Considerations for Drought Planning in a Changing World

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Introduction

Recent weather patterns have put stress on freshwater supplies throughout the world. During 2012 much of the United States experienced severe and prolonged drought. On August 8, 2012 a National Geographic headline read, "July Hottest Month on Record in U.S. - Warming and Drought to Blame?"[1] At the beginning of 2013 many news outlets were reporting on the National Oceanic and Atmospheric Administration (NOAA) announcement that 2012 was the hottest year on record and the 15th driest year.[2] An analysis of the 2012 drought in the Great Plains reported that the months of May through August were the driest on record for the region, with rainfall deficits exceeding the years of the Dust Bowl.[3] One year later headlines in the media refer to California experiencing its driest calendar year on record.[4] Hot and dry weather has been common in recent years, as have extreme weather events. Some long range climate forecasts predict warmer and drier conditions in the future.

Drought makes it difficult for water providers to offer reliable service, and can threaten the livelihood of a region. Many water providers have plans in place to deal with drought, but not all do. Existing plans may not be up to date, and the same may be true of an agency's general water supply plans and demand forecasts. This paper explores drought planning in a changing world and highlights important considerations to be included in the process. It begins by describing common short-term and long-term demand reduction strategies, briefly reviews the concept of demand hardening, includes examples of past drought response in the United States, provides information about Australia's Millennium Drought and Australian drought strategies, identifies emerging and proactive drought strategies, and discusses climate change and weather uncertainty. The paper concludes with a summary that ties all of this together.

The American Water Works Association (AWWA) M60 Manual defines drought as, "a deficiency of precipitation over an extended period of time, resulting in a water shortage for some activity, group, or environmental purpose." It goes on to say, "A water shortage occurs when supply is reduced to a level that cannot support existing demands."[5] Drought often has a compounding effect on municipal water service areas in that irrigation requirements increase due to the lack of precipitation. In the context of this paper the term drought will adhere to the above definition and focus on municipal water use.

[1] National Geographic Daily News. August 8, 2012. July Hottest Month on Record in U.S. - Warming and Drought to Blame? http://news.nationalgeographic.com/news/2012/08/120808-hottest-month-july-warming-temperature-dust-bowl-nation-science/

[2] NCDC Announces Warmest Year on Record for Contiguous U.S. - http://www.ncdc.noaa.gov/news/ncdc-announces-warmest-year-record-contiguous-us

[3] An Interpretation of the Origins of the 2012 Central Great Plains Drought. March 2013. NOAA Drought Task Force. http://www.drought.gov/media/pgfiles/2012-Drought-Interpretation-final.web-041013_V4.0.pdf

[4] Reuters. (November 27, 2013). California water woes hit hard in driest year on record - http://www.reuters.com/article/2013/11/27/us-usa-california-water-idUSBRE9AQ0M520131127

[5] American Water Works Association. 2011. *Drought Preparedness and Response*. Manual of Water Supply Practices M60. AWWA. Denver, Colorado.

Long-Term Demand Reduction Versus Short-Term Curtailment

Long-term water demand reduction programs and short-term curtailment strategies are two different actions with different goals. Examples of each are discussed in this section and key characteristics of them are outlined in Table 1.

Table 1: A comparison of long-term demand reduction and short-term curtailment

	Long-Term Demand Reduction	Short-Term Curtailment
Purpose	Permanent service area water use reductions.	Respond to drought or other emergency shortage.
Plan Type	Water efficiency and conservation plan.	Drought emergency plan.
Typical Strategy	An economically evaluated, extended plan that incorporates efficiency and conservation into a portfolio of management strategies.	Water use restrictions to manage short-term supply deficits at various stages of drought.
Justification	Often based on the economics of avoided costs or least cost planning.	To provide service that meets basic needs during a supply shortfall.
Outcome	A gradual and sustained reduction in water demand.	An immediate reduction in water demand.

Long-Term Demand Reduction

Long-term water demand reductions are often achieved via increases in efficiency, and represent water supply strategies that maximize utilization of existing resources. They are designed to:

1. Reduce the demand for water;
2. Improve efficiency in use and reduce losses and waste of water; and
3. Improve land management practices to use water more efficiently.

Components of a long-term demand management program often include:

- Full metering and measurement of all customers and water uses.
- Conservation-oriented water rates and pricing.
- Conservation program staff.
- Integrated resources planning.
- Incentives to encourage installation of water efficient fixtures and appliances.
- Programs to improve landscape irrigation efficiency and efficient landscape design such as xeriscaping.
- Efficiency reviews and audits for large commercial and landscape customers.

Water providers often utilize water efficiency programs as an effective means to reduce service area water demand over long-term time horizons. Implementation of such programs may arise from a need to manage demand so it does not exceed available supply, being identified as cost-effective

alternatives to capital improvement projects to expand storage and treatment capacities, or may be politically or environmentally induced. Drought may also be a driver for long-term efficiency program implementation.

The most tried-and-true long-term water efficiency measure is the toilet replacement program. In a home with inefficient fixtures, toilet flushing represents the largest indoor use.[6] Toilet replacement programs are often initiated through a rebate offered by the water provider, or via direct installation. These programs are relatively straightforward to plan and administer, and in the past have provided large reductions in indoor water use. Due to the success of many toilet replacement programs and the natural replacement of older inefficient toilets with 1.6 gpf or less toilets via the Energy Policy Act of 1992 (and a consumer marketplace now dominated by 1.28 gpf fixtures) toilet replacement programs are becoming less appealing. That is, the water efficiency community was so successful with replacement programs, changing federal toilet standards, and promoting market innovation that giving customers financial incentives for toilets provides less certain results than it once did. Every service area is different, however, and many may still have significant opportunity for savings via toilet replacements. Most other indoor residential uses are also now very efficient due to federal standards and a plumbing fixture market place saturated with efficient options. The Energy Policy Act of 1992 created more efficient standards for showerheads (2.5 gpm) and faucets (2.2 gpm) as well. Codes have even reduced commercial faucets to .5 gpm. Clothes washers were assigned efficient standards by the U.S. Department of Energy that began in 2011 and will become increasingly stringent in 2015.[7] Residential dishwashers, urinals, and pre-rinse spray valves also have federal efficiency standards that generate passive savings.

Water efficiency programs often produce a benefit that exceeds the investment. For example, the costs of implementing an efficiency program such as staff salaries, rebates, and marketing materials may produce benefits such as reduced short-run operating costs and avoidance of expensive water treatment and storage expansion. Every service area has a unique set of circumstances that determine the cost-effectiveness of efficiency programs. The Alliance for Water Efficiency paper, *Transforming Water: Water Efficiency as Stimulus and Long-Term Investment* contains cost estimates for a diverse assortment of water efficiency programs that range from $170/million gallons (MG) (USD) ($55/acre-feet (AF)) for rate reform and water budgets to $1,600/MG (USD) ($520/AF) for industrial process. The average cost estimate is approximately $575/MG (USD) ($190/AF). The authors suggest a conservative estimate of $1,000-$1,500/MG (USD) ($325-$490/AF) for a realistic, diverse, and well-implemented set of programs. These costs will vary based on what types of measures a water provider selects for implementation.[8]

Another example of the cost of conserved water can be pulled from the Los Angeles Department of Water and Power (LADWP). LADWP's Technical Assistance (TAP) program provides custom performance-based incentives for retrofitting water-intensive equipment such as cooling towers. LADWP's TAP program has an estimated unit cost of $700/MG (USD) ($228/AF) saved. LADWP's costs for wholesale water from the Metropolitan Water District of Southern California vary, but the base rate

[6] Mayer, P. W., & Deoreo, W. B. (Eds.). (1999). *Residential end uses of water*. American Water Works Assoc.
[7] 2012-05-31 Energy Conservation Program: Energy Conservation Standards for Residential Clothes Washers; Direct final rule: http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0019-0041
[8] Alliance for Water Efficiency. (2008). Transforming Water: Water Efficiency as Stimulus and Long-Term Investment. http://www.a4we.org/uploadedFiles/News/NewsArticles/NewsArticleResources/Water%20Efficiency%20as%20Stimulus%20and%20Long%20Term%20Investment%20REVISED%20FINAL%202008-12-18.pdf

reported in its 2010 *Urban Water Management Plan* was $1,485/MG (USD) ($484/AF) for untreated water.[9] The LADWP 2010 *Urban Water Management Plan* also includes estimates of costs for other sources of supply, alternative sources, and conservation. Those values are displayed in Table 2.

Table 2: LADWP estimated unit costs (USD) of various sources of supply and conservation from the 2010 UWMP

	Cost Per AF	Cost Per MG
Los Angeles Aqueduct	$563	$1,728
Groundwater	$215	$660
Metropolitan Water District	$527 - $869	$1,617 - $2,667
Conservation	$75 - $900	$230 - $2,762
Recycled Water	$600 - $1,500	$1,841 - $4,603
Water Transfer	$440 - $540	$1,350 - $1,657
Stormwater Recapture		
Centralized	$60 - $300	$184 - $921
Distributed		
Urban Runoff Plants	$4,044	$12,411
Rain Barrels	$278 - $2,778	$853 - $8,525
Cisterns	$2,426	$7,445
Rain Gardens	$149 - $1,781	$457 - $5,466
Neighborhood Recharge	$3,351	$10,284
Seawater Desalination	$1,300 - $2,000	$3,990 - $6138

The Alliance for Water Efficiency recently published an article that spotlights how demand reductions in Westminster, Colorado helped keep water rates down due to avoided infrastructure expansion. The findings counter a common argument against water conservation and efficiency as a culprit of rate increases due to lower water sales. Per capita water use decreased by 21 percent in Westminster, CO from 1980 to 2010. It was estimated that without this decrease Westminster, CO would have been required to secure an additional 2,380 MG (7,300 AF) of additional water supply to meet customer demand. The cost of the new supply expansion was calculated to be $92,100 (USD)/MG ($30,000/AF). The authors estimate that current combined water and wastewater rates would be 91 percent higher without the 21 percent decrease in per capita demand. [10]

Long-term demand reduction strategies come in a variety of options and target different sectors. Table 3 lists common water efficiency practices, fixtures that may be replaced or retrofitted to improve water use efficiency, and example sectors. Table 4 includes a sample of current programs being implemented by various water providers in the United States and Australia. Conservation pricing and policies such as ordinances (other than watering restrictions) and plumbing codes are not included in Table 3 or Table 4, but can be effective initiatives. Table 4 represents current efficiency programs and initiatives that are listed on water providers' websites, and does not reflect past or future efforts.

[9] Los Angeles Department of Water and Power. (2010). Urban Water Management Plan. http://www.water.ca.gov/urbanwatermanagement/2010uwmps/Los%20Angeles%20Department%20of%20Water%20and%20Power/LADWP%20UWMP_2010_LowRes.pdf

[10] Alliance for Water Efficiency. (2013). Conservation Limits Rate Increases for a Colorado Utility: Demand Reductions Over 30 Years Have Dramatically Reduced Capital Costs. http://www.allianceforwaterefficiency.org/westminster.aspx

Table 3: Example water efficiency fixture replacements, practices, and targeted sectors

Residential Indoor	Commercial and Industrial Indoor	Commercial and Industrial Indoor Continued	Example Commercial and Industrial Sectors	Outdoor
Surveys	Audits	Waterless Woks	Schools and Institutions	Surveys
Toilets	Toilets	Wet Cleaning Devices	Government Buildings	Irrigation Smart Controllers
Clothes Washers	Faucets	Cooling Towers	Office Buildings	Smart Water Application Technology (SWAT) Initiative
Showerheads	Urinals	Boilers and Water Heating	Food Service	Irrigation Heads
Faucets	Commercial Laundry Facilities	Humidifiers	Supermarkets	Rainfall Shutoff Device
Dishwashers	Laundromats and Common Area Laundry Facilities	Medical and Health Care Systems	Industrial Processes	Soil Moisture Sensors
Leak Detection and Repair	Ice Cream Machines	Steam Sterilizers & Autoclaves	Hospitals and Healthcare	Irrigation System Leak Detection and Repair
Hot Water Distribution Systems	Ice Machines	Swimming Pools and Spas	Vehicle Washing Facilities	Turf Replacement
Evaporative Cooling	Dipper Wells	X-ray Film Processors	Golf Courses	Landscape Design
	Combination Ovens	Package Graywater Recovery and Treatment Systems		Xeriscape
	Dishwashing	Alternate On-Site Water Sources		Natural Landscaping and Native Plants
	Food Steamers	Process Water Efficiency Improvements		Watering Restrictions
	Pre-rinse Spray Valves			Swimming Pools and Spas
				Water Features
				Water Brooms

Table 4: Example current long-term demand reduction strategies for various water providers

Seattle PUC and Saving Water Partnership	EBMUD	LADWP	SAWS	Tampa, FL	Cary, NC	New York, NY	Santa Fe, NM	Sydney, Australia	Victoria, Australia DEPI	Victoria, Australia DEPI (state level)	City West Water, Australia	Perth Water Corporation, Australia
Residential Toilet Rebates	WaterSmart Tips	Turf Replacement	WaterSaver Plant List	Build Your Own Rebate	High-Efficiency Toilets	Toilet Replacement Program	High-efficiency Clothes Washers	Education	Clothes Washers	Shower Timers/Shut-off Valves	Dual Flush toilet	Water Saving Tips
Free Toilets for Low-Income Housing	Commercial Conservation Rebates and Services	Clothes Washer Rebates	WaterSaver Home Checkup	Home Improvement Education Scholarships	Rain Barrel	Upstate Water Conservation Program	High-efficiency Toilets	Toilets	Swimming Pool Covers	Permanent Greywater Treatment Systems	Washing Machine	WaterWise Specialists
Leak Fixing Education	Water Conservation Publications and Resources	Rain Barrels	Irrigation Design Rebate	Free Plumbing Retrofit Kits	Irrigation Consultation	Water Reuse Program	Water Free Urinals	Water Fix Program	Rainwater Tanks Connected to Toilet or Laundry	Toilet Flush Valve	Pool Cover	H2O Assist Program. Not rebates. Assists in purchase and installation of:
School Education Programs	Home Surveys	Soil Moisture Sensors	Conservation Ordinance	Free Pre-Rinse Spray Valves	Beat the Peak - Pledge	Education	Commercial Process Efficiency	Water Saving Kit	Water Efficient Showerheads	Water Data Loggers	Showerhead	
Local Case Studies	High-Efficiency Toilet Rebates	WBICs	Residential Toilet Rebate	Put a Lid on Leaks	School Education		Rainwater Harvesting	Rainwater Tank	Dual Flush Toilets	Flow-control Devices	Permanent Greywater System	Dual Flush Toilets
Information on Rainwater Harvesting	High-Efficiency Clothes Washer Rebates	Rotating Nozzles	Free Water-Efficient Fixtures	Rain Barrel Workshops	Block Leader Program		Education	Hot Water Circulator	Water Reuse Systems	Hot Water Recirculators	Rainwater Tanks (connected to toilet and/or laundry)	Rainwater Tanks
Outdoor water use education and guidance	Lawn Conversion & Irrigation Upgrade Rebates	High-Efficiency Toilets	Leak Fixing Education	Rain Sensors	AquaStar Program		Rebates for HOAs and Condo Boards		Rainwater Tanks	Pool Covers with Roller/Reel for Covering	Water Conservation Audit	Pool Covers
Compost Calculator	Multi-Family Submeter Retrofit Incentives	Many Energy Related Rebates	Commercial Custom Rebate	Water Use Efficiency Survey					CII Rebates:	Automatic Rainwater Tank to Mains-water Switching System	Hot Water Recirculator Device	Automatic Irrigation Controllers
Watering Index	Graywater Systems	CII Custom Performance Program	Commercial Toilet Rebate Program						Rainwater Tanks Connected to Toilet, Laundry or Other Process	Laundry Systems Using Ozone Technology	Water Saving Tips	Re-programming of Irrigation Controllers
Water Budget Calculator	Mulch Discount Coupons	CII Custom Water Projects	WaterSaver Rain Sensor Coupon						Dual-flush Toilets	Condensate Recovery Systems	Water Saving Heroes	
Sprinkler Calculator	Free Water-Saving Devices (showerheads, faucets)	Free Water Conservation Items	Certified WaterSaver Program: Restaurants						Pre-rinse Nozzles	Hand-held Rinse Sprays		
		Savings Tips	Commercial Irrigation Design Rebate						Water-efficient Washing Machines	Process Water Reuse		
		Small Business Direct Install	Commercial Cooling Tower Audit						Commercial Glass Washers	Water-efficient Combi Steamers		
			Certified WaterSaver Program: Car Washes						Water-efficient Dishwashers			
			Power Washing Program						Waterless Wok Stove			
			Irrigation Checkup						Commercial High-pressure Water Cleaners			
			Drought-Tolerant Grass Varieties						Waterless or Low-flow Urinals			

Short-Term Curtailment

When drought occurs, immediate action must be taken to reduce the demand for water. This action is often referred to as "short-term curtailment" because it is implemented on a temporary basis, and is typically composed of water use restrictions. Planning for drought in advance is essential. Contingency planning before a shortage allows selection of appropriate responses consistent with the varying levels of severity. Most water providers create increasingly restrictive actions for progressive stages of drought. Public outreach and education are a critical component of this process.

The 2011 *M60 Drought Preparedness and Response Manual* from the American Water Works Association identifies seven crucial steps for drought preparedness and response. These steps are:

1. Form a water shortage response team.
2. Forecast supply in relation to demand.
3. Balance supply and demand and assess mitigation options.
4. Establish triggering levels.
5. Develop a staged demand reduction plan.
6. Adopt the plan.
7. Implement the plan.

The AWWA *M60 Drought Preparedness and Response Manual* is an excellent resource to help water providers prepare for drought. The M60 Manual was prepared over several years by a dedicated group of water supply and demand management experts and includes a number of useful examples of recent utility drought response efforts.

Short-term curtailment strategies will vary depending on the severity of the shortage, but may include the following:

- Public outreach and education.
- Customer behavior changes.
- Shut-off valve requirements for all hoses.
- Landscape watering restrictions (assigned days and times; severity depends on level of shortage).
- Water budgets or drought water allocations.
- Drought surcharges and other pricing strategies.
- Temporary ban on new customer connections.
- Vehicle washing prohibitions.
- Sidewalk, driveway, and other hard surface washing prohibitions.
- Water only upon request at restaurants.
- Pool cover requirements.
- Police enforcement of, and citations for, water waste or failure to adhere to restrictions.

Some of these practices have become part of daily operations, even when weather patterns and water supplies are at normal levels. For example, many service areas have some kind of water use restrictions permanently in place. What makes this particularly poignant are the existence of permanent outdoor water use restrictions in Midwest communities such as Buffalo Grove, IL, Aurora, IL, and Northville Township, MI.[11] All of these communities have an average annual rainfall over 30 inches.[12]

There has been concern about the potential for diminishing effectiveness of short-term curtailment strategies due to the implementation of permanent restrictions and the success of long-term water efficiency efforts. This phenomenon has been dubbed "demand hardening" and is discussed in the next section.

[11] Buffalo Grove, IL - http://www.vbg.org/index.aspx?NID=414
Aurora, IL - http://www.aurora-il.org/development_services/publicworks/waterproduction/conservation.php
Northville Township, MI - http://www.northvillemich.com/index.aspx?page=84
[12] National Oceanic and Atmospheric Administration's National Climate Data Center. (2013). 30 Year Average. http://www.ncdc.noaa.gov/

Demand Hardening

It has been argued that long-term water efficiency efforts make it more challenging to respond during water shortages and thus "harden demand." This section identifies discussion of demand hardening in the literature and contains examples of the terminology being used by water providers in planning documents. The first documented use of the term "demand hardening" was found in a 1994 California Urban Water Agencies (CUWA) paper based on interviews with 12 water professionals. In it, they offer the following definition: "The diminished ability or willingness of a customer to reduce demand during a supply shortage as the result of having implemented long-term conservation measures (pg. 11)."[13]

CUWA's report noted, "Most agencies felt that the positive benefits of long-term conservation far outweighed the option of doing nothing. Others did not see significant demand hardening arising out of long-term conservation." Additionally, others stated, "Long-term conservation is a given and an important component in many agencies' long-term planning. It will greatly improve overall supply reliability (pg. 12)."

The Journal of the American Water Works Association published an article by William DeOreo in 2006 titled, *The Role of Water Conservation in a Long-range Drought Plan*. The paper concluded that it is a good strategy to have water conservation measures in place well before a supply shortage occurs.[14] Howe and Goemans (2007) say, "...to ignore long-term conservation benefits and to build excess water supply capacity simply to facilitate cutbacks during drought can be highly uneconomic, akin to overfeeding people so that dieting will be easier (pg. 25)."

There is evidence of water providers acknowledging demand hardening in plans. In the 2011 Hampton Roads, Virginia Planning District Commission's *Regional Water Supply Plan* demand hardening is recognized, as is the importance of water conservation.

> "Future improvement in lowering per capita usage will be more difficult because of water demand hardening. Demand hardening occurs as the discretionary use of water diminishes, leaving only necessary water use; which is more difficult to reduce. While water conservation may be difficult in the future, it remains a priority for Hampton Roads (pg. 5-18)."[15]

Denver Water's 2011 *Drought Response Plan* conceptualizes the idea of demand hardening in a unique way. The below text is quoted from the plan and fundamentally states that water saved through Denver Water's conservation program will be used to both supply future growth, and to strengthen water supply reserves.

[13] Tabors Caramanis & Associates. (1994). Long-term Water Conservation and Shortage Management Practices: Planning That Includes Demand Hardening. *Report to the California Urban Water Agencies*.
[14] DeOreo, W. B. (2006). The role of water conservation in a long-range drought plan. *Journal-American Water Works Association*, *98*(2).
[15] Hampton Roads Planning District Commission. (July 2011). Regional Water Supply Plan. http://www.hrpdcva.gov/uploads/docs/FINAL_HR%20RWSP_Jul2011_Report_only.pdf

"...there is an obvious interaction between the demand reductions that occur from water use restrictions in a drought and long-term water conservation. Though the current realities of the interaction are really quite complex, generally, as Denver Water's customers become more efficient, it is more difficult for them to reduce their usage in a drought, than when they were less efficient. This is not to say that Denver Water encourages its customers to remain inefficient so that greater savings can be attained with restrictions in a drought. Rather, the interrelationship of savings in a drought with long-term conservation implies careful consideration of how best to use the savings from conservations [sic], including whether they should be used to supply water for new population growth or reserved within the water system as buffer against severe drought and other future risks.

In the 2007 Supplement to the Board's Resource Statement, the Board reinforced its commitment to a diverse portfolio of resources to serve future need and to minimize risks, including the risk of severe drought restrictions. For the near-term, the Board determined that water conserved under the enhanced conservation program will be used to fortify the Strategic Water Reserve which is the buffer against future uncertainties including the risk of severe drought. This has the ancillary environmental benefit of more water in streams and reservoirs for a period of time. Therefore the Board chose to use a portion of the saving from conservation to supply future demand growth and reserved a portion as a buffer against future risks including severe drought (pg. 10 of Technical Appendices)."[16]

The Los Angeles Department of Water and Power notes in its 2010 *Urban Water Management Plan* that price elasticities were reduced in one of its demand forecasting models to avoid double counting conservation. That is, they assumed water demand will respond less to price signals due to established gains in efficiency. Below are related quotes from the *LADWP Urban Water Management Plan*.

"The price elasticities reflect a reduction of approximately 1/3 from those tabulated in MWD's 2010 IRP. However, MWD's 2010 IRP Appendix A.1 states that consumers respond to price increase by installing water-conserving fixtures and appliances. As more water efficient fixtures are installed, the impact of changing water using behavior through rates is reduced. This is known as "demand hardening." Reducing price elasticity is done to avoid double-counting conservation savings and to account for demand hardening (pg. 44)."

"… it can be argued that hardware based conservation devices will continue to be developed, piloted and implemented, such as the previously discussed weather based irrigation controllers, thus improving the ability to further conserve in the future. During droughts, consumers will respond to the call for more conservation by behaviorally adjusting their water use through methods such as not leaving water running and taking shorter showers. Additionally, full saturation of current conservation devices has not occurred. For these reasons, others believe demand hardening is irrelevant and there is a continued need for aggressive conservation programs."
…
"As a worst case scenario, demand hardening and its effects are considered in LADWP's water demand forecasts to ensure that the appropriate supply of water is planned for. However, LADWP will continue to maintain its aggressive water conservation program discussed within this section (pg. 75)."

A thorough search revealed acknowledgment and discussion of demand hardening, but there are no documented cases of water providers being unable to make the necessary demand reductions during a

[16] Denver Water. (December 2011). Drought Response Plan. http://cwcbweblink.state.co.us/WebLink/ElectronicFile.aspx?docid=157757&&&&dbid=0

drought due to previously implemented long-term water efficiency measures. While past improvements in efficiency might make it more challenging to curtail water use during a shortage, efficiency may ultimately make supply more reliable by requiring less water for nondiscretionary uses. More empirical research is needed to fully understand the potential implications of demand hardening. The term may well prove to be a red herring, but deeper analysis of the concept in relation to real world supply and demand scenarios could help strengthen water providers' understanding of, and ability to predict, curtailment potential during water shortages.

Past Drought Response Strategies in the United States

A search was conducted to identify examples of drought response in the United States that include documented estimates of savings. Examples of savings achieved via water use restrictions and other drought strategies help water providers in planning for drought, as they demonstrate what has been achieved in the past. There are examples from Raleigh, North Carolina, Birmingham, Alabama, the Front Range of Colorado, the East Bay Municipal Utility District in Oakland, California, and Austin, Texas. Recent state level efforts in California are also included.

Raleigh, North Carolina

In 2007 North Carolina faced its worst drought in recorded history. In October of that year the City of Raleigh reportedly banned lawn irrigation due to lingering drought conditions. This was in addition to the previously implemented Stage 1 restrictions. Stage 1 restrictions alone caused an 18 percent drop in water demand from 65.4 MGD to 54.17 MGD. Violators of the restrictions received a $200 (USD) fine for the first offense, a $1,000 fine for the second offense, and a third violation could have resulted in an interruption of water service. During the first seven weeks of the restrictions 299 first-time citations and 11 second-time citations were issued.[17]

Birmingham, Alabama

In June 2007 Birmingham Water Works initiated Stage 3 drought restrictions that included a drought surcharge. Residential customers that exceeded 8,977 gallons per month incurred a surcharge of 200 percent in addition to the regular water rate. According to the June 6, 2007 Birmingham Water Works press release regarding the surcharge, the average residential customer used 7,500 gallons per month in 2007.[18] Birmingham Water Works reportedly saw a decrease in water consumption from 114 to 95 MGD, a 17 percent reduction.[19] In addition to the surcharge the Birmingham Stage 3 restrictions include the following:

- "Customers will be allowed to water established lawns and landscaping one day per week using irrigation systems for no more than a total of one hour.
- Customers without irrigation systems will be allowed to hand water using a hose with a nozzle two days per week.
- New lawns and landscaping exempt from day of the week watering restrictions for the first 20 days after installation.
- Athletic fields may be watered Wednesdays and Saturdays between 4 a.m. and 9 a.m. when determined that said fields are hazardous to the health and safety of children and athletes, by being too hard by virtue of a lack of water.
- Golf courses to restrict watering to tees and greens only on Mondays, Wednesdays and Fridays between the hours of 1 a.m. and 5 a.m.
- Exemptions made for select commercial outdoor water users."[20]

[17] Town of Wake Forest, NC. (Accessed December 2013). Year-Round Lawn Irrigation Water Conservation Measures. http://www.wakeforestnc.gov/waterconservation.aspx

[18] Birmingham Water Works. (2007). Stage Three - "Drought Warning" Birmingham Water Works to implement surcharges for excessive use.http://www.birminghamwaterworks.com/index.php?option=com_content&task=view&id=43&Itemid=88

[19] Manuel, John. 2008. Drought in the Southeast: Lessons for Water Management. Environ Health Perspect 116(4): A168–A171. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2291006/

[20] Birmingham Water Works Drought Management Plan Summary. (Accessed December 2013). http://www.bwwb.org/sites/default/files/docs/doc-dmpsummary.pdf

Colorado Front Range

In 2002 communities along Colorado's Front Range were challenged by drought conditions. The drought response strategies implemented by eight of these communities were analyzed in 2004 by Kenney et al. In the review, the research team identified savings levels based on a variety of strategies ranging from voluntary measures to strict mandatory restrictions.

Of the eight communities, four limited lawn watering to once every three days (2.3 times per week), three limited lawn watering to two times per week, and one community limited lawn watering to one day per week. One of the communities with every three-day lawn watering restrictions was on a voluntary basis. The three communities with mandatory 'once every three-day' lawn watering restrictions reduced per capita water use by an average of 17 percent, the three communities with mandatory 'two times per week' restrictions reduced per capita water use by 31 percent, and the one community with a 'one time per week' lawn watering restriction reduced per capita water use by 55 percent.[21]

The article also noted a concern shared by some of the water providers, "...several managers expressed concern that some customers may feel obligated to water on their designated days even if rains had recently occurred or were forecast, thereby reducing the potential savings from this form of water restrictions (pg. 86)."[21]

During the drought of 2002 Aurora, Colorado employed a variety of strategies including water use restrictions, a public education campaign, fixture rebates and other long-term efficiency strategies, and changes in water pricing. The efforts resulted in a 26 percent reduction in total demand in 2003.[22] The team researching this noted that pricing strategies and restrictions do not work independently of one another. Specifically, they concluded that while restrictions are in place, an increase in price will produce less of a reduction in demand than if a price increase is implemented when restrictions are absent.[22] That is, customers who are already reducing water consumption via restrictions and other efforts will respond less to a price increase because they are already taking action. This is consistent with assumptions made in the previously referenced *2010 LADWP Urban Water Management Plan*. In Aurora, Colorado they estimated a price elasticity change from -0.60 without restrictions to -0.37 with restrictions. (An elasticity of -0.60 suggests that a 10 percent increase in the marginal price of water will result in a 6 percent reduction in demand. An elasticity of -0.37 suggests that a 10 percent increase in price will result in a 3.7% reduction in demand.) Additionally, they found that customers identified as high water users produced a larger shift, from -0.75 without restrictions to -0.24 when restrictions are in place.[22]

While the price elasticity of water demand is a complex subject, the findings from Aurora, Colorado indicate an important idea: that water use restrictions and changes in price do not function independently when they are in place concurrently. For example, if a water provider estimates a price elasticity of -0.60 and separately estimates that planned drought restrictions will result in a 6 percent reduction in water demand, a 12 percent reduction in demand should not be anticipated if both a 10 percent price increase and the restrictions are implemented. While they do not function independently, both appear to be effective strategies and can complement each other.

[21] Kenney, D. S., Klein, R. A., & Clark, M. P. (2004). Use and Effectiveness of Municipal Water Restrictions During Drought in Colorado. JAWRA Journal of the American Water Resources Association, 40(1), 77-87.

[22] Kenney, D., Goemans, C., Klein, B., Lowrey, J., Assessment, C. N. W. W., & Reidy, K. (2007). Residential water demand management in Aurora: learning from the drought crisis. Colorado Water, 14.

East Bay Municipal Utility District, CA

The East Bay Municipal Utility District (EBMUD) officially declared a drought in May 2008. The primary mechanism to reduce water consumption during the drought was a 10 percent increase in the volumetric water rate, and the creation of customer water allocations. Customers could request adjustments to their allocations. According to EBMUD, 90 percent of the 7,300 customers that requested an adjustment had their appeal honored. A surcharge of $2.00 (USD) was incurred for every hundred cubic feet consumed above the allocation. Other strategies included a recycled water truck program, local business visits, and distribution of water savings devices. EBMUD had a goal of a 15 percent water use reduction throughout the service area. By the end of September 2008 an 11.3 percent reduction had been achieved.[23, 24]

Austin, Texas

The City of Austin, Texas has aggressively pursued water efficiency in recent years and estimates that it saved over 8,500 MG (26,000 AF) of water from September 2010 through August 2011 due to a variety of water conservation efforts, including its Stage 1 water restrictions. Austin Water's Stage 1 restrictions allow watering two days per week. Residential customers with odd addresses can water on Wednesday and Saturday, residential customers with even addresses can water Thursday and Sunday, and commercial and multifamily customers can water on Tuesday and Friday. In addition, the Stage 1 restrictions have the following provisions:

- Irrigation systems can only be used before 5:00 a.m. or after 7:00 p.m.
- Hose-end sprinklers can only be used before 10:00 a.m. or after 7:00 p.m.
- Hand watering is allowed anytime on any day of the week.[25]

Austin currently has incentives for the following water efficiency programs listed on its website:

Table 5: Austin, Texas water efficiency incentives.
(http://austintexas.gov/department/water-conservation-rebates)

Rebates and Incentives for Residential Customers	Rebates and Incentives for Businesses
WaterWise Landscape Rebate	ICI Audit Rebate Pilot Program
Free Showerheads & Faucet Aerators	3C Business Challenge
Pressure Regulating Valve (PRV) Rebate	Washwise Rebate Program
Rainwater Harvesting Rebate	Rainwater Harvesting Rebates
Irrigation System Evaluations & Rebates	Commercial Process Rebates
Drought Survival Tools: Soil Moisture Meters, Treegators, and Hose Meters	Multi-Family Pressure Regulating Valve (PRV)
Watering Timer Rebate Pilot Program	Alternative Irrigation Compliance Pilot Program
Pool Cover Rebate	

[23] East Bay Municipal Utility District. (December 4, 2008). A Case Study of Water Management During a Drought https://www.watereducation.org/userfiles/09ExecutiveBriefingEileenWhite.pdf
[24] East Bay Municipal Utility District. (October 2, 2008). Nearly five months since declaring a drought emergency EBMUD's aggressive effort to meet water savings goal shows positive results. https://www.ebmud.com/sites/default/files/pdfs/Drought%20Status%20Press%20Release.pdf
[25] The City of Austin, Texas. (Accessed January 2014). Stage 1 Watering Restrictions. http://www.austintexas.gov/department/stage-1-watering-restrictions

The City also estimated water savings from Stage 2 restrictions from 2009 through March 2013 to be more than 8,150 MG (25,000 AF). It also estimated that an additional 1,300 MG (4,000 AF) were saved from March through July in 2013 from Stage 2 restrictions. Austin was in Stage 2 restrictions for four months in 2009 and for 21 of the 23 months leading up to July 2013. Revenue loss resulting from Stage 2 restrictions enforced from 2009 through March 2013 was estimated to be $47.1 million (USD). From 2009 to July 2013 the City issued more than 4,600 warnings and more than 7,700 citations. Citations were prosecuted through municipal court and carried a fine of $475 (USD) per violation. Citations are now issued via customer bills.[26] Austin's Stage 2 water restrictions are below:

Austin Water Stage 2 Water Restrictions

- "Your assigned watering day is determined by property type, type of irrigation used, and whether the street address ends in an even or odd number.
- Hose-end irrigation may take place between midnight and 10 a.m. and between 7 p.m. and midnight on your assigned watering day.
- Automatic irrigation systems may operate between midnight and 5 a.m. and between 7 p.m. and midnight on your watering day.
  - Please reduce system run times to fit within this schedule.
  - Please ensure that your system has a working rain sensor, or operate the system manually when rain is forecasted.
- Watering with a hand-held hose or a refillable watering vessel, such as a bucket or a Treegator®, is allowed at any time on any day of the week.
- Drip irrigation is exempt from the schedule, due to increased efficiency.
- To water trees, soaker hoses may be used under the drip-line of the tree canopy or you may use automatic tree bubblers. Irrigating trees in this manner is exempt from the watering schedule
- Watering a vegetable garden with a soaker hose is exempt from the watering schedule.
- Washing vehicles at home is prohibited. If you need to wash a vehicle, you may do so at a commercial carwash facility.
- Charity car washes are prohibited
- Fountains with either a fall or spray of water greater than four inches are prohibited unless necessary to preserve aquatic life.
- Restaurants may not serve water unless requested by a customer.
- Commercial properties (including restaurants and bars) may only operate patio misters between 4 p.m. and midnight."[27]

California

The end of 2013 marked the driest calendar year on record in California.[4] The state also experienced a severe drought from 2007-2009. During that time the state made several efforts related to urban water use:

- Creation of DWR drought website
- Scheduling of urban drought workshops
- Funding for water savings programs

[26] Austin Water Staff. (January 2014). Personal Communication.
[27] The City of Austin, Texas. (Accessed January 2014). Stage 2 Watering Restrictions. http://www.austintexas.gov/department/stage-2-watering-restrictions

- Funding for water recycling projects
- Funding for desalination research and development
- Financial assistance for drought programs
- Mandating water efficiency in all state-owned buildings
- Facilitating water transfers
- Establishment of a water bank
- Drought contingency planning as part of the California Water Plan process
- Technical assistance for small water systems and private well owners[28,29]

Documented cases of drought response in the United States demonstrate that short-term curtailment strategies, particularly outdoor water use restrictions, are largely successful. Surcharges and changes in rates are also approaches that can be used to encourage reductions in demand, and help maintain financial stability during a drought.

The Water Research Foundation's (WRF) *Drought Response Model* allows planners to analyze the impact of restrictions and changes in pricing on revenue, and represents a useful tool for planners. The Drought Response Model was created as part of WRF project 4175 - *A Balanced Approach to Water Conservation in Utility Planning* and is designed to, "simulate demand response and revenue effects of asking customers to reduce water use during a drought."

Regardless of which approaches are selected to curtail water use during a drought, communicating with customers is a crucial element. Below is an excerpt from Denver Water's *Drought Response Plan*.

> "The level of drought severity determines the level of communication efforts. If the drought is severe and requires the Board to impose mandatory drought restrictions, Denver Water's Public Affairs Division will employ aggressive public information tactics. Numerous tools are available for such efforts, including direct mail, Web updates, bill inserts, electronic newsletters, internal newsletters, social media, public meetings, Citizen Advisory Committee meetings, advertisements, press releases and media interviews (pg. 30)."[16]

A 2010 Water Research Foundation study that analyzed customer communications suggests that effective strategies should be broadly focused to reach a wide audience, and clearly articulate a goal such as a percentage reduction.[30] In the case of surcharges, the AWWA M1 Manual *Principles of water rates, fees, and charges* recommends a vigorous education campaign to achieve the desired reduction. An education campaign will help customers understand the reasoning for a surcharge and build acceptance.[31] The M1 Manual goes on to say the following about communication and education regarding surcharges:

[28] California Department of Water Resources. (2009). California's Drought: Water Conditions and Strategies to Reduce Impacts. http://www.water.ca.gov/news/newsreleases/2009/040209droughtrpt-gov.pdf
[29] California Department of Water Resources. (Accessed December 2013). Drought Timeline. http://www.water.ca.gov/watertransfers/docs/timeline-present.pdf
[30] Water Research Foundation. (2010) *Water Conservation: Customer Behavior and Effective Communications*- Project #4012.
[31] American Water Works Association. *Principles of water rates, fees, and charges*. American Water Works Association, 2012.

> "Working with the media during a drought is critical to providing information to customers about the severity of the drought, desired customer responses, and the need, purpose, and implications of drought pricing strategies.
> …
>
> It should also explain that drought surcharges are one tool in a set of measures that the utility is using to engage the community in effective water resource management (pg. 185)."[28]

To gain additional insight about drought response, the next section reviews the Australian Millennium Drought.

Australia's Millennium Drought

From 1997 to 2009 southeast Australia experienced its worst drought on record, and it is often referred to as the Millennium Drought.[32] The Millennium Drought parched the Australian landscape which impacted ecosystems, caused massive agricultural losses, gave rise to brushfires in catchment and other areas, and severely challenged water providers to deliver water to customers. Researchers say two thirds of the rainfall deficit in east Australia during that time can be explained by El Niño activity.[33] The drought ended in late 2010 with very high precipitation and flooding in southeast Australia due to La Niña activity. Southwestern Australia, however, experienced its driest year on record in 2010 as it is unaffected by La Niña activity.[33]

According to the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO), average annual rainfall from 1997 through 2009 was 12 percent lower than the average annual rainfall from 1900 through 2010.[33] A CSIRO presentation reported that precipitation trends in southeast Australia from 2001 to 2010 were as follows:

2001 - 7 percent below average
2002 - 26 percent below average
2003 - 4 percent below average
2004 - 12 percent below average
2005 - about average
2006 - 40 percent below average
2007 - 6 percent below average
2008 - 18 percent below average
2009 - 13 percent below average
2010 - 32 percent above average[34]

How did the federal government, state governments, and water providers respond to the Millennium Drought? To help answer this question activities at the federal level are discussed, as are efforts in Victoria (state level), Melbourne (a city in Victoria), and Perth, Western Australia. Existing drought restrictions are also included for the state of Victoria. A very detailed account of Australian drought restrictions through 2007 can be found in the Institute for Sustainable Futures' *Review of Restrictions* document.[35]

[32] CSIRO (2012). Climate and water availability in south-eastern Australia: A synthesis of findings from Phase 2 of the South Eastern Australian Climate Initiative (SEACI), CSIRO, Australia, September 2012, 41 pp, www.seaci.org/publications/documents/SEACI-2Reports/SEACI_Phase2_SynthesisReport.pdf.
[33] Dijk, Albert IJM, Hylke E. Beck, Russell S. Crosbie, Richard AM Jeu, Yi Y. Liu, Geoff M. Podger, Bertrand Timbal, and Neil R. Viney. (2013). The Millennium Drought in southeast Australia (2001–2009): Natural and human causes and implications for water resources, ecosystems, economy, and society. Water Resources Research.
[34] Dijk, Albert and Sardella, Carolina. (April 2012) The Millennium Drought in Australia. Australian Commonwealth Scientific and Industrial Research Organisation Presentation.
http://www.clivar.org/sites/default/files/VanDijk.pdf
[35] Institute for Sustainable Futures. (2009). Review of Restrictions Volume 1 – Review and Analysis
http://www.nwc.gov.au/__data/assets/pdf_file/0019/11755/Water_restrictions_Volume_1.pdf

Australian Federal Government Response

The Australian Constitution gives the right to manage water to the states.

> Section 100: "The Commonwealth shall not, by any law or regulation of trade or commerce, abridge the right of a State or of the residents therein to the reasonable use of the waters of rivers for conservation or irrigation."[36]

However, action was taken during the Millennium Drought to increase federal involvement, and in 2004 the National Water Initiative (NWI) was agreed upon by the Council of Australian Governments (COAG). The National Water Initiative is a national blueprint for water reform that includes water efficiency as a top priority. In accordance with the NWI the COAG has agreed to prepare water plans, achieve efficient water use, create registers of water rights and water accounting standards, expand water trading, improve management of urban demands and improve pricing for water storage and delivery.[37] Beyond spearheading the NWI, the Australian federal government also provided billions of dollars of funding in response to the Millennium Drought, and in 2008 created the $12.9 billion (AUD) Water for the Future Plan.[38] The National Water Commission is charged with overseeing state progress with the NWI and in 2011 released a National Planning Report Card that reported on jurisdictional progress in the water planning process.[39]

Water markets are also part of the Australia National Government's efforts. The water market allows the buying and selling of water from various water systems and political boundaries. According to the Australian government this ensures water is allocated to the highest value use during a shortage.[40] The federal government assists in water accounting and the creation of water registers to help facilitate water market activities.[41] The water market puts a cap on the amount of water that can be extracted for consumptive use and apportions water for the environment. Once the consumptive pool is determined, each specific use is assigned a limit. Water can then be reallocated among water right holders through trades.[42]

State of Victoria, Australia

The Department of Environment and Primary Industries (DEPI) manages water resources in the state of Victoria, Australia. The agency offers water efficiency rebates, provides education and technical assistance, develops state-wide uniform guidelines for local water corporations to enforce permanent water saving rules and water restrictions, and facilitates water trading. The DEPI is also pushing for advances in the state's use of rainwater, stormwater, and wastewater in its *Living Victoria Policy*.[43] To

[36] Section 100 of the Australian Constitution. (Accessed November 2013). http://www.aph.gov.au/About_Parliament/Senate/Powers_practice_n_procedures/~/link.aspx?_id=63B954D0FFB44EC78FC18B10C53EBCCE&_z=z

[37] Australian Government Department of Environment. (Accessed December 2013). National Water Initiative. http://www.environment.gov.au/topics/water/australian-government-water-leadership/national-water-initiative

[38] Australia National Water Commission. (2010). Administration of the Water Smart Australia Program. http://www.anao.gov.au/~/media/Uploads/Documents/2009%2010_audit_report_21.pdf

[39] Australia National Water Commission. (2011). National Water Planning Report Card. http://archive.nwc.gov.au/library/topic/planning/national-water-planning-report-card-2011

[40] Australian National Government. (2012). Water Market. http://www.nationalwatermarket.gov.au/

[41] Australian Government. (2013). The National Water Market System Project. http://www.nationalwatermarket.gov.au/site-information/index.html

[42] Australia National Water Commission. (2011). Water Markets in Australia: A Short History. http://www.nwc.gov.au/__data/assets/pdf_file/0004/18958/Water-markets-in-Australia-a-short-history.pdf

[43] Victoria, Australia Department of Environment and Primary Industries. (2013). http://www.depi.vic.gov.au/water

help provide supply reliability the Victorian government built a seawater desalination plant capable of supplying 150 billion litres (40 billion gallons) of water per year at a cost of $5.7 billion (AUD). Due to the recovery of storage volumes following the Millennium Drought, the desalination plant is not currently providing water to the Melbourne supply system.[44,45]

Table 6 (next page) lists Victoria, Australia's four stages of drought restrictions. Due to the large amount of information presented in the table it required small print and if hard to read, a link is included that goes directly to the corresponding website. The state also has permanent water use rules that require hoses to be leak free with use of a trigger nozzle at all times, rules for residential, commercial, and public lawns and gardens, fountains and water features, and cleaning of hard surfaces.

[44] Victorian Desalination Plant. (Accessed December 2013). Victoria Department of Treasury and Finance. http://www.dtf.vic.gov.au/Infrastructure-Delivery/Public-private-partnerships/Projects/Victorian-Desalination-Plant

[45] Melbourne Water (Accessed January 2014). Desalination. http://www.melbournewater.com.au/whatwedo/supply-water/Pages/Desalination.aspx

Table 6: The state government of Victoria drought restrictions
(http://www.depi.vic.gov.au/water/saving-water/water-restrictions)

	Permanent Water Rules	Stage 1	Stage 2	Stage 3	Stage 4
Hand-held hose	Water from a hand-held hose must not be used for any purpose (whether or not the use is subject to a permanent water saving rule) at any time unless the hose: is fitted with a trigger nozzle is leak-free.				
Residential and commercial gardens and lawns	A residential or commercial garden or lawn cannot be watered except: with a hand-held hose, bucket or watering can at any time; with a watering system between the hours of 6 pm – 10 am on any day.				Residential or commercial gardens and lawns cannot be watered at any time.
Hand watering		You can water residential or commercial gardens and lawns at any time, on any day using a hand-held hose fitted with a trigger nozzle.	You can water residential or commercial gardens at any time, on any day using a hand-held hose fitted with a trigger nozzle.	You can water residential or commercial gardens on alternate days between 6 am – 8 am using a hand-held hose fitted with a trigger nozzle.	
Watering systems		You can water gardens and lawns using a watering system (manual, automatic, spray or dripper) only on alternate days between 6 am – 10 am and 6 pm – 10 pm.	You can water gardens using a watering system (manual, automatic, spray or dripper) only on alternate days between 6 am – 8 am and 6 pm – 8 pm.	You can only water gardens using a dripper watering system on alternate days between 6 am – 8 am.	
Public gardens, lawns and playing surfaces	A public garden or lawn area or a playing surface cannot be watered except: with a hand-held hose, bucket or watering can at any time; with a watering system fitted with a rain or soil moisture sensor between the hours of 6 pm – 10 am on any day; or in accordance with an approved Water Use Plan.				Public gardens, lawns and playing surfaces cannot be watered at any time.
Hand watering		You can water public gardens, lawns and playing surfaces at any time, on any day using a hand-held hose fitted with a trigger nozzle.	Public lawn areas cannot be watered at any time. You can water public gardens and playing surfaces at any time, on any day using a hand-held hose fitted with a trigger nozzle.	Public lawn areas cannot be watered at any time. You can water public gardens and playing surfaces on alternate days between 6 am – 8 am using a hand-held hose fitted with a trigger nozzle.	
Watering systems		Public gardens, lawns and playing surfaces can also use a watering system only on alternate days between 6 am -10 am and 6 pm – 10 pm or water in accordance with an approved Water Use Plan.	Public gardens and playing surfaces can also use a watering system only on alternate days between 6 am – 8 am and 6 pm – 8 pm or water in accordance with an approved Water Use Plan.	Public gardens and playing surfaces can also use a dripper watering system only on alternate days between 6 am – 8 am or water in accordance with an approved Water Use Plan.	
Fountains and water features	Water cannot be used in a fountain or a water feature unless the fountain or water feature recirculates the water.	You can fill and operate your fountain or water feature as long as it recirculates the water.	Water cannot be used to fill or top up a fountain or water feature at any time.	Water cannot be used to fill or top up a fountain or water feature at any time.	Fountain or water features cannot be filled or topped up at any time.
Hosing down of hard surfaces	Water cannot be used to clean hard surfaces (including, driveways, paths, concrete, tiles, timber decking) except: where cleaning is required as a result of an accident, fire, health hazard, safety hazard or other emergency; if staining to the surface has developed, and then only once a season; in the course of construction or renovation, and then only by means of: a high pressure water cleaning device, or if such a device is not available, a hand-held hose or a bucket.	You cannot hose down hard surfaces including driveways, paths, concrete, tiles, timber decking and other paved areas except where cleaning is required as a result of an accident, fire, health hazard, safety hazard or other emergency. You can use a high-pressure cleaning unit, or if such a unit is not available, a hose fitted with a trigger nozzle, or a bucket in the course of construction or renovation.	You cannot hose down hard surfaces including driveways, paths, concrete, tiles, timber decking and other paved areas except where cleaning is required as a result of an accident, fire, health hazard, safety hazard or other emergency. You can use a high-pressure cleaning unit, or if such a unit is not available, a hose fitted with a trigger nozzle, or a bucket in the course of construction or renovation.	You cannot hose down hard surfaces including driveways, paths, concrete, tiles, timber decking and other paved areas except where cleaning is required as a result of an accident, fire, health hazard, safety hazard or other emergency. You can use a high-pressure cleaning unit, or if such a unit is not available, a hose fitted with a trigger nozzle, or a bucket in the course of construction or renovation.	You cannot hose down hard surfaces including driveways, paths, concrete, tiles, timber decking and other paved areas except where cleaning is required as a result of an accident, fire, health hazard, safety hazard or other emergency. You can use a high-pressure cleaning unit, or if such a unit is not available, a hose fitted with a trigger nozzle, or a bucket in the course of construction or renovation.

(continued on next page)

Vehicle washing		You can wash your car, boat or other vehicle at home using a high-pressure cleaning unit, a hand held hose fitted with a trigger nozzle or a bucket or watering can, at any time, any day of the week; or at a commercial car wash.	You can wash your car, boat or other vehicle at home using a high-pressure cleaning unit, a hand-held hose fitted with a trigger nozzle or a bucket or watering can, at any time, any day of the week; or at a commercial car wash.	You can wash the windows, mirrors, lights, registration plates and for spot removing corrosive substances of your car, boat or other vehicle at home using a bucket or watering can; or at a commercial car wash, and only where cleaning is required for health and safety reasons, safety hazard or other emergency.	You can wash the windows, mirrors, lights, registration plates and for spot removing corrosive substances of your car, boat or other vehicle at home; or at a commercial car wash, using a bucket or watering can, and only where cleaning is required for health and safety reasons, safety hazard or other emergency.
Sporting grounds		Councils and schools can water sportsgrounds and gardens in accordance with the times under Stage 1 restrictions or submit a Water Use Plan to efficiently water outside of the prescribed hours.		Councils and schools can water sportsgrounds and gardens in accordance with the times under Stage 3 restrictions or submit a Water Use Plan to efficiently water outside of the prescribed hours.	Councils and schools cannot water sporting grounds and gardens at any time.
Pools, spas and water toys					
Filling		A new pool or spa of up to 2,000 litres can be filled by means of a hand-held hose, bucket or watering can or an automatic water top up device. However, a new or existing pool or spa of greater than 2,000 litres can only be filled in accordance with a Water Use Plan. Contact your local water corporation for more information.	A new pool or spa of up to 2,000 litres can be filled by means of a hand-held hose, bucket or watering can or an automatic water top-up device. However, a new or existing pool or spa of greater than 2,000 litres can only be filled in accordance with a Water Use Plan. Contact your local water corporation for more information.	A new or existing pool or spa of any capacity cannot be filled. However, new or existing public pools or spas of any capacity can be filled in accordance with a Water Use Plan. Contact your local water corporation for more information.	A new or existing pool or spa of any capacity cannot be filled.
Topping up		An existing pool or spa of any size can be topped up using an automatic top-up device or a hand held hose, bucket or watering can. A mobile spa can only be filled or topped up in accordance with a Water Use Plan.	A new or existing pool or spa of any size can be topped up only on alternate days between 6 am – 8 am and 6 pm – 8 pm using a hand-held hose, bucket or watering can; or by using an automatic water top-up device at any time. Pools and spas can also be topped up at any time in accordance with an approved Water Use Plan. A mobile spa can only be filled or topped up in accordance with a Water Use Plan.	Only existing residential or commercial pools or spas of any size can be topped up on alternate days between 6 am – 8 am using a hand-held hose, bucket or watering can; or by using an automatic water top up device. Pools and spas can also be topped up at any time in accordance with an approved Water Use Plan. A mobile spa can only be filled or topped up in accordance with a Water Use Plan.	New or existing pools or spas can only be topped up using a bucket or watering can. A mobile spa can only be filled or topped up in accordance with a Water Use Plan.
Water toys		A water toy connected to a hose cannot be used at any time.	A water toy connected to a hose cannot be used at any time.	A water toy connected to a hose cannot be used at any time.	A water toy connected to a hose cannot be used at any time.
Warm-season grass 28-day exemption		From 1 September 2010 households and businesses can apply for a one-off, 28-day exemption from water restrictions to enable new warm-season lawns to be established.			

Melbourne

Between January 2007 and August 2010 Melbourne, Victoria implemented Stage 3 (or its variant Stage 3a) water restrictions, which was the most severe stage being implemented for the city during the Millennium Drought.[46] Stage 3 restrictions completely disallowed the use of potable water for lawn watering, although it did allow residential gardens to be watered, and included the following as per the *Drought Response Plan* restriction schedule of April 2010:

"Residential Gardens

- Even/odd address watering schedules
- Manual watering between 6:00 a.m. and 8:00 a.m.
- People age 70 and older can water between 8:00 a.m. and 10:00 a.m.
- Automatic dripper systems can be used to water plants as required on specified watering days between midnight and 2:00 a.m.

Sports Grounds

Councils and schools can water sports grounds in accordance with the Drought Response Plan or submit a water conservation plan. Special allowances are made for exempt playing surfaces which include: turf cricket wickets, golf tees and greens (not fairways), tennis courts, bowling greens, hockey pitches, running tracks, croquet greens.

Vehicle Washing

An efficient commercial car wash that uses 70 litres of water or less per vehicle can be used. Cars may not be washed at home with drinking water. A bucket filled from a tap can be used to clean windows, mirrors and lights; and spot remove corrosive substances.

Industry

Businesses using 10 megalitres of water or more per year must complete a water conservation action plan (waterMAPs program).

Pools and Spas

A new pool or spa of any size capacity cannot be filled with drinking water. However, a new or existing swimming pool or spa may be filled with an alternative water source such as groundwater. An existing pool or spa of less than 2,000 litres may be filled by means of a watering can or bucket filled directly from a tap. An existing pool or spa of greater than 2,000 litres must not be filled except in accordance with a water conservation plan (contact your local water business for more information). An existing pool or spa must not be topped up except by means of a watering can or bucket, filled directly from a tap. Hoses must not be used.

Alternative Water

Greywater, rainwater and recycled water can be used at any time. For guidelines on safe use, visit www.epa.vic.gov.au. Restrictions do not apply to rainwater collected in a storage tank, provided it is not supplemented with drinking water supply.

Penalties and Enforcement

Stage 3 water restrictions must be followed and water patrols are out in force across Melbourne. If you breach the restrictions, you may have your water supply restricted and face fines."

[46] The savewater!® Alliance. (Accessed November 2013). Stage 3 water restrictions apply across Melbourne. http://www.savewater.com.au/uploads/pdffiles/OWOF%20Stage%203%20fact%20sheet.pdf

On December 1, 2012 water restrictions in Melbourne were lifted (from Stage 1) while permanent water use rules remained in place.[47] The permanent water use rules include key requirements regarding hand-held hose, garden and lawn watering, fountains and water features, and cleaning of hard surfaces. The Drought Response Plans for the three Melbourne retail water corporations (City West Water, South East Water and Yarra Valley Water) were revised in 2011 to incorporate the Water Outlook approach which is an adaptive water management strategy based on learnings from the Millennium Drought. [48,49] The plans state that the three Melbourne retail water corporations and Melbourne Water will jointly publish a Water Outlook for Melbourne by the first of December annually, which is, "a summary of the state of Melbourne's water supply and demand" indicating the system storage levels in three zones: high, medium, or low. The December 2013 *Water Outlook* indicates that Melbourne's water storage levels were assessed as being in the high zone and the permanent water use rules will remain in place. The *Water Outlook* includes short and medium term strategies or action plans to manage water security comprising efficiency programs, planning, education, benchmarking, water loss control, rainwater harvesting, stormwater harvesting, use of recycled water, and may include water restrictions.[50]

The three Melbourne retail water corporations also have a Water Restriction By-law that contains a schedule for the four stages of restrictions.[51] As an example, the City West *Drought Response Plan* references the *By-law* (e.g., "The Drought Response Plan may include regulating the use of water via a By-law for water restrictions)."[52] The latest *By-law* and the *Drought Response Plan* were published in June 2012.

Included in the restrictions are rules regarding:

1. Watering gardens, lawns, and playing surfaces
2. Using water for aesthetic purposes
3. Using water in swimming pools and toys
4. Storing or transporting water
5. Cleaning vehicles with water
6. Using water for other cleaning and maintenance purposes
7. Using water for commercial production of plants and/or animals
8. Other uses

The extensive details of each can be found on pages 21 through 27 of the *By-law*. [51]

Southwestern Australia

Information on the Millennium Drought often focuses on southeastern Australia. Southwestern Australia was also hit hard, and did not receive the abundant precipitation experienced in southeast Australia toward the end of 2010. In fact, 2010 was its driest year on record.[33]

[47] Melbourne Water. (Accessed November 2013). Water restrictions.
http://www.melbournewater.com.au/getinvolved/saveandreusewater/Pages/Water-restrictions.aspx
[48] Tan, K.S. and Rhodes, B.G. (2013). Drought severity estimation under a changing climate. Australian Journal of Water Resources, Vol. 17, Issue 2, p143-151.
[49] Rhodes, B.G., Fagan, J.E. and Tan, K.S. (2012). Responding to a rapid climate shift - Experiences from Melbourne Australia, World Congress on Climate and Energy, International Water Association, 13-18 May 2012, Dublin, Ireland.
[50] Melbourne Water. (December 2013). Water Outlook for Melbourne.
http://www.melbournewater.com.au/getinvolved/saveandreusewater/Documents/Water%20Outlook%20December%202013.pdf
[51] City West Water Corporation. (June 2012). Water Restriction By-law.
http://www.citywestwater.com.au/documents/by-law_001_2012.pdf
[52] City West Water Corporation. (June 2012). Drought Response Plan for City West Water Corporation.
http://www.citywestwater.com.au/documents/drought_response_plan.pdf

The Water Corporation of Western Australia delivers water to Perth, which is the largest population center in the state of Western Australia. The agency is governed by the Western Australia Department of Water, which makes rules for the use of water. Perth was in Stage 4 (of seven) water restrictions from 2001 to 2007.[53]

"Stage 4

(1) A person must not water a lawn or garden except by —
(a) reticulation during either, but not both, the morning period or the evening period on one or both of 2 days of the week specified in relation to the relevant property in Schedule 3 Division 2; or
(b) a handheld hose with one outlet; or
(c) a handheld watering can.
(2) A person must not water a grass-covered sporting ground except by —
(a) reticulation during either, but not both, the morning period or the evening period on one or more of 3 days of the week specified in relation to the relevant property in Schedule 3 Division 1; or
(b) a handheld hose with one outlet; or
(c) a handheld watering can.
(3) A person must not spray a building, building site, demolition site (including vacant land resulting from a demolition), path, paved area or road except —
(a) with —
(i) a high pressure water cleaner; or
(ii) a handheld hose with one outlet, to the minimum extent necessary for the cleaning of the building, building site, demolition site (including vacant land resulting from a demolition), path, paved area or road so as to avoid a threat to public health or safety; or
(b) with a handheld hose with one outlet to the minimum extent necessary for purposes related to the construction, demolition or repair of the building, path, paved area or road.
(4) A person must not water a synthetic sporting ground except for 10 minutes or less before a sport is played or practised on the sporting ground."[54]

Under the 2013 Water Service Regulations, Area Three (Perth) is as follows:

"The stage of restrictions that applies in relation to the use of water in Area 3 is —
(a) from 1 June to 31 August in a year — Stage 6; and
(b) at any other time of the year — Stage 4."[55]

The use of stage six from June 1 to August 31 puts a winter sprinkler ban in place.

"Stage 6
(1) A person must not water a lawn or garden except by —
(a) a handheld hose with one outlet; or
(b) a handheld watering can.

(continued on next page)

[53] Institute for Sustainable Futures. (2009). Review of Restrictions Volume 2 – Appendices. http://www.nwc.gov.au/__data/assets/pdf_file/0020/11756/Water_restrictions_Volume_2_appendixes.pdf
[54] Western Australian Consolidated Regulations. (Accessed December 2013). Water Agencies (Water Use) By-Laws 2010 - Schedule 2. http://www.austlii.edu.au/au/legis/wa/consol_reg/waub2010297/sch2.html
[55] Western Australian Consolidated Regulations. (2013). Water Service Regulations 2013 - REG 78. http://www.austlii.edu.au/au/legis/wa/consol_reg/wsr2013284/s78.html

(2) A person must not water a grass-covered sporting ground except by —
(a) reticulation during either, but not both, the morning period or the evening period on one or more of 3 days of the week specified in relation to the relevant property in Schedule 3 clause 1; or
(b) a handheld hose with one outlet; or
(c) a handheld watering can.
(3) A person must not spray a building, building site, demolition site (including vacant land resulting from a demolition), path, paved area or road except —
(a) with —
(i) a high pressure water cleaner; or
(ii) a handheld hose with one outlet, to the minimum extent necessary for the cleaning of the building, building site, demolition site (including vacant land resulting from a demolition), path, paved area or road so as to avoid a threat to public health or safety; or
(b) with a handheld hose with one outlet to the minimum extent necessary for purposes related to the construction, demolition or repair of the building, path, paved area or road.
(4) A person must not fill a swimming pool except —
(a) to replace water lost from the pool through evaporation or ordinary use; and
(b) to the minimum extent necessary for the proper functioning of the pool.
(5) A person must not water a synthetic sporting ground except for 10 minutes or less before a sport is played or practised on the sporting ground."[39]

In the 2009 Institute for Sustainable Futures' *Review of Restrictions* report it was estimated that the restrictions in place from 2001 to 2007 saved 44.2 billion litres (11.7 billion gallons) per year.[35]

The same report noted that the Water Corporation of Western Australia actively patrolled to enforce restrictions during the Millennium Drought, and issued citations. From the text, "The penalties for non-compliance are a warning followed by $1,000 (AUD) fine for second and subsequent offences. Up to 16 staff carry out enforcement activities, which are estimated to cost approximately $600,000 per year (pg. 27)." According to the report there were 17,426 warnings and 6,114 fines issued from July 2003 through February 2007. If 6,114 fines were issued at $1,000 (AUD) it would have generated $6,114,000 (AUD) in revenue.

The Water Corporation of Western Australia is also proud of an aggressive pursuit of alternative water supplies. According to its website, The Water Corporation has committed to recycling 30 percent of its wastewater by 2030. At present it recycles approximately 13.5 percent of wastewater. The Water Corporation of Western Australia goes on to say that, "Over the last 10 years we have increased the total volume of recycled water by almost 70% across WA. In 2012/13 we recycled 21 billion litres (5.5 billion gallons)."[56]

In 2006 the Water Corporation of Western Australia constructed a seawater desalination plant. The plant is reported to produce 45 billion litres (12 billion gallons) of water per year, or 17 percent of Perth's supply.[57] Another desalination plant was constructed in 2011 and later expanded in 2013. It is now able to produce 100 billion litres (26 billion gallons) per year. Together, the two desalination plants are capable of providing almost 50 percent of Perth's water needs.[58]

[56] Water Corporation of Western Australia . (2013). Water Recycling. https://www.watercorporation.com.au/water-supply-and-services/solutions-to-perths-water-supply/water-recycling
[57] Water Corporation of Western Australia . (2013). Perth Seawater Desalination Plant. https://www.watercorporation.com.au/water-supply-and-services/solutions-to-perths-water-supply/desalination/perth-seawater-desalination-plant
[58] Water Corporation of Western Australia. (Accessed December 2013). Southern Seawater Desalination Plant. https://www.watercorporation.com.au/Home/Residential/Water%20supply%20and%20services/Solutions%20to%20Perths%20water%20supply/Desalination/Southern%20Seawater%20Desalination%20Plant

Key Takeaways

Water resource professionals in the United States often question how Australia made it through such a prolonged water shortage, and they seek to learn from the Millennium Drought. The restrictions imposed were severe, but fairly typical of what may be found in a drought plan of a U.S. water provider. Melbourne actually reached such an extreme shortage that it prohibited all lawn watering. The literature also points to water providers aggressively patrolling for violators, and issuing citations and fines. Water use restrictions seem to be the primary mechanism that helped Australians get through the drought. Other strategies include the use of water markets and the building of costly seawater desalination plants. The Millennium Drought also seems to have accelerated the pursuit of alternative water use both on a small and large scale. Water providers, and even the Australian government, have offered a variety of rebates for permanent graywater systems and rainwater tanks and for the expensive connections to toilets and clothes washers. At the time of this writing Victoria seems to be the only entity offering such rebates, perhaps indicating that they are not cost-effective.[59] Water providers in Australia are also developing large scale alternative water supply systems, as is evident from Melbourne, Sydney, and Perth.[50,56,60]

[59] The savewater!® Alliance. (Accessed December 2013). Rebates for Greywater Systems. http://www.savewater.com.au/how-to-save-water/in-the-home/greysmart/suppliers-and-rebates/rebates

[60] Sydney Water. (Accessed December 2013). Stormwater treatment and reuse. http://www.sydneywater.com.au/SW/water-the-environment/what-we-re-doing/current-projects/stormwater-management/index.htm

Emerging and Proactive Drought Management Strategies

What can water providers do beyond the more traditional drought response strategies such as restrictions, pricing, and surcharges to make communities more resistant to the impacts of drought? The examples from Australia reveal large efforts in alternative supply developments, graywater systems, stormwater capture, water reuse, and seawater desalination. Time will tell if these investments are practical and generate benefits that outweigh the costs. Other less traditional ideas for dealing with drought, identified from a variety of sources, are presented below.

The Florida Department of Environmental Protection published, *Recommendations for a Drought Resistant Florida* in 2007. In it, six workgroups identified "drought smart ideas" for the future which included the following actions:

- Implement automated meter reading programs to provide real-time identification of high water usage.
- Increase in the number of mobile irrigation labs for improving efficiency in landscape irrigation.
- Develop more effective enforcement and education programs to promote compliance with landscape irrigation restrictions.
- Create a certification program for irrigation design, auditing, and installation professionals.
- Increase the use of reclaimed water.
- Create emergency orders requiring utilities to implement a water audit program for all ICI customers.[61]

The inclusion of automated meter reading on the list points to the use of new technology to better manage water resources. Technological innovations can be utilized any time to better manage water demand, and can be particularly useful during a drought. Advanced metering infrastructure (AMI), for example, measures customer consumption at a minimum of an hourly frequency and allows utilities to closely monitor water consumption. During a drought, AMI can be used to identify problems such as high water users and leaks, and measure relatively immediate impacts of restrictions.

Programs like WaterSmart Software and H_2O Score represent methods that can be used to provide customers with periodic water use profiles, including a comparison against similar households. A recent study estimated a water use reduction of 4.6 percent and 6.6 percent for two separate study groups in the East Bay Municipal Utility District service area. Customers receive reports either by paper mail or electronic mail. The authors estimate that the unit cost of saved water via WaterSmart Software email reports is between $770-$1,810/MG (USD) ($250-$590/AF) and between $890-$1,750/MG (USD) ($290-$570/AF) for paper reports. The study indicates that participants are more likely to take part in efficiency programs and that the reports are an effective way to communicate with customers.[62]

The Albuquerque Bernalillo County Water Utility Authority's *Drought Management Strategy* contains a couple of unique approaches to reach out to customers. For example, rebates of $20.00 (USD) are offered to customers that take a "DroughtSmart" class on managing landscape water use during drought. Additionally, the *Drought Management Strategy* indicates that if Stage 3 drought measures are introduced a rebate will be provided to customers who pledge to, and successfully accomplish, a 20 percent reduction in water use during a drought period. The Albuquerque Bernalillo County Water

[61] Florida Department of Environmental Protection. (2007). Recommendations for a Drought Resistant Florida. http://fyn.ifas.ufl.edu/materials/Drought%20Smart%20Report%20July%208%202007.pdf

[62] Mitchell, D. and Chesnutt, Thomas. (December 2013). Evaluation of East Bay Municipal Utility District's Pilot of WaterSmart Home Water Reports http://californiawaterfoundation.org/uploads/1389391749-Watersmart_evaluation_report_FINAL_12-12-13%2800238356%29.pdf

Utility Authority's *Drought Management Strategy* also contains specific estimates of savings from the prescribed strategies, rather than broad based reduction goals found in many plans.[63]

The El Paso, Texas Water Utilities - Public Service Board is implementing a variety of strategies beyond its aggressive efficiency programs to improve its resilience. This includes reclaimed wastewater effluent, new conjunctive use supplies, groundwater recharge with treated surface water (aquifer storage and recovery) when demands are low, and desalination of irrigation return flows.[64]

The San Antonio Water System and the City of Kerrville represent two other Texas water providers with aquifer storage and recovery (ASR) programs. According to a 2011 report that assessed the use of ASR in Texas, both communities have been able to avoid severe drought restrictions because of the ability to recover water stored in an aquifer.[65] The SAWS ASR capability was developed, "to capture surplus water during wet months and store it underground for drought management and emergency relief (pg. 18)."[65] Aquifer storage and recovery is utilized throughout the United States but appears to be most prominent in the arid Southwest.[66] The largest ASR project is located in Las Vegas and has been utilized to store 105 billion gallons (320,000 AF) of water. Aquifer storage and recovery has been used in Florida as well, and it is currently being studied for possible use in the Comprehensive Everglades Restoration Plan.[67] The state of Washington has nine ASR projects, and the practice seems to be common in California and the Carolinas as well.[68,69,70] Examples are certainly not limited to the aforementioned, but they demonstrate the geographic and climatic variability of existing ASR projects. Aquifer storage and recovery is a strategy that can help communities save water for times of drought, and there is documentation to demonstrate its role in avoiding severe drought restrictions in two Texas communities.

Short-term curtailment strategies tend to be focused on outdoor water use. The 2011 *WaterSense Specification for Weather-Based Irrigation Controllers Supporting Statement* estimated that as of 2005 there were 13.5 million residential irrigation systems installed in the United States. The reports also estimated that one-third of new homes built will include an irrigation system. As of the 2011 writing, only 10 percent were estimated to use weather-based controllers to schedule irrigation.[71] The 1999 *Residential End Uses of Water* study found that homes with in-ground irrigation systems use 35 percent more water than homes without. Additionally, homes with an automatic timer to control their irrigation system used 47 percent more water than those that operate the irrigation system manually.[72] An update to this study will be released in 2014 and will include more current findings.

[63] Albuquerque Bernalillo County Water Utility Authority. (2012). Drought Management Strategy. http://abcwua.org/uploads/files/Your%20Drinking%20Water/dms2012.pdf
[64] El Paso Water Utilities. (Accessed December 2013). Past and Present Water Supplies. http://www.epwu.org/water/water_resources.html
[65] Pirnie, Malcolm, and Sjoberg Jackson. (2011). An Assessment of Aquifer Storage and Recovery in Texas. https://www.twdb.state.tx.us/innovativewater/asr/projects/pirnie/doc/2011_03_asr_final_rpt.pdf
[66] United States Environmental Protection Agency. (2012). Aquifer Recharge (AR) and Aquifer Storage & Recovery (ASR) http://water.epa.gov/type/groundwater/uic/aquiferrecharge.cfm#inventory
[67] South Florida Water Management District. (Accessed December 2013). Aquifer Storage and Recovery. http://www.sfwmd.gov/portal/page/portal/xweb%20-%20release%203%20water%20supply/aquifer%20storage%20and%20recovery
[68] State of Washington Department of Ecology. (Accessed December 2013). Aquifer Storage and Recovery (ASR) and Shallow Aquifer Recharge (SAR): tools to supplement water supply. http://www.ecy.wa.gov/programs/wr/asr/asr-home.html
[69] California Environmental Protection Agency. (2013). General Waste Discharge Requirements for Aquifer Storage and Recovery Projects that Inject Drinking Water into Groundwater http://www.swrcb.ca.gov/water_issues/programs/asr/index.shtml
[70] Kenel, P., Moresi, R., and Bloetscher, F. (2004). Survey of ASR Systesm in the Carolinas.
[71] United States Environmental Protection Agency. (2011). WaterSense Specification for Weather-Based Irrigation Controllers Supporting Statement. http://epa.gov/watersense/docs/final-controller-supporting-statement_102611_final508.pdf
[72] Mayer, P. W., & Deoreo, W. B. (Eds.). (1999). Residential end uses of water. American Water Works Association.

In 2008 the Southern Nevada Water Authority (SNWA) commissioned the development of, and then tested, devices that mechanically adjusted automatic irrigation systems to comply with watering restrictions. The device was referred to as the Water Group Assistant, in reference to the six geographical watering restriction groups. During the time of the product testing SNWA had one day per week restrictions in the winter months, three day per week watering restrictions in the spring and fall months, and unrestricted watering days in the summer months. The devices reportedly resulted in increased compliance with restrictions, and lower water use during restricted times, but annual water savings were similar to a treatment group that did not have the Water Group Assistant. At present the devices have not been distributed beyond the test group or pursued further.[73,74]

Many water providers and communities promote drought tolerant landscapes as a way to curb outdoor water use. Landscapes designed to withstand drought will be more likely to survive a period of low precipitation that is combined with outdoor water use restrictions. This will lessen the costs associated with loss of landscape vegetation during a drought, place less of a hardship on customers, and lessen the demand on water supplies. Some water providers have demonstration gardens and promote the use of native and drought tolerant vegetation via guidebooks and/or a list of plants.[75,76,77] Ultimately, it is possible for customers to have drought tolerant landscapes that are attractive and can be enjoyed. There are even ways to manage turf grass to make it more resistant to drought such as the height at which is cut and how it is watered.[78]

In California, the 2006 *Water Conservation in Landscaping Act* required cities and other political entities to adopt efficient landscape ordinances. The Department of Water Resources (DWR) released the *Model Water Efficient Landscape Ordinance* that was approved by the Office of Administrative Law in September 2009. Local agencies had until January 1, 2010 to adopt the DWR's model ordinance or tailor their own as long as it was at least as effective as the model in regard to water efficiency.[79,80] Los Angeles County adopted the *Drought-Tolerant Landscaping Ordinance* in 2008 as part of its Green Building Program. The *Drought-Tolerant Landscape Ordinance* contains regulations for all new construction and major renovations. The ordinance became effective on January 1, 2009 and applies to unincorporated areas in Los Angeles County. The County also provides a guidebook and a list of drought tolerant plants and turf.[81]

[73] American Water Works Association. (May 2008). SNWA Working on Devices that Automatically Adhere to Water Restrictions. Journal of American Water Works Association.
[74] Sovocool, Kent et al. (2011). SNWA Watering Group Assistant Study. Presentation at the WaterSmart Innovations Conference and Exposition. http://www.watersmartinnovations.com/2010/PDFs/11-T-1113.pdf
[75] City of San Diego, California. (Accessed January 2014). The Greenhaven at Ridgehaven Xeriscape Demonstration Garden. http://www.sandiego.gov/environmental-services/geninfo/ridgehaven/garden.shtml
[76] City of Prescott, Arizona. (2006). Low Water Use Drought Tolerant Plant List. http://www.cityofprescott.net/_d/plant_list.pdf
[77] Las Virgenes Municipal Water District. (2009). A California-Friendly Guide to Native and Drought Tolerant Gardens http://www.lvmwd.com/home/showdocument?id=711
[78] United States Environemntal Protection Agency. (2013). Water-Smart Landscapes Start With WaterSense®. http://www.epa.gov/WaterSense/docs/water-efficient_landscaping_508.pdf
[79] California Department of Water Resources. (September 2009). Model Water Efficient Landscape Ordinance. http://www.water.ca.gov/wateruseefficiency/docs/MWELO_TbContent_Law.pdf
[80] California Department of Water Resources. (October 2009). The Updated Model Water Efficient Landscape Ordinance. http://www.water.ca.gov/wateruseefficiency/docs/MOBrochure.pdf
[81] L.A. County Green Building Program. (Accessed January 2014). http://planning.lacounty.gov/green

Los Angeles County, California, Code of Ordinances - Section 22.52.2230 Drought-Tolerant Landscaping Requirements.

All projects shall comply with the drought-tolerant landscaping requirements of this Section 22.52.2230

A. The total landscaped area of a lot or parcel of land on which a project is situated shall satisfy the following:

1. A minimum of seventy-five (75) percent of such total landscaped area shall contain plants from the drought-tolerant plant list;
2. A maximum of twenty-five (25) percent of such total landscaped area shall consist of turf, however, in no event shall turf be planted in strips that are less than five (5) feet wide, and in no event shall the total landscaped area contain more than five thousand (5,000) square feet of turf;
3. All turf in such total landscaped area shall be water-efficient. The green building technical manual shall contain a list of turf that meets this requirement; and
4. The plants in such total landscaped area shall be grouped in hydrozones in accordance with their respective water, cultural (soil, climate, sun, and light), and maintenance requirements.

B. For single-family residences, in addition to the landscaping requirements of subsection A of this Section 22.52.2240, in calculating the maximum square footage of turf used, the turf in the residence's rear and side yards shall be included in the measurement of the turf used for the total landscaped area. [82]

The United States Environmental Protection Agency identified drought-related climate adaptation strategies for water utilities in its 2013 *Adaptation Strategies Guide for Water Utilities*. While efficiency was included in the list, below are less common approaches offered in the paper:

- "Practice conjunctive use (i.e., optimal use of surface water and groundwater).
- Finance and facilitate systems to recycle water, including use of greywater in homes and businesses.
- Acquire and manage ecosystems, such as forested watersheds, vegetation strips, and wetlands, to regulate runoff.
- Build infrastructure needed for aquifer storage and recovery, either for seasonal storage or longer-term water banking, (e.g., recharge canals, recovery wells).
- Diversify options to complement current water supply, including recycled water, desalination, conjunctive use, and stormwater capture.
- Expand current resources by developing regional water connections to allow for water trading in times of service disruption or shortage.
- Increase water storage capacity, including silt removal to expand capacity at existing reservoirs and construction of new reservoirs and/or dams.
- Increase or modify treatment capabilities to address treatment needs of marginal water quality in new sources.
- Retrofit intakes to accommodate lower water levels in reservoirs and decreased late season flows.

[82] Los Angeles County, California, Code of Ordinances - Title 22 – Planning and Zoning - Division 1 - Planning and Zoning - Chapter 22.52 - General Regulations - Part 21 Drought-Tolerant Landscaping - Section: 22.52.2230 Drought-Tolerant Landscaping Requirements. http://library.municode.com/HTML/16274/level4/TIT22PLZO_DIV1PLZO_CH22.52GERE_PT21DRLELA.html#TIT22PLZO_DIV1PLZO_CH22.52GERE_PT21DRLELA_22.52.2230DRLELARE

- Build or expand infrastructure to support conjunctive use.
- Build systems to recycle wastewater for energy, industrial, agricultural, or household use."[83]

Many of the drought strategies in this section represent proactive approaches to provide stability in future times of drought rather than the reactive strategies common in most drought plans. Reactive curtailment strategies are critically important and effective in managing water demands during a shortage. Proactive strategies like the use of alternative water sources may help water providers better prepare for and cope with future droughts.

[83] United States Environmental Protection Agency. (2013). Adaptation Strategies Guide for Water Utilities. http://water.epa.gov/infrastructure/watersecurity/climate/upload/epa817k13001.pdf

Weather History and Climate Change

Weather has a direct impact on water use, and weather data play a key role in planning for the future. Past weather averages are often used in water demand forecasts and the drought of record is frequently referenced as a worst case scenario for drought plans. Using averages or examples of extreme events from our recorded history of weather data may prove to be insufficient for two reasons. (1) Weather patterns before our recorded history may have been quite different than what has been documented, and (2) future changes in weather may not adhere to what we have come to perceive as normal.

To understand weather patterns before our recorded weather data, many researchers are studying tree rings. According to Cleaveland et al. (2011), many water providers in Texas use the drought of the 1950s, which occurred from 1950-1956, as a worst case scenario. Their research indicates that droughts of the past were longer lasting and more intense than the drought in the 1950s.[84] Stahle et al. found that droughts in the 1750s, 1820s, and 1850s-1860s were similar to the 1950s drought but found evidence of a megadrought in the 1500s that, "far exceeded any drought of the 20th century." It is estimated that a megadrought lasted around 40 years in the Southwest and Mexico.[85]

Herweijer et al. also discuss the megadroughts of the last millennium and note the much longer multi-decade durations. The authors also go on to say that in their research they have identified a relationship between La Niña and drought in North America, "cool 'La Niña–like' conditions in the tropical Pacific are consistent with North American drought (pg. 1353)."[86]

A look into the past, beyond our weather records, indicates droughts have lasted much longer than those of the last century. What about future droughts?

The U.S. Global Change Research Program's 2009 *Global Climate Change Impact in the United States* report indicates that future changes in climate could result in widespread increases in heavy precipitation events with longer dry spells in-between. A region could receive less overall precipitation but have an increase in heavy rain events. Due to rising temperatures there may be less snow pack in the future, which many water providers rely on for water supply. The report also suggests that changes in atmospheric circulation will likely move storm tracks northward. This will make droughts in arid regions of the Southwest longer and more severe. The authors' key messages in regard to the impact of climate change on water resources are:

- "Climate change has already altered, and will continue to alter, the water cycle, affecting where, when, and how much water is available for all uses.
- Floods and droughts are likely to become more common and more intense as regional and seasonal precipitation patterns change, and rainfall becomes more concentrated into heavy events (with longer, hotter dry periods in between).
- Precipitation and runoff are likely to increase in the Northeast and Midwest in winter and spring, and decrease in the West, especially the Southwest, in spring and summer.
- In areas where snowpack dominates, the timing of runoff will continue to shift to earlier in the spring and flows will be lower in late summer.

[84] Cleaveland, M. K., Votteler, T. H., Stahle, D. K., Casteel, R. C., & Banner, J. L. (2011). Extended chronology of drought in south central, southeastern and west Texas. Texas Water Journal, 2(1), 54-96.
[85] Stahle, D. W., Cook, E. R., Cleaveland, M. K., Therrell, M. D., Meko, D. M., Grissino-Mayer, H. D., ... & Luckman, B. H. (2000). Tree-ring data document 16th century megadrought over North America. EOS, Transactions American Geophysical Union, 81(12), 121-125.
[86] Herweijer, C., Seager, R., Cook, E. R., & Emile-Geay, J. (2007). North American droughts of the last millennium from a gridded network of tree-ring data. Journal of Climate, 20(7), 1353-1376.

- Surface water quality and groundwater quantity will be affected by a changing climate.
- Climate change will place additional burdens on already stressed water systems.
- The past century is no longer a reasonable guide to the future for water management (pg. 41)." [87]

Others suggest global warming will not cause droughts, but that it will cause droughts to set in faster and be more severe.[88]

A look at past weather history via tree ring data suggests that droughts have lasted for up to 40 years in the United States. The climate of the future may also bring droughts of varying severity and duration. Additionally, dry regions may see an increase in aridity. Planning for future drought should consider the possibility for large deviations from long-term averages and droughts of record.

[87] Karl, T. R., Melillo, J. M., & Peterson, T. C. (Eds.). (2009). Global climate change impacts in the United States. Cambridge University Press.
[88] Trenberth, K. E., Dai, A., van der Schrier, G., Jones, P. D., Barichivich, J., Briffa, K. R., & Sheffield, J. (2014). Global warming and changes in drought. *Nature Climate Change*, *4*(1), 17-22.

Summary

The title of this paper is, *Considerations for Drought Planning in a Changing World*. What specifically is changing?

- Population and economic growth is putting pressure on water supplies in some locations even under normal weather conditions.
- The U.S. climate is changing which may alter precipitation and temperature patterns. Additionally, more frequent extreme weather events have been predicted.
- Our understanding of "normal" weather patterns is being challenged by research that looks at weather before recorded history.
- Many water providers have permanent water use restrictions in place that, in the past, represented the front line of drought management strategies.

What can be done to adapt to these changes? Improved planning and adoption of new strategies will likely play a key role in responding to future droughts. Below are themes that emerged during the research for this paper.

Planning

- Plan with a new perspective on drought of record and "normal" weather.
- Plan for climate change based on available regional and local projections.
- Plan for and monitor short-term climatic events that drive changes in temperature and precipitation such as El Niño and La Niña.
- Consider an approach like Denver Water's, if feasible, that allocates a portion of water saved through long-term efficiency programs to a drought reserve.
- Update water demand forecasts and water supply plans regularly.
- Profile the various end uses in the service area and identify those that can be curtailed during a shortage with the lowest economic and societal costs.
- Create detailed estimates of savings for variety drought response strategies such as restrictions and changes in pricing.
- Analyze the revenue impacts of changes in demand resulting from short-term curtailment and have a plan in place to create stability.
- Identify supply options (if any) that can be called upon during a shortage and weigh the costs against costs of curtailment.

Topics that Emerged in Literature Review that Represent Emerging Drought Management Options Beyond Traditional Restrictions and Surcharges

- Advanced metering infrastructure (AMI) use to closely monitor water consumption during droughts to identify leaks and high water users, and to track progress of curtailment efforts.
- Large scale water reuse projects.
- Conjunctive use.
- Aquifer storage and recovery.
- Water transfers and trading.
- Innovative customer education and interaction.
- Drought tolerant landscapes.
- Landscape irrigation efficiency improvements and managing landscape water use in times of drought.
- New technological options for managing automatic irrigation systems.

- Landscape irrigation restriction enforcement and education regarding compliance.

Being prepared for drought will increase service reliability and help reduce the social, environmental, and economic costs associated with water shortages. All service areas have unique supply and demand characteristics that will determine what approaches will be realistic and effective. Traditional short-term curtailment strategies are still proving to be reliable demand reduction options. Changes in water pricing and the use of surcharges, combined with good communication and outreach to customers, have also demonstrated efficacy. There are past case studies to learn from, changes in planning to consider, and emerging options that can be pursued, all of which will help communities become more resistant to drought.