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The role of water markets in climate change adaptation

Final Report

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THE ROLE OF WATER MARKETS IN CLIMATE CHANGE ADAPTATION

Final report prepared for the National Climate Change Adaptation Research Facility

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The role of NCCARF is to lead the research community in a national interdisciplinary effort to generate the information needed by decision makers in government, business and in vulnerable sectors and communities to manage the risk of climate change impacts.

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Cover image

Lock 1 at Blanchetown in South Australia © Murray Darling Basin Authority, taken by Arthur Mostead

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GLOSSARY OF TERMS

Adaptive management—provides structured links between knowledge, management, evaluation and feedback over time. The process recognises that new knowledge is always becoming available and must be considered. It includes setting clear objectives, identifying and testing uncertainties, improving knowledge, 'learning by doing' and changing practices and policies in response to new knowledge.

Allocation account—instrument for tracking an individual water user's availability, use and balance of water in a season, and from season to season under carry over provisions.

Allocation water—provides a specific volume of water to a water entitlement holder in a given **water year** (season), based on **announcements** provided during the water year. Allocation water is recorded in an **allocation account** and may be used by the entitlement holder (if they have an appropriate **water access right**) or transferred to another allocation account. Unused allocation water may be stored as **carry-over** into the next water year once such ability has beenced.

Announcement—public declarations of seasonal water allocations and other policy decisions (e.g. **carry-over** conditions or changes in the ability to trade between **trade zones**) made during a given **water year**. These announcements may have an impact on the price or value of **water access rights** or **allocation water**, and may influence the decisions of persons considering buying or selling such rights.

Annual crops—agricultural commodities that are planted, grown and harvested all within one season. As such, the decision to proceed (or not) with annual crops can be made independently each year depending on seasonal, price and other factors. Examples include cotton, rice, cereals etc.

Basin Plan—the overarching document aimed at managing **water resources** in the MDB for social, environmental and economic outcomes. Once ratified, the Basin Plan will not be fully implemented until 2024 when various state and territory **water resource plans** expire. A review of progress toward Basin Plan outcomes will be undertaken in 2015. The current environmental water access right reduction target is 3,200 **Gigalitres**. This figure may also change before full implementation.

Basin states—Queensland (Qld), New South Wales (NSW), the Australian Capital Territory (ACT), Victoria and South Australia (SA).

Bulk water entitlement—a large consolidated water access right held by an authority or **irrigation infrastructure operator** to extract water to supply water for irrigation, urban or other uses.

Buy-back—program of reducing the pre-existing level of **extraction** in the **MDB** through purchasing **water entitlements** from willing sellers in the Basin. The current total budget is set at $3.6 billion over 15 years to 2024 (excepting 2012, which will not see any non-strategic buy-back activity). All water entitlements acquired through the program become part of the **held environmental water** portfolio of the **CEWH**.

Cap—an upper limit on the volume of water available for **consumptive** use from a waterway, catchment, basin or aquifer.

Capacity sharing system—these systems disaggregate **water access rights** by defining rights to water in terms of shares of storage **inflows**, storage volume or losses. Users are then credited water based on either the **water access right's** share of inflows or the amount of space remaining in the user's 'storage right'—whichever is the least.

Carry-over—an arrangement that allows the holder of a water **allocation account** to retain **allocation water** not used in one **water year** (accounting period) and then take or trade it in the next water year (accounting period).

COAG—the Council of Australian Governments is the peak intergovernmental forum in Australia, comprising the Prime Minister, State Premiers, Territory Chief Ministers and the President of the Australian Local Government Association (ALGA).

Commonwealth Environmental Water Holder (CEWH)—federal government department established as the legal owner of **held environmental water** and charged with applying that held water (together with **planned environmental water** where appropriate) toward the satisfaction of **environmental requirements** as determined under the MDB's **Environmental Watering Plan**.

Consumptive use—describes the use of water for irrigation, industry, urban and stock and domestic use, or other private purposes.

Dams or storages—infrastructure built within a watercourse, lake, wetland or aquifer for the purpose of **extraction** of significant volumes of **water resources** for **consumptive** or other purposes.

Diversion—the movement of water from a river system by means of pumping or gravity channels.

Economic efficiency—an activity is economically efficient if it maximises the wellbeing of the community through improving the way resources are allocate and used.

Ecosystem functions—describes a community of plants, animals and microorganisms interacting with one another, and with the environment in which they live. Important functions include the physical, biological and chemical processes that support movement of nutrients, organic matter, re-oxygenation and sediment transfers in rivers.

Ecosystem services—describe the benefit people obtain from ecosystems, such as food, water, timber and fibre. Less tangible services include: i) the regulation of climate, floods, disease, wastes and water quality; ii) recreational, aesthetic and spiritual benefits; and iii) soil formation, photosynthesis and nutrient cycling.

Environmental assets—include water-dependent ecosystems, ecosystem functions and sites of ecological significance (e.g. **Ramsar**-listed wetlands, the Murray River mouth, etc.).

Environmental requirement—describes a dependence of **ecosystem functions** on periodic or sustained flooding, waterlogging or significant inputs of surface water or groundwater to continue functioning.

Environmental water flows—the water provided to wetlands, floodplains or rivers to achieve desired outcomes (under the **Basin Plan**). Outcomes include benefits to **ecosystem functions**, biodiversity, and improved water quality and **water resource**

health. At priority sites, these flows must be expressed in terms of flow volumes, duration, timing, frequency, cycle, inundation depth and dependence on groundwater.

Environmental watering plan—as specified under the **Basin Plan**, safeguards existing environmental water, plans for the recovery of additional water and sets out arrangements to coordinate the use of environmental water throughout the **MDB**. As such, it is a voluntary agreement between the **MDBA** and the various holders of **held environmental water**, and/or managers of **planned environmental water** that is made to coordinate **environmental water flows** and application.

Exit fee—a charge (often per **megalitre**) imposed on the permanent trade and subsequent loss of a **water access entitlement** out of an irrigation district or area. These fees are charged to maintain the delivery infrastructure or any **stranded assets** that remain after the water access entitlement has left the area.

Extraction—includes the capture of surface water or groundwater that would otherwise flow directly into a watercourse, lake, wetland, aquifer, dam or reservoir. An extraction activity may include building new **dams or storages** on private property, constructing pumping infrastructure along a water course or establishing extensive tree plantations.

General (low) security entitlement—a **water access entitlement** (right) that varies significantly from year to year, such that the water supplied is uncertain. The supply under general (low) security may be expressed as providing water in, for example, 40% of years.

Gigalitre (GL)—equates to one billion litres of water.

Held environmental water—water available under a **water access right(s)** for achieving targeted environmental outcomes.

High security entitlement—a **water access entitlement** (right) that does not vary significantly from year to year and is expected to be available in all but the worst droughts. The supply under high security may be expressed as providing water in, for example, 98% of years.

Inflows—water generated by rainfall that runs off the land and enters surface water or groundwater systems to form **water resources**.

Irrigation infrastructure operator (IIO)—may be a company or corporation (or other legal person) that operates the infrastructure for delivering irrigation water.

Lease—the passing of benefits and responsibilities associated with ownership of a water access right or allocation to another person for a fixed (long-term) period.

Megalitre (ML)—equates to one million litres of water. One thousand megalitres equates to one **gigalitre**.

Murray-Darling Basin (MDB)—Australia's largest externally emptying catchment comprising the confluence of the Darling and Murray Rivers (and 21 other associated tributaries). Made up of 19 surface water resource areas and 23 groundwater resource areas the MDB represents 14% of Australia's total land area.

Murray-Darling Basin Authority (MDBA)—statutory body created under the *Water Act* (2007) to administer the **MDB** and oversee the creation of the **Basin Plan** and associated documents.

National Water Initiative (NWI)—agreement between the Australian, state and territory governments (**Basin states**) to: i) improve the management of the nation's **water resources** and; ii) provide greater certainty for future investment.

Off-allocation—when **regulated** tributary inflows or spills are sufficient to supply irrigation needs and downstream obligations. These rights have now been largely abolished.

Option contract—an agreement entered into between two (or more) parties where the first party agrees to supply goods or services (e.g. allocation water) at a future time when the second party demands them. To bind the parties an initial (strike) price is set and paid to the supplier. When the second party activates the agreement terms, full settlement of the agreed remaining transaction price will take place.

Over-allocation—the issuing of more **water access rights** to extract water than can be physically achieved and sustainably provided by the system in light of **sustainable diversion limits**. The inclusion of previously unconsidered environmental needs for water allows a higher probability of this scenario occurring.

Over-use—a predominant application of **water resources** to one use, rather than to other available uses.

Permanent crops—agricultural commodities that typically are planted, take 2-5 years to mature and then provide regular seasonal harvests for a prolonged period thereafter. As such, the decision to proceed (or not) with permanent crops cannot be made independently each year depending on seasonal, price and other factors and unfavourable input or output conditions must be endured. Examples include fruit trees, grapevines, nut plantations etc.

Planned (rules-based) environmental water—water committed by legislation to achieving environmental outcomes, and which cannot be used for other purposes except under very specific circumstances.

Private diverter—this is an irrigator who has invested in their own infrastructure to extract water from a river for productive gain. These types of users differ from those in irrigation districts, who have their water delivered through shared infrastructure arrangements.

Ramsar convention—is an international treaty on wetlands of international importance, which provides a framework for national action and international cooperation for the conservation and use of wetlands and their resources.

Refugia—comprise areas of refuge where animals and plants can survive when conditions are challenging (e.g. during extended drought). For example, semipermanent wetlands provide refuge areas for plants and animals when they cannot survive in other parts of the landscape. These populations can then breed and repopulate larger areas when conditions improve.

Regulated streams—waterways where users are supplied by releases from storages. A **water access entitlement** for a regulated stream specifies a base water entitlement defining the holder's share of the resources from the stream.

Reliability—the frequency with which water allocated under a **water access entitlement** is able to be supplied in full. See also high security and/or general (low) security entitlement above.

Sales water—a (now defunct) Victorian term where inflows to the **water resource** are so large that greater than 100% seasonal **allocation announcements** can be made to water users. Allocations above 100% then become known as 'sales water'. The maximum total sales water allocations in the Goulburn and Victorian Murray systems were 200%, while in the Campaspe Basin sales water allocations could reach 220%.

Storage inflow—this is the volume of water that flows into storages over a period of time from upstream tributaries, storage catchment runoff and/or rainfall on the storage itself.

Storage release—the volume of water released from a dam, weir or other storage facility to meet downstream demands. Note that this may be less that storage demand due to release or operational constraints.

Storage spill—the volume of water discharged from a storage facility (usually over designated spillway structures or large capacity outlets) in excess of storage capacity and/or demand.

Stranded assets—an asset that is worth less on the market than it is on the balance sheet because it has become obsolete before being fully depreciated by an **irrigation infrastructure operators** (IIO). In irrigation areas, when there is a permanent decrease in the demand for water delivery services the assets of IIO can become unused or underused and are then said to be stranded.

Sustainable diversion limits—the maximum long-term annual average quantities of water that can be taken on a sustainable basis from the Basin's total **water resources** and from each SDL resource unit (area). If exceeded, the extraction would likely compromise one or more of the following:

- Key **environmental assets** of the water resource
- Key **ecosystem functions** of the **water resource**
- The productive (**consumptive**) base of the water resource
- Key environmental outcomes for the water resource

Third-party interests—other water users not involved in a **trade**, or non-water users who could potentially be impacted by a trade or **carry-over** decision.

Trade—change of ownership (in this case of a **water entitlement** or **allocation water**), either absolutely or for a fixed period.

Trade zone—a specific area-based district where water can be traded to and from. These are typically based on physical irrigation water delivery system boundaries.

Unbundling—the legal separation of rights to land and rights to access water, have water delivered, use water on land or operate water infrastructure.

Unregulated stream—streams that are not controlled or **regulated** by releases from storages. The ability to take water from unregulated streams may be based on opportunistic flood flows or events.

Water access right(s)—any right determined by state law to hold and/or **extract** water from a water resource. Water access rights include stock and domestic rights, riparian rights, **water entitlements** and **water allocations** (in Qld).

Water entitlements—confer the owner with perpetual access to a share of water from a specified **consumptive** pool. Transferring a water entitlement shifts ownership of the access right from one legal entity to another. Water resources are only available under a water entitlement through provision of **allocation water**.

Water recovery measures—represent ways to acquire water resources, other than through reduction of existing water entitlements, in order to return water to the environment. This can include purchasing **water entitlements** from willing irrigation sellers (buy-back) and/or investing in water saving technology, such as infrastructure **water use efficiency** improvement.

Water resources—includes all surface water or groundwater such as a lakes, wetlands, watercourses or aquifers within or beneath the Murray-Darling Basin, excepting groundwater in the Great Artesian Basin. Also included are the water, plants, animals and other organisms and components that contribute to the physical state and environmental value of the water body.

Water resource plans—set out how **water resources** will be managed, usually for a 10-year period. Water resource plans are developed by the states or in certain circumstances by the **MDBA** under approval of the Commonwealth Water Minister.

Water use efficiency (WUE)—improvements in the utilisation of water resources so that beneficial objectives (e.g. increased delivery volumes due to reduced leakage) or better outcomes (e.g. consistent crop yield from a lower volume of water applied to the field) can be achieved.

Water year (accounting period)—describes a 12-month period from July 1 to 30 June, similar to a financial year. For critical human needs the period alters to between 1 June and 31 May. In the report this may also be referred to as a water season.

ABSTRACT

Water markets were first introduced in Australia in the 1980s, and water entitlement and allocation trade have been increasingly adopted by both private individuals and government. Irrigators turned to water markets (particularly for allocation water) to manage water scarcity and Governments to acquire water for the environment (particularly water entitlements. It is expected that further adoption of water markets will be essential for coping with future climate change impacts. This report reviews the available literature related to the relationship between southern Murray-Darling Basin (sMDB) water markets and anticipated climate change effects; the economic, social and environmental impacts of water reallocation through markets; and future development requirements to enhance positive outcomes in these areas.

The use of water markets by irrigators can involve both transformational (selling all water entitlements and relocating or switching to dry land) and incremental (e.g. buying water allocations/entitlements, using carry-over, changing water management techniques) adaptation to climate change. Barriers to both adaptations include: current and future climate uncertainty; poor (or non-existent) market signals; financial constraints; information barriers; mental processing limits; inherent attitudes toward or beliefs about climate change; institutional barriers and disincentives to adapt.

A better understanding of trade behaviour, especially strategic trade issues that can lead to market failures, will improve the economic advantages of water trade. There remains community concerns about the impacts of transfers away from regional areas such as reduced community spending and reinvestment; population losses; loss of jobs; declining taxation base, loss of local services and businesses, regional production changes; and legacy issues for remaining farmers. However, it is hard to disentangle these impacts from those caused by ongoing structural change in agriculture. Rural communities that are most vulnerable to water scarcity under climate change and water trade adjustment include smaller irrigation-dependent towns. Communities less dependent on irrigation are better able to adapt. Further, where environmental managers use water markets to deal with water variability and to ensure ecological benefits, irrigators are concerned about its impact on their traditional use of markets to manage scarcity.

Climate change and water scarcity management are intertwined, suggesting that policy, institutional and governance arrangements to deal with such issues should be similarly structured. Water users will adapt, either out of necessity or opportunity. The cost of that adaptation at individual, regional and national levels – particularly to future water supply variability – can be mitigated by the consideration of the existing advantages from future opportunities for water marketing in Australia.

EXECUTIVE SUMMARY

In the past decade, Australia has used a range of programs and incentives, but in particular water markets, to reallocate water from consumptive users to the environment in the southern Murray-Darling Basin (sMDB). Irrigators used water markets as a risk-management strategy to manage water scarcity. The extremely dry period between 1998/99 and 2009/10 could be used as an indicator of future climate change impacts and water user adaptation.

Across all water user groups, further adoption of water markets will be part of the package of adaptation strategies for coping with future climate change impacts. This report reviews the literature related to the relationship between sMDB water markets and future climate change effects; the economic, social and environmental impacts of water reallocation through markets; and discusses potential water market developments needed. It identifies how water markets augment national capacity to deal with future water scarcity issues under climate change.

Predicted Murray-Darling Basin (MDB) climate change outcomes

Predicted water scarcity outcomes include:

- Population growth and climate change will put water security at risk.
- Drought frequency will increase in the southern and south-eastern regions (e.g. sMDB), whereas heavy rainfall and tropical cyclone events will increase in the north eastern regions of the MDB. Southern drought impacts will be exacerbated by decreasing rainfall and increasing temperatures.
- Total MDB surface water availability is predicted to decline by 11% in a median 2030 scenario, with reduced end-of-system flows in South Australia.
- Supply reliability will suffer, with the security of general water entitlements in NSW and low security water entitlements in Victoria being particularly affected.
- There will be an increase in extensive and prolonged flooding, causing infrastructure damage and production/environmental losses.

Water user adaptation

Water users will need to continue to adapt to changing water supply and demand conditions. Adaptation in response to perceived or actual climate change will likely occur via:

- **Transformational adaptation** of livelihood, location or identity (e.g. farm exit and relocation to a different area, selling part or all of their water entitlements and/or shifting to dry-land farming practices); and/or
- **Incremental adaptation** of actions, decisions or information sources (e.g. adopting water-use efficiency improvements, investing in more water or land and/or diversifying income from new commodity or off-farm sources).

Barriers to adaptation include current and future climate uncertainty; poor market signals; financial constraints; information barriers; mental processing limits; inherent attitudes toward or beliefs about climate change; and disincentives to adapt. Irrigation productivity seems to be adaptable to drought in the short-run, but water supply and water use efficiency will become increasingly important, and further research on long-term impacts is needed.

Water markets

It is apparent that water trade (particularly water allocations) has become entrenched as a key risk-management tool to manage water scarcity, particularly during severe droughts.

Periodic water shortages have driven the expansion and development of markets to reallocate scarce water resources between different users (including urban) in a relatively effective/efficient manner. As climate change is set to exacerbate water scarcity and variability, the usefulness of water markets as an adaptation tool becomes increasingly important.

Economic impacts

The economic benefits of water trade for climate change adaptation include allocative, dynamic and productive efficiency – which has resulted in reasonable reallocation of scarce water resources during the last few decades. Water markets have performed relatively well in drought impact mitigation, resource reallocation and economic production facilitation.

The expansion of direct market intervention by governments since 2003 has brought focus on the progress, outcomes and development of water markets to deliver economic and environmental welfare changes. A better understanding of trade behaviour, especially strategic behaviour which can lead to market failures, will improve economic benefits.

Social impacts

Nevertheless, there remains limited evidence of negative social impacts from water trade. Community concerns over water transfers away from a regional area includes: reduced community spending and reinvestment; population losses; employment losses; declining taxation base, loss of services and businesses, regional production changes (e.g. shifts to dry-land farming); and legacy issues for remaining farmers (e.g. higher variable farm operating costs, stranded asset problems and/or pressure to rationalise marginal operations). Although repeatedly associated with water trade, many such social issues are associated with ongoing structural change in agriculture and it has been proven difficult to disaggregate them and establish causal relationships between trade and social change.

Smaller irrigation-dependent towns are most vulnerable to water scarcity under climate change. Less dependence on irrigated agriculture makes rural communities more adaptable. Around 10 districts in the MDB have been identified as having a particularly low adaptive capacity index—several of them associated with irrigation areas (e.g. south of Griffith in NSW, south of Mildura in Victoria and along the SA Murray River).

Environmental impacts

For the most part, water trade has benefited the environment in terms of river flows, lower salinity, downstream movements, and a larger portion of water holdings for the environment. However, the largest negative consequence of water trade stemmed from the activation of significant water entitlement volumes after a cap on extraction was imposed. Previously, these water entitlements were un-utilised or under-used, resulting in increased stream-flow.

Other negative environmental impacts are difficult to identify—in part because of data issues. Common concerns include:

- Concentrating water use in areas suffering from high water tables.
- Moving water into locations where its' use might have a negative impact on river water quality due to e.g. higher groundwater salinity levels.
- Moving water use upstream, thereby resulting in reduced river flow from the new point of extraction to the old point of extraction.
- Activating previously unused water leaving less water in the river to support ecosystems.

In response, a variety of controls have been put in place by state governments to limit potential environmental harm increasing transaction costs.

Modelling suggests that the hydrologic and environmental impacts between 1998/99 to 2010/11 were small and largely positive; due to the downstream movement of water reducing summer flow stress without changing winter flow patterns.

Regulatory change such as carry-over has enabled water users to avoid previous strategies of either consuming all of their water each season (which could result in increased seepage, high water tables, larger return flows) or trade surplus water on the market (enabling changes to location, timing and use of water)

Future water market improvements

This report has focussed on **three broad areas of water market reform**:

Institutional: removing trade restrictions to allow for more efficient transfers to facilitate more fluid farm adjustment; better groundwater regulation to avoid over-allocation; expanded water trade products and markets (and cross-sector interaction); improved approval procedures; and greater transparency where potential conflicts of interest may arise;

Informational: more robust and detailed market price signals; greater use and prediction of future climatic information; improved seasonal water allocation announcements; and research into farm adaptive responses (and capacity) across regions and industry sectors; and

Political: regulation for brokers to assure market confidence and avoid catastrophic (e.g. massive confidence loss) events; improved carry-over rules across states and districts; investigation into the opportunity cost of further infrastructure investments or alternative recovery programs; and education of farmers and rural communities in order to address climate change beliefs, attitudes and improve adjustment and adaptation responses.

1. EXPECTED SOUTHERN MURRAY-DARLING BASIN CLIMATE CHANGE IMPACTS

1.1. Background

This report constitutes the major deliverable component of a National Climate Change Adaptation Research Facility (NCCARF) funded project [SD11-16]. The project developed from a national need to better understand the relationship between water markets, irrigators' adaptability to water supply variability, anticipated future climate change effects and consequent water reallocation requirements.

1.1.1. Purpose of the report

The purpose of this report is to undertake a literature review of the consequences of sMDB water markets. This review of the ecological, social and economic water market consequences provides some evidence of how water users can adapt to future climate change.

To achieve this outcome the report seeks to cover a wide range of disciplines, building upon current National Water Commission (NWC) overviews into the social and economic impacts of water trade (for example, NWC, 2011b, NWC, 2012a, NWC, 2011g, NWC, 2011f). In particular, we will detail how a range of water market participation strategies used (e.g. type of water market used, type of security traded, the timing and/or volume of sale/purchase) influence farm or ecosystem viability. Further, we will examine what effect changed institutional structures, water allocations, and rainfall events have on particular bidding and offering strategies among sMDB water users. Finally, we will provide evidence-based policy recommendations on how to make water markets more efficient and better positioned to allow water users to adapt to changing water supply conditions in the future.

1.2. Introduction

Water resources in Australia are under pressure due to rapid population growth and anticipated climate change and variability (Chowdhury and Beecham, 2012). The country's population has doubled since 1955 and was 22 million in 2009. It is anticipated that an additional 4.5 million people will be added in the next quarter of a century. This projected population growth will increase water demand. A great challenge for the agricultural sector will therefore be to produce more food from less water, particularly in arid and semi-arid regions of Australia which suffer from water scarcity (Hassanli *et al.*, 2009).

The Intergovernmental Panel on Climate Change (IPCC, 2007) has predicted that Australian average temperatures will increase by between 0.6 and 1.5°C by 2030, while annual rainfall will decrease in the southern and north-eastern region and available moisture will also decrease all over Australia. Drought frequency will increase in the southern and south-eastern region, whereas heavy rainfall and tropical cyclone events will increase in the north eastern regions. Therefore, both population growth and climate change will impose significant pressures on the country's water security.

Rainfall is the key climate variable that governs the spatial and temporal availability of water. Evidence of global warming is becoming widely accepted, for example IPCC (2007). However, evidence of change on a local scale can be more equivocal. Within Australia, the effect of changing climatic conditions in the MDB, which covers 14% of the land area, is of particular concern. Over the last one hundred and twenty years, there have been three particularly notable droughts affecting the MDB (see Figure 11): the Federation drought which began in the mid-1890s and reached its devastating climax in 1902; the World War II drought which started in 1937 and lasted until 1945; and the recent Millennium drought which was the worst recorded Australian drought. In the presence of climate change induced uncertainty, water systems need to be more resilient and multi-sourced (Horne, 2012a). This is partly because of decreasing volumetric rainfall trends in many parts of the world, which might have severe effects on reservoir yields and operational practices. Further, severe intensity rainfall events can cause flood inundation problems (Beecham and Chowdhury, 2012).

In addition to this increased vulnerability, there is also strong evidence that the probabilities and risks of extreme events are changing in response to global warming. In their Fourth Assessment Report (AR4), the IPCC of the World Meteorological Organization and the United Nations Environment Program reports a worldwide increase in the frequency of extreme rain storms for the late 20th century as a result of global warming (IPCC, 2007, WMO, 2009). Based on climate model simulations with different future greenhouse gas (GHG) emission scenarios, IPCC (2007) furthermore concluded that it is very likely that this trend will continue in the 21st century. The consequences of these changes have to be assessed in a perspective of sustainable development. Water managers have to anticipate these changes in order to limit flood risks for communities.

1.3. Rainfall Variability

Australian rainfall exhibits a high degree of spatial and temporal variability (Chowdhury and Beecham, 2010). Knowledge and understanding of rainfall variability and the factors influencing the variability are important for managing water resources. In recent decades, the Australian climate has been changing, with higher temperatures and less rainfall. From 1910 to 2006, the mean temperature increased at a rate of 0.09°C/decade and from 1970 to 2006 this rate increased to 0.19°C/decade. In the southeast region of Australia, from 1997 to 2006, only 2 years exceeded the 1961-1990 mean rainfall value (Murphy and Timbal, 2008).

The period 2001 to 2005 has been identified as the driest period since 1968 and the warmest period for the New South Wales (NSW) region (Rakich and Wiles, 2006). According to Murphy and Timbal (2008), the southeast region has been experiencing an annual rainfall downward trend at the rate of 20.6 mm/decade since 1950. Simmonds and Hope (1997) suggested that many aspects of climate experienced change around 1950. They describe how these changes are reflected in the persistence nature of Australian rainfall.

In recent years most of Australia has been suffering from an extended dry period that has led to a number of economic and environmental impacts. The River Murray, which is the largest river system in Australia, received only 40% of the long-term mean inflows during 2001 to 2005 (MDBC, 2006b). In the lower Murray region, floodplains and wetlands have been under severe environmental threat due to the lack of flooding in recent years. South-eastern Australia (Victoria, parts of New South Wales and South Australia) has been experiencing low rainfall since 1997, and a 61% decline has occurred in the autumn season (March-May) (Murphy and Timbal, 2008). Taschetto and England (2009) investigated post 1970 Australian rainfall trends. They identified an increasing trend to the west (except coastlines) and a decreasing trend on the northeast coast. Smith *et al.* (2000) reported a significant decrease in winter rainfall in the southwest region of Western Australia since the 1960s. The recent decline in rainfall in some parts of Australia affects the availability of freshwater and subsequently agricultural production.

1.3.1. Trends in Rainfall Processes

Due to natural climatic and sampling variability it is difficult to distinguish trends from variability (e.g. Frei and Schar, 2001, Rauch and de Toffol, 2006, Verworn *et al.*, 2008). The smaller the scale or the more extreme the values, the more difficult this becomes. Averaging over larger regions reduces the natural variability more than averaging over smaller areas. Due to the climate oscillations, trend testing results may be biased (as discussed previously) but may also strongly depend on the period selected. For example, in Australia, the relatively low rainfall in the first half of the twentieth century provides some precedent for the decreases since 1990. It is plausible that there are a few abrupt changes in rainfall and temperature time series, perhaps influenced by annual changes in ocean currents, rather than some more systematic trends.

1.3.2. Climate Indices and their Influence on Australian Hydro-climatic Variables

The concept of “drivers” of climate variability is useful and is widespread in similar studies overseas (Chowdhury and Beecham, 2010). However, it is important to note that indices that have predictive power in the current climate may have lesser influence in a future changed climate.

Among various hydro-climate variables (rainfall, evapotranspiration, temperature, humidity), rainfall is the most important and most studied variable because of its significance for sustainable water, agriculture and ecological management. Several previous studies have investigated rainfall characteristics, variability and trends as well as mechanisms for their spatial and temporal changes in Australia (Murphy and Timbal, 2008, Chambers, 2003, Chowdhury and Beecham, 2010, Beecham and Chowdhury, 2010) and around the world (Cheng *et al.*, 2004, Ventura *et al.*, 2002, del Río *et al.*, 2005, Rauch and de Toffol, 2006). Generally, Australian rainfall exhibits a high degree of spatial and temporal variability. Chowdhury and Beecham (2010) and Beecham and Chowdhury (2010) have identified significant temporal variability at fine temporal scales (sub-daily). The persistence characteristics of Australian rainfall have been identified by Simmonds and Hope (1997).

Australian rainfall is believed to be influenced by several natural climate phenomena that originate from the Pacific, Indian and Southern Oceans. Identified key climate drivers include the El Niño Southern Oscillation (ENSO), the Pacific and Indian Ocean sea surface temperature (SST) variability, the sub-tropical ridge, the Southern Annular Mode (SAM) and the Madden-Julian Oscillation (MJO) (Cai *et al.*, 2011, Chowdhury and Beecham, 2010, McBride and Nicholls, 1983, Smith *et al.*, 2000, Drosdowsky, 2005, Donald *et al.*, 2006, Hendon *et al.*, 2007, Meneghini *et al.*, 2007). Recent studies have claimed that the ENSO and Indian Ocean Dipole (IOD) phenomena significantly influence eastern and southern Australian rainfall, respectively (Cai *et al.*, 2011). In addition to the Pacific Ocean SST, influence from the Indian Ocean SST was identified in some previous studies (Ummenhofer *et al.*, 2008, England *et al.*, 2006).

The influences from these climate phenomena generally vary spatially within Australia. The relative influence of these phenomena on rainfall and their teleconnection pathways is of current research interest. Recent variability in Australian rainfall imposes a challenge for the sustainable management of water resources. Understanding this variability and the factors influencing this phenomenon are very important for water managers and policy makers.

1.4. Hydro-climatic Projections of Rainfall and Runoff

Projection of water availability in a changing climate is a well-researched area. Three steps are generally followed in hydrological projections. First, global climate models (GCMs) are used to predict scenarios of climate variables. Second, an appropriate stochastic or dynamic downscaling technique is used to generate catchment scale climate scenarios from the GCM outcomes. Third, a calibrated hydrologic model is applied for runoff scenario development. Several studies examine the changes in rainfall patterns and their effects on hydrology, stormwater management, agricultural practices and stream ecosystems (Willems and Vrac, 2011, Chiew *et al.*, 2010, Beecham and Chowdhury, 2012, Cheng *et al.*, 2004). Among climate variables, rainfall is the key parameter that significantly affects runoff scenarios (Chiew, 2006, Xu, 1999). Therefore both rainfall and hydrologic modelling processes are important in climate change impact assessment on catchment hydrology.

A large number of studies have been carried out in rainfall modelling in order to generate synthetic rainfall data considering future climate change and variability scenarios (Srikanthan *et al.*, 2005, Rosenberg, 2004, Coombes *et al.*, 2003). Several stochastic and dynamic downscaling techniques have been used for catchment scale rainfall scenario generations (Chiew *et al.*, 2009, Chiew *et al.*, 2010). While each technique is adequate in reproducing historical rainfall characteristics, a wide range of variability has been observed in generated rainfall scenarios. These lead to a wide range of variability and uncertainty in hydrological projections.

Climate change adaptation and mitigation policies are generally developed based on projected changes in rainfall and runoff (Kirono *et al.*, 2007). Hydro-climatic projections are particularly important for Australia, where rainfall and runoff exhibits significant spatial and temporal variability (Chowdhury and Beecham, 2010, Beecham and Chowdhury, 2010) and where supply of water resources is a major constraint for spatial urban area development (Evans and Schreider, 2002).

The recent Millennium drought from 1997 to 2009 caused severe reductions of water runoff and water use in the southern MDB. The impact of climate change on rainfall and resource reductions is uncertain. In Australia areas with severe below average rainfall conditions are located in the south-east, the south-west, and south-east Queensland (Figure 1). Similar future conditions are likely to occur with slight regional runoff reductions in southern coastal areas under wet extreme projections (Figure 2).

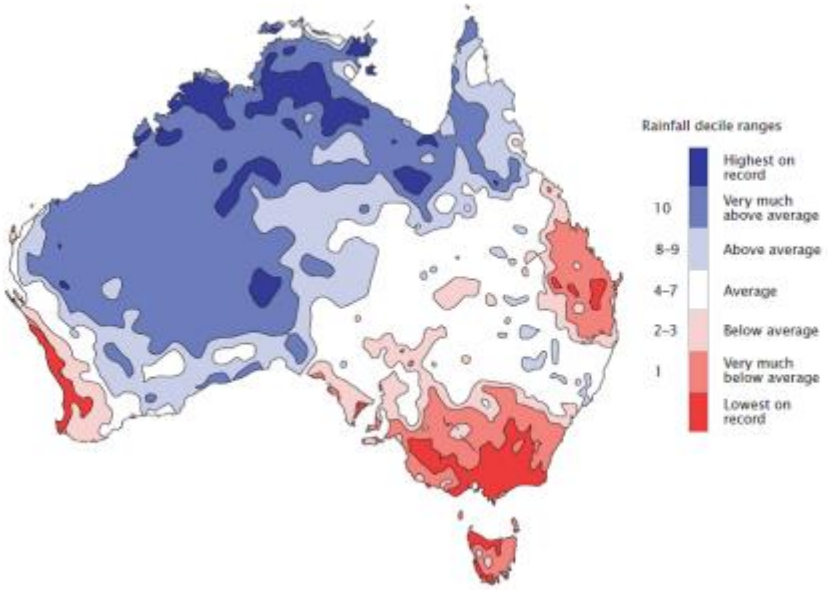

Figure 1 Rainfall deciles across Australia (01.01.97 – 31.12.2009) based on climatology 1900 – 2009

Source: CSIRO (2008b)

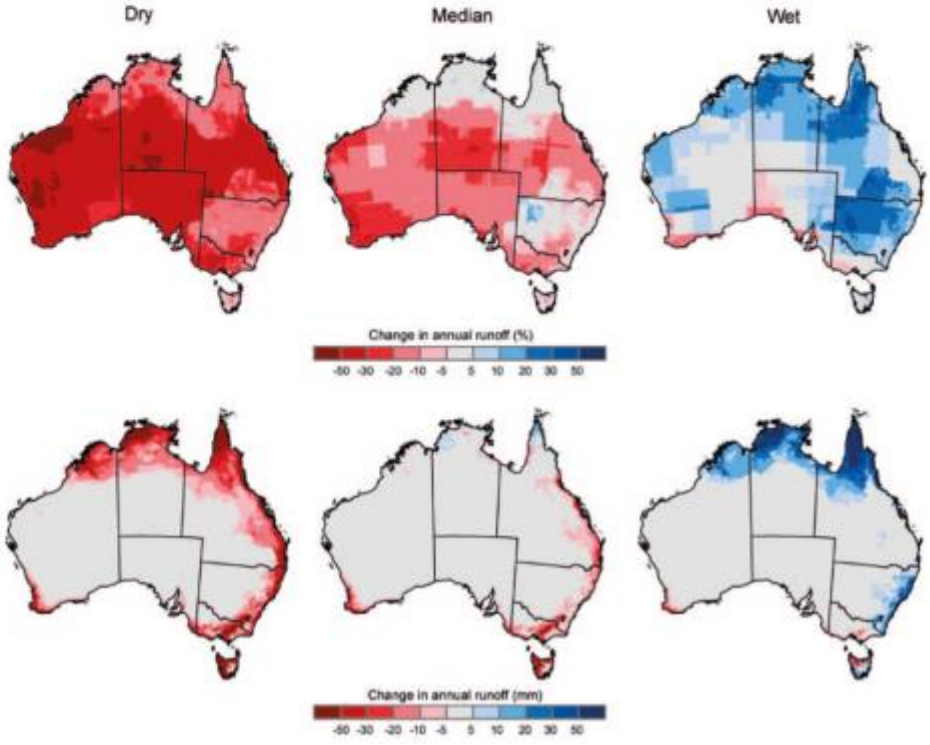

Figure 2 Change in average annual runoff for 1°C global warming (2030 vs. 1990)

Source: CSIRO (2008b)

In general, average annual runoff could only be maintained in north-west Australia. Most severe reductions are seen to be in the south-west of Western Australia (-25%) and the southern MDB (-10%).

1.4.1. Murray-Darling Basin Hydro-climatic Projections of Rainfall and Runoff

Several studies have projected hydrological consequences of climate change in Australian catchments (Chiew and McMahon, 2002, Chiew, 2006, Chiew *et al.*, 2009, Chiew *et al.*, 2010, Evans and Schreider, 2002, Schreider *et al.*, 1997, Whetton *et al.*, 1993, Close, 1988, Nathan *et al.*, 1988). Most of them have developed annual runoff availability scenarios for some regions. Limited studies have actually focused on catchment scale projections of hydrological characteristics and their possible consequences.

As discussed above, the recent Millennium drought had a major impact in these areas due to reduced storage levels in reservoirs, less allocated water for irrigation especially in the southern MDB, urban water restrictions, and partly suspensions of water sharing arrangements. It is likely that such conditions—similar to characteristics of the Millennium drought—will become more frequent in the future with major economic, environmental and social impact. South-eastern Australia comprising the entire MDB was heavily affected by the recent drought period (Figure 3).

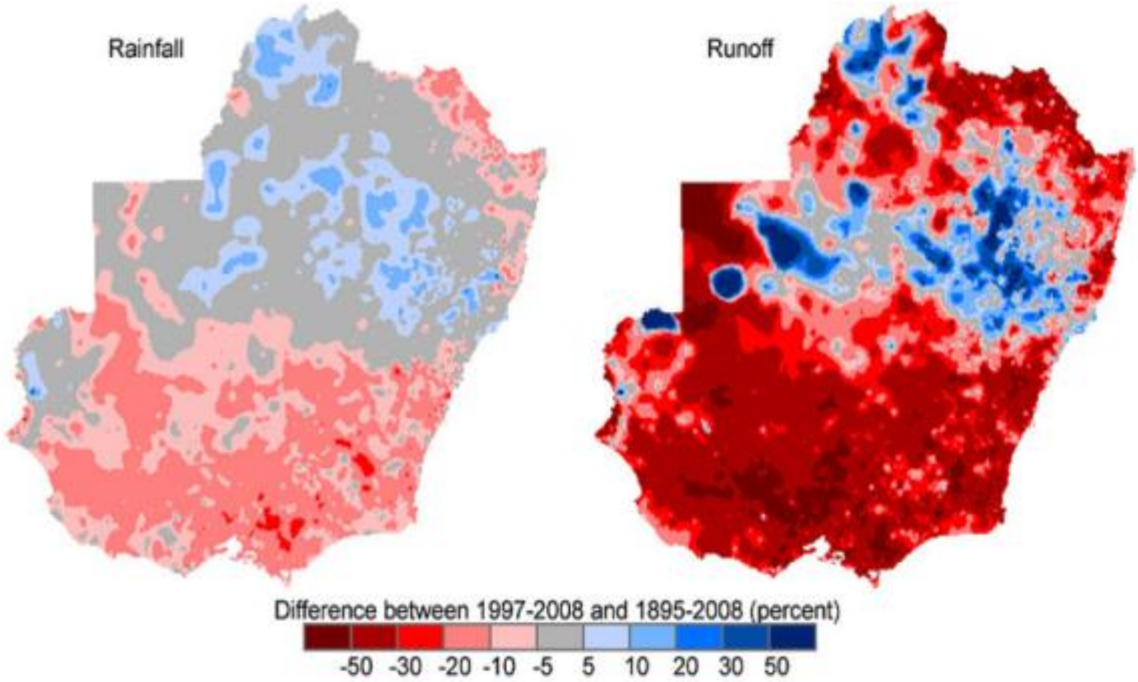

Figure 3 Difference (%) between mean annual rainfall and runoff in 1997 – 2008 and the long-term means (1895 – 2008)

<u>Source</u>: CSIRO (2008b)

Before continuing, it must be noted that in this report we focus much of our discussion on the southern MDB, because that is where much of the Basin's water trade takes place. This is in no small part due to the nature of the interconnected river systems and trade regimes. This should not be interpreted as a measure of disinterest on our part in the northern Basin and its issues. On the contrary, there are many interesting and important trade issues that will form part of a Nation Water Commission project exploring emerging groundwater markets, water quality markets and other surface water trade issues outside the MDB. However, for our purposes a larger proportion of data and measures are available from the southern trade zones, so we tend to focus our discussion on that context.

Compared to the long-term mean, runoff in the southern MDB during the recent drought period was far below the long term mean and mostly twice as low as the lower mean rainfall. Reduced runoff has never been as severe as during the Millennium drought. By 2030 the impact of climate change on average runoff is seen to be relatively minor (reduction), whereas the amplitude of annual and decennial variability is projected to be much stronger. In the future, droughts are predicted to be more intense while floods may become less frequent (Saleth *et al.*, 2011). The discrepancy between water supply and demand may therefore increase. By 2070 the average runoff could reach a level similar to levels during the recent drought.

The most comprehensive analysis so far in the MDB has been the MDB Sustainable Yields Project, conducted by CSIRO for MDBA. The MDB Sustainable Yields Project assessed the anticipated impacts of climate change, catchment development and increasing groundwater extraction on the availability and use of water resources in the Basin. The report uses long-term (1895-2006) and recent (1997-2006) historical data, as well as future climate scenarios applying multiple global climate models and considering potential developments (Figure 4).

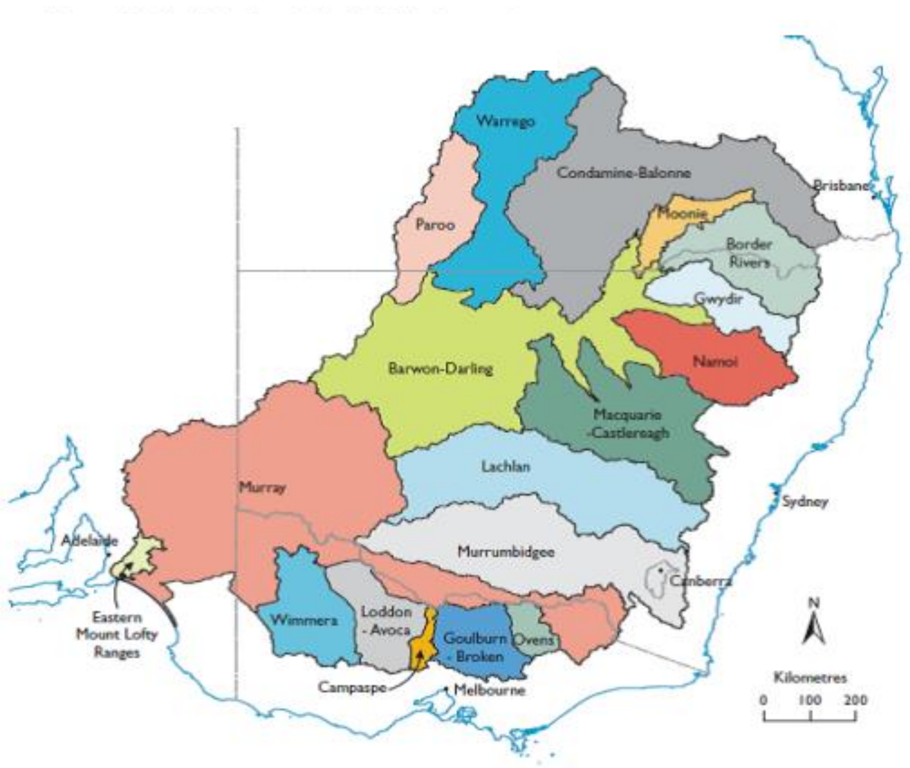

Figure 4 Overview of Murray-Darling Basin Sustainable Yields Project regions

Source: CSIRO (2008b)

The report findings suggested that downstream at the mouth of the River Murray the total flow of water has been reduced by 61%, with the river not flowing through the mouth 40% of the time. The question of how climate change will affect the system is not without uncertainty. A range of scenarios were considered: median, dry extreme and wet extreme. It seems highly likely that surface water availability will decline in the MDB. By 2030 the surface water availability is projected to be reduced by 11% in the median scenario (i.e. 2,481 GL/year less surface water across the MDB), ranging from 9% in the northern part of the MDB and 13% in the southern MDB.

Under the median water availability decline scenario, total surface water use would reduce by 4% under current water sharing arrangements. Consequently, there would be larger impact at the mouth of the river, with flows reduced by 24% and losses increased by 12%. About two thirds of the total diversion reduction would occur in the regions Murray, Goulburn-Broken and Murrumbidgee. This reduction would mean that less than a third of the total flows would reach the Murray mouth. Therefore, it can be stated that future volumetric reduction is rather caused by climate change impacts on environment than by changes in water use. The effect on reduced surface water will be much greater in years of drought.

In support of these findings are the more recent key findings from the south eastern Australian climate initiative (SEACI) project (CSIRO, 2010, CSIRO, 2012). This project finds that climate drivers in the region have shifted southward, translating into considerable reductions (between 2 and 22 per cent south of 33° latitude) to winter and annual rainfall runoff if the average global temperature increases by 1°C. Predictions for northern MDB climate change were less certain across models, with some rainfall and runoff increases predicted. In general, the SEACI recommendations were for water managers and users to identify robust and adaptive processes to suit a wide range of future uncertain climate and stream-flow scenarios. To assist water users adapt to stream-flow variability, the Australian Bureau of Meteorology (BoM) has been tasked with providing improved stream-flow forecasting tools, which may interact with water markets to enhance regional information provided to users during extreme events (see for example http://www.bom.gov.au/water/ssf/).

A strong variation of surface water diversion development in the future is very much dependent on the regions within the MDB. At the regional level, under median global warming scenarios water diversions in driest years would fall by 10% in most NSW regions (increasing to around 20% in Murray and Murrumbidgee), and by between 35% and 50% in Victorian regions by 2030. Considering the extreme dry scenario these numbers would change to 40-50% in NSW (or over 70% in Murray), and between 80% and 90% in Victorian regions.

By 2030 surface water diversion could also reduce up to 10% in the Wimmera region related to historical climate and current water resource developments. Other above average affected regions are Gwydir and Lachlan (both 8%), Moonie, Loddon-Avoca, and Goulbourn-Broken (all 6%), and Campaspe (5%). Obviously, on the basis of these predictions Victorian water regions would be more affected. The extent of surface water availability and use would vary greatly according to extremely dry or wet conditions. The impact of climate change is seen to be greatest in the south-east MDB (Figure 5). The Murray, Goulburn-Broken and Murrumbidgee regions would be most affected by reduced surface water availability. The major issue regarding the relationship between projected available water, water use and a potential continuation of current water sharing is the water supply for the environment within the system. Consumptive water users would be less affected.

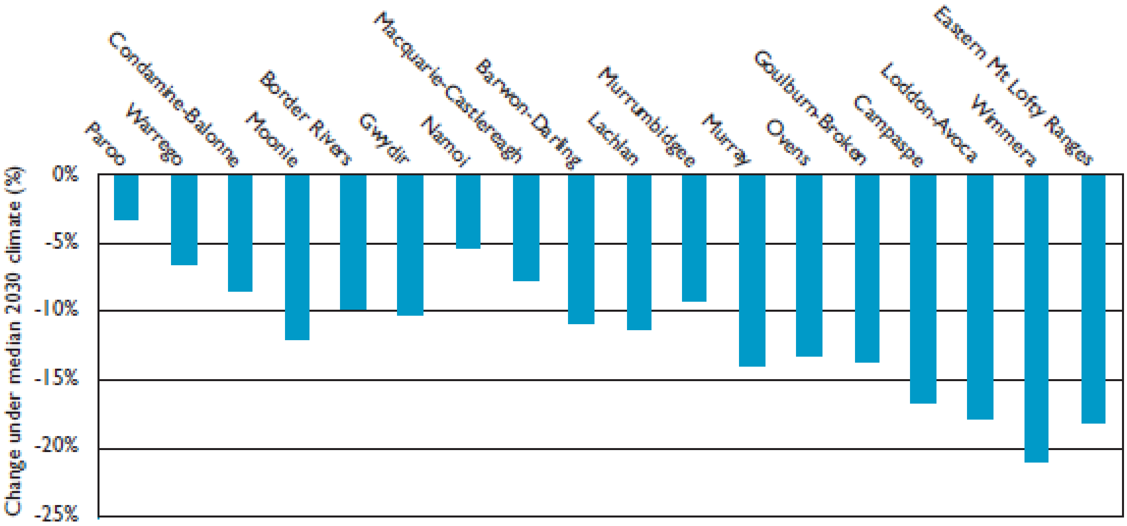

Figure 5 Percentage changes in average surface water availability by region (median 2030 climate projection)

Source: CSIRO (2008b)

1.4.2. Groundwater in the MDB

By 2030 groundwater use in the MDB could nearly double from currently 16% to over 25% as a share of total water use, although such estimates may significantly underestimate future demand pressures (Barron *et al.*, 2011). In many high-use groundwater areas practices are unsustainable, with 11 out of 14 national groundwater aquifers determined to currently experience between 60% and 80+% use by agriculture, domestic and town supply and/or commercial and mining uses (Barron *et al.*, 2011).

Regarding the future development in ground water, changes in rainfall recharge and ground water levels would be relatively small compared to future changes in extraction, which could reach nearly 1,800 GL/year by 2024 (MDBA, 2011b); much of that increase at costless or heavily discounted access prices for users (Cosier *et al.*, 2012).

Table 1 Proposed changes in MDB water extractions by catchment/region

Catchment	**Trading Zone**	**Net Change in Volume**	
		Groundwater	Surface water
Condamine	Northern	29.8	-60.0
Border Rivers QLD	Northern	95.7	-8.0
Warrego Paroo	Northern	264.0	-9.0
Namoi	Northern	0.0	-10.0
Central West	Northern	0.0	-65.0
Maranoa Balonne	Northern	19.9	-40.0
Border Rivers Gwydir	Northern	353.0	-49.0
Western	Northern	277.9	-6.0
Lachlan	Unconnected	481.2	-48.0
Murrumbidgee	Southern	0.0	-320.0
North East	Southern	0.0	-32.9
Murray 1	Southern	0.1	-7.9
Goulburn Broken	Southern	-21.6	-387.3
Murray 2	Southern	1.3	-131.0
North Central	Southern	0.0	-194.5
Murray 3	Southern	1.1	-117.9
Mallee	Southern	84.8	-30.4
Lower Murray Darling	Southern	0.1	-13.2
SA MDB	Southern	210.8	-101.0
	TOTAL	**1,798.0**	**-1,631.0**
Further Reduction Trading Zones:			
	Northern		-143.0
	Southern		-971.0
	Total surface reductio		**2,745.0**
	TOTAL Net Change (Ground + Surface)		**-947.0**

Source: (MDBA, 2011b)

Regions like Border Rivers, Lower and Upper Lachlan and the SA Murray would not be sustainable due to increases in ground water extraction levels. Rainfall recharge of groundwater is expected to slightly decrease in the south and slightly increase in the north of the MDB under median climate conditions by 2030. Overall, water exchange would see no net impact across the MDB. Extreme climate conditions such as the recent Millennium drought period are likely to become more common. If and to what extent such developments are attributable to global climate change remains uncertain although research indicates a potential relationship.

CSIRO (2008c) also revealed that high reliability water, e.g. for town water supplies, will not be affected by climate change. However, ‘general security’ and ‘low reliability’ water products would be more affected in future regarding average seasonal allocation volumes and the portion of time when 100% allocation could be assigned. Regions with relatively high surface water use would be most affected by reduced water reliability. The same applies to regions which water availability is highly vulnerable to climate change. Also water products that are already on a low reliability level will be more affected by reliability reduction. The regions Murray, Goulburn-Broken, Campaspe, Loddon-Avoca and Wimmera would see highest reductions in water reliability. Under the dry extreme 2030 climate reliability reduction would generally be larger. Therefore under current development and given historic climate patterns, the relative level of MDB surface water use could increase by 4% to 60%. This is because surface water use would reduce less than surface water availability.

1.5. Effects on Evapotranspiration

Finally, in terms of water markets and particularly irrigation, it is important to understand how climate change will influence not only rainfall and runoff but also evapotranspiration and other parts of the water balance including infiltration to groundwater. Evapotranspiration (ET) is the sum of evaporation and plant transpiration. Evaporation is the movement of water to the air from sources such as soil, vegetation interception and water bodies. Plant transpiration is the movement of water within a plant and the subsequent loss of water as vapour through stomata in its leaves (Rothfuss *et al.*, 2010). Changes in evapotranspiration over land are controlled by changes in precipitation and solar-radiation intensity and the changes would, in turn, impact on the water balance of runoff, soil moisture, water in reservoirs, the groundwater table and the salinization of shallow aquifers (IPCC, 2007).

A plant’s water requirement is very complex to predict in practice. For agricultural crops, in order to achieve optimum yield, irrigation and rainfall should replace the total water lost through evapotranspiration (Nouri *et al.*, 2012). In many agricultural systems, there is a uniformity of plant density, height, vigour and water availability which provide a straight forward approach for evapotranspiration measurement, although estimating the water requirements of such environments is not without challenge. With climate change, evaporative demand, or ‘potential evaporation’, is projected to increase almost everywhere (IPCC, 2007). This is because the water-holding capacity of the atmosphere increases with higher temperatures. However, relative humidity is not projected to change markedly. Water vapour deficit in the atmosphere increases as a result, as does the evaporation rate (Trenberth *et al.*, 2003).

1.6. Discussion

In general, long-term historical trends due to anthropogenic climate change are difficult to quantify and verify because of limited data, instrumental or environmental changes, inter-annual variations and longer term climate oscillations. The problem of data limitation is very relevant when analysing trends. As highlighted by Frei and Schär (2001) and Schmidli and Frei (2005), the signal-to-noise ratio in a trend analysis depends on the record length, the trend magnitude, the ‘noise’ level (e.g. the magnitude of the variations), and the frequency of events under consideration.

In the case where a historical trend is present and can be detected, extrapolation of this trend to future decades can be made but these will have an even higher degree of uncertainty.

1.7. Key points

The major points from this section include:

- It has been predicted that Australian average temperatures will increase by between 0.6 and 1.5°C by 2030, while annual rainfall will decrease in the southern and north-eastern region and available moisture will also decrease all over Australia. Drought frequency will increase in the southern and south-eastern region, whereas heavy rainfall and tropical cyclone events will increase in the north eastern regions. Therefore both population growth and climate change will impose significant pressures on the country's water security.

- In the presence of climate change induced uncertainty, water systems need to be more resilient and multi-sourced. This is partly because of decreasing volumetric rainfall trends in many parts of the world, which might have severe effects on reservoir yields and operational practices. In addition, severe intensity rainfall events can cause flood inundation problems, and the probabilities and risks of extreme events are changing in response to global warming.
- It has been predicted that surface water availability will decline in the MDB, by up to 11% in the median scenario by 2030, with more impact expected in the southern MDB. Flows as the end of the river would also be reduced, and more variability would be experienced in various regions (with Victoria most affected). In particular, the regions of Murray, Goulburn-Broken and Murrumbidgee would be most affected by reduced surface water availability. By 2030 groundwater use in the MDB is predicted to nearly double, and there are indications that in many high-use groundwater areas practices are unsustainable.
- Security of water products will be affected, and in particular, 'general security' and 'low reliability' water products would be most affected in the future.
- There are a range of measurement, data collection and analysis issues that must be taken into account when making and assessing climate change impacts predictions. However, the aggregate global and regional assessments of changes to Australian agriculture are expected to be significant over the next 20 to 30 years.

2. AGRICULTURAL CLIMATE CHANGE IMPACTS

2.1. Agriculture and Water Supply

Water is critically important in food production regionally and worldwide. More than 80% of global agricultural land is rain-fed with crop productivity depending solely on precipitation (IPCC, 2007). In many arid and semi-arid regions, including Australia, the productivity of this land is limited by climate and as such agricultural production is very vulnerable to climate change (FAO, 2003).

Irrigation accounts for approximately 70% of total water withdrawals worldwide and for more than 90% of consumptive water use. While irrigation only accounts for 18% of agricultural land it generates about 40% of total agricultural output. This is because irrigated crops yield on average 2–3 times more than their rain-fed counterparts (FAO, 2003). While too little water leads to vulnerability of production, too much water can also have deleterious effects on crop productivity, either directly by affecting soil properties and by damaging plant growth, or indirectly by harming or delaying necessary farm operations (IPCC, 2007). Extreme precipitation events, excessive soil moisture and flooding disrupt food production and rural livelihoods worldwide (Rosenzweig *et al.*, 2002). Therefore by affecting crop productivity and food production, water plays a fundamental role in food security.

Water availability for food production may well be threatened by climate change, as a result of projected mean changes in temperature and precipitation regimes, as well as due to projected increases in the frequency of extreme events, such as droughts and flooding (Rosenzweig *et al.*, 2002). Climate impact assessments of food production depend strongly on the GCM precipitation projections used (IPCC, 2007) as discussed in Section 2. A wide range of precipitation scenarios is currently available. Hence it is very important to understand climate change and variability in order to assess the increased vulnerability in a future climate.

The likely impacts of climate change need to be understood within an established history of climate variability in Australia. Farmers have always had to deal with climatic unpredictability. However, the way climate change and the uncertain, variable factors that traditionally shape Australia's climate will interact is unclear (NWC, 2012b). Farmers therefore will be faced with a greater degree of unpredictability in the future. Moreover, the likelihood of greater uncertainty about water availability and decreased water security due to climate change need to be set within a wider context of increasing demand for water from agriculture, industry, urban populations and an increasing demand for the formal inclusion of an environmental flow (Bjornlund *et al.*, 2013, Chiew *et al.*, 2011). In this sense, climate change will exacerbate an existing trend toward multiple, competing demands for water. Bjornlund, *et al.* (2013) point out that at present, there is increasing consumptive demand for water, as well as an increased push for better environmental flows. Yet the likelihood is that there will be decreasing supply because of climate change and limited potential for water infrastructure development.

Lower latitude countries like Australia are more likely to be significantly affected because they are close to the limits of heat tolerance and moisture levels. Adaptation, not just mitigation, is crucial and will depend on the existence of effective strategies and the capacity to implement them. Limits to climate change are absolute obstacles to adaptation and cannot be overcome, while barriers are obstacles that can be overcome. Despite the lack of certainty about the impact of climate change on what is already a highly variable, unpredictable climate, it can be safely said that climate change will have significant consequences. It is likely to entail a number of features which will have obvious implications for individual farm management and agriculture as a whole. These changes are likely to be both incremental and involve extreme weather events; they include:

- increases in temperature (both mean temperature and variations in temperature);
- increase in the number of heatwaves;
- decreases in both rainfall and runoff;
- increases in events of extreme rainfall falling within a short space of time ;
- increases in areas experiencing exceptionally dry years; and
- increases in the number of dry years (NWC, 2012b).

Australia is likely to be more affected by climate change than any other country, and agriculture is likely to be most adversely affected of any sector with a projected decline of 17% in productivity by 2050. This has significant consequences for many family farms and for rural communities. It has been found, for instance, that rural industry stakeholders do not like the term climate change because of scepticism about its existence and cause. Others found that farmer's willingness to act on climate change was hampered by their uncertainty and conflicting views about its reality, lack of clear information and a belief that any occurrence was natural (Buys *et al.*, 2011).

It is suggested that the farm profitability cycle observed in the past (3 years profit, one year loss, 4 years breakeven) may change to one year of profit and three years of loss. These risks will have to be managed. The NWC endorses this point by observing that one means of adaptation to reduced water supply is accepting lower yields and returns while continuing production (NWC, 2012b). In addition to the risk posed by climate change, managing the uncertainty is a key element of risk management (NWC, 2012b).

2.1.1. Irrigation in Australia

Pearson (2008) suggests that more research has been directed toward understanding the impact of climate change on dry-land farming than on pasture based enterprises. Less is known about grazing, dairy, viticulture and horticulture.

The size of the pie-charts in Figure 6 symbolise the volume of irrigated water used in Australian states. The exception is that the use of irrigation water in Western Australia, Tasmania, and Northern Territory was significantly smaller than the pie-charts indicate and the charts were enlarged (indicated by lines).

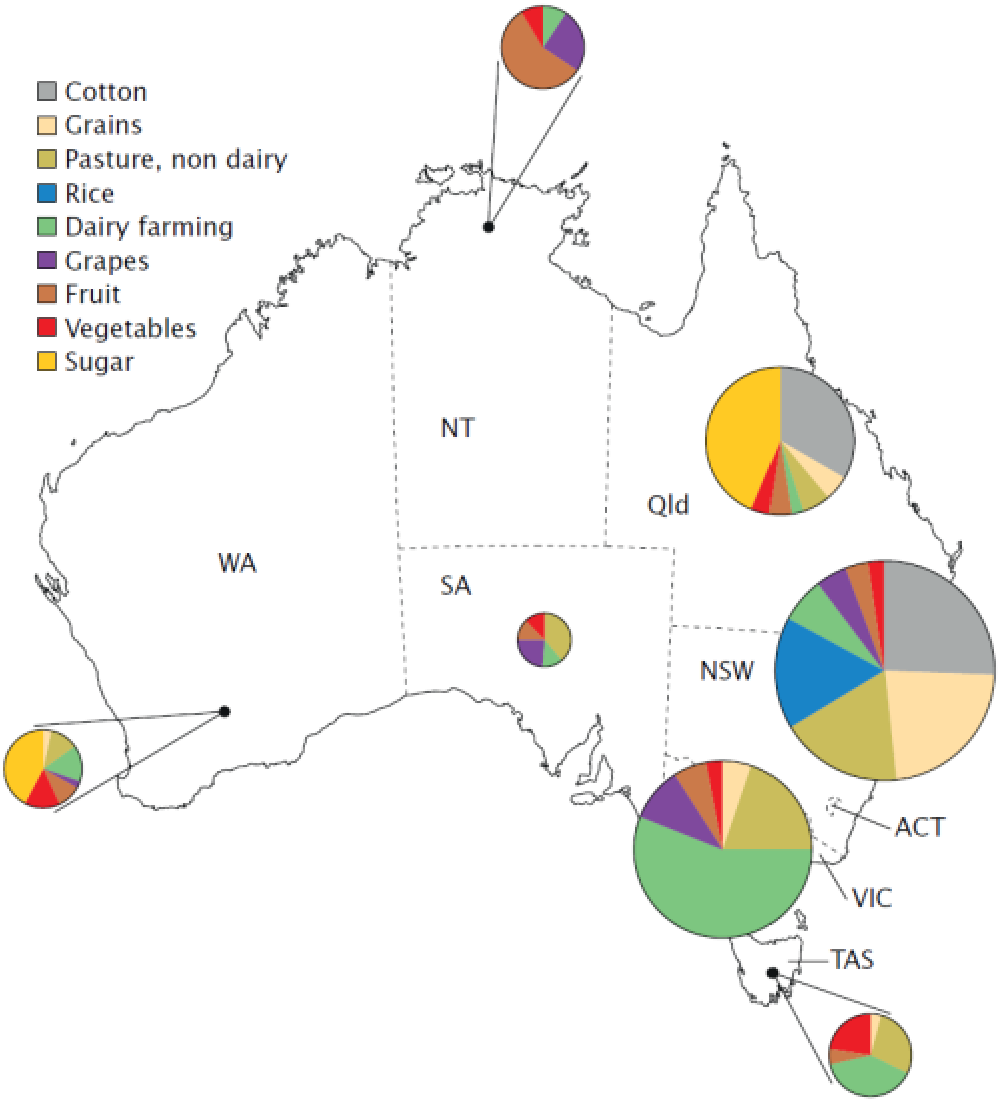

Figure 6 Water use (GL) in 2004-05 by state and irrigation commodity

Source: (Prosser, 2011)

The Millennium drought caused a 70% reduction in irrigation water use in the 2000s. However, the gross value of irrigated agricultural produce fell only by 14%. Hence, irrigation productivity seems to be relatively adaptable to drought, mainly influenced by increased prices—especially in dairy and cereals—but also because of water trade and flexible adaptation of production in annual crops for example cotton (Prosser, 2011).

If we compare industries by water consumption in Australia, agriculture uses most water by far. On the other hand, when considering gross value per used water, mining and manufacturing are the two major high value users followed by forestry and fishing, and electricity and gas supply (Kiem and Austin, 2012).

2.1.2. Irrigation in the MDB

Table 2 summarises the major agricultural commodity activities for each of the southern MDB regions. Generally, agricultural production can be categorised into horticultural (e.g. fruit trees or wine grapes), rice and other annual crops (e.g. cereal, pasture and vegetables), dairy cattle using purchased or self-grown feed and mixed farming operations where irrigated and dry-land production is combined (Grafton and Jiang, 2011).

Table 2 Predominant irrigated agricultural commodities in the southern MDB

Region	*Horticulture*	*Rice/Annuals*	*Dairy*	*Mixed farming*
NSW Murray		✓	✓	✓
Murrumbidgee	✓	✓		✓
SA Murray	✓	✓	✓	
Victoria Goulburn	✓	✓	✓	✓
Victoria Murray	✓	✓	✓	

These different agricultural production activities have different water demand schedules as a result of varying elasticities of demand, which also drive water trade activity. For example, horticultural production is relatively water demand inelastic in the short-term due to high risks of investment loss should the crops fail/die. Water allocation trade will be used by horticultural producers in times of low supply, and/or water entitlements may be purchased to provide additional security/reliability. Rice and other annual crops, conversely, can be decided on a yearly basis when water availability, prices and marginal commodity returns are known. Water demand elasticity for annual crops is therefore relatively elastic.

Dairy farmers also enjoy a degree of flexibility in their production options, selecting between the purchase of water allocations to grow their own feed crops or selling some (all) their water allocations to fund the purchase of off-farm hay to meet some (all) of their feed requirements—depending on the relative price differential between water and hay. As such, dairy farmers' water demand elasticity can also be relatively elastic. Finally, mixed farmers have highly elastic demand schedules for water, since they can substitute irrigated for dry-land farming production relatively quickly and easily based on price differentials between the commodities that they grow and water market prices. Giving evidence to these water demand elasticities, an inverse relationship between announced annual allocations and the volume of water allocation trade can be identified. Between 2001/02 and 2005/06 increasing announced allocations result in decreasing volumes of water allocation trade, while the period between 2006/07 and 2010/11 experienced relatively higher volumes of water allocation trade as announced allocations decreased during low inflows.

It might be expected that if water is scarce, agricultural production will decrease and drive commodity prices higher. However, since commodity prices are typically established from world demand and international terms of trade it is often impossible to identify strong differentials between cropping and water market prices. On the other hand it is possible to identify a strong inverse relationship between seasonal allocation levels and both the prices of, and trade in, agricultural water. As shown, during 2007/08 to 2009/10 early-season (i.e. July to October) water prices are unstable as uncertainty persists about water availability from limited market supply and/or future announced water allocation levels.

2.2. Water User Adaptation

Water users across the sMDB will have to adapt to climate change and reduced water allocations more so in the future. Water supply and use efficiency becomes more and more important for agricultural irrigation because of lower water availability projections and increasing irrigation demand. Past experience shows that there has been much adaptability by farmers and irrigation communities, as classes of users; especially given recent drought experience.

Adaptation has been defined as adjustments in human-environmental systems in response to observed or expected climatic changes. It is influenced by a farmer's willingness to adopt new strategies. Park *et al.* (2012) outline a theory of Adaptation Action Cycles, where they define the difference between ***incremental*** and ***transformational adaptation***. ***Transformation adaptation*** occurs when ecological, economic, or social conditions make existing systems untenable, and it signifies a major change in livelihood, location or identity. ***Incremental adaptation*** is more related to the adoption of actions that do not require major decisions or information to adopt.

We have classified various adaptation strategies for water users into the two categories of incremental and transformational change. Table 3 (Wheeler *et al.*, under review, used with permission) illustrates a wide range of incremental adaptation measures irrigators, for example, can adopt to improve their water use efficiency, reduce climate change and water security risk, and restructure their farm. Adopting these measures (from each of the categories of information, trade, agronomy, farm structure, land, infrastructure and environment) will be crucial for many irrigators who have sold water entitlements, if they want to remain farming in the future.

Table 3 Incremental Irrigation Adaptation Measures

Type	Strategy	Specifics
Information	• Utilise a variety of information to predict risk of water scarcity for the season, through a) utilising historic records of inflows and allocations; and b) utilising Southern Oscillation Index data and a range of climate projections for rainfall and evaporation predictions • Utilise info. on water trade patterns to understand intra-seasonal prices/demand	• Provides better predictions about risk of crop failure, whether to plant or trade water for the season • Similarly, use crop insurance to hedge against climate risk • Can sell/buy water allocations/entitlement at the point in the intra-season where private gains are maximised
Trade	• Utilise alternative water market products (options, entitlement leasing) • Buy (or sell) more water allocations and/or entitlements	• Helps to even out price hikes, provides more certainty about prices and returns over the medium term • Swap lower security entitlements for higher security entitlements • Make greater use of resources not yet fully allocated or subject to formal extraction caps

Type	Strategy	Specifics
	- Carry-over	(such as groundwater) - Use carry-over techniques (where available) & buy water allocation when cheaper to carry-over
Land	- Buy (or sell more land) - Increase (or decrease) irrigated areas (e.g. irrigate a larger section and improve input efficiency or only irrigate part of an area) - Dry-land practices	- Larger enterprises provide a number of benefits in terms of business scale – a larger enterprise can build in greater flexibility and may have the capacity to respond more quickly to changed conditions or to withstand volatility - If production is limited by available water supply, irrigators may need to abandon the idea that production can be maximised on individual paddocks. It is likely that optimal farm performance in irrigated settings will be arrived at by sub-optimal paddock performance & spreading the water where land is abundant - Learn & implement dry-land practices (e.g. stubble retention and/or supplementary feed for livestock) to increasingly diversify in future
Farm structure	- Increase off-farm work - Portfolio management - Develop ownership structures to better manage risk	- Reduce risk associated with one income source - Have a number of undertakings to optimise responsiveness to water availability, such as a mix of permanent & annual plantings. Put mechanisms in place to share/transfer risk - This may mean further consolidation, possibly at an accelerating rate, to larger, better capitalized family enterprises or corporate structure agricultural enterprises. Establish succession early on for the farm - Develop longer-term supply contracts
Agronomy	- Change basic agronomy and management farm practices	- Different crop mixes, diversify, varieties, planting dates, irrigation & fertilizer regimes, soil management practices, substitute bought feed for produced feed, fallow production area, shift timing of livestock reproduction; focus on more water flexible & annual/semi-annual crops; use deficit irrigation when needed
Infrastructure	- Adopt more efficient irrigation water infrastructure - Improve irrigation management	- E.g. install automatic bay gates, drip irrigation, laser grade paddocks, update reuse system, recycling system, solar energy use, on-farm water storage - E.g. improve irrigation scheduling, soil moisture monitoring, decrease furrow lengths
Environment	- Employ sustainable practices on farm	- Plant trees, crop cover, grade banks, improve soil management, conservation tillage

Such strategies highlight the individual nature of adaptation to changing water availability and security under climate change, as discussed in detail below.

2.2.1. Influences on irrigator adaptive variability

There is a general agreement that water markets have devolved greater responsibility for managing water and its part in farm management to individual irrigators (Loch *et al.*, 2012, NWC, 2012b, Bjornlund, 2006a). Others argue that there has been a more general shift in the way farming is conceptualised, and responded to by policy makers. In the neoliberal regime that has governed Australian agriculture for the past three or four decades (see Section 1), policy emphasis has shifted away from emphasising the structural influences on agriculture to placing greater onus on 'farm productivity' and 'farmer efficiency' (e.g. NWC, 2006, Brooks and Harris, 2008, Qureshi *et al.*, 2011). This changing orientation places greater weight on the capacity of individual farmers to adapt to, and effectively manage, uncertainty. The onset of climate change is likely to increase the demands on individual farmers to manage uncertainty and risk. Risk management will become an integral aspect of farm management and challenges will come from many directions. Previous research has clearly shown that early-adopters in the initial water markets (up until mid-2000s) played an important role in assisting irrigators in managing supply risk (Bjornlund, 2006a).

The NWI risk assignment framework delineates how the risks of reduced water availability and increased uncertainty about water availability will be shared among water entitlement holders and governments (Crase, 2012b). It aims to provide entitlement holders with certainty in planning and investment by providing clear indications about how changes in water availability will be dealt with. This will generate a transparent and sustainable planning and entitlement framework. However, the implementation of this framework has not been fully implemented and some stakeholders are unclear about some elements of risk assignment. Risk assignment is crucial in the context of climate change and the framework clearly specifies that entitlement holders are to bear the risks of any reduction in their entitlements. However, in some instances, governments will assume complete or partial responsibility for changes in the underlying reliability of that entitlement where, for instance policy changes or there is improved knowledge about the level of extraction that is compatible with sustainability (NWC, 2012b).

2.2.2. Influences on irrigation community adaptive variability

Despite the existence of several strategies to adapt to drought, a major factor limiting the capacity to incorporate climate change into water resource management is not access to information, but rather uncertainty about potential adaptive responses and their effectiveness. This can be exacerbated by minimal specialist skills and a limited number of resources (Kiem and Austin, 2012).

The impacts of climate change will depend on the vulnerabilities of industries, communities' assets and regions. In turn, this vulnerability is influenced by degree of exposure and the sensitivity to that exposure by populations, economic assets, human activities and natural and physical systems. In turn, sensitivity is influenced by demographics, physical geography, production characteristics, wealth and income distribution and government policy (regardless of whether it is related to climate change. Accordingly, the impact of climate change on an irrigation community will depend on extent of reduced water availability (exposure) and extent to which the community is dependent on irrigation (sensitivity) (NWC, 2012b). The degree of adaptive capacity is also an important function of vulnerability. This refers to the capacity of a given sector / vector to adapt to climate change stimuli, their impacts and the associated risks.

For example, people in an irrigation community may be able to change their water use and crop types, or they may have the capacity to develop other industries in response to less available water (NWC, 2012b). Pearson and Langridge (2008) add weight to this observation by suggesting there are two ways of conceptualizing vulnerability. One (outcome vulnerability) is well suited to modelling linear changes in a tightly controlled system. A second way of thinking about vulnerability acknowledges the importance that context plays in shaping both the extent to which vulnerability exists and the way in which context can shape response to that vulnerability. While there may be biophysical limits to the way crops are vulnerable to changed climate patterns, the vulnerability of communities to climate change, and their capacity to respond, are likely to be more flexible and variable (Pearson *et al.*, 2008).

2.2.2.1. Barriers to adaptation

Factors that reduce adaptive capacity or willingness to adopt are therefore potential sources of limits and barriers to achieving farm-scale climate change adaptation. Limits to adaptation are absolute obstacles that render adaptation ineffective as a response to climate change and as such cannot be overcome, while barriers are obstacles that can be overcome with, for example, concerted effort, creative management, or changed thinking (Kolikow *et al.*, 2012).

The list below considers some barriers to adaptation:

- *Uncertainty*: Much literature has focussed on the social factors that impede uptake of adaptation strategies. Uncertainty is likely to be a bigger barrier to adaptation than risk or climate variability. Farmers are unlikely to commit to adaptation in the face of uncertainty about climate change and what it will mean and in the absence of certainty about the long-term effectiveness of adaptation strategies (Kolikow *et al.*, 2012).
- *Lack of Market signals*: Even where there is partial recognition of the need to adapt to climate change, market signals don't always give the right impetus for individuals and business to make the necessary changes. Market mechanisms might not allow for climate change, nor do they always provide the information or incentives to make changes. Further, they don't necessarily facilitate cooperation needed for effective information (DCCEE, 2010). Economic factors are more likely to prompt the adoption of innovative practices that are relatively simple to implement.
- *Financial factors:* Debt levels, access to finance, stage in the farm investment cycle, are all likely to influence response and adaptation to climate change (NWC, 2012b).
- *Information barriers*: Even when information is available, the tools and capability to translate it into decisions and actions are sometimes lacking; in other instances, specific information is not available. At other times, the skills and abilities to change farming techniques or modify crop mix are not available.
- *Cognitive barriers*: These arise from psychological factors that influence understanding of, and response to, climate change. Attachment to place and lifestyle can limit the willingness to take effective action. While agriculture has a long history of managing climate related risks and variability, there is a concern that climate change will present agriculture with challenges beyond its normal capacity for change and flexibility. Failure in agriculture will have huge consequences for rural communities. Sociological factors can be more closely

linked to the adaptation of innovative practices that are more complex, particularly in relation to acquiring new knowledge or skills. This is particularly the case because such factors are likely to have to be somewhat tailored to individual farms, which makes the information more complex and harder to obtain. A further factor is that some innovations are somewhat invisible in terms of their effects and may only be realized in the medium to long term.

- *Disincentives for preparedness*. For instance, many households are under-insured in relation to risks associated with extreme weather events. This can give rise to moral hazard if governments become, in effect and by expectation the insurer of last risk, as happened with the Queensland floods and the National Drought Policy. The Productivity Commission suggests that exceptional circumstances support programs do not encourage adaptation among farmers. It has been suggested that future government action should be directed toward encouraging farmers to improve their resilience and capacity to manage risks. This includes training in managing risks, trialling of innovations, assisting landholders to tap alternative income streams and natural resource management (DCCEE, 2010).
- *Climate change Beliefs*: The debate about whether or not climate change is occurring—and its causal factors—mean that cognitive variables may play a more prominent role in climate change adaptation than other adoptions. Farm surveys suggest that Australian farmers are far more sceptical about climate change than the general public. Donnelly *et al.* (2009) found that only 27% believed in climate change in 2009 (n=148), while Hogan *et al.* (2011) found the figure to be 55% in 2008 (see Box 2.1), and Wheeler *et al.* (forthcoming-a) found it to be 32% in 2010-11. Buys *et al.* (2011) make the point that people's understanding and conceptualization of the science underpinning knowledge of climate change is influenced by their existing socio-cultural frameworks and belief systems. For example, people of conservative persuasion are much less likely to accept the science of climate change. This certainly applies in Australia, where those of conservative political values are much less likely to agree that climate change is anthropogenic. Despite a long history of adapting to climate, Hogan (2011) found that the majority of farmers were unwilling to make long term adaptations because of short term pressures (commodity prices, input costs, condition of on-farm resources, drought). The daily (routine) challenges encountered by farmers was a major barrier to adapting; hence they need to be convinced that climate change is likely to exceed any previously encountered climate variability. Anything that affects farmers will also affect rural communities and it is therefore important to understand how they conceptualize climate change (Buys *et al.*, 2011).

Box 2.1: Australian Farmer Clusters

Hogan et al. (2011) point out that there is a considerable body of research that identifies significant differences among farmers, including cultural and socio-economic differences. Recent work has begun to explore how farmers differ in their willingness and capacity to adapt. This means it is important to study sub-populations of farmers. Hogan et al. identified three clusters of farmers in their study of general Australian farmers:

Cluster 1: cash poor, long-term adaptors (55%)

They report high (42%) or medium (31%) level of belief in climate change and expressed very strong levels of wish for government financial help (only 6% expressed no desire for such assistance). They reported high levels of social connectedness (52%) and were not inclined to use sources of information with 57% being lower level users. 49% reported high levels of adverse farm conditions, while only 15% reported low levels of adverse farm conditions. A large majority reported feeling financially pressured by the adaptations required by climate change; only 23% reported having the finances necessary to make the required changes.

Cluster 2: comfortable, non-adaptors (26%)

They tended not to believe in climate change, with 39% reporting low levels of belief in climate change. Few had a desire for government assistance, with just 1% reporting high level of need for such. As a cluster they had high levels of social connectedness. They were more mixed than cluster 1 (primarily business oriented) in regarding the farm as both business and lifestyle. With the exception of facing market pressure, 92% did not report problems with farm conditions and they considered they faced low levels of risk. On the whole, they were not concerned about their financial viability in the face of climate change. Few among this group were interested in making adaptations in the face of climate change, though 51% reported having the funds to make changes if they wished to do so. As a whole, they tended to think climate change was real and that there was a moral imperative to reduce greenhouse emissions, but they didn't take extreme weather events as evidence of climate change (Hogan et al. 2011: pg. 4063).

Cluster 3: Transitioners (19%)

Most believed in climate change, with 39% expressing high levels of belief. They were much more mixed than other clusters in their desire for government assistance and reported low levels of social connectedness in comparison to the other clusters. Farm conditions were poor, with two-thirds saying they had high levels of adverse farm conditions. A significant majority in this cluster said they could not cope with any more change. About half believed in climate change, while the rest were uncertain or did not believe it. Yet, they were still concerned with the moral imperative to reduce greenhouse emissions.

Wheeler *et al.* (forthcoming-a) investigated the influences associated with sMDB irrigators' planned adaptation behaviour. Their index of adaptability was made up of three broad strategies: a) *expansive*: those designed to increase efforts and production; b) *accommodating*: those that seek to accommodate change by adopting more efficient infrastructure and changing crop mix; and c) *contractive*: those that involve a reduction in effort and resource ownership. Incremental adoption was examined only. Overall, the study found that incremental adaptation was positively associated with younger (and healthier) farmers, farms that have identified successors, more productive farms, and more innovative, traditional and/or environmentally focused farmers. They also found that farmers who believe in climate change are less likely to be adapting their farm overall, especially if they are far less likely to plan for more expansive farm strategies. Believing in climate change was associated with implementing more accommodating strategies.

Wheeler *et al.* (forthcoming-a) also found that belief and planned behaviour was often endogenous (i.e. there could be no direct causal link initially established between them). In particular, they suggested endogeneity was more likely to be found with accommodating planned behaviour than expansive type planned behaviour. These results suggest that, as well as attitudes influencing behaviour, adaptation behaviour can influence attitudes, and this loop is most likely to occur for water risk management strategies. Finally, the paper suggested there is an element of path dependence in farmer behaviour. Once farmers are on a certain track of expansionary or contractive behaviour, this will continue to influence planned behaviour. This may be a result of cognitive factors, socio-demographics, spatial or market factors.

2.3. Consequences of Climate Change for Industry and geographical variation

2.3.1. Industry

Different agricultural sectors have differing levels of capacity to respond to fluctuations in water availability. Horticulturalists and dairy farmers must have access to water during drought; both have high capital investments, often associated with high debt that requires constant service. Annual crops, on the other hand, can reduce their water use without such dire consequences and they can be compensated by selling water to higher value producers (Bjornlund *et al.*, 2013). Efficiency gains will be easier in a sector such as dairying, because there is currently such a variation in efficiency capabilities. However, such gains are likely to be harder to achieve in sectors with a high degree of efficiency throughout the sector; they will therefore face particular challenges if more gains are required (e.g. rice). Industries such as cotton are likely to need to substantially change the way they irrigate crops (Stubbs *et al.*, 2010).

Rising costs of water is likely to promote an increased proportion of regular water use going to horticulture and viticulture, which are higher up the value chain. However, in those sectors where water is a much larger proportion of costs, and the return per unit of water is lower such as rice and cotton, productivity will suffer. A shortage of water might lead to some industries moving to a dry-land model to free up water for industries in which water is essential, such as perennial crops. Dairy farmers, for example, may curtail irrigation and substitute it by buying in fodder. Such developments are likely to drive closer links between irrigated and dry-land agriculture (Stubbs *et al.*, 2010).

Modelling by Quiggin *et al.* (2010) predicts increasing salinity will initially lead to a transition away from stone fruits to grapes, with no stone fruit being produced in the sMDB by 2030 (Goesch *et al.*, 2009). This will be followed by a transition away from grapes toward citrus as salinity continues to increase. By 2050, the area devoted to grapes is estimated to decline by around seven per cent while the area devoted to citrus is estimated to increase by around 30 per cent (Goesch *et al.*, 2009).

Quiggin *et al.* (2010) found that water availability in the MDB would be significantly reduced in the future. In regard to this finding, adaptation is found to be a useful and effective response in the middle-term (until 2050). In the far future adaptation alone may not be a sustainable response due to further inflow reduction projections. A complementary effect between adaptation and mitigation is expected.

Quiggin *et al.* (2010) also found that under some climate change scenarios the Darling River system may eventually develop into a disconnected system (i.e. no longer contribute to the Murray River flows and trade), meaning that irrigated agriculture therefore could not be practiced sustainably. Using a state-contingent analysis they found that: i) costs of securing a constant water supply, e.g. for horticultural crops, are seen to increase; ii) opportunity cropping without irrigation during droughts will be more prevalent in the future; iii) a further response to climate change and severe droughts in agriculture is likely to be limiting irrigation to only the most critical areas; iv) crop changes will be more common; and v) shifts from high water consuming production of citrus and grapes to less demanding vegetables such as tomatoes or rockmelons are expected.

2.3.2. Location

The geographic location of production may shift as a result of climate change. Hotter temperatures are likely to have a southward drive, while a desire to minimize evaporation losses will tend to push production up the Basin. Reduced water availability will tend to shift production away from areas of heavy flood soils to areas of lighter dry soils, a process that will be facilitated by the development of suitable water application technology (Stubbs *et al.*, 2010). The production of certain commodities will cease in some areas and be replaced with new ones. This would have significant consequences for specific agricultural sectors and regional economies, such as:

- Viticulture could move to areas previously considered too cool, notably southern Victoria and Tasmania.
- Dairy production in southern Victoria and Tasmania could expand at the expense of dairying in the sMDB.
- Cereal crops may be grown in areas previously deemed too cool or wet.
- Wine grape varieties developed to suit particular areas could be adversely affected by higher temperatures and extreme weather (frosts and heatwaves).
- As a consequence of higher summer temperatures and less winter chill some areas currently producing stone fruits might not be able to continue to do so in the longer term.
- Higher temperatures in MDB dairying areas are likely to create stress for livestock and higher energy demand for cooling production sheds (NWC, 2012b).

2.3.3. Costs

Reduced runoff will lead to less secure entitlements for irrigators and could shrink the size of the irrigation sector and change the mix of permanent and annual crops grown. This could lead to rural water supply networks being less well utilized, increasing the cost of supply or reducing the viability of supply to a contracting customer base (NWC, 2012b). The NWC also suggests that the increased water costs resulting from the generally increasing price of electricity generation will be limited—because energy is a relatively small cost for most businesses, in terms of overall cost. However, the Renmark Irrigation Trust suggests otherwise. They argue that they are already facing a 27% increase in electricity prices. This will increase further under the introduction of the carbon tax, with the increase in costs flowing through to individual irrigators (ABC News, 2012a).

Salinity may also pose a serious, albeit less recognized, cost hazard. It is estimated that globally about 1/3rd of irrigated land is effected by salinity; adding extra irrigation water is usually regarded as the best solution (Connor *et al.*, 2012). Climate change is likely to make the issue of salinity worse, while reducing traditional ways of dealing with it. Climate change impacts on salinity are expected to occur in two ways: i) the first is decreased salt loads from less drainage; and ii) increased salt concentrations from reduced flows. Reduced flows, however, have the greatest impacts (Connor *et al.*, 2012). Increases in salinity are likely to be proportionately greater in downstream sections of the river. Irrigators' incomes can also be affected by changes in salinity (Goesch *et al.*, 2009). Connor *et al.* (2012) conclude that increasing variability in supply is likely to drive up irrigator costs in excess of those associated with lower overall flows. This is likely due to increased variability leading to increased opportunistic cropping that requires leaving irrigation assets idle during periods of low water availability. Further, during drought irrigators employ 'deficit irrigation', which leads to reduced productivity even while fixed costs remain the same (Connor *et al.*, 2012). Increased variability of supply is likely to pose particular challenges for those growing perennial rather than annual crops (Connor *et al.*, 2012).

2.4. Key points

The major points from this section include:

- Irrigation accounts for approximately 70% of total water withdrawals worldwide and for more than 90% of consumptive water use. Irrigation also generates about 40% of total agricultural output, yet irrigated land only represents 18% of global agricultural land.
- Australia is likely to be more affected by climate change than any other country, and agriculture is likely to be more adversely affected of any sector with a projected decline of 17% in productivity by 2050, with corresponding influences on farm profitability.
- The Millennium drought caused a 70% reduction in irrigation water use in the 2000s. However, the gross value of irrigated agricultural produce fell only by 14%, indicating that irrigation productivity can adapt in periods of crisis, but future water supply and use efficiency will become more important.
- Adaptation is adjustments in human-environmental systems in response to observed or expected climatic changes. Transformation adaptation signifies a major change in livelihood, location or identity (e.g. farm exit, sell all water and go dry-land) while incremental adaptation is more related to the adoption of actions that do not require major decisions or information to adopt (e.g. adopt irrigation infrastructure, buy more water/land, diversify).
- Barriers to adaptation include uncertainty, lack of market signals, financial factors, information barriers, cognitive barriers, climate change beliefs, and disincentives to change or adapt.
- Costs of climate change will include rising energy costs, more frequent droughts (hence loss of production), increased salinity, reduced water availability.

3. AN INTRODUCTION TO WATER MARKETS

3.1. Background

Current programs by Australian governments to reallocate water from consumptive (i.e. irrigation) to environmental uses in the southern Murray-Darling Basin (sMDB) are unprecedented in history. Australia provides a leading example that other countries are watching closely. Water markets play a key role in those program outcomes—including the potential for environmental water trade. However, in the face of recent extreme water shortages irrigators have also increasingly adopted water markets as a strategic tool to manage water scarcity risks and farm viability requirements. Therefore, across all water user groups it is expected that further adoption of water markets, as well as improved water management and use, will be essential for coping with future climate change impacts.

The purpose of this report is to undertake a literature review of the consequences of climate change for (in particular) sMDB water markets. As such, it is **not** to provide a literature review of all other water markets in the world. For readers interested in worldwide water market trade issues, useful references include Grafton *et al.* (2011b) (2011a) and Maestu (2013).

3.2. Water market background information

Water marketing involves the exchange of water rights or shares between willing sellers and buyers within a market framework Griffin (2006). Although different from state to state in Australia, rights to access water are commonly divided into two categories:

- *Water entitlements*: a set share of the total consumptive pool of water resource(s) with a reliability of supply factor (low, general or high), and[1]
- *Water allocations*: an amount of water that the water entitlement holder receives during a given water year (season), dependent on the available water in storages, expected inflows, system losses, demand expectations, delivery capacity and other factors (NWC, 2011a).

Water entitlement trading can be motivated by changes in long-term demand patterns as well as changes in the location and purposes of local water use. Examples include transfers of previously unused water entitlements to greenfield irrigation sites, or changes in use as irrigators with surplus water sell to environmental managers (Hanemann, 2006). Water allocation trade can be motivated by the need to adjust to short-term changes in seasonal conditions, commodity prices or other strategic decisions by reallocating water between different users for the duration of a season (Clifford *et al.*, 2004).

General drivers of water trade therefore include: i) prices; ii) irrigation demands for different commodities; iii) short- and longer-term climate change effects; iv) regulatory impacts designed to address past over-allocation and uncertainty over future water

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[1] Where regulated water supply systems are supported by major water storage infrastructure (e.g. dams) higher reliability water entitlement holders receive their water ahead of lower reliability holders. For example, a water entitlement holder with an estimated reliability factor of 90% would expect to receive an allocation in 90 out of every 100 years. Levels of water reliability vary by supply district and infrastructure; see 0 for further detail.

use and trade; v) varying trade rules and processes; vi) water charges; vii) water product attributes and reliability differences between states; and viii) recent government participation in water markets to recover environmental water (NWC, 2011a). Many of these drivers interest economic analysts, who have long taken an interest in the efficient allocation of water resources through market-based structures that lead to beneficial social outcomes in aggregate.

3.2.1. Economic efficiency from water markets

The main economic advantage of water markets is that, under reduced market failure conditions, they should enable limited resources to be put to their most productive uses (i.e. economic efficiency) by distributing them to those that value them most highly over short- and long-term periods (Bennett, 2005). This reallocation results in three distinct forms of economic efficiency, dependent on the timeframe involved:

- ***Allocative efficiency***: Changes in water resource demand or use motivated by seasonal conditions, commodity price adjustments, cropping choices and other short-term decision-making requirements is most often achieved through water allocation trade.
- ***Dynamic efficiency***: Changes in water resource demand or use that stem from structural alterations such as new investment opportunities, regulatory shifts in access arrangements (e.g. extraction limits or embargos) or personal strategic choices (e.g. retirement) is most often achieved through water entitlement trade.
- ***Productive efficiency***: Changes in the price of both water entitlements and allocations offer incentives for the efficient use of water resources as either an investment or input for productive outcomes.

As such, water markets require four key elements to drive efficient use and outcomes. These include:

1 A fixed limit to resource availability (set consumptive pool) that is ideally: i) credible and based on accurate science; ii) monitored and enforced; and iii) consistent with sustainable levels of extraction;[2]

2 Once the consumptive pool is set, users are provided with entitlement shares in the form of secure property rights to that consumptive pool, but which cannot exceed the total limit;

3 These shares, and the water allocated to them each season, are tradeable under low transaction costs and entry/exit barrier conditions such that ownership, control and use can change over time; and

4 Prices for these shares and allocations that take into account externality costs to third-parties are established in a market using the value placed on water use from a depth of well-informed buyers and sellers (NWC, 2011f, ACCC, 2010).

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[2] Sustainable levels of extraction relate to permitting water diversions that contain environmental change (i.e. health of the environmental resources) within socially acceptable boundaries, and no others (CSIRO, 2008a).

In Australia, the MDB provides a dominant example of differences between water resource supply and demand due to highly episodic and stochastic inflow patterns (Musgrave, 2008), an emphasis on irrigated agricultural development over time (Watson and Cummins, 2010), and where institutional arrangements have developed over time to manage divisive water-sharing and use issues (Scanlon, 2006).

3.2.2. Water Market Operations - Seasonal allocations

Historically, irrigators used to receive all their water entitlement, and indeed, those with high security entitlements used to receive more water than they actually owned. This situation first started changing in the late 1990s, and significantly changed in the 2000s. As shown in 0, a significant number of water entitlement holders, particularly in South Australia, for the first time in 2002/03 did not receive their full (i.e. 100%) seasonal allocation.

This outcome arose from declining rainfall and storage inflows that began in the late 1990s and continued through to 2010/11 (Figure 7). Annual rainfall during this period was typically below average levels; potentially mimicking likely future climate change outcomes. Water storage levels fell from highs of around 70% to 90% in the early 1990s to around 15% for three consecutive seasons between 2006/07 and 2008/09. Spatial differences in water availability due to the hydrologic nature of the MDB (Craik and Cleaver, 2008, Williams, 2011), as well as relative differences in water demand elasticities among agricultural users drove water trade activity in the southern MDB (Wheeler *et al.*, 2008b, Loch *et al.*, 2012).

Table 4 Closing water allocations in the sMDB (by security type)

	High reliability entitlements					Lower reliability entitlements			
Year	Vic Goulburn	Vic Murray	NSW Murray	NSW Murrumbidgee	SA Murray	Vic Goulburn (low)	Vic Murray (low)	NSW Murray (general)	NSW Murrumbidgee (general)
1998-99	100%	100%	100%	100%	100%	0%	100%	93%	85%
1999-00	100%	100%	100%	100%	100%	0%	90%	35%	78%
2000-01	100%	100%	100%	100%	100%	0%	100%	95%	90%
2001-02	100%	100%	100%	100%	100%	0%	100%	105%	72%
2002-03	57%	100%	100%	100%	100%	0%	29%	10%	38%
2003-04	100%	100%	100%	95%	95%	0%	0%	55%	41%
2004-05	100%	100%	97%	95%	95%	0%	0%	49%	40%
2005-06	100%	100%	97%	95%	100%	0%	0%	63%	54%
2006-07	29%	95%	69%	90%	60%	0%	0%	0%	10%
2007-08	57%	43%	50%	90%	32%	0%	0%	0%	13%
2008-09	33%	35%	95%	95%	18%	0%	0%	9%	21%
2009-10	71%	100%	97%	95%	62%	0%	0%	27%	27%
2010-11	100%	100%	100%	100%	67 %	0%	0%	100%	100%
2011-12	100%	100%	100%	100%	100%	0%	0%	100%	100%
LTAAY[a]	0.95	0.95	0.95	0.95	0.9	0.35	0.24	0.81	0.64

[a] % of total LTAAY (long-term average annual yield) accounted for by that type of water security in that region;

Source: NWC (2011b) and Wheeler et al. (under review)

Seasonal allocations for MDB users are calculated on the basis of the nature of the water entitlements being either high or general (low) security, the volume of water in storages and the sum of minimum expected inflows and system losses for a water year; that is, 1 July to 30 June (Deloitte, 2011). Rainfall and subsequent inflow reductions in much of the MDB from 1997/98 (Figure 7) meant that storage levels decreased resulting in lower seasonal allocations—especially lower opening allocations. Similar extended periods of low inflows had not been experienced since the World War II Drought (1937-1945), which predated much of the extensive irrigation/rural community development and its reliance on water infrastructure.

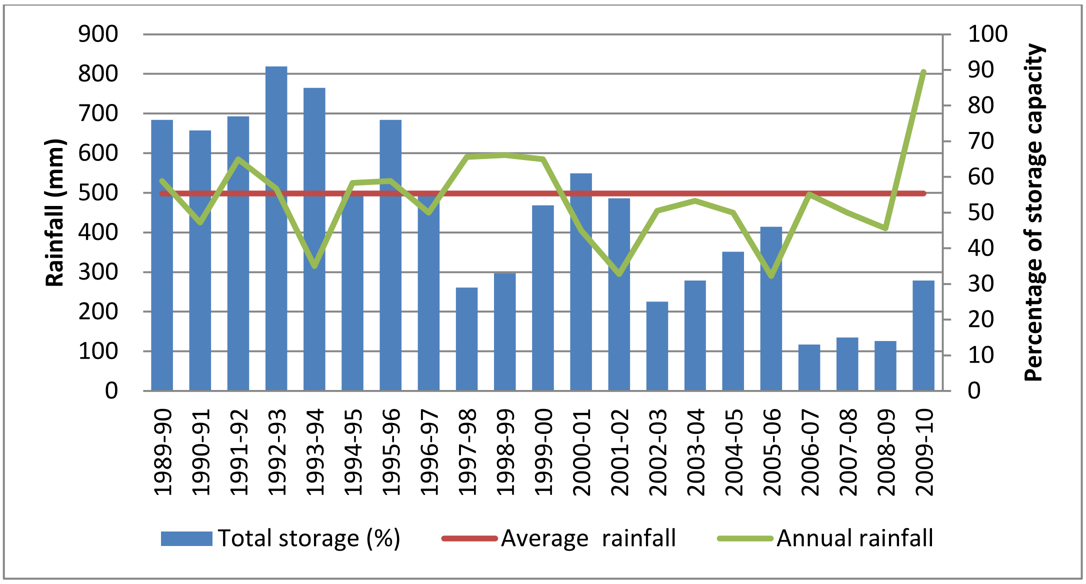

Figure 7 **Rainfall & storage levels - major MDB dams 1989/90 - 2009/10**

Source: NWC (2011a, pg. 19)

Consequently, seasonal allocations for irrigators declined sharply from 2002/03, especially for general (low) security water entitlements respectively in New South Wales and Victoria. In Victoria, the calculation for seasonal allocation levels was altered in 1998 from using total average expected inflows to using the expected minimum inflows over the season to set opening allocations and then adjusting the levels during the season according to actual inflows. This resulted in significantly lower opening allocations, effectively shifting the risk management burden associated with variable seasonal inflows from water managers to irrigators (Bjornlund, 2006a). This shift subsequently had an important impact on the use of water markets in the whole of the MDB.

Until 2005/06, relatively little interstate transfers of water had taken place. However, as low supply and seasonal allocation variation became the norm, South Australian irrigators imported significant volumes of allocation water from New South Wales in order to maintain high-value permanent crops (e.g. wine grapes). In 2009/10 Victoria also imported relatively high levels of allocation water from New South Wales for agricultural crop maintenance By 2010/11 higher than average rainfall saw seasonal allocations return to 100% levels. The following section provides further detail.

3.2.3. Water Market Intermediaries, IIOs and Irrigator Numbers

Water market intermediaries' is a general term that includes water brokers and water exchanges. Water brokers such as Waterfind and Percat Water in South Australia and Water Trading Australia in Victoria perform a number of roles for their clients including finding a trading partner, advising their customer on price and water trading rules, negotiating with a trading partner, and/or completing the necessary paperwork for a trade to proceed. Not all brokers perform all these services. For example, some brokers will find a trading partner and complete the necessary paperwork but will not provide advice about price. Brokers also often conduct trades through exchanges. Water exchanges operate as a trading platform by matching buyers and sellers, either through an automated process or a bulletin board.

Water exchanges also organise and submit the necessary paperwork to the relevant trade approval authority (ies), and may also provide information on trading rules, prices and trading volumes. There are a number of water exchanges operating currently, including WaterExchange, Murray Water Exchange, Murrumbidgee Water Exchange and the National Water Market. There has been much flux with water exchanges, for example, WaterMove recently shut down in mid-2012, with its future unknown at this stage. These exchanges match bids to buy with offers to sell, as well as co-ordinating the paperwork required for trade approvals. ACCC (2010) provide a breakdown in Appendix A of the range of brokerage costs across exchanges and brokers, and found costs ranged from 1% to 4.4%.

An irrigation infrastructure operator (IIO) is any person or entity who owns or operates water service infrastructure for the purpose of delivering water to another person for the primary purpose of being used for irrigation. As at 2010-11, there were at least 19 IIOs in the MDB, with a wide diversity in entitlements and customers. Table 5 illustrates this diversity, and suggests that in 2010-11 there were over 26,500 irrigation customers of IIOs in the MDB. However, many of these customers were not irrigation farmers and just own a few ML for stock and domestic use. ABS (2011) suggested that there were 15,347 irrigating farms in the MDB in 2010-11, with an average of 78 hectares irrigated per farm, and 294 ML water used per farm.

Table 5 Characteristics of reporting IIOs in the MDB in 2010-11

Irrigation infrastructure operator	*Irrigation customers*	*Water access entitlement (GL)*	*2010−11 revenue ($'000s)*
Goulburn-Murray Water (GMW)	14792	1244.7	70066
Murray Irrigation Limited (MIL)	2125	958.7	26050
Murrumbidgee Irrigation Limited (MI)	3191	995.1	25516
Lower Murray Water (LMW)	2785	132.4	13498
Coleambally Irrigation Co-operative Limited	473	433.5	9933
Central Irrigation Trust (CIT)	1268	129.3	6825
Western Murray Irrigation Limited	431	55.2	2797
SunWater	55	50.1	2758
Renmark Irrigation Trust	551	41.1	2234
Trangie-Nevertire Irrigation Scheme	43	67.4	1474
Narromine Irrigation Board of Management	123	49.5	1459
West Corurgan Private Irrigation District	250	61.5	1165
Jemalong	115	80	1133
Moira Private Irrigation District	94	38	691
Marthaguy Irrigation Scheme	24	12.3	567
Tenandra Irrigation Scheme	28	28	428
Buddah Lake Irrigators Association	14	32.5	397
Hay Private Irrigation District	90	8.1	301
Eagle Creek Pumping Syndicate	79	17.2	161

Source: ACCC (2012)

3.3. *The Murray-Darling Basin (MDB)*

The Murray-Darling Basin (Figure 8) represents an iconic area for agricultural economic production, ecological importance, recreational significance and cultural values.

Figure 8 The Murray-Darling Basin with major irrigation districts

Source: (MDBA, 2012c)

Agriculture is an important economic function of the MDB, where over one-third of Australia’s food supply is produced (Figure 9). This pattern would have changed dramatically after 2000/01 during the Millennium Drought, particularly in the case of broadacre, annual cropping and dairy cattle uses. However, following return to wetter conditions these patterns may be re-emerging in the landscape. Typically, where 0.6% of land in Australia is allotted to irrigation production, in the MDB irrigated land accounts for 2% of total use. Overall, 65% of all irrigated land in Australia is located in the MDB (MDBA, 2010a). The Basin therefore produces 53% of all cereals (including

100% of the rice crop and 93% of the cotton crop), 95% of all oranges, and 54% of the national apple crop. In livestock terms, the MDB accounts for 28% of the national cattle herd, 45% of sheep and 62% of pigs (MDBA, 2009, DAFF, 2011). Much of that production is dependent on the reliable and economically efficient supplies of irrigation water.

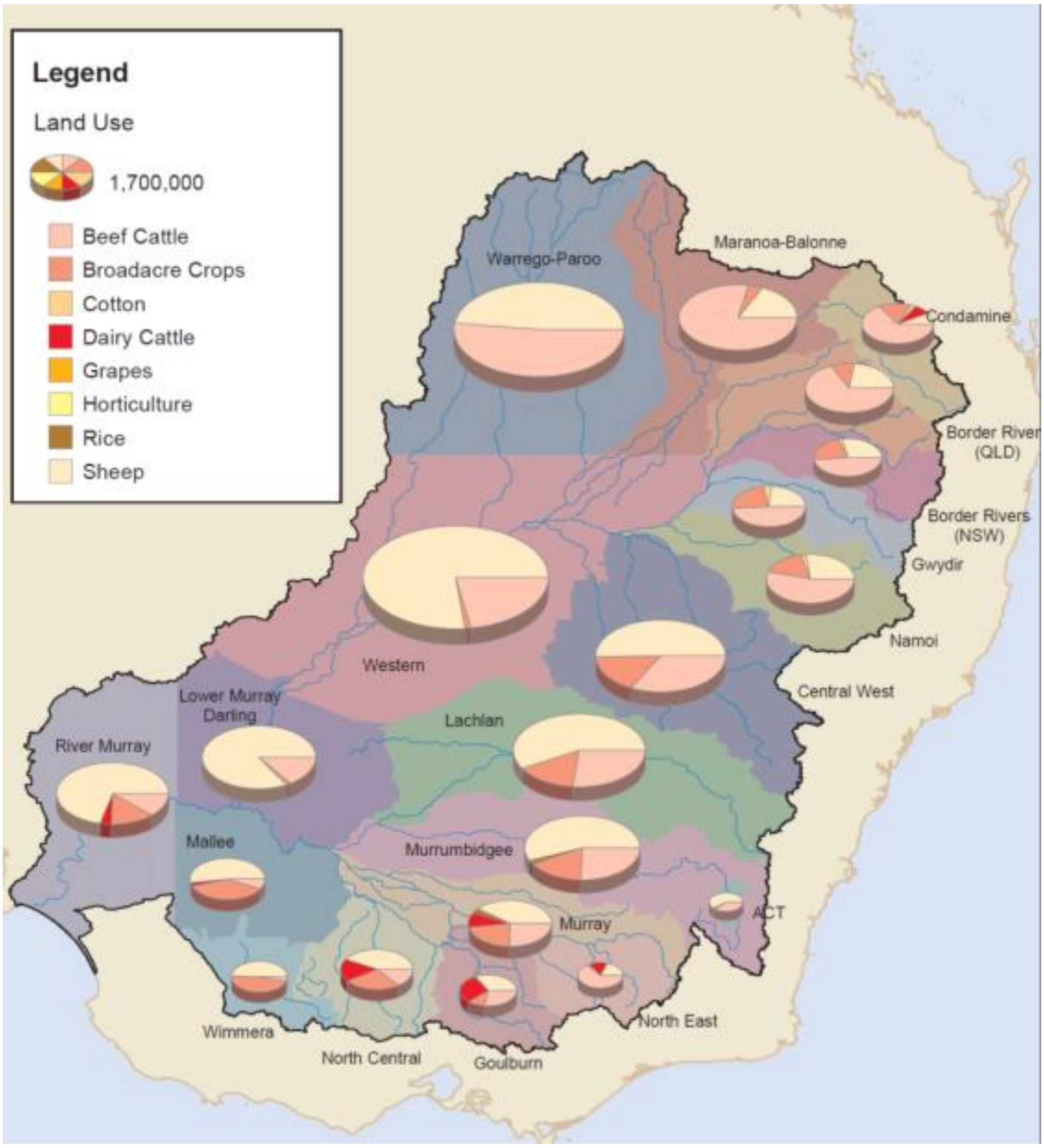

Figure 9 General land use patterns in the MDB, 1996/97 - 2000/01

Source: (Bryan and Marvanek, 2004)

There is considerable variability in rainfall and runoff across the MDB (Figure 10). For example, the Murrumbidgee, Goulburn, upper Murray, Mitta, Ovens, Broken and Loddon river catchments account for a significant 35% of total runoff, but comprise only 12% of total surface area. The Darling system in contrast, contributes up to 32% of runoff from 60.4% of the MDB area. During very wet years (e.g. 2010/11), some

86% of the MDB is expected to contribute virtually no runoff into the extended river systems (MDBC, 2005b). Australia experiences higher runoff variability than any other continental area, save Southern Africa (Rowan *et al.*, 2011), and the MDB is no exception to this (Figure 11). Much of the surface runoff also flows into wetlands, floodplains and floodplain lake systems where it evaporates. Under pre-water resource development conditions, up to 11,000 GL per annum evaporates or percolates into groundwater systems, while only an estimated 12,890 GL of runoff reaches the sea (MDBC, 2005b).

As such, the MDB is characterised by significant variability in regard to the flows and volumes of water made available in each season—which does not lend itself well to 'average' or 'mean/median' assessments of river, water usage and/or environmental conditions.

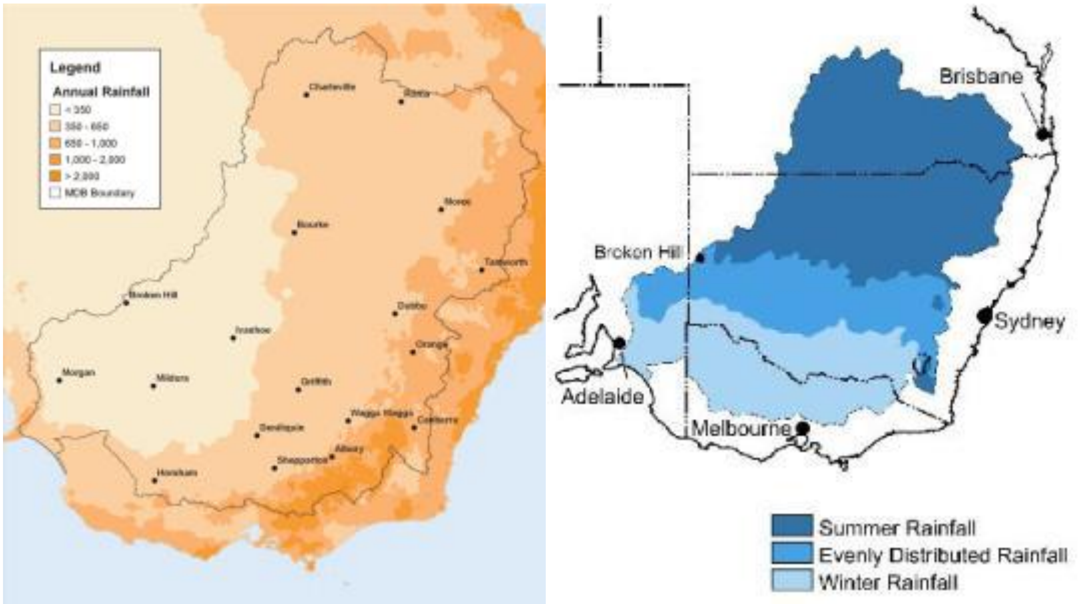

Figure 10 Average MDB annual rainfall distribution patterns

<u>Source</u>: (MDBC, 2005b) <u>Source</u>: (CSIRO Land & Water, 1999)

The Basin is also home to over 2 million people requiring access to reliable water supplies. The Basin also supplies approximately half of Adelaide's water needs via pipeline connections to the Murray River. Agricultural and community access to water in the MDB is subject to naturally high variation within years, between years and across lengthy periods. To smooth the supply of water to MDB users, major infrastructure (e.g. dams and weirs) has been constructed. The total storage volume available from MDB water infrastructure is just under 35,000 gigalitres (GL).

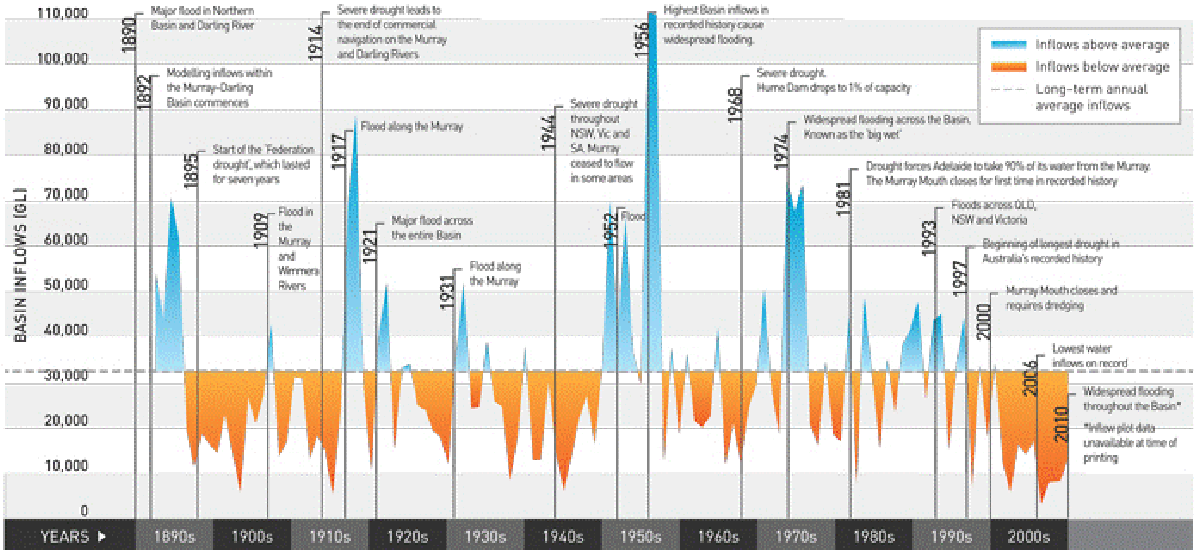

Figure 11 MDB water inflows, 1890 to 2011 (ML)

Source: (MDBA, 2012f).

A breakdown of how MDB water resources (including groundwater) are allocated across users is provided in Table 6. The share of water entitlements created in each water product category is also shown as a percentage of the total resource. As indicated, a total of 75% of total surface water resources have been assigned to consumptive (e.g. irrigation) users in the MDB (Black and King, 2009). Groundwater users have been assigned an estimated 58% of the total resource to use for consumptive purposes.

Table 6 Total water resources in the MDB—2010

	Total Resource (GL)	*Entitlements (GL)*	*Percentage**
Groundwater	2,450‡	1,424	58%
Surface water inflows	31,599	2,733[a]	8%
		10,890[b]	33%
		13,788[c]	42%
Outflows from Basin		5,142	16%
Inter-Basin transfers	954		
Total surface water	32,553	32,553	100%

* Expressed as a percentage of the total available water resource
‡ Sustainable annual yield for groundwater from the Basin (Goesch and Hafi, 2006)

[a] Interceptions
[b] Watercourse diversions
[c] Water used by environment and losses.

Sources: (MDBA, 2012e)

Table 6 highlights the significant role that MDB surface and groundwater resources play in the Basin's economy. However, the MDB is also home to critical ecosystems and natural habitats, all of which require water resources to maintain ecological health and sustainable refugia during times of reduced water supply (MDBA, 2010a).

Reducing the volume of water currently extracted by consumptive users and returning it to important hydrologic and key ecosystem functions will assist Basin managers to achieve an environmentally sustainable level of take (ESLT). Stemming from higher order Basin-wide environmental objectives and the need to protect key environmental systems, assets or productive bases the ESLT allows local environmental targets to be determined along with a range of management options to achieve those outcomes (MDBA, 2012c).

Finally, how much individuals (consumptive, social and environmental alike) rely on access to natural resources such as water can be an important influence on their decision-making and ability to adapt to change (Shorten, 2012). Water markets assist users to reallocate water when needed to suit their strategic decision-making, and we can examine evidence of this activity in broad MDB trade statistics.

Water trade has expanded rapidly during periods of drought, particularly in the sMDB. Over 90% of national trade is located in the sMDB hydrologically-connected zones, where water transfers are possible across large distances and over state borders. By 2009/10 a decade of drought had seen the annual turnover from water trade reach $3 billion—accounting for 11% by volume of water entitlements issued in the MDB and approximately 20-30% of water allocation in major NSW systems alone (NWC, 2011f). Importantly, without access to water trade sMDB drought impacts would have been significant—totalling between $2-3 billion each year in 2007/08 and 2008/09. However, with access to water trade arrangements sMDB production was estimated to be $4.3 billion higher between 2006/06 and 2010/11. Regionally, water trade in that period is estimated to have helped avoid state gross production reductions in NSW (-$760 million), Victoria (-$2,256 million) and SA (-$419 million) respectively (NWC, 2012a).

The development of water trade in Australia is examined briefly in the following section in order to establish some important drivers and influences of market development; most typically periods of extended drought.

3.4. A brief water market history

Although water markets in Australia may be thought of as relatively recent institutions, in fact their basis can be traced back to the period around Federation (Figure 12).

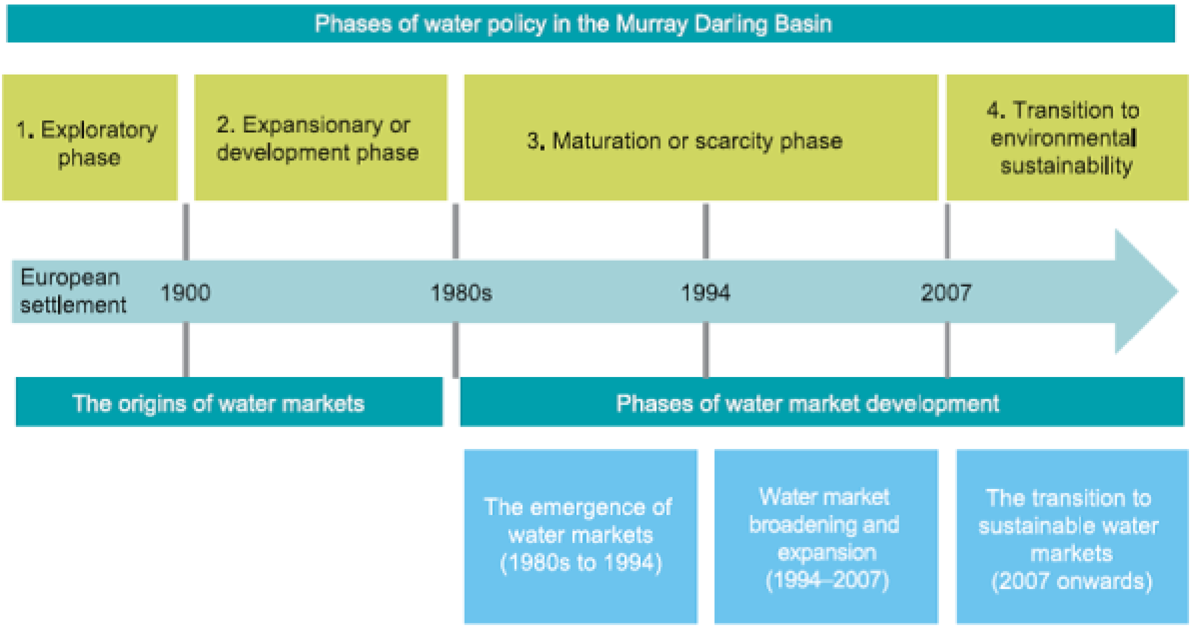

Figure 12 The evolution of Australian water markets

Sources: (NWC, 2011f, adapted from Musgrave (2008) and Watson and Cummins (2010))

The *Victorian Irrigation Act* 1886 sponsored by Alfred Deakin encouraged the reduction of traditional riparian rights to water, instead vesting the right to use, flow and control of water resources with the states. Deakin's view was that, by vesting ownership and control with the states, greater utilisation of water over larger areas could be achieved through centralised management (Musgrave, 2008). In many other countries (e.g. the United States) the continued existence of riparian rights under first-in-time first-in-right principles is a major impediment to the development of efficient water markets; as each right is different and location specific (NWC, 2011f). State control of water resources allowed the creation of entitlements to water that varied in accordance with climatic conditions (i.e. provided a proportion of available flow rather than a fixed volume), which was novel in comparison with the rest of the world (Connell, 2007).

Prior to Federation, state claims to the use of the River Murray centred on navigation and trade. While SA fought to retain its rights to river navigability on the basis that benefits could be generated from transport to the river mouth, NSW and Victoria were beginning to introduce irrigation settlements that required different access to water resources (Craik and Cleaver, 2008). At the time of Federation in 1901, Sec. 100 was included in the Australian Constitution stating that the Commonwealth would not 'by any law or regulation of trade or commerce, abridge the right of a state or the residents therein to the reasonable use of water for conservation and irrigation' (Waye and Son, 2010, pg. 433). This meant that continued cooperation between the states would be required to facilitate the appropriate use and management of River Murray water resources (Clark, 2002).

3.4.1. The origins of water markets

However, cooperation was difficult to achieve. Tension between the states continued until the signing of the River Murray Waters Agreement (RMWA) in 1915, which provided for equal flow-sharing between NSW and Victoria at Albury, state control of tributaries below that point, and a guaranteed minimum entitlement for SA (MDBC, 2007a). The RMWA marks the beginning of serious federal government involvement in water resource planning and irrigation financing (Smith, 1998).[3] Although the RMWA was altered twelve times during its life, the states continued to control operation and use of River Murray water resources with little or no federal government interference—other than to provide financial assistance (Hatton MacDonald and Young, 2001). This financial assistance funded government investment in irrigation activities in the sMDB between 1918 and the 1970s, including soldier-settlement schemes for returned servicemen from World War I, World War II and the Korean and Malayan operations (NWC, 2011f). Overall, there was a ten-fold increase in major dam storage capacity in the period between 1940 and 1990 (ABS, 2010). Such investment was broadly in line with paternalistic and protectionist attitudes toward the agricultural sector, which included tariffs on imported products, production controls and quotas, price reserve schemes and statutory marketing arrangements since the early-1900s (Industry Commission, 1991). From 1915 to the 1960s the focus of sMDB water demand also shifted from navigation/irrigation uses to irrigation-centric uses (River Murray Water Resources Committee, 1993).

State approaches to water allocation and use differed widely across the sMDB regions. In NSW agricultural enterprises were dominated by annual cropping such as rice. For example, by 1981/82 64% of irrigation water in southern NSW was used to grow rice (Musgrave, 2008). These growers were interested in maximising their yield each year rather than leaving water in the dams for the next season. Hence the allocation approach adopted in NSW was to use all available water in any given year. In Victoria predominant water users were the dairy industry—that depended on permanent pastures—and horticulture. These growers' interest was to maintain a secure and stable annual supply. Thus the Victorian allocation approach was more conservative, with water managers tending to store enough water for two-successive years and basing their seasonal allocations on that premise. Finally, in SA the horticultural industry was the predominant agricultural water user. For them annual supply security was paramount. Also, the SA interest in river navigation uses, their location at the end of the system and Adelaide's partial reliance on Murray River water tended to drive an even more conservative approach to allocations (Crase, 2008).

3.4.2. A recognition of over-allocation

The entitlement systems that developed in each state largely did not therefore provide incentives to conserve water—indeed irrigators could use as much water as they liked provided it was used on their defined irrigation areas (NWC, 2011f). However, the initial uptake of water entitlements offered by the states was relatively slow until the

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[3] Tension between NSW and Victoria continued due to storage accounting rules, where the two states shared what was left at the end of any given season regardless of how much they used. This was clearly to NSW's advantage as they maximized annual use, while Victoria was more conservative in their allocation and issuing of water rights/entitlements. This was not resolved until late 1980s when continuous dam accounting was introduced after Victoria threatened to build their own dam and divert their unused water into it at the end of each year.

drought of 1939-1944. In that period, the demand for issuing new water entitlements increased significantly, particularly in Victoria (Babie, 1997). Interestingly, during the 1940s drought there were stories of short-term unofficial trades between farmers, where the water bailiff would be told to 'send Joe's water down to me for the next two weeks' (Lewis, 2001, pg. 7). In general though, most water entitlements were issued at a time when the sMDB was in a 50-year wet period (compared to the previous 50 years), which contributed to the over-allocation of access rights (NWC, 2011f).

In the late 1960s a growing awareness of the potential negative consequences of sMDB water resource over-allocation began to emerge. In 1968 the SA government recognised of the potential negative impacts of water over-allocation, placing a moratorium on the issue of new water entitlements in 1969. This approach was followed in 1979 with the introduction of volumetric allocations for each entitlement—resulting in a general 10% reduction in the total volume of entitlements (Bjornlund and O'Callaghan, 2003). The volumetric allocation was set using a combination of the last three years actual use and projected future increases based on financial commitments already undertaken by the irrigators in the form of new planting and irrigation systems.

NSW also imposed catchment specific embargos on the granting of water entitlements in 1977, and a full embargo was subsequently adopted in 1981. In Victoria, licences to pump from unregulated streams during summer months were ceased after the 1967/68 drought. These embargos essentially capped extraction at existing levels of use, rather than at sustainable levels of diversion, and thus did nothing to alleviate the prospect of environmental degradation such as algal bloom outbreaks, rising soil salinity and the loss of aquatic plant and animal species over time (Connell, 2007). However, irrigators acted strategically to avoid the effects of these restrictions, by submitting (and approving) entitlement applications before embargos were completed, utilising increased groundwater extraction under licence and/or constructing on-farm dams, overland flow harvesting or other water interception schemes (NWC, 2011f). Therefore, by the end of the 1970s emphasis was shifting toward making the best use of available water resources (Lewis, 2001).

3.4.3. Scarcity impacts on water market development

The limits to increased entitlement growth meant that informal SA markets for seasonal or temporary water arose in the 1960s and 1970s as the state sought alternative means to redistribute limited water between consumptive users under their discretionary powers to grant and withdraw entitlements (Clark and Moore, 1985). One such example included water bailiffs simply accepting the redirection of allocations by farmers between farms during periods of drought (Bjornlund, 1999). Temporary transfers of water were also allowed in NSW during the 1966/67 drought and again in 1972/73 (Alvarez *et al.*, 1989). Trading was also allowed in Victoria, as a one-off measure to isolated and temporary water shortages, during the 1966/67 drought. Trade also occurred in a restricted manner from 1982/83 until the introduction of the first formal pilot market in 1986/87 (DWR, 1986) and the introduction of water trading in the *Water Act*, 1989.

In the 1970s and 1980s government interest in agricultural protection began to wane with the appreciation that closer settlement was an inefficient means of redistributing wealth and social justice (Musgrave, 2008). In addition, remaining options for further development of low-cost water storage infrastructure were exhausted. Finally, increasing examples of environmental impacts from over-allocation began to emerge through toxic blue-green algal bloom events and irrigation-induced land salinization. The RMWA was altered to reflect a need to manage these issues in the 1980s with the River Murray Commission powers being extended to cover the management of salinity, among other environmental issues (MDBC, 2007a).[4] While supply options were decreasing, however, water demand was increasing rapidly. Total water use increased by 65% during the period from 1983/84 to 1996/97 (NWC, 2011f). It was apparent that no further extraction rights could be offered without compromising the rights of existing entitlement holders and the environment (Sturgess and Wright, 1993), and that water markets should be used to reallocate water between competing users in future (Bjornlund and O'Callaghan, 2003). In 1984, the Australian Agricultural Economics Society held a joint seminar on water rights in Melbourne. It concluded that the primary mechanism for achieving water reallocation should be to 'expose production processes to market forces, with inputs [including water] and outputs valued as far as practicable at their economic cost' (AWRC, 1986). At the time there were concerns about using market mechanisms to reallocate water, including stranded assets and adverse regional economic impacts, monopolisation of water resources by 'water barons', and the exacerbation of salinity problems in the sMDB (Bjornlund, 1999). However, the drought of 1982/83 overrode these concerns, and the process of greater water market implementation and development took shape.

3.4.4. Emerging water markets and property rights

Before water trade could occur, complex legislative arrangements and property rights were required. Property rights define who is empowered to use a resource, as well as the extent of their powers and responsibilities (Griffin, 2006). An assignment of non-attenuated (i.e. secure) property rights is essential for efficient market exchange to occur; as well as to avoid commons dilemmas in natural resources (Smith, 1981). Australian water markets have developed beyond simple riparian access arrangements toward *de jure* property rights that are recognised by formal legal instruments which, if challenged judicially or administratively, would most likely be upheld (Schlager and Ostrom, 1992). Non-attenuated property rights—as well as innovation, technological advancement and increased marginal production from the resource base (North and Thomas, 1977)—are critical for encouraging investment in water use and productive outputs (Bjornlund and O'Callaghan, 2003). Secure property rights are also key to the successful market reallocation of natural resources (Demsetz, 1964), such as water.

Based on increasing pressure to deal with over-allocation, SA was the first state to offer provisions for the formal transfer of water entitlement and allocations in 1983 (Bjornlund, 2002). This was initially enabled by discretionary powers by the responsible minister under existing legislation. Trade within irrigation districts began in 1989 (Curd and Schonfeldt, 1990), but it was not until 1995 that trade between private diverters and irrigators within irrigation districts was allowed, following clear legislative backing in 1994. In NSW, legislation allowing the transfer of water allocations was also passed in 1983, with trading in water entitlements passed into law in 1989. However water entitlement trade involving irrigation districts was not possible until after 1991 and until individual irrigation districts were privatized (Pigram, 1999). Similarly, in Victoria water allocation and entitlement trade was formally included in the new *Water Act* in 1989. Trading in water entitlements did not take place until required regulations setting out the rules of such trade were passed in

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[4] The Commissions' mandate was expanded from managing water supply to encompassing research into environmental and water quality issues under the 1981 amendment of the Murray-Darling Basin Agreement. This was further consolidated in the 1987 and 1993 amendments of the Agreement (Bjornlund, 1999).

September 1991.[5] The first Victorian water entitlement transfers were therefore not formally registered until January 1992 (Wheeler *et al.*, 2008a). Inter-district water trade commenced in 1994 (Lewis, 2001).

In the MDB water property rights were granted by each of the states and initially attached to, and transferred only with, the parcel(s) of land it was used on. However, despite some difficulty in defining water property rights due to high supply variability and potential impacts from climate and land use changes (van Dijk *et al.*, 2006), the gradual separation or 'unbundling' of land and water property rights has subsequently occurred. This separation has been necessary for water markets to work effectively and efficiently (Wilson and Francis, 2010). Consequently, in the MDB well-defined, secure and unbundled water property rights have increasingly enabled irrigators to transfer water entitlement and allocation assets between one-another in response to risk attitudes, seasonal conditions or strategic planning.

The creation and development of increasingly consistent water trading institutions (i.e. arrangements, rules and approval processes) has also helped to strengthen water market activity and efficiency by, in part, reducing the transaction costs associated with transfers. Water trade institution and transaction cost reform can lead to innovative water use, management and transfers between consumptive users, as well as the creation of sustainable water use systems in environmental sectors (Martin *et al.*, 2008). Generally, irrigators remained wary of water markets though, and trade was far from common during this mid-1980s to early 1990s. However, water allocation trade was given its first real test during the 1994/95 drought, when water availability was much lower than in previous years. Trade activity increased dramatically, and irrigators experienced the real benefits of water trade under water supply and climatic variability (NWC, 2011f). This period of development provided an impetus for the further development of water markets in Australia.

3.4.5. Water market adoption and broadening

At the beginning of the 1990s, broadening of water reform and trade began in earnest. Numerous reports and enquiries concluded that the states were individually unable to manage MDB water resources effectively without coordination and investment by the Commonwealth (Connell and Grafton, 2011). Negotiation between the MDB governments resulted in a new Murray-Darling Basin Agreement in 1992, providing the basis for initiatives to drive management of land, water and environmental resources on a basin-wide scale (Papas, 2007) via market-based institutional arrangements to reallocate resources (Hatton MacDonald and Young, 2001). To maintain the momentum of this agreement, its objectives were included in subsequent Council of Australian Government (COAG) meeting agendas.

COAG established a Working Group on Water Resources Policy to examine, among other things, barriers to the effective transfer of water between competing uses (Working Group on Water Resource Policy, 1994). This led to COAG initiatives for the separation of land and water rights, and principles for water trading arrangements (ARMCANZ, 1996). Each of the states now worked to unbundle land and water assets, establish new water property rights, and develop the means of transferring those rights between users (Hamstead *et al.*, 2008). Transfers of water remained limited during these early phases. However, in 1995 an audit of river flow regimes in

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[5] In Victoria allocation trading was initiated in 1989 through the Act, as it did not require regulation.

the MDB concluded that median annual flow-to-sea levels were 27% of pre-development; and that severe drought-like flow patterns occurred in 60% of years as compared to 5% of years in natural conditions (MDBC, 2004). As growth in water extraction would exacerbate this problem a cap on further extraction increases across the MDB was made effective from July 1 1997, enhancing earlier efforts to address over-allocation and environmental water requirements (Bjornlund, 2005). The cap restrictions resulted, perversely, in the activation of previously unused (sleeper) or under-used (dozer) water entitlements (Crase *et al.*, 2009). Irrigators also sought to increase their access to supplementary water and/or take advantage of gaps in licence moratorium restrictions—such that between 1984 and 1994 MDB water diversions increased by nearly 8% (NWC, 2011f).

But, in concert with cap barriers to licence expansion, the gradual removal of water trade restrictions, increasingly efficient market transaction costs and 1994/95 drought effects slowly resulted in increased water allocation trade (Bjornlund, 2006a), while water entitlement trade remained subdued (Turral *et al.*, 2005).[6] It was expected that state-based water management and planning arrangements would address over-allocation issues via the reallocation of water resources. However, these instruments proved unsuccessful at addressing the central over-allocation task and by 2004 it was recognised that many of the states had failed to deliver on their commitments to provide sustainable levels of water extraction (NWC, 2007, Crase, 2012b). In response, an assessment of sustainable MDB water requirements was undertaken; concluding that at least 1,500 GL of water was needed for environmental flows to maintain a moderate probability of environmental health (Jones *et al.*, 2003). A prolonged period of drought that began in 1998/99 also started to impact on water resource availability in the sMDB, such that in 2004 dramatic development of water reform and markets took place once more. Since the early 1980s initiation of water markets in the sMDB, trade in water allocations and entitlements have increased considerably (Figure 13 and Figure 14).

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[6] Reasons for this include perceptions that interstate water allocation trade was less risky due its temporary and reversible nature. Interstate water entitlement trade commenced (under Schedule D of the MDB Agreement) with a geographically limited pilot project in 1998, close to the intersection between the NSW, SA and Victorian borders that initially involved only private diverters. An extension in May 1999 subsequently included high security entitlement transfers below Nyah. By 2003 the Murray-Darling Basin Ministerial Council had agreed to expand interstate trade to encompass the whole of the sMDB (NWC, 2011f). Other barriers included restrictions on water entitlement transfers out of irrigation districts or states, discussed in depth in Section 4.

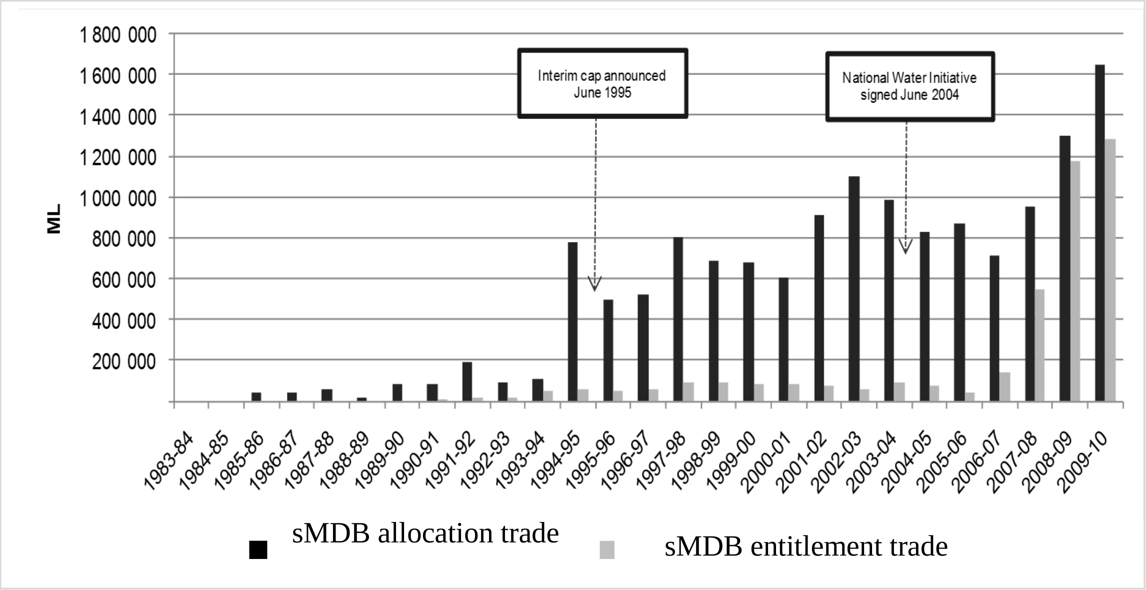

Figure 13 Water allocation and entitlement trade in the sMDB

Source: (NWC, 2011b, pg. 13)

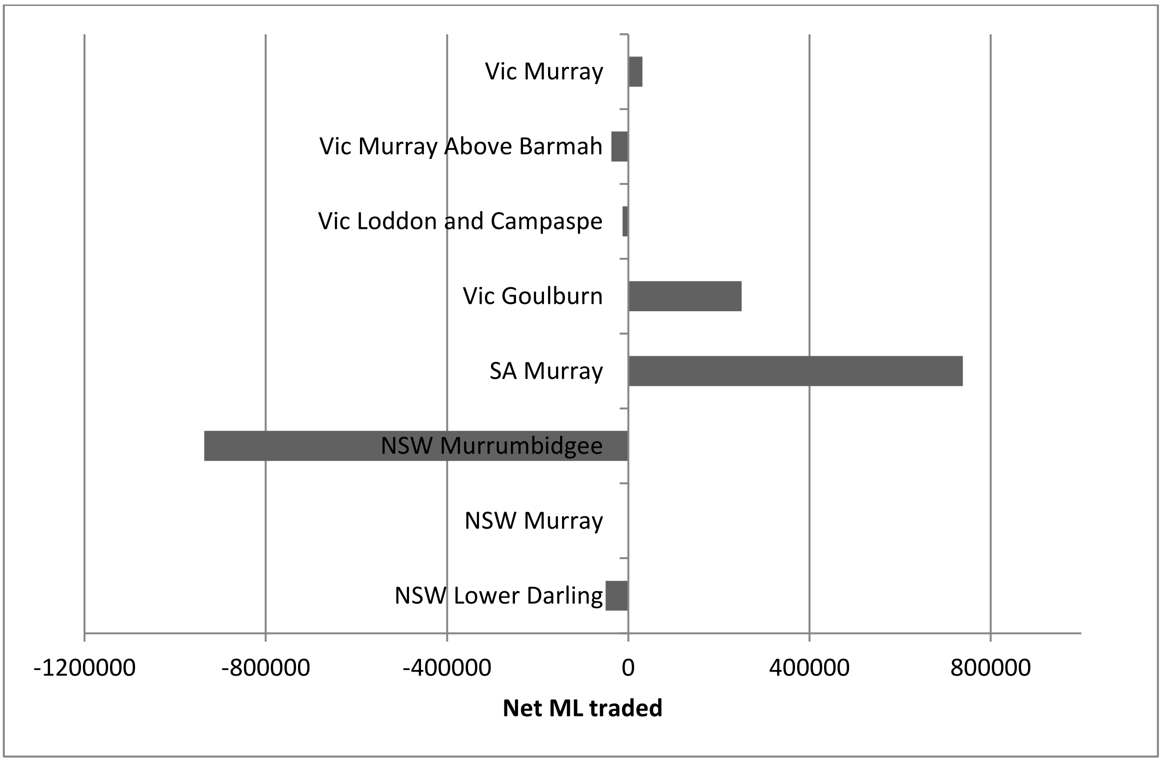

Figure 14 Net Water allocation trade in sMDB - 1998-99 to 2009-10

Source: (Wheeler et al., 2012c)

There was a significant increase in the volume of trade following the establishment of the interim cap in the mid-1990s, which capped the volume of surface water extractions. Over the decade, trade volumes have increased in response to climate and water supply variability and the implementation of water market reforms. Since 2007–08, there has been considerable growth in entitlement trade, driven primarily by federal government purchasing of water entitlements and severe drought (Wheeler *et al.*, 2012c).

Prices have also fluctuated widely, especially water allocation prices (Figure 15). Some major drivers of water trade activity include the availability of water supply in each region, the relative differences between commodity prices and water entitlement/allocation prices, the capacity of irrigators to adjust to short-term (water allocation) and long-term (water entitlement) seasonal change, and the expected availability of water in both current and future seasons (Bell *et al.*, 2007). Expected future water availability can be impacted, however, by the presence of carry-over provisions in the MDB. These are discussed in more detail later.

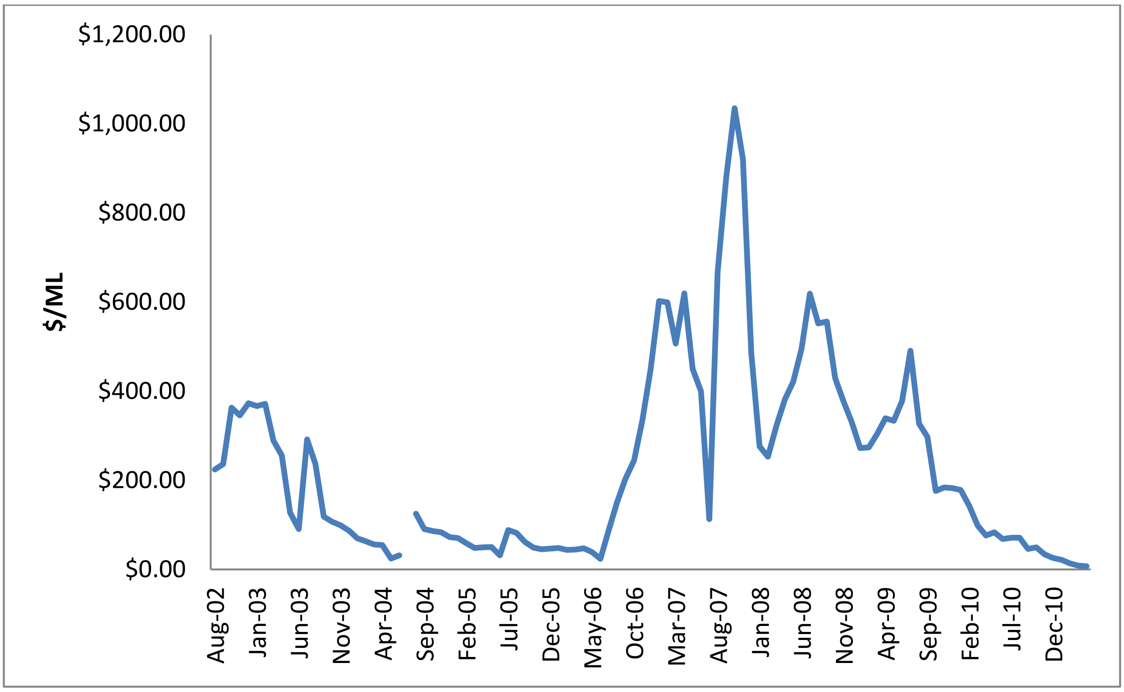

Figure 15 Mean monthly water allocation trade ($/ML) in the sMDB from 2002/03 – 2010/11

Source: UniSA data

3.4.6. Further Water market reform in the 2000s

Two intergovernmental agreements provided a basis for the move towards sustainable water markets—and a larger government intervention in their operation.

3.4.6.1. National Water Initiative (NWI) agreement

The first NWI agreement (NWIA-1) made states responsible for achieving environmental sustainable economic and social outcomes by defining water entitlements as a calculated share of the consumptive pool with risk-sharing conditions in the event of consumptive pool reductions (COAG, 2004a).[7] A principal component of the NWI agreement was the use market-based mechanisms or efficiency investments to recover water for environmental or other public benefit outcomes. A subsequent intergovernmental agreement specifically addressing over-allocation in the MDB (NWIA-2) strengthened NWIA-1 emphasis on water markets and efficiency improvements by making them the key policy instruments to achieve environmental objectives along the Murray River. This program was known as *The Living Murray initiative* (MDBMC, 2003, MDBMC, 2002, Findlay, 2004).

3.4.6.2. The Living Murray (TLM) initiative

The intergovernmental agreement on *Addressing Over-allocation in the MDB* established a targeted sMDB program to purchase water entitlements and invest in infrastructure improvement. This program sought to secure 500 GL of water for MDB environmental sites (COAG, 2004b). State and federal governments contributed an initial $500 million toward TLM programs (Findlay, 2004, MDBC, 2005a, MDBC, 2006a, MDBC, 2007b, Scanlon, 2006, Grafton and Hussey, 2006), which was supplemented with a further $500 million over five years from 2006-07 (COAG, 2006). Hence from 2004 to 2008 several state- and federal-based recovery programs operated to recover environmental water.[8] The most notable of these included the *Riverbank* program targeting water for the Macquarie Marshes, Lowbidgee Wetlands and Narran Lakes in NSW and the *Streamflow Tender* process where irrigators in the Olinda, Stringybark, Pauls, Steels and Dixons Creek areas of Victoria could alter their license conditions for financial compensation to provide environmental water (Crase *et al.*, 2009). However, of all these programs the TLM remained the largest.

The major TLM focus remained upon infrastructure or efficiency works rather than entitlement purchasing (Living Murray Initiative, 2006). It is possible that the governments remained uneasy about water market maturity in Australia (Crase *et al.*, 2009, White and Makin, 2008), and required more robust processes before prioritising a strategy of entitlement purchasing. The government's capacity to avoid market intervention was again diminished, however, by drought impacts in 2007.

The adopted strategy may also not have been suitable for meeting recovery targets. An assessment of TLM concluded that water recovery from efficiency investment was expected to be minor in volumetric terms and that, since only around 0.7% of all water entitlements were traded each year, willing irrigator sellers of water entitlements should not be relied upon to secure adequate environmental water, and that

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[7] While NSW adopted the NWI risk-sharing framework in full, other states adopted different views that affected the security of water entitlements throughout the period. For example, Victoria preferred to assign more risk to the government, whereas SA assigned more risk to irrigators (NWC, 2011f). However, the presence of government purchasing in the water market meant that, ultimately, the risk of water entitlement asset value and security was underwritten by (in some instances higher than) market-value compensation for any willing reduction to water entitlement rights.

[8] These included a pilot program through the Murray-Darling Basin Commission and later recovery activities by Water for Rivers using NSW, Victorian and Commonwealth funding to return water for the Snowy and Murray Rivers. Water for Rivers mainly focused upon infrastructure savings with some water purchasing where appropriate (Crase, *et al.* 2009).

governments could also purchase water in allocation markets (Goesch and Heaney, 2003).

Goesch and Heaney (2003) thus introduced the concept of government involvement in the allocation market to address over-allocation, but did not consider how that might be achieved without socio-economic impacts. As such, expanded government involvement in water markets remained minor and transfers of water toward environmental holdings remained relatively small over this period—it was expected that only 240 GL of the 500 GL target would be recovered over the five years to 2009 at a cost of $179 million (MDBMC, 2005).

The original 500 GL target also came under scrutiny when it was revealed that that risks such as climate change, uninhibited farm dam construction and corporate backed plantation forestry projects could decrease future MDB stream flows between 2,500 and 5,500 GL over the next 20 years (van Dijk *et al.*, 2006). While governments struggled to find an appropriate program for water recovery their capacity to avoid market intervention was diminished by drought in the MDB over a prolonged period and the impacts of water-plan suspensions for both consumptive and environmental water users. As such, water markets began to play an increasingly important role in the reallocation of water between users, and different uses, in the MDB.

3.4.6.3. Drought and water entitlement purchasing initiatives

As outlined above, from 1998/99 onwards irrigators in Victoria and SA experienced reduced allocations (Wheeler *et al.*, forthcoming-b). In the period following the introduction of the NWI and the TLM program total MDB system inflows were some of the lowest on record (DWLBC, 2009). The impact of the MDB drought first came to prominence in NSW. In that state, under Sec. 49A of the Water Management Act 2000 the Minister could suspend part or all of any water sharing plan for an area faced with severe water shortages (NSW Parliament, 2000). As the effects of drought became widespread in NSW several of their water sharing plans were suspended, the first in 2006 (NWC, 2009).

Irrigation and environmental requirements were sacrificed in an effort to preserve water supplies for rural communities. This signalled a formal deferral of the planning approach to the provision of environmental water and threatened the collapse of NWIA-1 objectives. The drought brought considerable political pressure to bear on the federal government, and instigated calls for the national management of water resources (Crase and O'Keefe, 2009). Faced with a lengthy drought period (Young and McColl, 2008), inaction by the states and possible impacts to longer term system inflows from risks such as climate change (van Dijk *et al.*, 2006) the federal government acted decisively.

3.4.6.4. The National Plan for Water Security (NPWS)

In early 2007 the Howard government released its *National Plan for Water Security* (NPWS) (Howard, 2007). In part, the NPWS plan aimed to:

- Achieve a 25% increase in water use efficiency, with saved water shared on a 50/50 basis between irrigators and the environment;
- Provide annual water savings of 2,500 GL in the MDB (3,000 GL in total), comprised of:
    - MDB irrigation delivery system efficiencies at a 90% benchmark, saving 1,500 GL per annum; and

- A \$1.5 billion investment in improved MDB farming and irrigation methods, yielding a further 1,000 GL of shared water savings.

In addition, under NPWS the Commonwealth was prepared to invest \$3.1 billion to purchase water entitlements and assist unviable irrigators to exit the industry. Within the NPWS, involvement in the water market was identified as a major means of providing water for the environment (ibid, pg. 4); the lesser investment focus was on efficiency investment and improvement. Any water savings from efficiency measures would be used to achieve environmental outcomes, and could be sold back to irrigators when not in conflict with environmental needs (ibid, pg. 11).

3.4.6.5. Water Act (2007)

About this time a new Commonwealth *Water Act* (2007) was also introduced to: i) establish and enforce environmentally sustainable limits on water extraction (e.g. the Commonwealth Environmental Water Holder [CEWH] and a Basin-wide environmental watering plan); ii) protect, restore and provide for ecological outcomes; iii) optimise economic, social and environmental outcomes (objective 3c, purpose $20_{(d)}$); iv) maximise net economic return to the Australian community (objective $3d_{(iii)}$); and v) achieve efficient and cost effective water management and administrative arrangements (objective 3g) (Australian Parliament, 2007). A new administrative body in the form of the independent Murray-Darling Basin Authority (MDBA) was also created (replacing the Murray-Darling Basin Commission) to address over-allocation and increase environmental flows (Waye and Son, 2010). The Authority Board is made up of 5 independent members and the Authority CEO.

The *Water Act* 2007 thus gathered disparate state water planning and trade mechanisms into a single over-arching framework requiring Commonwealth approval and deferral where conflict arose (Waye and Son, 2010). Purchasing water entitlements to meet environmental needs in the MDB using public tender rounds became prominent from 2008.

The *Water Act* 2007 also provided for the creation of a Basin Plan to recommend and account for required reductions in the consumptive pool to achieve sustainable water use outcomes (MDBA, 2012c). Proposed sustainable diversion targets have been set at 2,750 GL (MDBA, 2012b). To complement this, the federal government has made further provisions to obtain 450 GL via on- and off-farm efficiency measures and works that address delivery constraints (Burke, 2012). Setting a recovery target via the proposed Basin Plan will assist the water market recovery effort to progress, and for that progress to be assessed in terms of usefulness for delivering environmental water outcomes. However, ultimately additional water market development may also be required to achieve efficient reallocation results (Whitford and Clark, 2007).

3.4.6.6. The Water for the Future (WFF) initiative

In March 2008 the Rudd government created a further intergovernmental MDB agreement. It determined that, while the NWI arrangements had positively contributed to water reform and management, its' objectives would not be met without significant federal government intervention (DEWHA, 2008). The new agreement built on the NPWS focus on sustainable diversion limits, long-term MDB health and safeguarding community water needs (COAG, 2008). The major points of the new agreement were enshrined as *Water for the Future* (WFF) and publically released in April 2008 (Wong, 2008).[9] WFF encompassed a $12.9 billion investment over 10 years to 2018/19 (DSEWPC, 2011b) (overall summary shown in Table 7 below). In contrast with NPWS, however, WFF placed a significant emphasis on the role of water markets to recover water for the environment. A revised recovery target of 1,500 GL was set in line with the recommendations made by Jones *et al.* (2003).

Beginning in 2007/08, the federal government directly intervened in water entitlement markets to secure environmental water under its $3.1 billion *Restoring the Balance* (RtB) program (Wong, 2008, DEWHA, 2008, Crase and O'Keefe, 2009). Broadly speaking there has been limited coordination between the range of recovery programs and, while there are recent examples of program outcomes from *Riverbank* in NSW (Walpole *et al.*, 2010), the federal government has been somewhat selective in its release of detailed recovery information. As at 30 September 2012, WFF had recovered a total of 1,094 GL of long-term average annual yield (LTAAY) water from purchases of water entitlements and infrastructure efficiency transfers (e.g. NVIRP project savings in northern Victoria) across the MDB (DSEWPC, 2013).

Table 7 Water recovery policy summary—NPWS and WFF[†]

Policy	Water purchases (RtB)	Urban water or desalination	Improved water information	Exit packages	Township water security	Grey and rainwater initiative	Infrastructure efficiency investment (SRWU)
NPWS	$3.0b	$600m	$480m				$3.13b off-farm $1.64b on-farm $620m metering $500m operations
NPWS Total: $10.05b							
WFF	$3.1b	$1.5b	$450 m	$57.1m[‡]	$250m	$250m	$5.8b across areas similar to above
WFF Total: $12.9b							

† Figures do not add exactly due to incomplete funding information, and do not include additional funding in 2010/11 of up to $310 million per annum from 2014/15 to bridge any remaining gap between WFF and the final MDB Plan.

‡ In 2009, exit package funding increased to $107.1 million, with funds reallocated from SRWU.

Source: Loch et al. (under review - b)

As discussed later in Section 4, economic studies have indicated that reductions in current diversion limits will have only small scale long-run average impact on the gross value of irrigated production and employment within the MDB (Grafton, 2011). Nevertheless, the impacts are projected to be uneven and community resistance has prompted further socio-economic analysis of regional impacts. It is likely that water

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[9] The major components of the WFF plan include *Sustainable Rural Water Use and Infrastructure* ($5.8b); *Restoring the Balance* in the Basin ($3.1 billion); National Urban Water and Desalination Plan ($1 billion); Water Smart Australia ($937 million); Driving Reform in the Basin (DEWHA and ACCC) ($646 million); Improving Water Information (BOM) ($447 million); National Water Security Plan for Cities and Towns ($256 million); National Rainwater and Greywater Initiatives ($250 million); Raising National Water Standards (NWC) ($214 million); and finalising *The Living Murray* initiative ($185 million) (Wong 2008).

markets will remain a key mechanism in the water recovery process because they are associated with voluntary transactions between buyers and sellers. However, critics of WFF argue that there may be strong irrigator reluctance to part with water entitlements in the future (e.g. Waterfind, 2012). Irrigator concerns voiced in response to the Guide to the MDB Plan also resulted in strategic RtB program shifts in late 2011 (MDBA, 2010a).

Broad negative reaction to the Guide's proposed 3,000 to 4,000 GL recovery target to sustain key ecological sites (Quiggin, 2011) fuelled criticism of WFF's budget emphasis on water entitlement purchases. In response, a federal parliamentary inquiry was established to consider the Guide's impact and recommend future program arrangements (Australian Parliament, 2011). In 2011-12 the Department of Sustainability, Environment, Water, Population and Communities (DSEWPC) undertook a review of *Restoring the Balance* water entitlement purchasing to date in 2012, as discussed later in Section 4, partly to investigate claims against the program.

3.4.6.7. The Murray-Darling Basin Plan (2011)

In November 2012, federal Parliament passed the Murray-Darling Basin Plan into law, and several attempts to have the plan disallowed have since been rejected (as at 18 March 2013). The new target for SDL reductions was confirmed at 2,750 GL; an outcome to be achieved by 2019 with a performance (and target) review process scheduled for 2015 (MDBA, 2011e). At the time of passing the Basin Plan, the MDBA confirmed that (using 2009 as the base year) 1,315 GL had been recovered for the environment, leaving 1,435 GL to be recovered (DSEWPC, 2013).

Importantly, the Basin Plan provides significant opportunity for improving water trade rules, operations and integration in the southern MDB. Specifically, new requirements on water trading rules contained in Chapter 12 of the plan seek to enhance trade in groundwater entitlements, trade in delivery rights, clearer definitions of water user/service provider rights, delivery and reporting obligations, and allocation announcements. Completion of water trade reform is important to complete implementation of Australia's progress toward addressing environmental, social and economic issues (Horne, 2012b).

The emphasis in part on water trade as an instrument to reduce risks identified in the Basin Plan suggests the possibility of an increasing role for water trade in future. This conclusion is supported by CEWH interest in using allocation water trade to recover water for the environment (CEWH, 2011a), and enhanced water trade rules that have been developed to improve the efficiency and effectiveness of water markets for reallocation purposes (ACCC, 2009, ACCC, 2010, ACCC, 2011b). However, there has been an increasing emphasis on investment in infrastructure upgrades and water saving projects.

3.4.6.8. RtB strategic shift toward infrastructure investment over buy-back

Cessation of non-strategic water entitlement purchasing conformed to a recommendation from the Parliamentary Inquiry into the impact of the Guide (Australian Parliament, 2011). Specifically, the inquiry called for strategic water entitlement purchasing that prioritised low community impacts (i.e. where consequences for communities had been identified prior to purchase) and dealings with proactive sellers. The inquiry also recommended (amongst other things) that: i) the identification and implementation of viable efficiency works for the environment should be done immediately; ii) tax impediments to efficiency investment should be addressed; iii) tax-based incentives for irrigation efficiency uptakes should be introduced; iv) there should be immediate investment in R&D for efficiency uptakes; and v) a national water fund should be established to achieve these outcomes.

In February 2011 the federal government announced that, in response to irrigator concerns about the rural effects of water purchasing in sMDB districts, it would shift its program emphasis to smaller and rolling tender rounds to provide a measured and steady pace of water recovery (NWC, 2011b). Water purchases had to align with new criteria including: closer matches of purchasing locations to areas with scientifically proven environmental water needs; a demonstrated capacity to meet environmental needs; and cost effectiveness of the purchases relative to current market prices. In response, federal purchases in the sMDB fell from 488 GL in 2009/10 to 221 GL in 2010/11 and largely emphasized high reliability water entitlements over other reliability types (NWC, 2011b). The market price for sMDB water entitlements also fell by around 15% in 2010/11 (Waterfind, 2012). This price fall was largely consistent with modelling by Hone *et al.* (2010) that estimated federal government intervention in the water entitlement market had increased prices between 13% (northern MDB) and 18% (southern MDB) overall.

An emphasis on infrastructure investment has provided the basis for an additional $1.7 billion investment into water recovery via on-farm efficiencies such as channel-lining and farm evaporation reduction technology, as well as larger barrier reduction projects to improve environmental watering (Wroe, 2012). As a consequence, the total RtB water recovery target increased to 3,200 GL by 2024; or an additional 450 GL on current Basin Plan arrangements (MDBA, 2012c). On-farm benefits from infrastructure investment include greater farm flexibility and viability, reduced labour inputs and nutrient runoff and production stability from efficient supply (Burke, 2012). Community advantages can also accrue from short-term and long-term labour and capital injections, improved property values, and enhanced secondary/tertiary sector viability and adjustment periods to water reform requirements (MDBA, 2012d). [10] Where irrigation losses contribute minimal return-flows, infrastructure investments can also be cost-effective (Qureshi *et al.*, 2010).

However, the savings from such projects are often called into question (Ward *et al.*, 2007) and irrigators can be burdened with higher variable farm operating costs, as well as enduring water structure operation, maintenance and refurbishment costs (Crase, 2012a). Viable projects can also be difficult to identify, as many fail benefit-cost tests or contradict NWI requirements from state investments in water infrastructure (Crase and O'Keefe, 2009). Finally, total water recovery from

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[10] Although for an opposing argument to public social welfare benefits from infrastructure investment in private irrigation works see Crase (2012b).

infrastructure investment may not exceed 600 GL due to improvement limits or questionable reductions in seepage/evaporation losses (Quiggin, 2006b).

In response to the parliamentary inquiry recommendations, the federal government announced a range of further reforms in the sMDB. Specifically, in April 2012 the government announced that it would suspend all non-strategic water purchases in the MDB and shift its RtB spending emphasis toward infrastructure investment (ABC News, 2012b). By way of tangible support for this approach, in early November 2012 the federal government announced that it would seek to return a further 450 GL of water to the environment via an additional $1.77 billion funding package (i.e. on top of the existing SRWU program funds) toward infrastructure investments within the sMDB. The target date for returning water to the system was also extended out beyond 2019 to 2024.

Further research by Loch *et al.* (under review-b) suggests that there is not the increased demand for greater water infrastructure investment as commonly perceived. They found that irrigators marginally prefer infrastructure expenditure above the sum of a set of market-based options (namely water entitlement purchasing, temporary water market products and exit- based packages). However, their infrastructure preference weighting is less than current budget expenditure, and the use of market-based options has higher support from irrigators than current policy recognises.

3.5. Key points

The major points from this section include:

- Australia’s progress toward water markets has been long and costly. However, it is clearly apparent that during this time water trade has become entrenched as a tool to manage water scarcity, particularly during severe shortages associated with drought (e.g. the Millennium drought). However, active water markets are still mainly limited to the sMDB.
- A major element from this section is that periods of extreme dry (and wet) have seen water markets expand and develop as a tool for the effective and efficient reallocation of water resources between competing uses and users. This has primarily provided a basis for assisting sectoral, structural and community adjustment particularly in rural areas. As future climate change is set to exacerbate the twin issues of water scarcity and variability to a potentially greater degree than ever before, the usefulness of water markets and an adaptation tool for water users is clearly evident.
- The following section thus details the expected effects of climate change for water supply and agriculture in Australia and the sMDB in particular as a basis for examining how water markets might assist adaptation in that context.

4. ECONOMIC CONSEQUENCES OF WATER MARKETS

As noted in Sections 2 and 3, the effects of climate change in Australia and the MDB will potentially be quite severe. Changes such as reduced rainfall and surface runoff, together with increased temperatures and seasonal variability, will result in decreased water supply and/or water resource availability. As water resources comprise a key input for agricultural production, industrial manufacture and rural town supply requirements (e.g. critical human needs) any decrease in its supply will have economic flow-on effects for these sectors. This chapter outlines and discusses those economic flow-on effects and their mitigation by water markets.

Water markets enable water users to deal with allocation problems specific to their demands and their local environmental constraints (Anderson and Leal, 1992). Using an earlier approach adopted by Crase *et al.* (2004), the objective of this chapter is to provide insight into three questions. These include: (1) what advantages do current water market arrangements offer for the economic reallocation of scarce water resources; (2) do existing water market structures and arrangements provide economic capacity to mitigate likely future climate change impacts; and (3) where changes to existing water markets are required to improve/increase the capacity for economic adjustment, what changes would be needed? This chapter sets out to address these questions.

4.1. The perception of water markets – an overview

Fears about the community impacts of water trading have been widespread and vehemently expressed since markets were first introduced (Bjornlund and McKay, 1999, Bjornlund, 2002, Fenton, 2006, Edwards *et al.*, 2008a, Edwards *et al.*, 2008b, Edwards *et al.*, 2009, Productivity Commission, 2010). However, it is clear that irrigator views towards trading have become more accepting over time. Table 8 andTable 9 illustrate attitudes by irrigators towards various aspects of the water market, in 1998-99 and 2010-11 respectively. It is also clear that there has been more concern about entitlement trading than allocation trading, and trading out of districts than within districts. Users of the water market are more likely to agree that water markets are a good idea, while sellers are more likely to think that than buyers (Bjornlund *et al.*, 2011).

Table 8 Water Trade Attitudes by GMID and NSW Murray in 1998-99 (%)

	GMID (allocation buyers/sellers and non-traders)					*NSW Murray (allocation/entitlement buyers and sellers)*				
	SA*	***A***	***N***	***D***	***SD***	***SA***	***A***	***N***	***D***	***SD***
Water trade is a very good idea	46	27	13	5	10	48	24	10	7	11
I only agree with temporary transfers since the water stays on the property	35	27	12	13	13	31	20	12	18	19
It has to be possible to transfer water permanently otherwise it is not possible to make long term commitments	27	28	19	13	13	37	27	16	11	9
Water trade should not be allowed because it activates otherwise unused water and reduces annual sales water	9	15	15	28	32	12	13	15	27	33
Water trade is a good way for some farmers to get out of irrigation	25	39	11	11	14	27	34	15	19	9
It is essential to make allocations to the environment otherwise irrigation will not be long term viable	27	33	21	10	8	17	38	19	15	11
I am willing to reduce annual sales water allocations in order to ensure sufficient allocations for the environment	7	20	20	22	31	4	15	17	20	44

* SA = Strongly agree, A = agree, N = neutral, D = disagree and SD = strongly disagree.
N=300 (GMID) N= 311 (Murray)

Source: (Bjornlund et al., 2011)

Table 9 Water Trade Attitudes in NSW, VIC and SA 2010/11 (%)

	NSW					**VIC - GMID**					**SA**				
	SA	*A*	*N*	*D*	*SD*	*SA*	*A*	*N*	*D*	*SD*	*SA*	*A*	*N*	*D*	*SD*
I believe water trading has been good for farming	7	38	12	23	17	8	32	15	26	18	7	49	14	21	7
Trading water helps me cope with seasonal uncertainty	14	58	8	13	5	16	57	8	13	4	11	58	17	9	1
We would willingly reduce our seasonal allocations to ensure environmental water	1	5	9	42	41	0	9	7	41	41	0	17	10	42	28
Most irrigators think increasing environmental water flows is a good thing	1	21	10	48	19	1	20	11	47	16	5	64	11	17	3
Environmental allocations are essential otherwise irrigation will not be long-term sustainable	6	38	12	28	12	4	39	14	32	8	8	71	7	10	1
I am well informed about the trading rules in my district	16	68	6	6	2	15	68	6	9	2	8	78	4	7	1

N= 274 (SA), N= 358 (VIC), N= 313 (NSW)

Source: (Bjornlund et al., 2011)

Despite these concerns irrigators have widely adopted water trading over time, in particular the trading of allocations (Wheeler *et al.*, 2009) while the adoption of entitlement trade has been much slower and only started to accelerate in the past few years (Bjornlund *et al.*, 2012). Water trading is thus having an increasing influence on both who uses and who owns water. There is clear evidence to suggest that irrigators have used water markets to manage the adjustment process; and to manage water scarcity and production risk with respect to water supply (Bjornlund, 2002, Bjornlund, 2004, Bjornlund, 2006b). Despite the early reluctant acceptance of water trading, there is now a clear understanding within the irrigation community that without water trading the socio-economic impact of the current drought would have been much harsher.

4.1.1. Water trade background in the 2000s

In general, the sMDB market for water allocations was more volatile during the recent Millennium drought than the market for water entitlements. The total volume of water allocation trade roughly trebled from 8% to 30% of available water in the period from 2001/02 to 2007/08, as seasonal allocations began to diminish (NWC, 2011b). While relatively little water allocation was traded between the sMDB states from 2003/04 through to 2007/08, from 2007/08 to 2010/11 interstate trade grew from 19% to 65% of transactions to cope with differing state demands for water resources (Table 10). From 2006/07 the NSW Murrumbidgee became a net exporter of water allocations as rice and other annual crop growers elected not to produce, and sold their water allocation instead.[11] SA on the other hand became a net importer of water from 2007/08 to 2010/11 to meet demand from horticulture crops and demand for carry-over. In total, over 60% of NSW's water allocation exports went to SA, with the most substantial volume occurring in 2008/09 following particularly difficult allocation conditions in 2007/08.

Consequently, the 2007/08 period experienced high prices of water allocations, as irrigators unfamiliar with low allocation announcements engaged in 'panic' trade to secure adequate water supply (Loch *et al.*, 2012). The rumours in 2007/08 about the extent to which the government was going to intervene in the water market also drove up prices. Water allocation prices returned to lower levels in 2008/09, and fell dramatically at the end of the Millennium drought in mid-2010/11.

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[11] In November 2006 both the Murrumbidgee and the NSW Lower Murray-Darling Regulated Rivers water sharing plans were suspended to give general and high security water users greater flexibility in managing their water needs. This removed previous 100 GL total limits on interstate water allocation trade, and saw total transfers-out rise to around 400 GL in 2008/09. In response, an embargo was placed on out-of-district trade in the Murrumbidgee River in 2009/10 (Loch et al., 2012), which saw SA irrigators source water allocations from other regions such as the Lower Darling (NWC, 2011b). The trade embargo ballot-trigger point was not reached in 2009/10, so possible trade restrictions did not eventuate. In July 2011 the water-sharing plans were reinstated, along with the original 100 GL interstate trade limits.

Table 10 Intrastate versus interstate sMDB water allocation trade as a % of state trade—2007-2011

	NSW		Vic.		SA		Total	
Year	*Internal trade*	*Inter-state trade*	*Internal trade*	*Inter-state trade*	*Internal trade*	*Inter-state trade*	*Internal trade*	*Inter-state trade*
2010-11	83%	17%	77%	23%	35%	65%	73%	27%
2009-10	75%	25%	81%	19%	81%	19%	77%	23%
2008-09	58%	42%	94%	6%	96%	4%	67%	33%
2007-08	74%	26%	87%	13%	99%	1%	83%	17%

Note: To avoid double counting, interstate trade comprises only trades out of each state. For example, the substantial volume of trade that took place in 2008-09 from New South Wales into South Australia is included as New South Wales, rather than South Australian, interstate trade.

Source: (NWC, 2011b)

The National Water Commission (NWC) notes that the price of water allocations is usually unstable at the beginning of a water year but tends to stabilise as the water year progresses. As the prices of water allocations fall, smaller trades become unprofitable as the transaction costs associated with the transfer outweigh the revenue from the sale. This provides sellers with an incentive to carry-over water into the following season, and buyers the incentive to purchase higher than planned volumes to make transactions cost-effective, and then carry-over that water as well (NWC, 2011b).

It therefore appears as if the water entitlement and allocation markets have worked well in reallocating water within the sMDB in response to the Millennium drought by facilitating significant inter- and intra-state volumetric transfers. In the next section we examine the economic drivers for this reallocation in greater depth to develop lessons for future climate change impact mitigation from water markets.

4.2. *Economic studies of water trade and reallocation*

The ability to trade water provides flexibility for irrigators in water use, production and farm management strategies. As Qureshi *et al.* (2009) argued, trading in water markets is likely to increase and improve economic efficiency because market prices make the opportunity cost of water explicit; they provide incentives to adopt water-saving technologies and reduce inefficient uses of water. Peterson *et al.* (2004) estimated the gains from trade in a dry year at $495 million, the NWC (2010a) suggested that water trading in the sMDB increased Australia's gross domestic product by $220 million in 2008–09, and Qureshi *et al.* (2009) found that a reduction in water market barriers in the sMDB would increase annual net returns significantly. Jiang and Grafton (2012) use a hydro-economic model to examine the role that water trading plays under climate change and reduced surface water availability in the MDB. Results show that with inter-regional water trade, the on-farm impacts of climate change in periods of much reduced water availability is mitigated compared to without inter-regional water trade, emphasising the critical importance that water trade plays.

The above concerns associated with water reallocation in the Basin have prompted a range of socio-economic analysis of regional impacts (Connor *et al.*, 2011a, DAFF, 2011, Goesch *et al.*, 2011, Dixon *et al.*, 2011, ABARE-BRS, 2010a, ABARE-BRS, 2010b). In general, these studies find GDP would decline between 0.2% (Wittwer and

Griffith, 2011) and 0.7% (DAFF, 2011) under 3000GL/y recovery; but trade and dry-land farming would mitigate most losses. Heavily irrigation-dependent areas may experience larger impacts, but most regions could expect short-term negative impacts where: 1) adjustment was enhanced by unrestricted intra-regional trade; 2) cap barriers to water entitlement selling were removed; and 3) targeted buyback within strategic irrigation districts was undertaken. Broadly speaking, current water trading arrangements produce significant economic benefits for sMDB, and the states within it (NWC, 2012a).

One way in which the economic benefits of water trade could be measured is by calculating the gross value of irrigated agricultural production (GVIAP) and mapping it across years. Figure 16 summarises available ABS data for GVIAP in the MDB from 2005/06 to 2008/09 (NWC, 2012b). The data suggests that while water availability over the entire MDB dropped by 53%, GVIAP for the period fell by only 27%.

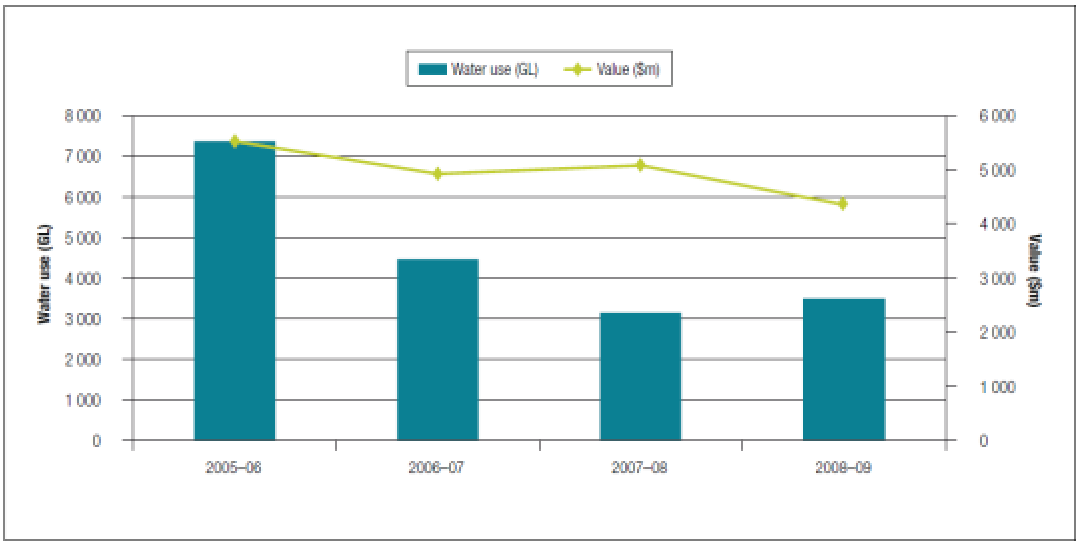

Figure 16 Gross value of MDB irrigated production, 2005/06 to 2008/09

Source: (NWC, 2012a).

However, the ABS (2012b) caution that GVIAP does not provide an accurate quantitative measure of irrigation water value-adding or the benefits of water trade, which are typically overstated in its reporting. To account for this issue, the NWC employ economic modelling techniques to estimate the relationships between water availability, water use, irrigated agricultural production and overall economic activity. Specifically the NWC, among others, use computable general equilibrium (CGE) models to examine aggregate economic effects of water trade on irrigator water adjustment within and across irrigation regions up to 2010/11 (NWC, 2012a). Economic impacts modelled include the impact on industries, production, employment, regional economies and local spending in response to given water availability scenarios. Dry-land productivity shocks as a result of drought or reduced water availability are also captured.

The findings suggest that, without access to water trade, the economic impact of water scarcity in the sMDB would have totalled between $2-3 billion each year in 2007/08 and 2008/09. However, when interregional and intraregional water trade is permitted in those same years, production gains of $1.05 billion and $1.2 billion respectively were realised. In total between 2006/07 and 2010/11 sMDB production was estimated to be $4.3 billion higher in the presence of water trade than it would have been if opportunities for inter- and intraregional water trade and on-farm reallocation of water were not available. Further, access to water trade mitigated flow-on declines in investment and avoided the loss of more than 1000 jobs. Finally, at the regional level water trade increased the net value of irrigated production of $136 million in NSW between 2006/07 and 2010/11. Further, in Victoria and SA the impact of water trade increased irrigated production by $885 million and $103 million respectively over the same period. Water trade thus helped to avoid state gross production reductions in NSW (-$760 million), Victoria (-$2,256 million) and SA (-$419 million) respectively (NWC, 2012a).

In addition, expanded intra- and inter-regional trade as a consequence of NWI institutional reforms were estimated to have reduced the impact of drought within the sMDB from $11.7 billion to $7 billion over the 2006/07 to 2010/11 period—with higher magnitude benefits being incurred during exceptionally dry years when the need to reallocate water was highest (NWC, 2012a). While significant water trade institutional and transaction cost reductions have been achieved, there is still considerable room for improvement (Hamstead *et al.*, 2008). However, efforts to reduce water trade barriers have resulted in beneficial transfer outcomes that would likely be repeated in future under predicted climate change impacts.

These results generally conclude that the ability to trade water plays a critical role in maintaining irrigation sector incomes during drought, with likely adaptation advantages under mild to moderate future climate change scenarios. However, where severe climate change impacts are expected, irrigation sector adaptation costs may increase with the move from perennial to annual crops to suit more variable and reduced water supply arrangements. Further, irrigation-dependent areas may experience larger impacts, which could be minimised if: i) adjustment was enhanced by unrestricted intra-regional trade; ii) cap barriers to water entitlement selling were removed; and iii) targeted buyback within strategic irrigation districts was undertaken (NWC, 2012a).

Wheeler *et al.* (2012c) investigated the impact of water ownership and trade strategies on irrigated farm profitability in the MDB. They found that higher net farm income was associated with lower debt, lower labour expenses and higher farm capital and production receipts. It was also sometimes positively associated with owning larger high security water entitlement, allocations received, and selling a higher volume of water allocations. However, larger ownership of low and general security water entitlements is often negatively associated with net farm income.

4.2.1. Restoring the Balance water recovery program

As described earlier, *Restoring the Balance* (RtB) is the largest market-based water recovery program in the world—and occurred largely during a period of extreme drought in the MDB. From 2007/08 to late 2011 the federal government purchased 990 GL of long-term average annual yield (LTAAY) water at a cost of approximately $2.1 billion through market tenders. Of the more than 15,500 water entitlement sales in that period, around 25% were to the Commonwealth. In total 3,150 MDB irrigators sold water entitlements, or around 13-17% of the irrigator population, depending on the population estimate used (Cheesman and Wheeler, 2012).

The assessment of RtB sellers was based on a survey of 589 irrigators who had agreed to be contacted for such purposes as part of their tender process. This participation request did not form part of the original tender round, and so those initial irrigator’s views were not able to be included. Of the 520 irrigators surveyed who had sold water, 60% had sold part of their water and were still farming, 10% had sold all of their water but were still farming and 30% had sold all of their water and exited farming altogether. Selling water entitlements to the Commonwealth had been a positive experience for the majority of irrigators (80%), because it allowed them to better manage their farm situation and achieve other personal objectives. Half of the irrigators who sold part of their entitlement did not experience any reduction in their farm production. Further, of those irrigators that had sold all of their entitlements and left farming, 70% reported that their farm was still being used for agricultural production and 25% reported that the farm was now fallow. Exiting irrigators were now either working in other jobs within the region (51%), had retired within the region (35%) or were unemployed (3%). It was estimated that a maximum of 10% had left the region, although this figure may be over-stated (Cheesman and Wheeler, 2012).

Interestingly, while about 50% of surveyed irrigators generally disagreed with the Commonwealth's environmental water recovery objectives a similar proportion believed that using water markets to recover water was appropriate—predominantly stating they believed that the approach had resulted in higher than normal market prices.[12] Water entitlement selling had allowed irrigators to generate cash flow during a difficult time that they then used to reduce farm debt, invested on-farm or in the region, or spent outside their region. Consequently, 50% of irrigators wanted to sell more water to the Commonwealth when asked in early 2012 and many wanted more frequent and shorter tender rounds (i.e. reduced transaction times). Of the 40% who would not sell water entitlements in future, most would be in the position of not having any further surplus water to sell (Cheesman and Wheeler, 2012).

A number of irrigators in the RtB survey had been initially prevented from completing their transaction by cap restrictions on out-of-district trade such as the Victorian 4% limit, which delayed and then ultimately resulted in their tenders being withdrawn. We consider cap restriction impacts on the water market in the next section.

4.2.2. Water market influences

A wide literature has studied the quantitative influences on water market prices and volumes (e.g. Wheeler *et al.*, 2008b, Wheeler *et al.*, 2010a, Brennan, 2006, NWC, 2011b, Bjornlund, 2003, Bjornlund and Rossini, 2004, Bjornlund and Rossini, 2005, Bjornlund and Rossini, 2006, Bjornlund and Rossini, 2007). Some important influences on water markets include:

- Institutional change: e.g.: development of property rights for irrigators under state water-sharing plans by the early 2000s and wider improvements to trade institutions, rules and approvals.
- Policy change: The NWI, TLM, WFF all impacted on water demand, trade suspensions, caps (see Box 4.1), and water allocation trade ballots.
- Rainfall and temperature: Higher temperatures and lower rainfall drive increased demand for water allocations;
- Timing: time of season impacts on water demand;

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[12] The states held different attitudes to the Commonwealth's environmental water recovery objectives, with 50% of SA farmers broadly agreeing with the program as against 35% of Victorian and NSW farmers.

- Seasonal allocations: The percentage of water received from an entitlement seasonally is a very important influence on water demand. The differences in seasonal announcements (for example, starting with a 0% in the start of the water season) can critically impact the timing of water demand;
- Differences in agricultural commodities, market and farm conditions across states, as well as changes in water pricing.
- Differences in carry-over access and conditions between states, with somewhat more favourable carry-over conditions available in Victoria (see Box 4.2).
- Differences in water charges.

Many of these factors have been discussed in the report elsewhere, with the exception of water charges. Table 11 highlights the differences in costs charged across the MDB by IIOs, as estimated by ACCC (2012) from reported IIO data.

Table 11 Total hypothetical irrigator bills for 2010−11 year, 50 ML, 250 ML and 1000 ML of entitlement with delivery of 100 and 50% allocation

		Total Annual Bills ($)					
		100 per cent allocation			*50 per cent allocation*		
Operator	*Hypothetical irrigator*	*50 ML*	*250 ML*	*1000 ML*	*50 ML*	*250 ML*	*1000 ML*
Buddah Lake		1577	7883	31530	952	4758	19030
CIT	High pressure	3418	17089	68356	2329	11644	46578
	Medium pressure	2870	14349	57396	2055	10274	41098
	Low pressure	2369	11844	47376	1804	9022	36088
Coleambally	General Security	3458	7812	24139	3361	7327	22199
Eagle Creek	General Security	888	4438	17750	646	3231	12925
GMW	Tresco	3113	15035	59741	2863	13785	54741
	Nyah	3209	15213	60228	2737	12854	50793
	Woorinen	3438	16536	65652	2926	13975	55407
	Torrumbarry	2269	11045	43954	2091	10156	40399
	Murray Valley	2353	10663	41826	2216	9978	39086
	Pyramid-Boort	2250	10149	39771	2084	9319	36451
	Rochester	2223	10014	39231	2072	9261	36221
	Central Goulburn	2924	12384	47857	2668	11103	42732
	Shepparton	3618	16253	63635	3228	14307	55850
Hay		2367	10207	39607	1992	8332	32107
Jemalong		2006	10028	40110	1329	6645	26580
LMW	Robinvale	8955	44373	177192	7504	37122	148187
	Red Cliffs	5832	28762	114749	4726	23228	92614
	Merbein	5010	24648	98293	3943	19317	76968
	Mildura	5721	27353	108473	4671	22103	87473
Marthaguy	General Security	2001	10003	40010	1397	6985	27940
MI	SAS—General Security	2812	8540	26720	2505	7006	20585
	SAS—High Security	3326	10576	32791	3019	9042	26656
	LAW—General Security	3202	7802	22914	2920	6392	17274
	LAS—General Security	3252	8466	25364	2945	6932	19229
	LAS—High Security	3821	10299	30579	3514	8765	24444
	IHS—High Security	6287	26065	95538	4387	16563	57528
MIL	B1 Class C	4095	10429	32306	3404	8446	26416
Moira		1638	8188	32750	1175	5875	23500
Narromine		2278	10590	41760	1553	6965	27260
Renmark		3627	18135	72539	2639	13197	52789
SunWater	St George	2662	13310	53240	2366	11828	47310
Tenandra		1721	8603	34410	1096	5478	21910
Trangie		2536	12678	50710	1661	8303	33210
West Corurgan		1615	8075	32300	1208	6038	24150
WMI	Curlwaa	3136	15678	62710	2111	10554	42215
	Coomealla	4052	20260	81040	2598	12990	51960
	Buronga	6244	31220	124880	4183	20915	83660

Notes: HP, MP and LP mean high pressure, medium pressure and low pressure, respectively. SAS, LAW, LAS and IHS represent different types of farms serviced by MI (see www.mirrigation.com.au/Customers/charges.htm).

Source: (ACCC, 2012)

Box 4.1: Cap impacts on sMDB water demand and trade

Cap restrictions on water entitlement trade limit the volume of water that can be transferred away from a district or region to a specific amount in a period (Frontier Economics, 2009). Supporters of entitlement trade restrictions argue that they are necessary to reduce the pace of rural adjustment under water reform and lessen problems associated with stranded irrigation assets. To provide such benefits to remaining users, Victoria places a 4% limit on the volume of water that can be trade out of an irrigation district in any given year; and a 10% limit on the volume of irrigation water entitlements that can be held by non-users in a given water system. NSW also imposed a 4% annual limit on the volume of water entitlements that can be transferred out of an irrigation district, together with a general embargo on water entitlement sales to the Commonwealth until September 2009. This restriction was lifted under an agreement between the federal and NSW governments to limit total annual water purchases in that state to 890 GL of general security water entitlements over five years from 2008/09 (Productivity Commission, 2010). In SA a 12% cap on the volume of water entitlements that may be traded out of an irrigation district over a two-year period has generally never been reached, and this limit was lifted in 2009/10 (Frontier Economics, 2009). Queensland and the ACT do not have any volumetric restrictions on water entitlement trade and, notably, similar cap restrictions on water allocation trade do not exist in any of the MDB states.

There are a number of clear economic inefficiencies that can be associated with cap restrictions on trade. These include allocative and productive inefficiency outcomes from foregone high-value crop production opportunities, dynamic inefficiency from distorted long-run decision-making, economic inefficiency from poor or avoided investment (divestment) decisions in irrigation areas, cash-flow management constraints, delays in adjustment to dry-land or less-intensively irrigated agricultural production and declines in local/regional economic activity (Frontier Economics, 2009). By way of example, it is estimated that in Victoria 94.5% of high reliability water shares (entitlements) in irrigation districts had reached the 4% cap by early 2008/09, preventing water transfers for a significant period of time. Further, the Victorian 10% rule prevented the processing of 50 GL of environmental water in 2009/10—with an estimated welfare loss of $6.8 million (Frontier Economics, 2009). The federal government estimated that as much as $80 million worth of environmental purchases had been prevented by 4% cap restrictions in 2009/10 (DEWHA, 2010), while in 2010/11 reaching the 80 GL annual cap in NSW for selling general water entitlement holdings to the Commonwealth excluded irrigators in that state from the $60 million third MDB tender round for that period (DEWHA, 2010). A further result of cap restrictions on water entitlement transfers is that prices can become higher than they would otherwise be (Productivity Commission, 2010). Markets can only provide effective and efficient means to price and transfer water between competing uses if the real values of all competing uses, including externality effects, are included. Such conditions, however, constitute perfect market contexts that are rare in reality and as such prospects for market failure are high (Challen, 2000). Specifically for water reform, a reduction in water supply availability for other users from cap restrictions (or as a consequence of climate change) is often foremost among the list of externalities considered (Colby, 1990).

Water market trade rules can change rapidly, making it difficult for users. For example, in April 2011 Victoria took the unprecedented step of suspending water allocation trades from NSW into Victoria for the remainder of the 2010/11 water season. This decision was based on high MDB storage levels at the close of the water season, which resulted in large volumes of unused water allocation, and threatened to impact on the 2011/12 announced allocations as a result of Victoria's carry-over rules (NWC, 2011e). Overall, 2000 GL of unused water allocation in the Murray and Goulburn systems toward the close on 2010/11—if stored in the Hume Dam—would dilute the rights of those already holding water in that storage.

Box 4.2: An introduction to carry-over

Carry-over is an arrangement whereby water allocation account holders can retain unused portions of their water allocation from one year to the next (Barma Water Resources Pty. Ltd et al., 2011). As such, carry-over redistributes water between seasons allowing individuals additional strategies for managing their water supply risk and societal welfare benefits from more flexible water use. To work properly, carry-over provisions must: i) not adversely impact third-parties; ii) have explicit cost and risk signals; and iii) have simple and consistent rules across connected water trading arrangements (DSE, 2010). Carry-over has been available in Queensland and NSW for some time, and provisions have been more recently established in Victoria and SA. In the NSW Murrumbidgee irrigation district, for example, carry-over limits of 15% of seasonal allocations applied between 2001/02 and 2007/08. In 2008/09 these limits were relaxed to 30% in response to drought and expected benefits from improved inter-temporal water management under scarce supply conditions. In the 2010/11 return to wet conditions, Murrumbidgee carry-over and seasonal allocations were capped at 100% of water entitlement, with surplus allocation above this cap immediately subject to forfeit (NSW Office of Water, 2010). In SA, where the need for carry-over had not been envisaged before, temporary access provisions were put in place in 2007/08 under agreement with the upstream states where storage space would be provided.[1] In 2008/09 SA irrigators were able to access 50% of approved carry-over, while in 2009/10 this level of access increased to 60% and then 100% by the close of the season.

In 2010/11 SA irrigators started the season with no carry-over access provisions under the cancelation of interim storage sharing agreements with the upstream states. However, in September 2011 the SA government renegotiated a long-term agreement that incorporated carry-over rights (SA Department of Water, 2011b).SA's reliance on upstream states offers an example of attenuated carry-over access rights that may weaken their effectiveness. When storage rights are not explicitly defined, or where carry-over access is heavily restricted to minimise externalities for other water users, these arrangements can further weaken their effectiveness (Hughes and Goesch, 2009). The Victorian system of carry-over introduced in 2010/11, however, represents an attempt to overcome these issues. Victorian carry-over was first introduced as an emergency drought measure in 2007, and then made permanent. To minimise third-party externality impacts and address water storage property and access right definition requirements (NWC, 2011d)

Victoria introduced spillable water accounts (SWAs). SWAs allowed water entitlement holders to carry-over unused portions of their allocation above 100%, as long as water storage capacity existed. SWA allocations could then be used or traded as usual. However, if a probability of a spill-risk is high (i.e. likelihood that the maximum storage level or spill-way will be breached), all SWA water is immediately quarantined from use and/or trade. In the event of a spill-event, all SWA water is immediately forfeit (DSE, 2010). Consistent carry-over rules and access provisions across the MDB should result in less intra-seasonal volatility and greater end of season stabilisation in the price of water allocations. This would particularly be the case following seasonal allocation announcements, as they involve slightly longer-term outlooks (NWC, 2011b). Carry-over may also create less inter-seasonal water allocation price volatility, since it allows regulators to reduce the urgency for early-season water allocation trade by enabling larger water allocation accounts to be developed in prior seasons. In support of this, simple analysis of end-of-season water allocation prices and volatility between 2007/08 and 2009/10 suggest that reductions in the total volume of water allocation trade under access to carry-over results in lower early season water allocation price volatility and increased water allocation prices towards the end of a season (Waterfind, 2009, Wheeler et al., 2010b).

An issue arose from the fact that, although water allocations could not be transferred from NSW into Victoria under the suspension, there was no initial restriction on trade from NSW to SA, and then back into Victoria (NWC, 2011b). Consequently, record water allocation trade occurred in April, May and June 2011 in response to both the trade suspension and state differentials in carry-over rules. In 2011/12, another round of water allocation trade suspensions were announced by Victoria (Walsh, 2012), NSW (NSW Office of Water, 2012) and finally SA (SA Department for Water, 2012) to halt interstate transfers until the next water season. These largely unanticipated decisions highlight shortcomings in the current water storage property right arrangements that ultimately led to confusion and reduced confidence in the water trade system since participants were given limited notice, had limited information and could not predict when restrictions would be imposed (NWC, 2011d).

The Water Market Rules and Water Charge (Termination Fees) Rules address barriers imposed by irrigation infrastructure operators (IIOs) that prevent irrigators from participating in water markets. Both sets of rules came into effect in 2009−10 (ACCC 2012).

The challenge for agriculture and the farms that comprise them is building productivity and profitability without depleting the resources on which they depend (MDBA, 2010b). A further challenge is to increase (or at least maintain) productivity and profitability in the face of a decreasing (e.g. water) resource-base. To that end, agriculture has often invested in new technologies to improve productivity through planning and practice changes (EBC *et al.*, 2011). Water trade and infrastructure upgrades represent a natural extension of this previous farming approach to productivity management. The final section in this chapter considers shortcomings in sMDB water markets and considers other market failures or deficiencies that may reduce the effectiveness of water markets as an adaptive tool for mitigating future climate change impacts.

4.3. Improving water markets

4.3.1. Basic elements for effective and efficient water markets

From our previous discussion, we can outline the basic elements required for effective and efficient water markets. These include (NWC, 2011f):

- Secure water access property rights;
- Well-informed market participants;
- Incorporating third-party externality impacts into water trade decisions;
- Low market entry barriers and/or impediments to trade;
- Low transaction costs;
- A balance between consumptive and environmental water uses, and
- Institutional arrangements that account for market regulation, trade platforms, registration of trades, compliance monitoring and enforcement.

The discussion above also highlights that sMDB water markets are continuing to deepen and broaden, and play an increasingly important role in allocating water within and between rural, urban and environmental water users (NWC, 2011f). Adapting to and mitigating likely future drought [or climate change] effects will involve significant institutional development that: i) increases opportunities to allocate water more efficiently through water markets and water banks; and ii) promotes cooperation between and across water catchments and diverse water interests (Schwabe and Connor, 2012).[13] However, there is scope for market failures to emerge in the water reform and resource management process, and as such a cautious approach to water market design and implementation is advisable (Crase *et al.*, 2004). Adaptive management is often recommended, where possible, to address market failure outcomes (e.g. Garrido and Dinar, 2009, Huitema *et al.*, 2009). But adaptive management can be constrained by issues such as path dependencies (Challen, 2000) and information asymmetries (Tisdell *et al.*, 2004).

All water markets offer degrees of adaptive management to facilitate drought or supply-shock responses, but the challenge is providing response flexibility to accommodate desired public good benefits of water use (Grafton *et al.*, 2011b).

To that end, an essential water market development involves establishing sustainable diversion limits (SDL) (CSIRO, 2008a) or baseline diversion limits (BDL) (DSEWPC, 2011a) to secure public benefit water use. In the context of the MDB these are defined in the MDB Plan. Recent modelling outside the MDB planning process suggested that the recovery target should be 3,200 GL (EnviroInfo, 2012). This change indicates recovery program uncertainty and policy-on-the-run tendencies, and reduces market confidence. However, the current MDB Plan (MDBA, 2012c) seeks to provide flexible water reforms to meet public good benefits from water use, as well as better scientific data, sustainable environmental flows, water quality considerations, and complementary basin and catchment-level water planning arrangements (Crase, 2012b). Therefore, strong connections between water reforms and water markets will likely be necessary to maintain and deliver desired public benefit outcomes (Grafton *et al.*, 2011b).

4.3.2. The influences of caps on water markets

Supply limit instruments like trade caps result in quota effects on the market and can result in significant welfare (real income or deadweight) and production losses. Further, cap limits can break the connection between demand and supply, potentially favouring sellers over buyers in water markets as demand increases result in shortages where substitutes are not available; e.g. where riverine supplies of water cannot be easily or realistically substituted for desalinised or recycled water supply (Jackson *et al.*, 2012).

Where cap restrictions are present there are likely to be uncertain substitution effects between water allocation and entitlement products. For instance, cap restrictions may motivate irrigators to increase the volume of water allocation sold in the markets, especially where they are uninterested in utilising that water for production purposes but remain constrained from selling part or all of their holding. Conversely, removing cap restrictions may reduce the volume of water allocation trade, as those previously unable to sell their entitlements are now allowed to trade freely. Loch *et al.* (2012) examined broad influences on water allocation selling and buying behaviour, concluding that cap restrictions on trade drive early season selling of water allocations in the sMDB. However, these effects of cap restrictions on water allocation trade require further investigation.

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[13] The ability to bank water across seasons has been recently introduced in the sMDB, with estimated agricultural productivity gains of around 12% in one case study example (Hughes and Goesch, 2009).

Loch (2012) investigated the importance of cap restrictions on water allocation trade via a survey of sMDB irrigators (n=946) in 2010/11. When asked if a cap had ever precluded them from trading a water entitlement, 18% indicated that it had, with varying responses according to state. In general, cap restrictions on water entitlement trade make water allocation buying less likely (*P*=0.01), suggesting that irrigators prevented from selling have progressed industry exit plans to the point where farming no longer features in their decision-making. Hence, there is no need to buy water allocations. No statistically significant influence on the decision to participate in water allocation selling was found.

However, in relation to the timing of water allocation trade Loch (2012) found that cap restrictions were significantly and positively associated with the likelihood of irrigators' decisions to sell water allocation early in the season (*P*=0.00), but reduced the probability of buying water early (*P*=0.02) or late in a season (*P*=0.01). Therefore, cap effects on water allocation trade tended to influence the timing of both buying and selling decisions, particularly early in a season. This would be consistent with irrigators resigned to industry exit but unable to divest their water asset, resulting in reduced plans to use existing water (or alternative sources of allocation water) for productive uses in 2009/10.

The study concluded that caps on water entitlement trade that avoid large volumes of entitlements being transferred away from an irrigation district run contrary to US National Research Council (1992, pg. 50) recommendations that 'while water transfers may bring negative effects, it must be recognised that a dynamic growing economy depends on processes that allow declining industries and firms to be displaced by growing firms and industries'. Therefore, while applying district restrictions on water entitlement transfers (e.g. the 4% limit rule in Victoria) may restrict transfers at that level of the market, they may effectively promote sales of water in the allocation market. For instance, potentially inefficient farmers that would have exited willingly but for the cap restrictions remain in the district contrary to reform objectives. However, by remaining and selling their allocation water these same irrigators provide important seasonal adjustment supply spill-over benefits.

Thus, caps on water entitlement trade can have negative structural adjustment and positive seasonal adjustment outcomes. If an ancillary objective of cap intervention is to reduce the level of inefficiencies generated by water use in the southern MDB until farmers can successfully exit agriculture, then it appears the allocation market is helping to drive that agenda. The policy may also help rural communities affected by the program to adjust gradually by retaining population and income in the area to support local businesses and services (see Section 5 below). However, in the face of potential future climate change impacts in the sMDB, recent experience in the Millennium drought period would suggest that the gradual reduction and eventual removal of state and irrigation district cap restrictions on water entitlement trade remains a positive policy outcome.

4.3.3. Water market Improvements needed

Finally, a NWC report on developments required to strengthen Australia's water markets identifies seven key priorities for market improvements (NWC, 2011c). These arise from the fact that many existing water market elements were established progressively in response to trade demand, and/or were add-ons to existing administrative structures. Different governance, institutional and administrative processes across states and jurisdictions—including water entitlement specification, trade rules and transfer processing arrangements—also creates inconsistencies in sMDB water markets. Overall, the report found that 'institutional fundamentals for efficient water markets coincide with the requirements for effective water resource management' (NWC, 2011c, pg. ix). Therefore, several recommendations were made to further improve Australian water markets:

- ***Groundwater entitlements and planning processes:*** As the demand for groundwater rises among existing and new users (e.g. Sutton, 2011) it will be important to identify and regulate the sustainable level of aquifer use. Complex and restrictive trading rules that arise from the interaction between surface and groundwater resources (Evans, 2011) may lead to restrictive trade rules and zones that impede efficient use of water resources. Indeed, there are a great many hydrological (Skurray *et al.*, 2012) and institutional (Skurray *et al.*, forthcoming) challenges to groundwater trade, but these could be managed with better price, property right and resource impact information to improve efficient resource use. Existing entitlement and planning arrangements therefore currently impede market development in otherwise conducive aquifers (NWC, 2011c).
- ***Trade approval processes:*** Different terminology for statutory instruments, water products and transfer conditions across jurisdictions adds unnecessary complexity to the water market. Trade approvals can also be delayed by a lack of readily available information on processing, assessment factors and critical requirements for different approval authorities. This situation adds to transaction costs and weakens trader confidence in the market and the transparency of its approvals process. To combat this, the NWC recommends greater disclosure of trade approval frameworks including: relevant rules and policies; steps involved in assessing complex trades; and trade terminology (NWC, 2011c). Water transfers would also be strengthened by an effective complaint handling process (possibly at the federal level) and trade processing standards covering a broader range of performance information.
- ***Conflicts of interest:*** Agencies involved in water reform can often assume multiple roles, such as commercial, regulatory and operational functions. A good example of this until recently was Goulburn-Murray Water that provided market platforms for water trade, declared seasonal carry-over rules and made regular seasonal allocation announcements. Where potential or perceived conflicts of interest arise in such agencies market damage can occur due to a loss of institutional trust (NWC, 2011c). Considerable concern has also been raised about federal agency conflicts of interest from CEWH involvement in water markets. While CEWH involvement in environmental watering takes shape (CEWH, 2011b), the agency has also flagged potential water allocation and entitlement trade ambitions (CEWH, 2011a). This ambition, if implemented properly, could be beneficial for the environment and irrigators alike (Wheeler *et al.*, 2013, Connor *et al.*, 2011b). However, the water market would benefit from greater clarity around future water trade activity and its likely impact.
- ***Market price information improvements:*** Water price information is key to any economic assessment of trade activity (Bjornlund and McKay, 1998). The move from centrally determined prices to market-based pricing has been an important step forward in the reform process (Harris *et al.*, 2009). However, a significant hurdle to water market analysis remains a lack in the quality and quantity of water price information. Fragmented and inconsistent price data availability decreases traders' ability to accurately appraise water values under different conditions and detect market aberrations (NWC, 2011c). Lack of price information stems from misreporting by traders, a lack of mandatory reporting requirements and/or instances where no consideration is involved

(e.g. transfers between related business holdings). It can also take considerable time for water entitlement price information to be made publically available. To address these issues, price disclosure should be mandatory for all water trades across a wider scope of market activity, together with a moderate level of price monitoring and verification (NWC, 2011c). By way of example, general information sharing can significantly improve multiparty adaptation to drought and climate change effects. Spain has information sharing systems and negotiation processes that facilitate water shortage mitigation via integrated river basin modelling, mitigation strategies and stakeholder committees involving key economic and environmental interests (Schwabe and Connor, 2012). Such approaches may provide insight for water market managers interested in improving information collection and sharing.

- ***Allocation announcement processes:*** The determinations of allocation announcements are not transparent, which can prevent some users from accurately assessing the reliability of their water entitlements. In the extreme, this may dissuade financial institutions from lending against or toward water entitlement investments, and higher than necessary transaction costs in the market as parties are forced to search for relevant information (NWC, 2011c, Martin *et al.*, 2008). The system of allocation announcements therefore requires both substantial up-front and periodic review to improve these issues for market and economic efficiency benefits.
- ***Market intermediary confidence:*** Some water market analysts believe that there is significant potential for water brokers and agents to experience misconduct or poor competency issues where mechanisms such as trust accounts, professional indemnity insurance, conflicts of interest disclosure and competency standards are not mandatorily required. While licensing is touted as an option, the costs of adopting such measures may outweigh the benefits (NWC, 2011c). Largely, this issue remains one of *potential* concern; therefore the NWC recommends continuing with current monitoring and code of practice adoption in the short-term.

Aside from these recommendations, several other water market development directions are also gaining attention. These include the introduction of expanded water trade products such as water allocation trade for environmental benefits (Wheeler *et al.*, 2013), counter-cyclical trade between irrigation and environmental water holders (Kirby *et al.*, 2006), and option contracts in rural (Heaney *et al.*, 2004, Byrnes *et al.*, 2010) and urban markets (Leroux and Crase, 2010).

As Cummins and Thompson (2002, pg. 5) argue:

> *"Options make intuitive sense for the water market. Those with most at stake in the event of water shortages, those with high cost/income ratios, could buy call options. These options could give them the right, but not the obligation, to call on the other side to provide them with water at a prearranged price. Those with lower cost/income ratios could buy put options that gave them the right to put, or sell, water at a prearranged price. The buyers of call options would effectively be insuring their crop production and insuring against the price of water rising. The buyers of put options might be prearranging a return from water that is greater than they can achieve by irrigating a crop. Or, they may be insuring against the price of water falling. Call options would presumably be more attractive to those irrigators with contracts to supply produce to food processors or wineries. Such contracts are becoming a common feature of Australia's irrigated agriculture."*

To successfully implement options and derivatives in Australian water markets, a wide range of information would be needed. Information on trading industries, valleys, seasonal and monthly water use, entitlement and security information, current and predicted information on prices, volumes and climate. And, it also requires irrigators to take risks and with the probability of incurring losses in the short-run, with the expectation they will benefit in the long-run (Cummins and Thompson, 2002).

Further, the transaction costs associated with water market trade are attracting attention as their importance toward market failure (McCann and Easter, 2004) and institutional performance (Garrick and Aylward, 2012) is recognised. A past constraint in this area has been data collection and analysis (e.g. Allen Consulting Group, 2006), but this is being gradually overcome with new approaches and metrics (Garrick, 2012). Finally, investigation of strategic behaviour by traders, the unbundling of water storage rights and state requirements for shared storage capacity, carry-over rule inconsistency, and parochialism by state and federal governments from time to time all need attention in future water market development discussions.

So what are the key lessons from an economic examination of sMDB water markets?

1. Where water supply is scarce and in demand from a variety of different users, well-designed water markets with strong property right characteristics can deliver significant economic benefits by signalling the value of water.

2. Water markets can improve the efficient use of water in the context of connected systems that experience seasonal water supply and demand variability, and where users have different elasticities of demand and/or capacity to adjust to water supply shortages.

3. Where there is pressure for adjustment in the existing structure of water users, for example under climate change impacts similar to previously experienced sMDB drought effects, water markets can be an effective means of reducing total economic impacts and production losses.

4. Water users tend to learn and adapt quickly to change where the institutions, arrangements and rules provide opportunities to adjust. As such, incremental approaches to water market design may be appropriate, but result in perverse outcomes if sub-optimal arrangement are left in place too long (NWC, 2011f).

5. Finally, while there are many economic benefits from the trade and reallocation of water resources among competing uses and users (Frontier Economics, 2011), trade activity will also have important impacts on social and environmental issues, requiring a careful balance between the governance, institutional and equity arrangements put in place (NWC, 2011f). These are discussed in the next two sections of this report.

4.4. Key points

The major points from this section include:

- The use of instruments such as secure property right arrangements, clear price and allocation signals, different supply and demand schedules and an emphasis on allocative, dynamic and productive efficiency objectives have all resulted in reasonable reallocation of scarce water resources during the last few decades, particularly in the sMDB. Further, an expansion of trade through direct market intervention by governments from 2004 onwards has bought renewed public focus on the progress, outcomes and future development of water markets as a means of delivering significant economic, social and environmental welfare changes in Australia.
- To that end, water markets have performed relatively well in a role of drought impact mitigation, resource reallocation and economic production facilitation. However, there is scope for water market improvement in the areas of trade rules (particularly among interstate trades following the implementation of the Basin Plan), trade product expansion into derivatives (Shorten, 2012), improvements in the depth and access of market information, and reductions in transaction costs associated with water trade activity. In addition, a better understanding of trade behaviour, especially strategic trade issues that can lead to market failures, is required in future (Loch *et al.*, 2012).
- However, any economic benefits associated with water markets must be balanced against social and environmental impacts from that activity. Therefore, the following two sections of this report consider the social and environmental impacts of water trade and how these might best be addressed.

5. SOCIAL IMPACTS OF WATER MARKETS

In many sMDB rural communities, the fear of water trade and its' potential impacts far outweighs the fear of climate change. Despite some recognition that climate change will likely result in further water supply pressure and a need for dramatic policy shifts to address its impacts (Mercer *et al.*, 2007), it has been suggested that most people have not given the issue of climate change much serious thought, nor believe in the need to do so (Kempton, 1997). This has led to skewed perceptions about its probability, impacts and a need for adaptation in response. On the other hand, the impact of prospective or actual transfers of scarce water resources away from rural communities is both clearly conceivable and assessable for most people, leading to fears about such outcomes.

Government's response to irrigation communities' fury over the Murray Darling Basin Plan (Quiggin, 2011) suggests that the needs of the environment will compete with those of agriculture and rural communities. Climate change is likely to add to issues of adjudicating competing claims for water if water is increasingly scarce and agriculture is profoundly affected. Yet while water markets may play an increasingly important role in assisting farmers, the environment and rural communities to adjust to changes in water supply variability inherent fears about the impacts of water markets have long threatened to override the rational design, implementation and development of water market rules, institutions and transactions. This section therefore examines the: i) likely issues that rural communities will face in future years; ii) specific fears related to water markets and their impact on farmer, community and government decision-making; and iii) state of rural community adaptive capacity and ability to cope with future risks.

5.1. Issues facing rural communities

Rural communities have faced a range of challenges in the past 40 years. Declining terms of trade for farmers have had negative implications for many local communities and this has been compounded by population loss, business closures and the withdrawal or corporatisation of services (Edwards *et al.*, 2008a). For many rural communities this has meant shrinking local economies, fraying of the social fabric and fears about their long-term viability.

Many of these changes predate the introduction of water markets and implicate historical, social, demographic and economic forces. Farmers and farming communities have faced a series of long-term structural change pressures, many of which are exacerbated by drought conditions and, as such, may become important issues under future climate change scenarios. These issues include:

- Declining terms of trade (i.e. the ratio of input to output prices), driving constant pressure to find economies of scale.
- Continuing decline in agriculture's importance and employment despite continued growth in productivity.
- General movement of people and services from smaller centres to larger regional centres. The loss of young people and competition for agriculture from the mining sector are particular current issues.
- Gradual aggregation of family farms into larger units, and fragmentation of smaller farms into lifestyle holdings—or the acquisition of agricultural land for non-agricultural purposes.
- Ageing farming workforce (EBC *et al.*, 2011).

On the basis of these historic issues, Kiem and Austin (2012) identify the following stressors likely to impact on rural communities in the future:

- Climate variability, including increasing water shortages and supply changes (as discussed in Section 2).
- Inconsistent projected impacts of climate change and increased uncertainty about climate change will impact on existing variability.
- Significant rural demographic shifts and financial/economic pressures on the traditional family farm operation.
- Increased psycho-social stresses for all community sectors from change across many dimensions.
- Increased economic uncertainty in terms of global market effects, mutable commodity prices and ongoing global financial crisis issues (e.g. world effects from uncertainty in Greece and/or Europe as a whole).
- Inadequate, failed or misplaced government support.

Expanding on their last point, Kiem and Austin (2012) suggest that recent reviews of government policy in relation to drought have moved from seeing them as exceptional events toward regarding them as normal parts of the climatic cycle.[14] In future therefore, exceptional circumstance assistance once thought of as a fixture in the agricultural landscape may no longer be available. In that context, water markets may have an even more significant role to play in assisting users to adapt to change experienced under climate change, as governments adopt a long-term focus on adaptation rather than polices aimed at short-term crisis management.

These views are supported by Williams *et al.*(2009). They argue that rural communities will only be able to cope with the increasing demands of social and economic adjustment if targeted and appropriate government assistance is provided. However, where there is a contention that MDB water planning processes are not taking climate change impacts and outcomes into account (NWC, 2012b), it may be possible to make similar claims about agricultural, water and rural community policy in the Basin. The following sections outline some of these commonly discussed fears.

5.2. General social fears related to water trade

Fears about the community impacts of water trading have been widespread and vehemently expressed since markets were first introduced (Bjornlund and McKay, 1999, Bjornlund, 2002, Fenton, 2006, Edwards *et al.*, 2008a, Edwards *et al.*, 2008b, Edwards *et al.*, 2009, Productivity Commission, 2010). The stubborn persistence of the unease about the community impacts of trading can be gleaned from the fact that while irrigators overwhelmingly acknowledge the beneficial consequences of trading for their individual businesses, 'they are less positive in their assessment of its consequences for their local community' (NWC, 2012a, pg. 58). Similar results were found by Cheesman and Wheeler (2012) in their survey of water sellers to the RtB.

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[14] Prior to 1989 Australia provided subsidies to the agricultural sector during drought events, which were treated as a natural disaster. This approach was counterproductive, as the policy did not enhance the sustainability of the agricultural and livestock sectors. Following 1990, new policy measures were adopted that removed coverage of drought under Natural Disaster Relief arrangements and implemented various relief schemes that encouraged on-farm sustainability and conservation practices. As such, aid was distributed to farms that demonstrated a long-term productive future in agriculture under the *Farm Household Support Act* (2003).

However, when gauging the real impacts of water markets on rural communities it is harder to disentangle these from the impact of the wider historical and structural forces that have constantly impacted on agricultural communities. For example Watson *et al.* (2007) and the NWC (2010b) suggest that the regional impacts of trade have been minimal. In more recent examinations of social impacts from water trade, the NWC (2012a) again concluded that inter and intra-regional water trading has had little to no impact on rural communities. Overall, these reports found that rural community socioeconomic trends continued in much the same direction, regardless of water trading patterns. Further, changes in welfare patterns were the same in both irrigation and dry-land rural communities. While it was suggested that water trading did have an adverse impact on some businesses that supply irrigation equipment or where there was large localized out-trading of water, the movement of water also provided for balancing positive development projects at other sites. Thus, these investigations tended to suggest that water markets were essential in helping irrigators and the communities that they lived in adapt to issues such as water scarcity, adjustment requirements and climate change.

As noted in Sections 1 and 4 drought, rather than water trading, has been a primary driver of reduced water use (NWC, 2012a). Since major water trade activity tends to occur during periods of prolonged drought, the prospect of disentangling the effects of one driver from the other becomes practically impossible (NWC, 2011f). Drought effects, however, offer something of a template for attempting to understand the likely ongoing impact of water trading and climate change. This is because such events provide insight into rural community effects of dwindling and/or uncertain water supply. Such effects can include:

- Reduced local economic expenditure;
- Reduced farm and community income levels;
- Falling house and land prices—and conversely rising water prices;
- Closure of some rural businesses;
- Reduced investment and general lack of confidence in the future;
- Reduced employment, both on farms and in local communities;
- Reduced provision of community and private services;
- Increased demand on human service providers in response to various stressors (e.g. suicide concerns, counselling requests); and
- Difficulty in finding volunteers for community events.

Typically, 75-80% of farm operating expenditure is spent within 50 km of the farm gate (i.e. locally). Across all farm sectors and regions in the MDB (except for the Gwydir) 55% of all expenditure was sourced from the nearest local town; with a further 20% being sourced from a major regional centre (EBC *et al.*, 2011). The changed irrigation environment will also have important implications for local businesses. Local and regional economies may be further affected indirectly through changes in purchases of inputs or sales of outputs to associated industries and flow-on expenditure on other goods and services. As businesses that supply irrigation begin to diminish in numbers, the cost of using that business or service increases, and consumers are likely to go to businesses in larger centres (EBC *et al.*, 2011). Downstream industries will be affected by the variability of irrigation production and the implications of 'opportunistic' farming with farmers shifting between crops in response to water availability. This will have implications for both capital and labour (see Section 4 above). While the receipts from sales of water entitlements or allocations can have beneficial impacts on local and regional economies where individual irrigators remain in the community and use the proceeds of sales in local businesses, changes to the base farming activity can result in significant structural adjustment requirements in secondary and tertiary support sectors. For example, when agricultural activities in certain regions move up the value chain, with a concentration on horticulture, gourmet foods and farm tourism (Hamblin, 2009) this can have a significant positive and negative impact in rural economies.

Changes in regional economic activity can therefore have social implications. Through its direct and indirect economic impacts (positive and negative), water trading could have (positive and negative) social impacts on regional communities. For example, reduced employment in agriculture may lead to rising unemployment in the region generally and put pressures on existing social services (NWC 2012). The Millennium drought between 1998/99 and 2009/10 provided plenty of incentive and opportunity to trade water, as well as evidence of expenditure and income impacts (Edwards *et al.*, 2008b, Kuehne *et al.*, 2010).

Many of these impacts created flow-on effects for rural council revenue. More specifically, they meant that councils needed to change their rating structures in order to recover their costs. However, that impact was not due to water trading *per se*; it simply reflected a more accurate and unbundled indication of the relative value of water and land (NWC, 2012a). Local councils also faced significant challenges learning to accommodate competing demands. The housing market adjusted, with some people leaving the area in search of jobs and others on transfer incomes entered the market due to lower property prices (Edwards *et al.*, 2008b). This reduced the confidence in the housing market, resulting in falling house prices. Transient employees were more likely to rent than buy and this creates a risk of asset fixity (EBC *et al.*, 2011). Therefore, councils looking to maintain and expand the rate paying base are likely to continue welcoming ‘tree changers’, as in rural communities like Kerang in northern Victoria. However, this brings with it an increased sense of displacement, and community anger related to perceptions of opportunism (Edwards *et al.*, 2007). It is not clear if this phenomenon will affect the availability of irrigated land. Yet there is the potential for farms in affected areas to become smaller as land prices increase.

However, the intervention of governments into water markets to secure large parcels of water for the environment, particularly after 2008, provided renewed emphasis from rural communities on the ‘evils’ of water entitlement trade—or buyback. These concerns are outlined below.

5.2.1. Community concerns about water buyback

As discussed previously, government intervention into water markets began in earnest in 2003/04 with the introduction of The Living Murray (TLM) program (see previous section). As water entitlement purchasing in this program constituted a smaller focus it is possible that the effects of government water market intervention were largely overlooked. However, with the announcement of large-scale water entitlement purchasing via the 2007 NPWS and 2008 WFF *Restoring the Balance* programs community concerns about the impacts of water selling and transfers appeared to take on greater significance.

These concerns for the most part mirror those associated with trading in general and can be summarised into the following broad categories:

- Community vulnerability and effects from water sales.

- Impacts on community spending and reinvestment.
- Population losses as farmers elected to move out of regional areas once water sales had been finalised.
- Impacts on current and future local employment prospects, especially for younger people.
- Changes to the nature of production in regional areas (e.g. shifts to dry-land agricultural practices).
- Legacy issues for remaining farmers such as higher variable farm operating costs (e.g. electricity inputs), stranded asset problems, increased emphasis on the rationalisation of remaining ‘outer’ arm units etc.).

Each of these issues is discussed in turn below.

5.2.1.1. Conceptualising Vulnerability

Pearson *et al.* (2008) suggest there are two ways of conceptualising vulnerability. First, 'outcome vulnerability', is defined by the IPCC as the extent to which a system is susceptible to or unable to cope with climate variability and change. Second, ‘contextual variability’ focuses on the susceptibility of systems to disturbances, including exposure and sensitivity to 'perturbations' and its capacity to adapt. Outcome vulnerability is a more effective tool in linear and bounded systems, such as estimates of biophysical productivity changes. By contrast, contextual viability is more helpful in analysing open systems, particularly social systems, and is more sensitive to contextual and regional variation. Contextual vulnerability is therefore frequently included in qualitative analyses (Pearson *et al.*, 2008). However, combined qualitative and quantitative analyses of vulnerability can facilitate an integrated assessment of multiple hazards that are faced simultaneously.

5.2.1.2. Vulnerable community profiles

Much work has identified rural communities that are at risk of significant impacts from water reform, water transfers and reduced water availability as a consequence of climate change (ABARE-BRS, 2010b, Edwards *et al.*, 2008b, NWC, 2012a, EBC *et al.*, 2011). Rural communities most at risk of drought and water scarcity impacts generally have the following characteristics (EBC *et al.*, 2011):

- ***Size***: A population of greater than 10,000 was considered as the threshold for resilience, while a population under 2,000 is a significant risk factor.
- ***Diversity***: More diversity in industry, economic arrangements, agricultural product and social strata equals greater resilience.
- ***Dependence***. Where 15% of the population is working in irrigated agriculture, or a closely related industry, the risk level is much higher.
- ***Location***: Communities on the eastern edge of the MDB are better positioned than those in western regions, which face higher risks. In part, this is related to proximity to larger population centres.

Confirming earlier work by ABARES-BRS (2010b), size and dependency are the cardinal criteria. But the amount spent on irrigation per capita is also an important factor. The communities most at risk have issues related to their size, their dependence on irrigated agriculture, and the proportion of spend per capita that is related to irrigation.

Given this, it may be that water trading will have only limited capacity to redress long term reduction in water use. However, water trading did allow some rice production in NSW that would not have occurred otherwise.[15] While it is clear that low water allocations were the primary influence, the impact on NSW rice processors and their employees was substantial, with significant job losses and lack of investment in infrastructure. Over time, processing ceased entirely in some locations (NWC, 2012a) and it appears that in some of the smaller communities there was permanent population loss.

In the dairying region of northern Victoria herd sizes also decreased as water availability declined. At the height of the drought vine growers and horticulturalists aggressively entered the allocation market to protect their crops—pressing allocation water prices to levels prohibitive for dairy production. While initially some banks lent money to dairy farmers so that they could buy water and maintain stock numbers, as the drought continued this practice was unsustainable and ceased.

These examples suggests that while trading helps farmers adjust, in some situations it is not in the direction of economies of scale that predict greater productivity and profit margins (NWC, 2012a). While the productivity of the region declined sharply this was largely due to exchange rate and international commodity market influences, as much as water availability. Thus, the outward trading of water may have had a minor impact on declining productivity during the assessment period but it was small in comparison to the influence of the drought (NWC, 2012a).

EBC *et al.* (2011) identify four categories of community on a scale from 1 to 4 that may be influenced by the water reform and climate change according to their size and dependence on irrigation:

- **Category One—Small, dependent communities (e.g. Warren and Collarenebri)**: In general, these are typically regional areas highly dependent on irrigation, and often geographically isolated. Wider social and economic trends are driving reduced populations and contracting economies. The loss or reduction of irrigation water from water entitlement sales will likely exacerbate this trend. In the decade to 2001, there was some growth, especially in the cotton growing valleys. However, the early drought years (2001-2006) saw a general population decline in these smaller towns and rural areas. The loss was particularly notable for young people (aged 20-44), as well as significant reductions in people aged under 20 years. The loss of these population segments tends to also reduce the number of taxable incomes in the region as well as the number of businesses that rely on discretionary income (e.g. cafes and retail outlets). This appears to be part of a longer, wider trend (EBC *et al.*, 2011). Category One communities are likely to face ongoing challenges, such as difficulty attracting health and related services even with full post-drought restoration. Overall, these trends will be exacerbated by water entitlement buyback.

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[15] Admittedly because a significant proportion of the money used by farmers to purchase water in some of the early drought periods was heavily subsidised by the rice processing companies (NWC, 2011f). Without such support it would not have made economic sense to grow rice crops compared to the relative value of selling that water on the water allocation market, despite reasonable commodity returns being in effect.

- **Category Two—Small, diverse communities (e.g. Stanthorpe)**: These towns combine high value irrigation with tourism and other sectors. They are more insulated than Category One towns. Areas with such tourism assets can generate an increase in discretionary spending (e.g. tourism from high value wineries) and the population of most catchments in this category may thus remain static. However, to maintain stability in these areas high security water for viticulture will be necessary, as well as guaranteed water flow in rivers to attract tourists. Forms of mining also represent opportunities for these communities (Edwards *et al.*, 2008b, EBC *et al.*, 2011). As such, it is generally likely that the local service impacts will be limited for Category Two towns.
- **Category Three—Larger, dependent communities (e.g. Griffith, Moree, Robinvale and Loxton)**: These rural communities can be robust with current water levels, but would be vulnerable to reductions. Almost all such communities saw a decline of young people from 2004-2009; much of this due to the drought. During the drought period there was a population loss-related decrease in discretionary spending, despite an increasing percentage of indigenous residents in some areas. These areas also experienced an influx of lower socio-economic status people seeking cheaper housing; they were not well regarded and were seen as culturally incongruent. Overall, the loss of young people in particular had a serious impact on community groups and services. Category Three towns therefore face major challenges for service provision for the future.
- **Category Four—Larger, diverse regional centres (e.g. Toowoomba or Dubbo)**: These areas are relatively insulated from reduction in water availability issues. They experienced solid and sustained population growth over the period between 2001 and 2006. Further, there is evidence that they have soaked up the population of younger people who have left smaller areas. Many of them are quite independent of the economic impacts of irrigation, but many of them have smaller towns within their service catchments that remain dependent on farming. Category Four towns have typically witnessed a growth in many of their services. In support of these general conclusions, the NWC (2012b) found that—despite concerns about the impact of declining milk and agricultural production—Victorian communities of this category are quite resilient and have high adaptive capacity. This is due to their economic diversity and the presence of larger regional centres.

Thus, as we might expect, less dependence on irrigated agriculture makes towns more adaptable and less vulnerable to the impacts of water entitlement buyback. However, the vulnerability of regional and local communities may be driven by more complex issues than simple water market intervention. For example, in specific agricultural sectors it can be difficult to disentangle the effects of market intervention from a range of current issues facing the wine grape or almond industries; such as exchange rate issues, a decline in commodity prices and/or the collapse of managed investment schemes (NWC, 2012b). Further, individual irrigator attitudes toward the benefits of water trade appear widely divergent from more general community attitudes, particularly among Victorian dairy irrigators, NSW rice growers and SA horticulturists—wherein the farming business benefits of water trade are strongly endorsed, in variation with community concerns about the impacts of such transfers. This may stem from wider community fears beyond individual farm issues to problems of population loss, employment reductions and economic stagnation/reduction as outlined below.

ABARE-BRS (2010b) categorised vulnerability of irrigation communities with the following important identified variables: irrigation intensity; irrigation incidence; % of work in agriculture; ratio of agriculture to total employment; proportion of households with agricultural employment; ratio of employment of agriculture to downstream agri-industries employment.

5.2.1.3. Population loss

A great many rural community fears predominantly centre on population loss. The logic of this concern is that as farmers sell water, they will leave a district. This in turn means that local spending is reduced and that many services—such as schools—reduce in size or become difficult to sustain because of fewer service users. The economic and service related effects are then argued to constitute a downward spiral; that is, fewer people leads to less spending, causing community businesses to close, leading to more population loss and therefore a greater decrease in local spending. In general, these impacts thus contribute to decreased employment opportunities for local residents (EBC *et al.*, 2011).

Further, in the opinion of many rural residents, population reduction resulting from the separation of land and water leads to fewer families, which in turn reduce the rates-base available to local councils causing a further reduction in locally available services (Edwards *et al.*, 2008b, Edwards *et al.*, 2007). Declining population is also feared because it leads to declining house prices; and there is evidence that this has occurred in some rural settings (EBC *et al.*, 2011).

In addition, the population loss of long-standing farming families is viewed as changing local cultures and diminishing local community capacity by denying it a source of skilled, talented and volunteer labour (Edwards *et al.*, 2008a, Edwards *et al.*, 2007). Of particular concern is the effect on out-migration of young people who, when they go, take talent, skills, future leadership and the potential for family formation with them (Edwards *et al.*, 2007). Finally, when membership numbers decline because of falling population many local community, sporting, recreational clubs and volunteer services struggle to maintain themselves. These manifold concerns about the impacts of water trading on rural communities are also associated with concerns about worsening psycho-social impacts for remaining residents, particularly farmers, as discussed below. By way of evidence, the ABS noted a population decline in dry-land farming areas during the 1990s among wheat-sheep belts and/or mining regions. However, this decline was not apparent in irrigation areas prior to the Millennium drought with the exception of Wee Waa and Narrabri (EBC *et al.*, 2011).

5.2.1.4. Fears of conversion to dry-land production

Another concern expressed about both water markets and the impacts of climate change is that it will see previously irrigated areas converted to dry-land farming.[16] There are concerns that this will have adverse economic consequences. Irrigation farming generates a far higher level of demand for services than does the equivalent area of dry-land enterprises. A figure of $250/ha is accepted as a realistic figure for the annual operating expenditure per hectare for most dry-land crops. If we assume

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[16] Dry-land farming is essentially cropping undertaken with a reliance on opportunistic rainfall rather than certain water supply from irrigation supplies. While less costly in terms of infrastructure and water delivery expenditure, it is significantly more risky under existing (and expected) water supply variability and distribution changes under possible climate change scenarios.

that 75% of expenditure is spent locally, that will yield a local income of $185/ha. Most irrigated crops involve expenditure almost ten times this sum (EBC *et al.*, 2011).

Community representatives are thus concerned about a shift from irrigated to dry-land farming because it is nowhere near as lucrative, and provides fewer jobs directly and indirectly through processing opportunities. This then has flow on effects for depopulation and de-servicing, albeit with spatially diverse outcomes that in some cases are merely an acceleration of underlying trends apparent prior to this productive shift (Edwards *et al.*, 2008a, Fenton, 2007). However, Miller (2011) and Grafton (2011) suggest that more funds could be diverted from infrastructure upgrades to direct community assistance, with better effect. Ultimately, a greater concern may be the current trend toward larger and more professionally operated farming businesses. In short, sMDB farms are reducing in number, getting bigger in terms of size, outputs and operating debt/costs, and they are holding larger water assets and taking more corporate attitudes toward farming. In such instances, water markets play a significant strategic role and add to the list of business tools available for income/risk management in a sector that has always faced uncertainty as a rule (Crase, 2012b). However, these strategies also impact on succession (or the need thereof), which in turn impacts on strategic decision-making over entitlement selling, farm structure and the need for permanent/temporary water trade product access (Wheeler *et al.*, 2012a). Changing operations and lower total farm numbers also reduce the opportunity for agricultural sector employment or local people.

5.2.1.5. Fears of labour/skill shortages

The MDB employs about 10% of the total Australian workforce (around 920,000 people), with around 96,000 of those persons employed in agriculture-related work (ABS and ABARE-BRS, 2009). However, it is unclear how many people specifically contribute to MDB irrigated agriculture (NSW Office of Water, 2012). Further, under a shift toward low/general security entitlements (perhaps as a consequence of water entitlement selling)—or smaller allocations as a consequence of climate change—irrigation farms may experience reduced net farm production viability and/or some pressure to trade annually in or out of water markets. This may result in both a reduced requirement for unskilled farm labour coupled with an increased requirement for skilled managerial labour that can produce a range of commodities, coordinate operational activities as farms get larger and scan water markets for optimal trade activity.

5.2.1.6. Fears about stranded assets

Finally, a concern among community groups that is often discussed in relation to water entitlement buyback and community water loss is the issue of stranded assets and/or redundant infrastructure. A stranded asset is any component of the water delivery system (e.g. meter, off-take wheel, channel diversion box etc.) that is worth less on the market than it is on the balance sheet because it has become obsolete before being fully depreciated by an irrigation infrastructure operator (IIO). In irrigation areas, when there is a permanent decrease in the demand for water delivery services the assets of IIO can become unused or underused, and are then said to be stranded.

This impact of Commonwealth water purchasing on stranded asset increases was considered in reviews of the initial RtB water purchasing tender round (Breckwoldt, 2008), as untargeted purchases may produce stranded-asset or ‘Swiss-cheese’ effects from ad-hoc infrastructure removal and the spreading of operational costs across a reduced irrigator membership (Walsh, 2012). However, Cheesman and Wheeler (2012) surveyed up to one fifth of all sellers to the RtB and found that of the farmers who owned water in irrigation areas, 60% of them kept their delivery rights, while 94% of those who stayed farming after selling water kept their delivery rights. These results indicate uncertainty about the reality that stranded assets are being created. There is also an argument that there is a need for a severe rationalisation of irrigation areas anyway, and that large amounts of area need to be removed from the system.

Further diminishing the impacts of water purchasing and/or district water entitlement transfers outside the buyback program (which it should be noted still constitute the larger proportion of total entitlement sales (NWC, 2012a)), many IIO areas now impose termination or exit fees to cover the ongoing costs associated with stranded assets, where likely (Frontier Economics, 2008). These are a charge (often per megalitre) imposed on the permanent trade and subsequent loss of a water access entitlement out of an irrigation district or area. These fees are set by an independent body (ACCC, 2011) so that it will replace the selling irrigator's annual contribution to the maintenance of the delivery infrastructure. Despite persistent concern about this issue and its recurrent mention within the wider water reform debate there is little empirical evidence of significant negative community impacts from stranded asset issues.

ACCC (2012) report the most comprehensive analysis on terminations of water delivery rights in the MDB. In New South Wales and South Australia many irrigators' rights to water have to be transformed before they can sell, because their rights are specified as a share of their IIO's water access entitlements. There was an issue that IIOs had an incentive to impose high fees on irrigators who terminate their access to an irrigation network. The water market rules made it compulsory for operators to allow irrigators to transform rights by capping the fees that can be charged at 10 times the current annual fixed charges for network access (ACCC 2012). Table 12 below illustrates the terminations of water delivery rights by organisation. It shows that terminations were highest in 2009-10, with a greater terminations experienced in SA than other states.

Table 12 Terminations of water delivery rights, 2009−10 and 2010−11

Irrigation infrastructure operator	2009−10 Number	2009−10 Volume (GL)	2010−11 Number	2010−11 Volume (GL)	Percentage terminated since 1 July 2009
NSW					
Coleambally Irrigation	0	0.0	18	12.3	2.51%
Murray Irrigation (MIL)	124	65.4	13	2.9	5.87%
Murrumbidgee Irrigation (MI)	28	18.6	19	11.2	2.81%
Western Murray Irrigation (WMI)	37	1.9	17	3.1	8.30%
Other NSW	1	0.6	28	9.5	
Total NSW	**190**	**86.5**	**95**	**38.9**	
SA					
Central Irrigation Trust (CIT)	192	15.2	21	0.9	10.20%
Renmark Irrigation Trust (Renmark)	39	2.6	2	0.1	6.06%
Other SA	N/A	N/A	4	0.1	
Total SA	**231**	**17.8**	**27**	**1.1**	
Victoria					
Goulburn-Murray Water (GMW)	43	9.6	69	18.3	0.62%
Lower Murray Water (LMW)	90	15.3	11	0.9	3.28%
Total Vic	**133**	**25.0**	**80**	**19.2**	
TOTAL	**554**	**129.3**	**202**	**59.2**	

Source: ACCC (2012)

The discussion above highlights a range of rural community issues that, regardless of their actual or alleged impact, drive much of the policy debate and direction associated with community attitudes and behaviour towards water reform, water trade and—to a seemingly lesser degree—climate change. The remainder of this section is devoted toward an assessment of rural community capacity to adapt to this range of social issues, as well as the strategies most likely to assist them in that process. We conclude by examining those communities best positioned to adapt to the effects of further water reform and climate change in future.

5.3. Community adaptive capacity

As discussed in Section 3 above, the need to adapt to change can arise from different sources, including economic drivers. In the context of sMDB water reform, historic economic water reallocation drivers have included: conflicts over river uses for irrigation farming versus navigation for freight transport (Musgrave, 2008); the imposition of caps on further water extraction from MDB river systems (MDBC, 1998); calls for water to shift over time toward higher value and/or economically efficient uses (Mainuddin *et al.*, 2007); and requirements to assist irrigators cope with severe drought impacts in the sMDB between 1997/98 and 2009/10 (Kuehne *et al.*, 2010, Loch *et al.*, 2012).

More recently, the emphasis for economic change has shifted again (Kiem and Austin, 2012) toward reallocating scarce water resources—both now and under future climate change impacts—between consumptive users for adjustment purposes and from consumptive to environmental users in order to meet broader ecosystem sustainability objectives (MDBA, 2011a, DSEWPC, 2012).

It is expected that communities with low adaptive capacities (for example, Category One or two communities as discussed previously) will be least able to cope with external stresses. Adaptive capacity is also known as social resilience. Resilience can be classified as stability, which offers a buffer capacity against change; as an ability to bounce back, and as having the ability to make a transformation. Communities' adaptive capacity may be needed as a result of changes in the amount of irrigated agriculture due to water being traded in or out of the area. Figure 17 shows the variation in adaptive capacity across the sMDB.

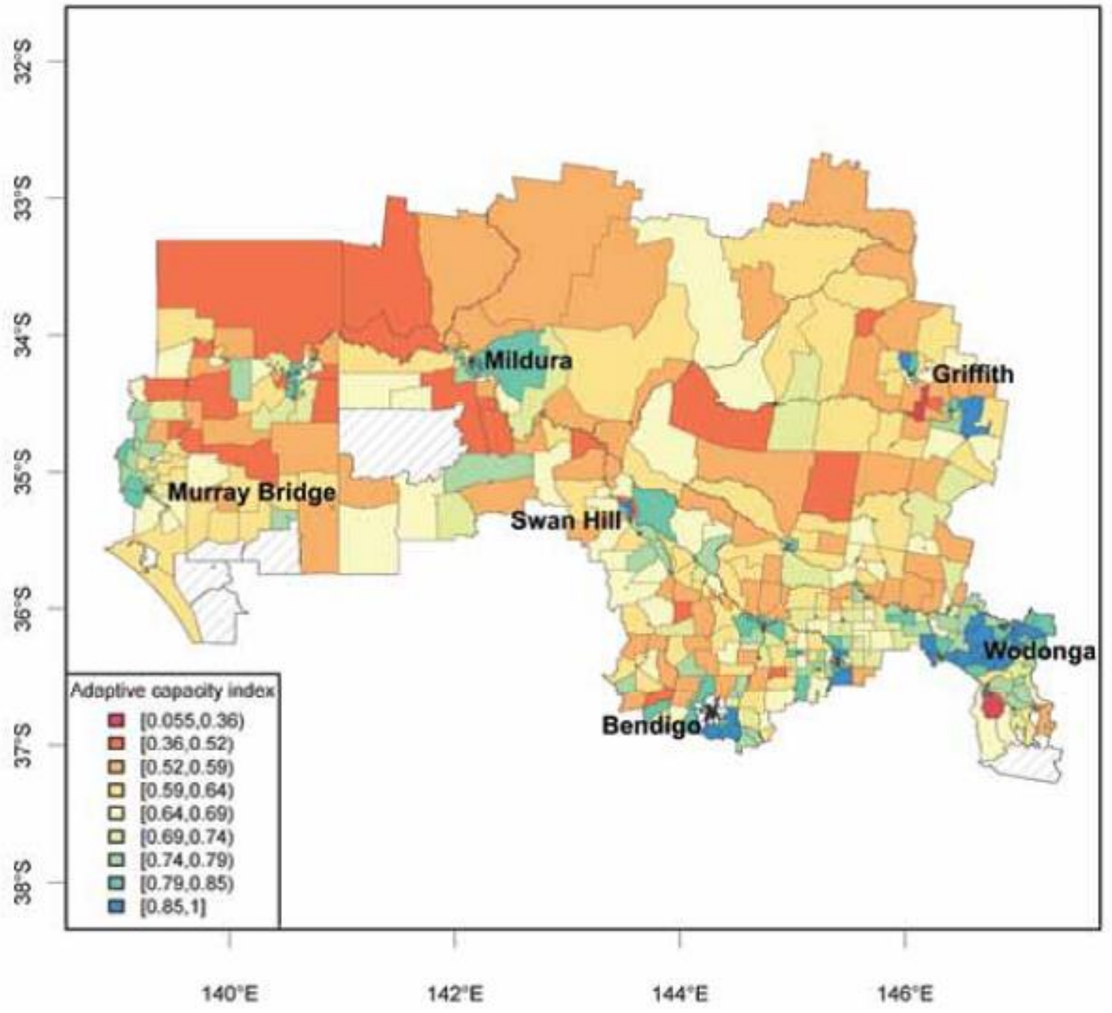

Figure 17 sMDB adaptive capacity index map, 2006/07

Source: (NWC, 2012a)

The basis for this index was 'collector districts' (CDs) each comprised of a population of 200 people or less within the sMDB (NWC, 2012a). From this index it is clearly evident that CDs with low adaptive capacities are spread throughout the rural areas of the basin and do not appear to be associated with a particular region or industry. However, higher levels of adaptive capacity are generally found closer to major towns and in the upper reaches of the catchment along major transportation routes and closer to the capital cities of Melbourne, Adelaide and Sydney.

Importantly, of the CDs with low adaptive capacities, many may not be highly vulnerable to changes facilitated by water trading because they have very little employment in irrigated agriculture or related industries. Rather, CDs with an adaptive capacity index in the lowest range and with more than 50% of the population employed in agriculture or manufacturing are most likely to experience a broader impact from any increases or decreases in the availability of water for irrigation. This analysis shows that in 2006 there were only 10 districts that stood out as having particularly low values of the adaptive capacity index. Looking at those CDs in greater detail, it is evident that there is considerable demographic diversity in the factors that contributed to their low adaptive capacity index scores. They include relatively high unemployment, the relatively low level of educational qualifications in the population and a high proportion of either low-income families, population in rented dwellings, labourers or people with English as a second language. Eight of the 10 CDs had some irrigation, ranging from just a few farms to most farms in the district (NWC, 2012b). Therefore, the NWC report broadly concludes that:

- Local and regional socioeconomic impacts depend on the adaptive capacity of rural communities. Some individuals and communities are better equipped than others to deal with, or take advantage of, changes due to water trading and climate change. Their adaptive capacity is influenced by their human, social and institutional capacity and economic diversity.
- Economic and social outcomes may influence internal motivations to trade water. For example, if community services are in decline due to factors unrelated to water trading, that may affect the desirability of continuing to farm in a particular region, which may influence water trading decisions.
- Other factors also drive agricultural production and local/regional socioeconomic outcomes directly.

The NWC thus suggested a need to encourage planned adaptation to future water variability, focussing on how adaptation to water scarcity can increase profitability and strengthen the viability of the farm. Invoking climate change predictions and consequences may be counter-productive. Policy-makers will also need to consider how to develop effective strategies to communicate water use and adaptation strategies, along with developing policies to address farm succession issues, water market inefficiency issues, and continual structural adjustment packages to help the transition out of farming for many farmers.

ABARE-BRS (2010b) categorised communities’ adaptive capacity according to the following important variables: % graduates; % in public sector; % over 15 with no qualifications; median weekly rent as a fraction of Australian median; median household income as a fraction of Australian median; income/mortgage differential; % one parent; % couple families; % single parent with family less than age 15; total unemployment; % 65 over; average number of persons per household; % lone person dwellings; % dwellings rented; % different address to 1 year ago; women in non-routine occupations; % voluntary work; economic diversity index.

5.4. Key points

The major points from this section include:

- Many rural communities have faced ongoing structural change (declining terms of trade, loss of people to urban areas – in particular young people, agglomeration of farms over time, and an aging farmer workforce) over the past fifty years; hence much change predates the introduction of water markets.

- Concerns about water trade include: community vulnerability and effects from water sales; impacts on community spending and reinvestment; population losses as farmers elected to move out of regional areas once water sales had been finalised; Impacts on current and future local employment prospects, especially for younger people; changes to the nature of production in regional areas (e.g. shifts to dry-land agricultural practices); legacy issues for remaining farmers such as higher variable farm operating costs, stranded asset problems, increased emphasis on the rationalisation of remaining ‘outer’ arm units etc..
- MDB communities that are small and/or dependent on irrigation are most at risk to water entitlement sales. Less dependence on irrigated agriculture makes towns more adaptable and reduces their vulnerability. It is expected that communities with low adaptive capacities will be least able to cope with external stresses such as climate change and water scarcity over time. Up to 10 districts in the MDB have been identified as having a particularly low adaptive capacity index.

6. ENVIRONMENTAL IMPACTS OF WATER MARKETS

This final section examines perceived and actual water market impacts on environmental issues and outcomes in the sMDB. The introduction of access to water trade generated significant concerns among different water users about impacts such as increased salinity, reduced end-of-system outflows, water quality problems and system accounting problems. It has been suggested that that trade may have detrimental impacts on the environment because it could result in: i) concentrating water use in areas suffering from high water tables; ii) moving water into locations where its' use could have a negative impact on river water quality; iii) moving water use upstream, thereby resulting in reduced river flow from the new point of extraction to the old point of extraction; or vi) activating previously unused water leaving less water in the river to support ecosystems. Concerns have also been expressed about the impact on the exporting land, which if abandoned and not farmed would have weed/pest consequences (Bjornlund *et al.*, 2013). The remainder of this section addresses these issues.

6.1. An overview of water, over-allocation and trade in the Basin

As discussed in Sections 1 and 4, the sMDB is comprised of several major connected river systems (e.g. the Murray, Goulburn-Broken, Murrumbidgee and Lower Darling Rivers) with variable hydrological inflow characteristics. The sMDB is also comprised of different production regions with different water demand elasticity characteristics due to cropping patterns (e.g. elastic NSW water demand versus inelastic SA water demand). Finally, the sMDB has a variety of water storage types, water use products and water-sharing arrangements. The availability of water resources, suitable soils, close proximity to markets and historical development investment programs (e.g. water infrastructure provision and soldier-settlement schemes) has also seen the sMDB experience significant and rapid water entitlement growth. Over time this has created a situation of over-allocation of available water resources in the region (0).

If we consider the sMDB specifically it is easy to conclude that water resources in the region are over-allocated. From Figure 18 we can see that total potential sMDB surface water extraction volumes equal 9,616 GL, or approximately 77% of the total LTAAY pre-development outflows. Given other estimates of LTAAY available surface water resources in the sMDB of closer to 11,000 GL (Young and McColl, 2009) this increases consumptive use closer to 87% of the total LTAAY.

The pre-development sMDB environmental flow and system loss proportional requirement is estimated at around 37%. Therefore, at the 11,000 GL system outflow volume, an average 20% reduction in current sMDB consumptive extraction levels would be required to meet non-consumptive water needs—based on pre-development conditions. However, since the sMDB represents post-development conditions with increased system losses, water quality changes and flow timing alteration the water volume requirement for environmental needs are more likely to be higher (Arthington *et al.*, 2006).

Table 13 sMDB surface water outflows (LTAAY GLs)[†] & water entitlement shares

Catchment	*Inflows (GL/y)*	*Envir. and losses (GL/y)*	*Outflows (GL/y)*	*HS[*] Ent's (GL/y)[§]*	*LS/GS[*] Ent's (GL/y)[§]*
Lower Darling/Lachlan				172	699
Ovens	1,804	76	1,728	—	—
Goulburn-Broken	3,559	300	3,521	1,096	672
Loddon- Campaspe	680	254	426	84	38
Murrumbidgee	4,791	1,943	2,848	377	1,888
Kiewa	689	7	682	—	—
Total Murray contribution (excl. Darling)	**11,523**	**2,580**	**8,943**		
Murray River (NSW/VIC)[‡]	4,436	1,628	11,751	1,330	2,404
Murray River (SA)[‡]	0	1,720	12,430	856	—
Mt Lofty Ranges	120	47	73	—	—
Total sMDB	**16,079**	**5,975**	**12,503**	**3,915**	**5,701**

† based on 1895 to 2009 without development LTAAY for surface water.
‡ Relative to Wentworth in NSW.
* HS = high security water entitlements; GS/LS = general or low security water entitlements
§ Adapted from Figure 18 below.

Source: (adapted from MDBA, 2010a)

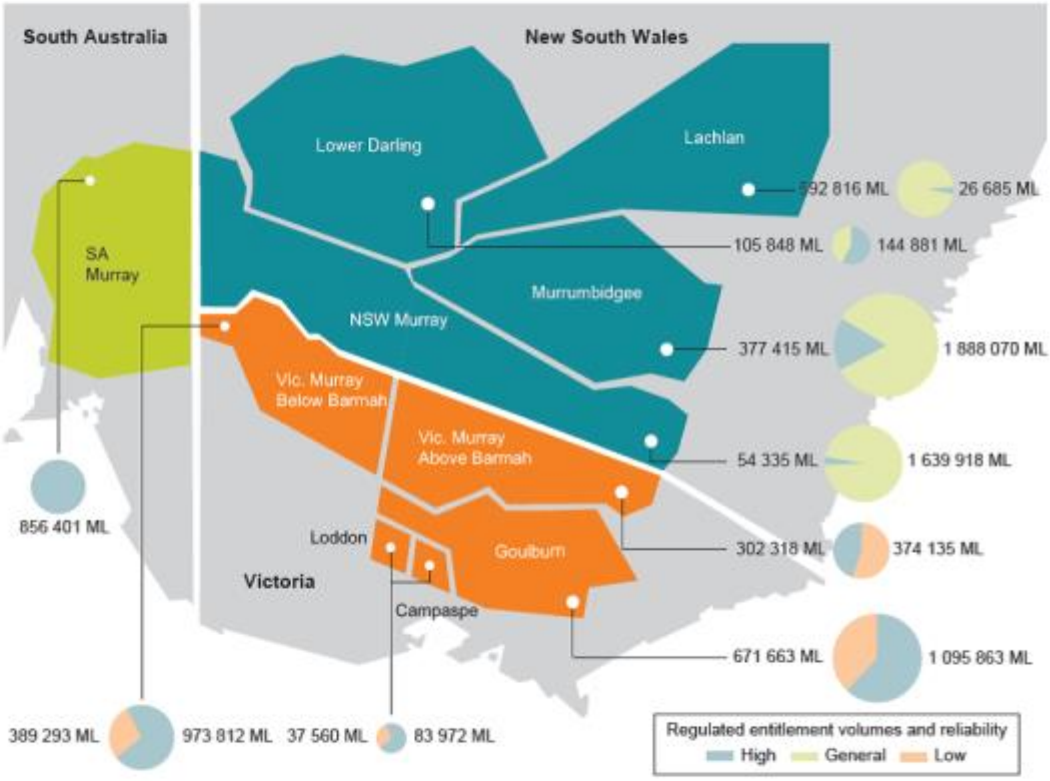

Figure 18 Location, volume & type of sMDB regulated water entitlements (ML)

Source: (NWC, 2011b)

However, farm type diversity and variable water demand context in the sMDB has also resulted in significant (and increasing) water trade so that significant volumes of water are reallocated annually (Figure 19 and Table 14).

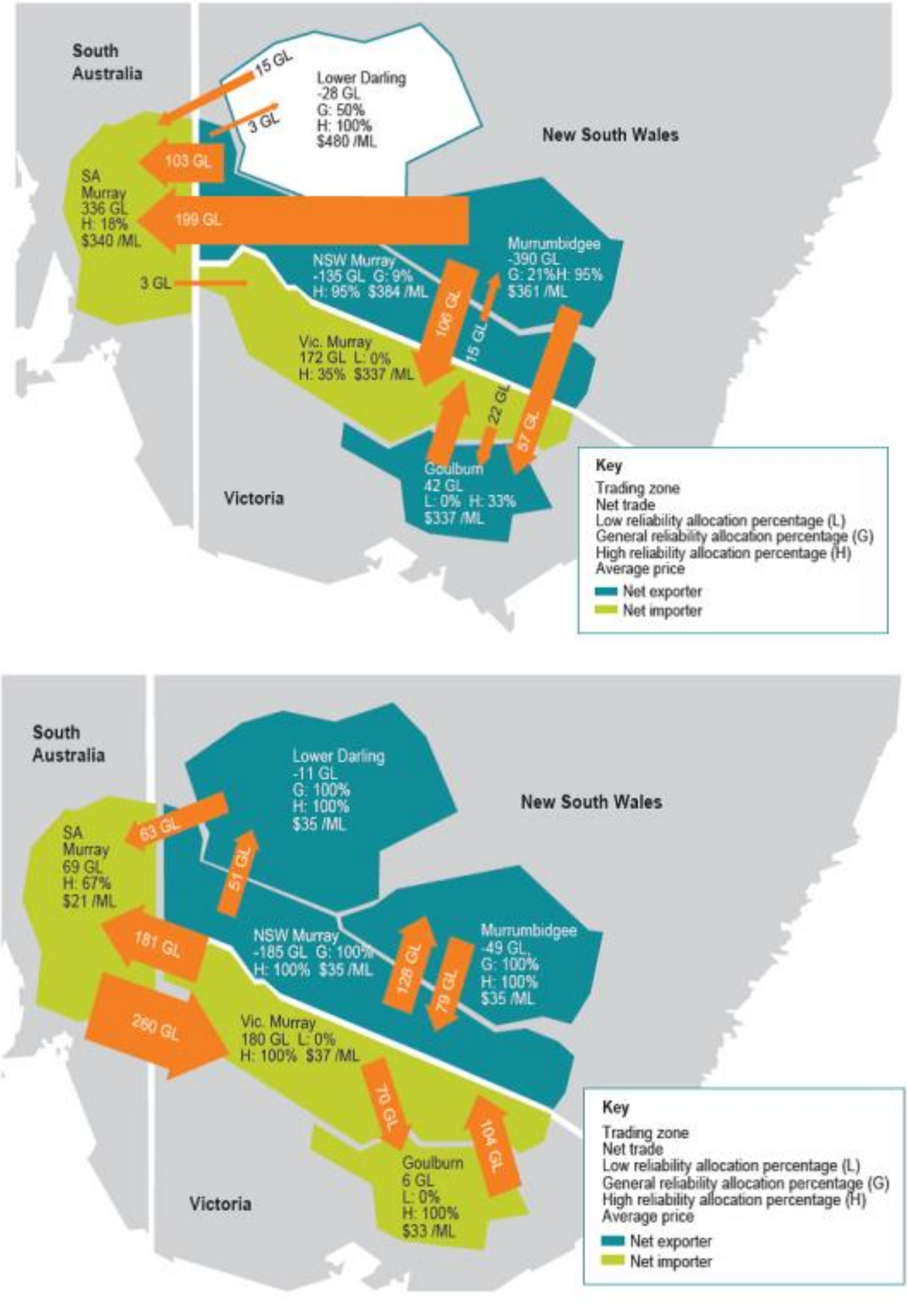

Figure 19 Movement of water allocation 2008/09 & 2010/11 by volume (GL)

<u>Source</u>: (NWC, 2011b)

Table 14 sMDB water entitlement and allocation trading by volume (ML/y), 2001/02-2010/11

	Volume of allocation trades	Volume of entitlement trades		
		Regulated entitlements[a]	Internal irrigation trades	Unregulated trades
2001-02	912 858	77 209	-	-
2002-03	1 102 680	62 193	-	-
2003-04	982 612	96 107	-	-
2004-05	831 268	75 656	-	-
2005-06	871 943	40 359	-	-
2006-07	716 214	139 169	-	-
2007-08	951 598	549 841	119 783	26 783
2008-09	1 304 119	1 128 640	163 285	63 260
2009-10	1 652 013	792 400	281 015	37 324
2010-11	2 701 206	320 524	164 107	67 776

Note: water entitlement data prior to 2007/08 does not include internal irrigation and unregulated water entitlement trades. It includes only trades of regulated water from the Lower darling, NSW Murray, Murrumbidgee, SA Murray, Victorian Murray, and the Goulburn and Campaspe-Loddon systems. Also excludes internal irrigation district trades.

[a] Regulated entitlements are from waterways where users are supplied by releases from storages. A water access entitlement for a regulated stream specifies a base water entitlement defining the holder’s share of the resources from the stream.

Source: (NWC, 2011b)

Generally, during the drier conditions experienced in 2008/09 large volumes of water were traded toward SA and Victoria from NSW. In the relatively wetter conditions in 2010/11 and as a consequence of carry-over rule issues (see section 4.2.2) trade activity appeared to be confined within state borders, except for large transfers between SA and Victoria to accommodate strategic water trading toward the end of the water year (SA Department of Water, 2011a). Table 14 makes it immediately clear that the volume of water traded in the market for water allocations has grown considerably between 2007/08 and 2010/11.

6.2. Hydrological and environmental impacts from water trade

Water trade can result in changes to the location and timing of water use, which can affect river hydrology and environmental outcomes (NWC, 2012a).[17] The recent rapid increase in water trade activity has caused some to question the impacts of large

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[17] Refer to section 1.4.5 for the discussion on perverse activation and trade in sleeper and dozer water access rights following the introduction of the cap on further right approvals in the sMDB.

resource reallocation on sMDB environmental conditions and outcomes. Here we examine these concerns and their validity.

6.2.1. *Historical impacts and policy*

When the cap was introduced, each of the state governments chose to recognise existing unused ‘sleeper’ and ‘dozer’ licenses (Quiggin, 2006a, Crase and O'Keefe, 2009). As the opportunity to purchase (and abolish) existing sleeper and dozer licenses was lost (Bell and Quiggin, 2008), and these licenses were subsequently activated through market trade, seasonal allocations for NSW and Victoria were reduced (DNRNSW, 2006). As a further result, there were increases in groundwater extractions which also impacted upon the security of water access elsewhere due to the interaction between ground and surface water (DEWHA, 2008).

To accommodate economic and environmental concerns about trade, each state government has introduced a variety of trade restrictions and approval processes to minimise harm. Some of these historical policies include:

- In SA buyers needed an irrigation drainage and management plan to show the intended use of the water would not have a negative impact on river water quality;
- In Victoria limits were placed on how much water could be traded onto a particular parcel of land (with volumes dependent upon irrigation and drainage infrastructure and soil type – with later changes emphasising best practice irrigation management on suitable soils);
- Placing spatial restrictions on water transfers;
- Transferring of risk management from water management agencies to irrigators through a change in how seasonal allocations were calculated;
- Water levies on transfers into high impact zones; and
- Exchange rates were introduced in instances where water is traded between different locations on the river, in order to offset the impact on stream flow and transmission losses.

These trading restrictions significantly increased transaction costs, and helped lead to unbundling of land from the ownership of the water entitlement (described in Section 4). The transferring of risk management meant that the introduction of water trade initially transferred even greater risk to the environment. The increasing activation of "sleeping" and "dozing" licences meant water for the environment was more likely to be reduced. More historical research on the size of this activation would be useful.

6.2.2. *In-stream flow regime changes from trade in the late 1990s to 2000s*

In summary, the hydrologic and environmental impacts of water trade between 1998/99 to 2010/11 were small and largely positive; due to the downstream movement of water during the drought that reduced summer flow stress and created no change to winter flow patterns. Negative impacts tended to occur where water trade resulted in a detrimental change to the volume, location and/or timing of water use (NWC, 2012a).

To assess the impact of water trade on in-stream river flows Sinclair, Knight Mertz developed an eco-hydrology ranking index capable of determining the flow stress experienced in various sMDB river systems (SKM, 2012). The index combined measures of low-flow conditions required to maintain in-stream habitat, high-flow conditions that create periodic disturbance and connectivity, and variability factors (e.g. timing and location) that drive ecosystem composition, structure and responses to flow conditions. A score of 1 indicates that the system experienced near-natural conditions, while a score of 0 indicates conditions significantly different from natural (NWC, 2012a). Overall, the measures suggest that water trade has led to improved flow stress ranking scores for the river systems assessed, particularly with regard to natural flow variability and better flow patterns in summer months (Figure 20). The findings also concluded that water trade would have beneficial ecological flow impacts under dry conditions compared with wet (NWC, 2012a).

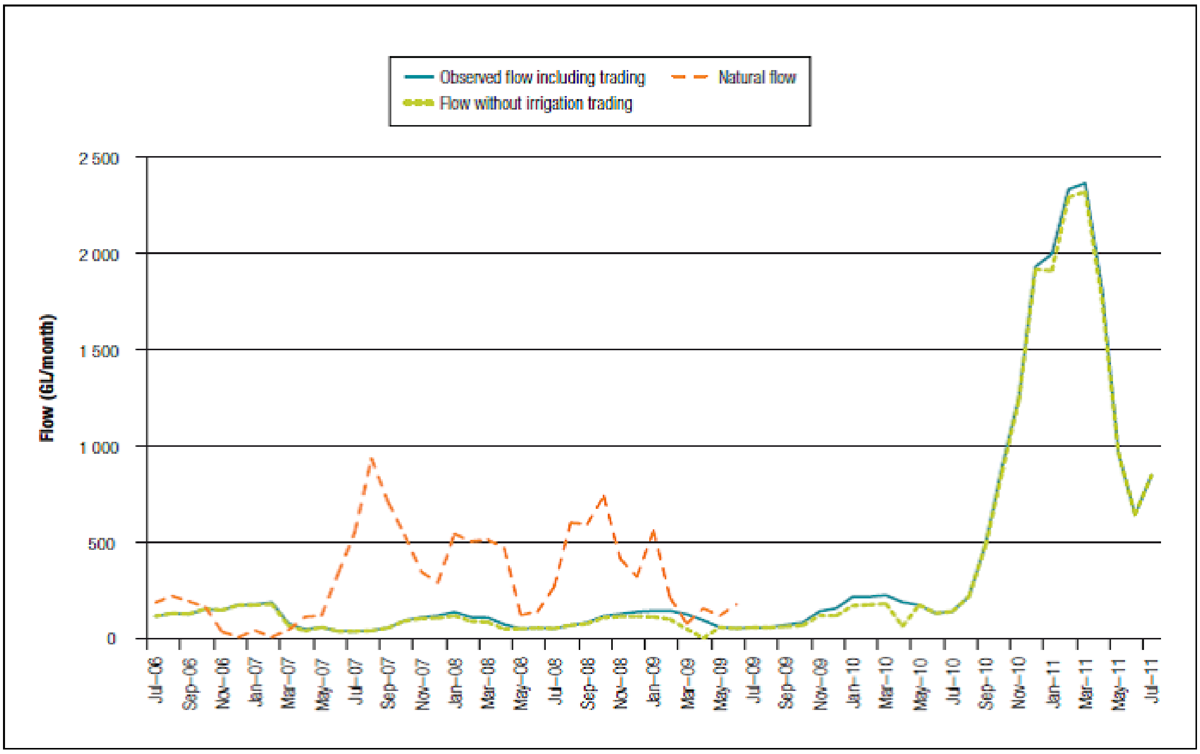

Figure 20 Natural, observed and without water trade flows for Murray River at SA border

Source: (NWC, 2012a)

In support of these findings, Connor *et al.* (forthcoming) applied a dynamic optimisation model to examine the beneficial effects of water allocation trade by a Commonwealth environmental water holder. The model used improved ecological conditions in the Lowbidgee floodplain area as the desired outcome from flow changes as a case study. The model objective was to avoid upward and exponential trends in an environmental damage index (e-damage); that is, the flatter the line, the better.

The study concluded that, assuming a 30% base reallocation of water entitlements to the Commonwealth for environmental use, water trade could be used to reduce environmental damage (i.e. reduce the duration between environmental flows of a level required to achieve either ecosystem maintenance and/or periodic freshes to rejuvenate habitat and species populations). Achieving such outcomes is indicated in the study results by realising flat (or flatter) lines in the variability of flows across time under different reallocation base scenarios and trade strategies. Figure 21 and Figure 22 show the differences between trade and no-trade model scenarios in dry and wet conditions, assuming a base water reallocation point of 30%. Like SKM, Connor *et al.*

(forthcoming) concluded that greater environmental benefits could be derived under dry conditions, compared with wet.

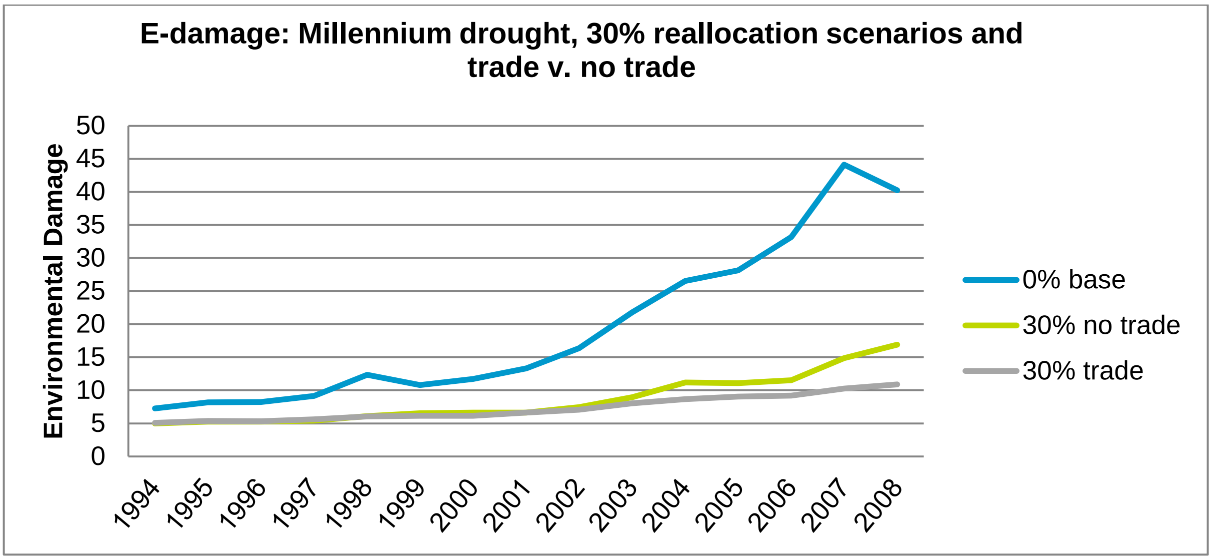

Figure 21 Low to moderate environmental flow impacts in dry conditions

Source: Connor *et al.* (forthcoming)

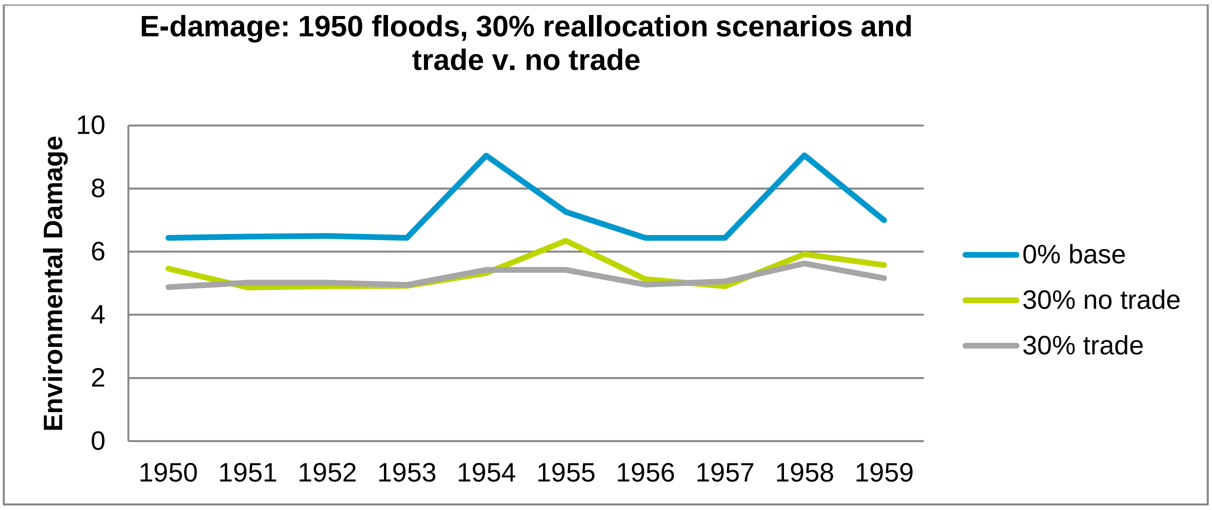

Figure 22 Low to moderate environmental flow impacts in wet conditions

Source: Connor *et al.* (forthcoming)

6.2.3. Salinity issues

Groundwater salinity levels are significantly higher in downstream sMDB river sections (e.g. the SA Murray area) (Heaney and Beare, 2001). Therefore, as water trade results in larger movements of water to downstream areas (see Figure 19) higher on-farm water use increases groundwater recharge and seepage to rivers, raising the probability of increased in-stream salinity. Poor farm management and water application practices can further increase the freeing of salt from soils, and transfer increased salt loads into watercourses (Marshall, 2004, CSIRO Land & Water, 1999)—although it is contended that water trade to higher value crops can assist in reducing the total level of poor farming practices by low value producers (NWC, 2012a).

By way of example, Wheeler *et al.* (2012b) found that irrigators who had less water overall were more likely to sell because: they were exiting the industry; they believed that irrigation was going to be increasingly problematic for them; or lack of water allocation during drought has had a cumulative effect, leading them to sell water. This was argued to have implications for environmental factors, because the exit of marginal irrigators or those in marginal areas with highly saline water that change their farming practices would have less detrimental impacts on the local environment and river systems overall.

The Basin Salinity Management Strategy is charged with managing sMDB salinity issues. The strategy has resulted in water trade limits, by identifying low to high salinity impact zones and/or preferred development zones across the three states, and restricting trade via higher development or salinity credit costs. Within each zones, a state must not exceed the salinity credits available under water use assessments and approvals. Salinity credits are generated by investment in salt interception schemes; and a unit of credit is measured using EC levels at Morgan, SA (NWC, 2012a). As credits are limited, a market on annual use-limits has established, and irrigated land developers have a preference for low-impact zones in the first instance. High-risk zones are managed through a variety of state-based approaches:

- In Victoria a range of additional water capital charges in salinity risk zones (i.e. $33/ML in low-risk zones increasing to $335/ML in high-risk zones) result in higher development, transaction and ongoing water use costs. The money raised is available for state investment in salt interception schemes.
- In SA available salinity credits are assigned to developers in low-risk zones, while in high-risk zones developers must propose methods to offset salinity impacts and generate site-specific salinity credits that will be enforced through licence or land-use conditions.
- In NSW salinity risk zones have not been identified, but a range of preferred development areas are available. In high-risk areas development approvals may require additional assessments and transaction costs, which provide disincentives for applications to develop high-risk areas.

Of particular note, Connor *et al.* (2012) observe that ignoring the combined effects of more variable (under climate change impacts) and increasingly saline water (potentially through trade impacts) may result in unexpected changes to agricultural water use—and subsequent flow-on effects for return water. For example, their modelling results suggest that irrigated areas with significant salinity concentrations (e.g. downstream sMDB areas) may require increased water application rates to leach salts through the soil and avoid substantial salt-related yield deficits. Further, in these downstream locations—where salinity impacts of reduced flows tend to be greatest—significant water use efficiency decreases may be needed to leach salt in more severe climate change scenarios. Therefore, while the current range of salinity credit and interception schemes may be keeping negative salinity issues at bay in the sMDB (MDBMC, 2008, MDBA, 2012a), under climate change these impacts may increase gradually, requiring altered measures to manage their impacts.[18] Overall, however, the impacts of increased water trade on salinity to 2010/11 appear to be inconsequential (NWC, 2012a).

6.2.4. Increased water use/trade due to carry-over restrictions

The inability to carry-over water for future use lead many consumptive users to adopt a strategy of either using all of their available water each season and/or trading surplus water allocation in the water markets (NWC, 2011f). Such strategies resulted in changes to the location and timing of water use, as well as generally increased water consumption each year with attendant potential environmental consequences. Further, anecdotal evidence from qualitative interviews with sMDB irrigators in 2008/09 suggests that without carry-over access water users would typically allow some unused water to flow downstream from under-extraction each season, with possible environmental flow and dilution effects (Loch *et al.*, 2012).

Figure 19 illustrates the impacts on volumetric flow direction under trade impacted by carry-over rules. As discussed in section 4.2.9, access to carry-over and strategic behaviour by water users led to the large volume of water allocation trade from SA into Victoria in 2010/11—and multiple decisions to suspend late-season water allocation trade in the sMDB. This is now being addressed under rule changes aimed at providing greater transparency to the process of trade suspension and a better alignment between spill-rules and storage management arrangements (DSE, 2012). These changes are aimed at reducing the level of uncertainty in water markets, the drivers of sudden trade suspension in future years and are in line with a current review of the Schedule D trade arrangements under the MDB Agreement (Frontier Economics, 2012).

6.2.5. Transmission losses

Consumptive transmission losses can occur from evaporation from surface water, seepage from the bottom river channels, leakage through river banks or overbank losses (e.g. onto floodplain areas such as the Barmah Forest area surrounding the Barmah Choke during high-flow events.[19] It is possible that combined water trade and regulated arrangements that provide flows across the entire spectrum of low in-stream flows to high overbank flooding could provide enhanced ecological outcomes for the sMDB (Loch *et al.*, 2011). However, changes to the location of water extraction from downstream water trade can create higher amounts of transmission loss as water is transported further along the river system. If an increase in transmission loses is not accounted for in the trade volume, it affects the general resource pool and environmental outcomes (NWC, 2012a).

Water trade is expected to have minimal impacts on surface evaporation or seepage losses as the surface area and size of the water delivery route remain unchanged. Further, the volume of trade would not typically exceed riverbank limits to result in

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[18] Although it has also been argued that engineering solutions to manage salinity provide perverse incentives to expand water use, thereby partially offsetting the mitigation benefits (Adamson et al., 2007). Further, Beverly et al. (2011) argue that in some areas perennial vegetation management strategies may provide more effective and less costly measures of salt interception and management within an integrated surface-groundwater context.

[19] It is necessary for the MDB to have large flushing flows to sweep saline water out to sea. Overbank flows are necessary for the health of the entire ecological system; rivers, floodplains, wetlands, lakes and estuaries must have regular flows over the bank to retain/regain ecological health (Williams, 2011).

significant overbank flooding losses (NWC, 2012a). However, since 2007/08 under increased levels of downstream water movement the potential for increased losses from leakage as the surface area of the river or channel will have increased (NWC, 2012a). In general, however, there is insufficient evidence to evaluate this assessment one way or the other (SKM, 2009) and it would be useful to have more access to information relating hydrological flow to transmission losses along water delivery zones via improved stream-flow data.

Issues related to transmission losses (as well as carry-over impacts) are also argued to be manageable under tagged trade or exchange arrangements (Etchells *et al.*, 2004), as discussed further below.

6.2.6. Exchange rate and tagged water trade

To limit the environmental and supply security impacts of water reallocation from water trade a system of exchange rates was applied to the Interstate Pilot Trade Program initiated in 1998 (Bjornlund *et al.*, 2013). The system was applied to limit river channel and supply reliability losses from transfers between NSW, Victoria and SA. For example, an exchange rate of 1.0 applies to all downstream transfers from NSW to Victoria or SA. However, an exchange rate of 0.9 applies to upstream transfers from SA into NSW, Victoria to counteract reduced supply security where the point of extraction is moved to above the confluence of the Darling System with the Murray. Under that arrangement, the new extraction point cannot be supplied by the flow coming out of the Darling River or stored in Lake Victoria (DEWHA, 2009).[20]

The application of exchange rates on water trades during the pilot program were designed to accrue net benefits to the environment, as any gains from the transfers are applied to the riverine environment. That is, transfers downstream were envisaged to leave water in the river environment for longer with expected positive environmental benefits. Victoria and SA subsequently signed an interstate trade agreement based on the pilot program exchange rate principles (DEWHA, 2009). Exchange rate trades must also be assessed against the sMDB salinity management strategy for credit or debit effects. High transaction costs associated with exchange rate trade have limited its expansion beyond the pilot interstate trade program, while tagged trade has increased.

Tagged trade allows the source water entitlement to retain its original access right and use conditions but become ‘tagged’ for use elsewhere in the sMDB. Water allocations made against the tagged water entitlement are conditional upon the source arrangements, but can be used at the destination site. As such, tagging allows a water user to hold a portfolio of rights across the sMDB with different reliability/risk characteristics commensurate with their preferences. Naturally, tagged water trade requires reciprocal agreements between states and territories to ensure recognition of water access rights and conditions across the jurisdictions (DEWHA, 2009). Such arrangements exist, but the level of annual tagged trade is reportedly low.

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[20] Exchange rate trades result in the cancellation of the original water right in the source area and its re-registration as a new water access right in the destination area—with the characteristics of that new water use area. Importantly, where seasonal water availability between the source/destination areas diverges from the expected LTAAY, exchange-based trade can negatively impact on existing rights-holders and environmental third-part rights. The magnitude of this impact will depend on the relative water availability, the exchange rate used and the volume of exchange trades that have occurred (ACCC, 2009).

While similar water allocation trade outcomes could be achieved via seasonal trade, tagged trade does not require annual or repeated approvals for water access and use (ACCC, 2009). Therefore, the transaction costs associated with tagged trade can be lower overall. In addition, third-party impacts (e.g. environmental flow reductions) potentially associated with exchange rate water trade is not likely to eventuate under the system of tagged trade arrangements.

6.2.7. Return flows

Different water use practices can have differing impacts on the return of unused agricultural water as surface-water runoff or ground-water recharge. Return flows affect river hydrology, with possible environmental impacts. Australia has never specified that water users should provide return flows but improvements in water use efficiency have seen less water returned to river systems over time. In most settings the response has been to decrease allocations proportionately to the efficiency gains achieved (Young, 2010). This is fundamentally a bad idea, as it collectivises the cost of the improvements and individualizes the benefits—sending poor economic signals.

In the period from 1993/94 to 2009/10 the volume of return flows to environment have steadily decreased as a consequence of extended drought, water use efficiency improvements, changes to on-farm practices and drainage collection improvements (URS Australia Pty Ltd., 2010). Water trade is expected to reduce return flows to riverine environments further again (Heaney and Beare, 2001, Heaney *et al.*, 2006), although actual measures and data on this relationship are not typically available. Studies have suggested that water buyers tend to be more efficient, have higher net farm income, use advanced technology and apply whole-of-farm planning to their operations (Young *et al.*, 2000, Wheeler *et al.*, 2010a, Wheeler *et al.*, 2009, Zou *et al.*, 2013). If climate change reduces water availability, further improvements in water use efficiency may lead to even lower return flows.

Interestingly, Qureshi *et al.* (2010) investigate the different outcomes of government policies to reallocate water toward environmental flows (i.e. water buyback versus investment in infrastructure efficiency upgrades). They conclude that infrastructure capital investments to improve on-farm irrigation practices and water conveyance result in relatively larger reductions in return flows under their modelled conditions. However, where irrigation losses produce little useful return flows (e.g. during drought condition or presumably under climate change impacts) efficiency improvement capital investments may provide some cost-effective options for government policy-makers. In general then, between on-farm and off-farm capital incentives for further efficiency gains (especially in light of predicted climate change impacts), return flows from the trade of water are not expected to contribute dramatically to environmental gains or losses—although investments in efficiency improvement may alter return flow patterns dramatically in the sMDB (Adamson and Loch, under review).

6.2.8. CEWH environmental water trade

Another way in which water trading may have direct implications for the health of the MDB is via Commonwealth Environmental Water Holder (CEWH) sponsored trade of environmental water under proposed arrangements currently being discussed (CEWH, 2011a). Concerns have been expressed that while federal government purchases may look impressive on paper, the volume of water delivered to the environment is likely to be relatively small (Thampapillai, 2009a, Thampapillai, 2009b). At present, estimates are that restrictions on water delivery and environmental works and measures mean that less than 50% of water available to the Commonwealth Water Holder was delivered in the sMDB to 2010/11 (NWC, 2012a).

There are further concerns that the purchases have not been strategic, heightening fears about poor links to environmental priority sites (NIC, 2010).

Restrictions on the ability to apply environmental water when and where it is deemed necessary, or on the usefulness of purchased water entitlements to meet required environmental site watering needs, may provide motives for increased water trade by the CEWH. Dependent upon the volumes involved, which could be significant given the holdings accrued under previous purchasing rounds, additional impacts on flow regimes, salinity impacts, transmission losses and the requirement for tagged trade, could all increase. However, based on the discussions above, the probability of negative environmental consequences from such activity would appear to be quite low—with the caveat that in some instances (e.g. transmission losses and return flows) further data and measures of potential impacts are recognised as being required (NWC, 2012a). In addition, the CEWH appear to be carefully considering the implications of their trade activity to ensure that limited third-party negative impacts accrue from any action its decides to undertake (Costello, 2012).

6.2.9. Seasonal Water Donations by Irrigators

Another source of water for the environment is donation of allocation water by consumptive water entitlement holders. Donation of water has been an important method of acquiring water for in-stream flows by private environmental organizations in the US (Wheeler *et al.*, 2013).This is where water can be donated for the benefit of the local environment, as well as water allocation and entitlement donations to environmental water organizations in Australia (such as members of the Water Trust Alliance). The federal government provided a grant of $705,000 for the development of a web-based environmental water trading system and mechanisms to facilitate water donations to approved environmental projects. Water donations over a certain amount are also now tax deductible; however there is still large transaction costs associated with donations. There is currently a threshold water value required to obtain a concession ($5,000), and a water valuation is required (which costs $800-900). The role of water donations needs further consideration as part of the adaptive water management push in Australia. It could potentially form part of a localism model for the MDB, helping areas identify, control and manage their own environmental assets, along with assistance from CEWH (Wheeler *et al.*, forthcoming-b). Bjornlund *et al.* (2011) found that between 6-17% of irrigators across the MDB stated they were willing to reduce their seasonal allocations to improve environmental flows (SA irrigators agreed the most, and NSW irrigators agreed the least). Such survey results indicate there seems to be strong support for the further development of water donation mechanisms, for the benefit of environmental flows.

6.3. Discussion

Although the advent of the water market may have initially caused inadvertent harm, on balance it seems to have proven effective at reallocating water among users without negative environmental consequences—although there are clear distinctions between the acquisition and management of environmental water that are yet to be fully tested (Wheeler *et al.*, 2013). While it is always possible that the environmental needs for water will be sacrificed for consumptive uses of water (NWC, 2012a), and that in principle water markets have the potential to lead to adverse environmental consequences, Grafton (2011) contends that in comparative terms, water markets in the MDB are performing well in helping promote the environmental health of the basin. Nevertheless, Australia does require more complete scientific data to optimise effective water resource planning.

Available data are 'patchy' for some catchments and in some instances are not publicly accessible. One major advantage for all water users in the sMDB—including government holders of environmental water—has come from reducing the need to fall back on risk-sharing principles. This has arisen from the water market's previous (and likely future) contribution to environmental water recovery via adequately compensated negotiation, and the clear scope for further adjustment through markets if necessary (NWC, 2011f).

Finally, on balance the evidence presented above suggests that environmental impacts of water trade have been small in comparison with the effects of drought and water resource development. This has clear implications for future adaptability and policy emphasis under likely climate change scenario impacts.

6.4. Key points

The major points from this section include:

- Common environmental concerns associated with water trade include that it may result in: i) concentrating water use in areas suffering from high water tables; ii) moving water into locations where its' use might have a negative impact on river water quality; iii) moving water use upstream, thereby resulting in reduced river flow from the new point of extraction to the old point of extraction; or vi) activating previously unused water leaving less water in rivers to support ecosystems.
- Historically, the existence of water markets meant that when the cap was introduced, many unused 'sleeper' and 'dozer' licenses were activated through market trade, which resulted in reduced seasonal allocations. A variety of controls have been put in place by state governments to limit further environmental harm from trade, which have increased transaction costs associated with trade.
- Recent modelling suggests that the hydrologic and environmental impacts of water trade between 1998/99 to 2010/11 were small and largely positive; due to the downstream movement of water during the drought that reduced summer flow stress and created no change to winter flow patterns. Negative impacts tended to occur where water trade resulted in a detrimental change to the volume, location and/or timing of water use. Overall, the measures suggest that water trade has led to improved flow stress ranking scores for the river systems assessed, particularly with regard to natural flow variability outcomes and better flow patterns in summer months. The findings also concluded that water trade would have beneficial ecological flow impacts under dry conditions compared with wet. Groundwater salinity levels are significantly higher in downstream sMDB river sections. Therefore, as water trade results in larger movements of water to downstream areas higher on-farm water use increases groundwater recharge and seepage to rivers, raising the probability of in-stream salinity. In the future, irrigated areas with significant salinity concentrations may require increased water application rates to leach salts through the soil and avoid substantial salt-related yield deficits. Overall, however, the impacts of increased water trade on salinity appear to be inconsequential.
- The introduction of carry-over water for future use did lead many consumptive users to adopt a strategy of either using all of their available water each season and/or trading surplus water allocation in the water markets. Such strategies resulted in changes to the location and timing of water use, as well as generally increased water consumption each year with attendant potential

environmental consequences. Controls are now being put in place to address environmental concerns that, in accordance with the discussion about flow regime changes above, would likely be positive from water trade of carry-over. CEWH will also need to carefully consider the implications of their trade activity to limit any potential third-party negative impacts.

7. FUTURE CHANGES TO WATER MARKETS TO SUPPORT ADAPTATION

7.1. Policy Responses for Adaptation

Climate change and water management are arguably two of the most important policy challenges facing contemporary Australia, and in particular, are the most important issues for the MDB in Australia. Current water policy is well-positioned to aid the management of impacts from climate change, especially for irrigators. Reforms to water pricing, entitlements and the development of markets are some of the best-practice examples of adaptation.

Adaptation has been defined as adjustments in human-environmental systems in response to observed or expected climatic changes. It is influenced by a farmer’s willingness to adopt new strategies, and can be either incremental (relatively common decisions for a farmer to make) or transformative (a rarer decision, as it represents a major change in livelihood, location or identity). We suggest that in the situation of the MDB, successful policy should be designed to consider both aspects of adaptation. First and foremost, policy should be focused on adaptive change for farmers, to help them adjust to future water scarcity and manage their land and resources as sustainably as possible. However, policy also needs to recognise that we cannot expect change from all farmers, and that perhaps some parts of irrigated districts in the MDB should no longer be supported into the future, given environmental conditions, irrigation infrastructure, future costs and soil productivity. Hence, policy will also need to be designed to facilitate transformative and structural change. Small block irrigated exit packages are one example of transformative policy change, and the target buy-back of farms on certain inefficient backbone or spur channels, which would no longer be serviced or upgraded, would be another option.

Policies and investment strategies related to climate change, energy and water are intertwined. It has both mitigation and adaptation strategies in its sights. While adaptation and mitigation responses are usually portrayed as dovetailing one another, they can be in conflict. For example, the adoption of irrigation efficient technologies to save water can increase energy use, increasing carbon emissions. On the other hand, a mitigation measure that can thwart adaptation is carbon capture and storage which can lead to increased use of and competition for water. Climate policy goals can be traded off in good and bad ways against other policy goals. For instance, promoting regional economic growth can lead to increased emissions. Until mitigation and adaptation strategies are on the same legal, financial, institutional and political footing there are likely to be serious imbalances in trying to harmonize them.

7.2. Further Water Market Changes Required for Adaptation

This report has explored a wide array of economic, social and environmental impacts of water markets, concentrating particularly on farmer adaptation of markets in the face of climate change. The potential for major structural changes in irrigated agriculture due to climate change, reinforce the need to fully implement best practice policies in relation to water planning and water markets.

We have categorised three key areas (institutional, information, policy) where we believe changes are needed.

7.2.1. Institutional

- *Removal of trade restrictions*: limits to inter-regional trade is likely to slow adjustment in regions that are seeking to sell water, while also potentially placing barriers in the way of irrigators seeking to maximise their farm income from selling surplus water allocations or buying additional water allocations for crop needs.
- *Groundwater entitlement and planning processes**:*** As the demand for groundwater rises among existing and new users there will be a growing need to identify and regulate the sustainable level of aquifer use.
- *New water products:* There are calls to introduce/further expand the range of water trade products such as the trade of water allocation for environmental benefits, water donations, and forward supply contract options in rural and urban markets.
- *New water markets:* Increasing attention needs to be given to the development of water markets in other settings (e.g. urban) to greatly increase flexibility and adaption for future climate change impacts.
- *Trade approval processes**:*** There is a need to reduce complexity in the water market, improve readily available information on processing, remove assessment factors, address complaint handling processes, and other critical requirements to reduce water trade transaction costs. Indeed, greater research on transaction costs and how to reduce them is needed.
- *Conflicts of interest:* The continuing maturity of the water market means potential or perceived conflicts of interest in relevant agencies must be reduced. This includes understanding how actions of environmental water holders may impact on the water market, and having clear understandings of how they may interact—or be involved in—water trade. The water market would benefit from greater clarity around future water trade activity and its likely impact.
- *Overall leadership:* There needs to be a debate in Australia over who is going to provide future leadership of water policy and change. Currently a variety of state and federal governments have responsibilities for water policy, and there may be benefits to be gained from an evolution of responsibility towards one key institution (e.g. the MDBA), particularly where the efficient and effective management of river resources becomes an increasingly important objective (Loch *et al.*, under review-a). For example, the National Water Commission has recently noted that a whole-of-basin implementation strategy with attendant agreements between the MDBA and basin states will be required before establishing cooperative and collaborative arrangements for implementing the Basin Plan (NWC, 2013). Such findings reflect the importance of resolving water sector leadership issues in as timely a manner as possible.

7.2.2. Information

- *Market price information improvements**:*** Water price information is key to any economic assessment of trade activity. A significant hurdle to water market analysis remains a lack in the quality and quantity of water price information. Fragmented and inconsistent price data availability decreases people’s ability to manage their water needs efficiently and effectively. General information sharing can significantly improve multiparty adaptation to drought and climate change effects. One of the most publicly available and detailed broker information on prices and volumes traded in Australia’s largest irrigation district of the GMID (WaterMove) is no longer available, which limits further academic analysis of institutional and economic drivers of water markets. Although the National Water Market System (resources available online at http://www.nationalwatermarket.gov.au/) may fill the gap in the future, its historical information will be limited and it is unknown whether bid and offer data will be made publicly available.

- *Allocation announcement processes:* Improve transparency of allocation announcements. The system of allocation announcements requires both substantial up-front and periodic review.
- *Farm management responses*: Improve information about potential adaptive responses and their effectiveness, across different industries and regions.
- *Further water market research:* Needless to say, the authors believe that further water market research is needed to truly understand water demand and supply issues. Although as a field of research water economics is evolving rapidly, and there has been a significant increase in the area in Australia, there still remains many topics that need researching. The authors also believe that there is a need to go beyond most of the simple analysis that has been conducted on water markets (e.g. NWC, 2012a), and develop much more integrated, sophisticated analyses of the Basin's trade as a whole. Such research will provide fulfil key informational needs for policy.

7.2.3. Policy

- *Market intermediary confidence:* Further licencing of water brokers may be required to reduce issues associated with unethical or inappropriate behaviour.
- *Greater incorporation of risk into decision making:* The uncertainty and scale of future climate change means that policy makers must adopt greater risk based approaches to decision making to plan for drier climate across the MDB. Again, the environmental water management process needs to evolve such that annual Basin state objectives are developed and aligned to the Basin-wide environmental watering strategy (NWC, 2013). Trade to manage risk issues will likely constitute some of that process.
- *Further monitoring:* Greater attention should be given to measuring and monitoring water diversions, as well as continuing to provide the ACCC with powers to monitor water trade, exit and variable charges of irrigation infrastructure operators.
- *More consistency in intertemporal water use:* Increasing flexibility in intertemporal water use through improvements in carry-over rules.
- *Market-based instruments*: There needs to be an extension of market based instruments to allow farmers to adapt to climate change. This may include increased policies to adopt sustainable agricultural practices, or further development of carbon farming policies. There also needs to be careful consideration of where the majority of government money is being reinvested in irrigation: in off- and on-farm infrastructure. The efficiency and effectiveness of such investment needs careful reconsideration, as well as examining the opportunity cost of such investment (for e.g., the return that may eventuate from spending on health or education instead). Regulation may be necessary in some instances.
- *Education*: Policy should be targeted at helping irrigators adjust to future water scarcity. Rather than using the term 'climate change', it should focus on the

risk of future water shortages, and how planning for water shortages increases profitability and farm viability. It should be noted that the adoption of true risk water management strategies will help change beliefs – there is an important intertwined relationship between water behaviour and beliefs.

A better understanding of trade behaviour, especially strategic trade issues that can lead to market failures, will assist to improve the future advantages of water trade. There remain many areas to further research in the area of water markets. For example, the water market is still not fully mature, hence its risk management potential is yet to be fully explored. The introduction of water markets in Australia has led to a wide range of economic, social, and environmental impacts, some of these positive, but also some negative. There are also lessons to be learned about participation in other resource markets (e.g. salinity trading, carbon farming, energy, etc.) and how these lessons might translate back to water markets (or from water markets to other areas).

On the whole, we suggest that water markets have been of net benefit for Australian irrigators. In addition, in the future water trading is likely to be crucial to allowing new adaptation in the face of climate change. This report has highlighted the many lessons to be learned—both by Australian and international water managers—from sMDB experiences during the Millennium Drought, where access to water markets and political investments assisted consumptive, social and environmental water users to avoid catastrophic outcomes. Climate change and water scarcity management are intertwined, suggesting that policy, institutional and governance arrangements to deal with such issues should be similarly structured.

Water users will adapt, either out of necessity or opportunity. The cost of that adaptation at individual, regional and national levels—particularly to future water supply variability—can be mitigated by the consideration of the existing advantages from and future opportunities for water markets in Australia.

Flexibility and adaptability will be required to achieve future sustainable policy change in the MDB. As such, water markets will need to keep evolving to provide greater adaptive measures. One of the great benefits of water markets is that they allow participants to play active roles in the reallocation of water, but individuals' ability to adapt is governed by institutional, information and policy issues. Hence, the ability to respond to future challenges needs a concerted effort across all levels to ensure future sustainability.

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