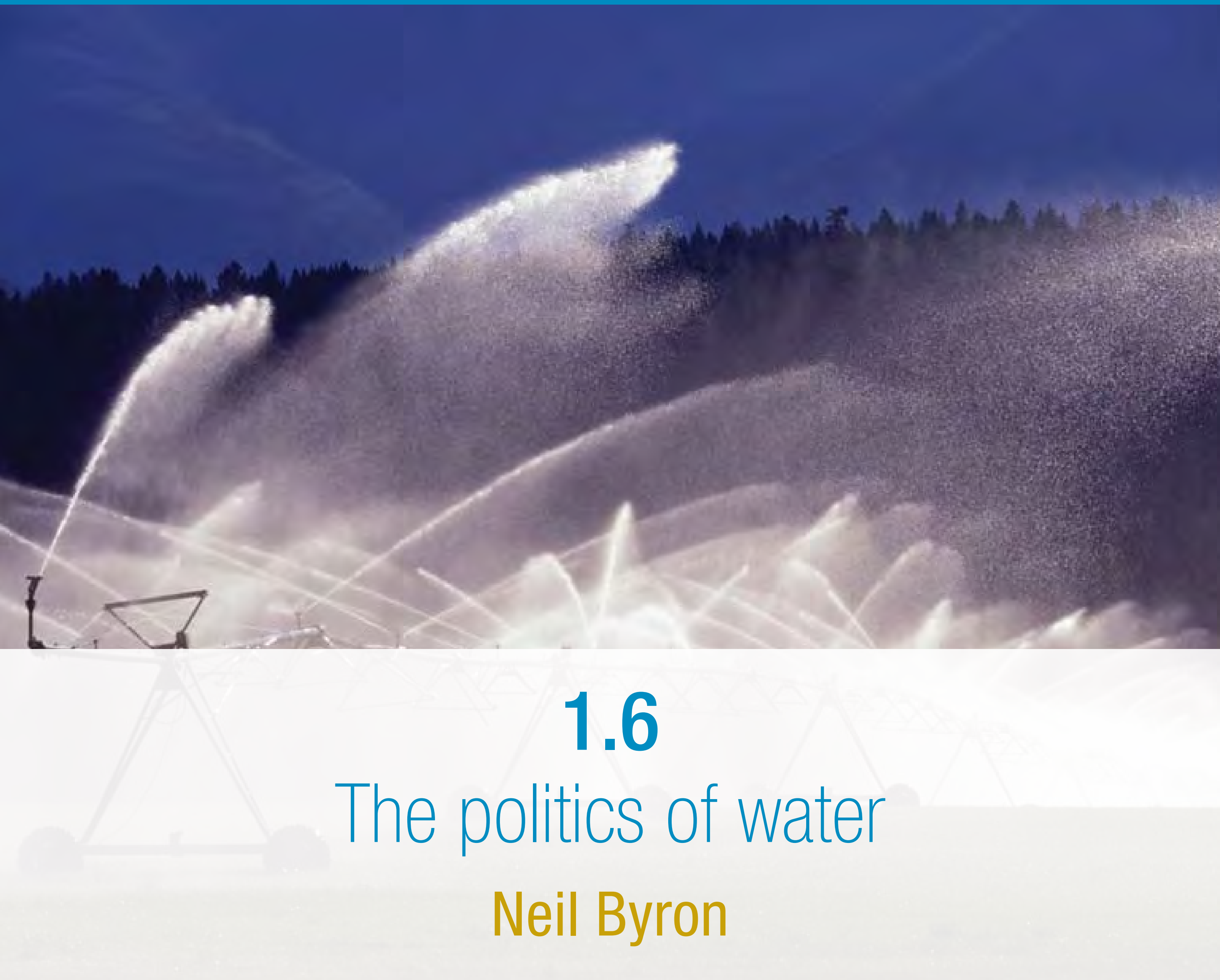
Murray–Darling Basin Authority (MDBA) (2010) Guide to the proposed Basin Plan, Murray–Darling Basin Authority, Canberra.

Young, M.D. and McColl, J.C (2008). Double trouble: the importance of accounting for and defining water entitlements consistent with hydrological realities. *Australian Journal of Agricultural and Resource Economics* 53:19–35.

Young, M.D. (2010). Environmental effectiveness and economic efficiency of water use in agriculture: The experience of and lessons from the Australian water policy reform programme. Consultant report prepared for the OECD, Paris, France.

Young, M.D. and McColl, J.C. (2003) Robust reform. The case for a new water entitlement system for Australia. *Australian Economic Review* 36(2):225-34.

Young, M.D.; Young, D.; Hamilton, A. and Bright, M. (2002) A preliminary assessment of the economic and social implications of environmental flow scenarios for the River Murray System. A report prepared for the Murray-Darling Basin Commission, Policy and Economic Research Unit, CSIRO Land and Water, Adelaide.



1.6

The politics of water

Neil Byron

Dr Neil Byron is an Adjunct Professor in Environmental Economics at the ANU's Crawford School of Economics & Government. He was previously Commissioner responsible for environment, agriculture and natural resource management issues in the Productivity Commission from 1998 to 2010.

Prior appointments include: research at the Bureau of Agricultural Economics in Canberra; running a UN Project in Bangladesh; directing the graduate program in Environmental Management and Development at ANU; and Assistant Director General of the Centre for International Forestry Research, based in Indonesia.

"Water is not a political issue until it becomes ***the*** *political issue."*

This paper briefly explores the way politics in Australia, for over a century, has been central to both:

- Decisions to build new water supply infrastructure; and
- Decisions about what the charges should be (to whom and on what basis) for the use of that infrastructure.

There are still serious disconnects between these two. Politicians frequently overstate the benefits of investing in water supply infrastructure, in attempts to justify further investments from the public purse. However, they consistently seem reluctant to recover much of the subsequent benefits to reimburse the public purse.

The central proposition is this: despite the self-evident failures of past patterns of tax-payer-subsidised development of irrigated agriculture, those patterns are still being repeated, particularly in the Murray-Darling Basin and potentially across northern Australia.

It will probably be impossible to prevent the politicisation of questions of building water supply infrastructure, and how the costs of doing so are recovered. However, it may be possible to highlight the consequences of doing this poorly, and to inject greater public transparency into these matters, by creating robust institutions to reveal the full economic consequences of political decisions.

Introduction

The history of irrigation development in Australia has already been documented in this volume and elsewhere.[1] With very few exceptions, it has relied on "visionary" political decisions to "promote development" and foster a sturdy yeomanry of prosperous small farmers protected from the vagaries of Australia's notoriously variable climate. It was seen as a "social responsibility" to drought-proof Australian agriculture, particularly when agriculture was the mainstay of the Australian economy.

This belief persists, although now generally implicit rather than explicit – that it is in Australia's long-term national interest to stimulate agriculture in marginal areas, and furthermore, the best way to do so is by government provision of cheap irrigation water (through subsidies from tax-payers).[2 and 3] So while many Australian politicians continue to promote agricultural development through subsidised water infrastructure, the history of paying for such schemes is vexed. Given this long history, it is unsurprising that many irrigators expect (or even consider it a right) that they should not have to pay "full price" for the services and inputs they receive courtesy of the public purse.

As earlier Chapters have documented, recent attempts to remove (or at least reduce) the explicit subsidies came through the 1995 CoAG reforms and the 2004 National Water Initiative (NWI). As Watson[4] (and others) noted, there were (and still are) at least three inter-related objectives:

- Concerns with economic efficiency;
- Environmental concerns; and
- The desire of governments for increased revenues.

These moves were stimulated by a series of revelations that almost none of the existing irrigation schemes across Australia generated sufficient revenue to cover the full costs of water supply, and many did not even recover the variable costs (i.e. they did not cover operating costs and made no contribution to the capital costs involved). These reforms have generally been referred to subsequently as ***"full cost recovery"*** including the capital costs of water collection, storage and distribution.

But this has, in turn, raised other complications. What is the value of Australia's water-supply infrastructure (in most cases built by governments) and what depreciation charges would be reasonable to impose on customers, in addition to the charges for the water itself?

The value of Australia's water and water supply infrastructure?

The Australian Bureau of Statistics (ABS) has recently been drawn into this controversy, publishing an information paper[5] which illustrates the complexity of these issues.

Hypothetically, if a number of prospective irrigators in an area formed a consortium to construct water-supply infrastructure and then deliver water to its members, (having first arranged a long-term contract with the government conferring permission to collect and store a certain amount of water, and having satisfied all environmental impact assessments) it would assess the investment, and then operate the facility, along normal commercial lines, to ensure its solvency and liquidity.

Let us take this hypothetical situation as a benchmark for comparison with what has been "normal practice" in Australia.

In contrast, decisions to construct or upgrade irrigation facilities in Australia have frequently ignored adverse benefit/cost analyses (where these were even undertaken) on the basis of political interests (marginal votes in marginal electorates) or assertions of "national interest".

The ABS has been challenged to estimate what the infrastructure is itself worth in such a context. The ABS correctly reasoned that, in most commercial contexts, such large physical assets would be valued on the basis of the Net Present Value (NPV) of the future stream of net revenues they are expected to generate. But when prices are set so low (usually under political pressures) that net revenues are zero or negative, does that imply the infrastructure itself is worthless (in an accounting sense)?

The ABS paper therefore proposes using the depreciated replacement cost of the infrastructure asset as the basis for calculating capital-recovery charges.

This creates a paradox. Why would anyone (in the public or private sector) spend millions or billions of dollars creating an asset which becomes technically worth zero as soon as it starts to operate? Alternatively, why use (depreciated) replacement cost as the basis for estimating the asset's value to society, when it is unlikely to ever be replaced, and arguably would never have been built in the first place if its subsequent non-viability had been known?

The explanation for this conundrum lies partly in the use of the same terminology by accountants and economists, with quite different meanings. As Watson explained:

> *"Accountants are concerned to recover the costs of the investment. The perspective of economists is to use existing resources to confer the largest social gains. Many pricing rules could be followed but no defensible rules require that the fixed costs of past investments* **must** *be recovered.… It is impossible to determine appropriate capital charges for water without being explicit about the underlying economic rationale of pricing. … Attempting to put a value on the irrigation system to determine a "full cost" price of irrigation water is the reverse of what is needed for economically sensible decisions about irrigation. The price of water influences the value of the irrigation system, not the other way around."* [6]

To return to our hypothetical consortium, its members might choose to recover their initial investment over the life of their asset through a fixed annual capital charge to be connected to the system, a distribution charge per mega litre (ML) taken each year (perhaps constant in real terms) plus a price for each ML water itself that passes through the system – a price that varies with scarcity for season to season, or even with time of year. Even after paying these capital and operating charges sufficient to finance the construction of their asset, the members of the consortium would usually find that the value of their land had risen, because of its improved prospects of generating higher and more reliable incomes.

When water infrastructure is built, owned and operated by a government agency, and water is subsequently distributed to users at a "price" or charge that does not even cover the costs of provision/distribution, is the water itself worth nothing? Under some interpretations, that is what the customers are paying for it, even though clearly it is a very valuable input into agriculture. The fact that some states have moved to a two-part tariff – a flat annual charge to be part of the system, which goes towards capital costs, and a separate variable charge per ML of water actually taken – has added to the confusion.

Where subsequent operation has been in the hands of state agencies, it has been relatively easy to conceal the ongoing drain on the public purse. Where irrigation companies have been corporatised or privatised as in NSW, it has often been with internal governance structures which preclude reform of delivery obligations and charging arrangements, thereby perpetuating inefficient and unsustainable operations until failure becomes inevitable.[7]

It is essential to appropriately link the economic decision of ***whether to build*** the infrastructure (if the sum of the expected benefits based on the estimated true social value of water – the "shadow price" – exceed the expected costs all based on their shadow prices) and the question of ***how much to charge*** for use of the infrastructure once it is built. If a system is only worth building *ex ante* if water is distributed at a charge of $X, then *ex poste*, the charge should actually be $X, not half of that.

In Australia over the past 50 or more years, politicians have frequently confounded the two issues and come to incorrect conclusions on each. They have rarely addressed the third component of water charges – how much to charge for the water that moves through the infrastructure.

Box 1
A secondary market in discount certificates

Imagine a certificate that entitled the owner to purchase 1000 litres of petrol at a price of 40 cents/litre less than the market value over the coming year.

The market value of this certificate would be about $400 – few people would pay any more, but at any lower price, the certificate would be worth acquiring. A market might emerge.

Now imagine an otherwise identical certificate that entitled the owner to purchase 1000 litres of petrol at the full market value over the coming year.

Its market value would be approximately nothing, unless people expected shortages where just an assured right of supply (regardless of price) might have some value. Very few people would bother trying to acquire such a certificate.

The revealed value of irrigation water

In the Murray-Darling Basin, especially the southern connected part where trade in water allocations occurs freely over considerable distances in three States, secondary markets for water have emerged, as described in previous chapters of this volume. The substantial prices being paid for seasonal allocations (particularly during droughts) and for entitlements reveals the substantial discrepancies between what water is sold for in the primary market (by the Bulk Water Authority or Irrigation Company to the right-holder) versus what it is worth when the primary right-holder on-sells to other users. Box 1 provides a simple illustration of the principle.

Despite almost two decades of commitments by State and Commonwealth Governments to move towards full cost pricing for irrigation water, it still hasn't occurred. In normal times, this is a recurring cost on taxpayers, to support irrigators in proportion to how much water they use – the biggest users attract the greatest public subsidy, and these are not necessarily those most in need of public assistance (if any). The implicit subsidy on the costs of water delivered to irrigators has been capitalised into the value of the water entitlements (the limited number of valuable "discount certificates").

But the recent buy-back of water entitlements as part of the *"Water for the Future"* program since 2008 has highlighted the consequences. If governments had moved, over the period 1994 to 2008, to increase charges for irrigation water towards *either* the full economic value of that water (what it is worth) *or* its true economic costs of collection, storage and distribution, then the value of water entitlements in the secondary markets could have been more like $20 per ML than $1200 or $2000/ML. The taxpayers could have bought sufficient water to meet their environmental objectives for much less than $3 billion. Moreover, irrigators facing the real price of water would presumably have decided that the amount they need (at that price) is much less than the amount they would like when it is heavily subsidised (i.e. that irrigators' demand for water is not a fixed quantity, but is in fact quite price–sensitive).

Substantial inequities also arise within the irrigation sector. Many have received their water entitlement "certificates" as a gift from governments (presumably in return for expectations of political support) but newcomers have purchased their rights at then current market values. While a move towards full-cost recovery pricing of irrigation water "claws back" for the taxpayers some of the economic rents that the original group of irrigators have enjoyed, those who purchased entitlements in the past five years or so (since trade expanded significantly) have already "purchased" the stream of economic rents and can be expected to complain very loudly if their assets were trimmed back.

This seems to be another instance of where the sequencing of economic reforms matters almost as much as their content:

- If sleeper and dozer licences had been extinguished, or at least taken out of circulation at the outset (at low cost) rather than purchased back (at full price) after activation; and
- If State Government agencies had delivered on their commitments to move substantially towards full cost recovery pricing.

The reality is that this genie was released years ago and cannot be put back in the bottle now. But an intelligent society would learn from that experience and not repeat the mistake in other basins, or with groundwater.

Replumbing the Basin?

I have described elsewhere[8] my assessment of the dubious political processes and seriously flawed and incomplete economic analysis that led to the 10 year, 10-point $10 billion plan to "save" the Murray-Darling Basin, which was endorsed by every federal politician, from all parties, in both houses, twice, in 2007 and 2008. As is well known, the strategy was in three (unrelated) parts:

- A water buy-back of about $3 billion of entitlements (a market-based approach);
- Investing almost $6 billion in upgrading irrigation infrastructure (an engineering approach); and
- A new statutory planning Authority, the Murray-Darling Basin Authority (MDBA) which would establish and enforce Sustainable Diversion Limits (a planning/regulatory approach).

There as still been no public explanation of why these three mechanisms were chosen, now they are supposed to intersect with one another[9] or, more importantly for this discussion, how the amounts of $3 billion and $6 billion were chosen and why those proportions.

As already argued above, if there *was* to be a buy-back, it should only have occurred After the long-promised pricing reforms had been implemented (unless the intent was to deliberately shower irrigators with $3 billion of taxpayers funds to buy their acquiescence, in which case it clearly failed).

Despite protestations that the subsidised upgrades of infrastructure would be justified – by a combination of environmental benefits and enhanced productivity and profitability for irrigated agriculture, to date almost none of the $6 billion allocated has been spent. This reality is because virtually none of the projects proposed have come even close to meeting normal (very weak) requirements for government investment in these areas. The most expensive and controversial to date has been Northern Victoria Irrigation Renewal Project – Phase I of which has absorbed $1 billion of Victorian taxpayers' funds and Phase II of which would call for another $1 billion from all Australian taxpayers.

Given that few, if any, existing irrigation schemes have been able to generate sufficient revenue at current (administered) water charges to cover their existing capital costs (not to mention the operating costs or the opportunity costs of the water itself) one has to wonder whether the new generation of investments in water infrastructure will fare any better? How long might it be before users find themselves unwilling or unable to cover the new higher costs, and request that these assets also be gifted to them by the taxpayers at a nominal price. Perhaps we already have robust institutions and governance arrangements in place that would prevent history repeating itself again, but the evidence for that is weak. The simplest test would be whether those clamouring for new water infrastructure would be willing to underwrite the full costs, with zero possibility of a public bail-out in the future, or whether they only want the new infrastructure as the public will foot most of the bills, again.

Clearly Australia has the analytical capacity to undertake rigorous economic analysis of the economics of constructing and operating water infrastructure – the Bureau of Agricultural Economics was doing that even in the 1960s. What seems to be consistently missing is the mechanism to constrain those who want to raid the public purse to support a particular constituency in the guise of "national interest".

Endnotes

1 See Davidson, B. R., 1969; Australia, wet or dry? : the physical and economic limits to the expansion of irrigation. Melbourne University Press. Also Watson, A.S. 1995, *Conceptual Issues in the Pricing of Water for Irrigation.* Dairy R&D Corporation, Melbourne.

2 See Northern Australia Land & Water Taskforce 2010 http://www.nalwt.gov.au/; Also 'Abbott's network plan for northern foodbowl' The Australian p 6. 17/09/2011

3 Others might argue that various forms of agriculture receives other forms of state subsidies: drought relief; diesel rebates; beef roads; rail freight subsidies; etc

4 Watson op cit p 7

5 Comisari, P, L. Feng and B Freeman, 2011. *Valuation of water resources and water infrastructure assets.* Information Paper to 17th London Group Meeting, Stockholm 12–15 Sept 2011 Accessed as http://unstats.un.org/unsd/envaccounting/londongroup/meeting17/LG17_12.pdf

6 Watson, *op cit* p 8

7 The outcomes are made even worse when state price-regulators of (natural monopoly) utility services decide that distribution charges should not reflect any capital costs because the relevant assets have been 'gifted' to corporate operators, in effect saying "this asset has no economic value because you did not write a cheque to buy it". Such a concept would have interesting implications if applied to bequests, lottery winnings or other ways of acquiring valuable assets without making an explicit purchase.

8 Byron, R.N. 2011 'What can the Murray-Darling Basin Plan Achieve? Will it be enough?' pp 385–398 In D. Connell and RQ Grafton (eds) Basin Futures: Water Reform in the Murray-Darling Basin. ANU E-Press, Canberra.

9 Productivity Commission 2010 Market Mechanisms for Recovery of Water in the Murray-Darling Basin. Australian Government, Canberra.

Section 2.0

Maintaining healthy ecosystems: rebalancing water shares

2.1 Editors' overview

2.2 The Living Murray Initiative
Gary Jones and Ann Milligan

2.3 The economic impact of the buy-back program
Glyn Wittwer and Peter Dixon

2.4 Critiquing the Water Act (2007) John Briscoe

2.5 Managing the Lower Lakes Dominic Skinner

2.1

Editors' overview

Australia has one of the most variable rainfall patterns in the world. Consequently, Australian rivers naturally cycle through a boom-bust process of floods and droughts. The birds, fish and plants that rely on Australia's freshwaters have developed strategies to thrive in these variable conditions. The rollout of large public water storages along the Murray-Darling Basin and other Australian river systems in the 20th century provided more stable flow and reduced this boom-bust cycle. This resulted in significant environmental damage to important Australian water systems.

By over-allocating water in the Murray-Darling Basin, Australian governments have restricted options available to environmental managers who need access to a flow entitlement to maintain important ecosystem functions. The need to rebalance the share of water between agricultural users and the environment is now the dominant issue in improving the health of freshwater ecosystems.

Successive attempts to address this imbalance have had mixed outcomes. Initially, the Living Murray produced successful initiatives that balanced environmental and community interests. While the Water Act (2007) introduced concepts such as sustainable diversion limits and created the Murray-Darling Basin Authority, it deviated significantly from processes used in the Living Murray program that had successfully achieved a balance between people and the environment.

It is important to appreciate how Australia has successfully achieved this balance so we can do so again. The environmental consequences of failure are potentially catastrophic collapses in irreplaceable ecosystems, such as the Lower Lakes of the Murray-Darling Basin, with dire results for regional communities.

About the contributors

- Gary Jones and Ann Milligan describe the Living Murray initiative and its implications for rebalancing water use in the Murray-Darling Basin;
- Glyn Wittwer and Peter Dixon undertake economic modelling of the water entitlement buy-back program's impacts on regional economies;
- John Briscoe discusses institutional and legislative issues associated with the Water Act (2007); and
- Dominic Skinner describes the environmental lessons for management of the Lower Lakes in South Australia.

Discussion

The Murray-Darling Basin has had over 100 years as a highly irrigated river system. It no longer contains pristine ecosystems but heavily regulated ones. Australia has extensive experience in dealing with environmental damage caused by excess water extraction for agriculture. As a consequence, water managers have historically engaged communities in developing a consensus about the level of water to return to the environment. This bottom-up consultative process managed to successfully reconcile stakeholder groups' interests and environmental concerns.

The Living Murray program is an example of Australia's water policy expertise and of what can occur when environmental rebalancing engages in a democratic process influenced by experts and the community. Based on objective scientific evidence of environmental damage that was communicated in a clear fashion, the Living Murray program established a water entitlement buy-back level with clearly articulated outcomes. This is important because the costs of removing water are explicit and quantifiable for regional communities while the environmental benefits are more difficult to quantify. Unless regional communities have meaningful input into determining environmental outcomes, and a scientific consensus on environmental consequences is achieved, efforts to rebalance water shares will ultimately fail. However, while the process of rebalancing water shares was proven to be successful with the Living Murray model, the volume of water returned to the environment was always considered a first step.

While there are numerous claims about the regional impacts of the buy-back program, economic modelling found that it is considerably less detrimental than may have been anticipated. Water trading ensures that the impact of reduced water allocation on agricultural productivity is minimised. It also acts as an automatic stabiliser allowing marginal irrigators to realise an asset and exit the industry while encouraging greater water saving initiatives among the remaining irrigators.

The extended drought exposed the damage high levels of water diversion had caused to the River Murray's ecosystems. While water trading enabled irrigators to adjust to reduced levels of water allocation, it highlighted the consequences of over-allocation in the river system. These consequences included acid drainage, extensive algal blooms, salinisation and black water events that are felt by all water users. The ecosystems of the Lower Lakes at the Murray mouth came perilously close to ecological collapse and required substantial community investment to avert disaster. While it was the recent drought that led to severe changes in the Lower Lakes, it was the lack of secure water entitlements for the environment which prevented the system being managed appropriately. Much of the necessary water already flows into the Lower Lakes. What is required is to secure the right volume at the right time.

In attempting to resolve a lack of rain through legislative processes, the Water Act (2007) took a detour from the successful processes of the Living Murray program. The Act did not engage Australia's water scientists or regional communities and adopted a top-down “experts know best” approach to resolving environmental damage. It was not successful in engaging the relevant stakeholders and did not achieve a successful rebalancing of water shares.

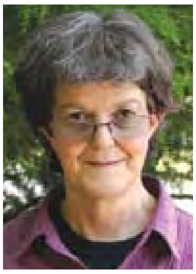
It is important to return to the well established processes of resolving environmental damage. The Lower Lakes of the Murray-Darling represent a bellwether for the health of the entire river system and it will take rigorous, and contestable, scientific knowledge to determine the level of flow required to maintain the health of the Lower Lakes while also engaging the communities that will be affected.

2.2

The Living Murray Initiative

Gary Jones and Ann Milligan

Professor Gary Jones is Chief Executive of eWater Cooperative Research Centre (CRC), former Chief Executive of the CRC for Freshwater Ecology, and Chairman of the International River Foundation. A former aquatic scientist with CSIRO, he has wide experience of environmental flows management and of communicating science to the water industry. He has led a number of high-level committees and collaborative research initiatives, including the scientific teams that produced the ecological basis for the Living Murray decisions.



Ann Milligan is a former natural resources scientist with CSIRO who has been communicating science for over three decades. She was Communication Manager for the CRC for Freshwater Ecology, and is currently an Executive Officer with eWater CRC and a freelance science communicator.

Introduction

This is a story of rebalancing water allocation between humans and the environment in the Murray-Darling Basin ("the Basin").

It is a story starting in the 1970s–80s of concern growing among scientists and NGOs who could see the environment and ecology of the Basin changing; and of scientists and technical bureaucrats building a case for action. Subsequent management programs focusing on water quality, habitat restoration, key species and pests helped but were not enough – they still did not remove the symptoms of ecological decline.

Ultimately, water managers and politicians realised they had to take action to recover the hydrology underpinning the "flow regime" the Basin ecosystems needed to regain their ecological health and support economic productivity and sustainability.

The story shows how science can connect successfully with major public policy – something that does not happen often enough in Australian and international environmental management.

Finally, this paper looks at several crucial factors: knowledge built on science, public communication, leadership and, later after decades of hard work, big dollars from government, coming together and culminating in, first, the National Water Initiative in 2004, and then the Murray-Darling Rescue Package announced by Prime Minister John Howard in January 2007, and the *Water Act 2007* passed a couple of months later. Those latter decisions marked a critical point in a more than 20-year journey in restoring the Basin to sustainability, and the start of a new phase that we are currently navigating, unfortunately with enormous difficulty.

Building the case for action

Looking back, the path followed – the recognition of environmental degradation arising from excessive water use, the policy response and resulting actions – which can all be seen clearly.

During the 1960s and 1970s, as more and more water was extracted from rivers of the Basin, scientists and concerned citizens began noticing and investigating changes that were happening to the rivers' fauna and floodplain wetlands and vegetation.

The case for action[1] in the Basin's rivers and wetlands was built during the 1970s and 1980s, with ecologists such as Keith Walker, Terry Hillman and others publishing papers and reports on the decline in floodplain River Redgum forests and wetlands, of keystone fish such as the Murray Cod and Trout Cod, and of invertebrates such as crayfish and mussels. Knowledge grew, and evidence became more and more detailed, quantified and compelling, that there were causal links between biodiversity and habitat loss and changes to flow regime.

By the late 1980s, a solution was seen as necessary to help maintain the health of the Barmah-Millewa Forests, leading the Murray-Darling Basin Ministerial Council (MDBMC) to allocate an annual environmental flow[2] of 100GL, from 1993 onwards, and to begin specifically focusing on conserving sensitive ecosystems[3]. Implementing the complexities of watering individual wetlands was taken on by an innovative and ultimately very successful partnership between floodplain farmers and government, known as the Murray Wetlands Working Group, established in 1992.

Notwithstanding the Barmah-Millewa decision, flow regime impacts were still not widely accepted as a major environmental issue. Attention was more focused on land and water salinisation, which was a real and growing problem, and on water quality more broadly. The National Water Quality Management Strategy was established in 1992, the National Dryland Salinity Program soon after that, and land clearing, soil erosion and salt interception became foci for management organisations in the Basin states.

Eutrophication was only a minor concern until the 1000km long bloom of toxic blue-green algae in the Darling River in the summer of 1991–92, which brought blanket national news coverage for several weeks.[4] To any observer, and certainly to politicians and the Australian media, this was an unequivocal sign that health of the Basin's rivers was in serious decline. Though we did not fully understand it at the time, subsequent scientific research[5] proved conclusively that very low river flows, and the consequent thermal destratification that they bring about in Australia's hot climate, was the root cause.

In the early 1990s, policy and management began to take serious notice of these signposts of a river system gone wrong. Running in parallel with a growing debate on environmental flows was a similar conversation on over-allocation and inefficient use of water by irrigation more generally. Widespread salinity problems in soils and streams had convinced water managers that the rapid expansion of dam building and water use which had occurred almost unabated from the 1950s to 1980s had to stop. The cap on water use declared by the MDBMC in 1995 saw to that[6] (although the subsequent unchecked growth in groundwater use was both foreseeable and inevitable).

In 1994, the Council of Australian Governments (COAG) water reforms formally commenced. This process set out to deal with over-allocation of water, inefficient and unsustainable use in rural and urban settings, and to provide environmental flows for stressed rivers. The February 1994 COAG Communiqué[7] made a clear statement that water needed to be allocated to the environment, though with no detail on how that might happen.

The first national set of policy and management guidelines was provided in 1996 in the *National Principles for the Provision of Water for the Environment* published by ARMCANZ and ANZECC.[8] Following this, the Basin states, particularly Victoria, went into a round of environmental flow panel analyses of environmental water requirements for their "stressed" rivers (indeed, Victoria had commenced this process earlier and was a major influence in the development of the 1996 Principles[9]).

Research organisations, most notably the CRC for Freshwater Ecology (CRCFE) under the guidance of the late Peter Cullen, had already begun to take a collaborative multi-disciplinary approach to environmental flows research and analysis[10], providing a strong scientific underpinning to the planning and management validations being undertaken by the Murray-Darling Basin Commission (MDBC) and state governments.

Finally in the 1990s, the Murray Mouth, where the rivers of the Basin discharge to the Southern Ocean, began to close due to sand accumulation and lack of river flow. This led to years of continual dredging — a costly exercise but necessary, both ecologically and politically, to keep the mouth of the River Murray open.

Both the massive Darling River toxic blue-green algal bloom, at the beginning of the decade, and the closure of the Murray Mouth at its end, were powerful signals for the public and for politicians that something had to be done to restore flows in the Basin. Policy intent had been set out with the 1994 COAG Water Reforms, but real action was clearly needed.

Towards the Living Murray Initiative

As 2000 approached, the MDBC, led by Don Blackmore, commissioned a detailed scientific assessment of the River Murray and Lower Darling River.[11] In his foreword to the report, MDBC CEO Don Blackmore encapsulated the shift in emphasis away from supply and salinity control to focus on flow. He said:

> *"The need to provide adequate flows for the environment to ensure that our rivers remain healthy has been acknowledged as one of the primary environmental issues in current times. This has been recognised by both Federal and State Governments in the Council of Australian Governments Water Reform Agenda and in the National Principles for the Provision of Water for Ecosystems, and through funding provisions of the Natural Heritage Trust. All states now have mechanisms for water allocation which recognise the need to provide water for the environment while providing for other users."*

That study involved a multidisciplinary team of scientists, myself included: specialists in hydrology, geomorphology, vegetation, algae, wetlands, fish, birds, invertebrates and water quality. Besides reviewing the science, the team also travelled the rivers talking with local communities along the way. It provided "the first integrated scientific evaluation available on environmental flow regimes" for the River Murray, as an input to future decisions on water allocations.

The MDBMC followed that report by commissioning in 2001 a more detailed study by an Expert Reference Panel (ERP) that I (Jones) chaired. This new study[12] made an assessment of currently available evidence, and undertook detailed analysis of eco-hydrological data, to explore the kinds of volumes of water the rivers might need to recover ecological health.

It is likely that the politicians and officials of the MDBMC expected only relatively modest water recovery volumes would be needed. The ERP's findings that, on a risk-assessment basis, it would take up to 4000GL/year of environmental flows, plus changes to infrastructure and operations, to have a "high likelihood" of restoring the River Murray to a "healthy, working" condition were probably a shock to all (except perhaps river scientists).

This was the point at which the Living Murray Initiative began, with the aim of turning a working river into a "healthy working river"[13] — one managed to achieve a "sustainable compromise between the condition of the natural ecosystem and the level of human use". To quote from the MDBC at the time:

> *"The Living Murray is Australia's most significant river restoration program. It aims to achieve a healthy working River Murray system for the benefit of all Australians. This includes returning water to the River's environment."*[14]

The next panel study commissioned by the MDBC, in 2002, was the one that led to the First Step Decision in late 2003.

Scientific Reference Panel study for the Living Murray

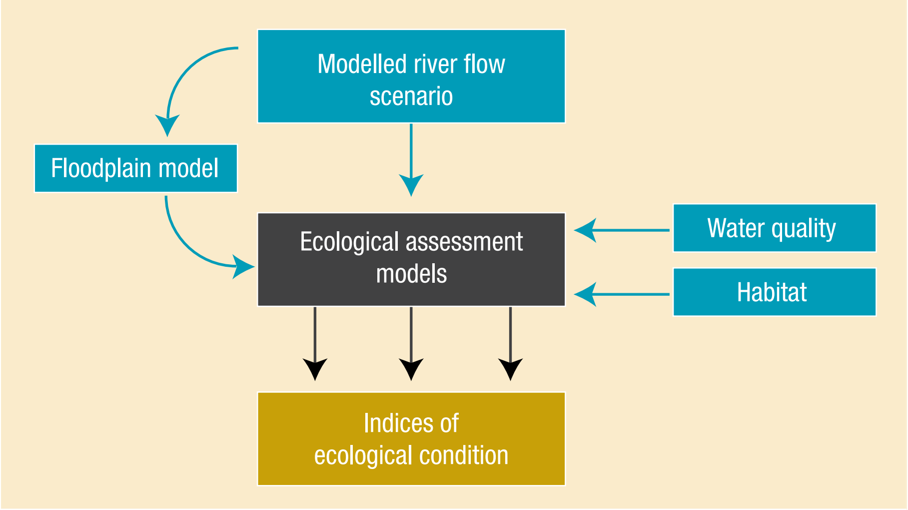
In April 2002, the MDBMC called for an even more comprehensive assessment of the costs and benefits to the environment, industries and communities of returning additional water to the River Murray system[15] as environmental flows. The CRCFE was asked to assemble a new Scientific Reference Panel (SRP) for this task which I again chaired. The SRP was given three potential environmental flow recovery volumes (350, 750, 1500GL/year) to evaluate. (Politically, 4000GL was seen as too much water to recover for the environment at that point in time.) Proposed structural and operational modifications were also to be assessed, along with scenarios targeting particular ecosystems (now known as the Icon Sites) and ecological indicators.

This SRP study called for a different approach from the earlier ERP report. Whereas the ERP had provided an overall analysis of environmental flow needs for the River Murray, the SRP was asked to produce detailed scientific evidence for various "icon" ecological sites in and along the river and its floodplain: local communities needed to understand local benefits of environmental flows. New demand from the community for more open scientific analysis that could be publicly scrutinised also meant that the "expert" and effectively "closed" approach of the ERP would no longer be politically or socially acceptable. The scientific data and assessments had to be presented in a form that allowed (informed) members of the public to evaluate the science themselves.

As the SRP study was expected to investigate reaches and sites so as to make the necessary assessments at local and regional scales, the SRP established 10 regional evaluation groups (REGs), each comprising scientists with specific discipline expertise and local knowledge. Our aim was two-fold: to build sufficiently detailed analyses to show the local river communities the predicted outcomes in their regions, *and* to bring together as many ecological scientists as possible. Overall, 60–70 scientists from across the Basin, and beyond, were involved in the study.

With only a short timeframe it was also essential to apply a highly structured scientific assessment method that was both transparent and repeatable, ensuring that all the REGs applied the method in the same way. The SRP realised that some form of model or decision-support system was need to ensure this outcome. After a review of national and international options, we chose the CSIRO's EFDSS (environmental flow decision

FIGURE 1
SCHEMATIC DIAGRAM OF THE MURRAY FLOW ASSESSMENT TOOL (MFAT) FRAMEWORK



support system)[16]. At CSIRO, Bill Young, Sue Cuddy and colleagues worked hard and fast to adapt it to the needs of the SRP. The resulting Murray Flow Assessment Tool (MFAT) was conceptually simple; however, its knowledge-management system allowed the repeatable handling of very large amounts of data and other evidence.

The MFAT was essential for structuring and formalising the inputs of the REGs. When 60–70 scientists in a range of disciplines work on a topic, if you are not careful there can be 60–70 different approaches and viewpoints in play. The SRP's need for everyone to work to the same objectives with the same sets of methods meant some compromises had to be made by individual discipline specialists. With the MFAT — a knowledge-management system rather than a model — the consistency in scientific assessment and synthesis that was so essential across the 10 river reaches of the River Murray system was achievable.

During the regional assessment process, the SRP maintained close contact with each REG and provided guidance and advice when required. This "secretariat" role of the SRP was led and managed by Anthony Scott, Bronwyn Rennie and Sarah Cartwright through the CRCFE where there was already a strong track record of managing multi-partner, collaborative research. The SRP's scientists also continually reviewed the draft reports from each REG, to confirm the consistency of the assessment process across all REGs, and to coordinate the scientific evidence and interpretations within and between the REGs. Overall quality assurance came from international peer review.

In summary, using MFAT, the SRP was able to:

- Capture and use the best available scientific knowledge;
- Reliably generate whole-of-river-scale ecological assessments based on assessments at local and regional scales;
- Consistently and repeatably assess the "likely" ecological outcomes of the various flow scenarios; and
- Transparently document the sources and reliability of supporting ecological evidence.

At the end of the process, the SRP report[17] clearly and unequivocally advised that 1500GL/year had only a moderate likelihood of restoring the Murray to a "healthy working river" condition. The iconic Murray Cod were not likely to benefit from only 1500GL/year. Some improvement could be expected from 1500GL/year for waterbirds, River Redgum forests, wetland and floodplain vegetation, river salinity and Golden Perch, but the smaller flows (750GL and 350GL per year) were predicted to provide less benefit — they would reach fewer floodplain sites. On the plus side, however, even 350GL/year of extra flow would reduce the likelihood of blue-green algal blooms.

Although the report was "interim" and the SRP expected to be asked for further analysis and discussion, as it turned out the guidance on flow and non-flow management of the River Murray system was seen as enough, and the Ministerial Council accepted the report as final. However, that was never announced, leaving some commentators[18] to complain that the final report had not been published.

The Ministerial Council's momentous "First Step Decision"[19] to invest $500 million for recovery of 500 GL/year for the River Murray followed on directly from the SRP's report. This was the biggest environmental water investment decision made in Australia and possibly in the world, at that time, and a very significant step for the MDBMC to take, even though it was also significantly less water than the environment needed for long-term sustainability.

Telling the ecology story to policy

By the time the National Water Initiative (NWI) was tabled in 2004[20] the case for "water for the environment" (as environmental flows had become known), was clear and unarguable across virtually all water use and management stakeholder groups in Australia, but especially so in the Murray-Darling Basin. The NWI reaffirmed and strengthened the commitment of COAG to the provisions of water for the environment, and the *Commonwealth Water Act 2007* ultimately has environmental water needs as its central platform.

The story of how this came about has also been a story of policy and science working together through broadscale interactions that included community water users.

The MDBMC in 1986 appointed a Community Advisory Committee which was a means for decision-makers to listen to the natural resources wisdom residing in the Basin's regional communities. While that process may not have been as effective as communities may have wished, it was still better than nothing. In 2001, Leith Boully (Committee Chair) said:

> *"Across the vast distances of our greatest river system we have acted, and still act, with limited co-ordination and little understanding of one another's agendas and needs.*
>
> *"Scientific research and information is not enough, although it will be the foundation on which effective response must be built. Sound policy and partnerships are not sufficient, although without them nothing that is enduring will be achieved. Political resolve alone will not be adequate, although it remains a vital element of any comprehensive approach.*
>
> *"In the end it will be people that make the difference. It is us — the people who put our own meaning on events, actions and situations, and make our own decisions, who will finally decide on the future of our river country."*[21]

Science alone is not enough, as Leith Boully says, but it is an essential component of river management into the future to sustain the Basin's productivity and communities.

Without well-structured, repeatable, defensible, peer-reviewed science, in the Living Murray's SRP process, there could not have been a First Step Decision. In fact, there would not have been conclusions on which to base the decision without the solid structure provided by the MFAT.

Leadership was also a vital element of the science–policy–community interactions. The social dynamic of group science is not easy and needs to be carefully managed and structured. Traditionally, scientific research tends to be done by individuals or small groups, within a single discipline and with a small-group focus (there is nearly always a single research-group leader). Bringing 60–70 scientists together on a project is a different proposition.

For the SRP process, three main factors helped achieve harmonisation between the disparate scientist teams. They were:

- Strong planning and leadership from the SRP and CRCFE (which understood from experience that individuals and individual scientific discipline interests, such as birds vs fish vs plants, would, if unmanaged, tend to over-ride the need for integrated ecological thinking);

- A well structured group method and hierarchy (overarching leadership of the SRP and the head office team at CRCFE and the REGs); and
- A knowledge-management tool (MFAT) that directed the science process, structured the cumulative knowledge base in a consistent and transparent manner, and allowed scientific consensus to be reached and for it to be broadly communicated.

When the scientists, myself and others, presented the final report to stakeholders along the River Murray, our openness and credibility, and our willingness to meet the communities, were vital and highly scrutinised. Landholders and irrigators with big financial investments in their farm businesses do not, and should not be expected to, take science or scientists at face value. At a number of very well attended, and at times heated, public meetings after the report was released, it was important for us to communicate and explain the results of the science in an objective way, looking stakeholders in the eye, giving advice not advocacy. All SRP members were fully conscious that while we were building a case for restoring the health of the River Murray, the outcomes of our report might, in future, negatively influence the livelihoods of local people. It was important not to promote a particular water recovery target but to communicate the science honestly and with integrity.

In the end, effective leadership by the SRP, the CRCFE and by the MDBC itself was critical to the success of the Living Murray science process — and, by any standards of public policy setting, it *was* successful. Don Blackmore, in particular, as CEO of the MDBC, reasonably and at arm's length regularly set goals for the SRP and ensured that we delivered the right kind of information in the right form. He understood that doing "good" science was not, on its own, enough.

Communication and particularly communication from a credible and trusted source, as Peter Cullen demonstrated so well[22], was obviously essential. Good public communication of science is about telling the story — in this case, the scientifically factual story that is the "biography" of the Basin's rivers and wetlands — in a way that keeps your audience engaged.

The story must present the issues and potential solutions, clearly, conveying information that is scientifically accurate and also that everyone can understand.

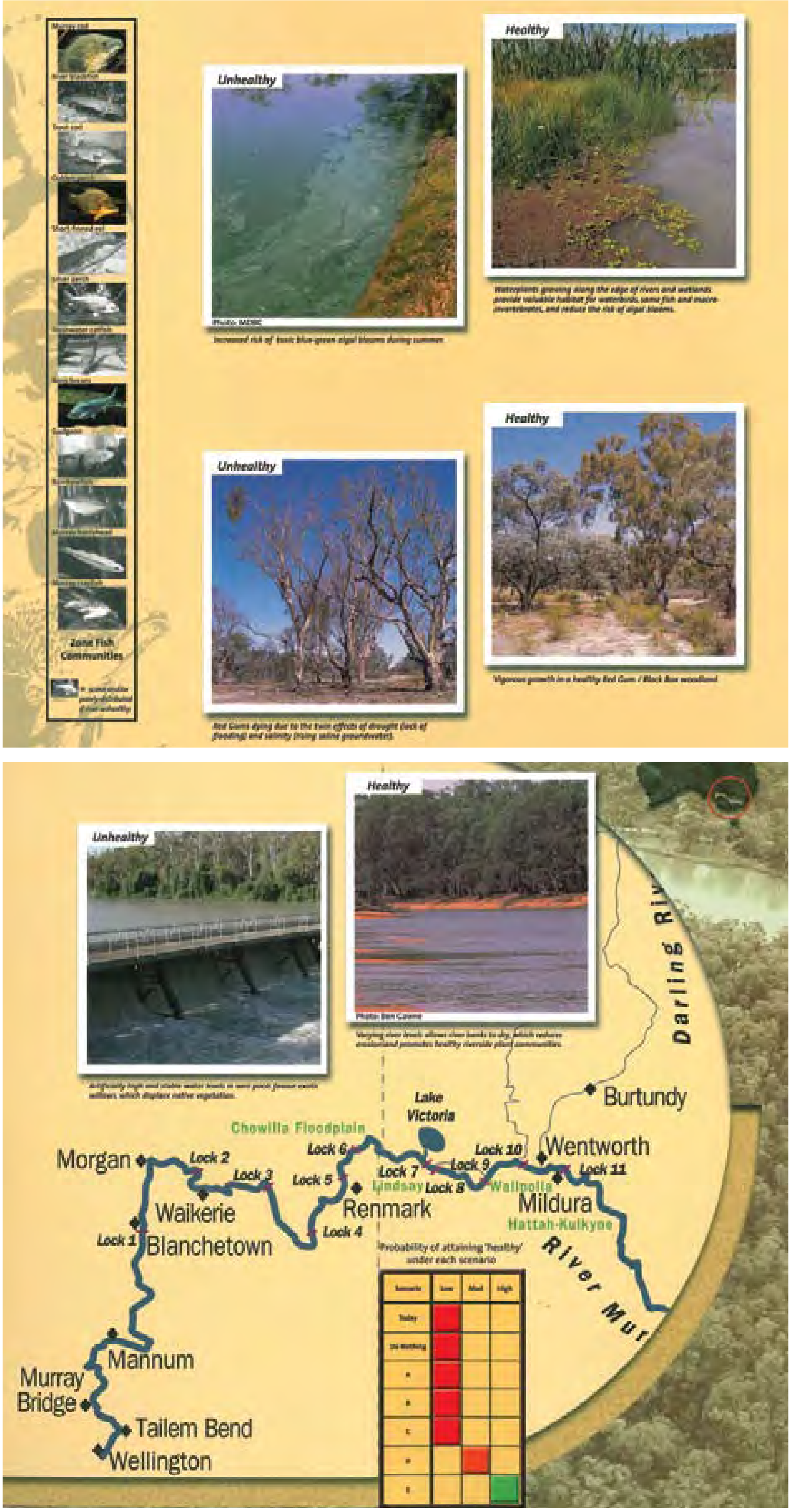
To help politicians and senior officials understand the issues besetting the River Murray, the MDBC commissioned the CRCFE to prepare a limited-edition pictorial book.[23] Based on the 2001 independent Expert Reference Panel findings, *Future Visions for the River Murray* illustrated how the river looked then, and how it might look in the future, with and without intervention. The book was built from extensive preliminary thought and discussion followed by a flight along the river to locate and photograph examples that contrasted the parts of the river that were in healthy or unhealthy condition. It includes maps and devices to show risks and benefits. The ERP's assessment of how each river-reach might look in the future under different environmental flow scenarios was also represented photographically and pictorially.

This book was an important communication tool. A river may look "restful" to a townsperson unfamiliar with rivers, and may simultaneously look ecologically unhealthy to the eyes of an ecologist. Words are not really enough to explain that. The book summarised the factors that indicate poor ecological condition in pictures so that non-ecologists had a chance to see through the eyes of an ecologist.

FIGURE 2

EXAMPLE ILLUSTRATION OF HEALTHY AND UNHEALTHY CONTRASTS FOR THE LOWER MURRAY, FROM *"FUTURE VISIONS FOR THE RIVER MURRAY"*.

Fish photos in greyscale show species expected to be scarce or poorly distributed in unhealthy river conditions; the grid shows estimated chances of attaining healthy conditions, for each of the management scenarios assessed.



Source: Jones & Cartwright 2002

Since the Living Murray

"Water for the environment" is increasingly part of mainstream river management (albeit, delayed by drought) — not merely policy or rhetoric. For the Basin, this situation, first envisaged by ARMCANZ in 1996, can be attributed to the First Step Decision and other subsequent investments. Money is on the table to buy water for the environment, and good volumes of water are already in the collective (Commonwealth and state) environmental water accounts and starting to be applied. Most of this has come through the Federal Government's *Water for the Future* fund and water recovery program, worth approximately $5–6 billion (depending on how you do the sums). However, the states' own programs, as well as the Living Murray and Snowy River investment[24] ($375 million to recover 282GL for the environment, as 210GL for the Snowy River and 70GL for the River Murray), are worth close to an additional half a billion dollars.

All those investments have been built on science, trust, leadership and communication, not just from scientific panels but from the collaborative science and communication that were hallmarks of a golden era of "science speaking to policy". The late Peter Cullen was perhaps the best-known exponent of that, with his capacity to integrate science into straightforward messages that could be trusted and that helped COAG decision-makers take action.

The momentum of the Living Murray towards recovering water for the Basin's rivers has continued, though approaches have changed, unfortunately not always for the better.

A full decade after COAG began to focus on national water reform, the burgeoning evidence of ill-health of lowland river environments from a range of causes — not forgetting the need to dredge the Murray Mouth continually to keep it open — resulted in COAG's announcement of the signing of the Intergovernmental Agreement on a National Water Initiative in June 2004.[25]

June 2004 was not just a significant month federally. In Victoria, the Premier Steve Bracks and Water Minister John Thwaites released their paper Our Water Our Future. In NSW, Minister for Infrastructure, Planning and Natural Resources, Craig Knowles, released his vision for securing NSW's sustainable water future, saying: "Smart and innovative solutions to provide more water to the environment and to minimise the impacts on entitlement holders will be emblematic of our new approach."[26]

So much policy formation happens out of the public eye. In his book *Lazarus Rising*[27], John Howard credits John Anderson MP with "campaigning strongly for reform of water policy" (p. 557). He explains how Anderson "talked on a one-on-one basis to his counterparts in the various state governments" culminating in agreement for a national water policy at the COAG meeting on 29 August, 2003. Interstate water trading was an important feature of the agreement we are told. Howard attributes the National Water Initiative to Anderson's persistence in applying "genuine cooperative federalism".

By 2004, however, Australia's variable climate was complicating the picture of river health and water reform. The long drought in eastern states added its stresses to the effects of years of overuse of catchments and surface-water and groundwater supplies, predictably and preventably. Perversely, this may have been a good thing, when we look back, because the threat of insufficient water possibly as a result of climate change has driven many initiatives to boost water security.

The drought was another crisis apparently helping to stimulate the formation of environmental water policy, and calling for leadership and investment. Both were on view on 25 January 2007. John Howard reports that with Malcolm Turnbull he began devising a Murray-Darling Rescue Plan in late 2006, which he then presented to the nation that day, along with a commitment of $10 billion.[28]

This major investment contributed to buy-backs of water entitlements for the environment by the states, and to new irrigation infrastructure to save gigalitres of water. It showed understanding that if governments aim to take away use of natural resources that have been the basis of huge business investment and the livelihoods of numerous communities and millions of people, then there must be substantial financial compensation.

Howard's announcement of water reform and the Murray-Darling Rescue Plan, which led to the *Water Act 2007*, gave control of the Basin to the Commonwealth, via the Murray-Darling Basin Authority (MDBA), which is currently preparing the Murray-Darling Basin Plan, due for release in 2011–12.

However, Commonwealth control of water usage in the Basin, via the MDBA, has not immediately solved the over-allocation of water. Partly that is because planning to recover water failed to involve the people most concerned. Not only irrigators and rural communities, but also the river scientists who had been part of the Living Murray Initiative were left largely unconsulted and unengaged during development of the Guide to the Murray-Darling Basin Plan, released in late 2010. This meant that their collective knowledge, both scientific and local, was not built into the first assessment set out in the Guide.

Unfortunately the Commonwealth-run MDBA looked inwards for solutions and analysis, not outwards.

That situation can be turned around, but it will take a new vision, leadership, collaboration, and broadscale communication, as well as interactions based on integrated science and open conversations with both river scientists and river communities.

At the time of writing, with the Basin Plan now under the leadership of the current MDBA Chair Craig Knowles, and the Minister responsible for water and the environment Tony Burke, the signs are positive for renewed collaboration and sharing of knowledge.

Whether the final Basin Plan will provide an ecologically sustainable balance between human and environmental water use, or merely a politically acceptable compromise, only time will tell.

References

1 Adapted from Jones, G 2010, 'Water for the environment — key drivers and impacts', Presentation at *Water and its Interdependencies in the Australian Economy*, International workshop series, 22–23 June 2010, Sydney. The Australian Academy of Technological Sciences and Engineering (ATSE).

2 Barmah-Millewa Forum 2000, *The Barmah–Millewa Forests Water Management Strategy*, Murray-Darling Basin Commission on behalf of the Barmah-Millewa Forum.

3 *Ibid.*

4 Crabb P 1997, *Murray-Darling Basin Resources*, Murray-Darling Basin Commission, Canberra, p. 140.

5 See e.g. Jones, G 1994, *River Flow and Blue-green Algal Blooms*, Seeking Solutions No. 21, CSIRO Division of Water Resources, Canberra.

6 See e.g. Blackmore, D 2001, 'Water, salinity and the politics of mutual obligation', Deakin Lecture, Melbourne Town Hall, 19 May 2001, accessed at http://www.abc.net.au/rn/deakin/stories/s299073.htm, 20 September 2011.

7 COAG 1994, 'Council of Australian Governments' Communiqué 25 February 1994', accessed at http://www.coag.gov.au/coag_meeting_outcomes/1994-02-25/index.cfm#water, 20 September 2011.

8 ARMCANZ & ANZECC 1996, *National Principles for the Provision of Water for Ecosystems*, Occasional Paper SWR No.3 July 1996, Agriculture & Resource Management Council of Australia & New Zealand and Australian & New Zealand Environment & Conservation Council, accessed at http://www.environment.gov.au/water/publications/environmental/ecosystems/water-provision.html, 20 September 2011.

9 Doolan, J 2007, 'An institutional perspective on governance — the evolution of integrated river management in Victoria, Australia', *Governance as a Trialogue: Government–society–science in transition* (Eds AR Turton, HJ Hattingh, G Maree et al.), 305–317, Springer and CSIR, Berlin.

10 CRC for Freshwater Ecology, 2005, 'Who were we? 12 years of CRCFE', accessed at http://freshwater.canberra.edu.au, 20 September 2011.

11 Thoms, M, Suter, P, Roberts, J et al. 2000, *Report of the River Murray Scientific Panel on Environmental Flows: River Murray — Dartmouth to Wellington and the Lower Darling River*, Report to the Murray-Darling Basin Commission, Canberra.

12 Jones, G, Hillman, T, Kingsford, R *et al.* 2002, *Independent Report of the Expert Reference Panel on Environmental Flows and Water Quality Requirements for the River Murray System*, Report to the River Murray Project Board, by CRC for Freshwater Ecology.

13 Whittington, J 2002, 'Working rivers', *Watershed*, February 2002, pp. 3–4, CRC for Freshwater Ecology, Canberra, accessed at http://freshwater.canberra.edu.au/publications.nsf (Watershed), 20 September 2011.

14 Murray-Darling Basin Commission 2008, 'The Living Murray', accessed at http://thelivingmurray2.mdbc.gov.au/, 20 September 2011.

15 The 'River Murray System' comprises the regulated rivers of the southern Basin, effectively the Murray and its tributaries, where about 80% of Basin irrigation water is used.

16 Scott, A, Milligan, A & Rennie, B 2003, 'MFAT: transparent in process if not in name', *Watershed*, December 2003, pp. 4–7, accessed at http://freshwater.canberra.edu.au/publications.nsf (Watershed), 20 September 2011.

17 Jones, G, Arthington, A, Gawne, B et al. 2003, *Ecological Assessment of Environmental Flow Reference Points for the River Murray System*, Interim report, Scientific Reference Panel for the Murray-Darling Basin Commission, Living Murray Initiative, CRC for Freshwater Ecology, Canberra, accessed at http://publications.mdbc.gov.au/download.php?download=234, 20 September 2011.

18 Crase, L & O'Keefe, S 2008, 'Acknowledging scarcity and achieving reform', *Water Policy in Australia: The impact of change and uncertainty* (Ed. Lin Crase), 166–183, RFF Press, Washington DC USA.

19 Murray-Darling Basin Commission 2005, 'The Living Murray Foundation Report on the significant ecological assets targeted in the First Step Decision', accessed at http://www2.mdbc.gov.au/subs/dynamic_reports/foundation_report/1.html on 20 September 2011.

20 National Water Commission 2011, 'National Water Initiative', accessed at http://www.nwc.gov.au/www/html/117-national-water-initiative.asp, 20 September 2011.

21 Boully, L 2001, 'The city and the bush — the waters divide', Alfred Deakin Lecture, Melbourne Town Hall, 19 May 2001, accessed at http://www.abc.net.au/rn/deakin/stories/s299073.htm, 20 September 2011.

22 Cullen, P 2001, 'Delivering ecological knowledge to the water industry', *Watershed*, March 2001, pp. 1–2, CRC for Freshwater Ecology, Canberra, accessed at http://freshwater.canberra.edu.au/publications.nsf (Watershed), 20 September 2011.

23 Jones, G & Cartwright, S 2002, *Future Visions for the River Murray: A pictorial companion to the Independent Report of the Expert Reference Panel on Environmental Flows and Water Quality Requirements for the River Murray System*, CRC for Freshwater Ecology and Murray-Darling Basin Commission, Canberra.

24 Dept of Sustainability and Environment Victoria 2011, 'The Snowy River — an historic agreement', accessed at http://www.water.vic.gov.au/environment/rivers/snowy/agreement, 20 September 2011.

25 National Water Commission 2011 op. cit.

26 Jones, G 2004, 'The role of science and innovation in Australia's water policy reform', *Watershed*, October 2004, pp. 1–3, CRC for Freshwater Ecology, Canberra, accessed at http://freshwater.canberra.edu.au/publications.nsf (Watershed), 20 September 2011.

27 Howard, J 2011, *Lazarus Rising: A personal and political autobiography*, Harper Collins, Sydney.

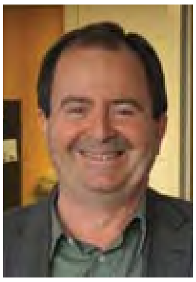
28 ibid

2.3

The economic impact of the buy-back programs

Glyn Wittwer and Peter Dixon

Since 2001, **Dr Glyn Wittwer** has been a Senior Research Fellow at the Centre of Policy Studies. His expertise is in regional Computable General Equilibrium (CGE) modeling. He has played a major role with Mark Horridge in developing databases for TERM versions for Australia and China. In addition, he has developed a TERM version of the U.S. economy. In 2007, he was joint winner of a CSIRO Land and Water Strategic Excellence award for his modelling of future urban and rural water demands and supplies. He has been the major developer of dynamic TERM-H2O. He has used the model extensively in work commissioned by various state and Australian government departments.



Professor Peter B. Dixon, BEc (Monash), PhD (Harvard), is known internationally for his work in computable general equilibrium modelling. After working at the International Monetary Fund and the Reserve Bank of Australia, Dixon joined the IMPACT Project in 1975.Dixon was appointed to the Chair in Economic Theory at La Trobe University in 1978 and to a Visiting Professorship at Harvard in 1983. From 1984 to 1991 he was Director and Professor in the Institute of Applied Economic and Social Research at the University of Melbourne and from 1991 to 2004 he held the equivalent position in the Centre of Policy Studies at Monash University. In July 2004 he became Professor and Principal Researcher in the Centre of Policy Studies. In 2006 he was appointed Sir John Monash Distinguished Professor by Monash University. Dixon's publication list contains about 200 articles and seven books.

Introduction

Australian economists have a long history of sector-wide modelling for agriculture and economy-wide modelling with an agricultural emphasis. Guise and Flinn (1970) investigated the optimal allocation of water in part of the Murrumbidgee Irrigation Area. Their main policy insight was that inefficient water allocations occurred through the lack of a market-driven pricing mechanism: the shadow prices on water in different uses varied widely. Starting in the 1970s, Australian economists developed economy-wide models with an agricultural emphasis. This enabled them to quantify the effects on agriculture of shocks from outside agriculture (e.g, a mining boom, Dixon *et al*.1978). In the ORANI model, Dixon *et al*. (1977) adapted the CET (constant elasticity of transformation) form for farm sectors devised by Powell and Gruen (1968). This theoretical attribute captured in the ORANI model reflects observed short-term flexibilities in the product mix of farms.

Several reforms emerged in the 1990s from the Council of Australian Governments (COAG) process. Until the 1990s, water trading occurred in the Murray-Darling Basin only in exceptional circumstances. Among the reforms, ownership of land was disentangled from water rights. A mature water trading system requires other institutional arrangements, including water trading services such as Watermove, established by Victoria's Department of Sustainability and Environment in 2002. Whereas earlier modelling indicated the possibility for economic gains from improved water allocations, the possibility for maximising these gains arose from water trading, with the water price determined by market conditions rather than institutional judgment.

Hall *et al*. (1993) formulated a model of irrigated agriculture for 18 regions in the southern Murray-Darling Basin to estimate the effects of water pricing and in particular, water trading. The study also assessed the impacts of a "water bank" which would buy water for environmental or urban purposes. The authors found substantial gains from water trading. However, a subsequent study showed that observed volumes of water trading were much smaller than modelled volumes (Hall 2001). This appears to reflect a learning process. In the 2002 drought, large volumes of water were traded, particularly away from rice production. The severe drought in effect made the potential gains from water trading obvious to irrigators. In the three year drought of 2006 to 2008 that affected the southern Murray-Darling Basin, water trading was essential in delivering sufficient water to perennials (vineyards and orchards) as allocations fell.

Over the past decade, very detailed economy-wide models have been developed (in particular, TERM, The Enormous Regional Model). In the first application of TERM, Horridge *et al*. (2005) found that drought wiped 1.5 per cent off Gross Domestic Product (GDP) despite agriculture's contribution to GDP being only three per cent in total in a normal year.

In this chapter we overview some of the key findings from TERM modelling of water-related issues.[1] First, we outline the modifications made to TERM to model irrigation water issues in the Murray-Darling Basin. We then outline the modelled regional economic impacts of removing water from irrigation production and diverting it to the environment. Starting with estimates derived from the model's database, we explain how modelled outcomes are smaller than initial estimates. Given that environmental water buy-backs started during drought, we regard it as important to compare the impacts of buy-back with the impacts of drought. Finally, we regress observed water prices against variables including water availability, a farm output price index and a drought index. The regression indicates that TERM-H2O results are defensible against observed data.

TERM applications

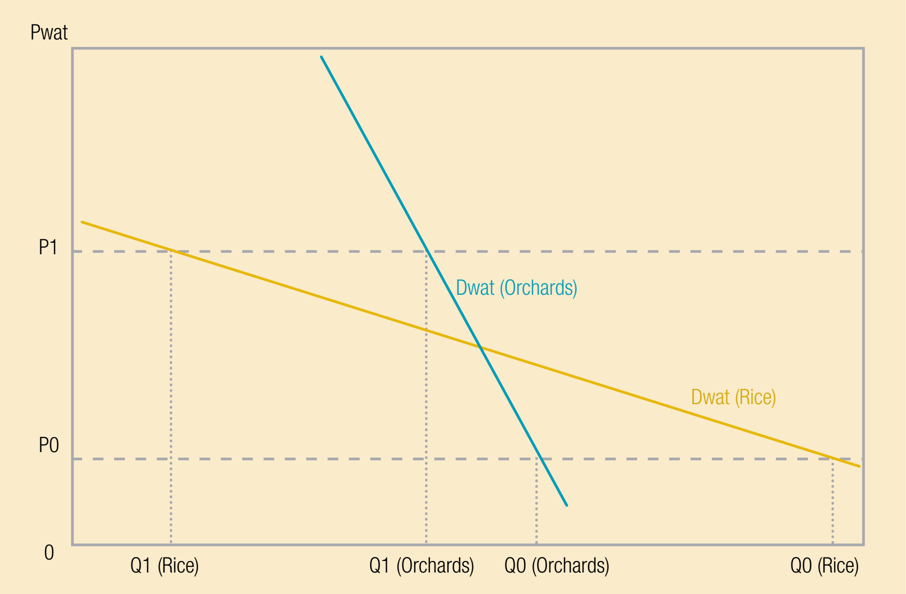
The first application of TERM performed well in explaining the negative income and employment impacts of drought (Horridge *et al*. 2005). Further enhancements were required for the model to become a useful tool for examining policy scenarios in the Murray-Darling Basin. In this version (known as TERM-H2O), these included:

- A split of farm sectors into irrigation and dry-land activities, with factor mobility between them;
- Water accounts for irrigation sectors and water-trading possibilities;
- A distinction between general purpose farm capital and specific capital;
- Catchment level representation of basin regions; and
- Dynamics.

One of the features of farming in the Murray-Darling Basin, at least in annual cropping and livestock production, is flexibility. Annual cropping can respond to changes in water prices or relative output prices. Dairy producers can move between irrigated pasture, dry-land pasture and hand-feeding, depending on seasonal conditions and water scarcity. The first enhancement reflects this flexibility.

Since farm sectors are split into irrigated and dry-land activities, it is important to include water accounts in TERM-H2O for irrigated sectors (the second enhancement). Water accounts show the volume and price of water of each user in the database. This physical quantity data sits alongside the usual input-output value data in the CGE model. The average product of water varies widely between irrigation uses, so that as water availability changes, water use will change between irrigation activities. We see this in Figure 1. Perennials such as fruit orchards require a minimum amount of water each year. Therefore, as the price of water rises (from P_0 to P_1 in Figure 1), demand by orchards falls only slightly, from $Q_{0\text{ (Orchards)}}$ to $Q_{1\text{ (Orchards)}}$. This contrasts with rice, which has a relatively elastic response to the water price, since water accounts for a large cost share in total production even at relatively moderate price levels. In addition, rice is an annual, so that irrigators can move out of rice production towards other crops as the

FIGURE 1
DEMAND FOR WATER: COMPARING ORCHARDS AND RICE



price of water rises. Therefore, in moving from $Q_{0(Rice)}$ to $Q_{1(Rice)}$ in Figure 1, rice moves from using more water than orchards to using less water than orchards in response to the same price hike.

In response to the shift in price shown in Figure 1, assuming that the cuts in allocations of rice and orchard irrigators are in equal proportions, rice irrigators would sell part of their allocation to orchard irrigators in the year of price P1. TERM-H2O allows water trading between regions of the southern Murray-Darling Basin, but is restricted to within-region trading in the northern part.

The third enhancement was to distinguish between capital that can move from one farm activity to another, and specific capital, such as an orchard or vineyard. This helps capture the difference in water price responsiveness of the orchard and rice irrigators, for example, as shown in Figure 1. That is, orchards have specific capital in the database but the rice sector has only mobile capital. Another enhancement was in a finer level of regional representation, at the statistical sub-division level. This enables us to represent catchment regions as in partial equilibrium models of irrigation water allocation.

Finally, TERM-H2O is a dynamic model. In dynamic modelling, we first run a forecast baseline, which is based on forecasts from various agencies of income growth, productivity growth and changes in commodity prices. Particularly in the case of water, for which the available volume and price vary more from year to year than for any other factor, there is considerable interaction between the baseline forecast and the policy scenario. For example, baseline water prices are much higher during years of drought than years of average rainfall. This in turn means that baseline conditions can have a marked impact on the welfare calculation in a scenario in which water is removed from production. Another example of a baseline condition that will affect impacts concerns commodity prices. If the baseline output price of one commodity starts to move down relative to other commodity prices, we would expect the output of that commodity to depress further the impact of buy-backs on the output of that commodity. In particular, we might think of farm commodities in the USA that compete with Australian farm outputs. In the case of two perennials, citrus and winegrapes, US competition will increase as the Australian dollar strengthens relative to the US dollar. If we assume that a high exchange rate continues for many years in the baseline, we would expect Australian citrus and winegrapes output to decline over time. This in turn would reduce the water requirements of perennials, which may be important in the policy scenario.

Analysing the impacts of water buy-backs in the southern Basin

Dixon *et al*. (2011) analysed the impacts of farmers selling water to the Commonwealth from the southern Basin. In the scenario, farmers eventually sell permanent entitlements equal to 23 per cent of pre-buy-back entitlements (Dixon *et al*. 2011, Figure 4). Using database weights, we can calculate a crude estimate of the impact on farm output. Irrigation accounts for 35 per cent of farm output in the southern Basin in the TERM-H2O database. If we assume that removing 23 per cent of water reduces irrigation output by 23 per cent, and there are no other effects, we would conclude that farm output in the Basin would fall by eight per cent (=-0.23 x 35 per cent). But this is wrong for three reasons.

First, irrigation water is not the sole source of water used in irrigation activities.[2] If we calculate the volume sold as a share of entitlements plus effective rainfall, the reduction in water supply shrinks to 18 per cent from 23 per cent. This reduces the estimated loss in farm output from eight per cent to 6.3 per cent. A second and more important problem with the crude estimate is the underlying assumption that farmers put non-water inputs used in irrigation activity to no other use when less water is available. This is contrary to the evidence. With a reduction in water availability, farmers switch their land and other farm factors from irrigated activities to dry-land activities. This is particularly evident for dairy. For example, as shown in Table 1, the reduction in water availability and consequent increase in the price of water in 2007–08 compared with 2005–06 led to a reduction in water used in dairying of 65 per cent, to 458GL from 1287GL. The corresponding reduction in dairy output was only 26 per cent. This reflected a shift of farm factors from irrigated dairy production to dry-land dairy production with increased reliance on hand-feeding. Water was so expensive in 2007–08 that dairy farmers profited from selling water and buying fodder. A third effect captured in TERM-H2O concerns substitution. By increasing the price of water, buy-backs led farmers to operate with higher usage of non-water factors in each unit of farm output. For example, with a higher price for water, vegetable farmers substitute capital (for example updated irrigation equipment) and labour (such as more rigorous checking for water leaks) for water.

Taking these three effects into account, TERM-H2O projects the outcome of a 23 per cent buy-back scheme as a 1.3 reduction in farm output, not an eight per cent reduction as in the initial crude estimate.[3]

TABLE 1
WATER USE IN THE MURRAY-DARLING BASIN BY ACTIVITY (GL)

	2005–06	2007–08
Livestock pasture/hay/silage	2571	997
– Dairy cattle water usage	1287	458
– Dairy output index	100	74

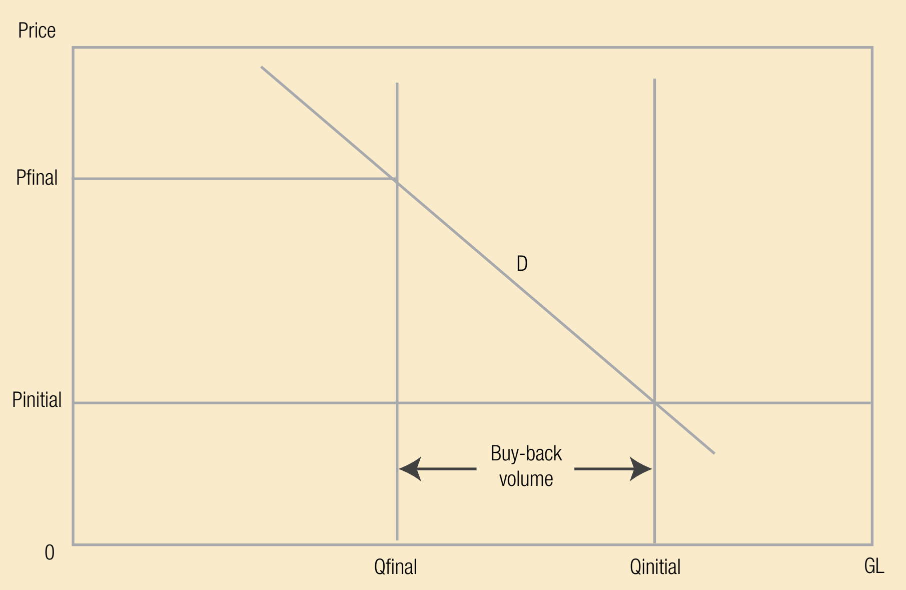
Source: ABS (2008), Table 3.20; ABS (2009), Table 2.9.

Yet this is not the end of the story. Farmers are being compensated at market prices for buy-back water. We can treat buy-back proceeds as an annuity that either adds to household spending or farm investment. This in turn has a positive marginal impact on regional employment.

How would farmers fare without compensation?

A starting point for overviewing the impact of buy-backs on basin regions is the idea that since farmers are fully compensated, any income losses will be offset by the annuity arising from buy-back proceeds. That is, farmers will be no worse off with buy-backs. Before exploring this point further, we examine the impact of buy-backs on the income of farmers in Figure 2. As irrigation water is sold to the Commonwealth, denoted by a fall in available irrigation water from $Q_{initial}$ to Q_{final}, the price of water rises. In isolation, this is a windfall gain for farmers. For farmers who do not sell, the asset value of their water title will increase, denoted in Figure 2 by an upward movement in price from $P_{initial}$ to P_{final}. Does this mean that these farmers are better off?

FIGURE 2
MARKET FOR IRRIGATION WATER



It can be predicted that while the value of water assets will rise with buy-backs, this will be offset by a decline in rentals on other factors. That is, with less water available per unit of other factors, the marginal product of other factors will decline. In the case of various forms of capital, stocks will adjust downwards over time in response to falling initial rentals, thereby gradually bringing rentals back towards base case forecast levels (i.e. levels they would have reached in the absence of buy-back). Since farm land is fixed in aggregate, all the adjustment in land will be via rentals. Rentals on irrigable land will fall more than for dry land, but the latter will also fall. This is because irrigable land moves into dry land production as irrigation water availability falls, increasing the supply of dry land and thereby lowering its rentals.

One argument that has persisted in the environmental water debate is that the international competitiveness of farm output in the Basin will be reduced as a consequence of buy-backs. Our modelling predicts that increases in the price of water would be largely offset by reductions in the rental price of irrigable land. With these offsetting changes in factor prices, the international competitiveness of Basin farming would be barely affected.

There is considerable variation among farmers in the Basin in both the mix of outputs produced and the holdings of various assets, including water and capital. Thus buy-backs will have strongly differing effects across farm enterprises.

Thinking first of individual farmers, it can be envisaged that a rice farmer who owns large volumes of water entitlements is likely to gain from the buy-back process, as the windfall gain in the asset value of water is likely to exceed losses in the value of other factors owned by the farmer. This contrasts with a grape grower, who is less able to sell off water, as it is required to maintain volumes of water in the vineyard each year. A grape grower may own valuable capital (such as the vineyard) but may not own a large volume of water. The Lower Murrumbidgee regions contains both rice growers, who stand to gain from the buy-back process, and grape growers, who may not be in the position to sell off water. This does not make the grape growers worse off. Rather, it means that outside particular circumstances such as a looming retirement (either of the ageing farmer or ageing vineyard), or the opportunity to cash in on realised water savings over time, there may be little motivation for grape growers to sell water.

The Lower Murrumbidgee region may experience income gains due to the buy-back process, even without including compensation payments. This is because the gains in the asset value of water holdings exceed losses from other factors. In TERM-H2O modelling of buy-back scenarios, Lower Murrumbidgee ends up being one of the largest net exporters of water to other regions plus the Commonwealth. Net exporters of water benefit from the price hike in water. In the southern Basin overall, based on the assumption that all buy-back proceeds stay within the Basin, aggregate household consumption increases slightly (0.34 per cent) relative to forecast as a consequence of buy-backs. We expect annuities to compensate farmers for a decline in farm output. That aggregate consumption rises above base case forecast levels reflects small terms-of-trade gains, as the demand curves faced by farmers for their output are not infinitely elastic. In practice, since some farmers may leave the Basin, we might expect the impact of buy-backs on aggregate consumption to be close to zero.

The distinction between drought impacts and buy-back impacts

Lobbyists have asserted, despite the actions of farmers in voluntarily selling buy-back water to the Commonwealth, that buy-backs will be like a permanent drought. In response to this assertion, we present the direct impacts of drought and fully implemented buy-backs respectively on dry-land productivity, rainfall and irrigation water availability.

Table 2 shows the direct impacts of drought as reported in Wittwer and Griffith (2011). A glance at the table shows that drought impacts are many-fold greater than direct buy-back impacts. Buy-backs do not reduce dry-land productivity, nor do they not stop the rain. Moreover, they are voluntary and fully compensated. In comparing columns (1) and (2) in Table 2, we see that drought is unambiguously worse than buy-backs.

TABLE 2
ESTIMATES OF DIRECT IMPACTS OF DROUGHT AND BUY-BACKS ON SOUTHERN MURRAY-DARLING BASIN FARMING

	Drought 2007–08 relative to no-drought base case (1)	Fully implemented buy-backs relative to base case (2)
Dry-land productivity[a]	–49%	0
Irrigation land: rain	–56%	0
Irrigation land: diverted water	–56%	–23%
Compensation	No	Full
Process	Involuntary	Voluntary

Source: Wittwer and Griffith (2011), Table 2.

[a] Change in dry-land productivity relative to a non-drought year.

It is not surprising therefore that the output and employment impacts of drought are many-fold greater than those for buy-backs. For example, in the buy-back scenario reported by Dixon *et al*. (2011), jobs in the southern Basin fall 500 below forecast by 2018. In the drought scenario, 6000 jobs were lost relative to forecast during the worst of the drought, and due to the lost years of farm investment during drought, jobs remain 1500 below forecast a decade after full recovery from drought.

Wittwer and Griffith (2011) used database weights (i.e., the respective shares of dry-land agriculture and irrigated agriculture in total income in each Basin region), multiplied by the drought-related shocks shown in column (1) of Table 2, to estimate the direct drought impacts within the southern Murray-Darling Basin. Their database estimates were a GDP loss of 6.7 per cent due to drought, with a 3.3 per cent loss contributed by dry-land farming and a 3.4 per cent loss contributed by irrigation sectors in 2007–08.[4] Water trading and other forms of farm factor mobility did much to reduce direct losses: the modelled loss in irrigation activity made a negative contribution of only 1.9 per cent to regional GDP instead of 3.4 per cent based on the initial calculation. In turn, due to movement of factors towards dry-land production, the GDP loss arising from dry-land production was only 2.7 per cent instead of 3.3 per cent.

Commentators often assert that regional multipliers result in a many-fold increase in direct losses. The version of TERM-H2O included a theory of excess capacity in down-stream processing sectors, thereby allowing a partial closedown in such sectors in response to a worsening scarcity of farm outputs. Even with this theoretical enhancement to the model, output losses in non-farm sectors contributed only a further 1.1 per cent to the overall GDP loss, which totalled 5.7 per cent (=–1.9 per cent [irrigation] + –2.7 per cent [dry-land] + –1.1 per cent [non-farm sectors]). Nevertheless, this income loss was large enough to reduce employment in the southern Basin by 6000 jobs relative to the base case forecast. Without water trading, the employment outcome would have been much worse.

Checking modelled outcomes against observed data

According to TERM-H2O results, the price of irrigation water is highly sensitive to drought conditions and moderately sensitive to the volume of irrigation water allocated each year. The model also predicts that a strengthening of farm output prices will lead to a hike in the rental of farm factors, including the water price. We are able to check whether these predictions align with observed data.

TABLE 3
DATA USED IN IRRIGATION WATER PRICE REGRESSION

	$/ML Pwat,t (1)	GL (2)	Drought index (3)	P (output) (4)
2001–02	35.00	7477	0	102.7
2002–03	364.02	4856	1.0	101.5
2003–04	66.63	5551	0	97.2
2004–05	60.03	5622	0	96.0
2005–06	57.25	6585	0	100.0
2006–07	440.59	3639	0.75	115.4
2007–08	562.16	2682	0.4	129.8
2008–09	338.57	2703	0.5	114.9
2009–10	153.52	4237	0	111.4

Sources: (1) Watermove; (2) NWC data scaled to ABS and authors' estimates; (3) Bureau of Meteorology; (4) ABARES Commodity Statistics 2010.

We do so by estimating a regression of observed prices against explanatory variables, using data shown in Table 3 for the southern Basin. Column (1) shows the price of irrigation water ($P_{wat,t}$),[5] column (2) the allocation of irrigation water ($V_{alloc,t}$) in the southern Basin and column (3) a drought index Dt, based on observed rainfall deficits for the nine month period March to November (i.e. the index for 2007-08 is based on the rainfall deficit for March to November 2007). Column (4) shows a price index of farm outputs ($P_{farm,t}$), based on ABARES indexes, modified to reflect production weights in the Basin. We use columns (2) to (4) to explain variations in the price of water:

$$\log(P_{wat,t}) \underset{\text{(t-stat)}}{=} \underset{(2.97)}{1.629} - \underset{(-4.41)}{0.129}{}^*V_{alloc,t}/1000 + \underset{(7.04)}{0.568}{}^*D_t + \underset{(2.354)}{0.009}{}^*P_{farm,t} \quad R^2=0.98 \quad (1)$$

In (1), each of the coefficients on the explanatory variables has the expected sign. As water allocations increase, the price of water falls. The presence of drought imposes dramatic upward pressure on the water price. The coefficient on farm output prices is positive as expected.

The alignment so far of TERM-H2O results with actual data is encouraging. As part of further model calibration, our next step will be to run TERM-H2O ascribing dry-land productivity shocks and water availability shocks year-by-year in the southern Basin, using the data in columns (2) to (4) of Table 3 as the basis of these shocks. The water prices and changes in the composition of farm output in the southern Basin generated by this exercise will enable us to fine tune TERM-H2O, thereby moving from a qualitative to quantitative checking of the model's performance.

Concluding remarks

Models are a good discipline when it comes to checking exaggerated claims. Without models you can get away with saying anything. This has been evident during the buy-back debate, as it was during the tariff debate of previous decades. In the earlier tariff debate, tariff cuts became the scapegoat for the impacts of a recession. Had Australia persisted with tariff protection, the nation would have been left behind, without, for example, access to cheaper and better cars. Concerning water, as a consequence of the prolonged drought of the previous decade, buy-backs have been blamed for drought-imposed hardship within the Basin. No modelling on evidence-based assumptions has found significant job losses in the Basin due to buy-backs. TERM-H2O has supported arguments, for example, that buy-back revenues are a useful source of funds for farmers during hard times. But modelling is only useful if the results can be explained and justified in terms of reliable data and realistic economic mechanisms.

One of the benefits in creating TERM-H2O has been to learn more about available data. Notably, changes in water use year by year give us insights into farm factor mobility in the Basin. It is through the use of actual data that we have modified the theory of TERM-H2O so as to reflect producer behaviour better. Growers of annual crops are flexible: if the price of water rises, some producers will sell their water or divert it to other activities. In the case of perennials, water trading allows producers to buy in water. The theory of TERM-H2O distinguishes the relative inflexibility of perennial producers through the use of specific capital.

Some commentators have not been satisfied with modelling results which show that buy-backs have relatively little impact on overall Basin farm output. They turn to the notion of regional multipliers. Again, the evidence points to such multipliers being relatively modest. The same commentators argue, quite correctly, that house prices are likely to be affected by buy-backs. However, they do not see the link between regional multipliers, a quantitative adjustment, and price impacts, which diminish these quantitative adjustments and consequent multipliers. Moreover, in some regions within the Basin, the impact of buy-backs on house prices could be positive.

Endnotes

1 TERM was also used to explore bio-security issues (see Wittwer *et al.* 2005).

2 Rice uses 12 to 14ML of irrigation water per hectare so the contribution of rainfall is small. Dairy production uses between three and five ML per hectare and grapes around five ML per hectare. For these activities, rainfall makes a significant contribution in an average year (given that two ML per hectare is equivalent to 200mm of effective rainfall).

3 Another way of thinking about the -1.3 per cent result is to work out the reduction in the area under the demand curve for water implied by the buy-back scheme; see Dixon *et al.* (2011), Figure 4.

4 The database weights in a drought scenario differ markedly from a normal year. In particular, the contribution of water to regional income increases due to relatively inelastic demand for water by irrigators. The respective shares of irrigation and dry-land activity in southern basin GDP are 6.1 per cent and 6.7 per cent. For irrigation, -3.4 per cent = -56 per cent x 6.1 per cent and for dry-land, -3.3 per cent = -49 per cent x 6.7per cent.

5 This is based on data from the Goulburn basin only. Anecdotal evidence indicates a close correspondence between prices across regions in the southern basin where inter-regional trading is possible.

References

ABARES (Australian Bureau of Agricultural and Resource Economics and Science) (2010). *Australian Commodity Statistics 2010.* ABARES, Canberra.

ABS (Australian Bureau of Statistics) (2008). *Water and the Murray-Darling Basin: A Statistical Profile, 2000–01 to 2005–06.* Catalogue 4610.0.55.007.

ABS (Australian Bureau of Statistics) (2009). *Value of Agricultural Commodities Produced, 2007–08.* Catalogue 7503.0.

Dixon, P., Parmenter, B., Ryland, G. and Sutton, J. (1977). *ORANI, A General Equilibrium Model of the Australian Economy: Current Specification and Illustrations of Use for Policy Analysis, First Progress Report of the IMPACT Project*, Vol. 2, Australian Government Publishing Service, Canberra.

Dixon, P., Parmenter, B. and Sutton, J. (1978). Some Causes of Structural Maladjustment in the Australian Economy, *Economic Papers*, 57(1):10-26.

Dixon, P., Rimmer, M. and Wittwer, G. (2011). Saving the Southern Murray-Darling Basin: the Economic Effects of a Buy-back of Irrigation Water, *Economic Record*, 87(276): 153-168.

Powell, A. and Gruen, F. (1968). The Constant Elasticity of Transformation Frontier and Linear Supply System, *Australian Journal of Agricultural Economics*, 9:315-328.

Guise, J. and Flinn, J. (1970). The allocation and pricing of water in a river basin, *American Journal of Agricultural Economics*, 52(3): 411–21.

Hall, N., Poulter, D. and Curtotti, R. (1993). *ABARE Model of Irrigation Farming in the Southern Murray–Darling Basin*, Canberra.

Hall, N. (2001). Linear and quadratic models of the southern Murray-Darling basin, *Environment International*, 27: 219-223.

Horridge, M, Madden, J. and Wittwer, G. (2005). “Using a highly disaggregated multi-regional single-country model to analyse the impacts of the 2002-03 drought on Australia”, *Journal of Policy Modelling*, 27(3):285-308.

Wittwer, G. and Griffith, M. (2011). “Modelling drought and recovery in the southern Murray-Darling Basin”, *Australian Journal of Agricultural and Resource Economics*, 55(3): 342-359.

2.4

Critiquing the Water Act (2007)

Professor John Briscoe

John Briscoe is the Professor of the Practice of Environmental Health, HSPH Gordon McKay Professor of the Practice of Environmental Engineering, SEAS Department of Environmental Health at Harvard University. Briscoe has served on the Water Science and Technology Board of the National Academy of Sciences and was a founding member of the major global water partnerships, including the World Water Council, the Global Water Partnership, and the World Commission on Dams. He currently serves on the Global Agenda Council of the World Economic Forum; is a member of the Council of Distinguished Water Professionals of the International Water Association; and will be the first Natural Resource Fellow of the Council on Foreign Relations. He has published extensively in economic, finance, environmental, health and engineering journals. Recently he authored Water Sector Strategy, India's Water Economy: Bracing for a Turbulent Future, and Pakistan's Water Economy: Running Dry.

Below is Professor John Briscoe's submission to the Senate Inquiry into the Provisions of the *Water Act 2007*, made earlier this year.

This submission provides analysis and insight into issues surrounding the *Water Act 2007*.

Why I make this submission:

For many years I was the Senior Water Advisor at the World Bank. In that capacity I visited Australia in 1996 and became interested in the emerging Australian experience with water management, especially in the Murray-Darling Basin. Over the intervening period I have followed developments closely, have visited Australia several times, and interacted with many Australian water professionals, in Australia and overseas.

I have followed developments relating to the *Water Act 2007* very closely. So I am a very interested outsider, who surely has many of the details wrong. If there is a value to my observations it comes from the fact that I have been privileged to see many reform processes in many countries, and have developed a nose for sniffing out the story.

Why do I care?

I care for two reasons. First, because I have many Australian friends and want what is good for them and your wonderful country. Second, because what happens in Australia matters hugely to the rest of the world.

Perceptions and facts

The Harvard historian David Blackbourn writes in his great book "The Conquest of Nature" of the dialectic of water challenges and responses. He describes how all water solutions are provisional, how each succeeding generation takes for granted the achievements of their fathers and forefathers, and how contemporaries always wonder how those who went before could have been so short-sighted and stupid.

There is no better illustration of this difference of perception than the situation of water management in Australia. Over the last 10 years Australia did something which no other country could conceivably have managed – in a large irrigated agricultural economy (the Murray-Darling Basin) a 70 per cent reduction in water availability had very little aggregate economic impact. Before the buts and the buts and the buts, this extraordinary achievement is, in my view, the single most important water fact of the 21st century, because it shows that it is possible (with ingenuity and investment) to adapt to rapid climate change and associated water scarcity.

What has been very striking to me on my visits to Australia, is how dramatically this perspective is different from the political and public perception, which is largely that "we have done a terrible job". Again and again I had to confront this "truism" in discussions in Australia. After all these discussions I concluded that there was a fatal misdiagnosis of "the problem". If one can conceive of a simple (and simplistic) equation in which:

Outcome = f(Exogenous Change, Institutional Response)

Ninety per cent of the political and public blame was placed on "institutional response". To cite just two (important) examples: The Honorable Malcolm Turnbull, author of the *Water Act 2007* claims that "our water management has been extraordinarily ill informed in years past"[1] and the MDBA's ill-fated Guide to the Basin Plan asserts that "over the past few decades… the focus has swung to looking at economics …and the role of the environment has been overlooked."

I found (and find) this diagnosis (a) extraordinarily widespread and (b) extraordinarily erroneous. What is obvious to me is that the overwhelming factor behind the dismal situation in the MD Basin was the dramatic reduction in rainfall and even larger reduction in river flows. It is equally clear to me that the Institutional Response (of the Murray-Darling Basin Commission, the Basin states, and farmers) was extraordinarily innovative and – within the bounds set by nature – effective. Not only for the economy but, as shown by the National Water Commission, for ameliorating the environmental damage of the terrible drought.

The politics of the *Water Act 2007*

In the course of my visits and in my reading, I have come to see opportunistic politics as a major factor in the development of the *Water Act of 2007* and the current impasse. Of course I know much less about this than any of the esteemed members of your committee, but because this perception underlies my analysis, let me summarise this understanding briefly.

The environmental vote was important in the election of 2007. After seven years of drought environmental conditions were poor, not least in the Murray-Darling Basin. The electoral arithmetic of Australia is such that most of the electorate live in the coastal cities. Most city dwellers have both little knowledge of the land and water environment of the world's driest continent, and a paternalistic and dim view of farmers and agriculture. He who could capture the environmental vote would strongly improve his chances in the election. Most environmental minded voters were Labor. If the Liberal Party were to woo some away it had to do something dramatic. The *Water Act of 2007* was one of the dramatic efforts.

The Act was hatched in a very short time, with very little consultation with any of Australia's great water professionals or its innovative farmers. (By the way, in the eyes of this observer at least, the smart city dwellers had been far less innovative vis-a-vis water than their dim-witted country cousins).

In the eyes of the architects of the Water Act, it was necessary to take power away from those who had made a mess of things (the States and farmers) and put it in the hands of the enlightened in Canberra. A major challenge was how to deal with the matter of the Constitution, which had given the states powers over water management, and which underpinned the inter-state consensual processes which had been the institutional bedrock of the MDB Commission. The primary author of the 2007 Act, the Honorable Malcolm Turnbull, is quite explicit about this:

> *"In the 1890s our founding fathers missed a big opportunity when they drafted our Constitution in not putting the management of interstate waters under federal jurisdiction. In 2007 we rectified that mistake with the Water Act."*[2]

Because constitutional amendments are not simple, and definitely cannot be done over a weekend before an election, the authors of the *Water Act 2007* had to find legal cover for usurping state powers. An alert and enterprising environmental lawyer found the fig-leaf, which was the Ramsar Convention, which the Commonwealth Government had signed, committing itself to protecting wetlands which are critical for migratory birds.

To avoid a constitutional crisis, the Commonwealth had to build the Water Act around this fig-leaf. So the Act became an environmental act, which was all it really could be, since it was in the name of the commonwealth's obligations to an obscure international environmental convention that it was taking powers from the states. And so the fundamentals of the Act were born – an environmental act in which Canberra would tell states and communities and farmers what to do.

The substance of the Act 1: Federal and State responsibilities

The framers of the *Water Act 2007* had not read their Churchill. Democracy is, indeed, the worst form of government, except for all those other forms that have been tried from time to time. Yes, the consultative, participatory model of the MDB Commission did have its flaws, because consensus was difficult and often slow. But it is now obvious that the commonwealth-bureaucrats-and-scientists-know-better-than-states-and-communities-and-farmers-do model has, once again, proved to be much worse and even much slower.

The highly secretive "we will run the numbers and the science behind closed doors and then tell you the result" MDB Basin Plan process was not, in my view, an aberration which can be pinned entirely on the leadership of the MDBA Board and management, but intrinsic to the institutional power concentration that is fundamental to the *Water Act 2007*.

The substance of the Act 2: Balance between the environment and human uses

There are claims that the *Water Act 2007* was not an environmental act but one that mandated balance between the environment and human uses. Digging deep into the turgid 236 pages of the Water Act for confirmatory phrases, the Honorable Malcolm Turnbull claims, now, that the Act was all about balance.

To a disinterested reader this is poppycock. The National Productivity Commission's interpretation of the *Water Act 2007* is that "it requires the Murray-Darling Basin Authority to determine environmental water needs based on scientific information, but precludes consideration of economic and social costs in deciding the extent to which these needs should be met". Similarly, the High-Level Review Panel for the Murray-Darling Basin Plan (of which I was a member) stated that: "The driving value of the Act is that a triple-bottom-line approach (environment, economic, social) is replaced by one in which environment becomes the overriding objective, with the social and economic spheres required to 'do the best they can' with whatever is left once environmental needs are addressed."

This interpretation was also very clearly (and reasonably, in my view) the interpretation taken by the Board and Management of the MDBA in developing the Guide to the Basin Plan. This was transmitted unambiguously to the members of the High-Level Review Panel for the Murray-Darling Basin Plan. (As an aside, I have wondered whether this logic is derived from (a) a belief that this is the right thing to do or b) an understanding that this was the only constitutionally-defensible approach given that state powers were being abrogated in the name of meeting the Commonwealth's Ramsar obligations).

The substance of the Act 3: The roles of science and politics

The Act is based on an extraordinary logic, namely that science will determine what the environment needs and that the task for government (including the MDBA) is then just to "do what science tells it to do".

In the deliberations of the High Level Review Panel, we pointed out that, taken literally, this would mean that 100 per cent of the flows of the Basin would have to go to the environment, because the native environment had arisen before man started developing the Basin. The absurdity of this point was to drive home the reality – that the Murray is one of the most heavily plumbed river basins in the world, and that the real choice was to decide which set of managed (not natural) environmental (and other) outcomes were most desirable.

The job of science in such an instance is to map out options, indicating clearly the enormous uncertainties that underlie any scenario linking water and environmental outcomes. In its final report, the High-Level Review Panel stated:

Far from being "value neutral", a set of value judgements are fundamental to the aspirations of all Acts, including the Water Act. It is a fundamental tenet of good governance that the scientists produce facts and the government decides on values and makes choices. We are concerned that scientists in the MDBA, who are working to develop "the facts", may feel that they are expected to trim those so that "the sustainable diversion limit" will be one that is politically acceptable. We strongly believe that this is not only inconsistent with the basic tenets of good governance, but that it is not consistent with the letter of the Act. We equally strongly believe that government needs to make the necessary tradeoffs and value judgements, and needs to be explicit about these, assume responsibility and make the rationale behind these judgements transparent to the public.

The process of formulating the Basin Plan

In all of my years of public service, often in very sensitive environments, I had never been subject to such an elaborate "confidentiality" process as that embodied in the preparation of the Guide to the Basin Plan. The logical interpretation was that the spirit of the *Water Act 2007* (environment first, science will tell, the Commonwealth Government will decide, the people will obey) required such a process. The High-Level Panel told the Chair and CEO of the MDBA that they understood that this was what the Act dictated but that it was the role of senior civil servants to explain that this would not, and could not, work. We were given to believe that there was no appetite for such a message at higher levels in the government in Canberra.

A corollary of this flawed process (and the ideas incorporated into the Act) was that there was very little recourse in the process to the immense, world-leading knowledge of water management that had developed in Australia during the last 20 years. Time and again I heard from professionals, community leaders, farmers and state politicians who had made Australia the widely-acknowledged world leaders in arid zone water management that they were excluded from the process.

Investments in water-saving infrastructure

A major complementary program for implementing the Water Act is the massive water infrastructure program. Indeed, the Honorable Malcolm Turnbull believes that "the real problem is (not the Water Act) but that the Labor Government has failed to invest in the water-saving infrastructure that was the centerpiece of the Howard Government's National Plan for Water Security".

In my visits to Australia I heard a chorus of opposition from economists about what they considered to be a program which paid a massive amount for every drop of water saved.

In my perception this program has been badly thought through. The economists are largely right – this is a very expensive way to save water and that many of the investments will be made in areas that will, sooner or later, go out of production.

But they also note that this is a "bribe" to farmers for the implicit breach of contract by the Federal Government. If this is the case, then the question should be approached differently.

For example, it seems highly probable that world food prices will continue to increase sharply in coming decades. Australia has developed great expertise in sophisticated and high-valued agriculture. This national asset is, it would seem to me, to be something that Australia would want to preserve and hone. If there were a clear vision for "the future of Australian agriculture in a changing world", and a clear definition of the areas where Australia has a comparative advantage, then investing in modernisation of the Australian agricultural economy might be a high-return use of public funds. This is quite different from a fund for "saving water" – it would be an investment in productivity and an investment in a strategic Australian capability. In my view a plan for water cannot be done in isolation from this complementary bit of strategic analysis.

My conclusion

Let me first repeat what I said at the beginning of this note. I am an outsider. I am flattered to be asked to share my views with your Commission of Inquiry. I am fully aware that there are likely to be many details that I have not got right. But I have worked on water policy issues in dozens of countries and have developed an instinct for what is central. I may have some notes wrong, but believe strongly that I am playing from the right hymn-book.

My conclusion is stark. I believe that the Water Act of 2007 was founded on a political deception and that that original sin is responsible for most of the detour on which Australian water management now finds itself. I am well aware that unpredictability is an enemy and that there are large environmental, social and economic costs of uncertainty. But I also believe that Australia cannot find its way in water management if this Act is the guide. I would urge the Government to start again, to re-define principles, to engage all who have a stake in this vital issue, and to produce, as rapidly as possible, a new Act which can serve Australia for generations to come. And which can put Australia back in a world leadership position in modern water management.

Endnotes

1 http://www.malcolmturnbull.com.au/blogs/the-water-act-and-the-basin-plan

2 Malcolm Turnbull, *The Water Act and the Basin Plan,* December 9, 2010, http://www.malcolmturnbull.com.au/blogs/the-water-act-and-the-basinplan/.

2.5

Managing the Lower Lakes

Dominic Skinner

Dominic Skinner wrote his doctoral thesis on the effects of drought and water level decline in the Lower Lakes. He is a 2011 fellow of the Peter Cullen Fellowship Trust and currently works as a Research Fellow at the University of Melbourne.

The Coorong, Lower Lakes and Murray Mouth region

The sixth and final “icon site” under The Living Murray program lies at the end of the River Murray in the Murray-Darling Basin. The River Murray fills two large, shallow lakes (Alexandrina and Albert) that are collectively referred to as the Lower Lakes and cover 820 square kilometres. Water flows out of Lake Alexandrina into the Coorong, a lagoon running parallel to the coast for over 100 kilometres. But the Murray Mouth, where water flows out to sea, is at the northern end of the Coorong, near its connection to Lake Alexandrina. This makes the Coorong a reverse estuary, getting saltier further from the river mouth, from brackish to hyper-marine at its southern most point.

Historically, water around the Murray Mouth was brackish, but freshened completely when the River Murray flooded. The Lower Lakes were predominantly fresh, with flows from the River Murray keeping estuarine water downstream.

The water between the River Murray, as it enters Lake Alexandrina, and the Murray Mouth, where it flows out to sea, is classified as a wetland of international significance. Because it encompasses the Coorong, the Lower Lakes and the Murray Mouth, the region is referred to as the CLLMM. This whole area is protected under the Ramsar convention and by other international agreements for migratory birds.

Having wetland habitats ranging from freshwater to hyper-marine provides an abundance and diversity of life throughout the area. The CLLMM provides a unique refuge for about 20 species of migratory birds that make the 12,000 kilometre journey to and from the Arctic Circle each year. Another 65 species of non-migratory birds are found in the CLLMM region throughout the year. The wide-range of salinities also provides habitat for almost 60 species of fish, half of which migrate between freshwater and marine water (or vice-versa) for different stages of their life cycles.[1]

The salinity gradient is essential for the maintenance of the ecological characteristics in the CLLMM. The gradient is reliant on tidal exchange through the Murray Mouth to provide connectivity between the ocean and the Coorong. Flows from the River Murray are needed to scour sand that is deposited in the Murray Mouth by ocean currents to keep the mouth open.

Drought in the early 20th century, combined with an emerging irrigation industry and the construction of weirs, reduced the flow available at the end of the River Murray. This affected the salinity gradient in the CLLMM, with saltwater intruding further upstream than was previously normal.[2]

In response, a series of five barrages were constructed to separate the freshwater in Lake Alexandrina from the estuarine water in the Coorong at the Murray Mouth. The barrages reduced the connectivity between the Coorong and the Lower Lakes, although fish ladders and boat locks have allowed some migration of fish moving up or downstream.

The barrages provided an artificial replacement to flow for separating freshwater and saltwater, but they removed the estuary downstream of the Lower Lakes where these waters historically mixed. Water resource development upstream continued and during drought in the early 1980s, flow over the barrages was insufficient to keep sand out of the Murray Mouth, which closed over completely. In 1981, dredges were brought in to re-open the Murray Mouth to maintain connectivity between the Coorong and the ocean. Dredges were again required to keep the mouth open between 2001 and 2010.

This chapter outlines the environmental objectives required to maintain the ecological character of the CLLMM region. These environmental objectives are primarily focused on salinity levels, which in turn, are dependent on the timing and volume of inflows from the River Murray. Following this, the effect of extended drought is used as a case study of the impacts to the CLLMM region when inflow requirements are not met. This section highlights the impact of the “Big Dry” (the drought between 1996–2009) on the physical changes to the system and how these affected the aquatic ecology. The chapter concludes with the challenges of managing such an ecologically diverse system in the context of returning the Murray-Darling Basin to sustainable levels of water diversion.

Key management issues for the CLLMM

Regulation and water diversions throughout the Murray-Darling Basin have changed the seasonal timing of flow and the frequency of floods. These effects have been especially strong in reducing the amount of small and medium floods through the system. Smaller, more frequent flood pulses are critical for flushing salt, derived from the Australian landscape and rising groundwater, through the rivers in the Basin. Salt and other contaminants accumulate along a stretch of river, so by the time water reaches the CLLMM, salt concentrations have become amplified and the salt load entering the Lower Lakes is increased. Unless this salt is periodically removed, it accumulates in the Lower Lakes and in the Coorong. Reducing the small and medium flood pulses has decreased the frequency with which salt is flushed out of the CLLMM. As a result, linking flow and salinity targets with key ecological indicators provides a method to predict the influence of different water allocations on the ecological character of the CLLMM.

Aquatic plants in the Coorong provide a food source for birds and habitat for smaller fish and invertebrates. There are two dominant species of plant that sustain a majority of the higher organisms in the food-web of the Coorong. They are *Ruppia tuberosa* and *Ruppia megacarpa*. Both have their coverage defined by salinity. *R. tuberosa* tolerates higher salinities than *R. megacarpa* and was historically found further from the Murray Mouth where salinity is higher. *R. megacarpa* overlapped the range of *R. tuberosa* but extended towards the Murray Mouth, so that together, the Coorong was well covered by plants.

This provided extensive habitat and a food source for higher organisms, leading to the seemingly endless flocks of water birds containing over 160,000 individuals that have made the Coorong a truly iconic wetland.

Over several decades, as water diversions and river regulation increased in the late 20th century, the salinity in the Coorong increased as the amount of flow to the Coorong decreased. The range of *R. tuberosa* began to constrict as the salinity increased and *R. megacarpa* was lost from the system. Because of their position at the base of the food chain, both types of *Ruppia* can be used as key indicator species for the health of the Coorong. And, because their salinity tolerance is known, the link between flow volumes and salinity can be used to develop water requirements for the Coorong to ensure its ecological character is sustained.[3]

For the Lower Lakes, diversity of aquatic plants is much higher. A simple salinity tolerance metric requires the comparison of multiple species of plant, fish and invertebrate to establish thresholds that lead to ecological deterioration.

Most vegetation in the Lower Lakes has a salinity tolerance of about 5000 EC (freshwater has a salinity < 700 EC and seawater is about 50,000 EC). But the Yarra Pygmy Perch (*Nannoperca obscura*), which is a small-bodied endangered fish found in the Lower Lakes, has a salinity tolerance of only 1000 EC. It can survive at slightly higher salinities for short periods of time, but because of its size, the Yarra Pygmy Perch has a limited mobility and has difficulty migrating away from rising salinity.[4]

The Yarra Pygmy Perch acts as another key indicator species for the CLLMM. Being endangered, its conservation is legislated for under Australia's Environment Protection and Biodiversity Conservation Act and the Ramsar Convention on Wetlands of International Importance.

To maintain habitat suitable for the Yarra Pygmy Perch in the Lower Lakes, a long-term annual average salinity target of 700 EC is required, with a salinity target below 1000 EC in 95 per cent of the years and a maximum salinity threshold of 1500 EC.

To achieve a salinity target of 700 EC, the flow over the barrages needs to average 4000GL per year over a three-year period.[5] Lower flows will meet the higher salinity levels, with a three-year rolling average of 2000GL per year maintaining a salinity of 1000 EC and a flow of 1000GL per year required to keep salinity below 1500 EC. In addition to these flows over the barrages, the CLLMM needs between 700 – 800GL per year to offset evaporation from the surface of the Lower Lakes.

Meeting these flow requirements for the Yarra Pygmy Perch in the Lower Lakes provides enough water to the Coorong to meet the freshwater flow requirements of both *Ruppia* species.

However, for the flow requirements of both the Coorong and Lower Lakes, considerable flexibility is needed in the timing of environmental water delivery to the site to ensure that the region avoids the extremely low flow scenarios that occurred during the "Big Dry". The changes to the CLLMM during this extended drought are discussed below.

Impacts of the "Big Dry" on the CLLMM

The drought between 1996 and 2009 had a significant and lasting impact on the CLLMM region, which essentially collapsed from lack of flows.

Changes began in the Coorong, and then shifted to the Murray Mouth before moving upstream into the Lower Lakes and eventually the lower River Murray as the drought progressed.

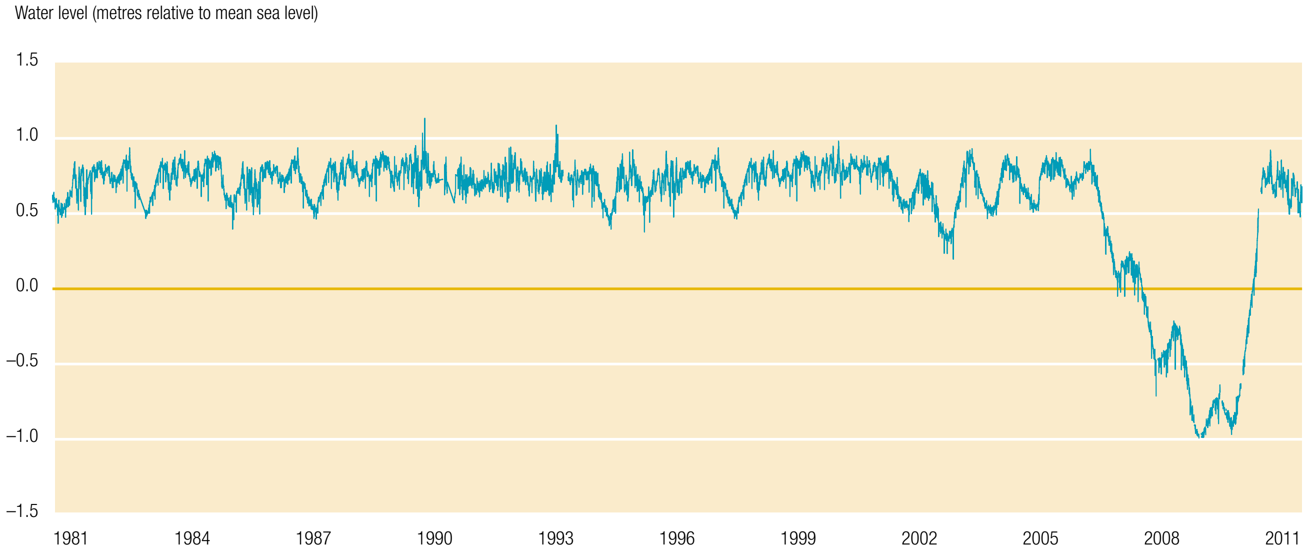
It was evidently a severe decline in basin-wide rainfall that caused changes to the CLLMM. However, the lack of any environmental water entitlement severely reduced the options available to managers of the region. Without any guaranteed entitlement, environmental flows are disproportionately lower and consequently the environment bears the largest share of water reductions.

Drought-induced changes were dominated by declining flow, which led to numerous secondary changes including rising salinity and lower water levels. In the Coorong, which was stressed before the drought, low flows over the barrages ceased completely in 2001.

As a result, increasing salinity confined *R. tuberosa* to an area that decreased in size and moved closer to the Murray Mouth. Beyond this area of *R. tuberosa*, salt concentrations continued to increase in the Coorong, until water furthest from the Murray

FIGURE 1

WATER LEVEL IN LAKE ALEXANDRINA BETWEEN 1982 AND 2011. WATER LEVEL IS SHOWN RELATIVE TO MEAN SEA LEVEL, WHERE WATER LEVELS BELOW ZERO ARE BELOW SEA LEVEL



Source: South Australian Department of Water

Mouth became hyper-saline. As the drought progressed, this intolerably high salinity, that had over five times more salt than seawater, expanded towards the Murray Mouth, until half of the Coorong supported very little life.

The constricted stretch of *R. tuberosa* and loss of *R. megacarpa* reduced the food available to support the abundance of birds that feed on aquatic plants. Grey Teal numbers declined from almost 60,000 birds in 1985 to less than 3000 individuals. Similarly, declines in the Curlew Sandpiper, a migratory bird that uses the Coorong as a summer feeding ground prior to its return journey to the Arctic tundra, were observed. In 1985, over 9000 individual Sandpipers were counted using the Coorong, whereas less than 100 birds used the region during the last five years of drought.[6]

The lack of flow over the barrages also led to the Murray Mouth filling with sand, so two dredges were brought in to maintain an open channel between the ocean and the Coorong from 2001 onwards.

The channel required full-time dredging to remove the sand that was continuously deposited into the Murray Mouth. This had an annual cost in the order of $5 million.[7] Without dredging, the entire Coorong would have received no water inputs from either the Lower Lakes or the ocean. And, within years, it would have become so salty as to be unable to support any life, before drying completely.

In the summer of 2006–07, adverse effects moved upstream into the Lower Lakes. The drought reduced lake inflows from the River Murray below the rates of evaporation and water levels in the lakes began to fall (Figure 1). Most aquatic vegetation was disconnected from the water as the shoreline receded, often by several kilometres from its normal position.

As water levels fell, salinity in the lakes increased as salt from the River Murray accumulated and barrages, designed to hold freshwater in rather than seawater out, leaked saline water into the Lower Lakes. Salinity increased above 7000 EC, which killed off the few remaining submerged plants that had been able to adjust to the fall in water level.[8]

FIGURE 2

ACID SULFATE SOILS (SHOWN BY THE ORANGE TINGE) ACIDIFIED AFTER SEDIMENTS WERE EXPOSED TO THE AIR. THIS IMAGE SHOWS CURRENCY CREEK IN 2009, LOOKING EAST TOWARDS THE LOWER REACHES OF LAKE ALEXANDRINA.

Source: South Australian Department of Environment and Natural Resources.

The Yarra Pygmy Perch suffered the combined effect of a loss of habitat and lethal salinity levels, causing it to become locally extinct from 2008 onwards. A few individual fish were kept alive in aquaria throughout the drought for release when conditions improved.

Another fish species, the Congolli (*Pseudaphritis urvillii*), was prevented from migrating downstream into the Murray Mouth estuary to breed during the low water levels. Consequently, no breeding event occurred for four years and Congolli was threatened with local extinction.

The rise in salinity in the Lower Lakes allowed an estuarine tubeworm (*Ficopomatus enigmatus*) to disturb freshwater ecosystems that were already suffering from salt stress. This tubeworm builds nests consisting of an expanding cluster of calcareous tubes onto rocks, bridge pylons and other infrastructure.

The two species of freshwater turtle in Lake Alexandrina (short-necked and long-necked) also provided scaffolding for this invasive worm. By having their shells weighed down with tubeworm constructions, hundreds of freshwater turtles were drowned due to a lack of mobility. Many turtles were rescued as local schools and volunteers searched for worm-laden turtles, broke the calcareous nests off their shells and provided them with a few days respite with access to freshwater before releasing them upstream in the River Murray were salinity was lower.

As water levels fell, large areas of sediment became exposed to oxygen in the atmosphere. The sediments of the Lower Lakes are rich in acid sulfate soils, which when inundated, are stable. However, when these acid sulfate soils are exposed to the air, they can acidify, releasing sulfuric acid and toxic heavy metals into the porewater around the sediment. During the drought, these soils reduced the pH in some fringing wetlands of both lakes to below two, which is more acidic than a car battery.

To prevent this acidic water from entering the lakes, and to minimise the risk of further acidification, a bund was built in 2008 between Lake Alexandrina and Lake Albert so that water could be pumped into Lake Albert to prevent it drying and exposing its sediment to the atmosphere. Water was pumped for 24 hours a day, seven days a week (for eight months of the year) to keep water levels in Lake Albert stable.

Two small tributaries to Lake Alexandrina, Currency Creek (see Figure 2) and Finniss River, also acidified after their sediments were exposed due to declining water levels. These were initially treated with finely ground limestone that was piled into blocking banks to capture the initial runoff and to neutralise the acidity. However, soon afterwards, a crop duster was retrofitted to cover exposed sediments with limestone to ensure that it was widely spread.

Another bund was built at Clayton and water was again pumped from Lake Alexandrina downstream to raise water levels and prevent further acidification.

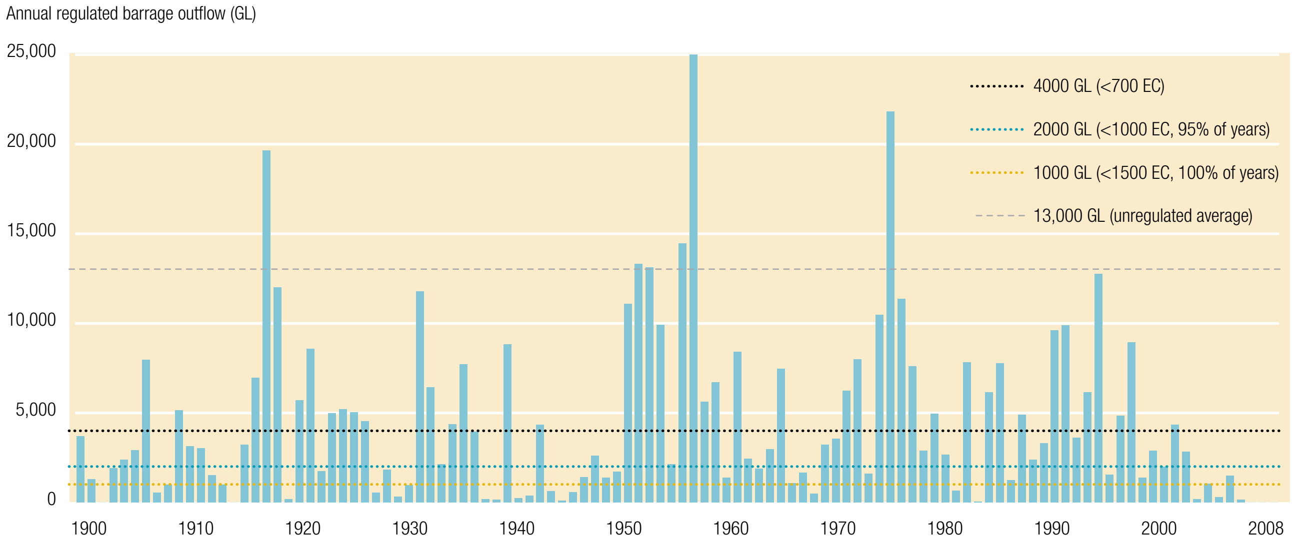
These management interventions were required to prevent irreversible environmental collapse as water levels dropped below sea level for an extended period of time and the risk of lake-wide acidification increased.

The last years of drought caused major changes observed upstream of the Lower Lakes, in the lower River Murray. The section of the River Murray between Lock 1 and the lakes has major drinking water off-takes for Adelaide and much of regional South Australia (Figure 1), providing water for up to 1.5 million people. The river channel is deeper than water in the Lower Lakes, so wind from the south-west sets up seiches that push lake water into the river channel. During the drought, lake water had much higher salinity than river water and pooled along the bottom of the channel. Persistent winds pushed lake water upstream that accumulated at depth. A few times during the drought, calm weather or wind from the north-east was all that prevented salty water reaching drinking water offtakes. This would have required river water to be desalinated by South Australia's water utilities.

Low water levels in the lower River Murray also removed support for riparian land, which led to riverbank slumping. Over 100 different events were recorded where land and public infrastructure, collapsed into the river as the riverbank dried. The economic and social impact of these incidences in the final years of drought were substantial, with direct costs in the order of $100 million.[9]

Overall, the cost of management interventions in the CLLMM region during the drought, including the eight years of dredging, construction of bunds and associated pumping costs have been estimated at $500 million.[10] This estimate doesn't include the cost of lost agricultural production around the lakes or the impact on local fisheries. Neither does this estimate include losses to the regional economies in other areas such as from declining tourism, all of which are expected to be considerable.

FIGURE 3
MODELLED FLOW OVER THE BARRAGES USING CURRENT LEVELS OF WATER RESOURCE DEVELOPMENT USING THE LAST 110 YEARS OF INFLOWS.



Source: Murray-Darling Basin Authority

Managing the CLLMM within the Murray-Darling Basin: Challenges of multiple spatial and temporal scales

Australia, along with parts of Southern Africa, has the most variable rainfall patterns in the world.[11] For the Murray-Darling Basin, this means larger floods and longer droughts. However, inflows come from a variety of sub-catchments in climates ranging from temperate to sub-tropical, giving the lower part of the Basin a natural buffer against this extreme variability.

The Darling River, in the north of the Basin, receives most of its inflows from sub-tropical summer rains. The Murray River, on the other hand, is fed predominantly by winter rains and spring snowmelt from the western slopes of the Great Dividing Range. Together, these provide more predictable inflows to the CLLMM region, but the inter-annual variability can still be high, as evidenced by the “Big Dry”.

The CLLMM receives about 94 per cent of its water requirements from the River Murray, with rainfall and small local rivers making up the remainder. Given that the ecology is flow-dependent, management of the CLLMM is ultimately determined by water use upstream.

However, the drought has changed the focus of lake management towards optimising environmental outcomes, often with the added benefit of reducing water requirements. For example, plans to reintroduce variable water levels (on average 35cm below historic levels) are expected to save over 50GL per year in reduced evaporation. This has the added benefit of reducing shoreline erosion and increasing the distribution and resilience of the aquatic vegetation in the Lower Lakes.

Actively operating the barrages to selectively release outflow from certain barrages that focus water towards the Murray Mouth is another option being considered. This would increase the amount of sand scoured from the Murray Mouth for a given amount of barrage outflow.[12]

These management strategies are aimed at increasing the resilience of the CLLMM region to extended periods of low flows. Of course, any active management plans will only remain effective while sufficient freshwater flows enter the system from the River Murray.

The water requirement to maintain a healthy ecosystem in the CLLMM is a rolling three-year annual average flow of 4000GL over the barrages. By way of comparison, the natural long-term average outflows from the Murray-Darling Basin was 13,000GL per year before river regulation and water diversions began (Figure 3).

However, this environmental water is not exclusively allocated to the CLLMM. Instead, it provides multiple benefits throughout the Murray-Darling Basin, including exporting salt from the entire Basin to sea, and meeting environmental water requirements for upstream Ramsar-listed wetlands and “icon sites” under the Living Murray Program.

In fact, modeling suggests that just meeting the environmental water requirements of the Chowilla Floodplain and Lindsay-Wallpolla Islands, on the state border between South Australia, New South Wales and Victoria, will provide enough flow into the CLLMM to maintain the key indicator species in the Coorong and Lower Lakes.[13] As a result, the CLLMM can be considered as a broad indicator of the health of environmental assets throughout the Murray-Darling Basin.

An average water requirement of 4000GL per year over three years also will not mean that this volume of water flows over the barrages each and every year. Instead, these are target flow levels to achieve specific environmental outcomes that will guide the calculation of sustainable diversion limits currently being assessed by the Murray-Darling Basin Authority. Furthermore, the majority of the water to achieve these targets already flows across the barrages under current water sharing agreements (Figure 3).

Increased environmental water allocations are sought to increase the number of years that salinity is maintained below 1500 EC from 94 per cent currently, to 100 per cent of years. Similarly, the target to keep salinity below 1000 EC in 95 per cent of years requires additional water, because this target is only currently met in 82 per cent of years. These flow-salinity targets are designed to give flexibility to water delivery so that environmental flow requirements can be assessed on a basin-wide scale rather than just for individual sites.

How much water these targets will be allocated, and how this is being balanced with other social and economic considerations is currently being determined by the Murray-Darling Basin Authority as part of the Basin planning process.

Conclusion

The severe shortages of water in the CLLMM region during the “Big Dry” led to degradation of its ecosystems and provided an example of the worst-case effect of insufficient flow.

The health of ecosystems in the CLLMM, like much of the Murray-Darling Basin, is driven by flow. This flow controls salinity levels, the habitat availability and the species abundance in the region.

While it was drought that led to severe changes in the CLLMM, it was the lack of secure water entitlements for the environment, equivalent to current irrigation entitlements, which prevented the system being managed with flow.

The science suggests that increasing the CLLMM’s water allocation to meet long-term salinity targets requires a three year average flow over the barrages of 4000GL per year. A lot of this water already flows over the barrages, so entitlements are required to secure the right volume at the right time.

The science also suggests that the water requirements of the CLLMM will be met if upstream environmental assets are provided with their water requirements. Consequently, the idea that water flowing into (or out of) the CLLMM has been wasted, is false. But, how much water is allocated to the environment, and the methods of its procurement, are bigger questions that deserve robust and comprehensive discussion.

References

1 South Australian Department of Environment and Heritage 2000, *Coorong, and Lakes Alexandrina and Albert Ramsar Management Plan*, South Australian Department of Environment and Heritage, Adelaide.

2 For more details see Fluin, J, Gell, P, Haynes, D, Tibby, J. & Hancock, G 2007, Palaeolimnological evidence for the independent evolution of neighbouring terminal lakes, the Murray-Darling Basin, Australia. *Hydrobiologia* vol. 591, pp. 117-134. and Sim, T & Muller, K 2004, *A Fresh History of the Lakes: Wellington to the Murray Mouth, 1800s to 1935.* River Murray Catchment Management Board, Adelaide.

3 Paton, D 2010, *At the end of the river.* ATF Press, Hindmarsh.

4 Lester, RE, Fairweather, PG & Higham, JS 2011, *Determining the Environmental Water Requirements for the Coorong, Lower Lakes and Murray Mouth Region: Methods and Findings to date*, Department of Environment and Natural Resources, Adelaide.

5 ibid. Flow requirements to maintain the ecological character of the CLLMM are more complex than just these three-year rolling targets, but for brevity these dominant flow requirements are presented alone. Other rules include: an absolute minimum barrage outflow of 50 GL in any one year, the minimum two-year requirement of 600 GL to maintain a healthy Coorong, and in 95 per cent of years the minimum two year barrage outflow should be 2500 GL per year. The Coorong also has some flooding requirements of 6000 GL per year with a three year return interval and 10,000 GL per year with a seven year return interval (return interval refers to the average flood occurrence over a 100 year period). The interested reader is referred to the full report available at http://www.environment.sa.gov.au/Conservation/Rivers_wetlands/Coorong_Lower_Lakes_Murray_Mouth/The_environment/Water_flows_levels/Environmental_water_requirements

6 Paton, *At the end of the river.*

7 Kingsford, RT, Walker, KF, Lester, RE, Young, WJ, Fairweather, PG, Sammut, J & Geddes, MC 2011, A Ramsar wetland in crisis - the Coorong, Lower Lakes and Murray Mouth, Australia. *Marine and Freshwater Research* vol. 62 no. 3 pp. 255-265.

8 Gehrig, S, Nicol, J & Marsland, K 2011, *Lower Lakes Vegetation Condition Monitoring – 2010/2011*, SARDI Aquatic Sciences, Adelaide.

9 Kingsford, A Ramsar wetland in crisis – the Coorong, Lower Lakes and Murray Mouth, Australia.

10 ibid.

11 McMahon, T & Finlayson, BL 1991, ‘Australian surface and groundwater hydrology – regional characteristics and implications’, *Water allocation for the environment. Proceedings of an international workshop – Centre for Water Policy Research*, University of New England, Armidale.

12 South Australian Department of Environment and Heritage 2010, *Securing the Future, Long-Term Plan for the Coorong, Lower Lakes and Murray Mouth*, South Australian Department for Environment and Heritage, Adelaide.

13 Pollino, CA, Lester, RE, Podger, GM, Black, D & Overton, IC 2011, *Analysis of South Australia’s environmental water and water quality requirements and their delivery under the Guide to the proposed Basin Plan*, Goyder Institute for Water Research Technical Report Series No. 11/2, Adelaide.

Section 3.0

Managing risk: city water supplies

3.1 Editors' overview

3.2 The risks of urban water management
Ross Young

3.3 Whole of water life cycle innovations
Rob Skinner

3.4 A national perspective on urban water
Erin Cini and Will Fargher

3.1

Editors' overview

The unprecedented nature of the recent drought drove an evolution in urban water management. It highlighted the lack of resilience in urban water supplies and the limitations of traditional urban water management.

There is considerable potential to increase the diversity of urban water supplies including sources that are not dependent on rainfall. The response of household consumption of water in the drought revealed the capacity to manage water demand while a much larger variety of supply augmentation options were deployed by urban water managers. Furthermore, research into sustainable cities suggested many vital reforms that can enhance the resilience of urban water supply.

If Australia is to future proof its cities vigorous urban water planning reform must be undertaken.

About the contributors

- Ross Young discusses the initiatives of the urban water industry in managing the risks of increasingly uncertain water supplies;
- Rob Skinner details the innovations and opportunities in whole of water cycle initiatives and outlines some opportunities for decentralised sources of water supply; and
- Erin Cini and Will Fargher provide a summary of the National Water Commission's report on urban water.

Discussion

The recent drought made it clear that managing urban water supply involves managing the risks on both the demand and the supply side of the water resource.

Melbourne has historically relied on water supply from reservoirs that, for 90 years, had relatively reliable inflows in an Australian context. This relatively high reliability meant that until 2005 Melbourne's water supply system was projected to be adequate until the 2030s, even with increasing population. As a consequence, no water supply augmentation was undertaken.

By 2007 this changed with the most severe drought on record in progress. The scientific advice was revised to a prediction that the drought could conceivably continue and planning for the water supply now had to take that into account. Estimates were made that the future had almost 40 per cent decline in water inflows into Melbourne's catchment areas. A similar pattern was predicted for all Eastern Seaboard capital cities requiring major urban water supply augmentation.

Perth has experienced a similar step change in weather patterns. Reduced levels of large rainfall events result in less run-off into dams. In Western Australia rainfall has declined by 30 per cent in water supply catchments over the past 15 years but inflows into dams declined by 80 per cent.

Water management issues became highly topical. Some commentators began predicting major capital cities would run out of water. Had corrective action not been taken they would have been right.

With water storages at critically low levels, when the climatic analysis changed, the response was significant levels of capital investment in various forms of water supply. Critics have stated that there were less capital intensive alternatives that could have been deployed, however they would not have been ready in the required time frame.

It is clear that historical Melbourne water supply systems, and those of other capital cities, did not have the resilience to cope with the dual shocks of greater than expected population growth and changed catchment yields. There resilience was based on either building new dams or water restrictions, the effectiveness of which is strongly influenced by weather patterns. On the demand side there is a limit to how much water can be reasonably rationed while on the supply side dam building is highly dependent on rain fed inflows. In a drought building another dam will not help. A portfolio of responses not dependent on rainfall patterns is needed to ensure the resilience of water supply. All State Governments commissioned desalination plants to provide a source of water independent of rainfall.

On the demand side a number of initiatives were launched to encourage water conservation, strict restrictions were introduced and household water use dropped. Without having reduced demand, Melbourne would have run out of water in 2009. It appears as though community use of water has experienced a sustained shift by implementing voluntary targets with lower levels of water use continuing in Brisbane and Sydney.

Water supply infrastructure is among the most capital intensive to deploy, particularly in an urban setting. This makes government decisions in urban water planning particularly important. Unfortunately, the interventions by State Governments in water supply investments generated confusion in terms of roles and accountability.

The planning institutions for urban and rural water supply buckled under the stress of an unprecedented drought. Furthermore, many of the responses available for building the resilience of water supply systems require water supply management to adopt a whole of water cycle approach. This involves appropriately pricing water. Current pricing has water from reservoirs has no economic cost associated with the infrastructure. Furthermore, whole of water life cycle pricing would also need to include benefits associated with a decentralised approach to urban water supply that are not currently captured. These include diminishing the impact of extreme events and improved environmental outcomes.

When the drought finally broke it was accompanied by flooding rains that caused extensive damage and destruction. Water management needs to be resilient in the face of extreme weather events, both droughts and flooding rains.

3.2

The risks of urban water management

Ross Young

Ross Young has over 20 years' experience in the urban water industry. He was a senior executive in Melbourne Water for over a decade and was involved in managing all aspects of the urban water cycle as well as sustainability and environmental issues. More recently he was the Executive Director of the Water Services Association of Australia. In this role Ross represented the Australian urban water industry both nationally and internationally. He has intimate knowledge on key aspects of the urban water sector including complex public policy formation, infrastructure creation and management, regulatory and governance arrangements in each of the states and territories and assisting the Australian urban water industry to adapt to more variable and unreliable climate.

Ross has been involved in numerous water resources planning projects right across Australia and has been an advisor to the Commonwealth, State and Territory governments on water policy.

At the turn of this century water supply planners, with the exception of those in Western Australia, had no idea what was going to confront them over the next decade. History now records that the first decade of this century was one of the most challenging experiences for water resource planners right across Australia. Of course Perth in Western Australia experienced a shift in climate some 20 years earlier which resulted in a dramatic reduction in surface run off into dams. In this respect Perth has been the canary in the coalmine for the Australian urban water industry. Yet in the early 2000s it was common for water resource planners to identify climate change as a risk, but few, if any, of the planners had the knowledge or the tools to predict precisely the magnitude of the impacts. At this time climate change was considered primarily as a risk to water security. As the climate dried it became apparent that virtually all aspects of the urban water cycle would be impacted by climate change and a holistic water policy approach was required to manage the myriad risks.

The story of what happened to the Australian urban water industry over the next decade is nothing short of extraordinary. The industry that exists today is nothing like the industry that existed in 2000. Essentially the Perth experience of the last two decades was replicated across Australia in a stunning manner that few predicted. Rainfall patterns changed, rainfall dropped sharply which resulted in the imposition of harsh water restrictions on households. The industry commenced a mad scramble to construct new sources of climate independent sources of water to mitigate climate risk. Many cities and towns across Australia lived with the fear of running out of water. As a consequence a water saving ethos was established in urban Australia that profoundly changed community attitudes about how water is used. This ethos remains largely today despite wide spread rain over the Australian continent (with the exception of Perth) in the summer of 2010.

As the decade ended the urban water utilities had invested over $30 billion in new water sources and in doing so they transformed the industry in a way that no one ever predicted. As the title of this chapter suggests managing a water utility is really about managing the risks on both the demand and the supply side of the water resource equation. In the context of the extraordinary variability of our climate, it was fitting that when it eventually started to rain again on the east coast of Australia it rained in a spectacular and deadly manner resulting in wide spread flooding that claimed many lives and caused billions of dollars of damage to homes, farms and infrastructure. These wild swings in climatic conditions were a brutal and timely reminder that the quintessence of managing Australia's water resources is not that we live in a dry country but we have the most variable and fickle rainfall patterns of all the continents on the planet. Quoting average rainfall figures is a futile exercise in much of Australia given the large standard deviations in rainfall.

The clouds disappeared

It was around 2003 that the east coast of Australia began to dry out. At first water supply planners were struggling to understand whether what we were experiencing was a step change associated with climate change or whether it was just the normal high degree of climate variability that we have always experienced in Australia. Context is important here. Over the previous two to three decades the urban water industry was commonly criticised for over investing and gold platting assets. It was assumed that an engineering culture prevailed in the water utilities and that engineers were fixated on creating new assets. So the industry was very cautious in making an early call that the climate had changed in case the community viewed this as an excuse for building more assets which would turn into white elephants once it started to rain again.

The water utilities had traditionally used the historic sequence of rainfall to determine the level of water security provided to cities and towns. The level of security was generally articulated as an example, the probability of having to impose water restrictions once every 25 years with a maximum duration of two years and at a maximum restriction of level two.

Just as historic performance of the share market is no indicator of future performance, water planners also started to contemplate that the same rational might apply to the historic rainfall records.

The large water utilities began undertaking studies on the impact of climate change on urban water resources. Initially these studies concentrated on the water supply system, but it quickly became apparent that climate change impacted on all aspects of the urban water industry including the stormwater and sewerage systems. Melbourne Water was one of the first utilities to engage the CSIRO to undertake a holistic study covering all aspects of the urban water cycle, including extreme events such as flooding and high intensity bushfires and impacts on assets.

Thus was a period of great uncertainty. The urban water industry at this stage largely relied of surface water run-off to fill dams. It quickly became apparent that being reliant on dams was a high risk approach in an era of climate change. Indeed one could argue that the first casualty of climate change was the rapid decline in surface runoff. The reduction of inflows into dams was not only due to a reduction in rainfall but it was the shift in climate patterns which resulted in the absence of large rainfall events. It seemed as though every time it rained the rain fell onto dry soil and the catchments never reached field capacity. As an example, in Western Australia over the last 15 years rainfall declined by 30 per cent in water supply catchments yet inflows into water corporation dams declined by 80 per cent.

As the great dry period extended unabated, all the surprises relating to rainfall were on the negative side of the ledger. Many pundits began to speculate on which Australian capital city would be the first to run out of water. Many regional towns across Australia where suffering from harsh restrictions that prevented any outdoor use of water. Daily and weekly targets where introduced so that communities could monitor water use on a regular basis.

Water policy makers, under pressure from key constituents began to agitate for a different approach. They claimed that the imposition of water restrictions was an obvious example of policy failure and the water industry needed to invest immediately in new sources of water to mitigate climate risk.

The key determinant factors that influence water supply security for a city or town are the climate and the population. Since the start of this century Australia experienced rapid population growth and the vast majority of the population growth occurred in cities and regional towns across Australia. The combination of rapid population and rapidly declining dam levels resulted in the perfect storm for the industry.

At this point there was a commonly held view that Australia did not need any new sources of water because water conservation measures would result in substantial reductions in per capita consumption, which meant that new sources of water could be delayed for decades into the future. There was some truth in this line of thought. However, in the context of rapid population growth and the alarming decline in dam levels servicing urban Australia, new water sources would be required. Although the community were willing to embrace water conversation the low hanging fruit of water conservation had been harvested in the previous decades and even with the more sophisticated and expensive water conservation programs it became self-evident that new sources of water were required.

Australia's cities looked dry and parched as water restrictions began to bite in earnest. Trees were dying along streets and in parks, weekend sports events were cancelled as the dry surfaces were unsafe for sport and home gardeners began to configure systems to allow their gardens to be watered by household grey water.

As time moved on with many cities and towns experiencing near to lowest inflows into dams it was clear that something had to give. Urban communities around Australia were becomingly increasingly frightened that they would run out of water. At this stage urban water issues were front and centre daily on the front page of newspapers and discussed regularly on talk back radio. Climate change studies, commissioned by water utilities, were concluding that we were in uncharted waters in relation the dramatic shift in our climate. These studies fuelled more angst in the community and community leaders and politicians were calling for action. At this stage nearly everyone was a water expert and water was a dinner table conversation across our increasingly desiccated continent.

Eventually, the combination of our enhanced understanding of the consequences of climate change, fear in the community that cities and towns would run out of water and month after month of cloudless skies, water utilities were able to convince state governments that an unprecedented investment in new water sources was required to mitigate the risks of climate change and rapid population growth. What followed was nothing short of a revolution as water utilities invested $30 billion in new sources of water alone between 2006 and 2011. The Australian urban water industry would never be the same again.

Time to push the augmentation button

The dramatic fall in dam levels since the start of the century had taught the urban water industry a valuable lesson – that although dams had served urban Australia well in the past with cheap and generally reliable and low carbon water it was time to move forward and develop new sources of water that were independent of rainfall.

"Security through Diversity" was the catch phrase coined by the Western Australians to describe this new approach. Share market analogies were used to explain why Australia could no longer rely on a single source of water just as a share market investor should not have his/her entire investment in the one stock. Hence good investment advice always recommends a diverse portfolio of stocks and this approach applies equally to the water industry.

During this period all the large water utilities and their state governments developed 25 to 50 year strategies based on in-flow forecasts, population growth and per capita consumption predictions. It was these strategies that guided the massive capital investment program into new water sources and demand management programs.

The new water sources being developed had one thing in common – they were much more expensive, more energy intensive and more technologically sophisticated than the traditional water systems. By virtue of the greater use of technology these new water systems required more highly skilled operators to manage risks and to optimise performance.

New water sources developed and other major investments in new infrastructure included desalination plants, recycled water schemes, ground water, water grids to link catchments, stormwater and rain water tanks.

Although the community were generally supportive of the investment program in new water sources there was a strong negative reaction initially to desalination plants with the exception of Perth. Perth was the first capital city to be supplied by a desalination plant and is now in the midst of building its second plant with what appears to be a high level of community support. This cannot be said about desalination plants on the east coast.

Once again the selection of which sources of water should be developed was a contested area in the court of public opinion. This again exemplifies the political, economic and social aspects of water resource policy and investment. Desalination plants were the most controversial sources of water developed as the community reacted negatively to the energy intensive nature of the process and the resultant increase in greenhouse gas emissions. Many thought it was the height of irony that the reaction to a drying climate due to climate change was to build energy intensive water supply sources. Concerns were also expressed about the potential impact on the marine environment resulting from the extraction of seawater and the discharge of brine back into the sea. Other interest groups were concerned that as desalination plants were able to produce potable water independent of rainfall, consumers would be reluctant to invest in water conservation as the new water sources had a so called “endless supply of water”.

To counter the concerns over greenhouse gas emissions state governments and utilities began to either build new renewable sources of energy such as wind farms or purchase green credits to off-set the energy consumed in the desalination process.

Desalination was debated to an extent that many in the community thought it was the sole response to improving the reliability of supply in an era of climate change. As mentioned earlier this was not the case as a broad range of water projects were constructed and commissioned. Water recycling schemes are a case in point. Although water recycling is relatively energy intensive compared to dam water there was broad community support even though the process of creating recycled water was almost identical to the desalination process. In 2000 the urban water industry recycled 70GL of water and this has now grown to 250GL in the 2009/10 year. An emphasis has now been placed on developing recycled water systems. Examples include supplying water to commercial and industrial customers, irrigation parks and sports fields and residential third pipe systems, just to mention a few.

The industry also invested heavily in reducing leakage and unaccounted for water. The prevailing view was that if the water utilities were calling for the community to comply with water restrictions and consume less water, the least the utilities could do was to reduce leakage rates. The program to reduce leakage has been very successful. Elements of the program such as reducing water pressure not only reduced leakage but also extended the life of assets. After considerable investment in the capital cities to reduce leakage, Australian capital cities now have leakage rates that are the envy of the rest of the world.

Water conservation programs

The extent to which per capita urban water consumption has declined over the last decade, is one of the great social changes in our society. Water restrictions are very successful in reducing the amount of water used for outdoor purposes but water restrictions are a blunt instrument and cause considerable hardship. Water restrictions don’t apply to internal use of water so water utilities around Australia began to implement water conservation programs with very successful outcomes.

The starting point for any water conservation program is to know your customers and community and work with them in the implementation of programs. Public information programs are required at the outset so that all water consumers understand the reasons for implementing water conservation measures. An educated community is then able to determine the best and easiest of measures to reduce water consumption.

The range of water conservation initiatives implemented for households included:

- Rebates for water efficient appliances such as washing machines and dishwashers;
- Shower head replacement programs;
- Toilet replacement programs;
- Programs that involved plumbers visiting houses for a small fee to check for leaks, replace shower heads, fix leaking taps and toilets and provide water conservation advice;
- Measures that improve the efficiency of outdoor irrigation; and
- Rebates on grey watering systems.

Water conservation programs were also implemented for the commercial and industrial sectors. Water utilities were once again at the forefront of assisting this sector to become more water efficient and there are numerous examples where water utilities were able to assist industry in reducing water and associated energy costs.

It is interesting to note that in cities where water restrictions have been removed such as Sydney and Brisbane the increases in water consumption have only been small indicating that many households now have water conservation measures ingrained and that the community are continuing to be frugal with water despite the recent rains and floods. Maybe at long last the message about Australia's variable and fickle rainfall patterns has hit home and the community still have vivid memories of what it was like fearing that some cities and towns would run out of water.

Conclusion

The last decade has been a roller coaster ride for the urban water industry. I don't believe that there would be many people who would have foreseen the dramatic change in our industry in such a short period of time. Who would have predicted back in 2005 that by 2013 there would be six desalination plants in Australia and that if these desalination plants were operating at the maximum capacity they would potentially be supplying almost 50 per cent of capital city water needs based on 2008/09 water consumption? Although there is some legitimate argument about the choice of and size of new water sources chosen there can be no disagreement that cities and towns across Australia now have a more resilient water supply systems which means they are better placed to manage the next dry period when it inevitably arrives.

This infrastructure has come at a great cost, but it is still much cheaper than running out of water.

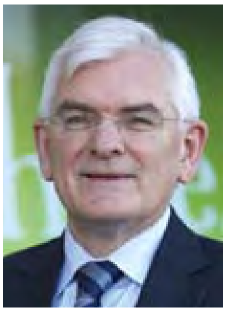
The essence of good water resource management is planning and it is imperative that utilities continue to review plans and adjust them to take account of changing contexts.

Based on recent history, I am confident that the industry is well placed to deal with the challenges associated with operating in a carbon constrained economy – and of course the inevitability of Mother Nature rolling the dice just to keep us on our feet.

3.3

Whole of water life cycle innovations

Rob Skinner



Rob Skinner is currently Professorial Fellow at the Centre for Sustainable Cities at Monash University. Previously he was Managing Director of Melboure Water was Managing Director of Melbourne Water from 2005 until March 2011.

Prior to joining Melbourne Water, he was Chief Executive Officer of a large municipal council in metropolitan Melbourne during which time he also held a number of key positions in the water sector as chairman or member of boards or government advisory committees.

He has been a Board member of the Water Services Association of Australia, Smart Water Fund and is still actively involved in a number of innovative sustainability initiatives in Melbourne. He has been a leading figure in Victoria's water sensitive urban development programs, most recently being appointed to the Ministerial Advisory Council for Water Sensitive Cities.

Mr Skinner has initiated a number of collaborative relationships between Melbourne Water and agencies in Singapore, UK, China, Israel and Timor Leste.

Melbourne Water is owned by the Victorian Government. It manages Melbourne's water supply catchments, removes and treats most of Melbourne's sewage, and manages rivers and creeks and major drainage systems throughout the Port Phillip and Westernport region.

Melbourne's centralised sources of supply

By 2006 the Victorian Government had released a Sustainable Water Strategy for the central Melbourne region. The strategy recommended that a range of augmentations be investigated, including a centralised source of recycled water from the Eastern Treatment Plant and a desalination plant for possible construction in future years or decades.

So what led the Victorian Government in 2007 to decide to construct in Melbourne one of the biggest desalination plants in the world, less than two years after concluding that no major augmentation would be needed for many years? The answer is simple – a new and higher level of uncertainty in future climate patterns and a lack of alternative options available in the time available.

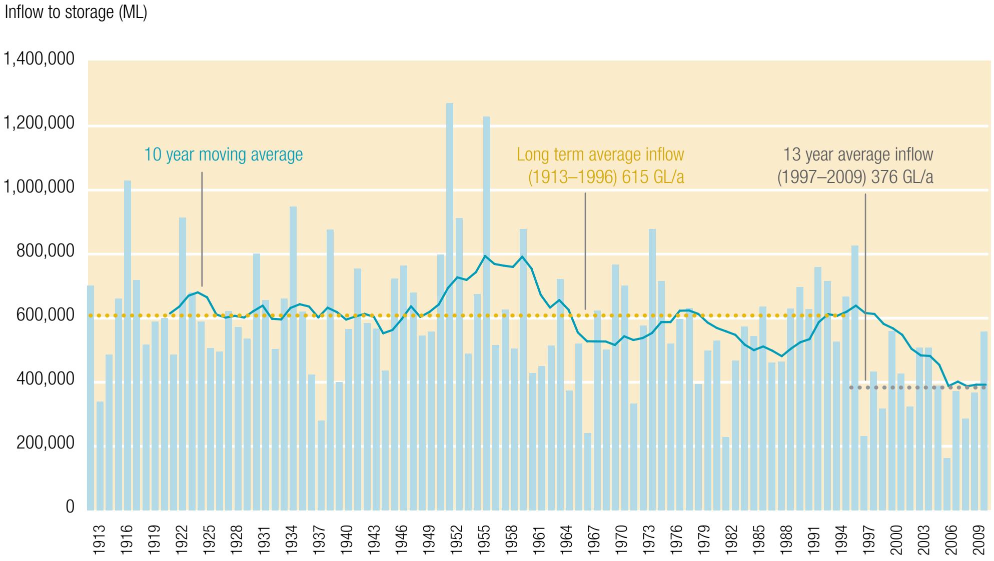
The Melbourne water supply system did not have the resilience to cope with the dual shocks of greater than expected population growth and changed catchment yields because of a dramatic change in climate pattern.

Melbourne's water supply system has traditionally been dependent almost entirely on water from reservoirs. Figure 1[1] records the streamflows into Melbourne's major reservoirs and illustrates that over the 90 years of recorded data, up until 1996, there had been regular cycles of variation in annual streamflows. As illustrated by the 10 year moving average, these variations had a frequency of approximately 20 years.

So in 2005, in the absence of any strong scientific evidence to the contrary, it would have been reasonable to assume that the Melbourne catchments were in the trough of a regular long term cycle (note that the 10 year moving average was at the lowest point that it had been on two other occasions over the past 40 years).

However, by 2007 two related factors combined to change this view – and introduced considerable uncertainty into the minds of planners. First, the drought continued (the moving 10 year average declined to record lows – see Figure 1) and there were climatic conditions that indicated that it could continue for some time.

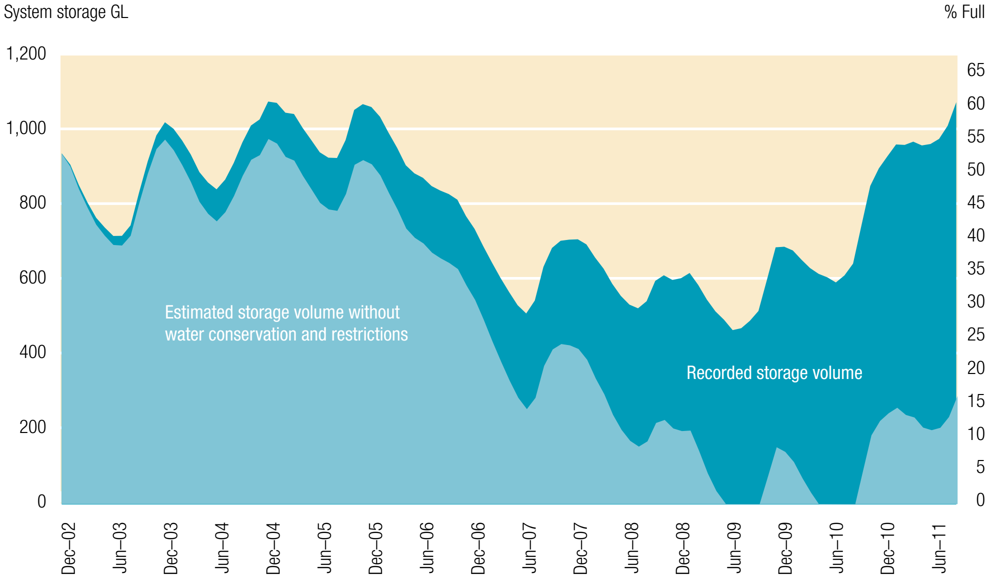
FIGURE 1
ANNUAL STREAMFLOW INTO MELBOURNE'S MAJOR STORAGES (THOMSON, UPPER YARRA, O'SHANASSY AND MAROONDAH RESERVOIRS)



Source: Melbourne Water

FIGURE 2

MELBOURNE'S STORAGES 2002–2011 – OBSERVED (WITH WATER EFFICIENCY MEASURES) AND WITHOUT WATER EFFICIENCY MEASURES



Source: Melbourne Water

Secondly, scientific advice was that there had been a statistically significant step change in rainfall patterns, indeed it was reported that the extended drought period had been the worst on record with a probability of occurrence of cumulative inflow (1997–2006) being less than 0.002[2]. It was concluded that the 39 per cent reduction in long term average streamflows that had occurred since 1996 could represent a new planning base – a step change that was similar (but not as big) to what had occurred in Perth 30 years earlier.[3]

The planning analysis at the time[4] indicated that in order to ensure adequate security of supply for Melbourne (similar to pre 1996 levels), if a streamflow sequence similar to that which occurred in 2004/2005 and 2006 was repeated, it was necessary to increase Melbourne's water supply capacity by 240 gigalitres per annum (GL/a) by 2012. This reasoning led to a decision[5] to construct a 150GL/a desalination plant and to invest in irrigation reform in northern Victoria to save an average of 225GL/a, of which no more than a third (75GL/a) could be transferred to Melbourne via a new North-South Pipeline. The third capital investment was the recommissioning of the Tarago Reservoir with the construction of a new treatment plant (an additional 15GL/a).

Part of the suite of decisions in 2007 was also a continuation of the highly effective water efficiency initiatives, combined with temporary water restrictions. This was important because if Melbournians reverted to the much higher water consumption patterns of the 1990s another 150GL/a of supply augmentation would be required.

Another way of appreciating the significance of the water efficiency measures that were implemented post-2000 is to consider the consequences to Melbourne's water supply had the water efficiency measures not been implemented and taken up by Melbourne consumers. Figure 2[6] illustrates that without these water efficiencies Melbourne would have run out of water.

The decision to build the desalination plant and the North-South Pipeline has been criticised by a number of commentators, many of whom have categorised it as a "panicked response". A common belief is that rather than investing in new and expensive centralised infrastructure, the problem should have been addressed by a range of alternative sources, such as rainwater tanks, recycled water, stormwater capture and reuse, a pipeline from Tasmania's northern lakes area, or more stringent water efficiency measures.

It is true that a combination of these alternatives could, when in place, have achieved an additional capacity of 240GL/a (it's not necessarily true that they all would have been cheaper) but unfortunately they could not have been implemented in any where near the time needed to meet the 2012 deadline. All of the reasonable alternatives – most of which are categorised as "decentralised" – require significant time to undertake the planning, construction and plumbing/retrofitting that would be involved.

The resilience of Melbourne's water supply system

Until 2005 Melbourne's water planners always felt blessed to have a water supply system that was fed almost entirely from the "ever reliable" Yarra and Thomson River catchments (refer again to Figure 1). Because of this perceived security, whenever Melbourne had needed additional supplies it was simple enough to build a new dam.

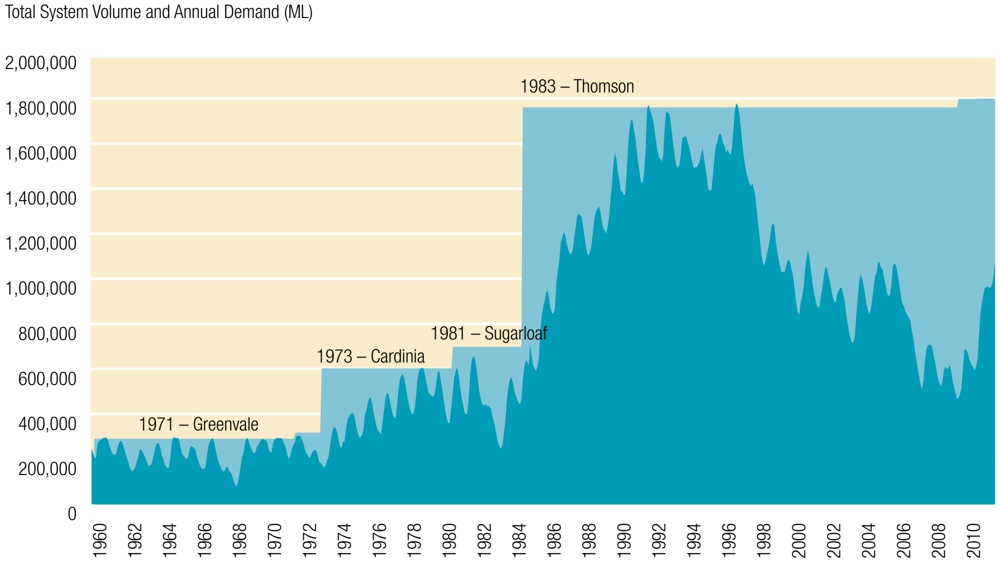
Figure 3[7] illustrates: The growth of total storage capacity between the years of 1960 and 2011 (the light blue shaded area); total water stored in any year (the dark blue shaded area); and annual water demand. It tells the story of lack of diversity of source options because of the belief in the long term certainty of the streamflows.

During the 1960s, Melbourne experienced a critical undersupply of water which triggered a period of major dam building, leading to an increase of total storage capacity from 300GL to 1760GL, including the construction of the Thomson Dam which alone increased total system storage by 1100GL. This meant by 1994 all the storages were full and the popular view of the day was that Melbourne was drought proof.

Until this point the resilience of the system was based on two components – new dams or water restrictions. That is, any new or unexpected demand for water could always be met by either building a new dam or, if extra breathing space was needed, the imposition of water restrictions. So by the time the reservoirs were less than 30 per cent full in 2007 with significant uncertainty around whether the storages would refill to any secure level in the foreseeable future, the resilience of the system was very low.

FIGURE 3

MELBOURNE'S MAJOR RESERVOIR STORAGE CAPACITY, TOTAL SYSTEM STORAGE AND ANNUAL DEMAND



Building more dams was not seen as an option (there were plenty of dams already, but they were not filling, and in any event it would take at least five years to build a new dam even if a suitable site could be found) and there was a limit to how much more water efficiency or water restrictions could be exploited.

In 2007, because of lack of diversity in the water system, new sources of water that were not catchment-dependent were needed urgently.

Resilience and liveability of cities – the role of whole of water cycle initiatives

The experience of 1996 to 2010 has provided a number of lessons. The first and most obvious is that there are great uncertainties surrounding the factors that determine water security for Melbourne, and the strategies to manage these uncertainties need to include a wide diversity of options, with maximum flexibility to apply them. Because such strategies were not in place at the time, there had been very little investment in alternative sources and there was inadequate resilience in the system to cope with the climate and population growth shocks that arose after 1996.

A second lesson relates to the realisation that the liveability and sustainability of a city is largely dependent on water. A city that has severe water shortages and is subject to strict water restrictions suffers in many ways – environmentally, socially and economically. In Victoria, this realisation has led to a new government policy that aims to "establish Victoria as a world leader in liveable cities and integrated water cycle management"[8]. Moreover, the policy has the ambitious aim of "driving integrated projects and developments in Melbourne and regional cities to use stormwater, rainwater and recycled water to provide Victoria's next major augmentation".

In recent years, sometimes under the rubric of Cities of the Future, there have been initiatives[9] to develop visions and principles for cities that are to be planned and designed taking into account whole of water cycle principles, so that the cities are:[10]

- Liveable – having attractive urban landscapes that support healthy communities, safe, fit-for-purpose water supplies, and improved flood protection;
- Sustainable – water systems and urban landscapes resilient to natural disasters and climate, smaller environmental footprints, and healthy waterways and bays with rich biodiversity; and
- Productive – adequate water security, affordable water services, a clear, transparent and contestable investment climate, and economic prosperity.

Whole of water cycle management therefore addresses both issues of water security (responds to traditional supply/demand challenges) as well as the broader issues of waterway health and urban liveability.

Viewed within a framework of "resilience and liveability" it is apparent that the challenges facing urban water planners are rarely engineering or technical in nature. At the end of the strategy and planning processes there may be the need for some structural or engineering solutions (a recycling plant for example) but, equally, the most efficient and effective solutions might well be non-structural in nature (urban planning and design for a water sensitive city, water efficiency measures and innovative pricing).

In other words, developing a whole of water cycle strategy is more than just a technical assessment of engineering options – it is an assessment of how water systems can be integrated into the urban planning process to deliver resilient and liveable cities. It represents a much bigger and more complex challenge.

The full range of water cycle options

To implement its Living Victoria policy in 2011, the Victorian Government established a Living Victoria Ministerial Advisory Council (LVMAC) to provide a "roadmap" for implementing the policy.[11] At the time of writing this piece the LVMAC was undertaking an assessment of the range of water cycle options necessary to achieve its stated objectives. For the purpose of evaluating alternative options a base-case was established which is characterised as business as usual (BaU) – that is; future supply augmentation would build on current day water storages, embedded water efficiencies and existing dual pipe systems supplemented by Melbourne's new desalination plant. For the sake of this exercise, the BaU option would provide for future growth in demand by expanding the existing desalination plant and the construction of new plants as necessary.

A range of alternative options, but one that is here termed a "decentralised option", is being evaluated in comparison with BaU. The decentralised option takes as a starting point the BaU assumptions regarding consumer behavior and existing infrastructure, but to cater for future growth in demand an investment profile is developed to achieve certain performance standards that include a combination of enhanced water efficiency measures, rainwater tanks (extending to stormwater and rainwater harvesting) and precinct scale wastewater treatment and distribution systems.

Based only on a traditional net present cost (NPC) analysis, which takes into account total system operating costs, capital costs associated with meeting growth in demand and necessary renewals of infrastructure, preliminary results for a 40 year period indicate the decentralised option has an appreciably lower NPC than BaU.

It is important to note that conventional NPC assessments of this sort do not purport to report on whether socially optimal outcomes are being achieved. A broader evaluation framework is required to provide an assessment of socially optimal outcomes, and in the context of assessing the broadly based range benefits and costs of total water cycle initiatives the following factors need to be considered:

- Resource value of water – currently investment decisions and subsequent pricing proposals are based on the assumption that water from reservoirs has an economic resource value of zero. With over 70 per cent of Melbourne's water coming from "free" river sources (once the new desalination plant is operating) there will be a significant distortion of investment decisions until such time that a shadow price is applied to the resource (or a market value, if urban water trading was introduced);
- There are a range of external benefits and costs that need to be internalised in the assessment process. Many of these externalities will favour the decentralised option quite significantly over BaU, the main ones being:
  - The reduction in nutrient loads and other pollutants to waterways and receiving bays as a result of a significant reduction in nutrient rich stormwater running off allotments or precincts in the decentralised option (as a result of performance standards being achieved through a variety of methods including rainwater tanks, rain gardens, bio-retention swales and pits at precinct levels). Waterways will be healthier and biodiversity values will be protected or enhanced;
  - As with the reduction in nutrients, the decentralised option will result in significant reductions in the quantity of peak stormwater flows from storm events (thereby reducing pressure on, and associated costs of, drainage infrastructure);
  - As a result of the significant increase in on-site and precinct level water capture in the decentralised option the city will become more of a water catchment itself
  - The additional water staying in the city (rather than being transported to waterways) will result in increased soil moisture which in turn support greener urban

streetscapes and parks – and increased urban amenity; and

- The greener city will be a cooler city resulting in measurable reductions in urban heat island effects[12], leading to reductions in heat stress related illnesses.

While alternative decentralised options provide greater resilience for the city as a whole, they also provide more flexibility (and therefore resilience) for coping with the significant differences in water system demands between geographical areas across the city.

It should be noted that the decentralised option is not creating a future city that will not have centralised infrastructure. The centralised assets such as reservoirs and the desalination plant will always have a key role to play in Melbourne's future water system. However, centralised augmentations will have a diminishing role to play in the package of options selected to cope with future water cycle challenges and in times of high uncertainty this provides a major advantage to decentralised alternative solutions. Being smaller in scale, components of the decentralised option can be implemented more quickly than larger centralised options if required to cope with unexpected shocks – and, just as importantly, they avoid large "lumpy" investments if the future isn't as demanding as expected. This is the essence of managing uncertainty and risks through "real options analysis".[13]

Institutional, governance and policy challenges for implementing whole of water cycle initiatives

Whole of water cycle planning is a cornerstone of liveable and resilient cities. While there is a considerable body of science and technology and case studies that underpins the development of a city that is water sensitive[14] , the transition from conventional water sector planning (based on "linear" supply/demand analyses) to a mode of planning that responds to much broader urban planning objectives is complex and requires a range of non-technical considerations.

A number of investigations[15] have examined the preconditions for successfully integrating water cycle planning with urban planning. Based on this work a common set of requirements or priorities is emerging. These are generally:

- For all stakeholders, together with the broader community, to agree on a vision for the contribution of water to urban liveability;
- The development of clear objectives for achieving such a vision, including an agreement on environmental, social and economic outcomes;
- Provide conditions and obligations to drive integration of urban and water planning;
- Optimise the use of all available water sources;
- Establish a common approach to economic evaluation;
- Review approaches to the pricing and valuing of all water resources;
- Facilitate greater customer choice and innovation;
- Strengthen the current institutional and governance arrangements; and
- Address the need for an appropriate culture to be developed in all relevant agencies and participants in the planning process.

Only items four and five require a high degree of technical expertise or structural response – the remainder of these requirements are in the domain of institutional, governance or policy reform. In this respect there are some underlying interdependencies that provide some insight or direction on how best to achieve a successful transition to fully integrated water and urban planning processes. These interdependencies are:

- An appropriate culture where all participants have a mindset that expects collaborative and constructive behavior will be the norm. This will only exist if the leaders of organisations themselves display such behaviour.
- Related to the need for constructive leadership is the necessity to align all participants to the vision and objectives of the reforms. Given that these reforms are linking two usually separate arms of government (water and planning) – an important step would be to embed the vision and objectives of the reform (which should be "owned" by government) in relevant water and planning legislation.
- Integrating water cycle and urban planning is complex – requiring the generation of a range of options (both structural and non-structural), a significantly different economic evaluation framework (see below), and working across a number of disciplines. These new demands will require a high degree of innovation and the prerequisites of innovation are collaboration and acceptable risk taking – both of which require a constructive culture of the sort outlined above.
- On the issue of innovation, a sure way to discourage innovation is to require compliance with prescriptive regulations. On the other hand innovation flourishes when performance based outcomes are specified, when both the public and private sectors are given the freedom to develop solutions unfettered by preconceived ideas of what works best.
- Only after the above matters have been resolved, should institutional and governance arrangements be addressed.

Conclusion

Centralised sources of water supply have served Melbourne well for over a century. However, the experience of the last 10 years has taught us that in times of increasing uncertainty (including the threat of significant climate change) the overall resilience and liveabilty of a city requires water system and urban planning to be integrated, and a main driver for this is integrated whole of water cycle planning. This in itself will drive the development of more decentralised alternative solutions.

Endnotes

1 Melbourne Water data

2 See: Tan, KS & Rhodes, B (2008), 'Implications of 1997–2006 on Water Resources planning for Melbourne', *Proceedings of Water Down Under, 2008.*

3 See: Skinner, R (2010), 'Adaptation to Climate Impacts on Water Supply', *Climate Change Impacts on Water Supply, An International Forum*, Washington DC.

4 Department of Sustainability and Environment, Victoria (2008), 'Augmentation of the Melbourne Water Supply System, Analysis of Potential System Behaviour'.

5 Department of Sustainability and Environment, Victoria (2007) 'Our Water Our Future: the Next Stage of the Government's Water Plan', *Our Water Our Future.*

6&7 Melbourne Water data

8 Victorian Government (2010), *Living Victoria Policy.*

9 See, for example, Binney, P, et al (2010), 'IWA Cities of Future Program – Spatial Planning and Institutional Reform", *World Water Conference*, Montreal.

10 Victorian Government, op cit

11 Living Victoria Ministerial Advisory Council (2011), 'Living Melbourne, Living Victoria Roadmap', Department of Sustainability and Environment, Melbourne.

12 See, for example, Coutts, AM. Beringer, J & Tapper, NJ (2007), 'Impact of Increasing Urban Density on Local Climate', Journal of Applied Meteorology, 47(4).

13 Borison, A & Hamm, G (2008), 'Real Options Analysis and Urban Water Planning in Australia', *WSAA Occasional Paper No. 20*, Melbourne.

14 Wong, T et al (2011), 'Transitioning to a Resilient, Liveable and Sustainable Greater Melbourne', *Final draft report to living Victoria Ministerial Advisory Council*, Melbourne

15 Living Victoria Ministerial Advisory Council, op cit

3.4

A national perspective on urban water

Erin Cini and Will Fargher

Erin Cini is a Director of Element Solutions, a consultancy dedicated to water and sustainability planning and project management. Erin has worked in policy, planning, design and construction of urban water infrastructure in NSW, Queensland, Victoria and the ACT, and holds an honours degree in environmental engineering. As the Project Manager of the *Urban water in Australia: future directions project*, Erin was responsible for the coordination of the iterative project process, including engagement of over 50 Australian and international water experts and a set of supporting research reports.

Will Fargher, General Manager of the Water Markets and Efficiency Group, is responsible for analysis and reporting of water reform matters involving urban water, water industry performance and pricing, water trading, rural water use and structural adjustment. Will has been working on water policy and management at the Australian state and federal level for the past nine years. He is a Churchill Fellow, and holds bachelor degrees in economics and arts, an honours degree in geography and master of environmental science.

Introduction – about the report

The National Water Commission's 2007 and 2009 biennial assessments of progress in the implementation of the National Water Initiative (NWI) raised concerns about the performance of the urban water sector (NWC 2007, 2009) and declared that the NWI did not give sufficiently clear guidance on the required direction for urban water reform.

To resolve this and provide evidence and analysis for the Commission's 2011 biennial assessment (NWC 2011a), and to inform governments' decisions on urban water policy, the Commission launched the Developing Future Directions for the Australian Urban Water Sector project in mid 2010.

The project built an evidence base of direct engagement with over 50 Australian and international water experts and a set of supporting research reports in order to:

- Assess the current performance of urban water policy and institutional settings against a set of clear objectives, and in the light of challenges and opportunities; and
- Make recommendations on nationally important urban water issues to ensure the sector is well placed to meet customer and community expectations in the future.

In *Urban water in Australia: future directions* (released in April 2011) the Commission catalyses an informed and practical discussion of national priorities for urban water and presents a sound and coherent program of action. This chapter briefly summarises that contribution.

Challenges and opportunities

The urban water sector faces many external and internal challenges in meeting customers' and the community's diverse and evolving water service requirements (see Box 1). In the Commission's view, the most pressing of these challenges are:

- Securing supply efficiently in the context of significant uncertainty about inflows to catchments and continuing growth in urban population;
- Meeting customer and community expectations in an effective and efficient manner; and
- Maintaining effective wastewater services and maximising opportunities for efficient integrated water management (IWM) solutions without compromising public health and the environment.

These challenges are also opportunities—it is vital that the arrangements put in place for managing urban water allow the sector as a whole to respond to them in the best possible way.

Box 1:
Challenges facing the urban water sector

While the precise nature and scale of the challenges vary around the country, they include the following:

Catering for rapid population growth:

Providing services to a growing population and rapidly expanding urbanised areas. The Water Services Association of Australia (WSAA) estimates that demand for water in the six major cities could increase by 40 per cent – 50 per cent, from 1505GL per year in 2009 to approximately 2100GL per year by 2026 (WSAA 2010).

Managing impacts of climate variability and climate change:

Managing and adapting not only to supply variability, but also to the potential impacts of climate change, which are likely to include the inundation of coastal infrastructure, flash flooding in urban areas, severe storms and more frequent bushfires (Hennessey et al. 2007).

Managing current and future investment programs and associated cost increases:

The WSAA (2010a) notes that at least $10.5 billion is being spent on major water and wastewater projects underway or to begin in 2010–11 in Australian capital cities. Major investments are likely in the future, including in the wastewater sector, where investment needs are large. While demonstrating value for money to customers and regulators, the sector must decide whether to replace ageing infrastructure or to consider other options.

Providing acceptable water and wastewater services in regional areas:

Ensuring safe, reliable and cost-effective delivery of water and wastewater services in regional towns and remote and isolated communities.

Optimising the use of and investment in a diverse portfolio of sources:

Optimising the use of multiple climate-dependent and independent supply sources to balance security, cost and other network constraints.

Managing energy use and greenhouse gas emissions:

Managing energy usage and costs while taking advantage of opportunities to generate energy at wastewater treatment plants.

Effectively harnessing technological development:

Technical advances are increasing the number and types of options available to meet customer water needs, particularly in the area of cost-effective water and wastewater treatment.

Continuing to protect public health in the context of increased recycling:

Managing the actual and perceived risks of greater interconnection between the water, wastewater and stormwater sides of the urban water sector and managing community concerns about the use of recycled water for drinking purposes.

Dealing with an ageing workforce:

Water is a sector that increasingly needs diverse and specialised skills and expertise and it may need to undergo significant culture and generational change to become less engineering-oriented and more diverse and customer-centric.

Findings

Australia's urban water sector has benefited greatly from its history of institutional and pricing reforms. While acknowledging the platform provided by earlier reforms, the Commission argues that to more successfully address the range of contemporary challenges outlined above, the sector needs to change:

- Current arrangements to ensure supply security is fully suited to Australia's climatic conditions and does not suffer from unclear accountabilities;
- There are opportunities to improve service delivery and complete the switch to genuinely focus on customers;
- Water quality regulation for the protection of public health and the environment is not cost-effective and creates barriers to integrated water management (IWM); and
- The sector's contribution towards broader sustainability and liveability needs to be better defined and responsibility properly allocated.

Further change is needed to institutional and policy settings in the urban water sector

In the Commission's view, transparency, accountability, economic efficiency and community confidence have been inadvertent casualties of Australia's response to the drought. While no city ran out of water, there were some close calls.

Governments intervened in water planning and investment decisions, first by restricting demand then by directing large-scale investments to boost supplies. This blurred the lines of accountability and created uncertainty about the roles and responsibilities of those involved in water delivery and regulation.

The community was left with question marks about approaches to water restrictions, water pricing and water quality. There are also questions about the cost-effectiveness of infrastructure investment decisions and programs aimed at managing demand, such as industry water-use efficiency audits.

In detailing the deficiencies in underlying policy and institutional arrangements the Commission presented evidence of ongoing inadequacies in:

- The definition of water security objectives;
- Institutional roles and responsibilities for supply–demand planning and investment;
- How policy and regulatory instruments (for example, pricing, water restrictions, demand management regulation, recycling targets, artificial policy barriers and government subsidies) are used to manage the supply–demand balance; and
- Planning assumptions, tools and processes (the drought accentuated the problems associated with planning on the basis of long-term averages rather than risks posed by sequences of low inflows).

There are opportunities to improve service delivery and the focus on customers

The Commission believes the water sector is out of step with other utilities in terms of genuine customer focus. Contributing factors include the following:

- The urban water industry in Australia is made up of government-owned monopoly businesses, with very limited direct competition;

- Customers in a number of regions do not yet benefit from fully independent economic regulation;
- Major investment decisions made by governments remain beyond the scrutiny of economic regulators, even though those investments account for most increases in costs and hence price increases to customers;
- In some cases, jurisdictions' approaches to regulation are inhibiting innovation by service providers;
- The capacity and resourcing of service providers in some rural and regional areas is inadequate, particularly in New South Wales and Queensland; and
- Transparency, evaluation and customer engagement in establishing service levels are insufficient.

As a result, customers, governments and service providers are missing out on opportunities for win–win outcomes. All stakeholders in the sector need to focus on how to remove barriers to more competitive and flexible approaches, rather than on reasons why those approaches might not work.

Current regulation of water quality, public health and environmental outcomes is not cost-effective and creates barriers to integrated water management

The Commission found that regulatory arrangements governing urban water quality, with the aim of protecting public health and safety and the environment, have served Australia well. Australia's drinking water is generally safe and of a very high quality.

However, the Commission was concerned that:

- Wastewater treatment and disposal standards are often over prescriptive, input focused, and set without enough consideration of the costs that they impose;
- Uncertainty about regulatory obligations is resulting in confusion and conflict between water service providers and regulators, particularly in relation to environmental outcomes (for example, there is debate over whether the costs of greenhouse gas emissions offsets can be passed on to customers); and
- Frameworks for water quality regulation, particularly for integrated water management, are jeopardised by insufficient and diffused technical expertise and inconsistent approaches to their implementation.

Confusion about the role of the urban water sector in delivering liveability outcomes is stalling progress

The urban water sector is receiving confused messages about its role in contributing to "water sensitive" or "liveable" cities. Opportunities to deliver integrated urban water solutions and adopt water-sensitive design mean water planning is central to urban planning. However, the Commission found that institutional arrangements were generally not yet clear about the role of the sector in:

- Making decisions about and delivering broader public and environmental amenity services;
- Agreeing on objectives and determining how to make trade-offs between costs and benefits that are inherently difficult to measure; and
- Determining who should pay for particular outcomes.

As such, confusion about roles is impeding progress across the board and creating coordination problems.

The lack of agreed objectives for the urban water sector is a fundamental barrier to change

The Commission's report reflected that there are widely divergent views on the future of urban water. The urban water sector is confronted with competing views on its boundaries and objectives, including about:

- Whether water conservation is a public policy objective in its own right or a contributor to economically efficient water use;
- Whether customer choice is worthwhile and whether it has adverse equity impacts;
- How customer service and broader community and environmental outcomes are balanced against the costs of achieving them;
- How potential trade-offs between equity and efficiency should be addressed (particularly in relation to pricing);
- The relative roles and appropriate use of centralised planning (by government) and decentralised decision-making by service providers, the market, or both;
- How sustainability is defined and achieved; and
- How much the urban water industry should be responsible for broader objectives (encapsulated in the term "liveable cities") in urban areas.

The Commission concluded that the absence of a coherent set of objectives for the sector is a major barrier to reform: it leads to policies that are ineffective and costly, that operate at cross-purposes, create confusion between means and ends, and undermine accountability and transparency.

Recommendations

Objectives

The Commission recommended a national statement of objectives for the future direction of the urban water sector:

> *The Australian urban water sector should provide secure, safe, healthy and reliable water-related services to urban communities in an economically efficient and sustainable manner.*

More specifically the Commission stated that in order to: address customer service needs, manage the impacts of the sector on public health and the environment, and play a positive role in shaping the future of urban areas, the sector should:

- Understand and meet the long-term interests of all water consumers in the price, quality, safety, reliability and security of supply of fit-for-purpose water and wastewater services through the efficient use of, and investment in, systems, assets and resources;
- Protect public health and the environment by ensuring that the impacts of the sector's operations and investments are managed cost-effectively in accordance with society's expectations and clearly defined obligations; and
- Enhance its effective contribution to more liveable, sustainable and economically prosperous cities in circumstances where broader social, public health and environmental benefits and costs are clearly defined and assessed, or where customers or other parties are willing or explicitly obliged to pay for the outcomes.

Box 2:
What will a successful Australian urban water sector look like?

The Commission's objectives require an urban water sector in which:

Water supply is secure

- An efficient and secure portfolio of fit-for-purpose water service solutions emerges over time to meet clearly defined and measurable supply security objectives.
- Roles and responsibilities of government, regulators and service providers, including for planning and security of supply, are clearly defined to ensure accountability for performance; policy, regulatory and service delivery roles are clearly separated.
- Calls on taxpayer funds via government subsidies for capital infrastructure projects are limited to circumstances where there are demonstrable public benefits that would not otherwise be able to be funded by the customer base.
- Supply options are not arbitrarily constrained or selected by political fiat.
- Major investment decisions are made transparently and withstand the test of time.
- The sector is well prepared to deal with extreme climatic events and other shocks.

Customers are provided with value-for-money services and have the opportunity to express their values and preferences

- Water and sewerage services are provided at the standards (quality, reliability etc.) customers require at the lowest long-term cost and there is sufficient evidence to demonstrate performance.
- All customers (residential, commercial, industrial and other) are able to choose from a range of water service products at different prices.
- Consumers do not feel guilty for using water to meet their daily needs and there is very limited recourse to water restrictions to balance supply and demand.
- All people in urban areas have access to essential water and sewerage services, regardless of their means.
- Pricing of water aims to achieve economic efficiency; it reflects the value of the resource, not just the cost of infrastructure and operations.
- Equity requirements, such as protecting vulnerable customers, are addressed directly through customer protection frameworks and transparent community service obligations.
- Natural monopoly elements of water and wastewater services are subject to effective, efficient and stable economic regulation applied in a way that promotes innovation and rewards efficiency.
- Innovative approaches and new suppliers are able to freely enter and compete on a level playing field, subject to well-developed regulatory frameworks to safeguard public health, the environment and customers' interests.
- Water service providers understand and have incentives to meet the diverse needs of their customers without facing unnecessary constraints; the industry is customer-driven and service-focused.
- The sector as a whole is able to meet and balance the competing needs and values of customers and the broader public good, based on an informed and open policy dialogue.

… continued next page

Box 2:
What will a successful Australian urban water sector look like? …cont

Public health and the environment are protected

- Public health is protected through consistent and effective risk-based regulation of drinking water quality, effluent discharge and recycled water.
- Waterways, the marine environment and other environmental assets are protected and enhanced through cost-effective, risk-based and outcome-focused regulation and other policy instruments with clearly assigned accountabilities.
- Environmental objectives and requirements are defined, measurable and achievable and are set based on customer and community input, with full recognition of the costs that they impose.
- Environmental flows and allocation arrangements define specifically how resources will be shared under all possible inflow sequences.
- IWM and alternative water sources, including decentralised and potentially privately owned solutions that are fit-for-purpose, are accepted and trusted by the public; regulation does not unnecessarily impede innovative IWM solutions, but such options stand or fall on their own merits.

The sector contributes effectively to broader sustainability and liveability outcomes

- Urban water service providers have clearly defined objectives for their contribution to liveability and look to relevant beneficiaries, not just urban water customers, to fund such broader public benefits.

The characteristics of an urban water sector that meets the Commission's objectives are summarised Box 2.

Council of Australian Governments

The Commission believes COAG has an important role to play in embracing change and establishing a more contemporary set of objectives for the urban water sector. Achieving these objectives requires a national approach to the implementation of priority reforms that are tailored to the needs of jurisdictions and reflect the different requirements of Australia's cities and towns. The Commission recommends COAG:

1. **Objectives:** adopt an agreed set of national objectives for the urban water sector and principles to guide reform.
2. **National approach to implementation:** pursue priority actions for each jurisdiction that contribute materially to national urban water sector objectives, and use stronger incentives and an improved monitoring and evaluation framework to drive timely and effective implementation.

State and territory governments

In addition, the Commission argues all jurisdictions need to act on:

3. **Objectives and accountabilities:** Governments should ensure that service providers, regulators and other parties have clear objectives, accountabilities and strong incentives, which align with specified roles, functions, resourcing and funding.

4. **Customer choice:** Governments, regulators and service providers should ensure that the urban water sector gives a greater voice to customers through exploring opportunities for customer choice in pricing and service delivery, much improved engagement on objective setting and the determination of trade-offs, improved customer protection frameworks, and competition.

5. **Efficient pricing and economic regulation:** Governments and regulators should recommit to using pricing to promote economic efficiency, broaden the coverage of fully independent economic regulation across all urban water systems, and ensure that economic regulation is more flexible to encourage innovation in price and service offerings and better reflect the value of water.

6. **Efficient supply–demand balance:** Governments should review and amend policy settings to ensure that there is a cohesive approach that allows an efficient portfolio of supply, and demand-side measures to emerge and evolve over time, without direct and ad hoc government intervention. Responsible agencies and service providers should adopt risk-based approaches to supply–demand planning. All parties should strive for greater transparency.

7. **Markets and competition:** Governments, regulators and service providers should work actively towards a goal of more market-determined bulk water prices and other market-oriented options.

8. **Regional and rural areas:** Governments and service providers should undertake reforms in regional, rural and remote areas to ensure that there is sufficient organisational, financial, technical and managerial capacity to meet service delivery requirements and protect public health and the environment, particularly in New South Wales and Queensland.

9. **Efficient and effective regulation:** Governments and regulators should better embed mandatory cost-benefit analysis and community engagement in the regulation of public health and the environment (particularly for investment in wastewater systems) to ensure that obligations are cost-effective and reflect community expectations.

10. **Liveability and sustainability:** Governments and service providers should clarify the roles and responsibilities of service providers and other organisations in contributing to more liveable communities. Decisions related to liveable communities need to be supported by more appropriate funding arrangements, based on robust evaluation of the full benefits and costs.

Further supporting recommendations are outlined in the body of the *Urban water in Australia: future directions report.*

Response to the recommendations

Since the release of the *Urban water in Australia: future directions* report the Commission has sought to continue discussion on urban reform with government water departments, regulators, and urban water utilities in Western Australia, South Australia, Tasmania, New South Wales and Queensland.

Discussions have focussed on the need to develop and adopt agreed objectives for the sector and to have general principles to guide reform. The opportunity for a more national approach to the implementation of reforms, including priority actions in each jurisdiction, stronger incentives and an improved framework to drive timely and effective action, has also been discussed.

Consultation and feedback has revealed broad agreement on the need for clear and agreed objectives and accountabilities, efficient pricing and independent economic regulation, efficient and effective regulation of public health and the environment, and more customer focus. It has also revealed preparedness in some quarters to debate the case for reform of regional and rural urban water service provision.

The benefits of implementing these recommendations

The recommendations in *Urban water in Australia: future directions* seek to ensure that urban water is managed using an efficient, adaptive, resilient and customer-driven approach that can respond to the challenges of increasing population, concerns about the affordability of water services, and the impacts of climate change and extreme rainfall variability.

Implementation of these recommendations is expected to produce major benefits to customers, taxpayers and the broader community, including improved customer satisfaction and value-for-money. The reforms will better ensure that water quality risks are managed as Australia adopts more integrated water management solutions, and will improve the resilience and adaptability of urban water systems.

While reform requires effort from governments, regulators and water service providers, they will also obtain major benefits:

- Governments will have greater confidence and certainty that supply security and other planned outcomes are being achieved and that risks are being managed;
- Governments and water businesses will be able to demonstrate performance achievements to customers and the community;
- Decisions will be made with greater confidence and certainty due to improved information, tools and processes;
- The sector as a whole will be more diverse and open to change, and better prepared to deal with known and unknown risks and future challenges;
- Regulators will be able to perform their enforcement roles with greater clarity and confidence; and
- Water businesses will have greater flexibility and incentives to meet customer needs in the most cost-effective manner.

An important lesson from the earlier reform era is that significant change takes time. Given the continued community and political debate about urban water, there is a need for governments, regulators and water service providers to prioritise and adequately resource a fresh cycle of policy and institutional reform effort with long-term benefits in mind.

References

Hennessy KJ, Fitzharris B, Bates BC, Harvey N, Howden SM, Hughes L, Salinger J and Warrick R 2007, Chapter 11, 'Australia and New Zealand', *Climate change 2007: Impacts, adaptation and vulnerability: contribution of Working Group II to the fourth assessment report of the Intergovernmental Panel on Climate Change*, Parry ML, Canziani OF, Palutikof JP, Van den Linden PJ, Hanson CE (eds), Cambridge University Press, United Kingdom.

NWC (National Water Commission) 2007, *National Water Initiative: First biennial assessment of progress in implementation*, NWC, Canberra.

NWC (National Water Commission) 2009, *Australian water reform 2009: Second biennial assessment of progress in implementation of the National Water Initiative*, NWC, Canberra.

NWC (National Water Commission) 2011a, *The National Water Initiative – securing Australia's water future: 2011 assessment*, NWC, Canberra.

NWC (National Water Commission) 2011b, *Urban water in Australia: future directions*, NWC, Canberra.

WSAA (Water Services Association of Australia) 2010, *The WSAA Report Card for 2009–2010: performance of the Australian urban water industry and projections for the future*, WSAA, Melbourne.

Section 4.0

Emerging developments

4.1 Editors' overview

4.2 Emerging food security challenges
Julian Alston and Phil Pardey

4.3 Creating smart water supply chains
Iven Mareels

4.1

Editors' overview

Agriculture was developed about 10,000 years ago and, for the majority of that time, productivity improvements were slow. Over the past 200 years, applying the practices of industrialisation, greater access to fertile land and technological advances in a range of fields have combined to drive a rapid increase in the availability of food and fibre. As a consequence, total production of cereals grew faster than population, from 877 million metric tonnes in 1961 to over 2494 million metric tonnes in 2009 while the world's population more than doubled to around seven billion and real per capita incomes tripled.

The fears the world's burgeoning population would run out of food were not realised because of human ingenuity and technological innovation. However, global food security is being challenged after the reprieve of the so called "green revolution" arising in response to the Club of Rome investigation into food security. Climate change will potentially reduce arable land at the same time that growing wealth in developing economies is increasing the overall human caloric demand. Unless addressed, there will be greater fluctuations and further political unrest over rising food prices.

About the contributors

The contributors to this chapter are:

- Julian Alston and Philip Pardey discuss agricultural R&D and productivity and recommend policies for maintaining long term agricultural productivity growth; and
- Ivan Mareels describes how methods of applying modern technology in *enabling the creation of smart water supply chains* that will help adapt water infrastructure.

Discussion

The long-run evidence on developed country crop yields and productivity tell a consistent story: measurable but comparatively sluggish growth prior to 1950, historically rapid growth for the subsequent four decades 1950–90, the green revolution, and then a substantial slowdown from 1990 forward. In Australia, even extracting the influence of the drought, recent productivity growth has been a fraction of that achieved in earlier periods.

The slow-down in productivity growth has coincided with a shift in focus of public research and development funding. While worldwide public investment in agricultural R&D increased by 35 per cent in real terms between 1981 and 2000, expenditure is focused on concerns such as the environmental effects of agriculture and food safety rather than farm productivity. Likewise, the private sector emphasises inventions that are amenable to various intellectual property (IP) protection options such as hybrid crops, patents, and more recently, plant breeders’ rights and other forms of IP protection.

The global decline in agricultural productivity is a result of the success of the green revolution which bred complacency. The urgency for policy makers is that there is a major lag between research and development and increases in productivity. Meanwhile, the impacts of climate change on productive agricultural land, growing use of biofuels and rising global caloric demand will combine to destabilise food prices and lead to political unrest, an existing phenomenon which will worsen. Considerably more investment needs to take place to improve the levels of productivity.

There is considerable scope to improve productivity of existing water supply distribution infrastructure by implementing smart operating technology. This infrastructure is currently both ageing and not capable of handling the extreme weather events associated with climate change but can be significantly improved through the application of technological advances.

One option is to create a smart grid that utilises cloud computing and network sensors to dramatically improve the efficiency of water distribution infrastructure. Such intelligent, interconnected infrastructure enables exploitation of existing civil infrastructure to full capacity, delivering a superior water distribution service. In addition it enables preventative maintenance, and allows operators to cope with extreme circumstances without greatly sacrificing performance.

The holy grail of smart water systems can be deployed throughout an entire water catchment area, that integrates both ground water and surface water, all water users (urban, rural, industrial as well as environmental), and keeps track of not only the water flow and water balance but also the water quality aspects. This would enable much higher levels of productivity from existing water infrastructure.

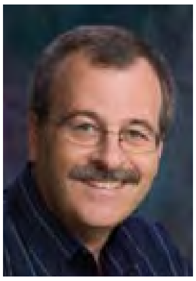
There are many significant regulatory and legislative reforms required for a catchment smart water system to be deployed. However, the technology is available and can deliver large improvements in economic return using the same inputs.

4.2

Emerging food security challenges

Julian M Alston, Philip G Pardey

Julian M Alston is a Professor in the Department of Agricultural and Resource Economics of the University of California, Davis, where he teaches microeconomic theory and the analysis of agricultural markets and policies. At UC Davis, he is a member of the Glannini Foundation of Agricultural Economics, Director of the Robert Mondavi Institute Center for Wine Economics and Associate Director for science and technology policy at the University of California Agricultural Issues Center. Alston was raised on the family farm in northern Victoria, Australia, and prior to beginning in his current position in 1988, he was the Chief Economist in the Department of Agriculture in Victoria, Australia. He has published many journal articles and books. A complete listing of publications is available at http://agecon.ucdavis.edu/people/faculty/julian-alston/selected-publications/.



Philip Pardey is Professor of Science and Technology Policy in the Department of Applied Economics at the University of Minnesota where he also directs the University's International Science and Technology Practice and Policy (InSTePP) center. Previously he was a senior research fellow at the International Food Policy Research Institute, Washington DC, and prior to 1994 at the International Service for National Agricultural Research in The Hague, Netherlands. He currently co-directs a Gates Foundation project, HarvestChoice (www.HarvestChoice.org), designed to inform and guide investments intended to stimulate productivity growth in African agriculture. Pardey is author of more than 220 books, articles, and papers. A complete listing of publications is available at www.apec.umn.edu/faculty/ppardey/publications.html.

Introduction: R&D, productivity, and scarcity

In the past half-century, agricultural science achieved a great deal. Since 1960, the world's population has more than doubled, from 3.1 billion to almost seven billion today, and real per capita income has more than tripled. Over the same period, total production of cereals grew faster than population, from 877 million metric tonnes in 1961 to over 2494 million metric tonnes in 2009, largely because of unprecedented increases in crop yields.[1] The fact that the Malthusian nightmare was not realised over the past 50 years is attributable in large part to improvements in agricultural productivity achieved through technological change enabled by investments in agricultural research and development (R&D). Looking forward, however, the prospects for the next 50 years do not appear as promising. Around the world we have seen a slowdown in agricultural productivity growth rates. Meanwhile, other demands are placing pressure on the stocks of natural resource available for agriculture, while the expectation of climate change is giving rise to increased demands for maintenance and adaptive research, simply to prevent agricultural productivity from falling.

These trends, coupled with increasing non-farm competition for water and land, and competition from biofuels demand for agricultural capacity, spell slower growth in the supply of food. In turn, these prospects raise concerns about the implications for the world food equation, the future price of food, the incidence of poverty and malnutrition around the world, and the resulting pattern of demand for land and water for agricultural use over the next few decades.

Productivity improvements in agriculture are strongly associated with lagged R&D spending.[2] Thus, the rate of growth of investments in agricultural R&D and the uses to which those research dollars are put will be a pivotal determinant of long-term growth in the supply, availability, and price of food over the coming decades, and the demands for services of natural resource stocks, including land and water.

A natural and appropriate policy response to the present circumstances would be to take steps to reinvigorate spending on agricultural science with a view to enhancing farm productivity in rich and poor countries alike. But only a few countries appear to be doing more than pay lip service to this imperative. In contrast, and even though rates of return to agricultural research are demonstrably very high, we have seen a slowdown in spending growth and a diversion of research funds away from farm productivity enhancement, especially in developed countries. In this chapter, we review the worldwide patterns of agricultural productivity growth and developments in agricultural R&D investments and institutions, with particular attention to Australia in that context, and draw inferences for policy.

Agricultural productivity growth

Agriculture was invented about 10,000 years ago. Since then, increases in agricultural production have been engendered through a combination of increases in resources devoted to production and increases in productivity, achieved through the application of improved methods and materials and changes in the scale and scope of farm enterprises. For much of human history agricultural productivity growth was relatively slow, and achieved mainly by informal processes of trial and error, tinkering and selection, by individual farmers. But in the past 200 years, supplanted increases in the amounts of measured land and labour employed as a driver of increases in total availability of food and fibre, and this accelerating productivity growth, was increasingly driven by public and private investments in organised agricultural science. Scientific crop breeding and modern approaches to agronomy, animal husbandry, and other agricultural R&D activities began to gather pace at the turn of the 20th century. The rates of agricultural innovation and productivity growth accelerated in the 1930s, 1940s and 1950s as waves of new technologies became available and spread over farmers' fields.

A global slowdown in agricultural productivity growth

In recent decades, on-farm productivity growth has been the main driver, and has contributed enormously to growth in supply of food and fibre. Over the past half-century aggregate agricultural productivity growth worldwide has generally fluctuated around a long-term average rate of between one per cent and two per cent per year, typically faster than productivity growth in the rest of the economy. These broad averages mask a lot of variation among places and over time, but the broad pattern is remarkably similar among the more developed countries, and in many countries we have witnessed a slowdown in farm productivity growth in the most recent 20 years.

Consider US agriculture, for which we have relatively detailed information, and which broadly represents patterns in many countries. In 2007, US agriculture produced more than four and half times the quantity of agricultural output produced in 1910. The 1.58 per cent per year increase in output from 1910–2007 was achieved with only a 0.16 per cent per year increase in the total quantity of inputs. Consequently, in 2007 it required only 1.2 times the 1910 quantity of inputs to produce 4.6 times the 1910 quantity of agricultural output, a very significant increase in agricultural productivity.

Measures of agricultural productivity growth for the US — be they crop yields, other partial factor productivity measures (for example, measures of land and labour productivity), or indexes of multi-factor productivity — show generally consistent patterns in terms of secular shifts, including indications of a slowdown in growth since 1990.[3] The long-run evidence on US crop yields and productivity tells a consistent story: measurable but comparatively sluggish growth prior to 1950, historically rapid growth for the subsequent four decades 1950–90, and then a substantial slowdown from 1990 forward.[4] This slowdown reflects in particular the fact that productivity grew at historically high rates during the decades of the 1960s, 1970s, and 1980s.

Paralleling productivity developments in the US, the evidence of a slowdown in crop yields throughout the world is quite pervasive. In more than half of the countries growing each crop, yields for rice, wheat, maize and soybeans grew more slowly during 1990–2007 than during 1961–90. Likewise, during 1990–2007 compared with 1961–90 (Table 1), land and labour productivity growth slowed considerably among the world's top 20 producers (according to their 2005 value of agricultural output), once the large, and in many respects exceptional, case of China is set aside (Table 2). Across the rest of the world, the slowdown was even more pronounced. For this group of countries, on average, land productivity grew by 1.74 per cent per year during 1961–90, but only 0.88 per cent per year thereafter; labour productivity grew by one per cent per year during 1961–90, but barely changed over the period since then.

TABLE 1
GLOBAL YIELD GROWTH RATES FOR SELECTED CROPS, 1961–2007

	Maize		Wheat		Rice		Soybeans	
Group	1961–90	1990–07	1961–90	1990–07	1961–90	1990–07	1961–90	1990–07
per cent per year								
World	2.20	1.77	2.95	0.52	2.19	0.96	1.79	1.08
North America	2.20	1.40	2.23	0.01	1.67	1.54	1.05	0.04
Western Europe	3.30	1.81	3.31	0.63	0.38	0.55	1.64	0.05
Eastern Europe	1.91	0.97	3.18	–1.69	– 0.41	1.07	1.90	2.29
High Income	2.34	1.48	2.47	0.06	1.07	0.54	1.14	0.02
Middle Income	2.41	2.12	3.23	0.85	2.54	0.81	3.21	2.08
Low Income	1.07	0.65	1.32	2.15	1.46	2.16	2.63	0.00

Source: Updated version of Appendix Table S1 in Alston, JM, Beddow, JM & Pardey, PG 2009a, *Agricultural Research, Productivity, and Food Prices in the Long Run*, *Science*, vol. 325, no. 4, September, pp. 1209 – 1210; see also Alston, JM, Beddow, JM & Pardey, PG 2009b, *Mendel versus Malthus: Research Productivity and Food Prices in the Long Run*, Department of Applied Economics Staff Paper No. P09 – 01, St Paul, University of Minnesota, January (revised September).

TABLE 2
GROWTH IN AGRICULTURAL LAND AND LABOUR PRODUCTIVITY WORLDWIDE, 1961–2005

	Land productivity		Labour productivity	
Group	1961–90	1990–05	1961–90	1990–05
World	2.03	1.82	1.12	1.36
excl. China	1.90	1.19	1.21	0.42
excl. China & USSR	1.91	1.57	1.13	0.73
Latin America	2.17	2.83	2.15	3.53
Asia	2.56	3.01	1.83	2.72
excl. China	2.45	1.83	1.69	1.24
China	2.81	4.50	2.29	4.45
Africa	2.18	2.21	0.68	0.90
Low income countries	2.00	2.39	0.46	1.03
Middle income countries	2.35	2.30	1.51	2.02
excl. China	2.18	1.37	0.39	0.81
High income countries	1.61	0.72	4.26	4.18
Top 20 producers	2.11	2.16	1.17	1.77
excl. China	1.98	1.38	1.33	0.63
Other producers	1.74	0.88	1.00	0.07

Notes: Labour is measured as economically active workers in agriculture. Land is the sum of area harvested and permanently pastured areas. Output is a value of production measure developed by the authors by weighting a time series of country specific commodity quantities (spanning 155 crop-related and 30 livestock-related commodities) with an unpublished 1999–2001 global average of commodity-specific international prices developed by Food and Agriculture Organisation.

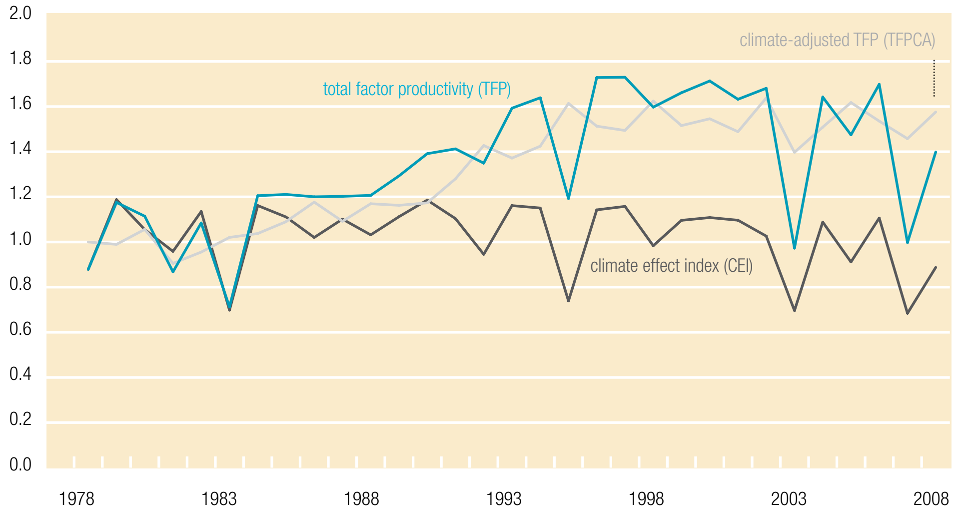
Source: Updated version of Appendix Table S2 in Alston, JM, Beddow, JM & Pardey, PG 2009a, *Agricultural Research, Productivity, and Food Prices in the Long Run, Science*, vol. 325, no. 4, September, pp. 1209–1210; see also Alston, JM, Beddow, JM & Pardey, PG 2009b, *Mendel versus Malthus: Research Productivity and Food Prices in the Long Run*, Department of Applied Economics Staff Paper No. P09–01, St Paul, University of Minnesota, January (revised September).

Australia’s agricultural productivity experience

The productivity pattern for Australia parallels that in other more developed countries, but with an important difference — the effects of the prolonged drought affecting much of Australia for most of the 21st century, which makes it harder to identify the effects of a slowdown in the underlying rate of productivity growth attributable to technological change and increasing efficiency of farm production. However, a recent ABARES study adjusted conventional measures of total factor productivity (TFP) for the effects of climate, and derived a climate-adjusted TFP (TFPCA) for all cropping farms in Australia.[5] Both TFP and TFPCA grew relatively rapidly up to the mid 1990s, but since then both productivity indexes fluctuated around an essentially flat (TFPCA) or declining (TFP) path (Figure 1).

FIGURE 1

AVERAGE CLIMATE-ADJUSTED TFP FOR ALL AUSTRALIAN CROPPING FARMS, 1977–78 TO 2007–08



Source: Hughes, N, Lawson, K, Davidson, A, Jackson, T & Sheng, Y 2011, *Productivity pathways: climate adjusted production frontiers for the Australian broadacre cropping industry*, ABARES research report 11.5, Canberra (Figure 16).

Hughes et al. (2011) decomposed changes in climate-adjusted TFP into three components: technical change, technical efficiency change, and scale-mix efficiency change.[6] They concluded that technical change — resulting from the development and adoption of new management practices and technologies — has been the primary driver of long-run productivity growth in the Australian cropping industry (including mixed cropping-livestock as well as cropping specialist farms). Even after controlling for climate effects, the rate of growth in productivity from technical change slowed for all farm types, from an average rate of 1.95 per cent per year during the period 1977–78 to 1999–2000 to 0.40 per cent per year during the period 1999–2000 to 2007–08.

In the light of these dismal findings, Hughes et al. (2011, p. 41) concluded:

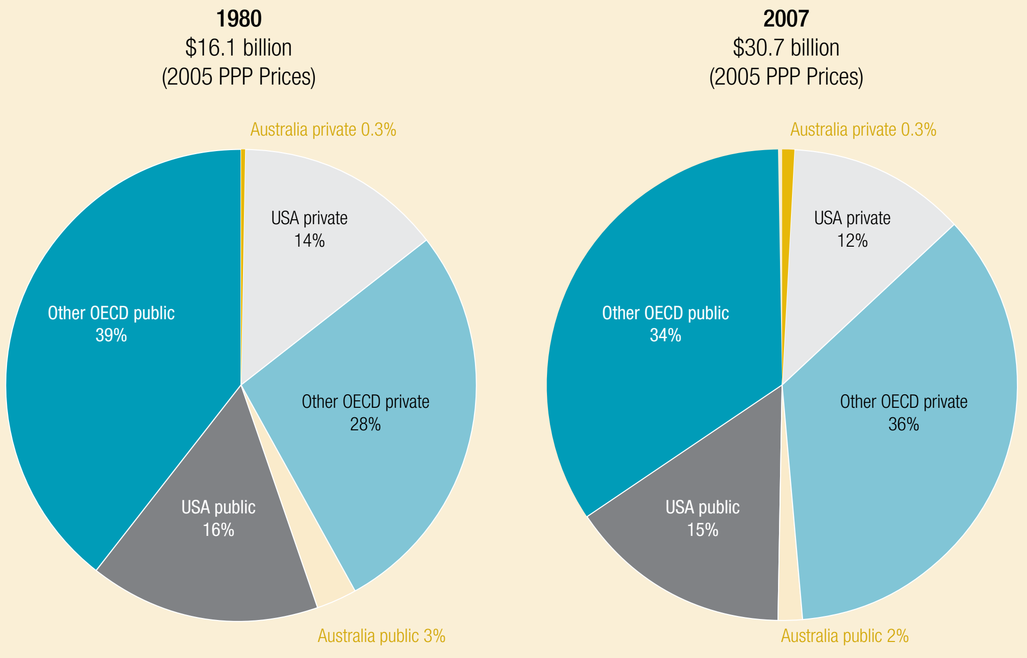
> *“The results from this study have direct implications for the size and mix of funding directed toward R&D, extension, and climate adaptation activities across the Grains Research Development Corporation (GRDC) region. They suggest that technical change, the component of TFP expected to be directly affected by the size and composition of R&D investment is the key driver of productivity growth in the grains industry over the long run.”*[7]

Agricultural R&D investments and institutions

Many factors may have contributed to the slowdown in agricultural productivity growth in Australia and in other countries. Besides changes in weather or climate, land degradation, shifts or expansion of the location of production into less favourable environments, farmer responses to resource scarcity or higher prices of inputs, changes in public institutions, and evolving pests and diseases may have contributed. Agricultural R&D is an important element of the story, a critical policy instrument that governments can affect to influence the path of agricultural productivity. The lags between investing in agricultural R&D and realising a productivity-enhancing return on that investment are long — a matter of decades not years — which dictates taking a very long-run perspective on R&D spending trends.

Total (public and private) food and agricultural R&D spending by OECD countries almost doubled from an estimated $16.1 billion dollars in 1980 to $30.7 billion in 2007 (both in 2005 purchasing power parity [PPP] prices), and the private share inched up from an average of 42 per cent in 1980 to 49 per cent in 2007 (Figure 2). The United States accounted for 27 per cent of all public and private agricultural R&D spending by OECD countries in 2007; the Australian share was 2.3 per cent. However, in recent decades, in a context of generally slowing growth of public spending the more-developed countries, that have historically contributed the lion's share of funding for both public and private agricultural R&D, have been diverting their capacity for science away from agriculture and, within their agricultural science budgets, away from farm productivity enhancement.

FIGURE 2
AGRICULTURAL R&D INVESTMENTS IN OECD COUNTRIES, 1980 AND 2007



Source: Pardey, PG & Chan-Kang, C 2011, 'Private and Public Agricultural Research Developments in High-Income Countries, 1970–2007', Department of Applied Economics Staff Paper. St. Paul: University of Minnesota (in preparation).

Public-sector agricultural R&D – global trends

Worldwide, public investment in agricultural R&D increased by 35 per cent in inflation-adjusted terms between 1981 and 2000, growing from an estimated USD $14.2 billion to USD $20.3 billion in 2000 international USD.[8] It grew faster in developing countries (from USD $5.9 billion to USD 10 billion, a 53 per cent increase), and the developing world now accounts for about half of global public-sector spending — up from an estimated 41 per cent share in 1980. However, developing countries account for only about one-third of the world's total agricultural R&D spending when private investments are included.

Public spending on agricultural R&D is highly concentrated. The US alone constituted almost 20 per cent of global spending on publicly performed agricultural research. The Asia and Pacific region has continued to gain ground, accounting for an ever-larger share of the world and developing country total since 1981 (25.1 per cent of the world total in 2000, up from 15.7 per cent in 1981). In 2000, just two countries from this region, China and India, accounted for 29.1 per cent of all expenditure on public agricultural R&D by developing countries (and more than 14 per cent of public agricultural R&D globally), a substantial increase from their 15.6 per cent combined share in 1981. In stark contrast, sub-Saharan Africa continued to lose ground — its share fell from 17.9 per cent of the total investment in public agricultural R&D by developing countries in 1981 to 11.9 per cent in 2000.

The substantial growth in public agricultural R&D investments over the long haul masks important details: notably a marked slowdown in the growth of spending in recent decades and a shift in the focus of the research away from growing more food and feed and towards other policy priorities. Moreover, research funds have been redirected away from farm productivity towards other concerns such as the environmental effects of agriculture, food safety and other aspects of food quality, and the medical, energy, and industrial uses of agricultural commodities. For example, in 1976, an estimated 65 per cent of all research conducted by the State Agricultural Experiment Stations in the US was directed to maintaining and enhancing farm productivity; by 2009 this share had slipped to 56 per cent.

Private sector agricultural R&D – global trends

The private sector emphasises inventions that are amenable to various intellectual property (IP) protection options such as hybrid crops, patents, and more recently, plant breeders' rights and other forms of IP protection. The private sector has a large presence in agricultural R&D, but with dramatic differences among countries. In 2000, the global total spending on agricultural R&D (including pre-, on-, and post-farm oriented R&D) was estimated to be US$33.7 billion. Approximately 40 per cent was conducted by private firms and the remaining 60 per cent by public agencies. Notably, 95 per cent of that private R&D was performed in developed counties, where some 55 per cent of total agricultural R&D was private, a sizeable increase from the 44 per cent private share in 1981.

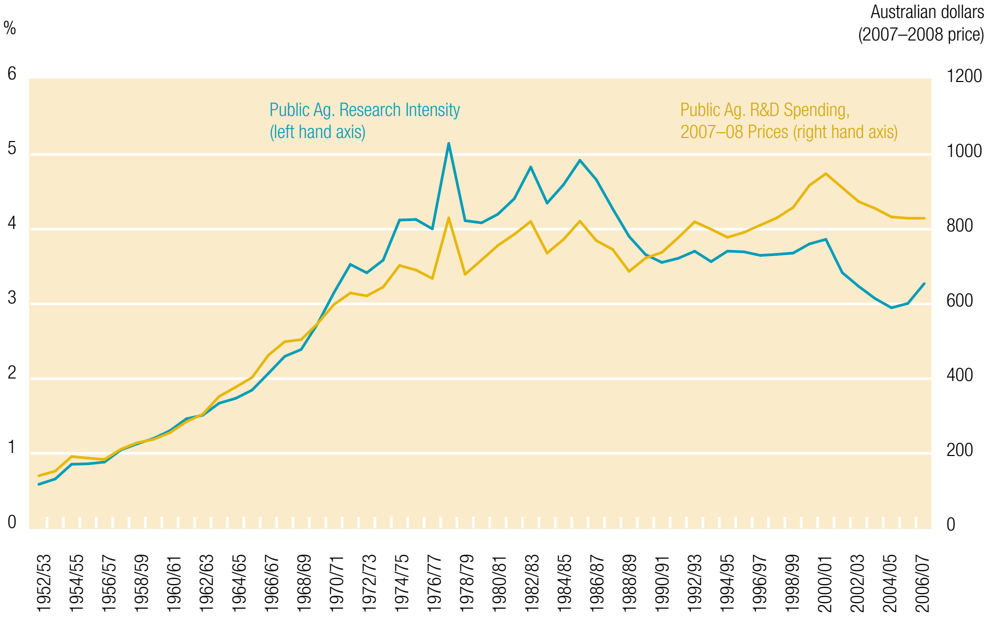
However, around the general trend was much country-specific variation. Compared with the US, Japan conducted a slightly larger share of its agricultural R&D in the private sector whereas Australia and Canada — both reliant on privately developed, technology-intensive imports of farm machinery, chemicals and other agricultural inputs

— had private-sector shares of agricultural R&D spending of less than 35 per cent in 2000.[9] In developing countries, only 6.4 per cent of the agricultural R&D was private, with large disparities in the private share among regions of the developing world.

Agricultural research in Australia

Australia has a unique national agricultural research system, with a central role played by R&D corporations that are funded using a combination of commodity levies and matching Commonwealth Government support. This structure might be expected to insulate Australian agriculture to some extent from the megatrends among the world's high-income countries that have been diverting funding support away from agricultural R&D and, within that, away from farm productivity enhancement. Nevertheless, the trends in real public investment and research intensity in Australian agriculture mirror those in many other high-income countries (Figure 3). Real (i.e., inflation-adjusted) public R&D investment in Australian agriculture has been essentially flat since the late 1970s, apart from a brief bump in the early 2000s, and anecdotal evidence indicates that a shrinking fraction of that fixed amount has been devoted to farm productivity enhancement; research intensity, the research investment expressed as a percentage of the gross value of farm production (GVP) has been shrinking, from a high of around five per cent in the late 1970s, to around three per cent in recent years. This slowdown in growth of spending on agricultural R&D directed at farm productivity enhancement contributed, along with the extended drought, to a slowdown in Australia's aggregate agricultural productivity growth.[10]

FIGURE 3
REAL PUBLIC R&D INVESTMENT AND RESEARCH INTENSITY IN AUSTRALIAN AGRICULTURE, 1952–53 TO 2006–07



Notes: Public agricultural research intensity is the ratio of public agricultural R&D spending relative to agricultural GDP expressed as a percentage.

Source: This is a modified version of Figure 1 in Sheng, Y, Gray, EM, Mullen, JD, Davidson A 2011, *Public Investment in Agricultural R&D and Extension: An Analysis of the Static and Dynamic Effects on Australian Broadacre Agriculture*, ABARES Research Report 11.7, Canberra.

Policy implications

Governments around the world have developed policies to encourage private investment in agricultural knowledge systems and to supplement that private investment with public investment. Conservative estimates of benefit-cost ratios for public investments in the range of 10:1 or 20:1 serve as evidence that these policies have paid handsome dividends, and that they have not gone far enough — we have been persistently underinvesting in agricultural science. We can speculate as to why. The most obvious and likely explanation is that research benefits are slow to come, in a world in which people and perhaps especially politicians appear to be increasingly impatient, and the effects of research are often difficult to discern from other factors. Partly, too, agricultural science may have been too successful for its own good. Many people now take for granted an abundant, cheap, safe and healthy food supply. In the so-called "Green Revolution", agricultural scientists successfully staved off concerns about food and resource scarcity that were rampant in the 1960s, but in doing so they may have left a legacy of misplaced complacency about the speed and extent to which we can innovate our way around the current concerns about the future capacity of the world to feed itself.

During the past 20 years many countries have experienced substantially slower farm productivity growth rates — typically in the range of one per cent per year or less rather than the two per cent per year of the 1970s and 1980s — especially among the high-income countries for which we have better measures. We see no evidence of a return to the earlier, faster rates. If these slower rates are sustained over the next few decades their cumulative effects will have significant implications for the pattern of productivity and production, and for the world's food supply and prices, for global poverty and political and economic stability, and for the demands placed on the stocks of natural resources.

Revitalised funding and improved institutional and evidence-based oversight of the disbursal of funding for agricultural R&D would go a long way toward reversing the productivity slowdown that has been apparent in recent years, and will be necessary to counteract the new challenges from a changing climate and competing demands placed on the bio-economy. However, the lags between investing in agricultural R&D and realising a social return on these investments are long (typically several decades or more). Thus a sustained (but managed and flexible) commitment is warranted, at least for the key strategic research that is required. If history is any guide to the future, that persistence will be well rewarded.

REFERENCES

Alston, JM, Andersen, MA, James, JS & Pardey, PG 2010, Persistence Pays: U.S. *Agricultural Productivity Growth and the Benefits from Public R&D Spending*, Springer, New York.

Alston, JM, Beddow, JM & Pardey, PG 2009a, 'Agricultural Research, Productivity, and Food Prices in the Long Run', *Science*, vol. 325, no. 4, September, pp. 1209–1210.

Alston, JM, Beddow, JM & Pardey, PG 2009b, 'Mendel versus Malthus: Research Productivity and Food Prices in the Long Run', Department of Applied Economics Staff Paper No. P09–01, St Paul, University of Minnesota, January (revised September).

Alston, JM, Chan-Kang, C, Marra, MC, Pardey, PG & Wyatt, TJ 2000, 'A Meta-Analysis of the Rates of Return to Agricultural R&D: Ex Pede Herculem', IFPRI Research Report No. 113, International Food Policy Research Institute, Washington, D.C.

Hughes, N, Lawson, K, Davidson, A, Jackson, T & Sheng, Y 2011, *Productivity pathways: climate adjusted production frontiers for the Australian broadacre cropping industry*, ABARES research report 11.5, Canberra.

Pardey, PG, Beintema, NM, Dehmer, S & Wood, S 2006, 'Agricultural Research: A Growing Global Divide?', IFPRI Food Policy Report, International Food Policy Research Institute, Washington, D.C..

Pardey, PG, Alston, JM & Ruttan, VW 2010, 'The economics of innovation and technical change in agriculture,' Chapter 22 in B.H. Hall and N. Rosenberg, eds. *Handbook of the Economics of Innovation*, Elsevier, Amsterdam.

Pardey, PG & Chan-Kang, C 2011, 'Private and Public Agricultural Research Developments in High-Income Countries, 1970–2007', Department of Applied Economics Staff Paper. St. Paul: University of Minnesota (in preparation).

Sheng, Y, Gray, EM, Mullen, JD, Davidson A 2011, *Public investment in agricultural R&D and extension: an analysis of the static and dynamic effects on Australian broadacre agriculture*, ABARES Research Report 11.7, Canberra.

United Nations Food and Agriculture Organisation (FAO), FAOSTAT online database, accessed at http://faostat.fao.org, September 2009.

ENDNOTES

1 Obtained from United Nations FAO, FAOSTAT online database, accessed at http://faostat.fao.org, September 2009.

2 See Alston, JM, Chan-Kang, C, Marra, MC, Pardey, PG & Wyatt, TJ 2000, 'A Meta-Analysis of the Rates of Return to Agricultural R&D: Ex Pede Herculem', IFPRI Research Report No. 113, International Food Policy Research Institute, Washington, D.C.; and Pardey, PG, Alston, JM & Ruttan, VW 2010, 'The Economics of Innovation and Technical Change in Agriculture', Chapter 22 in B.H. Hall and N. Rosenberg, eds. *Handbook of the Economics of Innovation*, Elsevier, Amsterdam.

3 See Alston, JM, Beddow, JM & Pardey, PG 2009a, 'Agricultural Research, Productivity, and Food Prices in the Long Run', *Science*, vol. 325, no. 4, September, pp.1209–1210; and Alston, JM, Beddow, JM & Pardey, PG 2009b, *Mendel versus Malthus: Research Productivity and Food Prices in the Long Run*, Department of Applied Economics Staff Paper No. P09–01, St Paul, University of Minnesota, January (revised September).

4 Alston, JM, Andersen, MA, James, JS & Pardey, PG 2010, *Persistence Pays: U.S. Agricultural Productivity Growth and the Benefits from Public R&D Spending*, Springer, New York.

5 Hughes, N, Lawson, K, Davidson, A, Jackson, T & Sheng, Y 2011, *Productivity pathways: climate adjusted production frontiers for the Australian broadacre cropping industry*, ABARES research report 11.5, Canberra.

6 Source: Hughes, N, Lawson, K, Davidson, A, Jackson, T & Sheng, Y 2011, *Productivity pathways: climate adjusted production frontiers for the Australian broadacre cropping industry,* ABARES research report 11.5, Canberra.

7 Source: Hughes, N, Lawson, K, Davidson, A, Jackson, T & Sheng, Y 2011, *Productivity pathways: climate adjusted production frontiers for the Australian broadacre cropping industry,* ABARES research report 11.5, Canberra.

8 Year 2000 is the last year for which internationally comparable data on agricultural R&D investments are presently available.

9 Pardey, PG, Beintema, NM, Dehmer, S & Wood, S 2006, *Agricultural research: a growing global divide?* IFPRI Food Policy Report, International Food Policy Research Institute, Washington, D.C.

10 Sheng, Y, Gray, EM, Mullen, JD, Davidson, A 2011, *Public investment in agricultural R&D and extension: an analysis of the static and dynamic effects on Australian broadacre agriculture*, ABARES Research Report 11.7, Canberra.

4.3

Creating smart water supply chains

Iven Mareels

Since 2007 **Iven Mareels** has been the Dean of The Melbourne School of Engineering. He is a Fellow of the Academy of Technological Sciences and Engineering, Australia (ATSE), a Fellow of the Institute of Electrical and Electronics Engineers (FIEEE, USA), a member of the Society for Industrial and Applied Mathematics (SIAM), a Fellow of the Institute of Engineers Australia (FIEAust) and is a Foreign Member of the Royal Flemish Belgian Academy of Sciences and Humanities.

Iven Mareels is registered as a Corporate Professional Engineer and he is a member of the Engineering Executives chapter of Engineers Australia.

Iven Mareels is a Professor of Electrical and Electronic Engineering, who has published widely. In 2008 he received a Clunies Ross Medal from the ATSE for his systems engineering work for irrigation systems.

Introduction

The application of technological advances from other sectors can significantly boost agricultural and urban water productivity. The design and construction principles underpinning water supply infrastructure, both urban and rural, were conceived in the 19th century. This infrastructure is both ageing and not capable of handling the extreme weather events associated with climate change.

One option is to create a smart grid that utilises cloud computing and network sensors to dramatically improve the efficiency of water distribution infrastructure[1]. Such intelligent, interconnected infrastructure enables one to exploit existing civil infrastructure to full capacity, delivering superior water distribution service. In addition it enables preventative maintenance, and allows operators to cope with extreme circumstances without greatly sacrificing performance.

The application of smart meters is being driven by ongoing drivers to improve the productivity of agriculture, to improve the resilience of water infrastructure, to alleviate a world wide crisis in water management and to manage water knowledge at the unprecedented scale required to manage water in a period of climate change.

A knowledge economy case for smarter water

The developed world is moving into the so called knowledge economy phase of the industrial revolution. This chapter highlights why the water supply chain cannot be left behind and how significant advances in technology are available to make water, its distribution and management an integral part of the world's knowledge economy. By doing so it will be feasible to create new wealth in the agri-business sector while remaining within the capacity limits of the environment.

Despite the opportunities there has been relatively little action in this direction, with some notable exceptions. These include:

- The significant investment in the Northern Victorian Irrigation Renewal Project – an important development which should be built on and leveraged further to unlock the significant potential of the region, while maintaining its unique environmental value.
- A subproject, the FutureFlow project has also won several major engineering awards for upgrading irrigation infrastructure providing near autonomous irrigation channel management with clear gains in water distribution efficiency; and
- The National Water Commission supported project *Farms, Rivers and Markets* has demonstrated further the economic potential within the setting of the Dookie Campus, The University of Melbourne's 2500 ha experimental farm and managed landscape environment. In this project research teams from land and environment and engineering as well as National Information and Communications Technology Australia (NICTA) worked together to demonstrate the enormous economic potential of data mining and on-farm knowledge management.

Internet based cloud computing services

Internet based cloud computing services can provide the tools to unlock knowledge available in the context of food production, land management and water management. Presently, only a small fraction of the available knowledge is utilised and most is not readily accessible by those who could benefit the most, those who manage the

FIGURE 1

SOIL MOISTURE MONITORING AT THE UNIVERSITY OF MELBOURNE'S DOOKIE CAMPUS

land, water and food production. This knowledge base is growing extremely fast, with contributions coming from around the globe. Knowledge expansion is so rapid that it is not feasible for any one person to read or even sort through it, or to decide what does or does not apply to the specific circumstances of interest. Computer aided tools are essential to unlock the potential of the existing knowledge base.

Moreover, as more measurements become available from networked sensors (sensors on the farm, in water channels, micro-climate measurements, remotely sensed data, irradiation, soil-water content, environmental sensors and so on) enormous opportunity exists to update the global knowledge base and develop a level of local understanding at an unprecedented scale of spatial and temporal resolution. Again these rich data sets cannot be manually interpreted, and when properly unlocked significant economic productivity can be gained. Indeed sub-projects in *Farms, Rivers and Markets* have shown that a 50 per cent improvement in economic return, using the same resources (land, water, energy) is feasible in the context of horticulture, viticulture and dairy.[2]

Building the tools to bring together the global knowledge data base with the local measurements data base so as to create new economic value from the farm level to the regional level, is an exciting research and development direction that needs to be vigorously pursued in this country.

It is only by combining the best environmental and agricultural science and engineering together with the local land knowledge that we will be able to chart a way forward in sustainable land management in pursuit of the real goal: to produce twice the amount of food in such a way that we do not deplete the environmental capacity and diversity, and maintain an economically attractive food production sector. Any other approach simply lacks credibility.

There are many issues in this context that need development. It is proposed that we create an environment where end-users interact seamlessly with practitioners, early technology adopters, research and development engineers and scientists to make this feasible. In this manner a relevant translation feedback loop between new science and engineering and economically relevant outcomes is created. The Dookie campus is uniquely placed to provide a home for such an enterprise, including a full demonstration site on a scale that is realistic from the small to medium farm perspective.

Internet based tools have to be conceived that allow all users to interact with the available knowledge, upload their information and data, and obtain relevant answers to their queries. The presently available tools are inadequate to this end.

Also not all data is created equal. So called “meta data” (digital information that describes the rest of the data in such a way that allows the uninitiated to interpret the meaning of the data) has to be maintained in order to archive the available measurements in a meaningful way. In particular, meta data should contain the answers to questions such as: what does the data represent? How was it obtained? What is the uncertainty associated with the data? A whole new level of standardisation needs to be considered, going well beyond what is conceived at present, and which assures the value of the measurement over time (and well past the use by date of the instrument).

Equally, managing local data opens up interesting legal, ethical and technological questions around security and privacy of the data. Some questions that need to be considered include: Who owns the data? Does anyone own the information in “their” ground water? Is water use a private piece of information? Or should this data serve the community? Is my water use limiting your water use? After all there is only one water system on the planet, we are all connected through the same water cycle. As someone said, there is a non-zero probability that you are drinking water that went through Julius Ceasar’s kidneys. What about water quality? Who will speak for the environment? In addition, is there a third level of ownership that we need to consider.

Besides the physical land ownership and water ownership, what about the information content of land and water? Should this belong to the community? Or could we contemplate a level of private ownership of such information, even assign it an economic value, different from the physical ownership of water and/or land, after all the interpretation of this data can lead to wealth creation, or at least a better exploitation of the physical resource. Should someone pay a penalty for not using water in the most efficient manner (as revealed by the data)?

An ageing water infrastructure and climate adaptation

The primary aim of water supply infrastructure is to provide a reliable service of water fit for purpose. The remainder of the water infrastructure is to ensure adequate drainage and sewerage. In the urban context this means in the first instance supplying healthy, potable water on demand; and providing support for a diversity of water services including such things as fire hydrant support.

In the context of irrigation water, by far the dominant demand for water, water infrastructure is about supplying a high quality of water in a scheduled manner, as well as ensuring adequate drainage.

The design and construct principles underpinning the civil infrastructure supporting water supply were conceived in the 19th century, and in the developed world most of the infrastructure itself was designed and built in the 20th century.

Perhaps even more importantly, certainly for the developed world, much of the existing infrastructure has to be critically examined from the point of view of sustainable water service. Moreover infrastructure will need to be augmented and adapted to provide for a diversity of supply sources, including a mix of desalinated water, recycled water, surface, as well as ground water.

Climate change is going to require significant adaptation of the available infrastructure and its exploitation. The main issue climate change brings to our infrastructure is a

FIGURE 2
AGEING IRRIGATION INFRASTRUCTURE

greater variance in the natural supply of water, most importantly an increase in the frequency of extreme events, like floods and droughts. Managing infrastructure under extreme event conditions is becoming more demanding as it will increasingly involve considerations well beyond the "water" part of the civil infrastructure (water events affecting transport and energy).

The ageing infrastructure, the need for a more sustainable water service, and climate adaptation all require an infrastructure response. One response option is to design for the extremes, longer life, and more versatility. This is a very safe but also a very expensive approach, perhaps acceptable in a greenfield environment, but particularly challenging in the context of existing and ageing urban infrastructure.

An alternative approach is to make the existing infrastructure smarter, by providing the civil infrastructure with an information infrastructure overlay: a substantial network of sensors and actuators, further supported by decision support software that can analyse the data from the sensors and suggest and/or evaluate a course of actions. This so called "smart water system" brings with it the promise of improved normal operations, extended life of the existing assets because of preventive maintenance, and a new ability to deal with extreme events, without necessarily having to upgrade the entire network to cope with these extreme events.

A world-wide water management crisis

Managing water better is essential, not only in Australia. It has been clearly identified as a major issue facing the world since at least 2000. The Vision Statement of the World Water Council, 2000 stated:

> *"Will continuing the way we manage water lead to a crisis? Yes. Indeed, many countries are already suffering a water crisis that affects their people and the ecosystems we all depend on. More than one billion people lack access to safe drinking water. More than three billion lack access to sanitation. Several countries lack sufficient water to produce food. And with increasing populations and demands on water, other countries will join them..."* [3]

In the mean time, little has changed, as the 2030 Water Resources Group's report *Charting our Water Future*, 2009,[4] indicates. The foreword from this report by His Royal Highness the Prince of Orange, Chairman of the United Nations Secretary-General's Advisory Board on Water and Sanitation states:

> *"The picture shown by the report is certainly sobering: The ever-expanding water demand of the world's growing population and economy, combined with the impacts of climate change, are already making water scarcity a reality in many parts of the world—and with it we are witnessing severe damage to livelihoods, human health, and ecosystems. In just 20 years, this report shows, demand for water will be 40 per cent higher than it is today, and more than 50 per cent higher in the most rapidly developing countries. Historic rates of supply expansion and efficiency improvement will close only a fraction of this gap. Unless local, national and global communities come together and dramatically improve the way we envision and manage water, there will be many more hungry villages and degraded environments—and economic development itself will be put at risk in many countries."*

The lessons learnt in relatively water scarce Australia experiencing serious climate change are going to be applicable in most of the world. Investing in "smarter water" makes a lot of sense, not only for managing Australia's water better, but to create new green-tech jobs that serve water management around the world.

The non-economic case for a smarter water supply

The lack of sufficient investment in water infrastructure is surprising. Why does a free market economy fail to provide adequate water management as is argued by the 2030 World Resources Group in *Charting our Water Future*. This is the more surprising as such a shortage in infrastructure will cause major problems from a health and an economic development point of view.

In the urban context, water's price may be derived from its value as a service. In the rural context the main economic value of water could be derived from it being an input into food production. In an industrial setting water is both a service and a good. Yet, the price of water is not set in terms of its real or perceived value. On the contrary, under the premise that water is in abundant supply on our planet, the water price is almost always set so as to recover infrastructure investments and maintenance discounted typically over a 50 year period. As a consequence, whether a service or an input into a value chain, water use is not really limited by price.

Nevertheless, as the last drought has taught Victorians, the amount of water available for supply does present a hard constraint.

Clearly the value of water and the price of water are simply not aligned, not for the end user, or for those who construct and exploit water infrastructure.

One possible conclusion could be that the present market regulations are simply wrong, and that the most appropriate response should be to liberate the water market from its regulatory shackles. But should water and its associated infrastructure be completely privately owned, and should water only be available to those who can pay? Water is so intrinsically linked to life on earth, that to answer these questions in the positive is almost unthinkable.

Alternatively, accepting present market regulations, there is a need for getting more from the existing water infrastructure, as well as a need for using water more efficiently. Clearly, doing "more with less" is not going to happen under a no-change-scenario.

Making the water infrastructure “smart” may go a long way towards solving this by providing more reliable and timely information into the hands of those that use water and manage water. Better information so that one can better understand the true consequences of one’s decisions will typically lead to improved behaviour, even in the absence of clear price signals. This is the argument for government led investment.

Behavioural changes are indeed key in this context. For example, Melbourne’s recent response to the water restrictions was great to behold. Target 155, running an entire city with an average water consumption of 155 litres of water per person per day was unthinkable a few years ago (and for most cities in the world it is still considered an impossible target), yet a concerned citizenry responded and delivered without price driven incentives.

Smart water infrastructure

As alluded to, smart water infrastructure consists of sensors, actuators, computers, all connected through a communication network, creating an internet of things (also called large scale, interconnected systems, or systems of systems) focused on water and water infrastructure. A proper design is essential to ensure that the coordination of these four assets serves a purpose. To this end, ideas from systems and control engineering are key[5].

Sensors (complete with an internet connection) are essential to gather the observations from the system under management. Measurements can be combined with general (background) knowledge to build mathematical models to interpret the data and present (predictive) scenarios for decision making.

In order to enable proper interpretation of the available data it is essential that the raw measurements are shared together with sufficient meta data. Meta data in this context should describe:

- The actual quantity being measured (pressure, flow, concentration, pH, temperature and so on);
- The principle of measurement as well as general calibration data (range, accuracy, repeatability, stability over time and range, responsiveness) of the sensor; and
- Failure modes and diagnostics.

Unfortunately, these aspects are often neglected. However, they are essential when a large number of sensors are deployed, and when data needs to be integrated with and compared with existing information.

Typically a modern sensor is often better described as a sensor system, as it will contain the basic sensor augmented with microprocessors, secondary sensors (for failure mode diagnostics) and a variety of interfaces to connect with the environment.

SensorML[6] is a particular standard under development that goes a long way towards enabling the exchange of sensor data, although it does not pay enough attention to the failure modes of sensors. However, it is early days in the development of such standards, and despite the impressive list of collaborators in the standard organisation, not many sensor vendors have subscribed to providing this level of detail, even with internet enabled sensors.

When deploying a large number of sensors across a vast geographic area, such as water systems typically occupy, it is particularly important to align the frequency of measurement (in space and time) with the dynamics or the spatio-temporal variability

FIGURE 3
REMOTELY CONTROLLED, AUTOMATED FLUMEGATE™ REGULATORS IN VICTORIA

of the variables that are to be managed.

Actuators, the brawn in the overall network, are essential to enable action to be taken on the civil water infrastructure so as to achieve a desired objective. Typically in a water network these will be valves or regulators to change the water flow (amount and/or direction) as well as pumps. Again, actuators have to be able to act on the water system on a time scale compatible with its dynamics.

In fact most actuators nowadays are typically better described as actuator systems, as they will contain a range of internal sensors (to verify that the action taken corresponds to the desired action, to diagnose operational conditions and to manage maintenance and conditioning), as well as microprocessors and various interfaces to interact with their environment.

Unfortunately, there are very few device standards, and the analogue of SensorML is still to be developed for actuators. A step in the direction of some form of standardisation can be found in The Open Device Vendor Association.[7] Nevertheless, there is no generally accepted standard in this environment as yet.

Meta data for actuators should include such items as range, power source, access to local software, linearity, time response data, as well as diagnostics and expected failure modes (preferably with their signal signatures). Meta data of this type are rarely available in an on-line manner for actuator systems.

In order to be fit-for-purpose inside an internet of things, the actuators must come with a full internet connection, enabling remote control, diagnostics and evaluation.

Communication network, traditionally Supervisory Control and Data Acquisition (SCADA) systems have been used to connect sensors using mainly propriety protocols. Open protocol internet based SCADA is essential to deploy a large scale internet to share the data. It alone offers a clearly scalable technology based on well established standards. Scalability and progressive deployment are absolutely essential to allow for the gradual retrofitting of existing civil infrastructure.

Where hard-wire based internet can be afforded it is a great asset, but in general in the context of water systems exhibiting relatively slow dynamics, wireless or radio based communication will suffice. Whatever the network, the latency due to data transmission should be minimised. In the context of "closing the loop", for example using the sensor information to decide on which actions to perform through the actuators, the latency in this communication loop is a performance limiting determinant. Reporting by exception is the way to go in these networks in order to minimise data bandwidth requirements and achieve best possible performance.

The network should be configured in such a way that sensors/actuators can communicate among themselves directly, without the intervention of a supervisory node, and certainly without the intervention of a central data collection node.

Computing resources are essential to interpret the data. In an internet of things, with sensors and actuator systems in place, the computing resources can scale linearly with the number of sensors and actuators. Central processing of data should not be relied on, as central decision making will incur the worst latency time on the network for the data. Moreover, any system based on central processing will suffer severe performance degradation when communications are even partially disrupted. The latter should be considered the norm in a radio-based internet environment.

Where significant knowledge exists, which often can be summarised in the forms of predictive models for the system under management, this can be exploited to great advantage. Moreover measurements and prior knowledge may be synthesised to create new knowledge that can be queried in a much more application and location specific manner. Such synthesis can be used to:

- Curate measurements, for example measurements can be rejected if clearly contradicting known facts;
- Update knowledge, measurements corroborate existing knowledge and provide location specific information, and allow one to track trends over time;
- Provide for scenario development;
- Respond to queries; analyse alternative scenarios; and optimise system behaviour.

All such actions require substantial computer resources both for storing the data, as well as interpreting data.

Systems engineering principles can be utilised with advantage to design "internet-of-things" systems (also called large scale, interconnected systems, or systems of systems). Besides establishing a fit for purpose design, the main issues are to ensure scalability and gradual deployment.

An introduction to the systems engineering principles in the context of open channel water distribution systems can be found in Iven Mareels et al, 2005[8]. For a more control theoretic and mathematical exposition of the design principles employed in this context, refer to Cantoni, et al[9], 2007.

If a "sensor only" system is being considered, the design problem is relatively simple. Such systems are in widespread use, for example the network of seismographs is one of the oldest and most extensive such networks of observation. A nice example of open data sharing is for example the IRIS network.[10] Another such example is the monitoring network on the Hudson river.[11] Communication network latency is generally less important in this context.

Where the sensor network complements an operational system with manually operated actuators, there is only a limited capacity to improve the overall system performance because the actuators are the limiting factor. Decisions and interpretations of the data are initiated by a “human-in-the-loop”. Nevertheless, the sensor network may still bring significant value, as the measurements will provide a better insight into the system behaviour, and enable the users to make better decisions. This is particularly the case when decision-support software is available to evaluate scenarios or present situation awareness beyond what normally can be achieved by a “human-in-the-loop”. Such systems hold significant promise for on-farm automation and on-farm decision making.

Sensor and actuator systems based on “human-in-the-loop” decision making are also relatively straightforward to design. Having the actuators available in the communication loop enables quicker responses, and a more coordinated management approach. A quantum leap in performance is normally achieved when the sensor and actuator system is managed autonomously, and the “human-in-the-loop” acts as the supervisor, rather than the direct decision making agent. In this manner, especially when the sensors and the actuators can operate significantly faster than the natural dynamics of the variables under management, significant gains are realised. It combines the best of the human decision making capacity with the reliability and effectiveness of the autonomous operation of the hardware. Designing for autonomous closed-loop behaviour, even with supervision, is considerably more challenging than designing for the “human-in-the-loop” system in particular when proper coordination across the system is pursued. For example in the traffic light control system, actuators and sensors operate autonomously but without much overall coordination, just using local traffic information rather than communicating between feeder intersections. When and where the latter is pursued considerably more investment in systems engineering is essential. The Australian developed SCATS system is one such example.[12]

An example – TotalChannelControl®

TotalChannelControl® was developed by Rubicon Water in collaboration with the Melbourne School of Engineering at the University of Melbourne. TotalChannelControl® is a fully autonomous system of sensors and actuators, connected through a radio based internet, overlayed on an existing network of open water channels for water distribution in response to irrigation water demand.

The sensors are integrated with the actuators, and measure water flow as well as water level. The actuators affect flow by restricting the area through which water can pass. Diagnostics are fully incorporated on both the sensors and actuators. Sensors are self calibrating and compensate for minor installation errors, and such effects as daily temperature variations. All sensor and actuator diagnostics are available on-line and can be accessed through the internet. Reliability is ensured through redundancy. This enables the capacity to verify the consistency of the sensors and allows for a sophisticated statistical evaluation of their accuracy across space and time. All sensor and actuators can communicate with each other, and back to base. Reporting is done by exception (when there is a sufficient change to warrant an update). All units’ software can be upgraded via the internet as well. Through the data derived from the network of sensors a real time water balance of the entire network is enabled. Data can be interpreted to identify unauthorised water diversion, evaporation losses as well as excessively leaky channels across the entire network. The latter allows for preventive maintenance such as lining of channels so as to reduce the seepage losses in the network.

Typically in fully autonomous TotalChannelControl® mode any actuator will adjust flow every few minutes in response to water demand (derived from water orders downstream) and the deviation between distant downstream water levels as its reference. Any

FIGURE 4
FLUMEGATES FEATURING INTEGRATED ACTUATION, WATER LEVEL AND FLOW MEASUREMENT

Photo: Michael Kai

actuator action is a combination of a relatively fast feed forward action derived from a prediction of downstream water demand and a slower feedback action derived from the deviation between desired water level and actual water level in the channel. Appropriately balancing feed forward and feedback actions, allows the TotalChannelControl® to satisfy water demand nearly on-demand and maintain the desired water levels with an accuracy that is simply not feasible under manual operation.

Sensors will report changes in water level and water flow, which is interpreted by the computers in the system to compute the actions to be taken. This information also allows one to infer the status of the actuators. Redundancy in the sensor information allows for a statistical evaluation of the sensors' performance.

Operating in this mode, a typical irrigation district can provide near on-demand water supply across a wide range of its operations. Moreover, the system delivers a much improved response in case of rain events and superior flood routing.

Sensors, actuators and the TotalChannelControl® operations are the subject of a series of patents held by Rubicon Water.[13]

Unsurprisingly, the software at the heart of the entire system is rather complex. The more so, as the software vertically integrates all aspects from the latest of the SCADA functionality to the highest level of supervisory actions: billing and asset management aspects of the entire hardware system. Such functionality is rare. Even in the much more confined operations of typical manufacturing the vertical integration from the control and SCADA layer to system operation management and enterprise management has rarely been fully implemented. There is a lack of standards in this area, as well as the enormous potential that vertical integration could bring to management.[14]

Conclusion

The technology to build smart water systems to support both water and water infrastructure management are commercially available. It has been demonstrated in the context of significant irrigation districts both here in Australia as well as overseas, with several systems in continuous autonomous operation since 2002.

Such intelligent, interconnected infrastructure enables one to exploit existing civil infrastructure to full capacity, delivering superior water distribution service. In addition, it enables preventative maintenance, and allows operators to cope with extreme circumstances without significantly sacrificing performance.

There is still much untapped potential. For example, in a future expansion we are envisaging leveraging the water distribution technology further with on-farm decision support that synthesises both the existing knowledge base and available sensor network data to provide location and time relevant information to the end-user. In this manner the entire water-value chain can be supported and becomes an integral part of a knowledge based economy with concomitant productivity and agri-business driven wealth benefits.

The holy grail in this context is the deployment of a smart water system on the scale of an entire water catchment area, where one integrates both ground water and surface water, all water users (urban, rural, industrial as well as environmental), and keeps track of not only the water flow and water balance but also the water quality aspects. The non-trivial synthesis of the data derived from such a system with the expanding knowledge about the environment, and the water enterprises will enable the pursuit of the best and most sustainable evidence based economic exploitation that is feasible within the capacity constraints of the natural environment. Clearly, in order for this to happen significant regulatory and legislative reforms will be required and one obvious obstacle that will need to be overcome is that water catchment geography does not align with existing administrative and/or political boundaries.

References

1 P. Albertos, I. M.Y. Mareels, Feedback and Control for Everyone, Springer, Jan 2010

2 Ooi, Su Ki; Cooley, Nicola; Mareels, Iven; Dunn, Greg; Dassanayake, Kithsiri; Saleem, Khusro; Automation of on-farm irrigation: Horticultural case study, Agricontrol, VoL (3) Part (1), 2010 doi 10.3182/20101206-3-JP-3009.00045

3 World Water Vision: Making Water Everybody's Business – World Water Council, 2000

4 2030 World Water Resources Group, Charting Our Water Future: Economic frameworks to inform decision-making, 2009

5 P. Albertos, I. M.Y. Mareels, Feedback and Control for Everyone, Springer, Jan 2010

6 http://www.opengeospatial.org/standards/sensorml

7 http://www.odva.org

8 Iven Mareels, Erik Weyer, Su Ki Ooi, Michael Cantoni, Yuping Li, Girish Nair; Systems Engineering for Irrigation Systems: Successes and Challenges, Annual Reviews in Control, Vol 29, 191–204, 2005, DOI 10.1016/j.arcontrol.2005.08.001

9 M. Cantoni, E. Weyer, Y. Li, S.K. Ooi, I. Mareels and M. Ryan, Control of large-scale irrigation networks, Proceedings of the IEEE, Special Issue on the Technology of Networked Control Systems (eds. J. Bailliuel and P. Antsaklis), Volume 95, Issue 1, Jan. 2007 Page(s):75 – 91 DOI 10.1109/JPROC.2006.887289

10 http://www.iris.edu

11 http://nexsens.com/case_studies/hudson_river_monitoring.htm

12 http://www.scats.com.au/

13 I. Mareels, E. Weyer, D. Aughton, Rubicon Research Pty Ltd, Control Gates, WIPO Number WO 02/16698, PCT Number PCT/AU01/01036, US Pat. 7,083,359 Filed Aug 21, 2001, issued August 1, 2006

I. Mareels, E.Weyer, D. Aughton, Rubicon Systems Australia Pty Ltd, Fluid Regulation, WIPO Number 02/071163, Australian Application Number 2002233060, PCT/AU02/00230, US Pat. 7,152,001 Filed Mar 1, 2002, issued December 19, 2006

14 M.Lees Information Infrastructures for Entreprise Sustainability, PhD thesis, 2011, The University of Melbourne.

National
Level 13, 440 Collins Street
Melbourne VIC 3000
GPO Box 2117
Melbourne VIC 3001
Telephone 03 9662 3544
Fax 03 9640 0849

**New South Wales
and the ACT**
Level 14
The John Hunter Building
9 Hunter Street
Sydney NSW 2000
GPO Box 2100
Sydney NSW 2001
Telephone 02 9299 7022
Fax 02 9232 7559

Queensland
Level 17, 300 Adelaide Street
Brisbane QLD 4000
GPO Box 2900
Brisbane QLD 4001
Telephone 07 3229 9955
Fax 07 3229 8166

**South Australia and the
Northern Territory**
Level 7, Qantas House
144 North Terrace
Adelaide SA 5000
PO Box 8248, Station Arcade
Adelaide SA 5000
Telephone 08 8211 7222
Fax 08 8211 8222

Victoria and Tasmania
Level 13, 440 Collins Street
Melbourne VIC 3000
GPO Box 2117
Melbourne VIC 3001
Telephone 03 9662 3544
Fax 03 9640 0849

Western Australia
Level 5, BGC Centre
28 The Esplanade
Perth WA 6000
PO Box 5631, St Georges Tce
Perth WA 6831
Telephone 08 9228 2155
Fax 08 9228 2166

ceda
committee for economic development of australia