Modelling variants of the Murray-Darling Basin Plan in the context of adverse conditions in the Basin

Glyn Wittwer
Centre of Policy Studies
Victoria University

March 2020

VICTORIA UNIVERSITY
MELBOURNE AUSTRALIA

This investigation has been commissioned by the Panel for the Independent Assessment of Social and Economic Conditions in the Murray-Darling Basin. The Panel has made this document available for public scrutiny as part of its commitment to transparency. The views in this report do not necessarily represent the views of the Panel. This is part of a series of literature reviews and research investigations that will help inform the Panel's eventual findings and recommendations.

Executive summary

This study starts by examining the background economic circumstances of the 2007 Water Act and the 2012 Murray-Darling Basin Plan. During the 1990s, a competitive Australian dollar contributed to an expansion of some sectors in the Murray-Darling Basin, notably wine grapes. From the turn of the millennium, two adverse background events brought difficulties for agriculture in the Basin. First, the millennium drought resulted in reduced irrigation water allocations and contributed to diminished dry-land productivity, notably in 2002-03 and from 2006-07 to 2009-10. Overall, in 10 of the 18 years since 2002, substantial areas of the Basin suffered marked rainfall deficits. Second, the Australian dollar appreciated markedly relative to levels of the 1990s in the wake of the mining boom. This diminished returns to agriculture. The dairy industry has suffered from a deterioration in the global market.

The Basin Plan is at present concentrating on on-farm and off-farm infrastructure upgrades. An updated version of TERM-H2O shows that a hypothetical $4 billion program on upgrades between 2020 and 2024 to procure almost 500 GL of water for the environment would result in a welfare loss of almost $1.13 billion. The investment in upgrades increases jobs in the Basin by around 1000 relative to no investment for each of the five years of upgrades. Thereafter, Basin jobs increase by around 100 relative to no upgrades, based on estimated productivity gains arising from the upgrades.

This study details an alternative $4 billion expenditure, with $1.5 billion on infrastructure between 2020 and 2024 and $2.5 billion over 10 years on human services in the Basin. In this scenario, the same volume of water rights, almost 500 GL, is set for environmental purposes. Each dollar spent on human services creates four times as many jobs as spending on infrastructure upgrades. Consequently, jobs in the Basin rise relative to base by between 1,500 and 1,600 between 2020 and 2024 and thereafter by more than 1200 as long as the additional human services spending of $250 million per annum continues. The cost to the economy as a whole (the welfare loss) is $0.74 billion.

Causes of adversity in the Murray-Darling Basin

Several events have impacted adversely on the Murray-Darling Basin in recent decades. These include:

(1) The millennium drought, first in 2002-03, and then, particularly in the southern Basin, from 2006-07 to 2008-09;
(2) The soaring Australian dollar due to the mining boom from 2007 to 2015;
(3) Ongoing structural change and access to human services; and
(4) Unforeseen international events.

We examine each of these in turn.

(1) *The millennium drought*

Wittwer and Griffith (2011) modelled the impact of drought in the southern Murray-Darling Basin using an earlier version of TERM-H2O. In the Central Murray region (based on now defunct statistical sub-divisions), in which agriculture accounted for 22% of regional income (based on the 2006 census), the modelled decrease in real GDP relative to no drought was 19.7%. Over 13% of this loss arose in agriculture, with a further 4.9% arising from net water imports, necessary to sustain perennials. Food processing, through a decline in inputs, and services, via a decline in regional spending, accounted for the remainder of the loss. The Lower Murrumbidgee region suffered a 10% loss in real GDP. Agriculture's contribution of 13% was greater than the overall real GDP, made possible because net water sales contributed a positive 3.8% to the change in real GDP.

Key points from the modelling were that the aftermath continued from drought for years after, with depressed investment. Drought-induced job losses in the southern Murray-Darling Basin were around 6,000, but even several years after recovery, jobs remained around 1,500 below base due to a diminished farm capital base. A conclusion of the study was that the strong Australian dollar would have been a greater concern than either the millennium drought or water buyback policy in years subsequent to 2011.

In retrospect, by the time a high dollar had become less of an issue, after 2016, drought conditions returned. Appendix B shows that since 2002, there have been 10 calendar years out of 18 in which substantial areas of the Basin received decile 1 rainfall or less.[1] Large areas of the Basin suffered a record dry year in 2019.

(2) The soaring Australian dollar due to the mining boom from 2007 to 2015

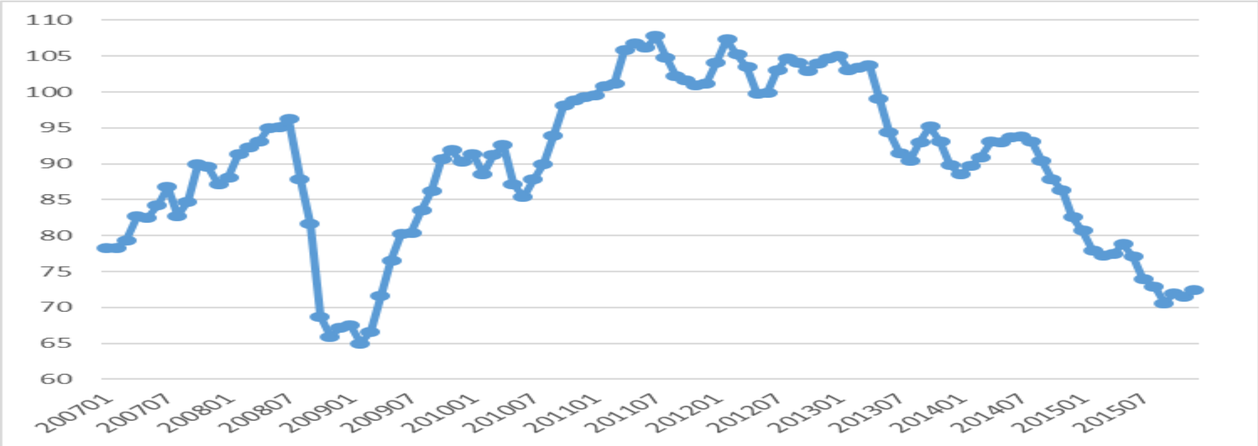
Australia's agricultural output is highly exposed to international competition. In the 108 months from January 2007 to December 2015, the Australian dollar traded at a monthly average exceeding US80c for 86 of those months (Figure 1).

Contrast this with period from January 1991 to December 2006. The Australian dollar did not reach US80c in a single month out of the 192 months in this time (figure 2). Many industries

[1] http://www.bom.gov.au/climate/cdo/about/definitionsrain.shtml:
"To determine decile 1 of a series of observations, they are first arranged in order from lowest to highest, and then divided into 10 equal groups. Decile 1 is the value at the top of the 1st grouping. Declie 1 In 10% of the years on record the monthly or yearly rainfall total did not exceed the decile 1 value."

took advantage in this time of the low dollar to expand and launch export sales. For example, Australia's vineyard plantings increased from 60,000 hectares to 167,000 hectares. Wine exports as a share of production volume rose from less than 14% in 1991 to over 50% in 2006.

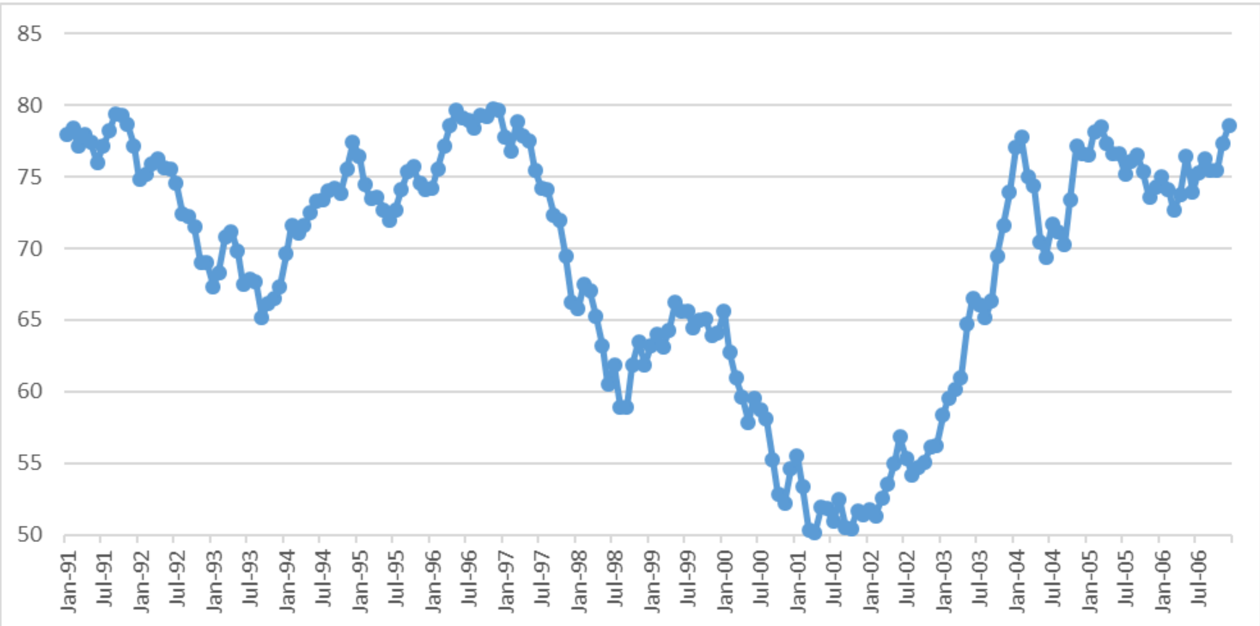
Figure 1: The US/AUS exchange rate, 2007 to 2015



Source: http://fx.sauder.ubc.ca/cgi/fxdata

There was stark contrast in the following years. A combination of prolonged drought from 2006 to 2008 and a stronger dollar thereafter lowered returns to grape-growers. From being a shining light in export expansion, the wine industry struggled with loss of competitiveness as the mining boom strengthened the Australian dollar. Drought diminished water allocations, raising the costs of grape productions as prices fell. Consequently, national plantings fell to less than 150,000 hectares by 2012 (Anderson and Pinilla, 2017).

Figure 2: The US/AUS exchange rate, 1991 to 2006



Source: http://fx.sauder.ubc.ca/cgi/fxdata

(3) Ongoing structural change and access to human services

In the early 1950s, agriculture's share of GDP in Australia was around 20% (Maddock and McLean, 1987). At the time, the national population was less than 9 million. Now, the national population exceeds 25 million and agriculture's share of GDP is well under 3%. In the Murray-Darling Basin, agriculture's share of regional income in 2015-16, based on the 2016 census, was less than 19%. That is, the Murray-Darling Basin, perceived by many as the food bowl of Australia, is now less farm-intensive in its total economic structure than all of Australia was in the early 1950s.

Some of this structural change is a success story: Australia's farm productivity has grown since the 1950s, with labour requirements falling markedly. Downstream processing of food and beverage products in the Basin accounts for around 5.5% of the income base of the Basin. That leaves three quarters of the income base of the Murray-Darling Basin in industries other than agriculture and downstream processing. With a changing economic structure over time, citizens in and out of the Basin are increasingly dependent on services. Quality of life depends on adequate access to human services. These include health, education, child care, aged care and recreational services. Provision of human services is heavily dependent on public funding. With any diminution of such funding, the Basin is vulnerable to disadvantage relative to other regions.

(4) Unforeseen international events

The dairy sector provides an example of how unforeseen external events have impacted on an industry. The sector historically has accounted for around one-sixth of irrigation water use in the Basin (ABS 2019). The dairy sector suffered during the millennium drought as water became scarce. Some dairy farmers sold their diminished annual water allocations during drought, using the proceeds to buy in stock feed. This adaptation enabled them to make the best of difficult circumstances. Regions outside the Basin had stock feed available at prices low enough to make the trade viable.

Circumstances have changed. Russian-backed rebels shot down Malaysian Airlines flight 17 over eastern Ukraine in July 2014. The European Union imposed trade sanctions on Russia in response. Russia retaliated by banning all imports from Europe. Europe's biggest market for dairy products before the ban had been Russia. Russia also banned Australian imports (Brooks 2016). These actions pushed global prices for dairy products down, adversely affecting the profitability of dairy farms, as modelled by Boulanger *et al*. (2015). Even without the drought that crept over the Basin in 2017 and worsened in 2018 and 2019, dairy farmers would have struggled given the aftermath of the MH17 disaster. Industry difficulties in Australia were exacerbated by a sharp drop in the price paid by Murray Goulburn for farmgate milk in 2016, after not following falling world price trends for several years prior.

Confusing policy and catastrophe

In an adverse event such as drought, critics may assign blame for economic losses to a coincident policy, in this case the 2007 Water Act (McCormick 2007). Community opposition to the Water Act may have arisen from structural stresses that farmers were experiencing at the time. As noted above, through 2007, the Australian dollar rose steadily. Drought was worsening in the Basin. Farmers and communities were under stress as jobs were being lost due to drought and declining international competitiveness. An unintended consequence of the Water Act is that some farmers felt during a time of stress that they were being treated as part of the problem rather than part of the solution.

The two main spending components of the 2007 Water Act were Commonwealth buybacks of irrigation water rights and public spending on infrastructure upgrades. Let us examine buybacks first. We note that buybacks fully compensated farmers at market prices and voluntary. Some contest the notion that buybacks were voluntary on the basis that some farmers were compelled to sell water rights due to financial stress. The alternative was potential bankruptcy.

Without any quantitative analysis, we can infer that if farmers sell water rights voluntarily at market prices, they are no worse off due to the buyback process. TERM-H2O modelling (Dixon *et al.*, 2011) revealed that far from depressing Basin regions, buybacks actually resulted in a small increase in overall spending.

Dixon *et al.*'s modelling showed an expected reduction in irrigation farm output, with some losses alleviated by increased water trading. Water moved to irrigation activities in which it was more valuable as it became scarcer due to buybacks. However, the reduction in irrigation output in a normal year was partly offset by an increase in dry-land output in the Basin with a transfer of some farm factors into dry-land activities. This unexpected model result that buybacks increase Basin household spending relative to no buybacks arises because the Commonwealth's purchases raise the price of water by reducing the volume available for economic uses. Since irrigators are the initial holders of water rights, they benefit from the rise in water price. Overall, there is a net export of water from irrigators to the Commonwealth, and the increase in water price contributes to a terms-of-trade gain for farmers.

Some critics of buybacks at the time asserted that they were equivalent to a permanent drought. We can compare the direct impacts of drought alongside buybacks (table 1). Drought diminishes dry-land productivity, rainfall on irrigated land and water allocations. There is no direct compensation and the process is involuntary. Buybacks provide a stark contrast: they are fully compensated and voluntary. A volume of 3500 GL proposed early in the process would have reduced water available for irrigation by around 32%, implemented over a number of years so that farmers could gradually introduce water saving measures, lessening the impact of buybacks on irrigated output.

Table 1: Estimates of direct impacts of drought and buybacks on Murray-Darling Basin farming

	Drought 2007-08 relative to base[a]	Fully implemented buybacks (3500 GL) relative to forecast
Dry-land productivity	-20%	0
Irrigation: rain	-52%	0
:water	-52%	-32%
Compensation	No	Full
Process	Involuntary	Voluntary

a Scaled to Basin-wide impacts from estimates of southern Basin impacts reported in Wittwer (2011).

Some groups including the NSW Irrigators' Council did not believe the modeled result that southern Basin farm output impacts would be small with fully implemented buybacks (NSWIC 2010). Their argument was that with the rise in the price of water, producers would lose competitiveness in international markets. But in addition to modelling an increase in the price of water of around \$100/ML, TERM-H2O results also indicated a fall in the rental on irrigated land which largely offset the water price increase, so that the impact on total costs of production was minor (Dixon *et al*., 2011).

To summarise, buybacks have become a scapegoat for adversity within the Basin for several reasons. First, the 2007 Water Act may have conveyed the impression that farmers were the problem in the Basin. Second, the Act was introduced at a time that Australian farmers were losing competitiveness due to a soaring Australian dollar resulting from the mining boom. Third, when the Act was introduced the Basin was in drought, which brought community stress, no matter how conditioned and resilient communities were to past difficulties. Fourth, global dairy prices have been depressed by trade sanctions.

A case for public provision of infrastructure upgrades

The historical methods used to establish irrigation schemes in Australia were not efficient. These included soldier settlement schemes introduced after each world war. Such schemes were likely to be inefficient because they assumed that returned soldiers would make able farmers. For some this may have been so, but for others, such schemes may have resulted in a mismatch of skills, aptitude and vocation. For decades, irrigation crops were subjected to heavy protection in Australia. However, the past few decades have seen substantial reforms with the removal of protection. Australian producers in the Basin are exposed to the vagaries of international markets.

Irrigation has enabled the establishment of plantations on land that otherwise would not receive sufficient rain to sustain perennials. It has resulted in flexible farm technologies. For example, in wet years the relative abundance of water ensures that rice production is profitable.

Council of Australian Government (COAG) reforms have resulted in separation of land and water rights. The establishment of water trading markets has enhanced flexibility within the Basin. Indeed, the millennium drought was a severe test of the resource allocation within the Basin. One issue that arose during the millennium drought was the vulnerability to reduced water allocations that arose from the extent of perennial plantings. At the time, a rapid expansion in vineyard plantings fueled by a low dollar and high grape prices in the late 1990s resulted in water shortfalls towards the end of the millennium. Water trading was a necessary mechanism to cope with drought but excessive perennial plantings may make it impossible to satisfy all water requirements as water allocations drop.

The historical context of irrigations scheme masked growers from market signals. An example of market failure might be that some water infrastructure is shared by many users. This applies to both irrigation works and town water supply infrastructure. There may be justifications on the basis of market failures for some public spending on infrastructure upgrades. However, infrastructure upgrades are not included in the federal budget, because they are regarded as part of capital rather than current expenditure. As capital works, they should be subjected to similar cost-benefit analysis as other projects. It is highly probable that if subjected to similar analysis as other projects, the spending on upgrades would be much less than past and proposed future spending.

Appropriate instruments to address policy issues

Dixon et al. (2011) showed that buybacks reduce farm output in the Basin by a small percentage, and that buyback proceeds are potentially beneficial to Basin regions. Wheeler and Cheesman (2013) presented details of the motivations of farmers for selling water to the

Commonwealth. Buybacks remain the most efficient way of procuring water for the environment, yet have blamed by many for damaging local economies. This is despite the willingness of farmers to participate in the buyback program and sell water to the Government on the understanding it would be placed in the hands of the Commonwealth Environmental Water Holder.

Structural change has been necessary in view of adverse seasons, an unfavourable exchange rate, international trade sanctions and improvements in technology. An appropriate public response to stress within and outside the Basin to adverse impacts in agriculture is to address market failures and welfare considerations.

This study presents two sets of results. The first examines the consequences of investing of $4 billion of infrastructure upgrades in the Basin in order to obtain environmental water, the latter amounting to nearly 500 GL. This proposed spending is hypothetical: actual spending in coming years may have a markedly different pattern in terms of value and actual expenditures. The second scenario imposes a similar diversion of water away from economic uses to the environment while spending $1.5 billion on upgrades and an additional $2.5 billion in the Basin on human services.

Modelling of proposed infrastructure upgrades from 2020 to 2024

The scenario depicted in this study allocates $800 million of infrastructure upgrades to Murray-Darling Basin regions in each of five years from 2019-20 to 2023-24. The objective is to increase efficiency in irrigated agriculture and town water usage so almost 500 GL of irrigation water entitlements are diverted for environmental purposes. Investments at the regional level have been mapped from data provided by Marsden Jacob at the natural resource management region (NRM) to SA3 regions within TERM-H2O.

The productivity of irrigation agriculture rises successively from 2021 to 2025. ABARES provided estimates of increased outputs. We assumed that three-quarters of the increased irrigation output estimated by ABARES was due to factor transfers and one quarter due to productivity gains.

Figure 3: Macro impact, Murray Darling Basin, scenario 1
(% deviation from base)

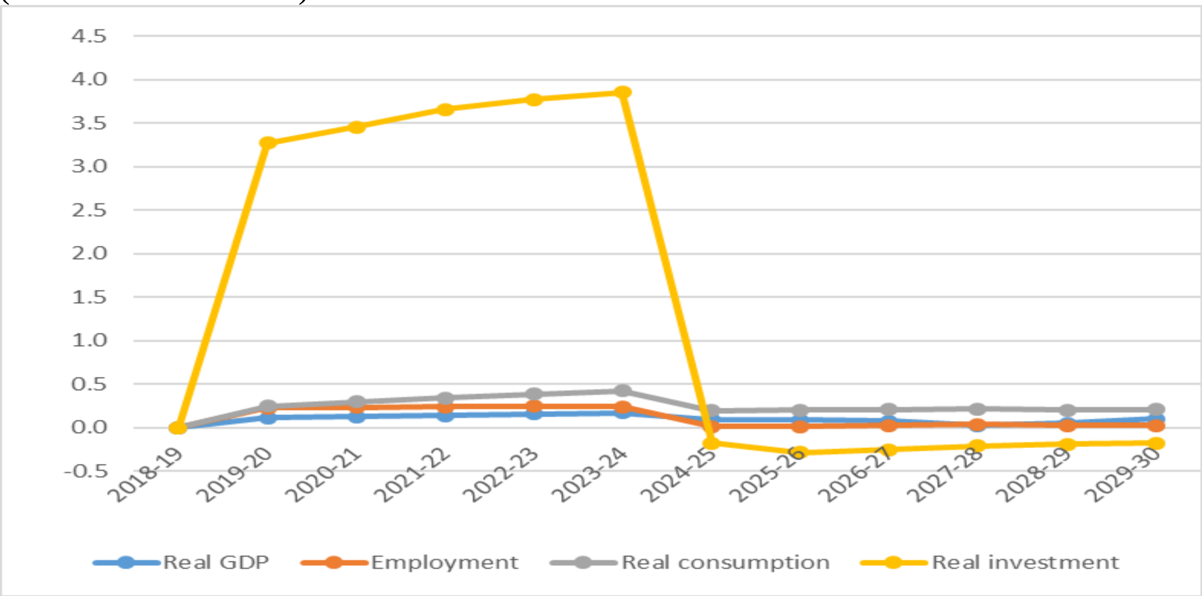


Figure 3 shows the percentage deviations in Basin-wide macro variables. The investment phase raises Basin-wide investment by 3.2 to 3.8% above forecast. At the same time, Basin-wide employment rises by around 0.25% or around 1000 jobs. Once the investment phase has ended and almost 500 GL of water rights allocated to the environment, employment moves back towards base. From 2024-25, Basin-wide employment increases by around 100 jobs relative to base.

During the investment phase, there are small output losses in some irrigation sectors relative to base. This reflects the removal of some irrigation water from economic purposes. Gradually, improved productivity more than offsets these losses.

Figure 4 compares year-on-year seasonal variations with the marginal impacts of infrastructure spending. Seasonal conditions result in substantial annual fluctuations in dry-land productivity and water allocated to irrigation. As is evident from comparing the scales of the respective graphs, the impacts of seasonal variation are much larger than the impacts of infrastructure upgrades across the Basin.

Figure 4: Value-added by broad sector and aggregate consumption, all Murray Darling Basin

($m year-on-year changes due to seasonal variation) ($m impacts of upgrades)

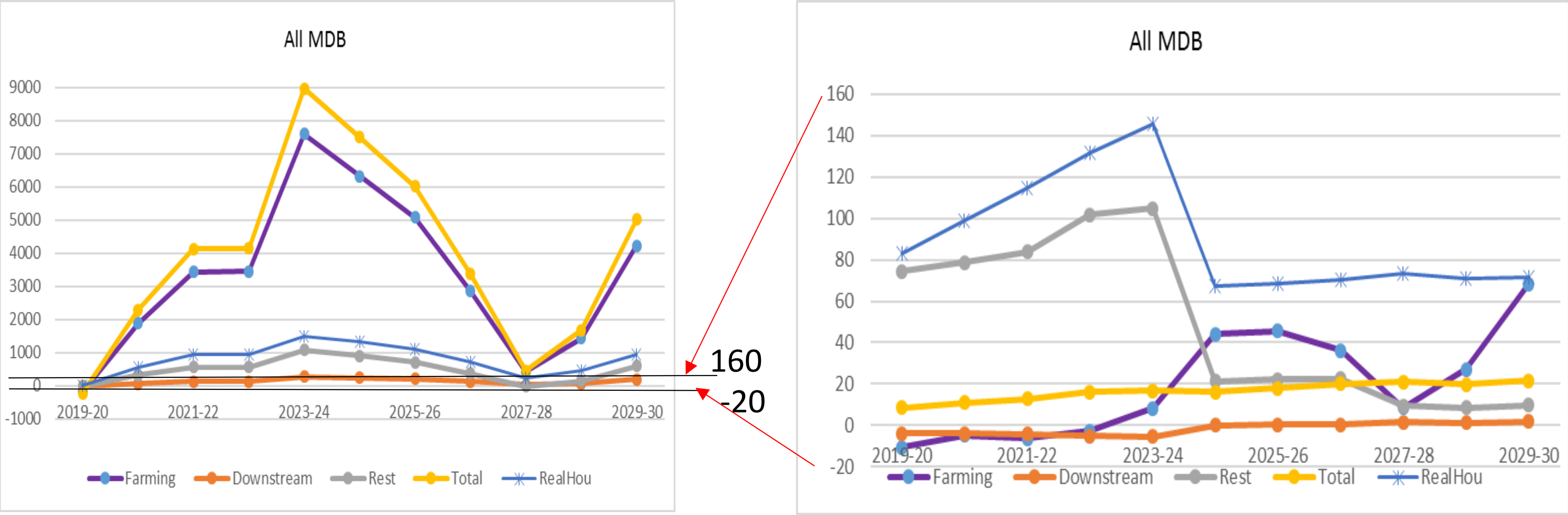


Table 2: Sectoral impacts of scenario 1, Southern Murray-Darling Basin

($m deviation in value-added)

	OtherAgriDRY	OthAgI	Vegetb	Grapes	FrutTr	Almond	OthrLivestok	Rice	GrainsDRY	GrainI	CottonDRY	CottnI	HayCerFodDRY	HayCFI	DairyCattle	Downstream	Rest	Total
2019-20	0.1	-0.3	-0.2	-0.6	-1.1	-0.7	-1.9	-0.1	-3.8	0.3	-0.1	-0.1	0.6	-0.4	-1.1	-6.5	83.5	67.6
2020-21	0.4	0.6	3.3	0.4	2.3	0.8	-1.6	-0.5	0.8	-8.0	0.5	-0.4	5.9	-6.1	-0.7	-6.6	88.3	79.4
2021-22	0.8	0.8	4.9	1.1	4.8	2.2	-2.3	-0.8	5.2	-16.7	1.9	-1.8	7.1	-7.7	-0.6	-7.4	94.4	85.8
2022-23	1.2	1.5	7.8	2.2	8.3	3.8	-1.7	-1.2	11.1	-25.4	3.0	-2.8	10.4	-11.5	0.0	-7.5	101.1	100.1
2023-24	1.9	0.9	11.7	3.6	13.1	6.2	-2.6	-1.0	16.7	-33.8	1.6	-0.5	13.2	-13.2	-0.1	-7.8	103.5	113.4
2024-25	3.1	2.3	15.6	5.8	18.9	8.9	6.0	-1.3	36.7	-47.6	3.1	-3.4	15.6	-16.7	4.4	1.5	9.7	62.6
2025-26	3.1	2.3	16.4	5.9	19.7	9.2	6.1	-1.5	35.6	-48.2	3.7	-6.6	14.0	-14.5	4.5	1.8	9.2	60.6
2026-27	3.5	2.2	20.2	6.1	22.1	9.5	6.8	-2.2	41.3	-58.8	6.6	-22.8	18.4	-19.7	4.3	2.3	9.0	48.9
2027-28	2.6	2.6	30.3	6.9	28.4	10.7	7.0	-3.9	43.3	-71.9	9.0	-67.1	13.3	-13.1	3.8	3.4	9.4	14.7
2028-29	3.2	1.9	23.7	6.6	25.0	10.3	6.7	-3.0	42.3	-63.8	8.4	-42.3	17.5	-19.0	4.2	2.8	8.4	32.9
2029-30	4.3	3.0	24.8	7.6	27.9	11.7	9.4	-2.1	48.1	-62.9	5.8	-17.9	20.8	-21.5	5.1	3.4	10.1	77.7

Table 3: Sectoral impacts of scenario 1, Northern Murray-Darling Basin

($m deviation in value-added)

	OtherAgriDRY	OthAgI	Vegetb	Grapes	FrutTr	Almond	OthrLivestok	Rice	GrainsDRY	GrainI	CottonDRY	CottnI	HayCerFodDRY	HayCFI	DairyCattle	Downstream	Rest	Total
2019-20	0.0	0.0	0.0	0.0	0.0	0.0	-0.6	0.0	-0.3	0.0	-0.1	-0.1	0.0	0.0	0.0	-1.3	4.6	2.3
2020-21	-0.1	0.1	0.0	0.0	0.0	0.0	-0.8	0.0	0.3	0.1	-0.2	-0.2	-0.2	0.1	0.0	-1.4	4.7	2.4
2021-22	-0.2	0.3	0.0	0.0	0.0	0.0	-1.0	0.0	0.6	0.1	-0.2	-0.3	-0.4	0.3	0.0	-1.6	5.0	2.6
2022-23	-0.3	0.4	-0.1	0.0	-0.1	-0.1	-1.0	0.0	1.0	0.2	-0.3	-0.4	-0.5	0.6	0.0	-1.6	5.3	3.1
2023-24	-0.7	0.3	-0.1	0.0	-0.1	-0.1	-1.4	0.0	0.7	1.4	-1.7	0.6	-0.9	0.7	0.1	-1.8	5.2	2.3
2024-25	-1.0	0.5	-0.2	0.0	-0.1	-0.1	0.1	0.0	1.8	1.9	-2.7	1.5	-1.0	1.2	0.0	0.1	0.2	2.4
2025-26	-0.9	1.1	-0.2	0.0	-0.1	-0.1	0.3	0.0	2.8	1.8	-2.4	1.2	-0.9	1.2	0.1	0.1	0.2	4.1
2026-27	-1.0	1.5	-0.5	0.0	-0.2	-0.1	0.1	0.0	3.7	1.8	-2.5	1.3	-0.8	1.2	0.1	0.2	0.3	5.0
2027-28	-1.0	1.5	-1.4	0.0	-0.3	-0.1	-0.2	0.0	4.3	1.8	-3.1	2.3	-0.7	0.8	0.0	0.2	0.4	4.7
2028-29	-1.0	1.6	-0.8	0.0	-0.2	-0.1	-0.1	0.0	3.1	1.9	-2.9	2.2	-0.8	1.2	0.0	0.3	0.4	4.6
2029-30	-1.3	1.4	-0.8	0.0	-0.2	-0.1	0.0	0.0	3.9	2.0	-2.8	1.5	-1.1	1.3	0.0	0.4	0.3	4.3

Table 2 shows the change in value-added at the basin-wide level for farming sectors. A reduction in available water moves it into activities in which the average product of water is higher. For example, vegetables output increases. There is an increase in perennial outputs relative to base as a consequence of productivity improvements arising from infrastructure upgrades. The sectors which lose are those that relatively water-intensive, namely rice, irrigated grains, irrigated cotton and irrigated hay. In the case of grains, cotton and hay, there is a movement of inputs into corresponding dry-land production. For example, irrigated grains value-added in 2029-30 is $61 million below base, whereas dry-land grains value-added is $52 million above base.

The annualised welfare impact of the upgrades is minus $45 million. If we use the usual NPV calculation (of deviation in current consumption minus the real discounted increase net foreign liabilities in the final simulation year), the welfare loss is $1.1 billion. That is, public spending of $4 billion results in a welfare loss that is a substantial proportion of the money spent.

At the regional level (see appendix B for a map of regions), we present broad sectoral results in two groups. The first group includes regions in the Northern Basin, in which infrastructure upgrade spending is relatively small. Assumed productivity gains are also relatively small. Consequently, both the sectoral and macro changes are small relative to base ("total" adds up regional income and "RealHou" is regional aggregate household consumption).

Figure 5: Value added by broad sector, selected Northern Basin regions, scenario 1 ($m deviation from base)

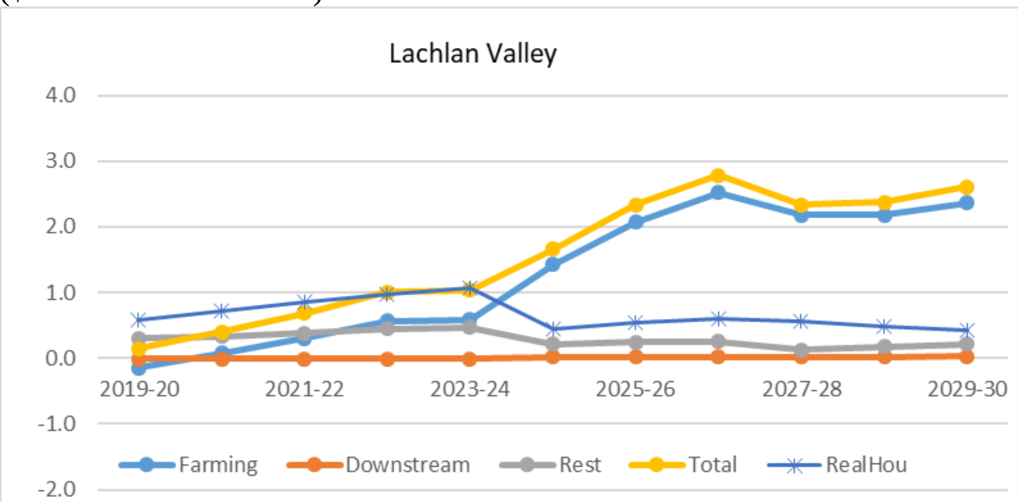
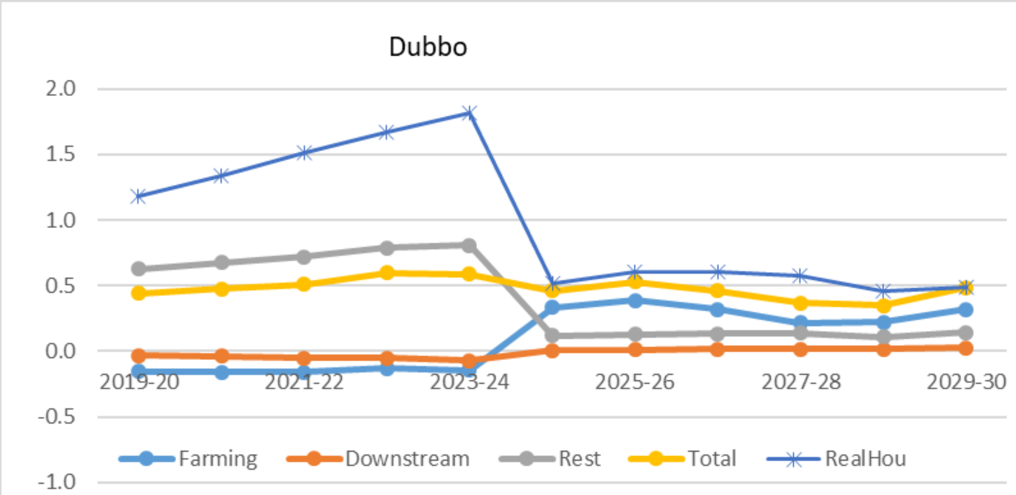


Figure 5 (cont.): Value added by broad sector, selected Northern Basin regions, scenario 1 ($m deviation from base)



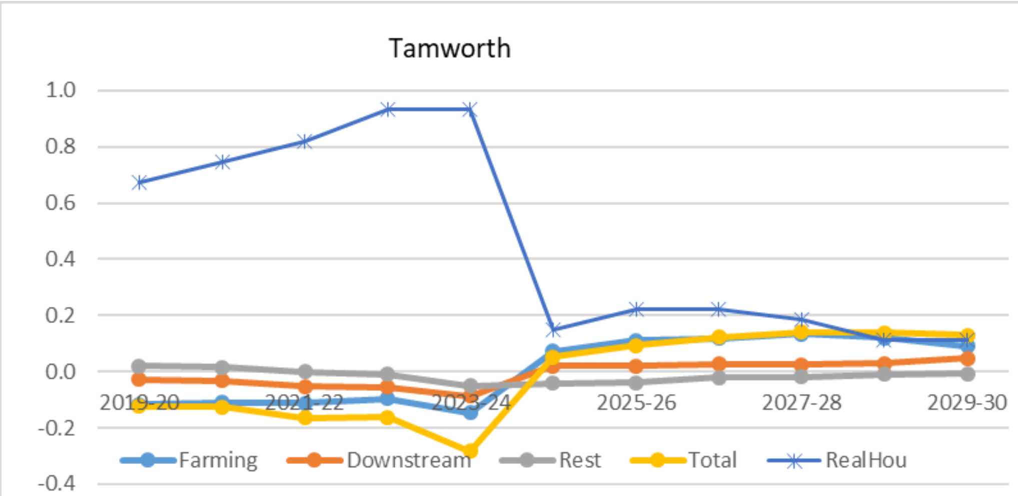


Figure 6 shows outcomes for selected regions in the Southern Basin. Infrastructure spending is generally larger than in northern regions, assumed productivity gains are larger and the story is complicated by water trading. We see that the first region in Figure 6, Griffith-Murrumbidgee, is a substantial net exporter of water to other regions in most years, relative to base. From tables A2 and A3, the basin is in drought in 2027-28. This results in the price of water being high in 2027-28, raising the income from net exports of water. In this year, Griffith-Murrumbidgee's farm output falls by around $70 million relative to base, but proceeds from net water exports exceed $50 million. Although total regional income falls relative to the no-upgrades base in this year, real consumption still remains slightly above base.

A contrasting region is Murray River – Swan Hill, whose net imports of water from other southern regions increase relative to a no-upgrades base in all years. Therefore, net water trades make a negative contribution to regional income. However, farm income rises above base in all years other than the first, 2019-20.

In summary, infrastructure upgrades may have marked impacts on water trading between sectors and regions across the basin. Some sectors lose out with a reduction in water availability but there may be partly compensating increases in dry-land production. The employment impacts are much larger during the investment phase of 2020 to 2025 than thereafter: although farming outputs across the basin increase relative to base with upgrades in place and with the realization of productivity benefits, they are relatively small at the regional macro level. Moreover, since farming is not labour-intensive relative to other activities, particularly services, the employment impacts after the investment phase is completed are small.

Figure 6: Value added by broad sector, selected Southern Basin regions, scenario 1
($m deviation from base)

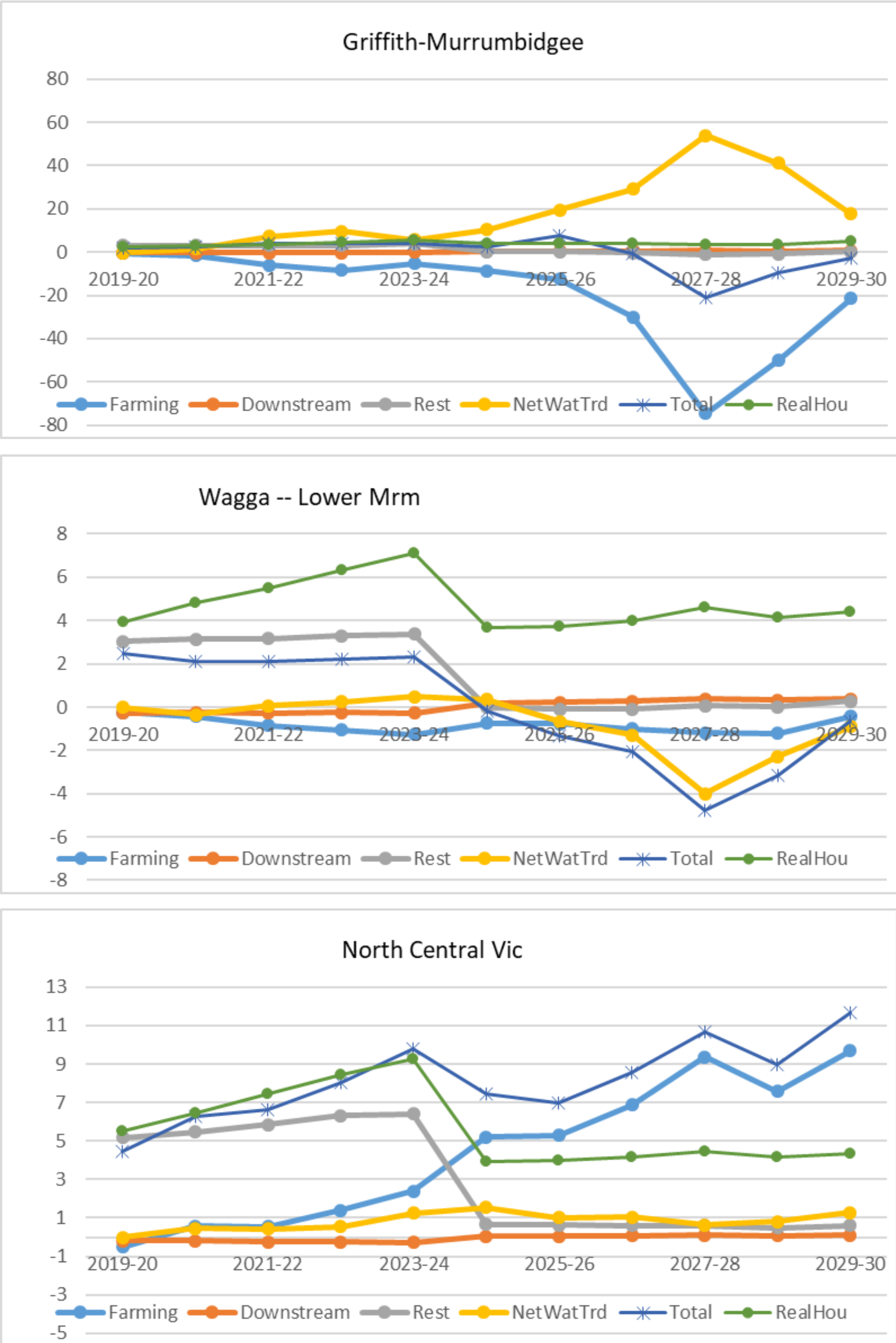


Figure 6 (cont.): Value added by broad sector, selected Southern Basin regions, scenario 1 ($m deviation from base)

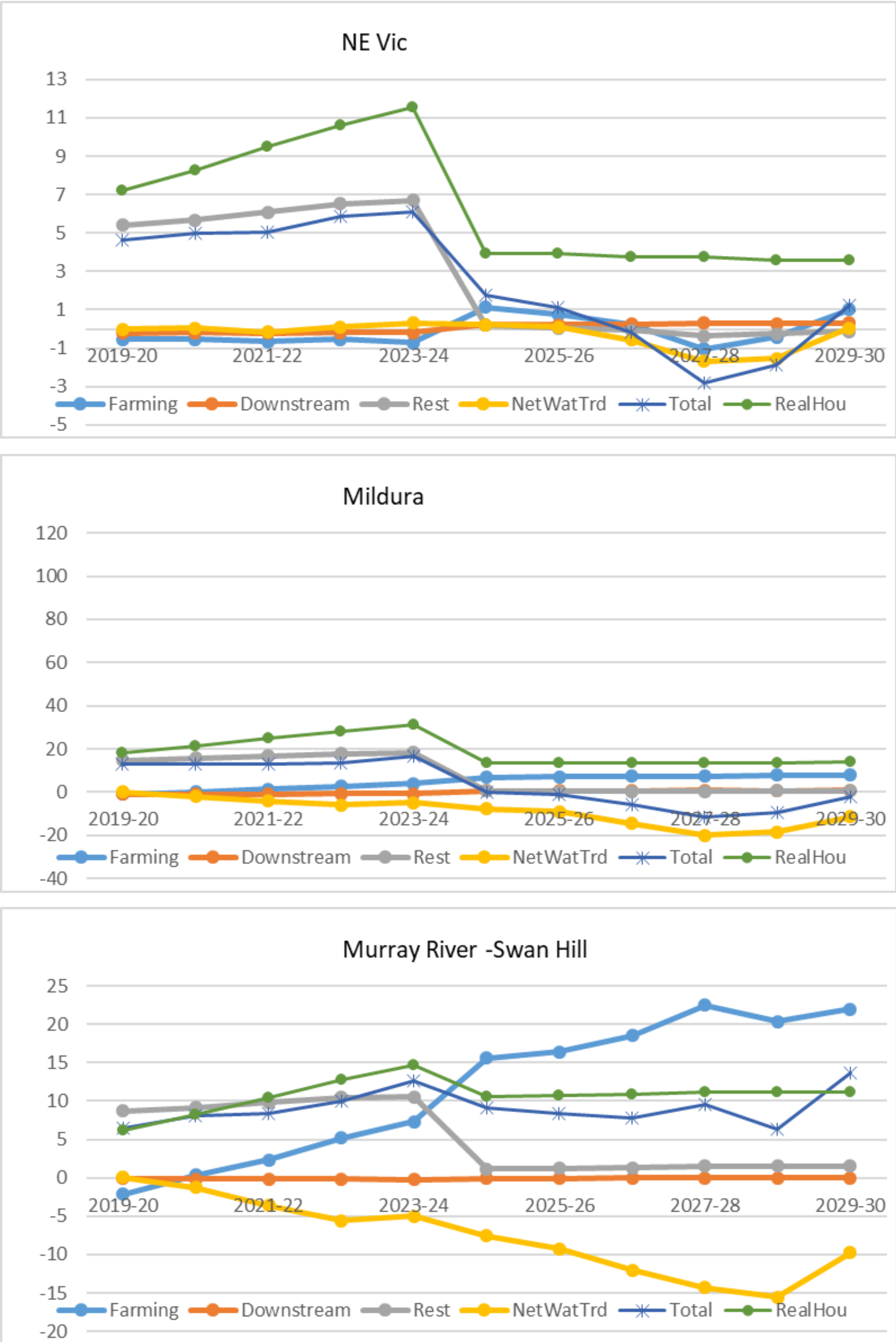
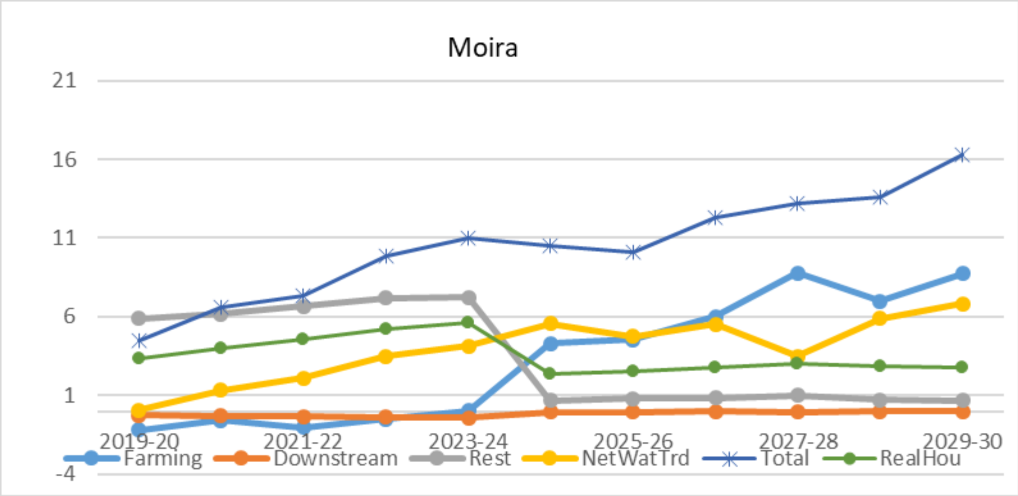
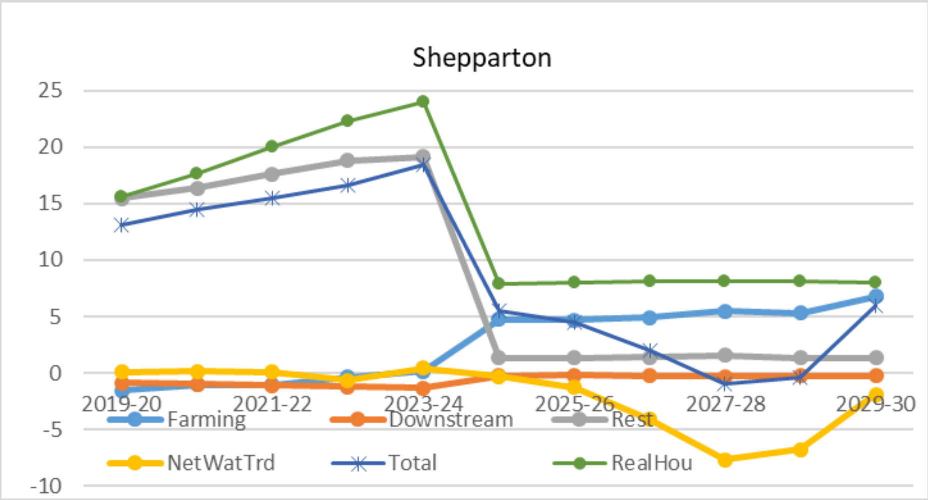


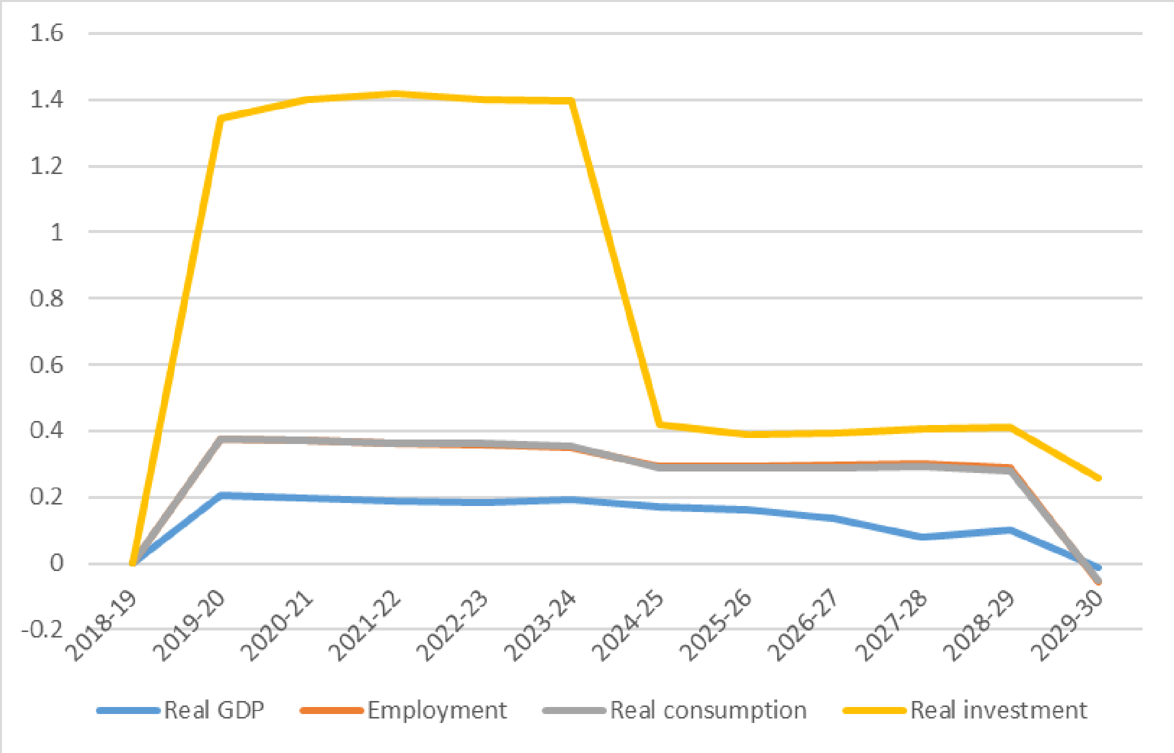
Figure 6 (cont.): Value added by broad sector, selected Southern Basin regions, scenario 1 ($m deviation from base)





Scenario 2: Modelling of $1.5 bn of upgrades from 2020 to 2024 and $2.5bn of human services from 2020 to 2029 in the Basin

Figure 7: Macro impact, Murray-Darling Basin, scenario 2
(% deviation from base)



In an alternative hypothetical scenario, we detailed the impacts of an alternative $4 billion expenditure, with $1.5 billion on infrastructure between 2020 and 2024 and $2.5 billion over 10 years on human services in the Basin. As in scenario 1, almost 500 GL of water rights are removed from economic use. This time, with infrastructure spending being smaller, the consequent productivity gains in irrigated activities are proportionally smaller. $2.5 billion fund human services, namely the health, education and community care sectors, from 2020 to 2029. Figure 7 shows the basin-wide macro deviations in this scenario. Figure 3 shows the corresponding macro results for scenario 1. Real GDP in the Basin rises to around 1.4% during the infrastructure investment plus human services expenditure phase (figure 8). Employment rises by 1500 to 1600 jobs across the Basin in this phase. Each dollar spent on human services creates four times as many jobs within the Basin as infrastructure upgrades spending. So as infrastructure upgrades end in 2024 and additional public spending on human services in the basin continues, jobs within the basin remain more 1200 above base for the duration of this spending. The finding that spending on human services creates four times as many jobs per dollar spent as comparable spending on infrastructure upgrades is consistent with Wittwer and Dixon (2013).

In this scenario, there is an unambiguous decline in farm output relative to base due to the removal of water from economic uses between 2019-20 and 2024-25 (figure 7). Again, in the drought years of 2027-28 and 2028-29, the losses are larger. But there is also an unambiguous gain in Basin income, driven mainly by an increase in services value-added. When additional funding ends, as in 2029-30, activities in services sectors return to near base.

Table 4: Sectoral impacts of scenario 2, Southern Murray-Darling Basin

($m deviation in value-added)

	OtherAgriDRY	OthAgI	Vegetb	Grapes	FrutTr	Almond	OthrLivestok	Rice	GrainsDRY	GrainI	CottonDRY	CottnI	HayCerFodDRY	HayCFI	DairyCattle	Downstream	Rest	Total
2019-20	0.1	-0.1	-0.4	-0.6	-1.3	-0.9	-1.4	0.0	-3.0	0.3	-0.2	-0.1	-0.6	-1.0	-0.9	-7.0	138.8	121.8
2020-21	0.6	-0.2	1.5	-0.2	0.3	-0.3	-1.2	-0.4	3.0	-8.4	0.7	-0.8	7.1	-10.5	-0.8	-6.8	138.1	121.8
2021-22	1.1	-0.7	1.8	0.0	0.8	0.0	-1.6	-0.6	8.1	-16.8	1.8	-2.0	11.0	-15.4	-0.9	-6.8	136.9	116.7
2022-23	1.8	-0.8	3.2	0.3	2.1	0.5	-1.2	-0.9	14.6	-25.4	2.9	-3.1	17.1	-23.0	-0.6	-6.5	136.4	117.4
2023-24	2.3	-0.5	5.4	1.0	4.3	1.6	-0.7	-0.7	23.6	-35.1	1.3	-0.5	19.3	-23.8	-0.6	-6.1	135.5	126.3
2024-25	2.8	0.0	7.1	1.7	6.5	2.5	1.8	-0.8	27.9	-38.6	2.0	-3.4	21.0	-26.0	0.7	-3.5	112.9	114.6
2025-26	2.9	-0.5	7.5	1.7	6.9	2.7	1.9	-1.0	27.2	-39.0	2.6	-6.7	20.6	-26.0	0.8	-3.3	112.2	110.4
2026-27	3.6	-1.3	10.3	1.9	8.5	2.8	2.6	-1.5	32.5	-48.6	5.3	-23.2	23.7	-31.3	0.9	-3.0	111.9	95.1
2027-28	3.0	-1.8	18.3	2.4	13.4	3.7	3.3	-2.8	35.2	-60.9	7.7	-68.9	16.9	-24.6	0.7	-2.3	112.0	55.2
2028-29	3.6	-2.1	12.7	2.0	10.2	3.1	2.7	-2.1	33.6	-53.1	7.0	-43.2	22.0	-30.7	0.8	-2.7	111.3	75.3
2029-30	4.4	-0.6	13.9	3.1	13.1	4.7	5.8	-1.4	40.2	-51.9	4.8	-18.2	27.7	-32.2	2.1	3.4	-28.7	-9.7

Table 5: Sectoral impacts of scenario 1, Northern Murray-Darling Basin

($m deviation in value-added)

	OtherAgriDRY	OthAgI	Vegetb	Grapes	FrutTr	Almond	OthrLivestok	Rice	GrainsDRY	GrainI	CottonDRY	CottnI	HayCerFodDRY	HayCFI	DairyCattle	Downstream	Rest	Total
2019-20	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	0.0	-0.1	0.0	-0.2	-0.1	0.0	0.0	0.0	-0.7	7.4	6.1
2020-21	-0.1	0.0	0.0	0.0	0.0	0.0	-0.4	0.0	0.6	0.0	-0.1	-0.3	0.0	0.0	0.0	-0.8	7.3	6.0
2021-22	-0.1	0.0	0.0	0.0	0.0	0.0	-0.5	0.0	0.9	-0.1	0.2	-0.6	0.0	0.0	0.0	-0.9	7.2	6.0
2022-23	-0.2	0.0	-0.1	0.0	0.0	0.0	-0.6	0.0	1.3	-0.2	0.2	-0.8	0.0	0.1	0.0	-0.9	7.2	6.1
2023-24	-0.3	0.0	-0.1	0.0	0.0	0.0	-0.7	0.0	2.2	0.1	-0.5	-0.6	-0.1	0.0	0.0	-0.9	6.9	6.1
2024-25	-0.1	0.0	-0.1	0.0	0.0	0.0	-0.2	0.0	3.4	-0.5	0.5	-1.9	-0.1	0.1	0.0	-0.3	5.0	5.8
2025-26	0.0	0.5	-0.1	0.0	0.0	0.0	-0.1	0.0	4.1	-0.6	1.3	-2.8	0.0	0.1	0.0	-0.3	5.0	7.0
2026-27	-0.3	0.7	-0.4	0.0	-0.1	0.0	-0.3	0.0	4.5	-0.7	1.6	-3.2	0.0	0.2	0.0	-0.4	4.9	6.6
2027-28	-0.6	0.3	-1.1	0.0	-0.2	-0.1	-0.5	0.0	4.5	-0.7	1.4	-3.0	0.0	0.0	0.0	-0.5	4.9	4.3
2028-29	-0.5	0.3	-0.6	0.0	-0.1	-0.1	-0.5	0.0	3.7	-0.8	1.3	-2.7	0.0	0.1	0.0	-0.4	4.9	4.6
2029-30	-0.4	0.5	-0.6	0.0	-0.2	-0.1	-0.2	0.0	4.7	-0.7	1.3	-2.8	0.0	0.2	0.0	0.0	-2.8	-0.9

Figure 8: Value added by broad sector, selected Northern Basin regions, scenario 2
($m deviation from base)

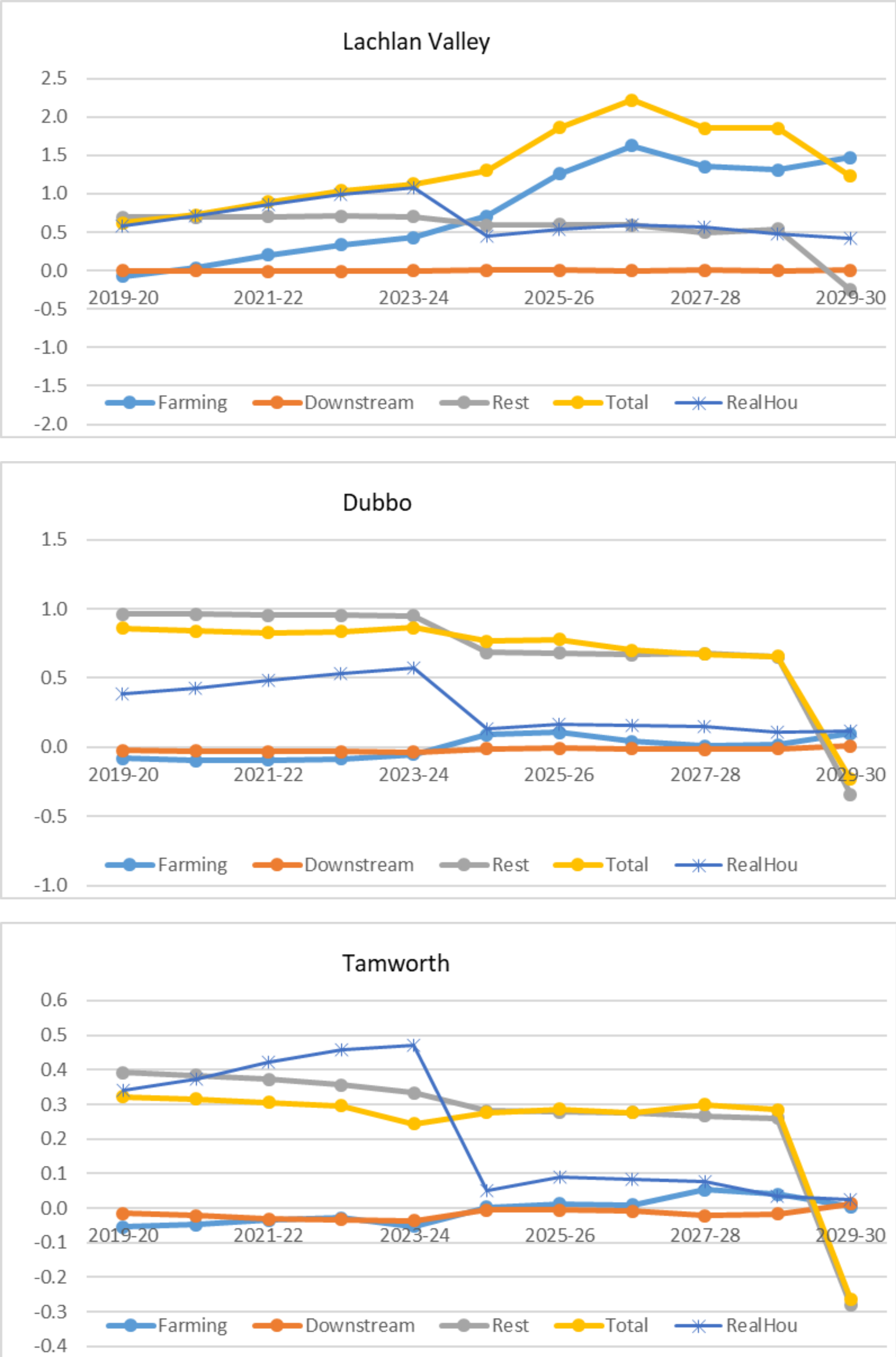


Figure 9: Value added by broad sector, selected Southern Basin regions, scenario 2
($m deviation from base)

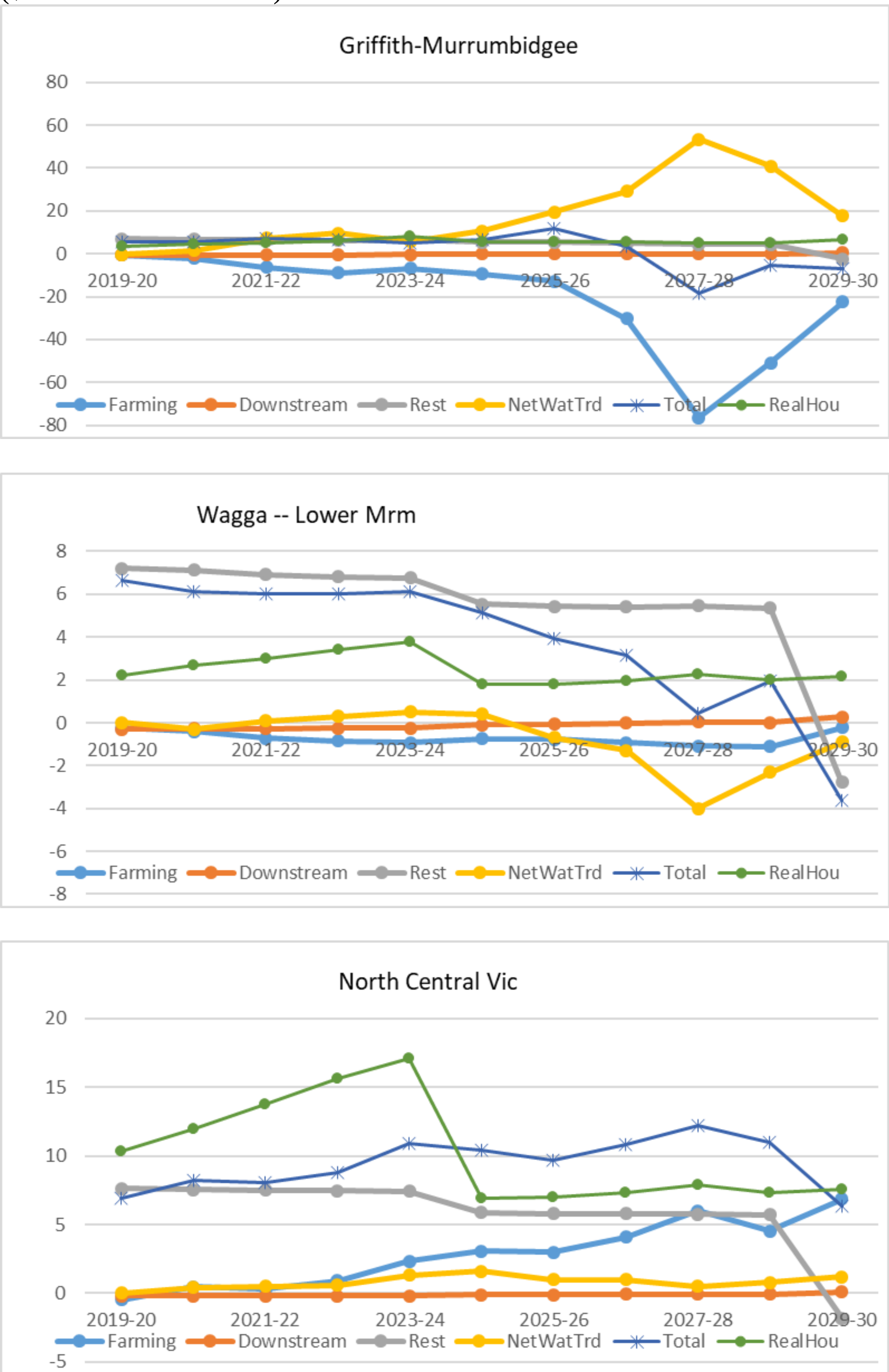
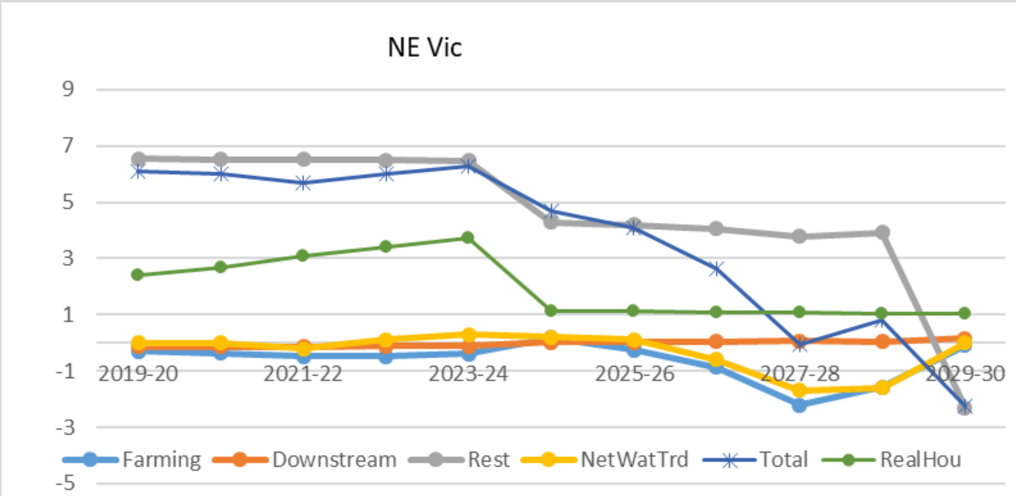
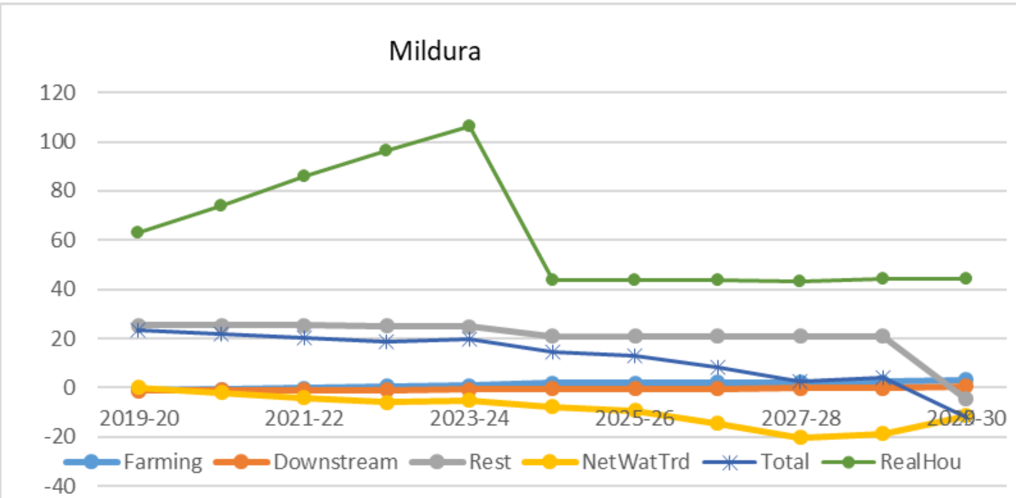


Figure 9 (cont.): Value added by broad sector, selected Southern Basin regions, scenario 2
($m deviation from base)





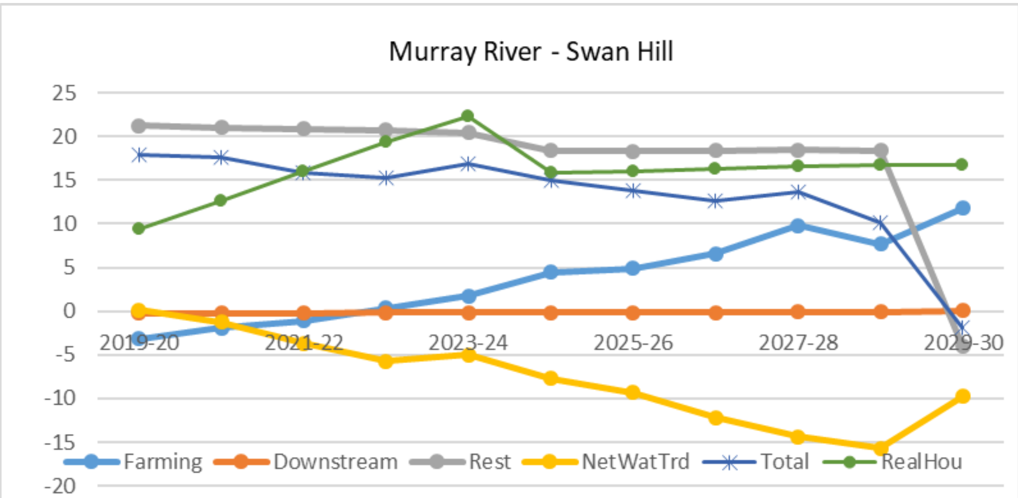
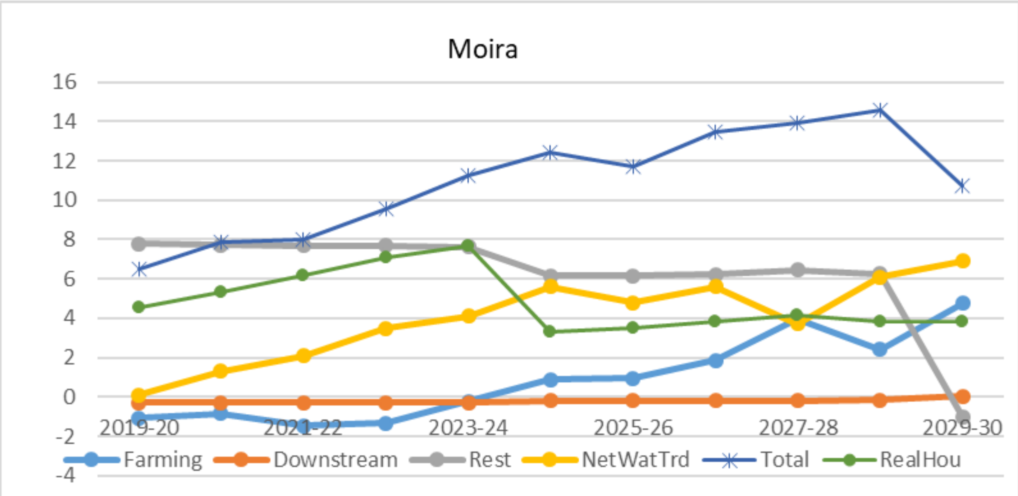
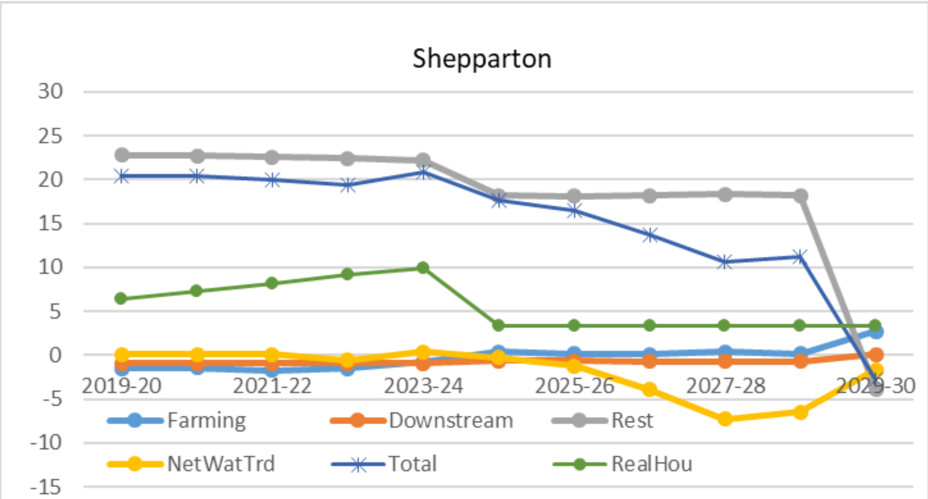


Figure 9 (cont.): Value added by broad sector, selected Southern Basin regions, scenario 2





The annualised welfare impact of a combination of instructure upgrades and increased public spending on Basin human services plus removal of 500 GL of water from irrigation is minus $30 million. The NPV calculation of the welfare loss is $0.74 billion. In terms of the national welfare impact and additional jobs created in the basis, this scenario provides a better use for public funds by bolstering human services in Basin regions. In neither scenario does the welfare calculation include the environmental benefits of improved environmental flows nor benefits that might arise from improved water security in basin towns arising from some upgrade expenditures.

We note that infrastructure upgrades result in lasting productivity gains beyond the five year spending package of scenario 1. However, jobs remain only around 100 above base after 2024-25. It could be that additional human services spending also has lasting productivity gains, particularly for labour productivity, to the extent that such services improve health, training and amenities within Basin communities.

Conclusion

The theoretical problem with infrastructure upgrades is they are seeking to address two policy objectives at once, namely to provide water for the environment and to support jobs and incomes within the Basin. It would be more efficient and more equitable to use two separate policies. Buybacks are a relatively efficient means of increasing environmental water flows and are much cheaper than upgrades. It would appear that buybacks have fallen out of favour due to a misdiagnosis of the causes of adversity in the Basin. Increases in public funding of human services within Basin regions will create many more regional jobs than upgrades. The contrast between the national welfare impacts of infrastructure funding relative to setting water aside for the environment while increasing human services spending is significant. In the infrastructure upgrade scenario, $4 billion of public spending results in a welfare loss of $1.1 billion, much greater than the welfare loss ($0.74 billion) from the alternative scenario.

A theoretical consequence of subsidies is that they lead to overinvestment in subsidized sectors. In the Basin, there may have been overinvestment in certain farm activities. In particular, the Basin is now over-exposed to almond plantings. Overinvestment may have occurred without publicly funded infrastructure upgrades, given the vulnerability of perennial plantings to booms and busts, but in all probability, such upgrades are partly responsible. Although at present prices, almond plantings are providing high rates of return, it has come at the expense of flexibility. That is, with too many hectares of permanent plantings, the Basin's annual water allocations in drier years may be too low to cover the water requirements of perennials. Moreover, almond plantings have pushed up the price of water within the Basin, thereby impacting on the profitability of the producers of other annuals who wish to buy temporary water in drier years.

References

ABS (2019), Water use on Australian farms, catalogue 4618.0. https://www.abs.gov.au/Ausstats/abs@.nsf/0/651F2B711AD032D5CA2575C10012DA4A?OpenDocument. Accessed 17 Janaury 2020.

Anderson, K. and V. Pinilla (2017), Annual Database of Global Wine Markets, 1835 to 2016, Wine Economics Research Centre, University of Adelaide, August (freely available in Excel files at www.adelaide.edu.au/wine-econ/databases)

McCormick, B. (2007), A national plant for water security. https://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/rp/BudgetReview_2007-_2008/National_Plan_for_Water_Security. Accessed 17 January 2020.

Brooks, E. (2016), "What You Need To Know About The Dairy Crisis**",** https://www.huffingtonpost.com.au/2016/08/29/what-you-need-to-know-about-the-dairy-crisis_a_21454074/. Accessed 17 January 2020.

Dixon, P., Parmenter, B., Sutton, J. Vincent, D, (1982) *ORANI: A Multisectoral Model of the Australian Economy*. Contributions to Economic Analysis 142, Amsterdam, North-Holland.

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

NSWIC (New South Wales Irrigators' Council) 2010, Submission to Productivity Commission: market mechanisms for recovery water in the Murray Darling Basin. Australian Government, Melbourne.

Wheeler, S. and Cheesman, J. (2013), “Key Findings from a Survey of Sellers to the *Restoring the Balance* Programme”. *Economic Papers* 32(3):340-352.

Wittwer, G. (2011), Confusing policy and catastrophe: Buybacks and drought in the Murray-Darling Basin. *Economic Papers* 30:289-295.

Wittwer, G. and Dixon, J. (2013), “Effective use of public funding in the Murray-Darling Basin: a comparison of buybacks and infrastructure upgrades”**,** *Australian Journal of Agricultural and Resource Economics* 57:399-421.

Wittwer, G. and Griffith, M. (2013), “Modelling drought and recovery in the southern Murray-Darling Basin”**,** *Australian Journal of Agricultural and Resource Economics* 49:342-359.

Appendix A

Preparation of a suitable CGE model for Basin scenarios: TERM-H2O

Water use by crop varies substantially across the Basin, driven by changes in seasonal conditions, water allocations and farm output prices. In the drought of 2002, water use in rice production dropped by more than 70% relative to the previous year. In 2008, water used in rice production was only 2% of that in 2006 (ABS cat. 4618.0). The challenge in devising TERM-H2O (Dixon et al., 2011) was to come up with theory that tracks approximately changes in water use in response to changes relative water scarcity.

Table A1 shows the substantial variation in water availability across the Murray-Darling Basin from 2007-08 to 2017-18. The data shown in the table includes updates from earlier studies (Dixon et al. 2011; Wittwer and Griffith 2011), including the relatively wet years of 2010-11 and 2011-12. The additional years of data serve to illustrate features of TERM-H2O that are useful in both dry and wet years.

2008-09 was the last season of the millennium drought in the southern Basin; in the northern Basin, the drought broke early in 2008. The water price shown reflects temporary water trades in the southern Basin. The water price reflects current water availability, rainfall conditions and farm output prices. For example, in 2007-08 prior to the GFC, a biofuels boom drove up crop prices and the marginal product of water with it. Table A1 (row 13) shows that the water price in 2008-09 was $298/ML with drought still prevailing in the southern Basin, whereas in the previous year it was $680/ML prior to the GFC-induced collapse in commodity prices. Rice is the most water-intensive of crops grown in the Basin and therefore the most responsive to changes in water price. In the past decade or so, the volume of water used in rice production has varied from 27 GL in 2007-08 to 1434 GL in 2012-13 (Table A1, row 3).

Turning to perennials, water used for grapes dropped below 400 GL only in the La Nina years 2010-11 and 2011-12, when rainfall was sufficiently high to reduce irrigation requirements (Table A1, row 6). The upward trend in water used by other perennials reflects a substantial increase in almond plantings since 2007.[2]

Table A1 also shows water used in pasture, hay and silage (row 8). These feed products are either inputs into livestock production locally, or are sold outside the Basin. The table shows a 40-fold difference in the price of water between 2007-08 (i.e., $680/ML) and 2011-12

[2] See http://growing.australianalmonds.com.au/wp-content/uploads/sites/17/2014/06/ Australian-Almond-Insights-2013-14-LR-WEB.pdf (accessed 29 August 2016).

($16/ML) (Table A1, row 13). Even in drought when the price of livestock feed rises, it is highly probable that a livestock farmer within the Basin would gain by selling water to fund feed purchases instead of using scarce water to grow on-farm livestock feed. Dairy farmers in the drought years up to and including 2019 did not regard this as an option due to depressed output prices.

Table A1: Water use in the Murray-Darling Basin

Year	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
1 Area irrigated ha*10^6	1.0	0.9	1.0	1.2	1.4	1.6	1.6	1.4	1.2	1.4	1.5
2 Not irrigated ha*10^6	94.6	95.1	94.2	83.8	93.6	88.4	89.1	87.8	82.8	88.7	NA
Crop			Water used (GL)								
3 Rice	27	101	205	755	1134	1434	912	876	299	935	725
4 Cotton	283	793	764	1789	1906	2735	2676	1114	1294	2420	2505
5 Other annuals	1044	1066	719	537	725	1334	1368	1226	815	912	1066
6 Grapes	434	439	428	303	365	463	415	431	428	374	410
7 Other perennials	356	374	450	379	475	567	713	502	664	598	678
8 Pasture, hay, silage	997	719	998	744	1270	2041	1941	2025	1438	1423	1681
9 Total	3141	3492	3564	4507	5875	8574	8025	6174	4938	6662	7065
			Source (GL)								
10 Irrigation schemes	NA	1573	1830	1705	2768	4228	3494	3212	2088	2874	3098
11 Groundwater	NA	1069	989	570	568	686	863	844	926	713	976
12 Other (dams, creeks, etc.)	NA	850	745	2232	2539	3660	3668	2118	1924	3075	2991
13 Water price (AUS$/ML)*	680*	298*	148*	26*	16*	51	64	106	168	85	120

Source: ABS Cat. 4618.0, various years.
*http://www.murrayirrigation.com.au/water/water-trade/water-exchange-history/ provided Murray Irrigation weighted sales that were reasonable indicators of average weighted southern MDB trading prices.

The baseline

The baseline against which the infrastructure upgrades scenario is modelled consists of variations in water allocations, rainfall and dryland productivity across regions. During a prolonged drought, dryland productivity may collapse before water allocations are reduced. During recovery, dryland output may recover before water allocations recover. The baseline adds to the difficulty of modelling but serves to make the scenario more realistic: farmers do not have average seasonal conditions every year and must deal with uncertainty. Marginal policy impacts may vary with seasonal conditions, particularly with respect to water trading in the southern Basin.

Table A2: Dry-land winter crop productivity in baseline
(2015-16 =100)

	NSW-MDB	Vic-MDB	Qld-MDB	SA-MDB
2015-16	100	100	100	100
2016-17	118	143	125	134
2017-18	78	124	83	103
2018-19	65	96	64	86
2019-20	67	96	64	86
2020-21	89	119	92	107
2021-22	112	119	92	107
2022-23	112	119	92	107
2023-24	140	149	115	134
2024-25	127	136	104	122
2025-26	115	123	95	111
2026-27	96	103	79	92
2027-28	77	82	63	74
2028-29	85	91	70	82
2029-30	107	114	88	102

Table A3: Irrigation water allocations
(2015-16 =100)

	NSW-MDB	Vic-MDB	Qld-MDB	SA-MDB
2015-16	100	100	100	100
2016-17	170	140	170	83
2017-18	158	130	158	100
2018-19	41	42	41	99
2019-20	41	42	41	79
2020-21	70	71	70	134
2021-22	86	87	86	115
2022-23	73	73	73	110
2023-24	109	110	109	105
2024-25	133	134	133	108
2025-26	160	160	160	86
2026-27	150	151	150	130
2027-28	71	71	71	149
2028-29	65	65	65	135
2029-30	110	111	110	134

Devising appropriate model theory from observed data

Table A1 points us to some necessary features of TERM-H2O. First, we require a split between dry-land and irrigated agriculture. The table (lines 1 & 2) indicates that irrigation makes up less than 2% of the land used in agriculture in the Basin. Lines 1 & 2 of the table show that the area of dry-land and irrigated agriculture varies from year to year, depending on water availability and output market conditions. The model requires some mobility of irrigable land between irrigated and dry-land technologies.

Line 6 of Table A1 indicates that rainfall variability alters irrigation water requirements. Water availability and rainfall are exogenous in the CGE model, but we need to distinguish between the two. That is, if there is a rainfall deficit, we need to shock water supply in the model (both rainfall and water allocations), which will lead to substitution away from water in the production function of the irrigated industry. We treat impacts in dry-land agriculture differently, by ascribing production shocks to depict the impact of drought.

Wide variations from year to year in water usage for rice and cotton indicate that we require flexibility in allocation of farm factors for annuals. Line 5 of Table A1 refers to other annuals that are less water-intensive, particularly vegetables. Since water is a smaller share of the total costs of production for other annuals, the responsiveness to changes in the water price is smaller than for rice or cotton. As was the case for grapes, other annuals used less water than usual in 2010-11 and 2011-12 due to above average rainfall.

Given the substantial investments that go into establishing vineyards and orchards, we need to depict factor rigidity in perennials. When water is scarce, as was evident in 2007-08 and 2008-09, perennial sectors purchase water from other users in response to diminished water allocations. Even if the water price soars, the costs of destruction to perennial plantations in terms of foregone future income may far exceed the additional water costs in a water-scarce year. Factor rigidity is imposed by including specific capital for perennials, whereas annuals use capital that is mobile between different farm activities.

Specific capital (i.e., the herd) in also used in livestock production. Feed inputs into livestock production are substitutable by region. On-farm pasture used to feed livestock is treated as a separate farm sector. In response to worsening water scarcity, feed inputs may switch from on-farm pasture to inputs from elsewhere.

Changes in relative output prices alter the allocations of mobile capital, operator labor, dry land and irrigable land between activities. These factors follow a constant elasticity of transformation (CET) form.

Another important feature of TERM-H2O concerns water trading possibilities. The main stylized assumption is that irrigation water is perfectly tradable between irrigation sectors and regions of the southern Basin. That is, water is traded at a single price in the southern Basin in the model, which approximates reality. In the northern part of the Murray-Darling Basin, which consists of far-flung tributaries, we assume that water is tradable within a region but not between regions.

The implication of the almonds planting boom

The water requirements of almond orchards increase as they near maturity. In the initial year 2015-16 in TERM-H2O, almonds use 335 gigalitres of water in the Basin. This may be higher than actual usage. This means that a relatively modest increase in almond water requirements in TERM-H2O may be needed to match expected future water requirements. If global demand for almonds and a favorable exchange rate keep almond prices relatively high for Australian producers, their increased water demands are likely to raise the price of water and divert it from other uses. In present circumstances, the dairy sector remains vulnerable to increasing demands from competing water users.

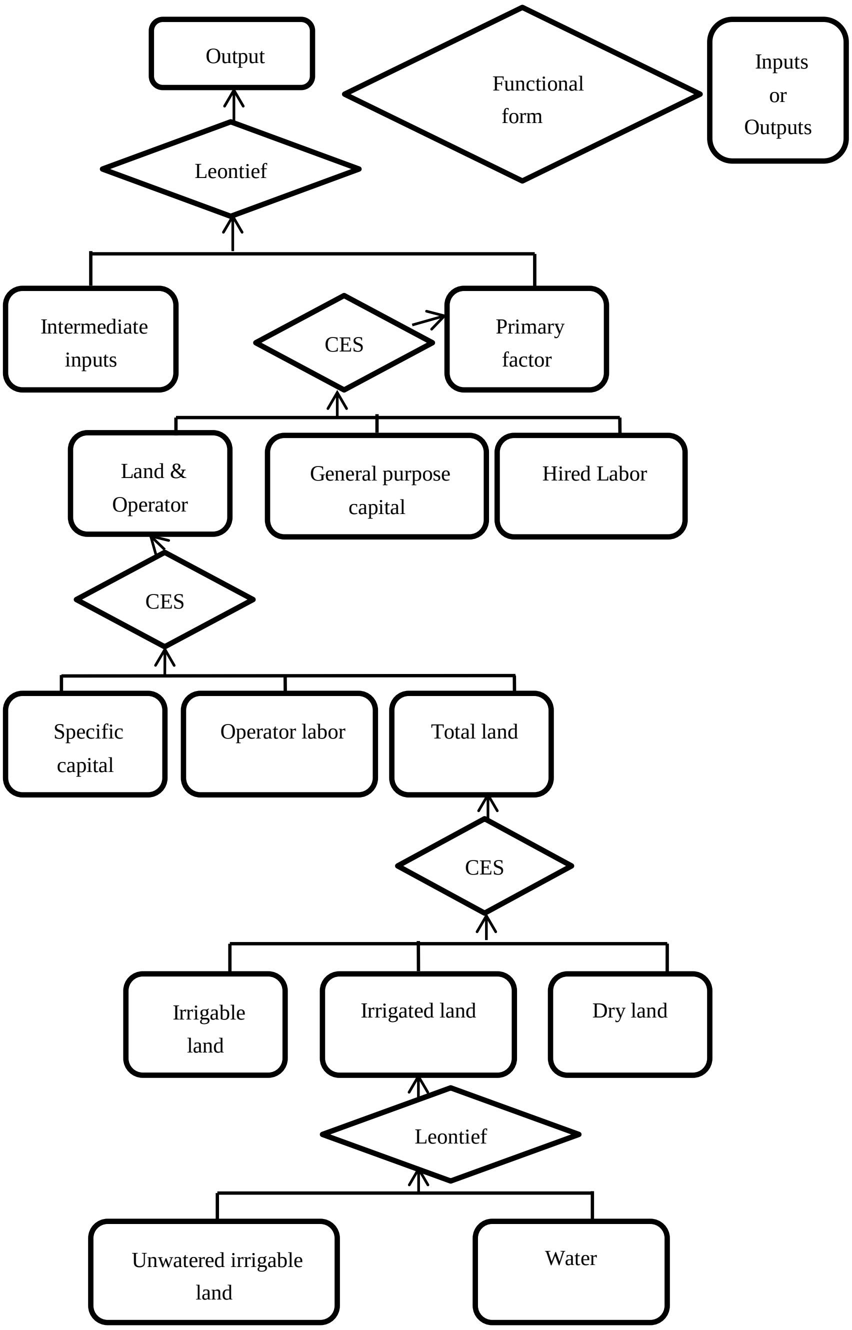
Main Modifications in TERM-H2O

Figure A1 shows us that TERM-H2O's Leontief bundle of intermediate input and primary factor follows the conventional theory of a CGE model in the Dixon et al. (1982) school. The key difference from a conventional dynamic CGE model emerges in the elaboration of farm factor mobility. The primary factor in Figure A1 is a CES nest of hired labor, general purpose capital and land & operator. Hired labor is a CES nest of occupations. General purpose capital, including farm implements and sheds, is mobile at the farm level between different activities. The land & operator factor is a CES bundle of specific capital, operator labor and land. Annual crops will use a negligible amount of specific capital, whereas it is significant in livestock and perennial production.

As is evident at the bottom of figure A1, land is a CES nest of three types of agricultural land, namely dry land, irrigable land without water and irrigated land. If water allocations fall, some irrigated land will switch to irrigable land without water, and may switch back in subsequent time periods with the restoration of usual water allocations. In terms of hectares, dry land, which cannot be irrigated, dominates farming in the Murray-Darling Basin (Table A1, rows 1 & 2). Without water, irrigable land is far less productive per hectare than with water. With water using technologies constant, a fixed amount of water inclusive of effective rainfall is required per hectare of irrigable land for a given output. An important modification to the updated version of TERM-H2O arose from the initial conditions of 2015-16. Table A1 shows that total water use in 2015-16 was far below 2012-13 levels. In earlier versions of TERM-H2O, total irrigable land used for irrigation was exogenous. Now, the hectares of irrigable land used for irrigation vary in proportion to aggregate regional water use. This prevents the price of water from collapsing as it becomes more abundant: 2015-16 was a moderately dry year.

TERM-H2O includes a dry-land technology and an irrigated technology for each of the following: grains, cotton, hay & fodder and other agriculture. Rice, grapes, almonds and vegetables have irrigation technologies only. The livestock sectors follow the theory of dry-land technologies but require substantial inputs of hay & fodder which may be either dry-land or irrigated, on-farm or purchased.

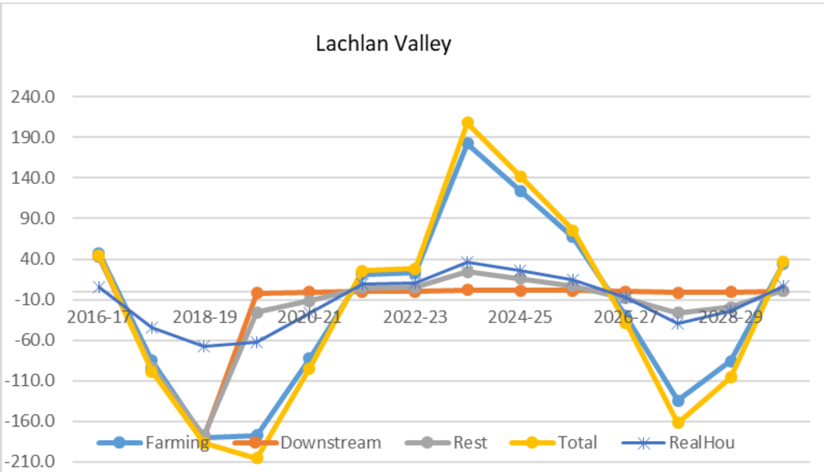
Figure A1: Production function for farm industries

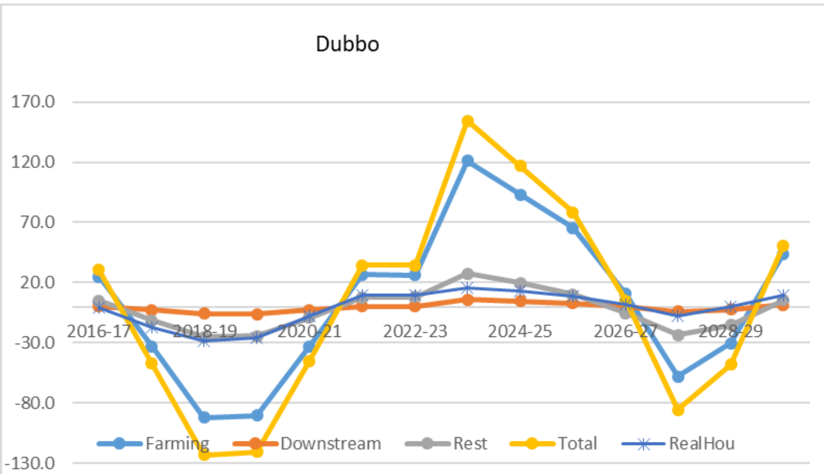


Macro deviations in baseline from a baseline without seasonal variations

Figure A2 shows the year-on-year macro deviations that arise from imposing seasonal dry-land productivity shocks and irrigation water availability as shown in tables A2 and A3. The purpose of this is to show how large these deviations are relative to the policy deviations in the main text.

Figure A2: Value added by broad sector, selected Southern Basin regions ($m deviation due to seasonal variation from a bland base)





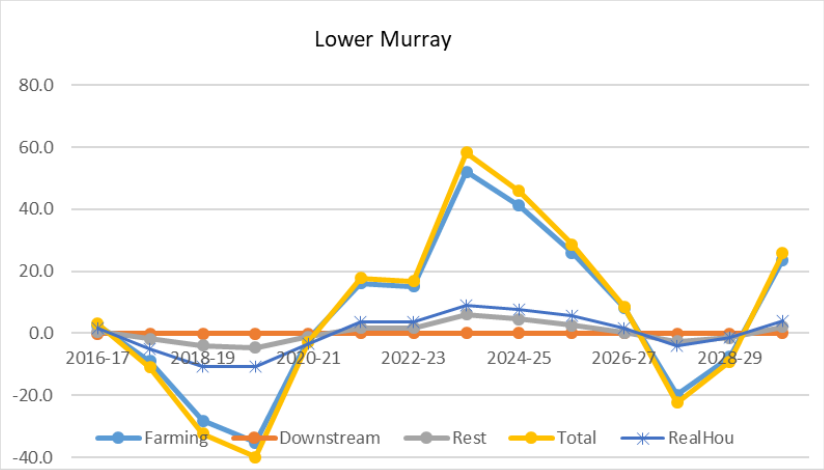
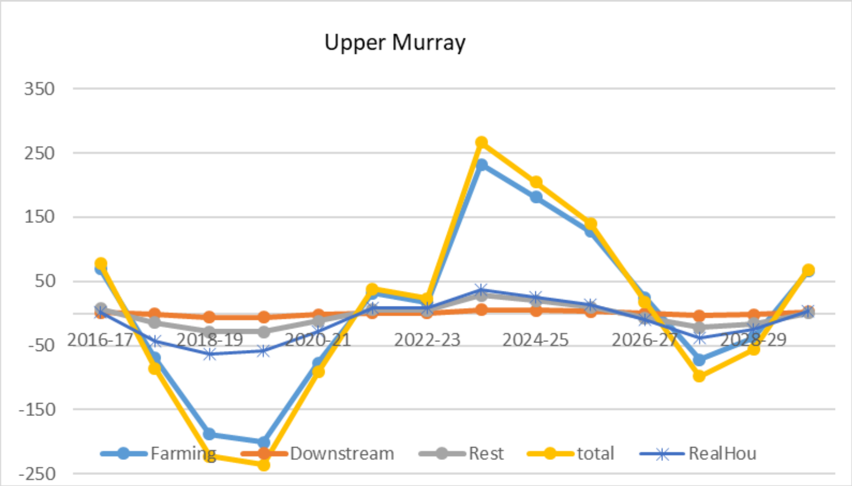
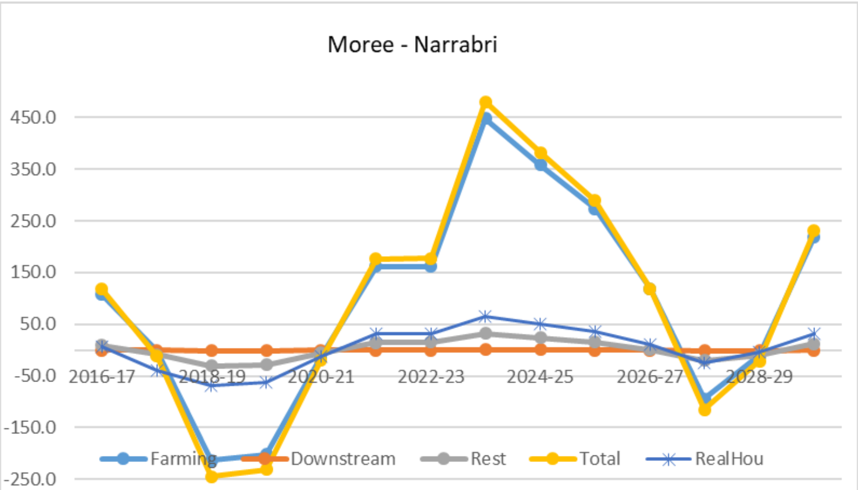


Figure A2 (cont.): Value added by broad sector, selected Southern Basin regions ($m deviation due to seasonal variation from a bland base)





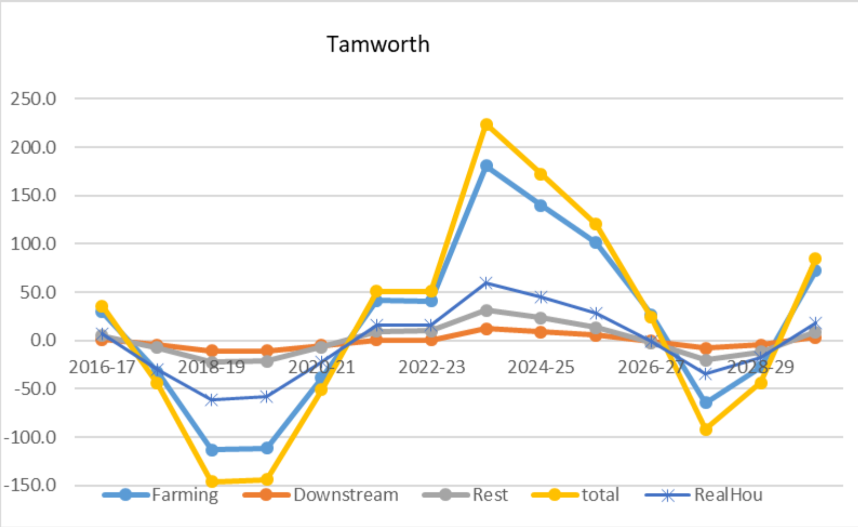
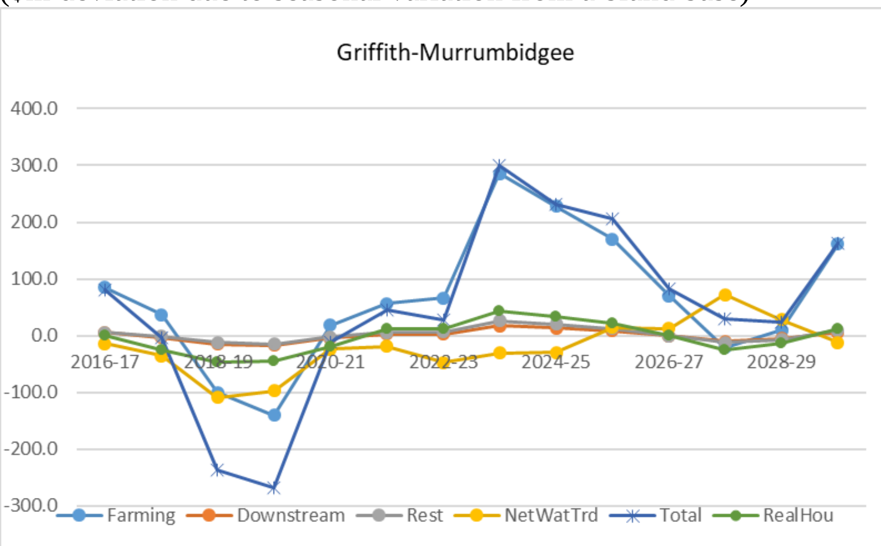
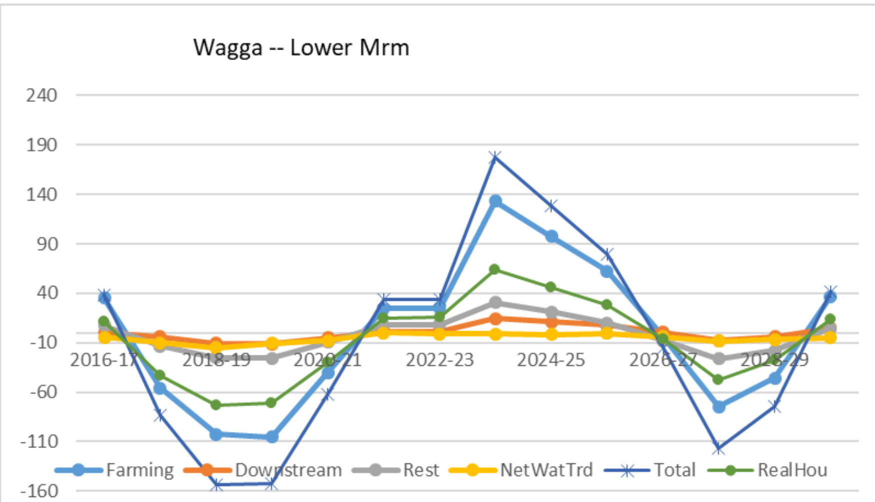


Figure A2 (cont.): Value added by broad sector, selected Southern Basin regions ($m deviation due to seasonal variation from a bland base)





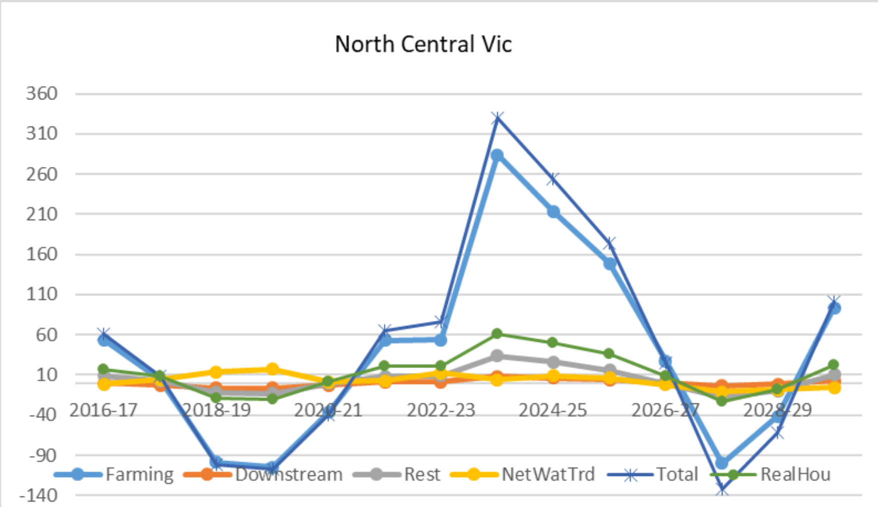
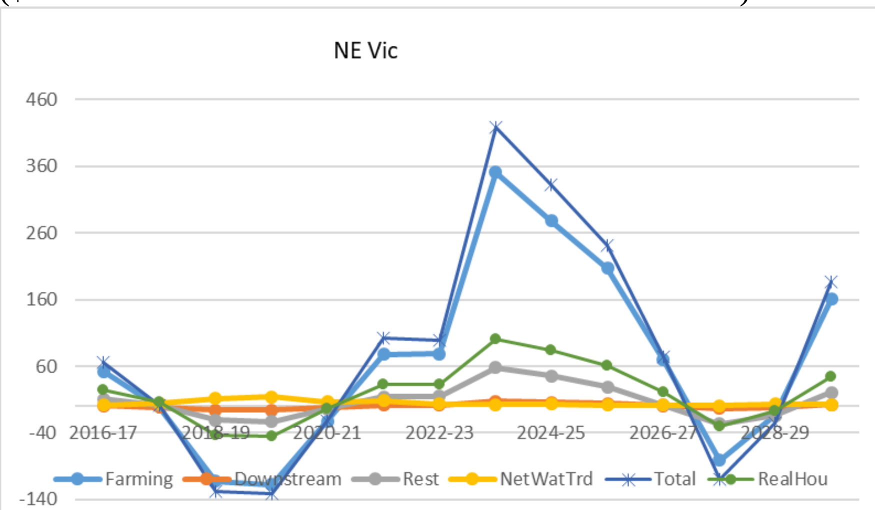
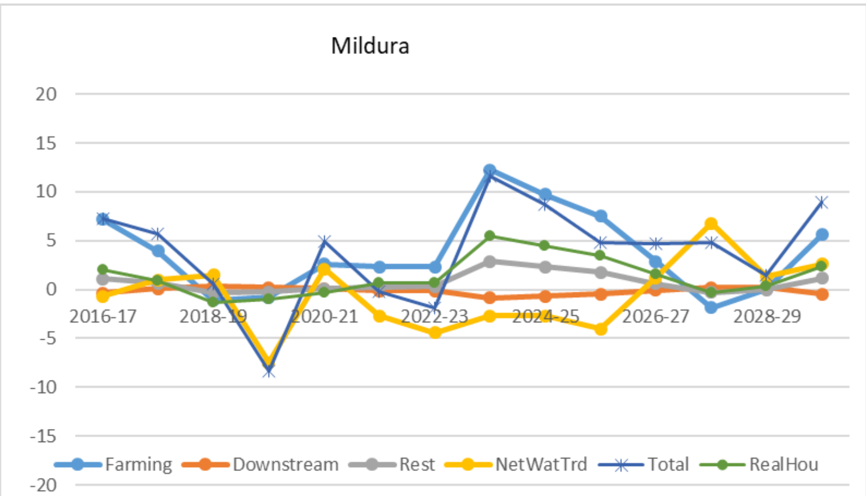


Figure A2 (cont.): Value added by broad sector, selected Southern Basin regions ($m deviation due to seasonal variation from a bland base)





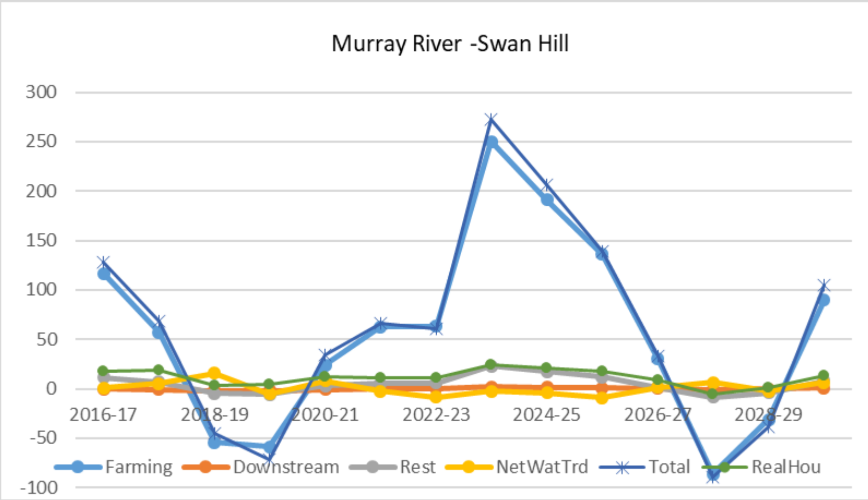
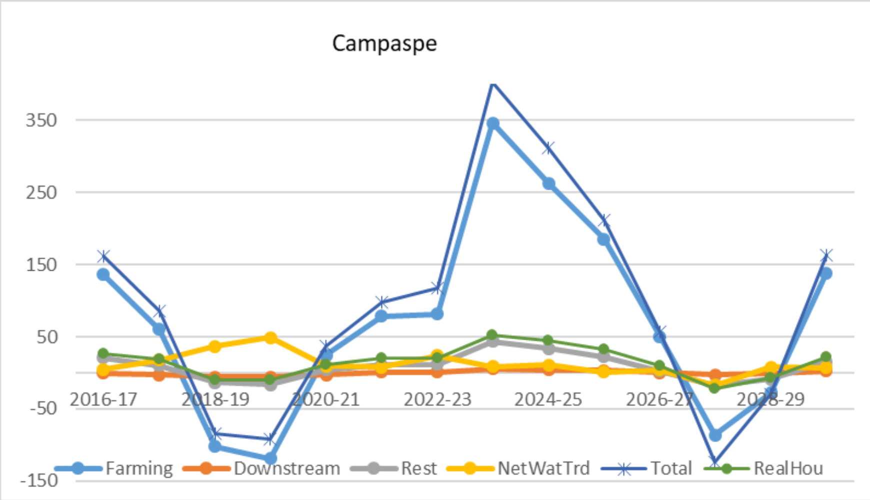
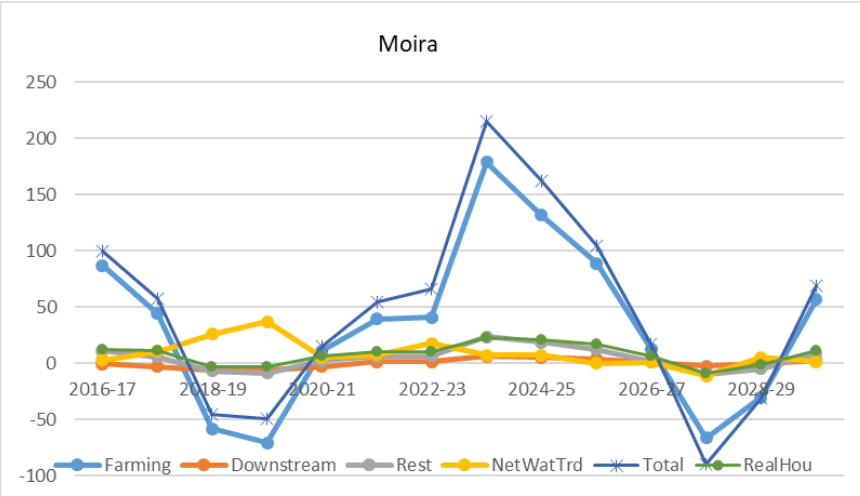

Murray River -Swan Hill
300
250
200
150
100
50
0
-50
-100
2016-17
2018-19
2020-21
2022-23
2024-25
2026-27
2028-29
Farming
Downstream
Rest
NetWatTrd
Total
RealHou

Figure A2 (cont.): Value added by broad sector, selected Southern Basin regions ($m deviation due to seasonal variation from a bland base)





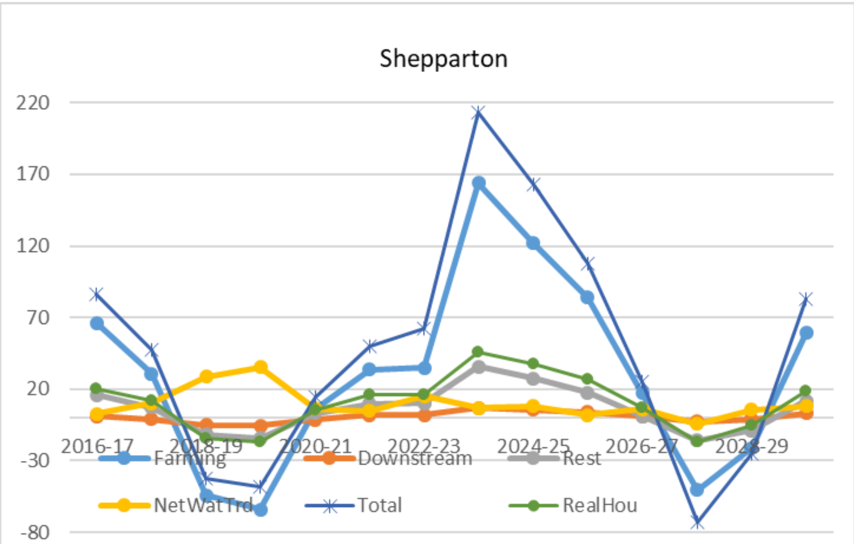
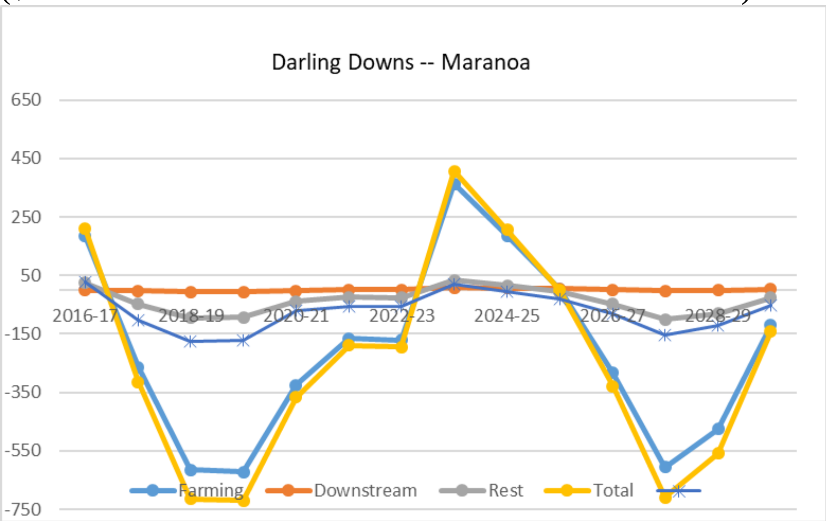
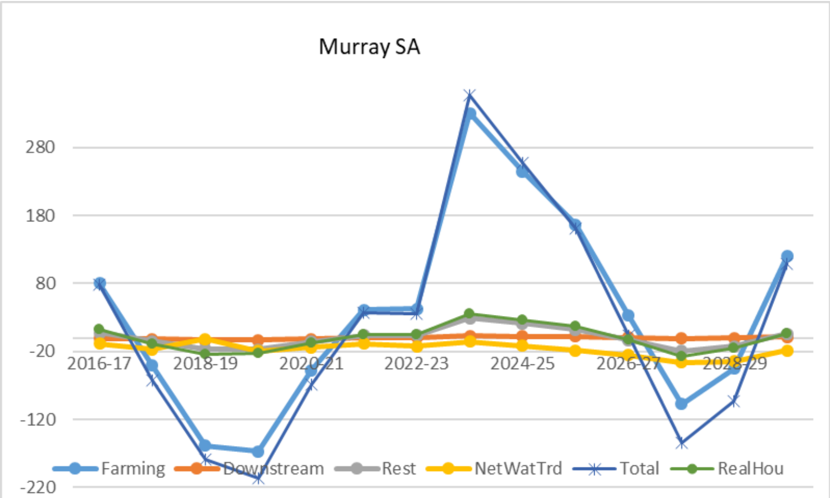


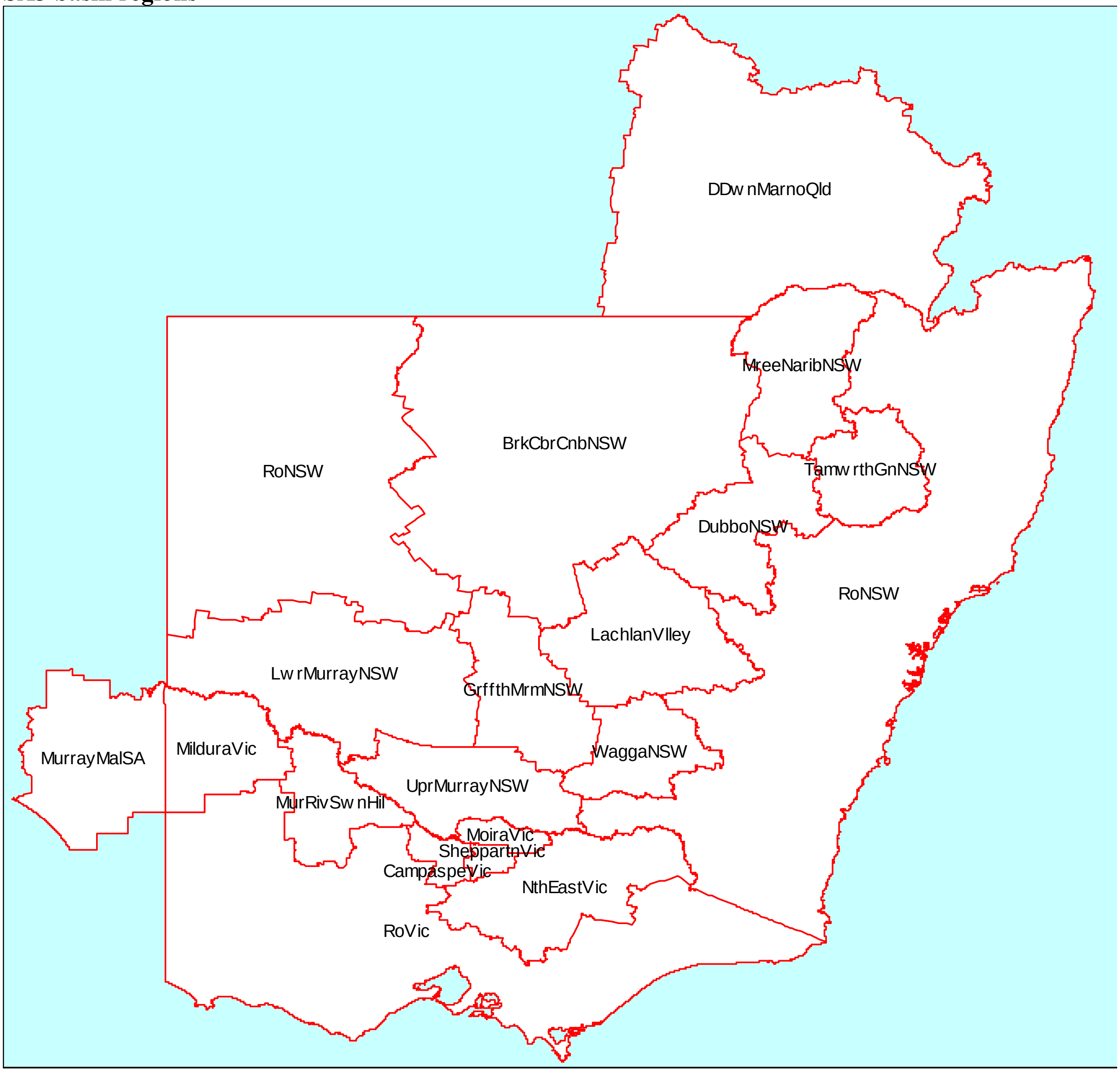
Figure A2 (cont.): Value added by broad sector, selected Southern Basin regions ($m deviation due to seasonal variation from a bland base)





Appendix B
TERM-H2O regions

SA3 basin regions

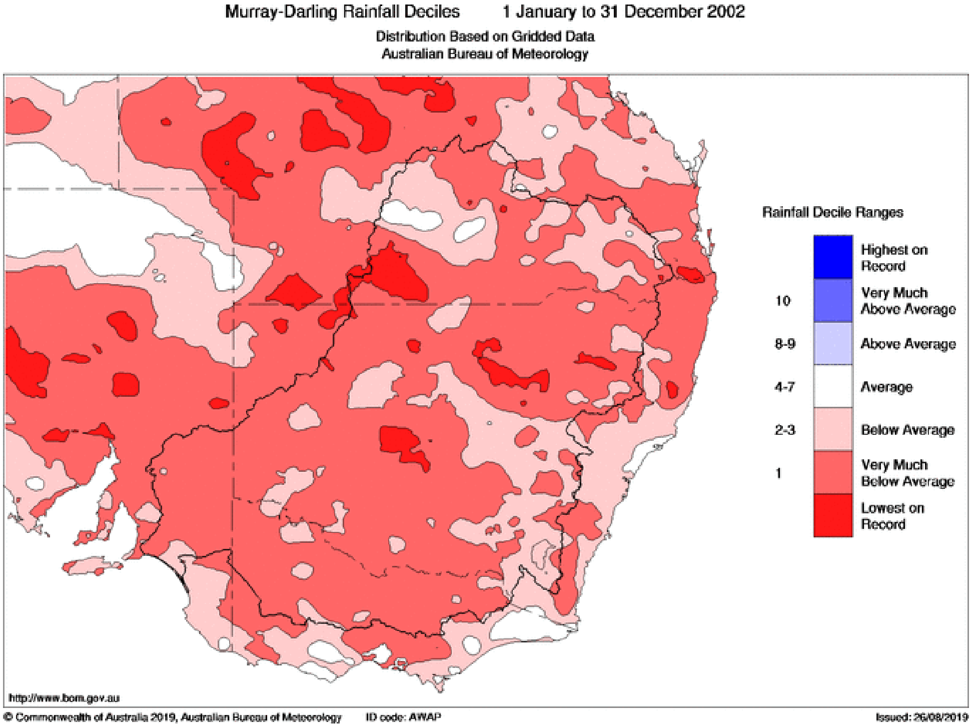


Note: Upper Murray does not include Albury which is predominantly urban + dryland farming. Darling Downs-Maranoa does not include Granite Belt.

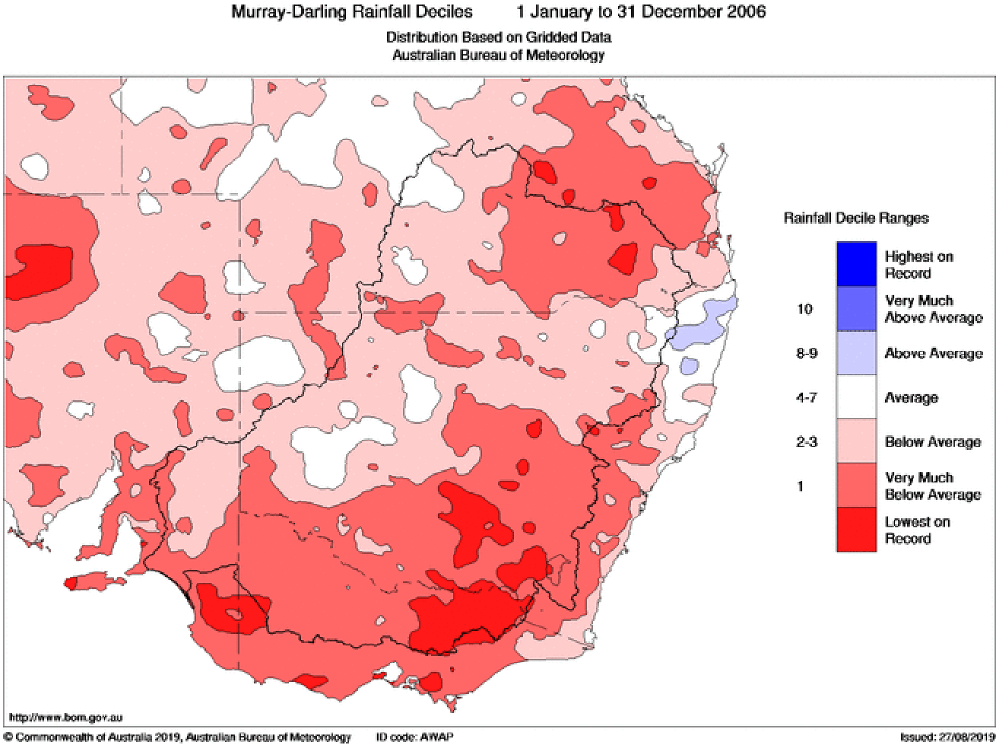
Appendix C

Drought years in the Basin from 2002 to 2019

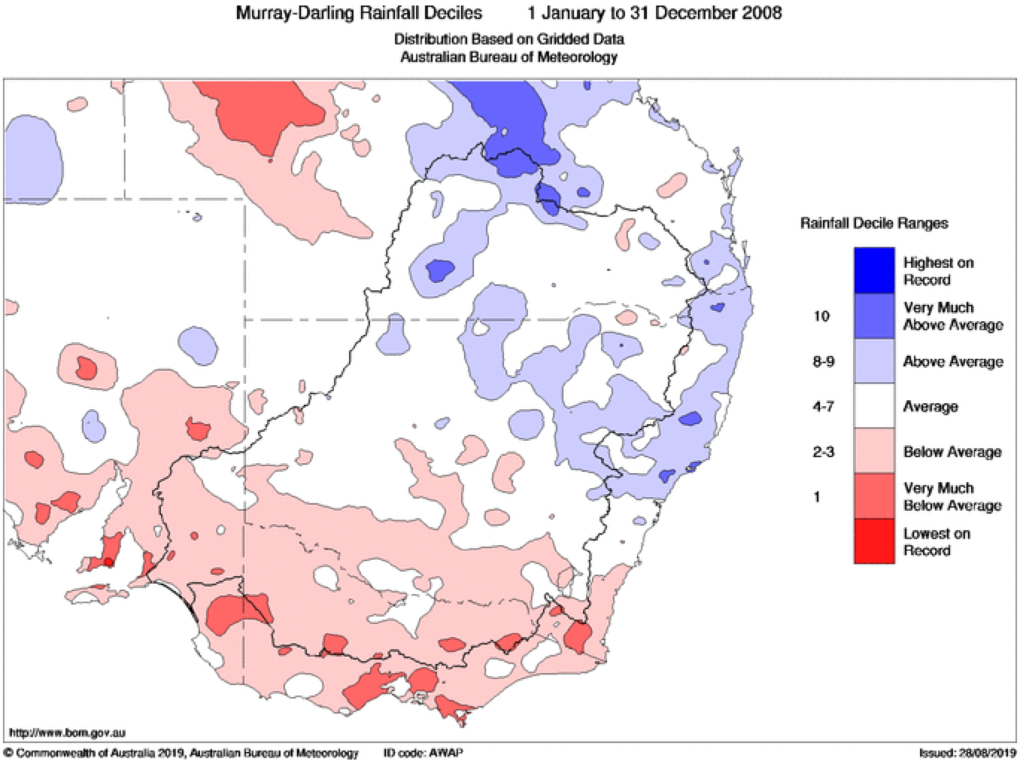
2002



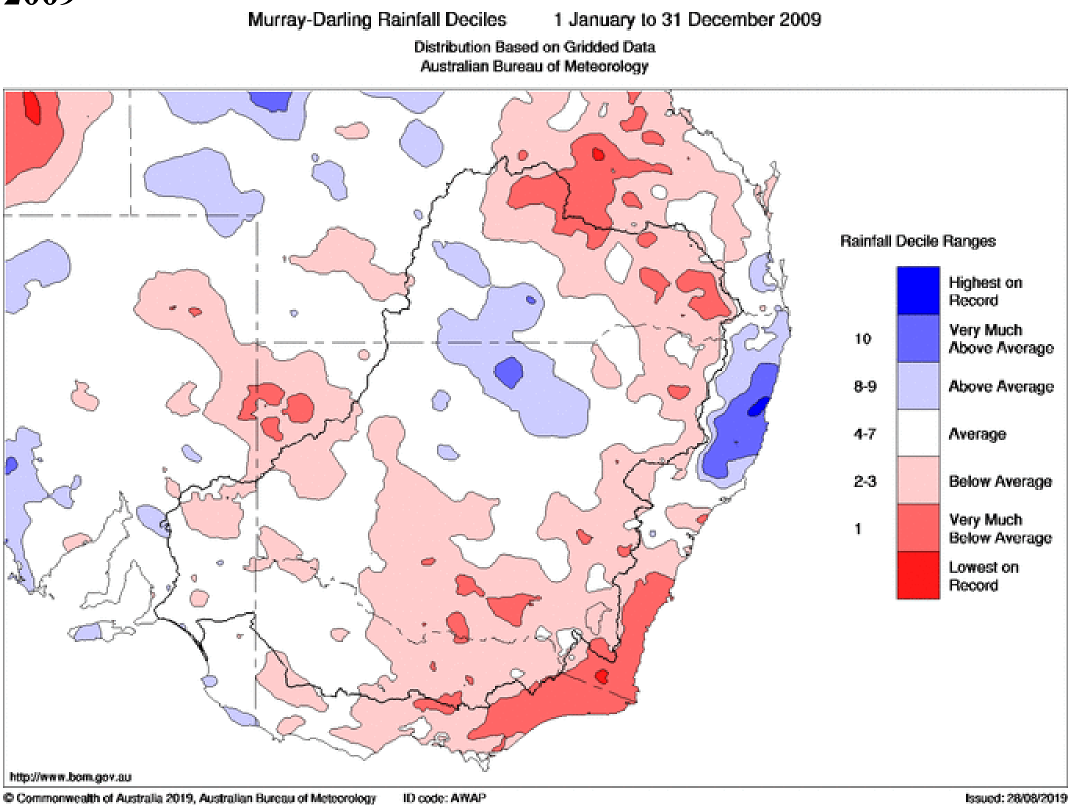
2006



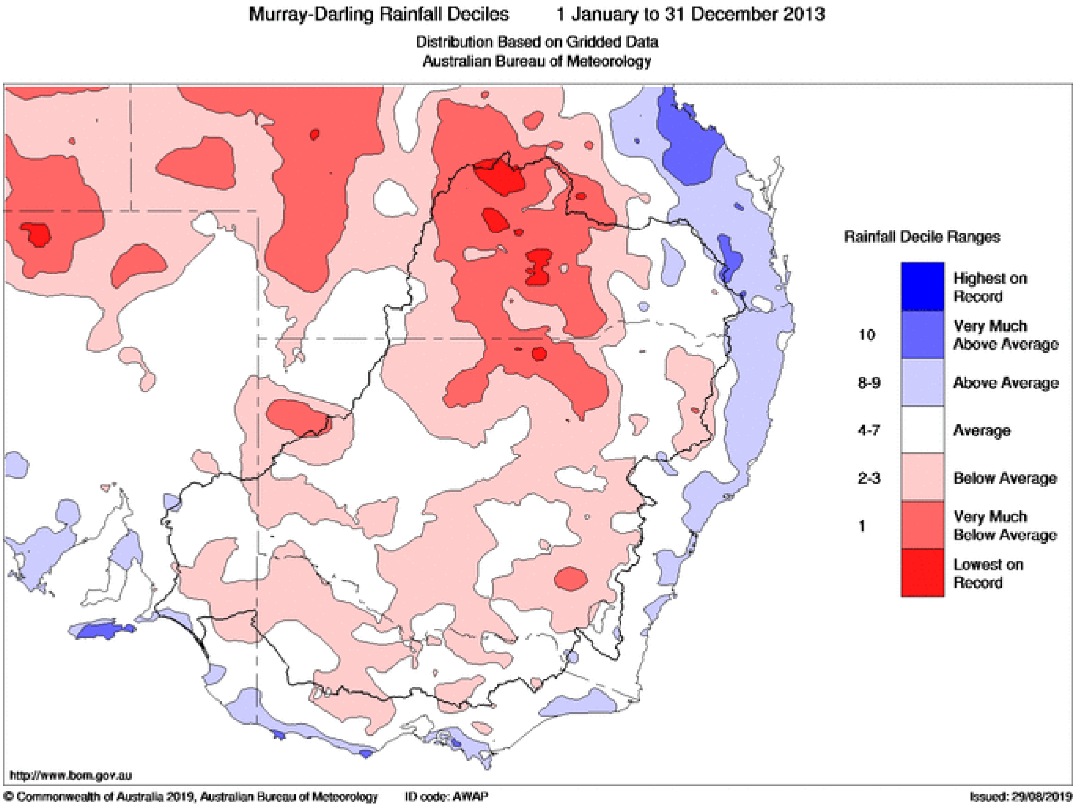
2008


Murray-Darling Rainfall Deciles 1 January to 31 December 2008
Distribution Based on Gridded Data
Australian Bureau of Meteorology
Rainfall Decile Ranges
Highest on Record
10 Very Much Above Average
8-9 Above Average
4-7 Average
2-3 Below Average
1 Very Much Below Average
Lowest on Record
http://www.bom.gov.au
© Commonwealth of Australia 2019, Australian Bureau of Meteorology
ID code: AWAP
Issued: 28/08/2019

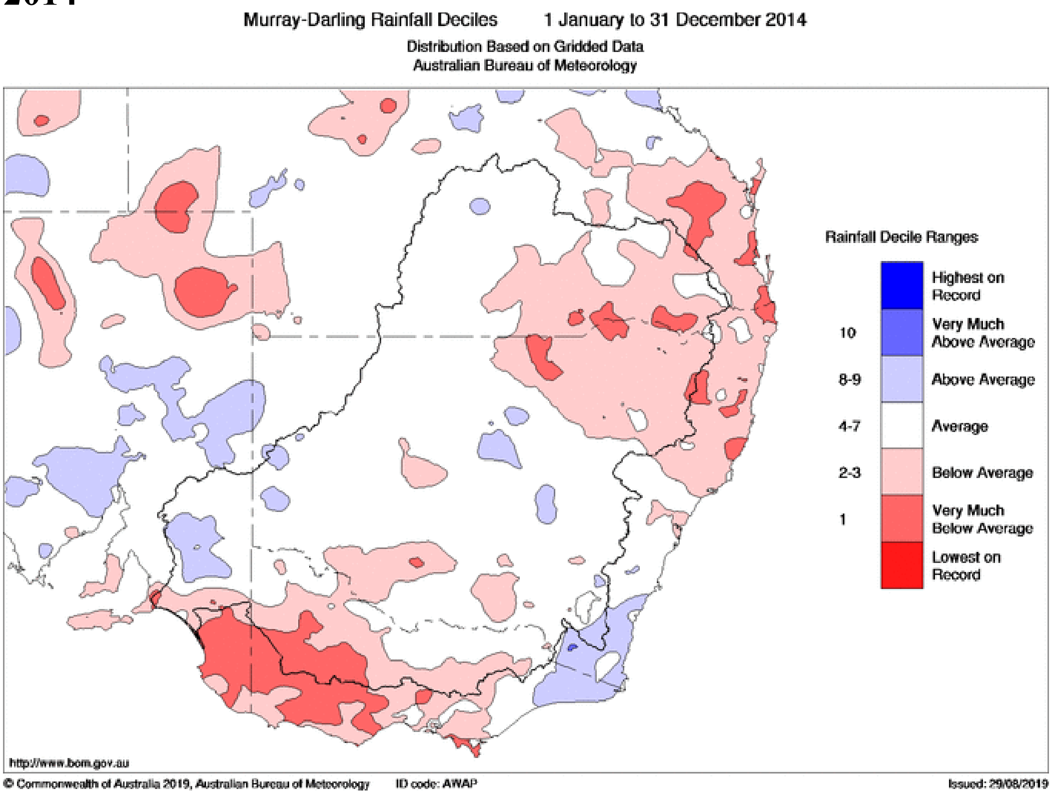
2009


Murray-Darling Rainfall Deciles 1 January to 31 December 2009
Distribution Based on Gridded Data
Australian Bureau of Meteorology
Rainfall Decile Ranges
Highest on Record
10 Very Much Above Average
8-9 Above Average
4-7 Average
2-3 Below Average
1 Very Much Below Average
Lowest on Record
http://www.bom.gov.au
© Commonwealth of Australia 2019, Australian Bureau of Meteorology
ID code: AWAP
Issued: 28/08/2019

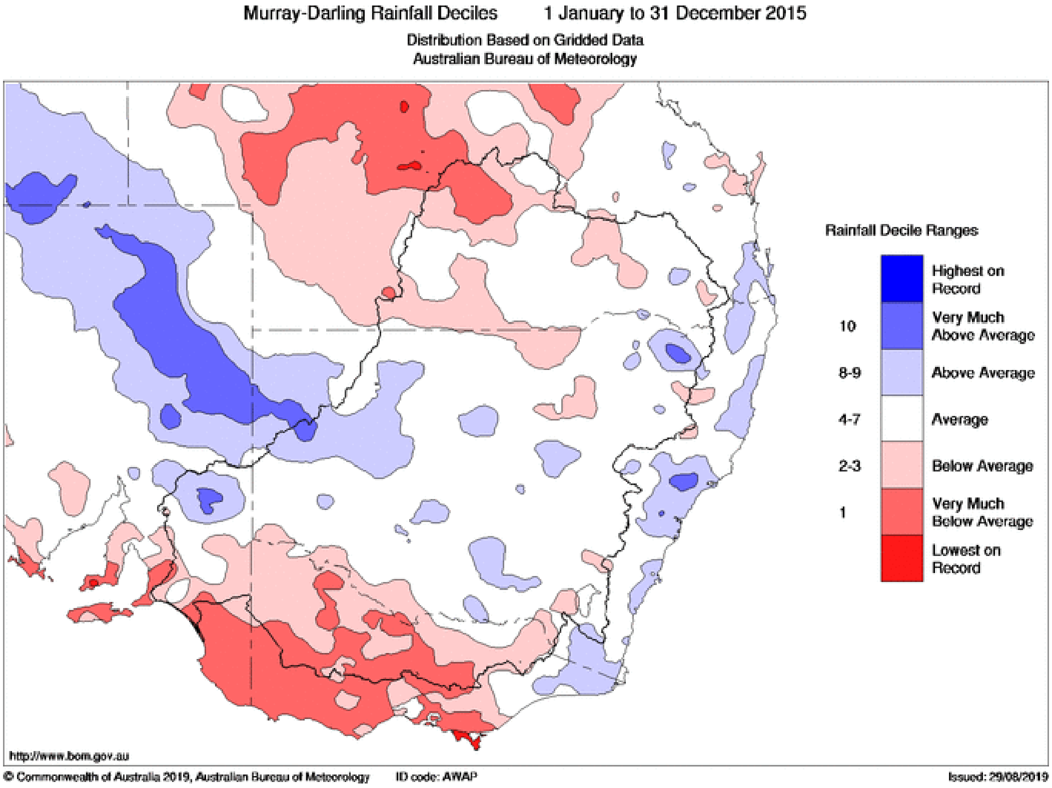
2013


Murray-Darling Rainfall Deciles 1 January to 31 December 2013
Distribution Based on Gridded Data
Australian Bureau of Meteorology
Rainfall Decile Ranges
Highest on Record
10
Very Much Above Average
8-9
Above Average
4-7
Average
2-3
Below Average
1
Very Much Below Average
Lowest on Record
http://www.bom.gov.au
© Commonwealth of Australia 2019, Australian Bureau of Meteorology
ID code: AWAP
Issued: 29/08/2019

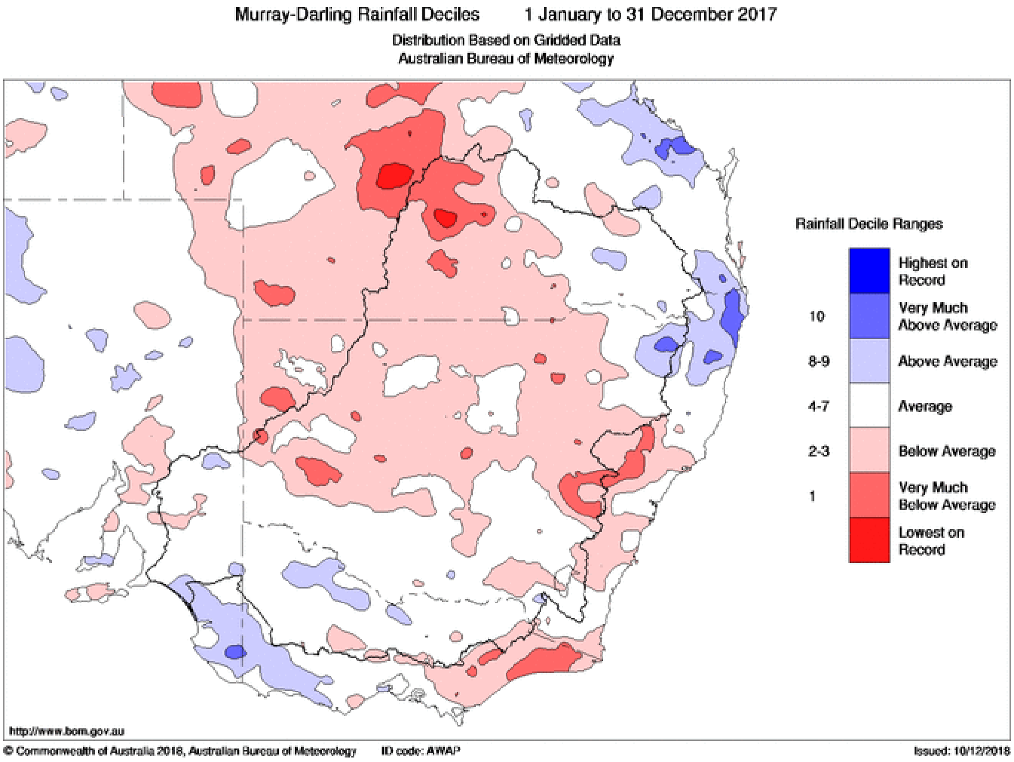
2014


Murray-Darling Rainfall Deciles 1 January to 31 December 2014
Distribution Based on Gridded Data
Australian Bureau of Meteorology
Rainfall Decile Ranges
Highest on Record
10
Very Much Above Average
8-9
Above Average
4-7
Average
2-3
Below Average
1
Very Much Below Average
Lowest on Record
http://www.bom.gov.au
© Commonwealth of Australia 2019, Australian Bureau of Meteorology
ID code: AWAP
Issued: 29/08/2019

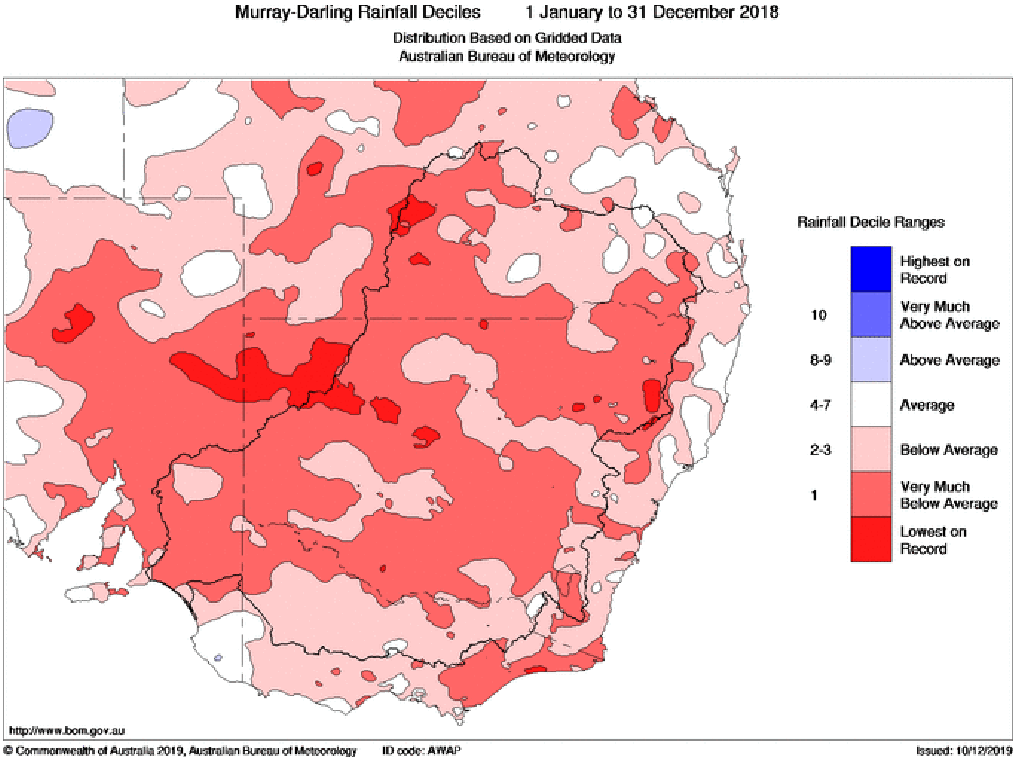
2015


Murray-Darling Rainfall Deciles 1 January to 31 December 2015
Distribution Based on Gridded Data
Australian Bureau of Meteorology
Rainfall Decile Ranges
Highest on Record
10
Very Much Above Average
8-9
Above Average
4-7
Average
2-3
Below Average
1
Very Much Below Average
Lowest on Record
http://www.bom.gov.au
© Commonwealth of Australia 2019, Australian Bureau of Meteorology
ID code: AWAP
Issued: 29/08/2019

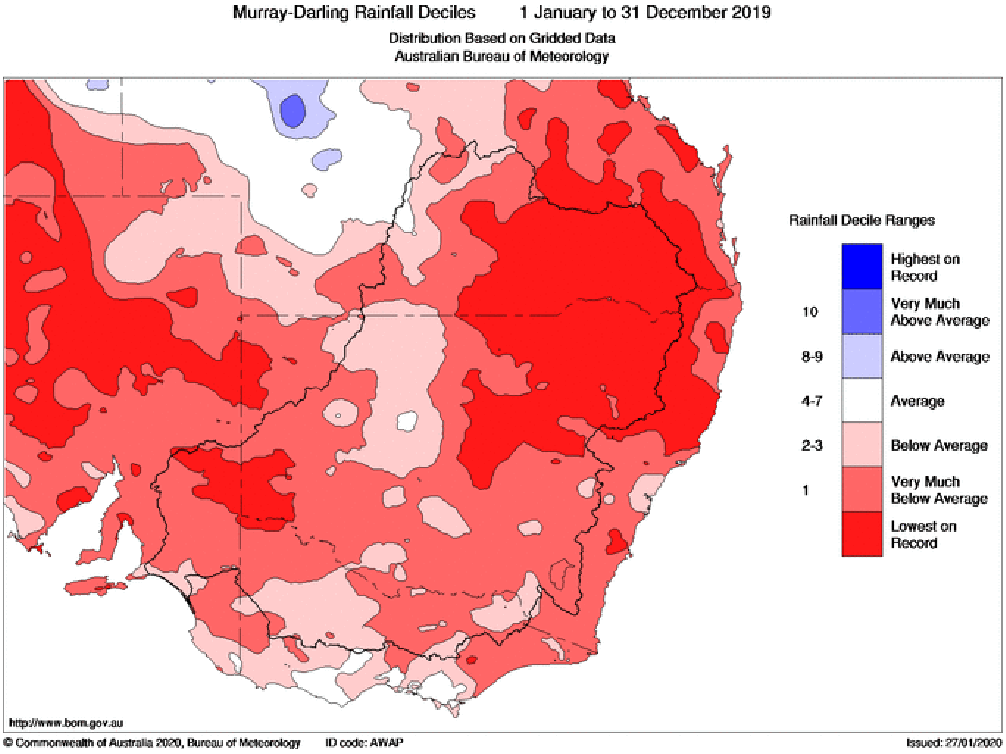
2017


Murray-Darling Rainfall Deciles 1 January to 31 December 2017
Distribution Based on Gridded Data
Australian Bureau of Meteorology
Rainfall Decile Ranges
Highest on Record
10
Very Much Above Average
8-9
Above Average
4-7
Average
2-3
Below Average
1
Very Much Below Average
Lowest on Record
http://www.bom.gov.au
© Commonwealth of Australia 2018, Australian Bureau of Meteorology
ID code: AWAP
Issued: 10/12/2018

2018


Murray-Darling Rainfall Deciles 1 January to 31 December 2018
Distribution Based on Gridded Data
Australian Bureau of Meteorology
Rainfall Decile Ranges
Highest on Record
10
Very Much Above Average
8-9
Above Average
4-7
Average
2-3
Below Average
1
Very Much Below Average
Lowest on Record
http://www.bom.gov.au
© Commonwealth of Australia 2019, Australian Bureau of Meteorology
ID code: AWAP
Issued: 10/12/2019

2019


Murray-Darling Rainfall Deciles 1 January to 31 December 2019
Distribution Based on Gridded Data
Australian Bureau of Meteorology
Rainfall Decile Ranges
Highest on Record
10
Very Much Above Average
8-9
Above Average
4-7
Average
2-3
Below Average
1
Very Much Below Average
Lowest on Record
http://www.bom.gov.au
© Commonwealth of Australia 2020, Bureau of Meteorology
ID code: AWAP
Issued: 27/01/2020