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# Shallow Groundwater Resources and Future Climate Change Impacts: A Comparison of the Ovens and Namoi Catchments, Eastern Australia

Category: Limits to growth

Abstract
The Murray-Darling Basin (MDB) river system is a critical province and water resource for Eastern Australia. Over the past decade the MDB has been subject to a protracted and severe drought, as well undergoing major institutional, social and economic reforms. A lesser understood area of MDB water resource issues is the status of groundwater, especially with respect to trends in groundwater resources, groundwater-surface water issues and the longer term susceptibility of groundwater to climate variability and climate change. Following the cap on MDB surface water allocations in 1994, a major expansion of groundwater use was observed across many parts of the MDB, which has probably been further exacerbated by the current drought leading to lower groundwater recharge. This paper presents an overview of the current status of Murray-Darling Basin groundwater resource use and management, contrasts two case study sites in the Ovens and Namoi catchments of Victoria and New South Wales respectively, assesses the potential risks that climate variability and climate change present, and finally considers some long term solutions to ensure that the MDB continues on its transition to a more sustainable future.

## 1. Introduction

Groundwater and surface water are not isolated components of the hydrologic cycle. Particularly within the Murray-Darling Basin (MDB), Australia, these two systems are intrinsically connected and are driven by rainfall and ultimately climate.

The MDB is of critical importance to agriculture in Australia, and groundwater within the MDB is the focus of this report. Two key case studies have been selected to give an appropriate cross-section of groundwater resources, interactions with climate and sustainability of the MDB – the Namoi catchment and the Ovens catchment.

The purpose of this report is to highlight the significance of climate change on groundwater levels and ultimately the availability of the resource. By developing a historical understanding of shallow groundwater resources, predictions for future climate change impacts can be made and managed using sustainability principles. The report provides a qualitative assessment by studying the historical trends in groundwater levels related to changes in rainfall, thereby facilitating improved understanding of climate variability and climate change impacts on groundwater. This allows a more relevant approach to sustainable management groundwater management.

## 2. Murray-Darling Basin overview

The Murray-Darling Basin (MDB) is Australia's largest river system, encompassing 14 % of the total area of Australia (Ife & Skelt, 2004). The MDB is located in the south-east of the continent (Figure 1). The Basin is of critical importance to agriculture to Australia, with two million people residing within the Murray-Darling Basin, and a further one million who are dependent on its water living outside the Basin (Ife & Skelt, 2004), as well as environmental values. After the 1995 Murray Darling Basin Commission Audit (MDBC, 1995) found that an increase in water diversions would severely limit the health, supply and reliability of surface-water resources, a limit was imposed on the volumes that could be diverted from the rivers for consumptive uses. This was known as 'The Cap'. A permanent Cap was set for New South Wales, Victoria and South Australia on 1 July 1997, defined as "the volume of water that would have been diverted under 1993/94 levels of development" (MDBC, 2008).

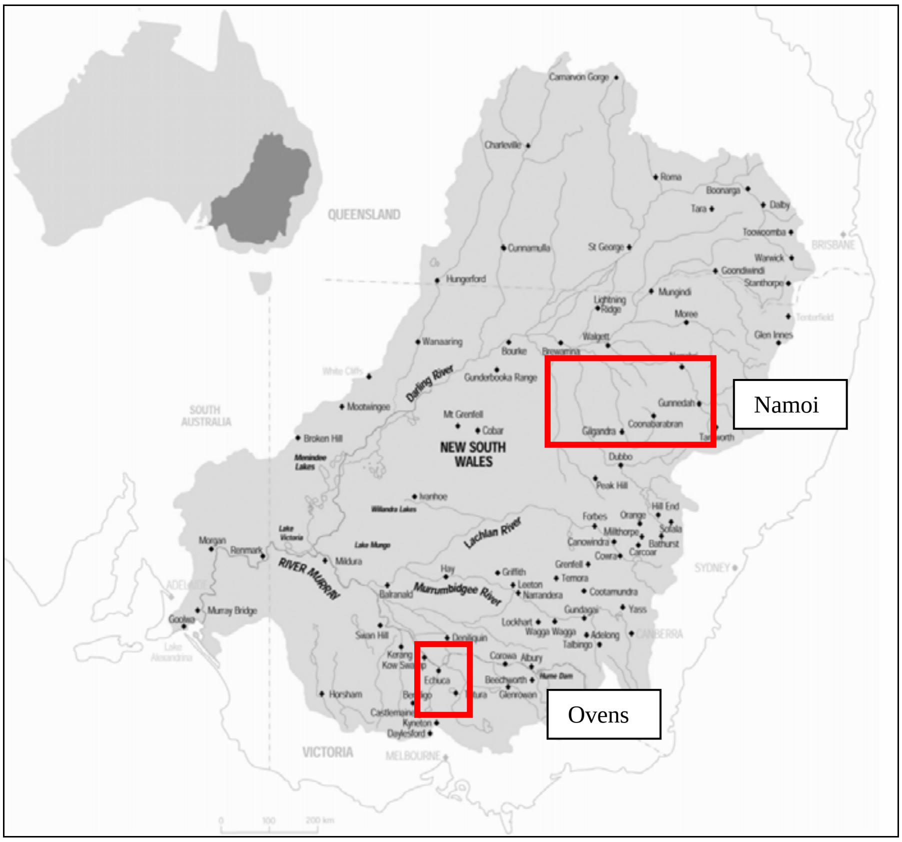


**Figure 1** Location of the Murray-Darling Basin in south-east Australia (MDBC, 2003) with Namoi and Ovens catchments highlighted.

### 2.1 Sustainable groundwater yield in the MDB

Sustainable yield of groundwater is generally defined as the volume of water extraction measured over a specified timeframe that should not be exceeded to protect the higher social, environmental and economic uses associated with the aquifer (NLWRA, 2000). Generally across MDB states (Queensland, New South Wales, Victoria and South Australia), groundwater 'sustainable yield' is defined by annual rainfall recharge, where sustainable yield is lower than the rate of recharge. Although Queensland, Victoria and South Australia include throughflow and rainfall recharge in the definition of groundwater sustainable yield, there is no mention in either surface water or groundwater sustainable yield definitions about the influence of climatic changes, such as drought periods, on extraction amounts.

Allocations of groundwater are therefore designed to be within these defined 'sustainable yield' limits. However, this is not always the case, with either more water than allocated being extracted, or water being 'over' allocated to users.

Groundwater extraction in the Basin has substantially increased over the last decade as 'The Cap' applies only to surface water use, causing a transfer of development pressure from surface water resources to groundwater. In addition to this, the ongoing drought has caused higher demands for groundwater resources within the region.

Access to groundwater for irrigation is rationed through a system of entitlements, issued through State and Territory governments. The increased pressure on MDB groundwater has triggered growth in new groundwater allocations in emerging irrigation areas and activated unused groundwater licences in areas where bans on additional groundwater extraction were in place (IAH, 2004). In New South Wales and Victoria, the increase in groundwater usage was more than 200% (IAH, 2004), although this was still within the limits of The Cap.

Although on average usage of groundwater across the Basin is below sustainable yields, many specific aquifers are heavily pumped above their sustainable yield. According to NLWRA (2000), 57 of the 538 Groundwater Management Units (GMUs) were pumped at a rate that exceeds their long-term capacity (Kalf & Woodley, 2005).

It could be expected that the declining trend in groundwater subsystems may pose a serious threat to the long-term availability of surface water in the MDB, because The Cap does not recognise the importance of surface water – groundwater interactions as one resource in management (AWR, 2005a). This is fundamentally due to the lack of new policy signals and the growth of new groundwater allocations due to transferred pressure from surface water use.

Sustainable yield must also consider ecological requirements, which could limit the allowable abstraction rates (Kalf &Woodley, 2005) as well as standard budget aspects (such as rainfall, extraction volumes etc). A basic ecologically sustained yield at equilibrium would be:

*Ecological sustainable yield = Ecological sustainable inflow – Residual outflow*

It should be noted that since all water systems interact, any change in conditions such as vegetation, land use, urbanisation, location of pumping wells, incorporation of new water supplies or climate change, would require a new calculation of sustainable yield (Sophocleous, 2000). In systems where connectivity of groundwater and surface water exists, the time lag between the start of groundwater pumping and the depletion of water from the stream is critical to management decisions (Braaten & Gates, 2001), as well as determining sustainable yield.

## 2.2 Groundwater sustainability in the MDB

Sustainability, particularly in terms of groundwater management, is a broad concept that can involve issues of ecology, water quality, and others, as well as 'sustainable yield', which holds a separate definition itself (Devlin & Sophocleous, 2005). 'Sustainability' also includes social and economic issues that should be considered when defining water management and allocation. Qualitative sustainability would include factors that cannot be quantified but are important to water system function, such as ecosystem health and associated social and economic issues in using the resource. True sustainability that accounts for all social, environmental, economic and ecological requirements is fraught with difficulty. A natural system cannot be used without altering it, and the more intensive the use, the greater the alteration (Sophocleous, 2000).

Currently within the MDB, assessing sustainability is emerging practice while comparing existing extractions with allocated “sustainable yield” values is still the minimum commonplace.

## 3. Climate change

The Intergovernmental Panel on Climate Change (IPCC) has defined climate change as the change of state of the climate that can be statistically identified by changes in the variability of its properties that persists for an extended period, usually decades or longer. It can be natural variability or due to human activity (IPCC, 2007). The IPCC also states that the present warming of the climate is unequivocal due to evidences of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level (IPCC, 2007).

Observational records and climate projections conducted provide clear evidence that freshwater resources are vulnerable and have the potential to be strongly impacted by climate change, with wide ranging consequences for human societies and ecosystems (Bates et al., 2008). There is increasing evidence that climate change will reduce the winter rains and increase evaporation in the MDB, leading to increased water stress and probable shortages (Fullagar, 2004). Predicted changes in average rainfall vary from -10% to +10% by 2030 and -35% and +35% by 2070, relative to 1990, with decreases being most pronounced during winter and spring (CSIRO, 2001).

Figure 2A represents the MDB under climate change conditions for a dry scenario – high sensitivity to climate change and a drier response. Figure 2B shows MDB with moderate sensitivity to climate change. Figure 2C shows MDB with a wet response to climate change.

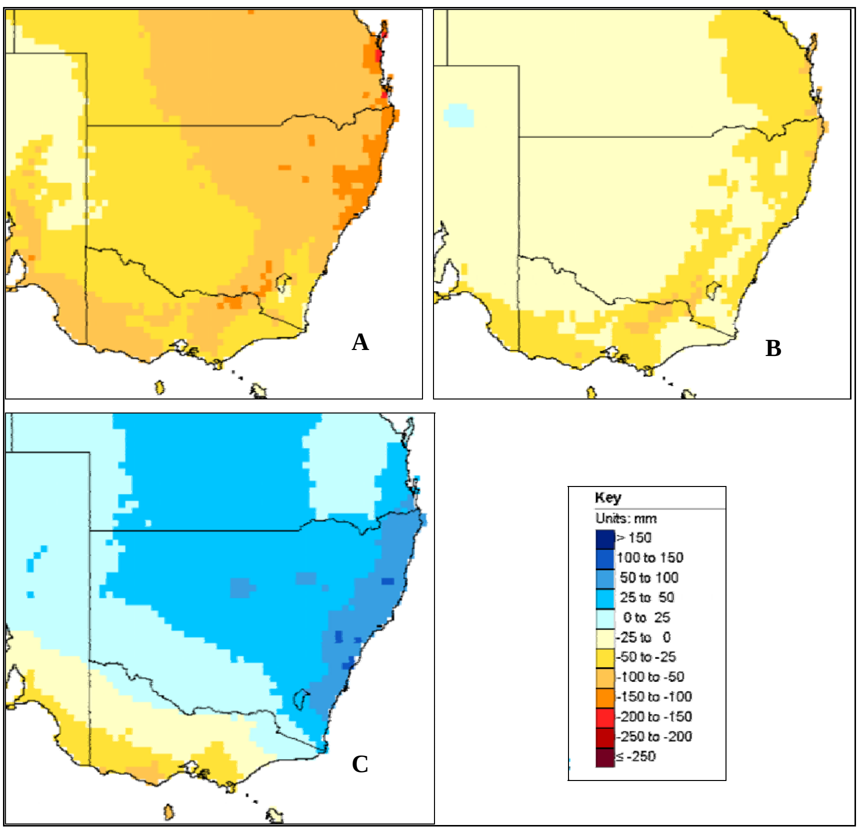


**Figure 2:** Change in total rainfall (mm) in MDB for 2030. (A) Dry response (B) Moderate response (C) Wet response (OzClim, 2008)

Figure 2A and 2B show a clear decline in the amount of projected annual rainfall by between 1 and 100mm. Conversely, Figure 2C shows that much of the Basin will experience an increase in annual rainfall between 1 and 50mm, with only Victorian and South Australia parts experiencing predicted decline.

In any scenario of climate change, there will be a change in the predicted annual rainfall in all parts of the MDB. Since groundwater, surface water and climate have ongoing interaction, sustainable yields should account for climate as a change in rainfall could determine the amount of water available to harvest – either from surface water or groundwater. Sustainable yields should be managed in a way that allows for reduction in allocated yields during dry periods, and a possible increase during wet periods. If this management approach is not adopted, sustainable yields will not be sustainable in the long-term due to impacts of agriculture, regional economies, environmental needs and community requirements.

## 4. Ovens case study

### 4.1 Overview

The Ovens catchment is located to the north-east of Victoria, in the south-east corner of the MDB. The Ovens catchment is 0.7 % of the total area of the MDB. The population is 46,000 – 2.3 % of the MDB total – concentrated in the major centres of Wangaratta, Myrtleford, Beechworth and Bright.

Major water resources in the Ovens catchment include the Ovens and King Rivers, fractured rock and alluvial aquifers, wetlands and water storages. Groundwater levels have shown no long-term change on average within Ovens Valley sub-catchment, with the exception of seasonal fluctuations and changing river levels (CSIRO, 2008). Groundwater extraction within the Ovens catchment accounts for 0.4 % of the total MDB groundwater extraction.

Figure 3 demonstrates the variability in annual and monthly rainfall in the Ovens catchment. Mean annual rainfall for the region is 1004 mm, varying from nearly 1600 mm in the south of the catchment to 550 mm in the north. Rainfall does vary considerably between years but winter is typically the wettest season. Despite the variability, the region's average annual rainfall has remained relatively consistent over the past 112 years. The mean annual rainfall over the past ten years is around 11% lower than the long-term mean.

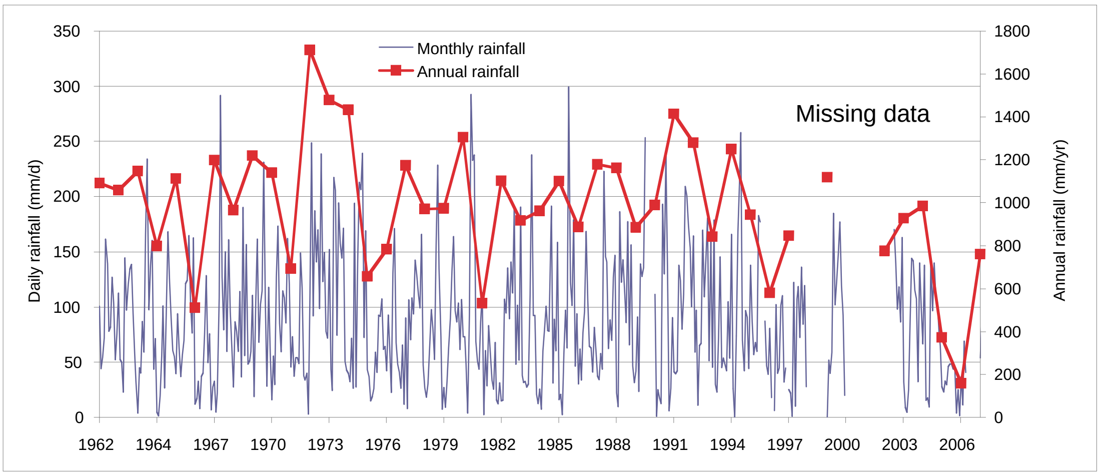


**Figure 3:** Annual and monthly rainfall for the Ovens catchment (station 83057 at Myrtleford, Ovens Research Station) (BoM, 2010)

## 4.2 Climate change

CSIRO (2008) undertook a model of future climate and current development to assess the likely range of climatic conditions in 2030 under high, medium and low global warming scenarios. Twelve out of fifteen models predicted a decrease in mean annual runoff, while only three predicted an increase over the three scenarios.

## 4.3 Historic rainfall and groundwater

Rainfall data for the Ovens catchment was plotted as a monthly Cumulative Deviation from Mean Precipitation (CDMP) chart. Figure 4 and Figure 5 show the hydraulic connection between groundwater monthly average Reduced Water Level (RWL) and CDMP for bore 109652 and 110739 respectively. Groundwater data for the Ovens catchment was sourced from the Victorian Water Resources Data Warehouse (VWRDW, 2010). There are clear correlations existing between groundwater level and rainfall at various points – the low rainfall point in 1983 and the beginning of dry conditions in 1996 are clearly shown in the average groundwater level.

In both figures, the CDMP for the Ovens catchment indicates that from the early 1980s, rainfall began to increase from the long-term monthly average. In 1996, the ‘drought’ began, which signified the start of the dry-period of the climatic cycle.

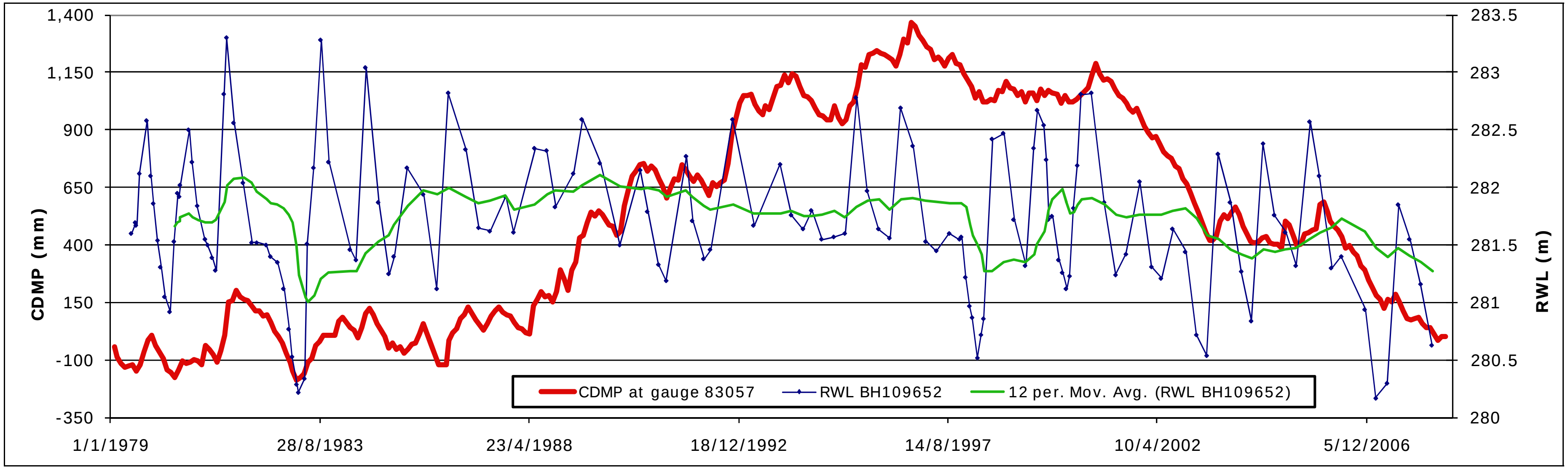


**Figure 4:** CDMP vs RWL for bore 109652 (Ovens)

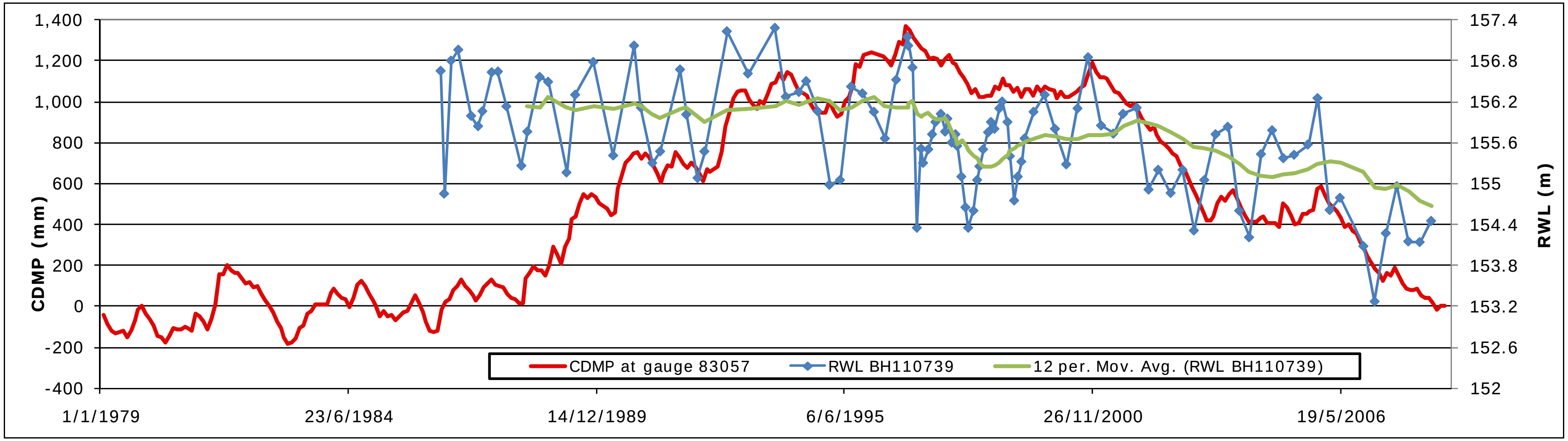


**Figure 5:** CDMP vs RWL for bore 110739 (Ovens)

5. Namoi case study

5.1 Overview

The Namoi catchment is located north-eastern New South Wales (Figure 9) and represents 3.8 % of the MDB. The population of the region is 88,000 – 4.5 % of the MDB total – concentrated in the major centres of Tamworth, Gunnedah, Boggabri, Narrabri and Wee Waa.

Groundwater resources within the Namoi catchment are the most intensively developed in New South Wales. The catchment has one of the highest levels of groundwater extraction within the MDB and groundwater use is 15.2 % of the MDB total. Additionally, the catchment uses 2.6 % of the total surface water diverted for irrigation in the MDB (CSIRO, 2007).

The average annual rainfall of the region is 641 mm, varying from 1300 mm in the east of the catchment at the Dividing Ranges to 400 mm in the west. The variability in rainfall in Namoi is demonstrated in Figure 6. Rainfall is generally higher in summer and that rainfall is extremely variable between years and seasons.

Groundwater within the Namoi catchment is primarily extracted from the alluvial aquifers associated with the main rivers and prior channels (CSIRO, 2007).

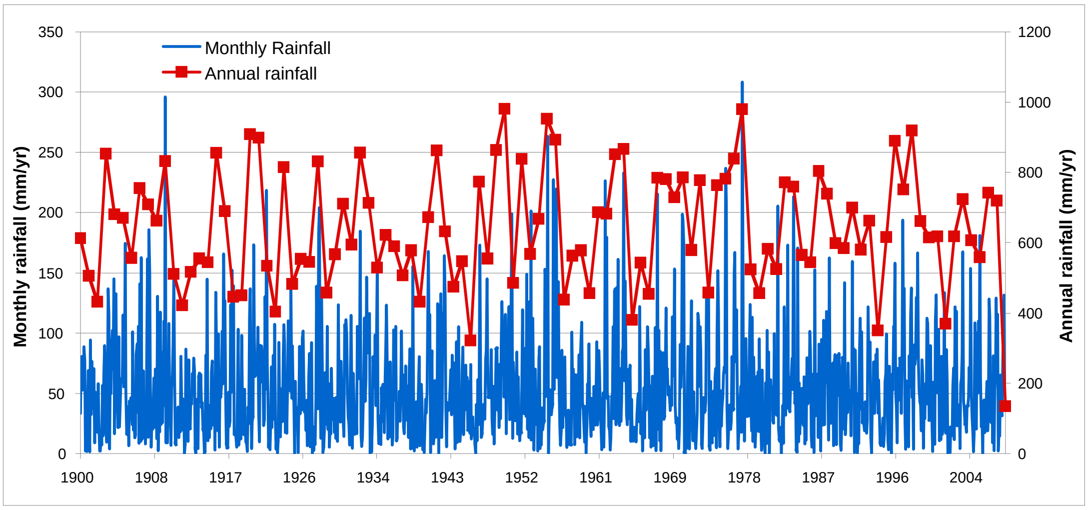


**Figure 6** Monthly and annual rainfall within Namoi catchment (Station 55031: Manilla Post Office)

5.2 Climate change

CSIRO (2007) undertook a model of future climate and current development to assess the likely range of climatic conditions in 2030. Of the fifteen models, ten predicted a decline in mean annual runoff, while five predicted an increase. Although considerable uncertainty exists for each of the estimates, the CSIRO study indicates that runoff around the year 2030 in the Namoi catchment will be more likely to decrease than increase (CSIRO, 2007).

5.3 Historic rainfall

A CDMP was plotted for the Namoi catchment between 1958 and 2008. Breaks within the plot are due to missing data from the BOM data set. The CDMP plot shows that 1995 experienced the greatest declining deviation from mean precipitation, with highly variable changes from the mean across the years.

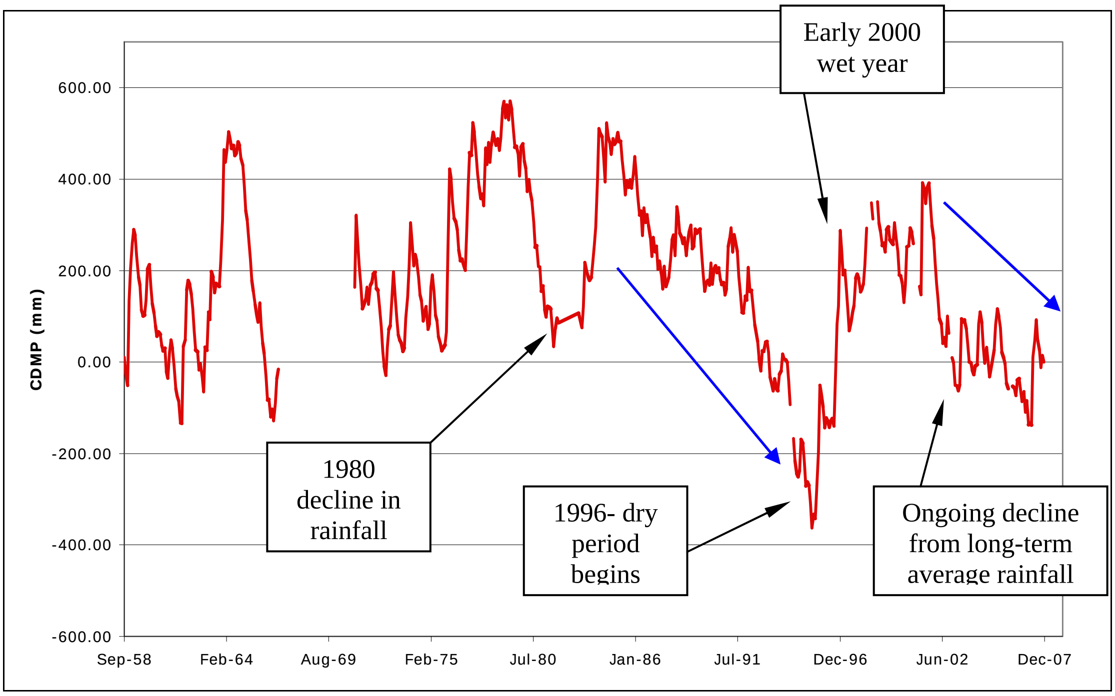


**Figure 7** CDMP Namoi catchment

## 6. Discussion

### 6.1 Climate variability

Surface water and groundwater are not isolated parts of the hydrologic cycle. With changes in rainfall, a change in the availability of recharge to both groundwater and surface water systems occurs. A change in groundwater levels can and will correspond to a change in surface water levels and availability.

Australian climate can experience both dry and wet periods. Figure 4 and Figure 5 (from the Ovens catchment) indicate that long-term climatic trends are linked with groundwater and surface water resources. By focusing on the amount of water available to a system, be it groundwater, surface water, or the two systems as a whole, sustainable yields and sustainability applications can be better quantified and justified.

Figure 8 (Hydrograph A and B) demonstrates that short-term climatic trends are not always indicative of the climate or long-term scenario. Both hydrographs have a rainfall and groundwater data set for the Namoi catchment. Hydrograph A contains rainfall data from 1973 to 2001. Hydrograph B contains rainfall data from 1906 to 1996. We can see that the general upward trend in rainfall shown in Hydrograph A is only a small portion of the long-term climatic trend shown in Hydrograph B. Groundwater levels in both hydrographs do not reflect the overall trend in rainfall as both bores are pumped beyond their sustainable range.

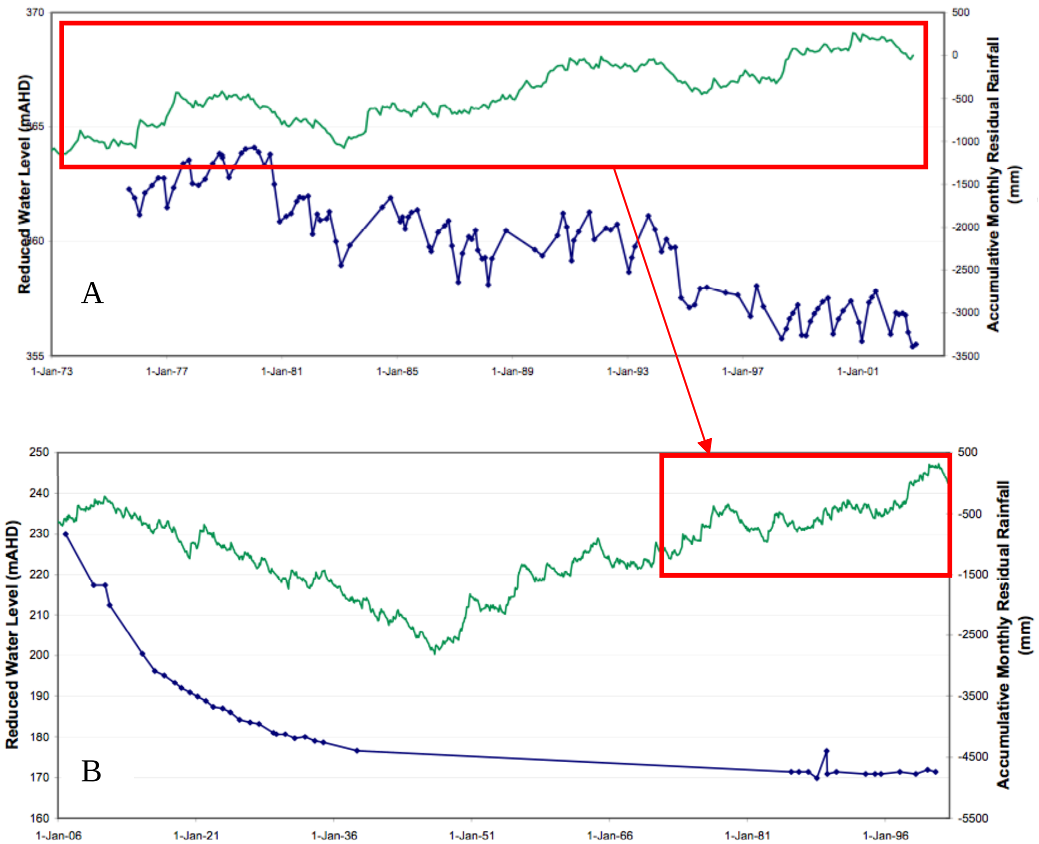


**Figure 8:** Two hydrographs from Namoi catchment showing differences between short-term and long-term climatic trends (Skelt, et al., 2004). Note that bore B is within the Great Artesian Basin.

There are differences between climatic conditions of Namoi, Ovens, NSW, VIC and all areas of Australia. Figure 9 shows the difference in CDMP plots for Namoi and Ovens areas.

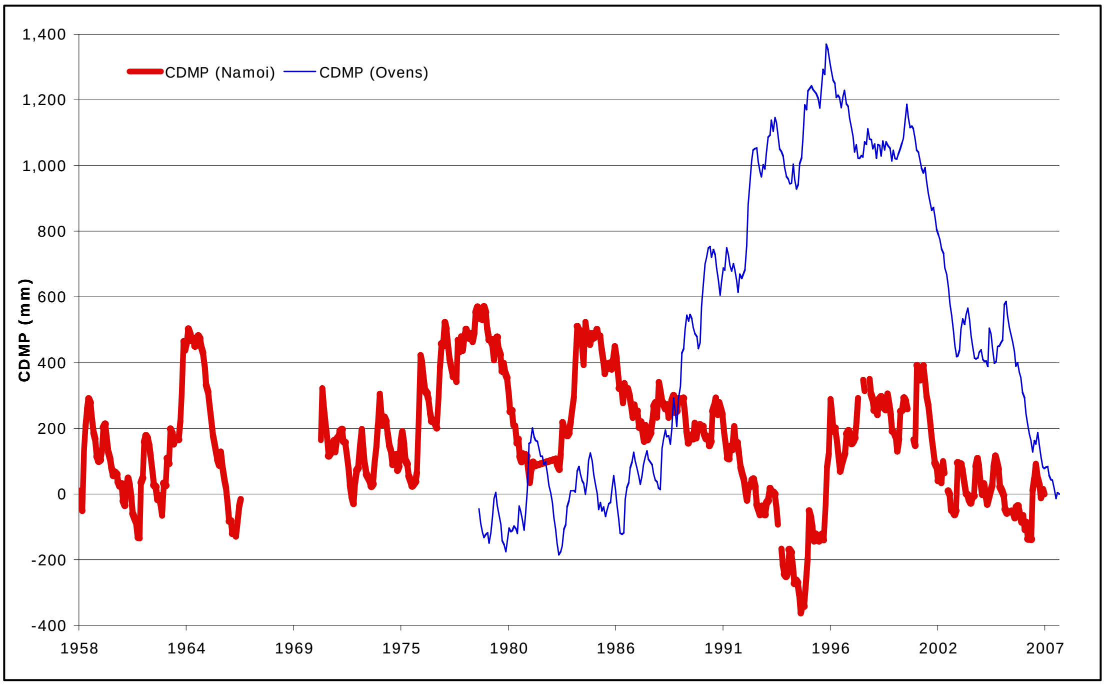


**Figure 9:** Comparison of CDMP for Namoi and Ovens

From Figure 9 there is a clear difference in CDMP for both areas. While Ovens experienced a rise from long-term average rainfall between 1986 and 1996, the Namoi was experiencing a dry period. This highlights that although water resources should be managed as one resource, differing sustainable yields and sustainability principles will apply to different areas with different rainfall conditions.

6.2 Climate change

When analysing climate change and the dry conditions of the Australian climate, conservative estimates and management should be used. Management of resources should account for variability and changes in availability of water.

The implication of the hydraulic connection between the two systems is that groundwater resources are vulnerable to changes in rainfall conditions. Groundwater and surface water are not isolated components of the hydraulic cycle – a change in rainfall availability that results in a change in groundwater levels can mean a change in surface water levels and availability.

6.3 Long-term sustainability

To ensure future sustainability, sustainability frameworks need to incorporate sustainability factors, such as economic, social and environmental factors, as well as a clear and consistent definition and methodology of determining sustainable yields. Additionally, water resources must be managed as one resource. That is, interactions between surface water and groundwater resources must be recognised and managed appropriately with climate. Climatic conditions and climate change cannot be managed, but variability and changes in amount of available rainfall can be accounted for through sustainable management and appropriate, flexible, sustainable yields. Historical groundwater and climatic trends must be appropriately recorded and understood to accurately predict future conditions. Climate and rainfall change over time, and so should the framework that manages water resources. If groundwater is to be pumped below levels of available recharge, then sustainable yields should be adaptive to increases or decreases in deviation from cumulative long-term mean precipitation.

## 7. Conclusion

The key points from this discussion are:

- The MDB is a critical water resource to Australia that requires appropriate management to ensure future sustainability of its resources. Groundwater and surface water are not isolated components of the hydrologic cycle and throughout many parts of the MDB they are intrinsically connected, where rainfall is the driving force of the overall system.
- Groundwater levels are strongly connected to long-term climatic trends – the implication being that groundwater resources are vulnerable to climatic changes and variability.
- Climate change predictions for the overall MDB indicate a reduction in available rainfall, and this will only be exacerbated by dry climatic cycles of the Australian climate. Being the one water resource, a reduction in rainfall will result in the reduction of groundwater levels and surface water levels. Frequent and reliable data needs to be recorded in all parts of the MDB so that conceptual models can be constructed to indicate current and predictive conditions.
- A framework needs to be designed and implemented to ensure future sustainability. This framework needs to include not only sustainability factors but also a clear, consistent and reliable definition and methodology to determine sustainable yields. The definition of sustainable yields itself need to be flexible and regularly monitored to account for deviations from long-term cumulative mean rainfall and predicted climate change. There is a high degree of consideration, planning, monitoring and managing to integrate all relevant components into a sustainability framework. Despite the difficulty in the task, however, groundwater and surface water must be managed as one resource with sustainable yields accounting for predicted climate change if future sustainability is to be achievable.

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