Technical Note

Residential Water Conservation in Australia and California

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Abstract: In much of the western United States, reducing residential water use is a major source of water conservation, especially as population growth urbanizes agricultural land. Although estimates of the potential of conservation are useful, the experience of Australia provides a realistic target for residential water conservation. Although reliability of urban water use data is often questionable, it is clear that Australians use less water than Californians, with a similar climate, economy, and culture. Per capita usage is compared, and explanations for use differences are offered. If California had the same residential water use rates as Australia, it could have reduced gross urban water use by 2,600 GL (2.1 million acre-feet) in 2009 and potentially saved 1,800 GL (1.5 million acre-feet) for consumptive use by others. **DOI: 10.1061/(ASCE)WR.1943-5452.0000225.** © *2013 American Society of Civil Engineers.*

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Introduction

Urban residential water conservation has been discussed as early as 1910 (Van Hise 1910; Hazen 1920). Nevertheless, residential water use still has significant potential for conservation, especially as urban growth displaces agricultural lands (Gleick 2003). Although estimates abound on how much water can be conserved from the residential sector [Gleick 2003; CALFED Bay-Delta Program 2006; California Department of Water Resources (DWR) 2010], these numbers are projections, based primarily on theory and assumptions. However, Australia provides an example of a country that has recently undergone substantial sustained reductions in urban residential water use. This paper compares residential water use in Australia and California, identifying realistic residential conservation behavior and objectives based on urban water use in Australia. California, and perhaps other regions, may be able to *see their future* in water conservation by looking at the Australian experience.

Australia makes for an excellent comparison with the western United States, particularly California. Population, economic development, culture, and hydrologic patterns are similar. The populations of California and Australia are of similar magnitude: 37 million and 22 million people, respectively (World Bank 2010). Australia's 2008, per capita GDP was AUD$46,500 [Australian Bureau of Statistics (ABS) 2008] compared with California's per capita gross state product of $48,600 [Bureau of Economic Analysis (BEA) 2010]. Average annual rainfall in New South Wales (Australia's most populous state) is approximately 51.8 cm (20.4 in.) with a standard deviation of 11.4 cm (4.5 in.), whereas California exhibits an average annual rainfall of 56.6 cm (22.3 in.) with a standard deviation of 16.3 cm (6.4 in.) [National Oceanic and Atmospheric Administration (NOAA) 2010; Australian Bureau of Meteorology (ABM) 2010]. Rainfall variability is also similar; both California and Australia have large weather swings, rather than a predictable, temperate rainfall pattern. California's climate is a bit more variable than southeast Australia's; the coefficient of variation was 0.29 in California and 0.22 in New South Wales over the past 100 years (NOAA 2010; ABM 2010). Average residential lot sizes are 740 m^2 (8,000 ft^2) in Australia and 840 m^2 (9,000 ft^2) in California (ABS 2005; Hanak and Davis 2006).

First, a comparison is presented of actual water use in each region, followed by a brief discussion of how Australia reached its lower levels of residential water use.

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Comparison of Australian and Californian Use

Before undertaking a comparison, some discussion of data availability and reliability is in order.

Data Reliability

The California DWR acknowledges that "easily retrievable, standardized, and comprehensive baseline urban water use data are not available in California" (DWR 2009). Although surveys are completed by water utilities each year (termed public water system surveys, or PWSS), consistent, reliable urban water use data are not published regularly (DWR 2005). PWSS results provide a statewide estimate, although its accuracy is questionable because of voluntary self-reporting without auditing. The other primary sources of information about usage in California are urban water management plans (UWMPs), which are required every five years (California Urban Water Management and Planning Act section 10610 et esq.). UWMPs include use data, but are not compiled annually into a statewide database. This paper follows the example of California DWR, using the population and usage estimates from the PWSS results (DWR 2011; Cahill and Lund 2011).

In contrast, Australia has a consistent system for collecting urban water data. Almost every three years, the Australian Bureau of Statistics publishes a *water account* with summary water statistics, including urban water usage. The data comes from surveys, water utilities, and research papers, and broadly consolidates water

J. Water Resour. Plann. Manage. 2013.139:117-121.

use information (ABS 2010b). In addition to the water accounts, a National Performance Report has been released each year since 2005. All major water utilities provide information for the audited report, with standardized reporting categories [Water Services Association of Australia (WSAA) 2011]. The National Performance Report would be analogous to an audited, expanded version of the PWSS results in California, if such a compilation existed.

With those caveats in mind, total per capita residential and urban water uses are compared, along with available information on the end uses of water. Urban use includes residential, commercial, and industrial uses.

Per Capita Residential Use

Examining per capita residential water eliminates the effects of population size. Table 1 shows the historical per capita residential water use in California and Australia.

Australians, on average, used nearly 200 L per capita per day (lpcd) (50 gal per capita per day, gpcd), less water than their Californian counterparts in 2009 (DWR 2011; WSAA 2011). Not only did Australia exhibit less per capita residential use than California as a whole in 2009, but nearly every major city in Australia used less water per capita than metropolitan areas in the western United States, as shown in Table 2.

Components of Residential Use

Total use estimates are helpful, but a breakdown by end use can better identify saving potential. The most difficult data to estimate are outdoor residential use. DWR estimated outdoor water use accounts for 54% of all residential use in 2005 (DWR 2009). However, the East Bay Municipal Utilities District (EBMUD) (2005) estimated outdoor use at 32% in the same year. The most recent end use study in California found outdoor water use to be 53% (DeOreo et al. 2011). Australian estimates also vary widely. One study estimated outdoor water use as 44% of all use, whereas another estimate pegged outdoor water use for the city of Perth at 56% (ABS 2004c; Loh and Coghlan 2003). The most recent study in Queensland estimates outdoor water use as only 12% of residential use (Willis 2009). However, the variations are small enough that per capita outdoor residential use remains much less in Australia than California. Indoor use estimates are more reliable and consistent than outdoor use estimates (DeOreo et al. 2011). An increasingly popular technique to estimate indoor end uses of water is to install data loggers that record meter readings at short time intervals (5–10 s), and then apply signal processing software to disaggregate water use events by end use from the meter readings. Table 3 shows the results of studies using this approach to estimate end uses of water in Australia and California from 1999–2009. Cahill and Lund (2011) expand on the differences in end uses between California and Australia.

From the end use studies, the biggest differences between Australian and Californian residential water use are, in order of magnitude, outdoor water use, toilet use, leaks and faucets, washing machines, other, and shower/bath. Over half of the total difference in residential water use is from Australia's much lower rates of outdoor water use.

Table 2. Water Use in Selected Australian and Western U.S. Cities, 2010

Location	Residential use[b], lpcd (gpcd)	Urban use[b], lpcd (gpcd)
Portland, OR	219 (58)	390 (103)
Albuquerque, NM[c]	282 (74)	587 (155)
Tucson, AZ[d]	367 (97)	544 (144)
Denver, CO	393 (104)	604 (160)
California	394 (104)	568 (150)
San Francisco	172[a] (46[a])	295[a] (78[a])
Oakland/East Bay	277[a]–316 (73[a]–83)	439[a]–469 (116[a]–124)
San Diego	277[a]–350 (73[a]–92)	490[a]–524 (129[a]–138)
San Jose	307–323[a] (81–85[a])	489–519[a] (129–137[a])
Los Angeles	345[a]–376 (91[a]–99)	450[a]–547 (119[a]–145)
Sacramento	428[a]–455 (113–120[a])	642–667[a] (170–176[a])
Australia	204 (54)	318 (84)
Melbourne	150 (40)	238 (63)
Brisbane	172 (45)	289 (76)
Canberra	191 (50)	288 (76)
Sydney	207 (55)	312 (83)
Perth	284 (75)	399 (106)

Note: Data sources are Portland Water Bureau (PWB) 2011; Yuhas 2010; Tucson Water 2008; Denver Water 2011; DWR 2011; San Francisco Public Utilities Commission (SFPUC) 2011; East Bay Municipal Water District (EBMUD) 2011; Los Angeles Department of Water and Power (LADWP) 2011; San Jose Environmental Services Department (SJESD) 2011; San Diego Public Utilities (SDPU) 2011; Sacramento Department of Utilities (SDU) 2011; WSAA 2011.
[a]This data is from the Urban Water Management Plan.
[b]This data does not include distribution system losses.
[c]This data is from 2009.
[d]This data is from 2007.

Contributing Factors to Australian Conservation

Whereas California's per capita use dropped approximately 10% from 2000–2009, Australia reduced per capita use by approximately 35% (DWR 2011; WSAA 2011). Three actions contributing to Australia's reduced water use are the adoption of outdoor water restrictions, lower-flush toilets, and water pricing.

Outdoor Water Restrictions

Outdoor water restrictions are a major reason that Australian outdoor use is less than in California. Even when water is not in short supply, many Australian cities limit outdoor water use. In Melbourne, for example, outdoor watering is prohibited from 10:00 am to 8:00 pm [Department of Sustainability and Environment (DSE) 2010]. If residents notice neighbors wasting water, they can call a hotline to report water wasters and impose fines of up to AUD$458 (DSE 2010). Similar permanent

Table 1. Historical Comparison of Average Residential Water Use in Australia and California, 1994–2009

Year	1994	1997	2000	2004	2005	2006	2007	2008	2009
California, lpcd (gpcd)	397 (105)	443 (117)	441 (117)	446 (118)	421 (111)	425 (112)	445 (118)	417 (110)	397 (105)
Australia, lpcd (gpcd)	290 (77)[a]	295 (78)[a]	315 (83)[a]	245 (65)	238–282 (63–75[a])	248 (65)	221 (58)	198 (52)	203–222 (54–59[a])

Note: Water use is in liters (gallons) per capita per day, i.e., lpcd (gpcd). Data sources are ABS 1997, 2000, 2002, 2004a, b, c, 2006, 2008, 2010a, b; WSAA 2011; and DWR 2011.
[a]From ABS Water Account.

J. Water Resour. Plann. Manage. 2013.139:117-121.

Table 3. Californian and Australian Residential End Use Measurement Studies, 1999–2009

Study location	Source	Sample size	End use	Toilet	Shower/bath	Washing machine	Faucets	Leaks	Other	Outdoor	Total
United States	Mayer and DeOreo (1999)	$n = 1{,}188$	Use, lpcd (gpcd):	70 (19)	48 (13)	57 (15)	41 (11)	36 (10)	16 (4)	382 (101)	650 (172)
			% of total	11	7	9	6	6	3	59	100
East Bay area, CA	EBMUD (2005)	$n = 33$	Use, lpcd (gpcd):	76 (20)	57 (15)	53 (14)	38 (10)	19 (5)	4 (1)	114 (30)	360 (95)
			% of total	21	16	15	11	5	1	32	100
California	DeOreo et al. (2011)	$n = 735$	Use, lpcd (gpcd):	48 (13)	49 (13)	39 (10)	42 (11)	39 (10)	7 (2)	252 (67)	476 (126)
			% of total	10	10	8	9	8	1	53	100
Perth, AUS	Loh and Coghlan (2003)	$n = 124$	Use, lpcd (gpcd):	34 (9)	52 (14)	41 (11)	26 (7)	7 (2)	4 (1)	209 (55)	373 (99)
			% of total	9	14	11	7	2	1	56	100
Melbourne, AUS	Roberts (2005)	$n = 100$	Use, lpcd (gpcd):	30 (8)	55 (14)	43 (11)	27 (7)	14 (4)	2 (1)	57 (15)	227 (60)
			% of total	13	24	19	12	6	1	25	100
Gold Coast, AUS	Willis (2009)	$n = 151$	Use, lpcd (gpcd):	20 (5)	58 (15)	30 (8)	27 (7)	2 (0)	2 (0)	19 (5)	157 (42)
			% of total	13	37	19	17	1	1	12	100

Note: Data sources are Mayer and DeOreo 1999; Loh and Coghlan 2003; ABS 2004b; EBMUD 2005; Roberts 2005; Willis 2009; DeOreo et al. 2011.

restrictions exist in all major metropolitan areas in Australia. During droughts, restrictions can increase significantly. Such uncertainty about outdoor water reliability has encouraged residents to adopt less water-intensive landscapes or invest in rainwater tanks, which are exempt from restrictions and reduce demand on the water supply system (AAP 2006). As of 2010, 43% of Australian dwellings had a rainwater tank, dwarfing the prevalence of such devices in California (ABS 2010a). Although tanks with small storage capacity have modest effectiveness, rainwater tanks contribute to the lower outdoor use rates in Australia. Water drawn from wells is also exempt from restrictions and reduces demand on the municipal water system, but only 4% of urban Australian households use wells as a water supply source (ABS 2010a).

California, in contrast, has no permanent water restrictions on residential uses. Although temporary restrictions can be effective during droughts, they are usually the prerogative of the local water utility. Californians might object to the loss of personal freedoms such water restrictions would cause, but these restrictions have dramatically reduced outdoor water use in Australia.

Lower-Flush Toilets

As the largest indoor residential end-use before the 2000s, toilets were a logical place to start conserving water in coastal areas. Australia has advocated dual flush toilets with a half flush option when a full flush is unnecessary. Caroma, the leading toilet manufacturer in Australia, developed a 3 and 1.5 gal/flush toilet in 1981, compared with previous 3.5 or 6 gal/flush models [State Library of South Australia (SLSA) 2006]. By 1984, the Victorian government required use of dual-flush toilets in all new construction; other Australian states followed similar paths (ABS 2004a). In 1994, Caroma succeeded in producing effective toilets using 1.6 and 0.8 gal for a full and half flush, respectively (SLSA 2006). By 2001, 64% of all households had dual-flush toilets; adoption was 86% in 2010 (ABS 2004b, 2010a).

California law mandated installation of 3.5 gal/flush in new construction after January 1, 1978. California's lawmakers acted slightly earlier than the federal government in requiring ultra low flow toilets (ULFTs), which use 1.6 gal/flush, in replacements and new construction after January 1992 (DWR 1998). Californians have not adopted the ULFTs as quickly as Australians. By 2000, only approximately 26% of toilets in California were ULFT, and roughly the same proportion was still 6 gal/flush models (Gleick 2003). The earlier passage of laws in Australia requiring more water-efficient toilets than California combined with strong rebate programs have reduced residential water use.

Water Pricing

Water prices are difficult to compare, because water is often priced in a block rate scheme, in which different prices are charged depending on consumption. The exchange rate further obfuscates the comparison—because the exchange rate between American and Australian currency has fluctuated in recent years, no attempt will be made to adjust for the exchange rate; all prices are given in native currencies. In April 2011, Australian and United States currencies have almost equivalent value, but the Australian dollar was worth US$0.80 on average from 2006–2011 (OANDA 2011). Cahill and Lund (2011) compare a single-family residential monthly water bill, at the average metropolitan consumption rate in 2005 and at a fixed household consumption rate of 145 gal/day (5.9 CCF/month), by city in 2009–2011. Wastewater charges (applying only to indoor use) are not included in the comparison, although they are often a significant component of a monthly water bill. Because Australians use less water outdoors than Californians, wastewater bills are higher in Australia than California.

Australians pay more for water than Californians, but this has not always been the case. Residents of Los Angeles paid approximately twice as much for water from 1993–1994 as residents of Melbourne (Horridge and Rimmer 1994; Mitchell 1994). The situation is reversed now, as Australians in nearly every major city pay more than Californians, despite their lower consumption rates. Per-unit consumption costs, rather than fixed costs, comprise a larger proportion of the total water bill in Australia. The higher price of water in Australia likely has contributed to reduced water use. Because of the higher water rates, utility revenues per residential connection are similar between Australia and California despite the lower use rates in Australia.

Potential Savings in California

The translation of per capita numbers into total numbers can give a sense of how much water could actually be saved from increased conservation. First, a distinction should be drawn between gross urban use reduction and *saved* water. Most water used indoors by upstream areas is returned to waterways after treatment for use downstream, so conserving indoors in inland areas reduces neither statewide net nor consumptive use. Outdoor water use is mostly consumptive (because of evapotranspiration losses, assumed to be approximately 80%), so reductions in inland outdoor water use make some water available for other uses (Hanak et al. 2011). Water used in coastal urban areas is not used by downstream

J. Water Resour. Plann. Manage. 2013.139:117-121.

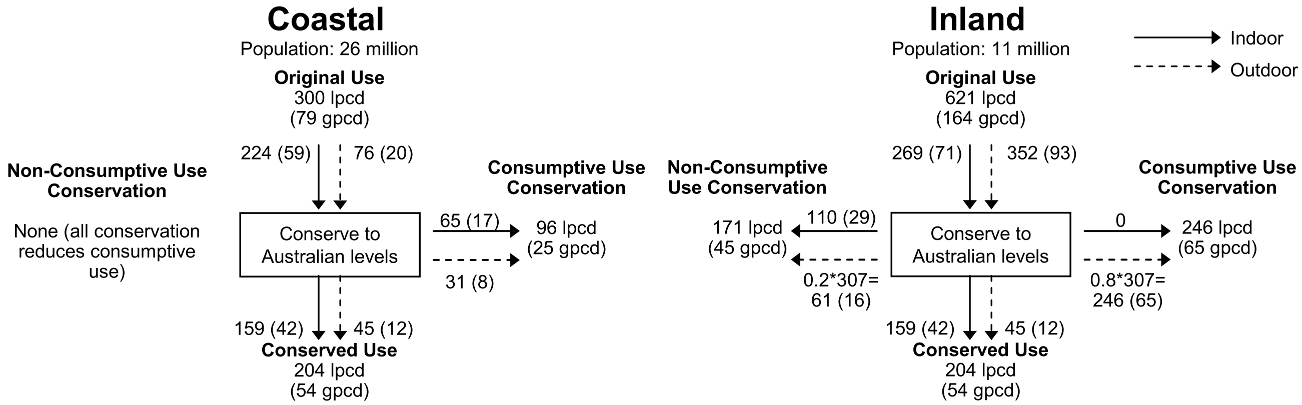

Fig. 1. Mass balance schematics for coastal and inland areas after conservation to Australian use levels, 2009: data is from United States Census Bureau (USCB) 2001a, USCB 2001b; DWR 2011; WSAA 2011; Hanak et al. 2011; Mayer and DeOreo 1999; DeOreo et al. 2011; SFPUC 2011; EBMUD 2011; LADWP 2011; SJESD 2011; San Diego Public Utilities (SDPU) 2011

areas, so all conservation in coastal areas reduces consumptive use. Therefore, *saved* water consists of total use reduction in coastal areas and roughly 80% of outdoor use reduction in inland areas.

If Californians had the same levels of residential use as Australians in 2009, gross use would have been less by approximately 190 lpcd (50 gpcd, see Table 1). This translates to a statewide residential use reduction of 2,600 GL (2.1 million acre-feet, maf) in 2009. Because the average Californian uses 397 lpcd (105 gpcd, see Table 1), and California coastal areas (with 26 million consumers) use approximately 300 lpcd (79 gpcd, see Table 2), a simple mass balance shows inland areas (with 11 million consumers) have average use rates of 621 lpcd (164 gpcd). Coastal areas will save 96 lpcd (25 gpcd) by achieving Australian use rates of 204 lpcd (54 gpcd), translating to a volume savings of 900 GL/year (0.7 maf/year), all of which is consumptive use savings. For inland areas, not all water conserved contributes to net or consumptive use savings. If we assume inland indoor use rates at 269 lpcd (71 gpcd) (Mayer and DeOreo 1999), approximately 307 lpcd (81 gpcd) of outdoor use would need to be conserved to reach Australian use levels. Because 80% of outdoor use is lost because of evapotranspiration, the consumptive use saved is 246 lpcd (65 gpcd), translating to a savings of 950 GL/year (0.8 maf/year). When the inland and coastal savings are combined, the total savings is 1,850 GL/year (1.5 maf/year). In other words, 750 GL (0.6 maf) of the total 2,600 GL (2.1 maf) gross use reduction would become available for downstream uses and not actually *save* water statewide. For comparison, the total urban use in California in 2005 was 10,200 GL (8.3 maf), and the average annual total water use (including agricultural and urban uses) is 53,000 (43 maf) (DWR 2005, 2009). Fig. 1 provides mass balance schematics for a coastal and inland area as they conserve to Australian use levels, neglecting modest levels of wastewater reuse in coastal areas.

As in Australia, such conservation would not come without cost and inconvenience. However, the change in water use in urban Australia, driven partly by drought and partly by longer-term conservation policies, is likely to pay dividends in terms of reducing water shortages for a long time.

Conclusions

Australia's progress in residential water conservation can be used to estimate realistic water conservation possibilities for California and elsewhere in the western United States. Australia's path to water conservation has not been entirely smooth, but their experience proves that extensive residential water conservation is possible. Although California is making efforts to reduce consumption, there is room for more conservation. Australia offers several lessons for reducing residential water use, including outdoor water restrictions, substantial and accessible rebates for water-saving devices, and increased water prices. If California had used the same amount of per capita residential water as Australia, the urban water use reduction would have been approximately 2,600 GL (2.1 maf) in 2009, with approximately 1,800 GL (1.5 maf) more water available for other uses.

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J. Water Resour. Plann. Manage. 2013.139:117-121.