POPULATION AND WATER: WHERE DOES IT MATTER?

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What are the implications of Australia's population growth as far as water is concerned? Population size and growth affect water supplies throughout the country but they matter more in some regions than others. Cities obviously need more water as their populations grow. However, in rural areas the issue is not population growth but how populations will deal with likely declines in future water availability.

INTRODUCTION

From time to time a debate has resurfaced about the environmental sustainability of Australia's growing population. In this journal, concerns have been raised in articles such as those by Foran (2003), Lines (2005) and Thomson (2009).[1] Since late 2009, the debate has gained renewed prominence following the apparent endorsement by the former Prime Minister of a 'big Australia'—which according to projections, could be home to more than 35 million people by the middle of the century.

The links between population and water appear obvious. In many urban areas, water services need to be planned for, and provided, to growing populations. In rural Australia, water is used to produce agricultural commodities, some of which feed Australians: hence, population growth, if it leads to increased agricultural consumption, could result in greater levels of water use.

However, the links between population and water are more complicated than an apparently simple 'more population = more water resource problems'. The links need to be considered in the context of demography, water policy, and the geographic realities of how Australia's water resources are constituted and used. While population matters everywhere to some extent, it matters more in some parts of Australia. Furthermore, population matters in different ways in different places. While in many urban areas population size and population growth are important, in some rural parts of Australia other population characteristics may be of greater significance. This paper proposes where, and why.

AUSTRALIA'S APPROACH TO WATER MANAGEMENT

Australia's water managers (which include, but are not limited to, Commonwealth, state and local government agencies, natural resource management organisations, local governments, and water utilities) are responsible for implementing water-related policies and programs as agreed by the Commonwealth, states and territories in: the 2004 Intergovernmental Agreement on a National Water Initiative; the subsequent 2008 Intergovernmental Agreement on Murray-Darling Basin Reform and associated Commonwealth *Water Act 2007*; the National Water Quality Management Strategy, which commenced in 1992; and other policies and legislation consistent with these agreements. While it is difficult to summarise Australia's approach to water management in a few paragraphs,[2] it has broadly been agreed that:

1. Recognising the environmental pressures caused by exploitation of water resources, governments and communities have committed to developing water plans which identify sustainable levels of water use, and set out how water resources should be allocated between

different users and the environment. In some cases (where the environment is being degraded because too much water is being used) water plans will restrict the amount of water that is available.

2. Water users (including both human users and the environment) should have statutory, secure legal rights to water. Water markets will be developed, through which water users can buy and sell their rights. This will give water users greater flexibility, particularly during times of water shortage (for example, drought), and help maximise the value of economic production from water (as it can be sold to those who will use it for more economically profitable purposes). Water markets also create a mechanism through which the government can purchase water for the environment.
3. Water will be used more efficiently. Water infrastructure (for example, urban water supplies, irrigation infrastructure) will be improved so that less water is lost from the system. Water will be priced so that the full costs of water planning, infrastructure investment and environmental externalities are recovered.
4. Governments will address adjustment issues[3] that affect water access entitlement holders and communities, as a result of reductions in water availability following water reforms.
5. Water quality will be protected, through management of diffuse and point source pollution, sewerage and stormwater systems. Through more sustainable water use, salinity will also be addressed.

HOW IS POPULATION RELEVANT TO WATER?

The way in which population is relevant to water depends on whether urban or rural water systems[4] are considered.

Urban systems

This paper proposes that water systems which are dominated by towns or cities can be defined as 'urban systems'. In these systems, a significant proportion of water use is for domestic purposes.[5] There are relatively direct links between population size, population growth, and water use (and thereby, water availability for the environment and for other users). This link has been recognised by the water industry: a July 2010 report by the Water Services Association of Australia[6] estimated that total urban water demand will increase by up to 631 GL over 2008–09 levels by 2026, and by up to 1,147 GL by 2056, if the Australian Bureau of Statistics' most recent series B population projections prove correct.[7] In addition, urban development (which is associated with a growing population) affects urban water quality.

Rural systems

Water systems in which agriculture accounts for the majority of water use can be defined as 'rural systems'.[8] Through land use change and use of chemical fertilisers, agriculture also significantly impacts on water quality. In these systems, the links between population and water are less straightforward. While agricultural production is obviously for human consumption, there is not (at least in Australia)[9] a simple association between the extent or nature of that agricultural production, and population size or population growth.

Much of Australia's agricultural output is for export. The water used to produce this output is therefore linked to the consumption (and hence population) of other countries, as well as to the Australian population. Furthermore, Australians don't just consume Australian agricultural products: they also consume imported goods. Therefore, population change in Australia affects water resources abroad as well as water resources in Australia.

Perhaps most crucially, economic factors (particularly commodity prices and the price of water) influence what agricultural products are produced and consumed, and how much water is used to produce them. Assuming that producers aim to maximise their profits, they will produce whatever maximises the gross value of production, while minimising the cost of factor inputs (including water). So even if Australian irrigated agricultural production were exclusively consumed by Australians, population change would still be only one factor in determining its impact on water resources.

Relationships between urban and rural systems

It is important to recognise that urban and rural systems can be connected. From a scale perspective, urban systems can be nested within rural systems. For example, the Murrumbidgee basin (a rural system) contains within it an urban subsystem, the Cotter basin, which supplies Canberra. Population will matter differently for the Cotter subsystem, compared to for the Murrumbidgee system as a whole.

Furthermore, some urban systems are linked with distant rural systems through built infrastructure. For example, Melbourne draws some of its water from the Goulburn River, and Adelaide draws water from the Murray, through pipelines.

Transient populations

In some parts of Australia, both urban and rural, tourism is important. There are also large numbers of itinerant workers, such as fly-in, fly-out mine workers, in some locations. In these (and potentially other) regions, short-term visitors could have a significant population impact, and thereby matter to water managers.

It was beyond the scope of this paper to investigate where transient populations matter most for water management. Further work to assess the impacts of tourists and other transient populations on water resources would be useful. Analyses could be focused on parts of Australia in which tourism and/or mining are significant, such as far North Queensland, Central Australia, outback Western Australia and Queensland, and the Snowy Mountains.

WHERE DOES POPULATION MATTER—AND TO WHOM?

A proposed approach

In the context of the approach to water management described above, and the differing characteristics of urban and rural water systems, where does population matter most? This paper proposes that three criteria can be used to find out where.

Firstly, population matters in urban water systems which are stretched—that is, where water supplies are already under pressure. Population growth could put even more pressure on these already stretched systems. In such cases, water managers need to either reduce per capita water demand, and/or find additional water supplies, while ensuring environmental sustainability. Increasingly, new approaches (as opposed to traditional dams and reticulated supply networks) to ensuring water security, such as water recycling, stormwater harvesting, desalination, water sensitive urban design, and rainwater tanks, are being pursued. Such approaches reduce the pressure on water systems, by reducing water use, obtaining water from outside the system (as is the case with desalination), and/or enabling water to be used more than once.[10] In planning and developing such initiatives, population (among other things) needs to be taken into account as it affects their economic and social viability.

Secondly, population matters in stretched rural systems. In these systems, water managers need to take action to improve the environmental sustainability of water use. But if water use is constrained

so that the environment receives a larger share, there could be significant socio-economic—and demographic—implications. Population needs to be taken into account when considering the implications of efforts to redirect water to the environment, and to address associated adjustment issues that may arise. Population characteristics might, for example, render a community especially vulnerable to change.

Thirdly, recognising that urban and rural systems can be nested or linked, either through geography or manmade infrastructure, population changes in urban systems can (at least in some cases) be highly relevant to associated rural systems.

These criteria are presented graphically in Figure 1.

Stretched urban systems

To identify which urban systems are most stretched, data on water storage levels, restrictions, and population growth were obtained from the Water Services Association of Australia,[11] the Australian Bureau of Statistics, and state and local governments. Refer to Table 1.

Table 1 shows that extremely high levels of growth are projected in some locations: Mandurah and Perth in Western Australia; Kilmore and Bendigo in Victoria; and the Gold Coast, Townsville, Brisbane, Cairns and Toowoomba in Queensland. At the other end of the scale, Dubbo, Orange, Taree and Goulburn in New South Wales; and Horsham and the Central Gippsland region of Victoria are not projected to grow so significantly. At the same time, some places have experienced particularly significant water shortages, such as Toowoomba, Bendigo, Ballarat, Gosford, Horsham and Goulburn.

To obtain a relative guide to which systems are under most stress, each system was given two scores: a score reflecting water storage levels over the three-year period to February 2010; and a score reflecting the projected percentage increase in population by 2026, relative to 2006. Each score was out of ten, with ten signifying a high level of population and/or water-related stress. The storage scores are roughly equal to

Figure 1: Proposed approach to identifying where population matters for water resources

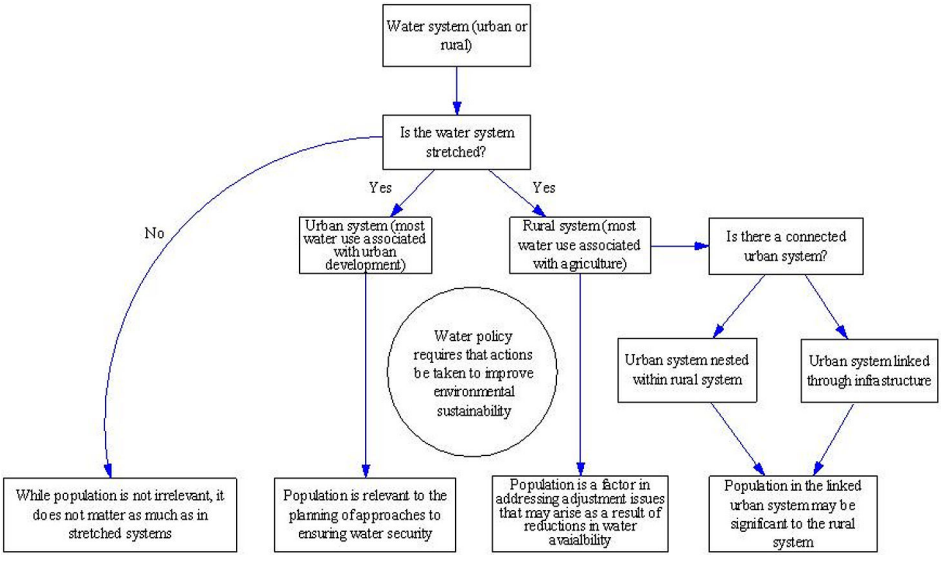

Table 1: Assessment of urban water systems

State	Urban area[1]	Water storage levels, per cent[2]			Water restrictions, February 2010[2]	Population			Assessment (larger equals more stressed)		Total score out of 20
		February 2008	February 2009	February 2010		Total persons, 2006[3]	Historical per cent increase, 1996–2006[3]	Projected per cent increase, 1996–2006[4]	Storage stress	Growth stress	
WA	Regional WA towns connected to the Integrated Water Supply Scheme (Mandurah and towns fed from Goldfields pipeline)	35	33.3	41.8	permanent water efficiency measures since 1 October 2009	71,917[3]	44	82	6	8	14
Vic	Broadford, Kilmore & surrounds	13.81	25.31	88.25	Stage 2 restrictions for Heathcote Junction, Kilmore and Wondong; all other areas are on stage 1	n/a	n/a	73	6	7	13
Qld	Gold Coast	100	100	100	restrictions suspended until the Hinze dam storage drops below 95 per cent	565,311	42	71 (to the year 2031)	0	7	7
Qld	Townsville	103.5	111.7	98.7	Level 1 restrictions since October 2007	153,249	25	55	0	5	5
WA	Perth	35.4	33.3	41.8	permanent water efficiency measures introduced on 1 October 2007	1,518,748	17	49	6	5	11
Qld	Brisbane	38.8	47.1	74.1	permanent water conservation measures (daily target 200L per person) in place from 1 December 2009	1,819,762	21	47	5	5	10
NT	Darwin	100	100	45	no restrictions	114,362	19	45	2	5	7
Qld	Cairns	61.7	100	100	permanent water saving restrictions	131,636	23	41	1	4	5
Qld	Toowoomba	12.9	10.3	15.60	Stage 5 since 25 September 2006	96,159	11	41	9	4	13
Vic	Bendigo, Castlemaine, Kyneton and surrounding districts	15.7	15.7	26.1	Bendigo Stage 3 restrictions since 1 January 2009, Kyneton and Castlemaine continued Stage 4 general exemption since January 2008	84,883[3]	14	40	8	4	12
NSW	Port Macquarie	Two reservoirs, 43 and 94.6	Two reservoirs, 79 and 100	Two reservoirs, 63 and 97	mandatory water conservation measures (Level 1 restrictions) since September 2006	71,284	25	36	2	4	6
Vic	Melbourne	35.5	31	35.7	Target 155 combined with Stage 3a restrictions in place from 17 May 2009	3,743,015	14	35	7	4	11
Vic	Ballarat (Ballarat & District)	9.8	17.1	22.5	Stage 3 restrictions from 1 January 2010	88,451	12	34	9	3	12
Vic	Geelong	49.6	22.1	30.80	Stage 4 restrictions from 9 December 2006; winter exemptions from 5 April to 4 October	167,718	10	31	7	3	10
Vic	Bairnsdale	73.3	79.3	95.50	permanent water savings	11,265[5]	n/a	31	2	3	5

State	Urban area[1]	Water storage levels, per cent[2]			Water restrictions, February 2010[2]	Population			Assessment (larger equals more stressed)		Total score out of 20
		February 2008	February 2009	February 2010		Total persons, 2006[3]	Historical per cent increase, 1996–2006[3]	Projected per cent increase, 1996–2006[4]	Storage stress	Growth stress	
NSW	Sydney	66.4	60	59.2	Water Wise Rules in place from 21 June 2009	4,281,988	10	27	4	3	7
ACT	Canberra	50.1	47.85	52.75	Stage 3 restrictions in place from 16 Dec 2006	333,839	8	25	5	3	8
NSW	Gosford	21.6	31.8	29.30	Stage 3 since 30 March 2008	282,798[5]	n/a	23	7	2	9
NSW	Newcastle	82.5	95.1	80.1	no restrictions	517,511	12	21	2	2	4
SA	Adelaide	61	63	67.50	permanent water conservation measures in place from 16 November 2009	1,145,812	6	21	4	2	6
Tas	Hobart	61	70.3	n/a	no restrictions	205,481	5	19	4	2	6
NSW	Bathurst	78	73.5	70.40	eased from Stage 1 to odds and evens system since 1 August 2007	32,257	11	14	3	1	4
NSW	Dubbo	water supply is run-of-the-river dependant			no restrictions	39,618	8	13	0	1	1
NSW	Orange	37.1	37.5	n/a	amended Level 5 changes as at 4 October 2009	37,108	7	11	6	1	7
NSW	Taree	water supply is run-of-the-river dependant			no restrictions	47,006	8	10	0	1	1
Vic	Horsham	3.9	4.2	11.40	Stage 4 restrictions for majority of district from 1 October 2006	14,124[5]	n/a	9	9	1	10
Vic	Central Gippsland (Sale, Traralgon, Warragul and surrounding towns)	81.67	80.3	85.30	permanent water saving rules since September 2007	76,291[5]	1	8	2	1	3
NSW	Goulburn	70	59.3	59.60	Level 3 restrictions since 5 July 2007	20,130[5]	n/a	3	7[12]	0	7

Sources: [1] Urban areas as defined by Water Services Association of Australia, 2010, op. cit., see note 11.

[2] Data from ibid.

[3] Data from *Australian Historical Population Statistics*, Australian Bureau of Statistics (ABS), Catalogue no. 3105.0.65.001, 2008 unless indicated otherwise. Note that population data for regional Western Australian towns connected to the Integrated Water Supply Scheme are for Mandurah only, and data for Bendigo, Castlemaine, Kyneton and surrounding districts are for Bendigo only.

[4] For capital cities, the percentage increase was calculated from data in *Population Projections, Australia, 2006 to 2101*, ABS, Catalogue no. 3222.0, 2008. For other centres, it was calculated from population projections prepared by the relevant state/territory government or commissioned by local councils.[13]

[5] Data from 2006 *Census of Population and Housing Datapack: Basic Community Profile, Release 2*, ABS, Catalogue no. 2069.0.30.001, 2007, for the following urban centres/localities: Bairnsdale, Central Coast, Horsham, La Trobe Valley, Goulburn.

100 minus the average storage level (in per cent) over the three-year period, divided by 10; the population scores are roughly equal to the projected growth (in per cent) to 2026, divided by 10. The two scores were then added together to give an overall assessment.

While this approach is to some extent arbitrary, it provides a useful starting point for identifying stretched systems. The scores suggest that some urban areas appear to be particularly stretched from a water and population perspective. These areas—with total scores of ten or more—include Mandurah and Perth in Western Australia; Kilmore, Bendigo, Melbourne, Geelong, Horsham and Ballarat in Victoria; and Brisbane and Toowoomba in Queensland.

Stretched rural systems

The matter of which of Australia's rural water systems are stretched is contentious. For political reasons, governments have often been reluctant to identify systems as unsustainable.[14] Nonetheless, work has been completed which gives a good indication of which systems are under the most pressure. The Australian Water Resources 2005 (AWR2005) report by the National Water Commission[15] assessed the extent of water resources, how those resources were used, and the health of rivers and wetlands in 2004–05. It assessed a sample of 51 water systems for their 'level of development' and also identified the top 20 water-using regions of Australia. Subsequently, the CSIRO's Murray-Darling Basin Sustainable Yields report assessed surface and groundwater availability in the Murray-Darling Basin, taking into account the historical and recent climate, and wet, dry and median projected climates in 2030.[16]

In the longer term, the Murray-Darling Basin Authority is working on a Murray-Darling Basin Plan, which is expected to be released in 2011. The plan will, among other things, describe in detail the status of water systems in the Murray-Darling Basin, and set environmentally sustainable limits on how much water can be diverted from the basin's water resources.

For the purposes of this paper, I considered that two criteria would give a reliable indication of which rural water systems are under the most pressure. Firstly, rural water systems were considered to be under pressure if they had been assessed by AWR2005 as being 'highly developed' through one or more of the tests applied in that report. Those tests were: (i) whether levels of water use were high relative to the sustainable yield of the system, where that sustainable yield was known; (ii) whether levels of water use were high relative to the inflows into the system during 2004–05; and (iii) whether levels of water use were high relative to the total available water resource, that being defined as the total inflows plus the total water already in storage at the start of the year.[17]

Secondly, I considered rural water systems to be under pressure (even if they had not been assessed by AWR2005 for level of development) if they had been identified by AWR2005 as one of the 'top 20' water using systems in Australia.

Using these criteria, 23 rural water systems were identified. Because they are the most exploited, these systems could reasonably be expected to be the ones in which water reforms will have the biggest impacts. Selected demographic data were then obtained for each system, drawing on customised 2006 census data and an area-based concordance of census collection districts to water system boundaries.

The findings of the above analysis are presented in Table 2. Ten systems (Murrumbidgee-Regulated, Goulburn-Broken-Campaspe, Namoi-Regulated, Northern NSW Rivers, Macquarie-Regulated, Hunter-Regulated, Lachlan-Regulated, Barossa Prescribed Water Resources Area, Macquarie and Wimmera) were identified

as 'highly developed' by AWR2005. Notably, most of these systems are in New South Wales or Victoria. They have a total population of over 600,000 persons, of whom just over 75 per cent live in urban centres or localities. Major centres associated with these systems include Wagga Wagga, Griffith, Shepparton, Tamworth, Dubbo, and Maitland. Assuming the AWR2005 assessment was accurate, communities in these systems, and in associated urban centres, can expect to be significantly affected by changes to water availability as a result of water policies.

Six systems (Condamine–Balonne, Border Rivers, Burnett, Lower Limestone Coast, SW Western Australia, and Barron) were identified as 'moderately developed' by AWR2005. These systems are in Queensland, South Australia and Western Australia. They have a total population of over 500,000, of which 76 per cent live in urban centres or localities. Major centres associated with these systems include Toowoomba, Bundaberg, Mount Gambier, Bunbury, Mandurah, and Cairns. Communities in these systems and associated urban centres could be affected by changes in water availability as a result of water policies, but perhaps less so than the communities in the first category.

Finally, seven systems were not assessed (for level of development) by AWR2005, but had very high levels of water use. For the purposes of this paper, I considered that they represent stretched rural systems, because their non-assessment by AWR2005 (which assessed only a sample of 51 water management areas from around Australia) does not preclude them suffering from high levels of development. Moreover, the high levels of water use in these systems make it highly likely that they are highly developed. These systems are home to over 640,000 people, of whom 77 per cent live in urban centres or localities. Major centres associated with these systems include Mildura, Albury–Wodonga, Ayr, Charters Towers, Bendigo and Rockhampton.

The above paragraphs describe which populations might be expected to suffer declines in water availability. While the sizes of these populations are interesting to consider, in the context of possible water reductions other population dimensions are also important. For example, some of these populations may have demographic characteristics which render them especially vulnerable to these declines. Recognising that it is a complex area of sociological work in its own right, it is beyond the scope of this paper to discuss indices of population vulnerability. Further analysis of which population characteristics make water systems more vulnerable would be useful.

Interconnected urban and rural systems

As noted earlier, urban and rural systems can be linked, either because the urban system forms a subset of the rural system, or because it is linked through infrastructure. A full exploration of these linkages is beyond the scope of this paper. However, some initial observations can be made. Urban populations within rural systems are generally not of great significance to the rural system, because the amount of water they use is small relative to agriculture (the major water user in rural systems). However, urban populations could be significant to rural systems if (i) there is a connection between the systems, (ii) the urban population is relatively large, or significant growth is anticipated, and (iii) the rural system is already under stress.

Drawing on Tables 1 and 2 and from other sources of information on water supply infrastructure, some urban populations which may be significant to connected rural systems are presented in Table 3.

The populations of Canberra and Wagga Wagga are potentially significant

Table 2: Assessment of rural water systems

Water system	Rationale for selection		Population			
	Level of development as identified in AWR 2005[1]	Identified as 'top 20' water use region by AWR 2005 (estimated water use in brackets)	Total population[2]	Population in rural balance[2]	Percentage in rural balance	Largest urban centres associated with each system[3]
Category 1: Highly developed systems[4]						
Murrumbidgee-Regulated (NSW)	High	Yes (1,820 GL)	104,513	16,474	16	Wagga Wagga (46,724), Griffith (16,207), Leeton (6,819), Tumut (5,926)
Goulburn-Broken-Campaspe (Vic)	High	Yes (1,362 GL)	180,968	64,492	36	Shepparton-Mooroopna (38,797), Benalla (9,127), Seymour (6,063)
Namoi-Regulated (NSW)	High	Yes (combined Namoi-Unregulated and Namoi-Regulated: 448 GL)	59,338	6,974	12	Tamworth (33,457), Gunnedah (7,542), Narrabri (6,096)
Northern NSW Rivers	High (only Gwydir subsystem assessed)	Yes (428 GL)	55,372	17,878	32	Inverell (9,738), Moree (8,082), Glen Innes (5,946)
Macquarie-Regulated (NSW)	High	Yes (combined Macquarie-Regulated and Macquarie-Unregulated: 289 GL)	55,316	5,726	10	Dubbo (30,556), Mudgee (8,258)
Hunter-Regulated (NSW)	High	No	63,068	9,216	15	Maitland (61,433); Singleton (13,658); Muswellbrook (10,220)
Lachlan-Regulated (NSW)	High	No	25,875	4,453	17	Cowra (8,430); Forbes (6,950)
Barossa Prescribed Water Resources Area (SA)	High	No	17,450	4,419	25	Nuriootpa (4,411); Tanunda (4,152)
Macquarie (Tas)	High	No	2,018	951	47	Campbell Town (773); Ross (294)
Wimmera (Vic)	High	No	48,887	14,644	30	Horsham (14,124); Stawell (5,881)
Subtotal			*612,805*	*145,227*	*24*	
Category 2: Moderately developed systems						
Condamine-Balonne (Qld)	Moderate	Yes (combined Condamine-Balonne, Border Rivers and Moonie: 1,122 GL)	184,281	37,912	21	Toowoomba (95,252); Warwick (12,556); Dalby (9,788); Roma (5,977)
Border Rivers (Qld)	Moderate		21,209	9,424	44	Goondiwindi (5,627); Stanthorpe (4,272)
Burnett (Qld)	Moderate	Yes (343 GL)	121,168	36,361	30	Bundaberg (46,963); Kingaroy (7,628)
Lower Limestone Coast (SA)	Moderate	Yes (335 GL)	55,609	15,119	27	Mount Gambier (23,509); Naracoorte (4,891)
SW Western Australia	Moderate (only Harvey and Collie subsystems assessed)	Yes (271 GL)	177,638	35,379	20	Bunbury (53,901); Mandurah (67,797); Busselton (15,383)
Barron (Qld)	Moderate	Yes (as part of Northern Queensland Coast: 271 GL)	55,481	11,744	21	Cairns (98,326); Mareeba (6,806)
Subtotal			*615,386*	*145,939*	*24*	

Water system	Rationale for selection		Population			
	Level of development as identified in AWR 2005[1]	Identified as 'top 20' water use region by AWR 2005 (estimated water use in brackets)	Total population[2]	Population in rural balance[2]	Percentage in rural balance	Largest urban centres associated with each system[3]
Category 3: Other systems where the level of development was not assessed, but with high levels of water use						
VIC Murray	Not assessed	Yes (1,253 GL)	147,434	32,646	22	Mildura (29,994); Albury-Wodonga (29,698); Echuca-Moama (12,363); Swan Hill (9,697)
NSW Murray-Regulated	Not assessed	Yes (1,047 GL)	88,320	12,357	14	Albury (43,775); Deniliquin (7,431); Corowa (5,629)
Burdekin (Qld)	Not assessed	Yes (combined Don and Burdekin: 913 GL)	68,852	19,550	28	Ayr (16,178); Charters Towers (15,936)
Don (Qld)	Not assessed		4,708	2,804	60	Bowen (14,960)
Loddon (Vic)	Not assessed	Yes (598 GL)	128,241	27,278	21	Bendigo (76,061); Maryborough (7,681); Castlemaine (7,250)
SA Regional	Not assessed	Yes (453 GL)	59,897	25,796	43	Goolwa (5,883); Renmark (4,337); Berri (4,013)
Fitzroy (Qld)	Not assessed	Yes (346 GL)	144,205	28,077	19	Rockhampton (60,856); Emerald (10,993
Subtotal			*641,657*	*148,508*	*23*	

Sources: National Water Commission, 2007, op. cit., note 5; customised census collection district data from *2006 Census of Population and Housing Datapack: Basic Community Profile, Release 2*, ABS, Catalogue no. 2069.0.30.001, 2007, concorded to water system boundaries.

Notes: [1] Corresponds to the highest rating against one or more of the three criteria used by AWR2005 to assess the level of water resource development. Note that an assessment of *overused* by AWR 2005 is reported as *high* in Table 2. Where the level of water resource development was only assessed for part of the water system, this is indicated.

[2] Population data were derived by concording 2006 census collection district (CD) data to water system boundaries. The rural balance population consists of CDs defined as rural balance for the purposes of the 2006 census, where those CDs fall within the relevant water system boundary.

[3] This column identifies urban populations that fall mainly within, or otherwise have an important association with, each water system. Note that some urban centres are geographically located across water system boundaries. The populations listed reflect totals for all CDs recognised by the 2006 census as belonging to each urban centre, rather than for only those CDs belonging to each urban centre that are also geographically located within water system boundaries. Hence, for example, while the majority of the population of Cairns (population 98,326) is geographically located outside the Barron system (population 55,481), Cairns has important ties to the Barron system (its water supply is largely drawn from the Barron system) and is therefore listed in the table.

[4] AWR2005 also assessed several other systems as highly developed. These systems are not listed in the table as they constitute urban systems for the purposes of this paper. They include the capital city water systems of Adelaide, Melbourne, Perth and Sydney; the Patawalonga system in South Australia (located within the Adelaide urban area), the Gnangara Mound in Western Australia (which supplies most of Perth's water); the Mereenie Sandstone-Alice Water Control District in the Northern Territory (which supplies water to Alice Springs); and the Carnarvon system in Western Australia (which supplies the town of Carnarvon).

to the Murrumbidgee system owing to the location of those cities within the Murrumbidgee system, the relatively large size of their populations, and the stress the Murrumbidgee is already under. A similar argument applies to Shepparton–Mooroopna in the Goulburn-Broken-Campaspe.

The populations of Melbourne and Adelaide are significant to the Goulburn-Broken-Campaspe and the River Murray, but for different reasons. As shown in Table 2, both of these rural systems are already under stress. Melbourne and Adelaide are respectively connected to them via the Sugarloaf Pipeline[18] and the Mannum–Adelaide Pipeline.[19] Further population growth in these cities will therefore affect these rural systems.

CONCLUSIONS

This paper has investigated where, in the context of Australia's water resources, population could matter most. It is overly simplistic to say that population matters for water everywhere in Australia. Rather, the extent to which population matters for water, and how, depends very much on location.

Population is definitely important in the context of urban water. Population size and population growth are likely to be particularly significant in a number of fast-growing and/or already water-stressed urban centres. Such centres are found particularly in Queensland and Victoria, and also in New South Wales and Western Australia. These include Brisbane, the Gold Coast, Townsville, Cairns, Toowoomba, Melbourne, Geelong, Ballarat, Bendigo, Port Macquarie, Orange, Goulburn, Perth and Mandurah.

In a different way, population could be significant in the context of some rural water systems. While, in a rural context, there are fewer significant associations between population size, population growth and water use, there are demographic dimensions to structural adjustments that may occur as a result of declining water availability. Such issues may be particularly significant in towns in the more highly stressed river systems (for example the Murrumbidgee, Goulburn–Broken–Campaspe, Namoi, Macquarie, Hunter and Lachlan), and/or in water systems which have population characteristics which render them especially vulnerable to change.

Transient populations may be significant in the context of some water systems. While further work is required to confirm where transient populations matter most, it is conceivable that they may be most significant to water managers in parts of Australia where tourism and/or mining are important, such as Far North Queensland, Central Australia, outback Western Australia and Queensland, and the Snowy Mountains.

Building on the analysis described in this paper, there is scope for further work to analyse in more detail how population is relevant to water management, in specific localities. In the Murray–Darling Basin, work is already underway to determine

Table 3: Examples of where urban populations may be significant to associated rural systems

Stretched rural system	Associated urban systems in which population growth may be particularly significant to the rural system
Murrumbidgee (NSW)	Canberra, Wagga Wagga
Goulburn-Broken-Campaspe (Victoria)	Melbourne, Shepparton-Mooroopna
Murray (Victoria, NSW and South Australia)	Adelaide

sustainable diversion limits for water extraction in the Basin, and assess the impacts of those limits on communities. The outcomes of this work (due to be released later in 2010) will shed further light on how population is relevant to water management, at least in the Murray–Darling Basin. This paper has also not considered the question of water quality, and how it is affected by population. This relationship is complex, and worthy of further consideration.

References

1 See B. Foran, 'Future dilemmas: a reply to the critics', *People and Place*, vol. 11, no. 4, 2003, pp. 1–14; B. Lines, 'Australian ambitions: population and sustainability', People and Place, vol. 13, no. 2, 2005, pp. 21–28; K. Thomson, 'Population reform—meeting the challenges', *People and Place*, vol. 17, no. 4, 2009, pp. 55–61.

2 For details of Australia's approach to water management, refer to National Water Commission, *Australian water reform 2009: second biennial assessment in progress in implementation of the National Water Initiative*, Commonwealth of Australia, 2009; and J.J. Pigram, *Australia's water resources: from use to management*, CSIRO Publishing, Melbourne, 2006.

3 The issue of structural adjustment and water reform is a complex one. For a more detailed analysis see J.C. McColl and M. Young, *Managing change: Australian structural adjustment lessons for water*, CSIRO Land and Water, 2005; or National Water Commission, 2009, op cit., note 2.

4 'Water systems' are hydrologically connected systems defined for management purposes. Examples include subcatchments, catchments, drainage divisions, groundwater management units, and aquifers. Refer to National Water Commission, 2009, op. cit., note 2, p. 267.

5 Examples include the Hawkesbury system in New South Wales, which services Sydney; the Bunyip, Yarra, Maribyrnong, Werribee and Moorabool systems in Victoria, which service Melbourne; the Cotter system which services Canberra; and the Logan and Moreton systems in Queensland, which service Brisbane. In these systems, household use makes up a relatively large proportion (typically 40 per cent or more) of total use. Refer to National Water Commission, *Australian water resources 2005: a baseline assessment of water resources for the national water initiative: key findings of the Level 2 assessment: summary result*s, Commonwealth of Australia, 2007.

6 See Water Services Association of Australia, *Implications of population growth in Australia on urban water resources: occasional paper no. 25*, July 2010, Melbourne, 2010.

7 The Water Services Association of Australia (WSAA) has estimated that from 2008–09 to 2026, total urban water demand will increase by 735 GL for the ABS's 2007 series A population projection, 631 GL for the series B projection, and 581 GL for the series C projection. WSAA also estimates that, by the year 2056, total urban water demand will increase by 1612 GL for the series A projection, 1147 GL for the series B projection, and 961 GL for the series C projection. The WSAA report acknowledges that population growth is not the only factor influencing future urban water demand, and that future demand will also be affected by commercial and industrial demand, climate change, housing type and design, uptake of water efficient appliances, water restrictions, water saving rules, the cost of water, economic growth, and the design of cities. See Water Services Association of Australia, 2010, op. cit. note 6, pp. 4–5. The series A, B and C projections would take the total population to 28.7, 27.2 and 26.0 million respectively in 2026 and to 42.5, 35.5 and 31.0 million in 2056. See *Population Projections, Australia, 2006 to 2101*, ABS, Catalogue no. 3222.0, 2008.

8 In most of Australia's water systems, agriculture accounts for in the order of 70 to 90 per cent of total water use. See National Water Commission, 2007, op. cit., pp. 35–36.

9 In the case of a closed, centrally planned economy—that is, if all agricultural production were for domestic consumption, and in the absence of market forces influencing how much is produced and consumed—there may be a more direct link between population and agricultural production. The author is not aware of anywhere that such a scenario would apply, but has not investigated the matter in detail.

10 See National Water Commission, 2007, op. cit., pp. 230–232.

11 See Water Services Association of Australia website at <www.wsaa.asn.au/Media/Facts/StorageLevels/> accessed 10 August 2010.

12 While its storage levels were relatively healthy during the three years to February 2010, Goulburn faced a severe water crisis for several years prior to this period. Refer to, for example, *ABC News*, 'Goulburn's water crisis receives Fed Govt attention', 31 May 2005 <www.abc.net.au/news/stories/2005/05/31/1380668.htm> accessed 1 August 2010.

[13] The percentage increase for Mandurah was calculated from a population projection for 2026 published by the City of Mandurah. See City of Mandurah, *Population forecast, Mandurah* <forecast.id.com.au/Default.aspx?id=260&gid=10&pg=30041> accessed 10 August 2010.

The percentage increases for Queensland centres were calculated from population projections for 2026 prepared by the Queensland Government, for the Gold Coast Statistical Division, Townsville local government area, Cairns Regional Council and Toowoomba Regional Council. See Office of Economic and Statistical Research, *Population projections* <www.oesr.qld.gov.au/subjects/demography/population-projections/index.php> accessed 10 August 2010.

The percentage increases for Victorian centres were calculated from population projections for 2026 by the Victorian Government, for the Latrobe Council (for Central Gippsland in the table), Horsham Rural Council, Mitchell Shire Council (for Broadford, Kilmore and surrounds), Greater Bendigo, Ballarat City Council, Greater Geelong and East Gippsland (for Bairnsdale). See Victorian Department of Planning and Community Development, *Victoria in future 2008: detailed data file*, Microsoft Excel file <www.dse.vic.gov.au/CA256F310024B628/0/EC6552E18DA39A12CA25764000206724/$File/VIF2008+Projected+Population+Totals+-+SLA+LGA+SSD+SD+2006-2026.xls> accessed 10 August 2010.

The percentage increase for Port Macquarie was calculated from a population projection for 2026 published by the Port Macquarie–Hastings Council. See Port Macquarie–Hastings Council, *Population forecasts* <forecast2.id.com.au/Default.aspx?id=231&pg=5000> accessed 10 August 2010.

The percentage increases for other New South Wales centres were calculated from population projections for 2026 prepared by the New South Wales Government, for the Goulburn–Mulwaree local government area, Gosford Wyong statistical subdivision, Bathurst Regional local government area, Dubbo local government area, Orange local government area and Greater Taree local government area. See Department of Planning, *NSW SLA population projections, 2006–2036*, Microsoft Excel file <www.planning.nsw.gov.au/LinkClick.aspx?fileticket=9qUv_Q8RwkM%3d&tabid=124&language=en-AU> accessed 10 August 2010.

[14] For a detailed discussion of the extent to which governments have identified water systems with unsustainable levels of water extraction, refer to Chapter 5 of National Water Commission, 2009, op. cit.

[15] See National Water Commission, 2007, op. cit.

[16] Commonwealth Scientific and Industrial Research Organisation (CSIRO), *Water availability in the Murray–Darling Basin: a report from CSIRO to the Australian Government*, Canberra, 2008

[17] For a detailed description of the AWR2005 assessment methodology, see National Water Commission, 2007, op. cit., pp. 58–69.

[18] See Sugarloaf Pipeline Alliance website at <www.sugarloafpipeline.com.au> accessed 10 August 2010.

[19] See SA Water Pipelines website at <www.sawater.com.au/SAWater/Education/OurWaterSystems/Pipelines.htm> accessed 10 August 2010.