TRUCKEE MEADOWS WATER AUTHORITY

Water Conservation Plan

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March, 2016

Submitted to Division of Water Resources, Nevada

Pursuant to NRS 540.121-540.151

Truckee Meadows Water Authority is a not-for-profit, community-owned water utility, overseen by elected officials and citizen appointees from Reno, Sparks and Washoe County.

Background

The Truckee Meadows Water Authority ("TMWA") submitted its first Water Conservation Plan to the Nevada Division of Water Resources ("NDWR") under NRS 540.121 through 540.151 in 2003. The Plan is based on TMWA's 2005-2025 Water Resource Plan which outlines how TMWA acquires and supplies water resources to customers within its service area. TMWA updated that Water Resource Plan and submitted its 5-year updated plan in July 2007. On December 16, 2009, TMWA's Board of Directors approved TMWA's 2010-2030 Water Resource Plan ("2030 WRP"). The 2030 WRP demand side management chapter contains substantial revisions to previous water saving programs undertaken by the utility.

In 2015, TMWA merged with Washoe County Department of Water Resources ("WCDWR") and South Truckee Meadows General Improvement District ("STMGID"). This merger expanded TMWA's service area to include an additional 27,500 water services. Moreover, during this time the Truckee Meadows region, like most of the Western U.S., was experiencing a fourth consecutive year of persistent dry conditions. In light of these new conditions, TMWA drafted its 2016-2035 Water Resource Plan, ("2035 WRP")[1]. The 2035 WRP's Chapter 5, *Conservation Plan*, included additional, substantial changes to the demand-side management actions TMWA can take during drought and non-drought years. The 2035 WRP was approved by TMWA's Board on March 16, 2016. TMWA's 2016 Water Conservation Plan is a direct result of the approved 2035 WRP.

Introduction

In the arid Western U.S., water is a scarce resource necessary not only for the well-being of a community's inhabitants, but also for the ecologic and economic vitality of a region. Nevada, and of interest to this plan, Washoe County, is characterized as a high desert environment that is in a constant state of drought, intermixed with brief periods of wet conditions. Such conditions imply efficient water use is not a concept that applies only during dry times, but is rather a way of life in Northern Nevada.

As the water purveyor for approximately 90 percent of Washoe County residents, TMWA has a substantial responsibility as a steward of the region's water resources. In southern Washoe County, the majority of the water resources come from seasonal snow melt that flows down the Truckee River. From year-to-year, the amount of snow melt can fluctuate greatly. In response to these climatic conditions, a robust conservation plan must be in place to successfully manage water supply and demand so that there exists an adequate bank of water reserves available during persistent dry hydrology conditions.

Water conservation is achieved through efficient storage and delivery of the water supply and effective management of demand for that supply. Water supply management has been defined as the control of the water supply by the water purveyor or authority (Stephenson, 2012). Water demand management has been defined as "the development and implementation of

[1] TMWA's 2035 WRP can be found online at http://tmwa.com/water_system/resources/.

strategies, policies, measures, or other initiatives aimed at influencing demand, so as to achieve efficient and sustainable use of this scarce resource" (Savenije and van der Zaag, 2002). TMWA's conservation plan contains the necessary elements to manage both the supply of its water resources as well as demand for those resources. TMWA's conservation plan has two components: 1) supply-side management programs ("SMPs") designed to reduce production and distribution losses and 2) demand-side management programs ("DMPs") designed to conserve water supplies by limiting water waste, inefficient use, and overuse. TMWA's SMPs are actions taken to maintain water resources and provide alternative sources to potable water in a cost-effective manner, as well as to ensure water is delivered to customers in an efficient manner. Once delivered, TMWA's DMPs target customers' watering practices in order to promote efficient use. During periods of extended drought, TMWA's DMPs can be enhanced to promote further reduction in water consumption by its customers. TMWA's Conservation Plan discusses how its SMPs and DMPs are used in response to non-drought and drought periods, which are determined based on annual projected hydrologic conditions evaluated each April.

To support the many benefits of effective conservation, the target goals of TMWA's conservation plan include:

1. Minimizing source water supply disruptions
2. Preserving community and customers' landscaping assets
3. Maintaining a low cost of service
4. Ensuring environmental preservation

Minimizing Source Water Supply Disruptions

When there is not enough Truckee River water to be shared between TMWA and other water rights stakeholders in the region, the priority of water rights dictates the amount of water provided to each stakeholder. TMWA is the largest holder of senior Truckee River irrigation water rights on the Truckee system. However, when the natural flow in the river is not able to provide adequate quantities of water for consumption, reductions in water use can decrease the amount of water to be released from TMWA's upstream and underground reserves. By banking or storing water in reservoirs when allowed under certain river operations, TMWA can minimize, if not prevent, supply interruptions to its treatment plants.

At the water user level, there are steps customers can take to ensure their water services are uninterrupted. When pipes break or leaks occur, not only is it an inconvenience to the customer, it wastes water in the process. TMWA is committed to ensuring its water delivery system stays up-to-date and in good working order. Also, TMWA takes every opportunity to educate customers on how to inspect and maintain their water systems on their property so the water stays on.

Preserving Community and Customers' Landscaping Assets

Property characteristics associated with landscaping add substantial economic value to the property. Government entities and property owners invest significant amounts of time and money in landscape-related assets, both at the time of installation and its ongoing maintenance.

Developed land is required by local ordinances to meet specific landscape requirements as part of the building permit process. TMWA requires a sufficient amount of water rights be dedicated for each new development and meet its obligation to serve water to the property in perpetuity. TMWA's Conservation Program is designed to promote efficient demand in general and lower demands during periods of drought, without requiring customers to sacrifice their investment in their landscape assets.

Maintaining a Low Cost of Service

The facility and operating costs to capture, treat and deliver water are the main components that determine the amount customers pay for service. While the majority of costs related to water production are fixed (i.e., there is a very high initial capital cost), there is a portion of that cost associated with system repair and maintenance that can vary annually. When demand for water is efficient, an optimal amount of water is produced and delivered. With optimal supply through the delivery system, wear and tear on the system's components (e.g., pumps, valves, pipes, meters, etc.) is minimized, prolonging their lifecycle. Capital improvement projects ("CIPs") designated to replace aging parts of the system are part of TMWA's supply-side management. Therefore, through effective demand-side management, TMWA is able to keep the associated supply-side management costs low, which in turn provides stable prices to its customers over time[2].

Ensuring Environmental Preservation

Maintaining adequate surface flows within the Truckee River has benefits above meeting customer demand. Higher river flows have benefits to the riparian ecosystem as well[3]. A variety of wildlife species, such as the Cui-ui and Lahontan Cutthroat Trout, depend on the habitat of in Lake Tahoe, along the Truckee River, and its terminus, Pyramid Lake. In times of drought, natural river flows are diminished, which has adverse impacts on native species of fish and other wildlife that rely on the riparian system. By conserving water, upstream reservoirs stay fuller longer. This additional storage allows TMWA to ensure river flows are supplemented during times when the level of Lake Tahoe cannot provide sufficient outflow, which indirectly benefits the riparian habitat along the Truckee River.

[2] Since 2002, on average, TMWA's per unit cost of service has increased by 13 percent, an increase less than the national average of 31.6 percent adjusted for inflation

[3] Riparian systems include those lands or areas situated along the banks of a watercourse.

TMWA’s Water Conservation Plan

TMWA’s conservation plan extends beyond a responsibility for resource stewardship and must fulfill specific provisions—including water conservation requirements per the JPA, the NRS, regional planning, and TROA. Under NRS 540.131, every water purveyor in Nevada must submit a water conservation plan to the State. This plan must include provisions related to: (1) increasing public education awareness; (2) encouraging reductions in the size of lawns and use of drought-tolerant plants; (3) managing for leaks in the supply system; and (4) increasing the reuse of effluent water. TMWA’s current Conservation Plan’s contains DMPs and SMPs that meet these requirements (Fig. 1). Figure 1 provides a diagram illustrating how various elements of TMWA’s Conservation Plan meet these NRS requirements (NOTE: expansion of TMWA’s water resources (i.e., wells and groundwater supplies) are discussed in Chapters 2 and 6 of the 2035 WRP).

The statute also mandates a contingency plan be in place to ensure potable water is available during drought conditions and a schedule for how such a plan will be implemented. The end of this Plan outlines TMWA’s Drought Response Plan, which provides how TMWA classifies drought conditions pursuant to TROA, the enhanced DMPs it takes given a certain drought condition, and an explicit timeline for when those enhanced actions occur. In 2007, a mandate was added to NRS 540.141 requiring each conservation measure specified in a purveyor’s conservation plan to have an associated estimate outlining the amount of water that will be conserved each year, stated in gallons per-person, per-day (see NRS 540.141 1.(g)). In addition, the NRS now states the rates charged for water will maximize conservation and the plan must estimate the manner in which rates will affect consumption (see NRS 540.141 2.(b)).

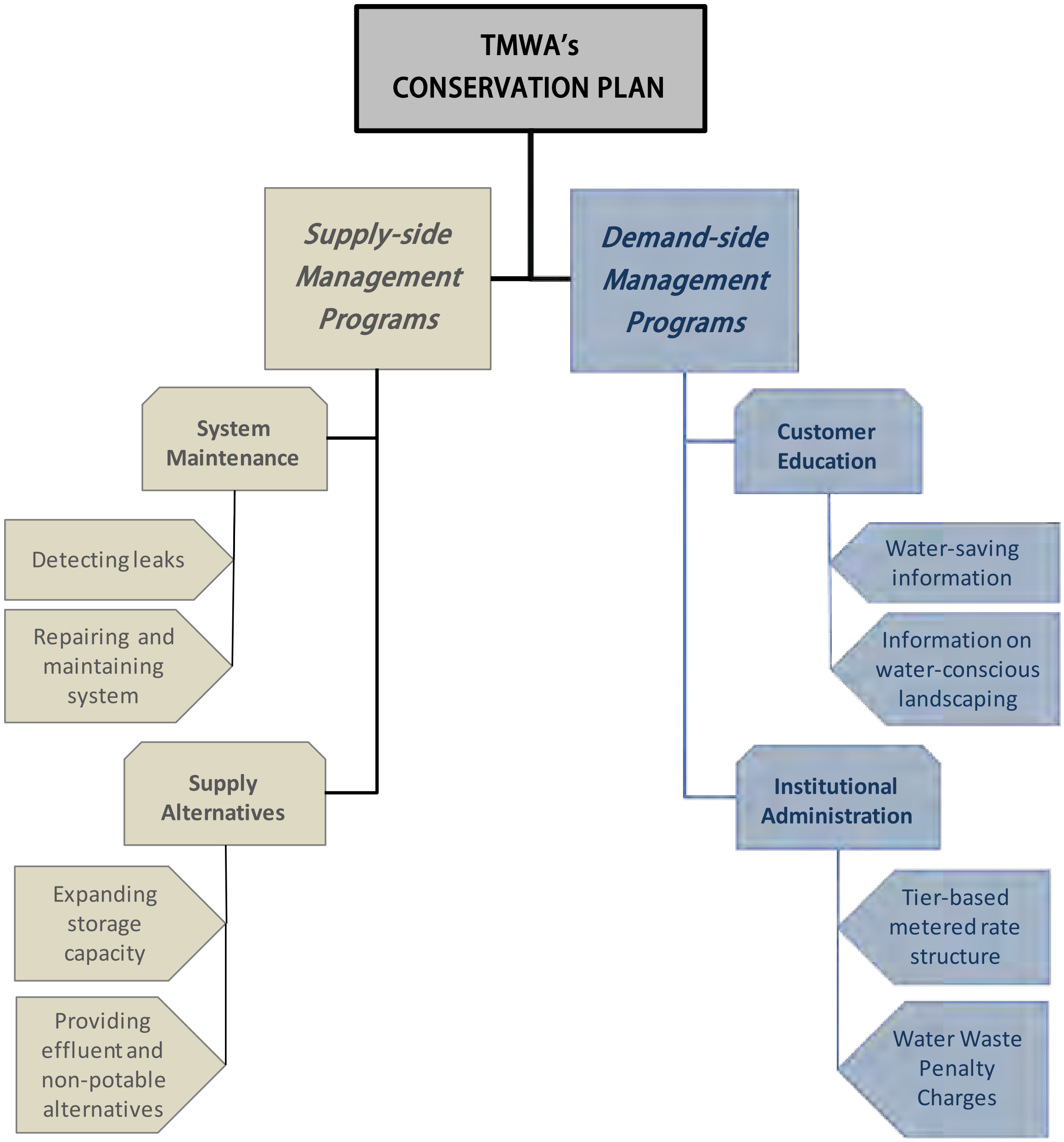

Figure 1. Diagram of TMWA's Conservation Plan as Related to NRS 540.131

In 2015, in order to address mounting concerns over drought, Governor Sandoval created the Nevada Drought Form. Six meetings were held between June and November of that year. In September 2015, the Governor held a Drought Summit at the State's capital, Carson City. As a culmination of those efforts, the Governor released the *Nevada Drought Forum: Recommendations Report in December of 2015*. To address the state's water resource challenges, the report outlined, among other things, recommendations on the best water conservation practices. Those conservation recommendations include all water purveyors' conservation plans include: (1) metering of all water connections; (2) the development of water efficiency standards for new development; (3) tiered rate structures to promote conservation; (4) time-of-day and day-of-week water restrictions; and (5) a request that local political subdivisions explore the implementation of water conservation measures where Covenants, Conditions, and Restrictions are in place. The following sections of this Plan outline TMWA's specific programs within its Conservation Plan, of which, are consistent with the recommendations identified in this report and have been deployed by TMWA for many years. A copy of the Nevada Drought Forum: Recommendations Report can be found in Appendix 1.

Overall, residential water use in the TMWA service area has become more efficient over time. By 2014, the average residential metered water service ("RMWS") used *11.6 percent less* water than the average service in 2003. TMWA's total water production has decreased by 7 percent while its number of residential services has nearly doubled during this same time period. Figure 2 shows this change in per-service efficiency since TMWA's inception. While the graph below shows a clear decline in individual water consumption overall, there are issues that can confound or preclude estimations of 'per-person, per-day' water savings for individual DMPs required under the NRS. Moreover, the effectiveness of SMPs do not directly relate to 'per-person, per-day' savings. SMPs are not savings *by* customers but rather savings on the supply-side that accrue in the distribution system. For such programs (e.g., leak repair, meter replacement, non-potable use, etc.) a 'percent of the total supply' savings is a more meaningful metric from which to estimate effectiveness.

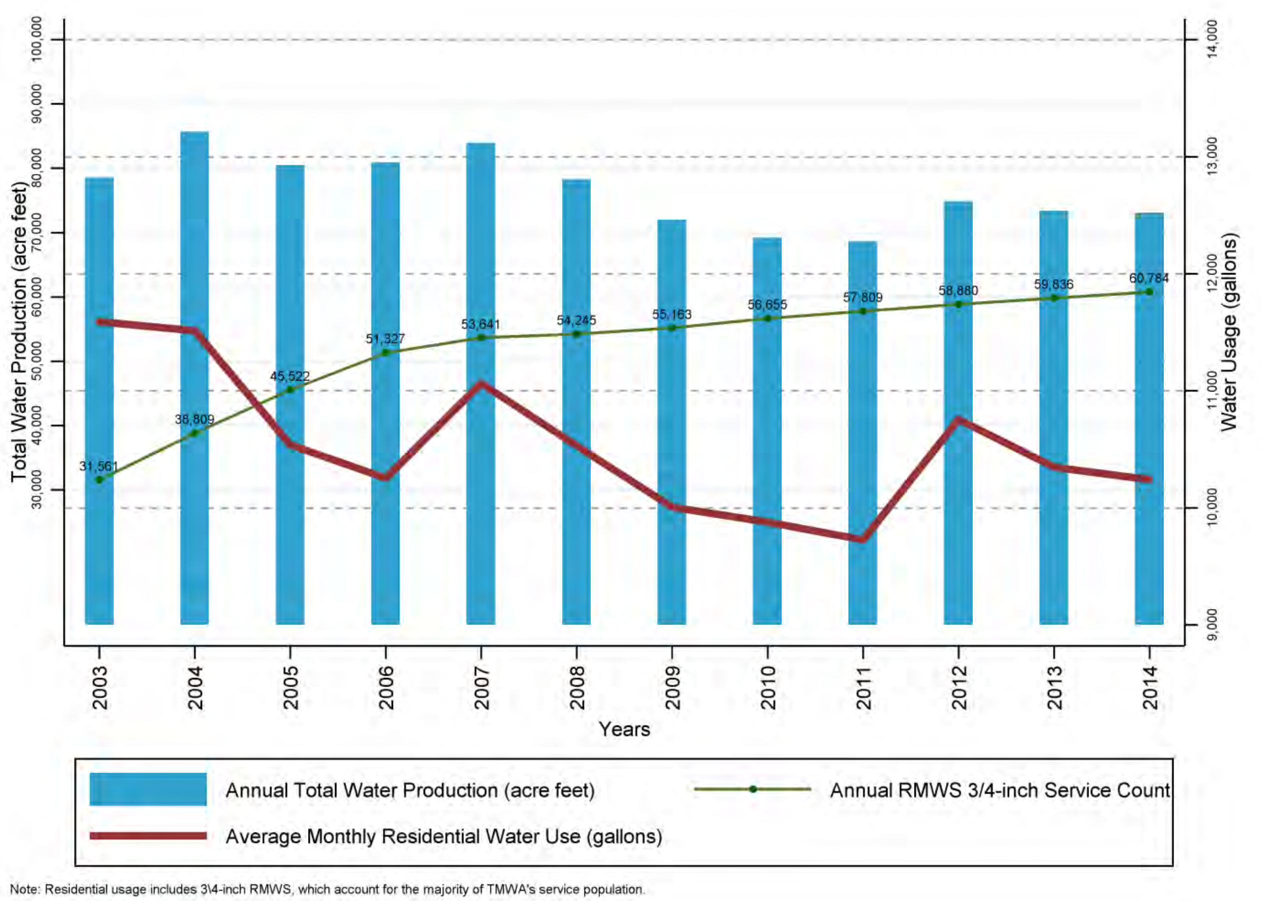

Figure 2. Average Residential Water Use and Total Production between 2003 and 2014

The major roadblock to quantifying efficacy of DMP's, for which 'per-person, per-day' metrics can be determined, is lack of data. Take for example educational programs (e.g. multi-media messaging, online resources, in-person workshops, etc.). It is not feasible to track the information to which customers have been exposed to each program. Even if such tracking was feasible, customers are exposed to information via a host of different formats, so any attempt to delineate the effect of any one program from another would prove unreliable in the uncontrolled environment. In such contexts, the combined effect of individual programs is the only possible estimate of effectiveness. This Plan provides estimates of benefits from each activity and states the measure of gallons saved 'per-person, per-day' whenever possible (or meaningful). For programs in which 'per-person, per-day' estimates are not relevant, the most meaningful metric will be provided. Programs for which there is no data available from which to estimate effectiveness will be noted.

In early 2015, TMWA partnered with the University of Nevada to conduct research on how different forms of communication and messaging influence customer behavior using a controlled study (i.e. treatment and control groups). TMWA is also investigating how customers conserve water in times of drought, their attitudes about drought, and their attitudes about TMWA's drought communication efforts. Results from this investigation will be available by the spring of 2016. These studies will offer a deeper understanding into the scope and effectiveness of TMWA's water conservation programs.

TMWA's Conservation Plan will continue to serve as the cornerstone of the region's efforts to conserve local water resources. Given primary reasons for TMWA's Conservation Plan is to promote efficient use of water resources and minimize water waste, each program within the plan plays a unique role in meeting these goals. While many of the water conservation benefits outlined above are interrelated, each program within the Conservation Plan is designed to elicit a specific response from a targeted customer base, in order to achieve a specific set of goals. Table 1 summarizes each program, along with its targeted goal(s) and customer(s).

Table 1. TMWA's Standard Conservation Plan Programs

Water Conservation Plan	Target Goal	Target Customer
Supply-side Management Programs/Activities		
System Maintenance		
Leaks and System Repairs	1,3	All users
Meter Replacement	1,3	All users
System Pressure Standards	1,3	All users
Supply Alternatives		
Non-Potable Water Service	1,3	Irrigation
Demand-side Management Programs/Activities		
Customer Education		
Conservation Consultant Program	2,3	Residential
Water Audits/Water Usage Reviews	1,2,3	Residential & Business
Public Workshops	1,2,3	Residential
School Educational Programs	1,2,3	Residential
Standing Advisory Committee	1,3,4	All users
Online Resources	1,2,3,4	Residential & Business
Conservation Materials	1,2,3	Residential & Business
Multi-media Messaging	1,2,3,4	All users
Institutional Administration		
Water Rates	2,3	All users
Assigned-Day Watering	1,2,3	All users
Watering Time Restrictions	1,2	All users
Water Waste Restrictions	1,2,3	All users
Unauthorized Use of Water	1,3	All users
Landscaping Regulations	2,3,4	All users

Target Goal
1. Minimize service disruptions
2. Preserve customers' landscaping assets
3. Maintain a low cost of service
4. Ensure environmental preservation

Supply-side Management Programs/Activities

To ensure water resources are captured and delivered to customers in an efficient manner, the majority of TMWA's SMPs are CIPs that maintain the integrity of its water system's infrastructure.

System Maintenance

As system components wear out, there is a greater potential for water loss. TMWA is constantly engaging in CIPs that reduce water loss within the delivery system by detecting and repairing aging infrastructure. TMWA continually monitors and maintains its water system infrastructure in order to ensure service disruptions are minimized. TMWA is also very conscious about the cost-effectiveness and expected benefits of system maintenance. Therefore, TMWA incorporates the likelihood and consequences of water main failure to reduce risks to the system associated with unplanned outages and emergency repair costs.

Leaks and System Repairs. Over time, parts of the water-system infrastructure degrade and require repair or replacement. TMWA actively monitors for leaks in the system. When assessing leak repairs, maintenance scheduling considers the safety to the general public and work crews, while providing minimal interruptions to public and private services, as well as minimal overtime expenditures. If water leaks are not large, not causing a safety problem, and are reported outside normal working hours, response staff will determine the urgency of the needed repairs and schedule repair work accordingly.

When the source of the leak is determined, TMWA implements a proactive maintenance program to fix the problem. Once the underground locations of other utilities are determined, the crew will excavate the leak site and make repairs. In the case of a leaking poly-butylene pipe, the crew will usually replace the entire service, as this type of pipe has proven particularly prone to repeated leaks. All leaks are reported and entered into a database.[4] Below are the numbers of main and service repairs since January 2012.

Table 2. Number of Service Repair 2012 - 2015

Fiscal Year	Mains Repaired	Services Repaired	Totals
2012	60	147	207
2013	58	216	274
2014	69	224	293
2015	49	287	336

In order to keep leak occurrences to a minimum, TMWA prioritizes system repairs and replaces aging infrastructure on a continual basis, before an incident occurs. Prioritization is given to pre-1960 systems made of steel, cast iron, concrete, or riveted steel. Coordination with local agencies' street and highway replacement programs has proven to be the most cost effective and least disruptive approach to system replacement and

[4] TMWA's Computerized Maintenance Management System was deployed beginning CY012; prior to that time leak data records are not as reliable

rehabilitation for TMWA customers. See Appendix 2 for more information on TMWA's Main Replacement Program.[5]

Quantification of Effectiveness: TMWA's system-wide leakage rate is very low at 3.1 leaks per 100 miles per year, indicating very high service levels currently exist. On average, TMWA loses approximately 6 percent of total supply through system leaks, well below the national average of 16 percent[6]. This 6 percent also includes non-revenue water (i.e., unmetered, authorized use in firefighting as well as hydrant testing and flushing) and apparent losses (i.e., unmetered, unauthorized use resulting from water theft). This means the real loss of water is some percentage lower than the reported amount. In 2014, TMWA produced approximately 75,000 AF of water. When compared to the national average for water loss, due to TMWA's proactive maintenance schedule, the reduced system loss resulted in 7,500 AF of water loss adverted that year. This equates to an additional 6.7 MGD available for customers.

Meter Replacement. In order to effectively identify leaks and other forms of water loss in the system, accurate metering is critical. Since the internal workings of a meter wear out over time, TMWA's Meter Replacement Program replaces meters as soon as they begin to show signs of failure (e.g., seemly incorrect readings). This practice ensures meters remain in good working condition yet still allows for an extended return on the investment. It is anticipated that TMWA will spend approximately $8.9 million in FYs 2016-2020 on meter and meter reading device replacement. As meters are replaced, additional water savings may be achieved, since improvements are made to the system when leaks in older facilities are found and repaired during the process.

Quantification of Effectiveness: At the time this report was written, no measure of water saved from meter replacement had been estimated.

System Pressure Standard. Pursuant to the Nevada Administrative Code ("NAC") 445A, TMWA's engineering design criteria plans for a max-day-demand-residual pressure of 40 pounds per square inch ("PSI") to be maintained at the customer's service connection. Pressures exceeding 125 PSI may increase the propensity for main breaks or accelerate the development of leaks, both on TMWA and customer facilities. Excessive pressure results in more water delivered through the tap since flow rate is proportional to pressure. This can result in such forms of water waste as sprinkler overspray and higher leakage flow rates.

Quantification of Effectiveness: At the time this report was written, no measure of water saved from TMWA's pressure standard had been estimated.

[5] Appendix 2 provides a narrative of the analytic process and findings with maps provided to give the reader a general characteristic of the range of TMWA's main replacement.

[6] Source: Water Audits and Water Loss Control for Public Water Systems, USEPA July 2013

Supply Alternatives

In order to maximize the amount of potable water available to customers, TMWA actively seeks out opportunities to provide non-potable or effluent sources of water whenever possible.

Non-Potable Water: TMWA has a Non-Potable Service ("NPS") tariff to provide customers that can use sources of non-potable water – either untreated Truckee River water or poor quality ground water – for specific applications with minimal capital investment. The non-potable water service is available at a reduced rate, providing incentive for qualified customers to switch to this service. The service reduces TMWA peak day demand and lowers system capacity needs. Irrigation and construction sites utilize NPS to conserve potable water, enabling existing water resources to go further.

Specific facility needs for each service connection are identified in the service agreements between TMWA and the customer receiving non-potable service. The recipient of the service demonstrates each site's ability to tolerate the interruptible nature of the service (due to system or drought requirements) and/or the potential to switch between treated and untreated water. For example, TMWA has worked with the Washoe County School District, one of TMWA's largest municipal customers, to implement non-potable watering solutions at Reno High School.

TMWA also coordinates with the Truckee Meadows Water Reclamation Facility ("TMWRF") to provide use of effluent water in lieu of TMWA's water supplies. TMWA has agreements with Reno, Sparks and Washoe County to ensure that the use of treated effluent is being applied for irrigation purposes at suitable sites where the infrastructure is, or is planned to be, installed. Providing service connections with effluent leaves capacity for new municipal demand that requires treated water. TMWA's rules require that new service applicants submit verification of whether or not the site applying for municipal, treated water is designated to be, or is within feasible range to be, serviced by effluent water. If the project meets the effluent provider criteria for service, treated effluent will be provided for irrigation purposes instead of potable water from TMWA. Replacement water rights are provided as required by TROA.

Quantification of Effectiveness: On average, TMWA's NPS supplies 34 million gallons of non-potable water annually, which saves approximately 93,000 gallons of potable water each day for use by other customers. Effluent water use reduces demand for TMWA's potable and non-potable water resources. On average, 3,810 AF of effluent water is provided to qualifying customers annually, which keeps 3,401,353 gallons of TMWA's water resources available for other services on a daily basis.

Demand-Side Management Programs/Activities

While many communities use conserved water to serve new growth, TMWA uses conserved water to ensure adequate supplies are provided to its existing customers. Once delivered to the customer, TMWA promotes efficient water use through its proactive DMPs. By utilizing a mix of education-based programs and institutional administration, TMWA's DMPs directly target customer behavior to promote efficient water use year-round and lower demands during periods of extended drought. By lowering demand during drought periods, DMPs reduce or eliminate the need for TMWA to use its drought reserves (aka POSW).

Customer Education

TMWA is deeply committed to public education about conservation and efficient water use. TMWA utilizes every opportunity to promote education. Since water use during the irrigation season is on average four times higher than during the winter months, much of TMWA's public education focuses on the efficient use of water for landscaping. TMWA facilitates efficient use by distributing information through various forms of communication including in-person workshops and events, multimedia messaging, and printed materials.

<u>Multi-media Messaging:</u> TMWA is committed to providing the public with the most recent information regarding the state of the local water supply. Using media outlets such as radio, television and billboards, TMWA produces targeted advertising to get its messages to customers. TMWA also uses social media platforms (i.e., Facebook, Twitter, YouTube and Google Plus) to help spread information regarding changing conditions in weather and the water supply, as well as, tips for efficient water use. TMWA also works with local news stations to help pass on accurate, up-to-date drought information to its customers.

Quantification of Effectiveness: Given the inability to track the customers whom were exposed to different forms of multi-media messaging, it is not possible to determine the individual effect the materials have on conservation. As of the writing of this report TMWA has 1,231 Facebook followers, 1,201 Twitter followers, and 17 Google Plus followers. Such participation rates are noted when considering the effectiveness of various messaging components. Moreover, when asked to reduce water consumption (via all forms of communication), customers' responses are on par with what TMWA requires to help withstand periods of drought. In 2014, a drought situation occurred in August and lasted through September. During this time, TMWA's request for customers to reduce their use by 10 percent compared to their use in 2013 was met favorably. This was the *first* time since TMWA's founding in 2001 that TMWA asked for a specific reduction in use beyond the annual DMP deployment. This request resulted in an average of 8.5 million gallons saved per-day in 2014 by TMWA customers. It is important to note that while the multi-media messaging campaign directly requested the 10 percent reduction, the subsequent educational programs detailed below help facilitate this additional reduction by customers. Therefore, the effectiveness of programs should be evaluated at the aggregate. More information regarding TMWA's Conservation Plan under drought situations can be found in the Drought Response Plan section. See Table 7 for a comparison in retail sales, by customer class, for the months of August and September in 2013 and 2014.

<u>Conservation Consultant Program:</u> TMWA's conservation consultants provide customers information regarding responsible water use, reducing water waste, and TMWA's regulations. During the irrigation months, TMWA ramps up its efforts by hiring additional seasonal consultants to provide both residential and business customers with additional information about leaks and water waste associated with outdoor watering. TMWA's water conservation consultants investigate water waste complaints and provide tips to customers that help curb excessive water usage and facilitate lower monthly bills.

Quantification of Effectiveness: At the time this report was written, no measure of water saved from TMWA's Conservation Consultant Program had been estimated.

<u>Water Audits/Water Usage Review:</u> In 2003, TMWA began a water audit program. The Water Usage Review Program is co-sponsored by TMWA and the WRWC. At the request of the customer, a TMWA technician will conduct an analysis of the customer's current water usage practices and provide recommendations on how the customer can reduce their water consumption and subsequently their monthly bill. Customer response to TMWA's Water Usage Review Program is extremely positive. As of December 2014, nearly 20,000 customer usage reviews have been completed (see Table 3). While the majority of water usage reviews are initiated by a customer's concern about a high bill, TMWA monitors spikes in individuals' water use to proactively assist customers in achieving a balance between water savings and maintaining a healthy landscape as well as detecting potential leaks.

*Quantification of Effectiveness***:** Preliminary analysis on the difference in means was performed on 1,239 RMWS customers who requested a water audit between 2003 and 2013. To be included in the comparison study, these customers had *at least* one full year of information on water consumption before a water usage review was conducted. Comparison of RMWS customers' monthly water consumption before and after an audit request was made indicated an average annual per-service water savings of 6.5 percent[7]. The greatest total savings (in terms of gallons per month) came at the peak of the irrigation season. During the months of June, July, and August, approximately 1,400 gallons per month (or 6.0 percent) were saved per customer service each month equating to a savings of 47 gallons 'per-service, per-day' during the peak of the irrigation season. At the time this report was written, analysis on effectiveness on commercial customers had not been performed.

[7] This difference in average usage is significant at the 99 percent level of convention.

Table 3. TMWA Customer Water Audits 2003 to 2014

Year	Residential	Commercial	Total	Cumulative Total
2014	1,351	162	1,513	19,754
2013	1,351	126	1,477	18,241
2012	1,522	141	1,663	16,764
2011	1,838	206	2,044	15,101
2010	2,949	381	3,330	13,057
2009	2,375	300	2,675	9,727
2008	2,196	265	2,461	7,052
2007	1,804	221	2,025	4,591
2006	661	70	731	2,566
2005	771	123	894	1,835
2004	431	66	497	941
2003	402	42	444	444

Public Workshops: Over the course of a year, TMWA provides regular workshops regarding landscaping and irrigation. Topics include: tree care, irrigation system start up, sprinkler maintenance, landscape and xeriscape design, and proper winterization. TMWA also co-sponsors seminars that address landscape design, operation and maintenance of irrigation systems, and related topics. During years when drought conditions are present, TMWA holds special workshops that help customers understand TMWA's water delivery system, how TMWA responds to drought conditions, and how customers can take action to help reduce water usage.

Quantification of Effectiveness: TMWA workshops are offered as an educational resource to promote conservation through efficient water use. Effectiveness is measured by both demand for the workshops and attendance. In 2014 and 2015, enrollment demand was such that additional sessions were offered most of which enjoyed capacity attendance. Unfortunately, it is not feasible to estimate the per-person, per-day water savings such programs would have but, like all of TMWA's customer-education efforts, the emphasis is placed on correcting wasteful behavior by increasing awareness of effective conservation practices.

School Educational Programs. TMWA representatives regularly engage students and teachers regarding northern Nevada's water resources through classroom participation and presentations.

Quantification of Effectiveness: Given the privacy concerns about connecting student participation in TMWA's educational programs to actual customer usage, it is not possible to determine the individual effect this form of education has on conservation. Regardless, early involvement in conservation is an important component in TMWA's conservation plan.

Online Resources. A key part of TMWA's educational messaging centers around understanding the region's water resources. TMWA's main website (www.tmwa.com) directs customers to information on local water supplies and how they are managed. Table 4 outlines the various online resources available to customers to help them use water efficiently and avoid water waste. In addition to its primary website, TMWA also deploys situation-specific "micro-sites". These temporary online resources contain enhanced messages that address specific concerns and goals during times of drought. Refer to this Plan's Drought Response Plan section for details on designating drought classifications. It is possible that some or all of these micro-sites will be incorporated into TMWA's primary website when it is updated.

Quantification of Effectiveness: Given the inability to directly track the conservation response of customers who access each website for information on efficient water usage, it is not possible to determine the impact such websites have on conservation. Regardless, these online resources are important components in TMWA's Conservation Plan and its positioning as a community leader in promoting responsible water use.

Table 4. TMWA's Online Conservation Resources

Program	Website	Description
Truckee River Flows and Storage	www.tmwastorage.com	Tracks water storage in the largest reservoir on the Truckee River system, Lake Tahoe.
Water Conservation Overview	http://tmwa.com/conservation	An overview of why conservation is important and directs customers to additional conservation links.
Water Conservation Checklist	http://tmwa.com/conservation/checklist	Tips to save indoor and outdoor water use
Winterization Tips	http://tmwa.com/conservation/winterize	A guide to winterizing residential homes
Finding and Repairing Leaks	http://tmwa.com/conservation/leaks	Provides information and links to online videos that help locate water leak.
Water Efficient Landscape Guide	http://www.tmwalandscapeguide.com	An interactive guide to help customers design and evaluate their landscaping choices.
Principles of Xeriscape	http://tmwa.com/conservation/xeriscape	Seven horticultural principles of xeriscape.
tmwa.com/save	www.tmwa.com/save	This micro-site was launched to provide customers with a simple list of things they can do to reduce their water use "at least 10%," (that summer's goal). The site will be updated as needed to support future conservation campaigns.

Conservation Materials: TMWA provides a multitude of written materials regarding ways customers can use water efficiently, reduce their usage, and avoid water waste. These conservation materials include:

- Direct Mail - In addition to providing detailed information on how water usage affects their monthly bill, TMWA uses its billing system to convey conservation messages and facts directly on customer's bills. These bill inserts serve as reminders about summer and winter habits that can conserve water.

- Landscape Design PDF resources – These downloadable PDF resources, found at TMWA's *Water Efficient Landscape Guide* website, provide detailed information on landscaping, irrigation, and plant and turf maintenance.

- Door hangers - Whenever a TMWA conservation consultant visits a home or business to remind customers of their watering times, a door hanger is left containing a variety of pertinent materials such as water times and restrictions, tips on tree and lawn care, etc.

- Water saving devices – Upon request by customers or whenever a TMWA conservation consultant visits a customer's premise, TMWA provides sprinkler timers, hose nozzles, low-flow shower heads, dye tabs, flow-rate bags, or faucet aerators to further assist customers in their water saving efforts.

- Enhanced Drought Information Materials – During times of drought, TMWA provides materials regarding detailed information and specific actions customers can take to help TMWA manage water demand. These enhanced materials include table tents for restaurants, stickers for public restrooms, and letters to homeowner's associations, etc. Refer to this Plan's Drought Response Plan section for details on designating drought classifications.

Quantification of Effectiveness: Given the inability to track the customers who receive different conservation materials, it is not possible to determine the individual effect the material have on conservation. Regardless, these printed resources are important components in TMWA's conservation plan.

Institutional Administration

TMWA has internal rules and regulations that apply to water supply services. Under state law, TMWA is not authorized to supply service to any customer who does not comply with all regulations. TMWA regulations can be found at http://tmwa.com/customer_services/waterrules/. Additionally, local governments and agreements within private developments have codes regarding landscaping design and water conservation practices. In general, municipal codes are designed to work in tandem with TMWA's rules and regulations.

Water Rates. In order to ensure customers use water responsibly and adequately recover costs, metered rates are employed. Municipal service rates are assessed using an inverted block structure with three to five tiers. This increasing rate structure allows for low costs associated with indoor water use and incentivizes customers to use outdoor water efficiently to avoid going into the more expensive tiers. Irrigation services pay a constant rate per 1,000 gallons, which varies according to a seasonal rate structure. During the peak summer months of June through September the rate is higher than during the off-peak months of October through May. This helps encourage conservation-related behaviors such as scheduling new plantings for cooler months when less intensive watering will be required. As part of the merger agreements with WDWR and STMGID, rate structures for their former customers have been maintained as of June, 2015. TMWA will continue to use a tiered volumetric billing rate structure for all non-irrigation services. Every few years, water rates and cost of service are reevaluated to account for customer base growth and system component requirements. For the most up-to-date water rates schedules, go to http://tmwa.com/customer_services/waterrates/.

Quantification of Effectiveness: Research conducted by the University of Nevada, Reno Department of Economics indicates that, on average, a 10 percent increase in price is associated with a 2 percent decrease in water usage by residential customers.

Assigned-Day Watering. Since 2010, TMWA has recommended a three-times-per-week, Assigned-Day Watering schedule, with a no-watering restriction on Monday to allow for treatment-operations recovery. The water days schedule and restrictions on times of the day under Assigned-Day Watering is summarized here:

Table 5. Assigned-Day Watering Schedule by Service Address

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
All “EVEN” addressed services	No	Yes	No	Yes	No	Yes	No
All “ODD” addressed services	No	No	Yes	No	Yes	No	Yes

Quantification of Effectiveness: TMWA began studying watering schedules beginning in 2004 through 2008 before converting from 2-day-a-week (required until such time that over 90 percent of the flat-rate single family residences were retrofit with a meter which occurred in 2009) to 3-day-a-week watering. Study results found that the three-day-a-week schedule results in less overwatering and waste than the prior 2-day-a-week watering schedule: during the 2-day-a-week schedule it was determined that over 55 percent of customers either were watering 3-days-a-week or were over-watering on their assigned days (see Appendix 3 for full report). However, because the system was not fully metered and the change in water schedule went into effect system-wide, no estimate of gallons ‘per-person, per-day’ could be made as the metered data did not exist at the time.

Watering Time Restrictions. Along with Assigned-Day Watering, TMWA discourages watering during the hottest, and typically the windiest, part of the day. Thus, there is a restriction on time-of-day watering between Memorial Day and Labor Day; there is no watering from 12:00 p.m. to 6:00 p.m. during this time of year. During drought years, these no-watering times are expanded by two hours: 11:00 a.m. to 7:00 p.m. Refer to this Plan’s Drought Response Plan section for details on designating drought classifications.

Quantification of Effectiveness: Water loss due to evaporation and wind has many associated factors (e.g., temperature, relative humidity, etc.) that vary daily, making estimating the effectiveness of the regulation problematic. At this time, no specific method of measuring effectiveness has been estimated for restricting water-times. However, watering-times are still considered an important regulation regarding water use efficiency.

Water Waste Penalties. In 2004, TMWA enhanced its rules by adding penalties for water waste violations and for watering on non-assigned days or times, which are billed directly to the customer. These rules provide for a warning followed by an increasing penalty of up to $75 per occurrence for repeat violations. However, TMWA has discretion on issuing citations and goes to great length to avoid penalties by instead using education to instruct customers on responsible water use. Many times customers are simply unaware that they are wasting water due to broken or misaligned sprinkler heads.

Quantification of Effectiveness: To date, TMWA has issued 297 penalties to commercial and residential water users. While the behavior is typically corrected, it is difficult to determine the amount of water saved through issuance of penalties.

Unauthorized Use of Water. Use of water without dedicated water rights or without TMWA's permission is not allowed under TMWA's rules. Examples of unauthorized use may include: two active service lines on a premise where one service is not being billed, an illegal tap off a water main, or an unauthorized hook-up to a fire hydrant. TMWA's rules and tariffs are designed to cover all costs to the utility in cases of illegal service taps, damage to TMWA facilities, and/or theft of water at $1,000 per occurrence. Use of fire hydrants as a water source is also illegal under municipal ordinances except for approved city vehicles. TMWA monitors its system to locate and correct unauthorized water use on an ongoing basis.

Quantification of Effectiveness: Since illegal water use is not separately metered it is difficult to estimate how much water is saved by identifying fraudulent water usage. Regardless of the impact, preventing and stopping illegal use is important to keeping customer rates low, preventing service disruption, and facilitating effective firefighting operations.

Landscaping Regulations. The Cities of Reno and Sparks, and Washoe County have landscape ordinances that regulate the types of landscaping developed land must have. In general, these municipal ordinances are designed to support TMWA's conservation efforts and allow enforcement of penalties to water wasters. TMWA conducted an initial review of the municipal ordinances, for Washoe County and the cities of Reno and Sparks related to water conservation and landscaping mandates, in 2005. In April of 2015, the codes for the three entities were revisited to 1) determine what changes have been made to these code provisions since TMWA last reviewed them, and 2) identify recommendations to the Reno City Council, Sparks City Council, and Washoe County Board of Commissioners regarding revisions to the current ordinances, as well as, the potential addition of new requirements. In a series of meetings with municipal planners, staff from the Washoe County District Health Department, and representatives from the building industry, TMWA identified fundamental changes in the landscaping/water conservation codes that occurred since 2005 and discussed recommendations to ensure new development planning in the region was more water-conscious. The major recommendations for new developments included: (1) expanding the minimum width of narrow turf strips to 8 feet with a 2 foot setback from any impervious surface; (2) setting a maximum total area requirement for allowable turf by zoning district; (3) setting a minimum requirement for drought-tolerant landscaping; and (4) requiring hydro-zoning (i.e., grouping plants with similar watering needs) irrigation plans be implemented whenever possible. A copy of the report can be found in Appendix 4.

Additional, legal agreements for private master developments can have regulations (e.g. Home Owners Associations' ("HOAs") rules and regulations) beyond what is required under municipal ordinances. During times of drought, TMWA asks HOAs to allow their residents the ability to comply with TMWA's requests for customers to reduce their water use without penalty. In 2005, a piece of legislation, NRS 166.330, was passed prohibiting HOAs from "unreasonable" restrictions of homeowners utilizing drought-tolerant landscaping on properties within their jurisdictions. However, in order for the homeowner to convert his or her landscaping from the approved vegetation type(s) to a drought-tolerant variety, the homeowner must first submit a detailed architectural plan of the new landscaping design. The HOA has the right to review the plan and can approve or deny the request; however, the HOA cannot deny a plan unreasonably, i.e., if, to the maximum extent possible, the altered design is compatible with the overall style of the community. While this statute clearly applies to all covenants, conditions and restrictions ("CC&Rs") that were established *after* the adoption of the law on October 1, 2005, it remains to be determined if such a law can apply to CC&R's prior to that date without impairing the existing contract.

Quantification of Effectiveness: Since municipal ordinances apply to all properties within a jurisdiction and these ordinances can vary both within and between jurisdictions, it is not possible to estimate the water savings that results from changes to municipal ordinances designed to further reduce water waste.

Drought Response Plan

Under normal circumstances when TMWA does not need to use its drought reserves, the aforementioned DMPs are adequate to promote efficient water use. However, if a Drought Situation is identified within the Truckee River Basin and drought reserves are required, TMWA's customers are expected to take additional actions to reduce their water use. Depending on the severity of the drought and the available quantity of TMWA's drought reserve water PSOW supplies (i.e., Independence Lake, Donner Lake, Stampede Reservoir), the aforementioned DMPs may be modified to achieve water reductions necessary to ensure TMWA's drought reserves are adequate to meet customer demand in the current and succeeding years. In these situations TMWA historically requests a 10 percent reduction in use and implements *enhanced* demand-side management programs ("*e*DMPs") to achieve this target reduction. The level and timing of which *e*DMPs are deployed can vary during the year, given the severity of the Drought Situation.

Pursuant to the operating criteria outlined in TROA, determination of a Drought Situation[8] takes place in April. That determination is dictated by the amount of water available for the Truckee River system based on available stored water in Lake Tahoe and Boca Reservoir, snowpack amounts, and run-off estimates for the current year; together these are early indications of when river flows will no longer support Floriston Rates. When the elevation of Lake Tahoe and subsequent Truckee River flows fall off significantly earlier than normal, this creates operational challenges for TMWA, forcing TMWA to use additional groundwater pumping and/or its POSW in order to meet the demands of its water customers during the irrigation season. For a full discussion of drought period operations, refer to Chapter 2 of the 2035 WRP.

TMWA uses a three-stage Drought Situation classification system (see Table 5). Per TROA, in a non-drought situation the elevation of Lake Tahoe is such that natural river flows will maintain Floriston Rates through Labor Day. Under this situation, no reserves are projected to be used, thus no *e*DMPs are necessary since demands typically are reduced after Labor Day. Similarly, when a Drought Situation is identified but Lake Tahoe and Boca Reservoir supplies remain adequate to maintain Floriston Rates until after Labor Day, no *e*DMPs need be deployed. While customer irrigation demands may remain high after Labor Day, even potentially requiring POSW to meet those demands, a certain amount of POSW must be released anyway to be in compliance with federal flood regulations. However, during a Drought Situation, if Lake Tahoe and Boca Reservoir supplies are not sufficient to maintain Floriston Rates in any month before Labor Day, then one of three levels of *e*DMP is identified and actions outlined to ensure customer demands are reduced in the current year and drought reserves are maintained in the event a successive Drought Situation occurs the following year.

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[8] Pursuant to TROA: "**Drought Situation** means a situation under which it is determined by April 15, based on procedures set forth in Section 3.D, either there will not be sufficient **Floriston Rate Water** to maintain **Floriston Rates** through October 31, or the projected amount of **Lake Tahoe Floriston Rate Water** in Lake Tahoe, and including **Lake Tahoe Floriston Rate Water** in other **Truckee River Reservoirs** as if it were in Lake Tahoe, on or before the following November 15 will be equivalent to an elevation less than 6,223.5 feet Lake Tahoe Datum."

Table 5. TMWA's Drought Situation Classification System

	NON-DROUGHT SITUATION	DROUGHT SITUATION	
	Upstream Reserve Supplies NOT Released	**Upstream Reserve Supplies Release AFTER Labor Day (Level 1)**	**Upstream Reserve Supplies Release BEFORE Labor Day (Level 2, 3, or 4)**
A. Watering Restrictions Between Memorial Day and Labor Day	12 to 6 P.M.	12 to 6 P.M.	11 to 7 P.M.
B. Public Education and Advertising	Standard programs	Standard programs	Increased programs
C. Water Waste Prevention	Standard enforcement	Standard enforcement	Increased enforcement
D. Other Actions			Additional *enhanced* DMP are deployed depending on the severity of the drought and time of impact to water supplies. These include but are not limited to; 1) Drought Rates during irrigation season 2) Reduced number of watering days 3) Daily water allotments set 4) See Appendix 5 of this Plan for other options

Figure 3 provides a generalized flowchart of this cyclical drought monitoring process. Pursuant to TROA, the process includes determination of whether or not a Drought Situation exists, its level of severity, and the potential impact on TMWA's drought reserves. From this determination a timeline for TMWA's Drought Response Plan can be developed.

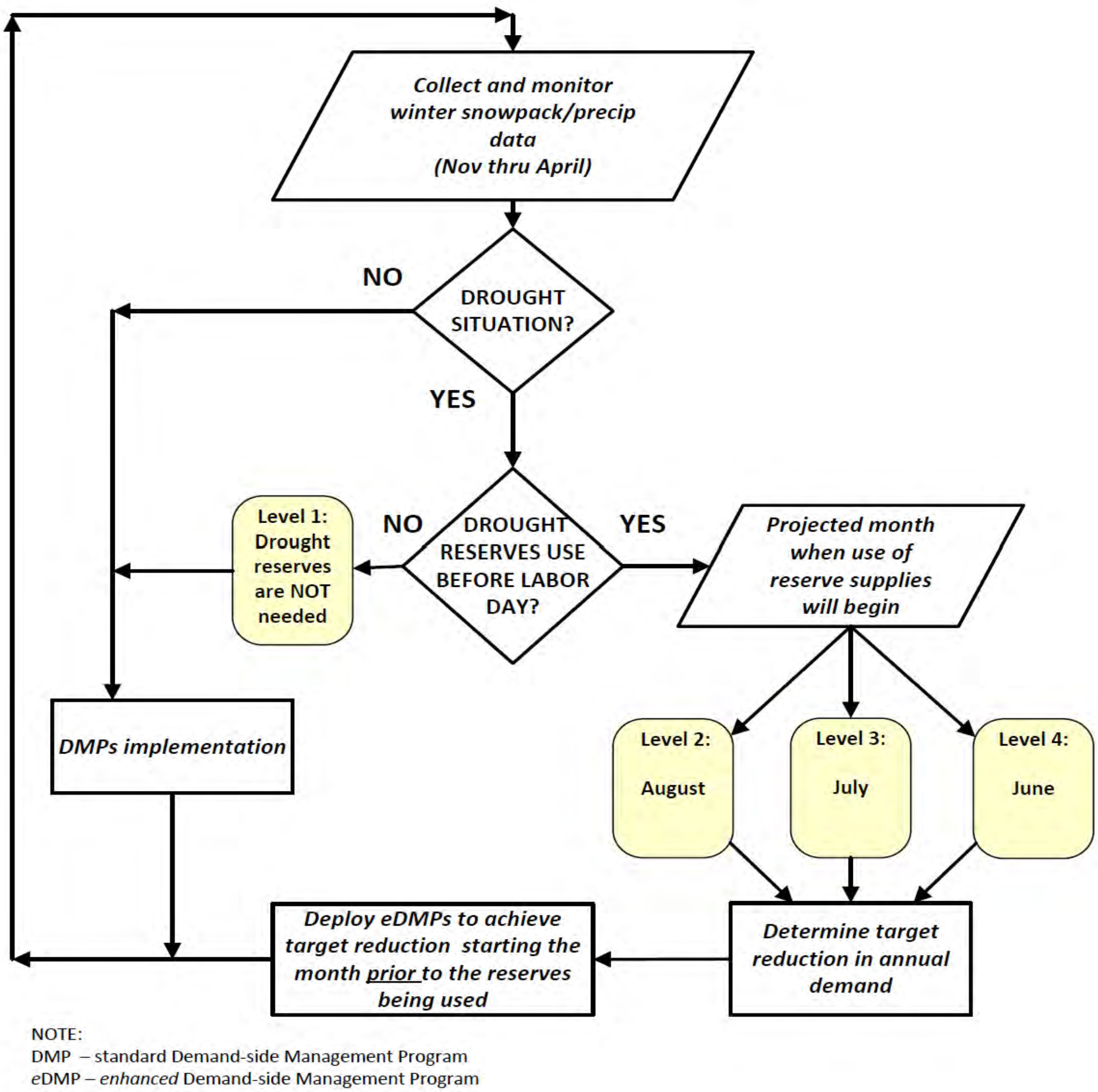


Figure 3. Drought Situation and Demand-side Management Response Flowchart

Each level of drought severity depends upon when Floriston Rates are anticipated to be lost. Once the level is known, TMWA will employ its enhanced messaging campaign ("EMC"), which provides the public with additional information on current water supply conditions and the target reduction TMWA will be expecting from its customers in the coming months. TMWA's Drought Situation classification system is presented in Table 6 along with recommended timing of TMWA's EMC and *e*DMPs, given the level of the Drought Situation.

Table 6. TMWA's Enhanced Demand Management Programs by Drought Situation

		Month					
		May	Jun	Jul	Aug	Sept	Oct
Non-Drought Situation		DMP	DMP	DMP	DMP	DMP	DMP
Drought Situation Upstream reserve supplies **not** needed before Labor Day	Level 1	DMP	DMP	DMP	DMP	DMP	DMP
Upstream reserve supplies needed *before* Labor Day	Level 2	DMP	DMP	EMC	*e*DMP	*e*DMP	DMP
	Level 3	DMP	EMC	*e*DMP	*e*DMP	*e*DMP	DMP
	Level 4	EMC	*e*DMP	*e*DMP	*e*DMP	*e*DMP	DMP

DMP - standard demand-side management program
*e*DMP - *enhanced* demand-side management program
EMC - enhanced message campaign begins at least a month prior to *e*DMP deployment

Quantification of The Drought Response Plan TMWA initiated in 2014 is a good example of the Plan's effectiveness. In April of 2014 a *Drought Situation: Level 2* was identified. Factors for this classification included a seasonal snowmelt which would result in Lake Tahoe falling below its rim in the Fall and Floriston Rates were expected to drop-off by late-July. This meant, in addition to groundwater pumping, release of POSW would be required in the late summer months. Starting in July, TMWA began its EMC by asking its customers to reduce their water use by 10 percent compared to their use in 2013 in the coming months. Overall, TMWA's customers responded well to the request for a voluntary reduction of 10 percent. Table 7 shows the reduction in use by TMWA's customer classes.

Table 7. Month Retail Water Sale for August and September 2013 and 2014

		Sept 2013 Use (x1000 gal)		2014 Use (x1000 gal)		Percent Change	
Customer Class	**Services**	**Median**	**Mean**	**Median**	**Mean**	**Median**	**Mean**
Single Family Metered	88,256	38	43.90	32	37.80	-11.80	-9.50
Single Family Flat Rate	3,866	84	101.50	70	84.50	-14.70	-12.30
Commercial	4,405	49	213.20	42	189.30	-5.70	-4.60
Metered Irrigation	2,328	218	417.90	192	373.80	-6.70	-4.90

Note: this study looks only at water services with 2013 and 2014 usage history.

In April of 2015, due to the worst snowpack on record it was determined that the drought period would extend into the next irrigation season. In response to these hydrologic conditions, TMWA elevated the Drought Situation to *Level 4*. In May of 2015—two months earlier than 2014—TMWA began its EMC and customers were asked to reduce their use by at least 10 percent in the coming months, again compared to 2013's usage. In the subsequent months the following *e*DMPs were deployed:

- television advertising,
- increased radio advertising,
- dedication of a conservation website (tmwa.com/save),
- increased Conservation Consultant staffing,
- conservation-car wraps (10 vehicles),
- internet advertising,
- table tents at restaurants stating water was served upon request,
- stickers in commercial restrooms reminding people to save 10 percent,
- increased educational programs, and;
- letters to HOAs requesting they not fine residents who let their lawns turn brown.

There was also a significant increase in media engagement with TMWA staff being interviewed almost daily. Table 8 compares the monthly retail water sales for June through September between 2013 and 2015. In addition, to TMWA normal customer classes, the table also shows the reduction by the newly acquired DWR and STMGID customer classes. In both years, customers went above and beyond with the average reduction being greater than the 10 percent requested.

Table 8. Monthly Retail Water Sale for June through September 2013 and 2015

		2013 Use (x1000 gal)		2015 Use (x1000 gal)		Percent Change	
Customer Class	**Services**	**Median**	**Mean**	**Median**	**Mean**	**Median**	**Mean**
Single Family Metered - TMWA	68,193	78	88.90	61	69.80	-19.70	-16.40
Single Family Metered - DWR	16,999	98	111.80	78	89.20	-19.10	-16.00
Single Family Metered - STMGID	3,164	146	160.40	112	125.10	-20.30	-18.50
Single Family Flat Rate - TMWA	3,473	185	219.60	137	165.40	-23.10	-21.60
Single Family Flat Rate - DWR	103	140	139.40	107	101.10	-24.60	-27.00
Single Family Flat Rate - STMGID	78	154	153.40	103	109.70	-29.10	-27.30
Commercial	4,945	92	423.20	71	368.20	-10.00	-8.70
Metered Irrigation	2,398	437	853.50	350	681.50	-18.00	-15.10

Note: this study looks only at water services with 2013 & 2015 data.

These past drought years exemplify the robustness of TMWA's Drought Response Plan and provide a good case study of how the eDMPs are flexible and can adequately control water demand given any level of drought severity. Should a drought occur, whose magnitude exceeds the worst drought on record, TMWA is engaged in a two-year, USBR-sponsored project to address climate change. TMWA will collaborate with UNR and DRI, to determine hydrologic conditions under "worst case" climate changes scenarios. The results will provide insight into the effectiveness of TMWA's current Drought Response Plan, given potential climate changes scenarios. It will also propose the level of need for an updated management framework should the existing Plan fail. The project's deliverable will be generalizable Decision Support System that can optimize water resource management given any water utility's situation. The final results of this two-year study will be available in July of 2017. Refer to Chapter 2 of the 2035 WRP for more details about this project.

Demand Management Programs and Emergency Supply Conditions

Natural disasters and other unforeseen events can interrupt TMWA's available water supplies. These include floods, extreme low precipitation years, earthquakes, equipment failure, or distribution system leaks. Sometimes the events are localized within the distribution system and sometimes the whole community can be affected in which cases the government can declare a state of emergency. Under such cases, TMWA's goal is to minimize service disruptions and, when necessary, the community is asked for, and has responded favorably to, increased and more aggressive conservation messages and calls for water use reductions and restrictions. Some of the *e*DMPs to be used during a state of emergency include mandatory water conservation (i.e., once-per-week or no outside watering during summer months, reduced laundry at commercial properties, use of paper plates in restaurants, no use of potable water for non-potable purposes, heavy fines for water wasters, temporary "drought" rates, etc.). For more information on potential DMPs please see Appendix 5.

TMWA's personnel train for management operations under various emergency situations. This training has proven successful as water supply interruptions have been mitigated as swiftly and efficiently as possible such as the April 2008 earthquake in Mogul which destroyed the Highland Flume thereby precluding gravity-fed delivery of water to the Chalk Bluff Water Treatment Plant. TMWA mitigated the incident by 1) turning on its Orr Ditch Pump Station and installed temporary pumps to feed Chalk Bluff, 2) turning on its Glendale Water Treatment Plant, 3) turning on its wells as needed for irrigation demands, and 4) installing temporary piping around the Highland Flume failure to deliver more water to Chalk Bluff. These actions avoided any water supply interruptions for TMWA customers. Increased conservation by TMWA customers during emergencies is just one element of successfully managing water supply interruptions. Chapter 2 of the 2035 WRP describes the types of response tactics TMWA deploys during emergency situations.

Summary

TMWA's Conservation Plan includes a comprehensive list of SMPs and DMPs. As water supplies fluctuate year to year—due to fluctuations in the seasonal snowpack—these programs ensure TMWA and its customers are able to conserve to the degree which is warranted. TMWA's current Conservation Plan meets or exceeds the state regulations (i.e., JPA, NRS, TROA) and recommendations for best practices (i.e., The Nevada Drought Forum: Recommendations Report). The success of any one program is evaluated depending on its scope and TMWA's ability to collect data on the participants and amount of water saved. Such metrics may include: the number of gallons saved (in total gallons or as a percent), the level of customer participation, estimated reduction of peak day usage, visibly improved water management practices, or the number of customers receiving water conservation education. Moving forward, TMWA will continue to assess the benefits from each SMP and DMP and may modify any to reflect new practices, technologies, or information regarding regional climate change.

The following highlights of this Plan include:

- TMWA's Conservation Plan meets the requirements of the JPA, NRS 540.313 through 540.151, and TROA.
- TMWA's conservation plan is consistent with the water conservation recommendations detailed in the *2015 Nevada Drought Forum: Recommendations Report*.
- TMWA will continue to be fully engaged in the regional dialogue on responsible water use and will implement programs for its customers that benefit the region and support regional water use goals.
- TMWA's water demand management programs pursue measures to efficiently use its available water resources by addressing water waste, system deficiencies (e.g., leaks, pressure changes, etc.), public education and outreach, watering schedules, and drought/emergency conditions.
- Demand management programs may be progressively enhanced during Drought Situations to address the need to reduce water use when water reserve supplies are impacted.
- Enhanced DMPs may be necessary in response to natural disasters and other events that have potential to interrupt TMWA's available water supplies.
- TMWA will continue to be engaged in the regional dialogue on responsible water use and will implement programs for its customers that benefit the region and support regional water use goals.
- TMWA will continually assess the benefits of implemented programs and may modify programs to reflect new practices, technologies, and regional climate information.
- New and innovative ways to improve efficient water use will continue to be assessed, including expanded uses of non-potable supplies.

TRUCKEE MEADOWS WATER AUTHORITY

APPENDIX 1

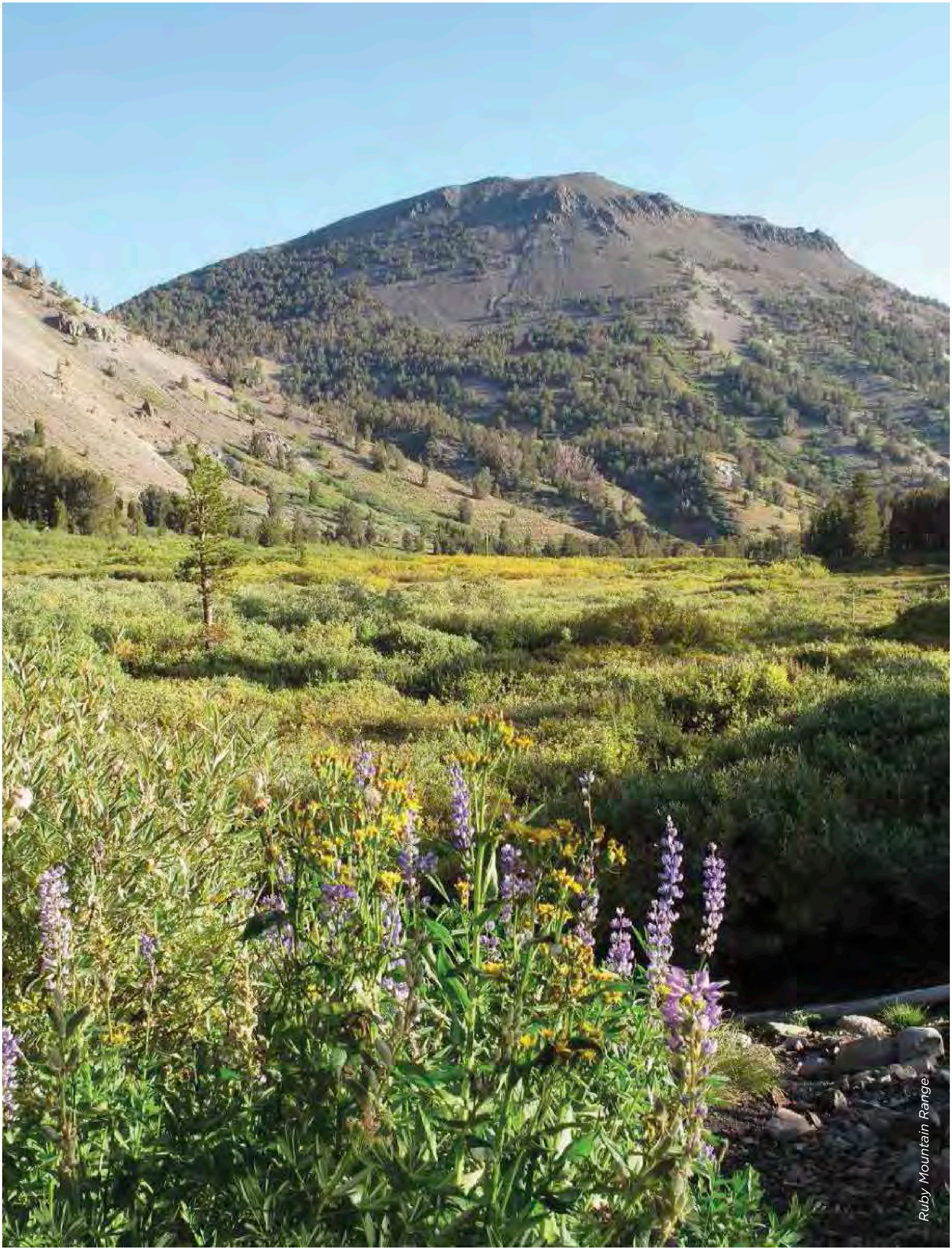
NEVADA DROUHT FORUM:

RECOMMENDATIONS REPORT

NEVADA DROUGHT FORUM

Nevada Drought Forum: *Recommendations Report*

Presented to ***Governor Brian Sandoval*** *• December 2015*



Ruby Mountain Range

Nevada Drought Forum Members

Leo Drozdoff, P.E. (Chairman)
Director, Nevada Department of Conservation and Natural Resources

John Entsminger (Vice Chairman)
General Manager, Southern Nevada Water Authority

Jim Barbee
Director, Nevada Department of Agriculture

Jason King, P.E.
State Engineer, Nevada Division of Water Resources

Dr. Douglas Boyle
Nevada State Climatologist, University of Nevada, Reno

Dr. Mark Walker
Dean, University of Nevada Cooperative Extension

Dr. Justin Huntington
Associate Research Professor, Desert Research Institute

Caleb Cage
Chief, Nevada Division of Emergency Management

The Nevada Drought Forum would like to express its sincere gratitude to the many stakeholders who helped the Forum to better understand the issues, challenges and opportunities related to drought response in Nevada.

Brian Sandoval, Governor


Wheeler Peak

Executive Summary

The Nevada Drought Forum (Forum) was formed by Governor Brian Sandoval in April 2015 through Executive Order 2015-03 to address water resource challenges related to severe and sustained drought conditions that have affected much of the state. The Forum was directed to facilitate a statewide dialogue among interested stakeholders and identify best practices for drought policy, preparedness and management.

As part of its responsibilities, the Forum prepared a Summary of Current and Future Actions, received a monthly Statewide Situation Report, participated in the 2015 Governor's Drought Summit, reviewed and considered the Western Governor's Association (WGA) Drought Forum Final Report, and met with stakeholders throughout the state to better understand issues and challenges, as well as to identify opportunities to enhance Nevada's drought response efforts.

The Forum met six times from June through November 2015. Meetings were broadcast to multiple locations throughout the state to provide transparency and encourage public involvement. As part of its meeting process, the Forum invited representatives from various stakeholder groups to share information on drought impacts, mitigation efforts and current or anticipated obstacles to doing business during drought. Additionally, Forum members participated individually in the Governor's Drought Summit, which further explored stakeholder drought response efforts, water conservation efforts, conservation barriers, and opportunities to improve conditions and/or Nevada drought resiliency moving forward. These efforts are detailed more fully herein, with supporting information available in the appendices and online at **drought.nv.gov**.

Together, these discussions provided a strong foundation for deliberations by the Forum. As the Forum worked to develop recommendations, members agreed that meaningful investments in time, coordination and funding in the following key areas could improve Nevada's overall drought response and long-term resilience:

- Water Conservation
- Nevada Water Law
- Monitoring and Research Data
- Financial and Technical Assistance
- Supply Augmentation and Long-Range Planning
- Information Sharing and Outreach
- Drought Declarations/Emergency Actions

As described within the balance of this report, the Forum recommended specific actions that allow for consideration of next steps. The Forum believes that the Governor's leadership in addressing water conservation and drought for the long-term benefit of the state and its residents, together with further consideration and possible implementation of some or all of these recommendations, will provide a substantial and meaningful step toward managing statewide drought impacts and maintaining sustainable water supplies.


Denio
McDermitt
Black Rock Desert
Santa Rosa Range
Humboldt
R
Independence Mts
Wells
Winnemucca
Elko
Battle Mountain
80
Ruby Mts
Pyramid Lake
Trinity Range
Lovelock
G R E A T
Stillwater Range
Carson Sink
80
Shoshone Mts
Reno
Sparks
Fallon
Austin
Eureka
Virginia City
Toiyabe Range
Ruth
Ely
Egan Range
Schell Creek Range
Snake Ra
Lake Tahoe
Carson City
Yerington
Monitor Range
Hot Creek Range
Wheeler Pk
13063
Gardnerville
Walker Lake
Mt Grant
11239
Round Mountain
Hawthorne
Grant Range
B A S I N
Tonopah
Boundary Pk
13140
Pioche
Panaca
Caliente
Pahute Mesa
Beatty
Sheep Range
Mesquite
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Indian Springs
Charleston Pk
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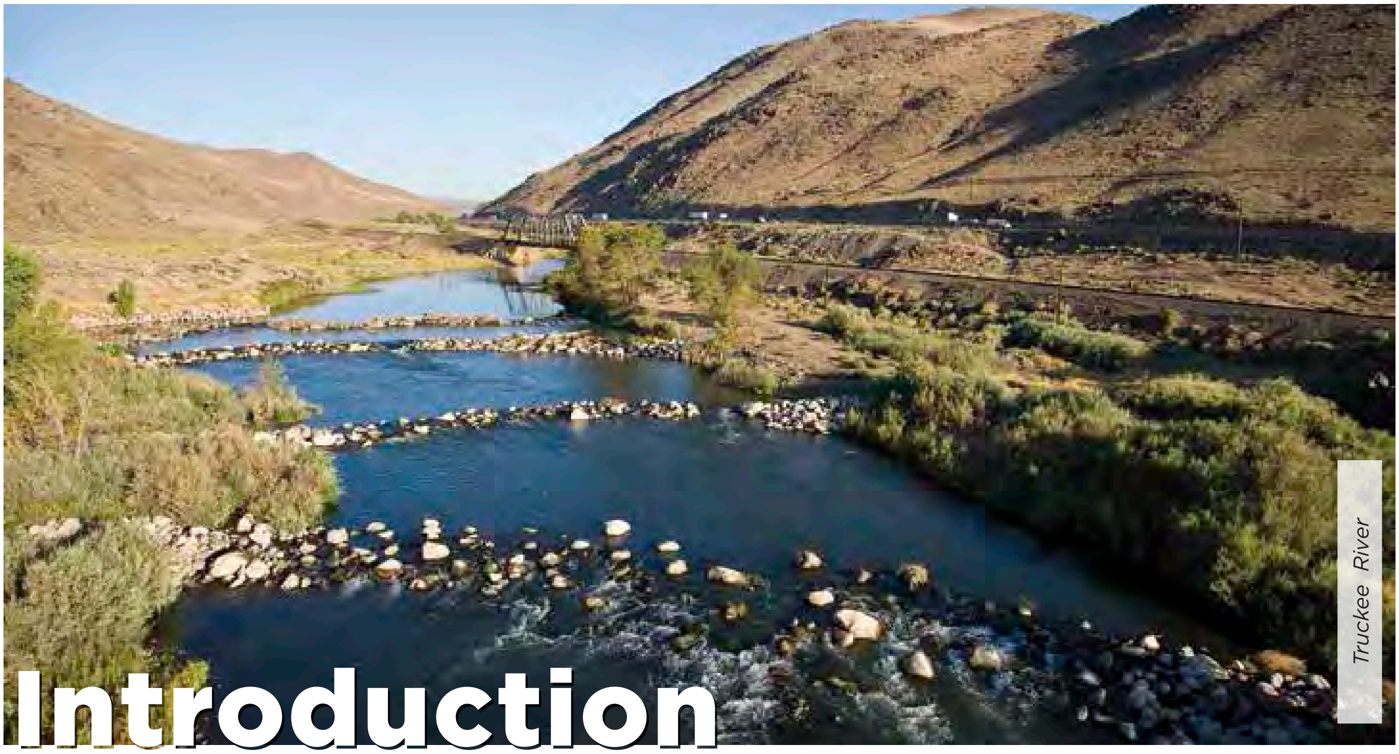
Lake Mead
North Las Vegas
Las Vegas
Henderson
Boulder City
River
Colorado
Lake Mohave
Laughlin



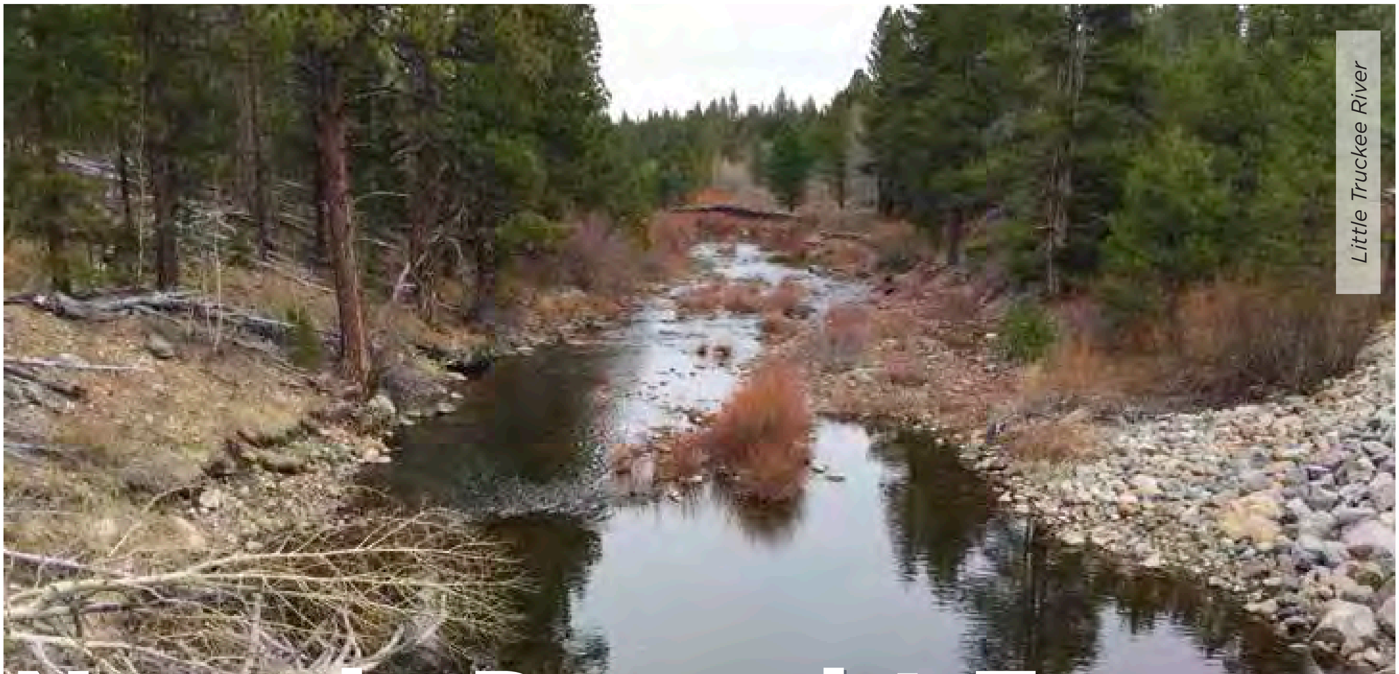
Truckee River

Introduction

Nevada is known for its rich and diverse landscape; it is also known for its harsh climate and hydrological extremes. The state is characterized as semi-arid to arid, with precipitation varying widely across its more than 500-mile stretch from northern to southern boundary. Temperatures can reach -40° F in some parts of the state and exceed 120° F in others. With nine inches of average precipitation annually, Nevada is the driest state in the nation.

Droughts and floods are common in the state—a place where water users have long coped with the dramatic changes that can occur from year to year. Despite its hardiness in responding to difficult water resource challenges, current conditions have tested Nevada's drought resiliency and are requiring unprecedented levels of action.

Four years of extremely dry conditions and below average snowpack in northern Nevada's mountain ranges have resulted in significant impacts to the Humboldt, Carson, Walker and Truckee river systems, as well as associated surface and groundwater water supplies. In the southern portion of the state, a 15-year drought in the Colorado River Basin has caused Lake Mead to drop by more than 130 feet. The reservoir is at its lowest point since it began filling during the 1930s, and further water level decline is expected. Central portions of the state have also experienced drier conditions. This has resulted in reduced recharge to groundwater basins, as well as inflow reductions to springs, seeps and streams that support healthy rangeland conditions and provide habitat for Nevada wildlife.



Nevada Drought Forum

To address the state's evolving water supply and demand challenges brought upon by severe drought, Governor Brian Sandoval established the Nevada Drought Forum (Forum) in April 2015 by Executive Order 2015-03 (Appendix A). The Forum was created to facilitate a statewide dialogue among interested stakeholders and to help identify best practices for drought policy, preparedness and management.

As part of its responsibilities, the Forum prepared a Summary of Current and Future Actions, which describes the current and planned activities of local, state and federal entities (Appendix B). The Forum also received a monthly Statewide Situation Report (Appendix C); participated in the September 2015 Governor's Drought Summit (Appendix D); reviewed and considered the Western Governors' Association (WGA) Drought Forum Final Report (Appendix E); invited stakeholders throughout the state to participate in Forum meetings (Appendix F) and received communications through the Drought Forum website (Appendix G).

These efforts helped establish a better understanding of how drought-related issues are affecting water users, industry and the environment, and informed the development of recommendations as presented in the latter portion of this document. The following provides a brief overview of the Drought Forum and key efforts since its formation.

DROUGHT FORUM REPRESENTATION

As established in the Governor's Executive Order, the Nevada Drought Forum is comprised of the following members:

- The Director of the Nevada Department of Conservation and Natural Resources
- The Director of the Nevada Department of Agriculture
- The State Engineer of the Nevada Division of Water Resources
- The Chief of the Nevada Division of Emergency Management
- The Nevada State Climatologist
- The Dean of the University of Nevada Cooperative Extension
- A representative of the Desert Research Institute
- A representative of the Southern Nevada Water Authority

SUMMARY OF CURRENT AND PLANNED ACTIONS:

In May 2015, the Forum issued a questionnaire to local, state and federal stakeholders. Respondents were asked to provide information on: water supply sources (groundwater, surface water, other); area of service (size, number of customers served, location); drought impacts on operations, resource availability and/or planning activities; actions taken, underway or planned; and, topics/issues for possible future discussion by the Forum.

The questionnaire was issued to more than 235 water users throughout Nevada, including municipal, state and federal agencies as well as private and other water users. Respondent information was summarized and posted to the Nevada Drought Forum website, **drought.nv.gov**, in August 2015.

The following describes reported impacts as well as current and planned drought response measures by user type.

Local Agencies:

Local agencies reported drought impacts that range in nature from no impact to significant impact. Several respondents noted higher customer water use due to drought conditions, as well as declining ground and/or surface water levels. For some, declining water levels do not have an immediate impact, but have the potential for impact if conditions persist. Others indicated that declining water levels have significantly affected water supply availability, facilities and operations.

Drought response measures vary by agency to include one or more of the following: water conservation plans, education/outreach, landscape development codes, irrigation audits, water budgets, watering restrictions, water waste prohibitions/enforcement, leak detection/repair, metered use/rates, incentive/rebate programs, industry partnerships, facility modifications/new facilities, new supply acquisition/development and other actions.

Other Water Purveyors:

Other water purveyors, including irrigation districts and private water companies, reported financial impacts due to decreased water use and declining groundwater levels.

Current and planned drought response measures varied to include one or more of the following: water conservation plans, outreach, landscape development codes, watering restrictions, water waste restrictions, cooling system restrictions, leak detection/repair, rebate programs, facility modifications and vegetative management.

State Agencies:

State agencies reported impacts that include water supply disruptions and facility failures due to reduced precipitation and/or inflow to surface and groundwater systems; impacts/potential future impacts on wildlife and environmental resources, recreation (boating), game (hunting and fishing) and park visitation; increased potential for wildfire; and drought-related impacts to finances/operations.

Current and planned drought response measures vary by agency to include one or more of the following: new/improved storage, stabilization of water levels, securing new resources/facilities, outreach, increased irrigation/watering restrictions, plumbing/infrastructure improvements, monitoring and mitigation, and drought-related assistance.

Governor Sandoval announces formation of Drought Forum and discusses Nevada's changing landscape in the face of persistent drought conditions.

Federal Agencies:

Federal agencies reported drought impacts to wildlife, recreation, cultural resources, success and magnitude of restoration efforts, minerals, rangeland/livestock forage (including impacts to grazing allotments), loss of agricultural production, livestock herd reductions and tree health. Potential impacts reported include health and resiliency of timber stands due to insects/disease, as well as fire hazards.

Current and planned response measures vary by agency to include one or more of the following: education/outreach, monitoring/mitigation, financial assistance, conservation compliance and other efforts.

The Summary of Current and Planned Actions is provided in Appendix B. Individual response forms submitted by agency/respondent are available at **drought.nv.gov**.

STATEWIDE SITUATION REPORT:

Between March and June 2015, the Nevada State Emergency Operations Center issued a monthly Statewide Drought Emergency Situation Report (Appendix C). Each report included a copy of the month's current U.S. Drought Monitor, which contained a listing of severity designations by county; information on emergency disaster programs; water level data; wildfire information; and other drought-related information and resources.

DROUGHT FORUM MEETINGS:

The Nevada Drought Forum held a total of six meetings between June and November 2015. Meetings were open to public and noticed in accordance with Open Meeting Law. Meetings were also broadcast to multiple locations throughout the state to provide transparency and encourage public involvement in the Forum's discussion and deliberations.

As part of its July 17, 2015 meeting, the Forum invited sector representatives from gaming, hospitality, mining, development, energy, commercial, industrial, tourism, recreation and general business to share information on drought impacts to operations, drought mitigation efforts, and current or anticipated obstacles to doing business because of drought conditions. The Forum continued this discussion at its August 19, 2015 meeting as it considered information from agricultural producers, tribal nations, non-governmental organizations, and public and private water providers/water authorities.

Meeting agendas and minutes, including a summary from presenters at the July and August Forum meetings, are included in Appendix F. Letters, comments and other meeting materials are available by meeting date at **drought.nv.gov**.

GOVERNORS DROUGHT SUMMIT:

Forum members attended and individually participated in the Governor's Drought Summit, September 21 – 23, 2015, at the Nevada State Legislative Building in Carson City. The Summit was opened by Governor Sandoval and included facilitated discussions involving more than 50 presenters, many of whom are national and state experts. The Summit also featured an evening at the Governor's Mansion that further advanced the valuable cross-sector discussions and idea sharing that occurred throughout the three days of meetings.

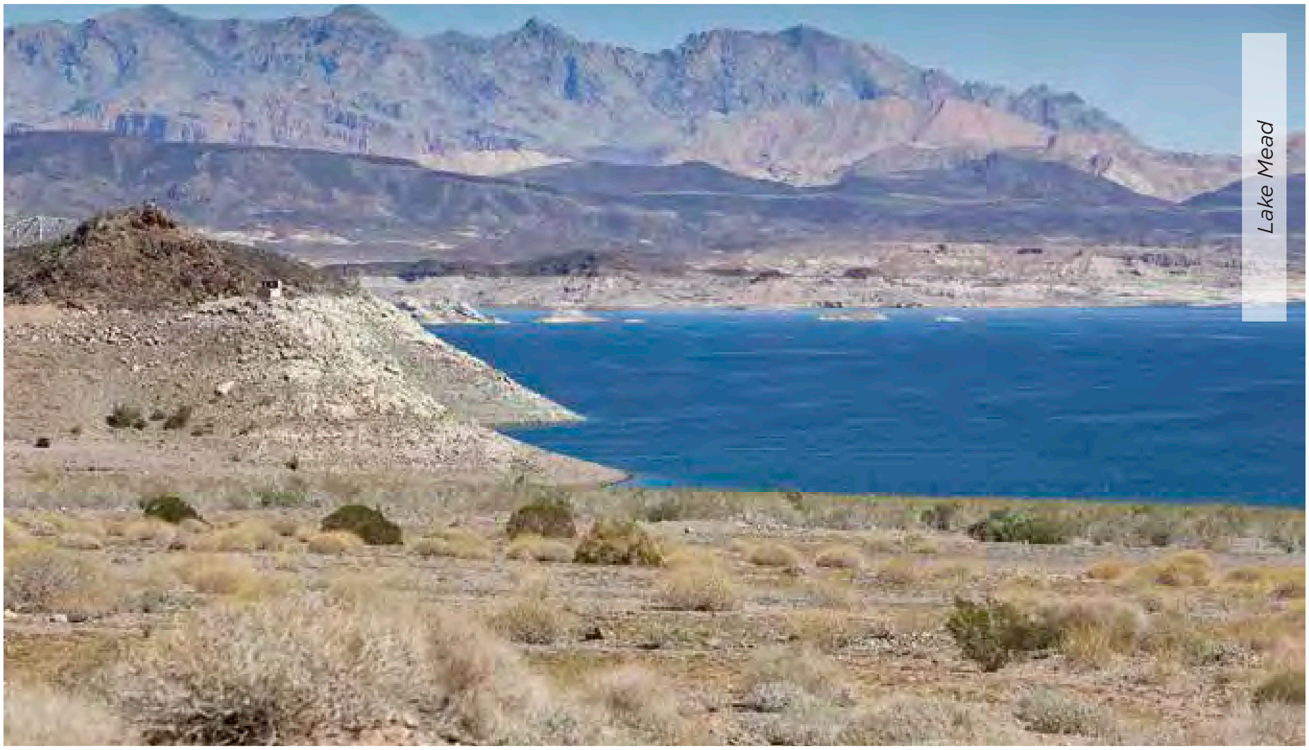
The Summit's panel discussions included such topics as defining and predicting drought; water history, law and past/current users; Nevada challenges; conservation success stories, which included participation by the media; water conservation communications/messaging; and a case study on regional water partnerships and solutions.

Participants were asked to share information on drought impacts, water conservation efforts, conservation barriers, and opportunities to improve conditions and/or Nevada drought resiliency moving forward. Members of the public were encouraged to submit questions and comments. Video recordings of the Summit are available at **drought.nv.gov**. The Summit program, together with comment cards submitted by attendees, is provided in Appendix D.

WESTERN GOVERNORS' ASSOCIATION DROUGHT FORUM FINAL REPORT:

Forum members received and reviewed the Western Governors' Association (WGA) Drought Forum final report released in June 2015, an initiative of 2015 WGA Chairman, Governor Sandoval. The WGA Drought Forum was created under Governor Sandoval's leadership to provide a framework for states, industries and communities to share best practices and policy options for drought response. Key themes identified for future exploration of the WGA Drought Forum include data and analysis; produced, reuse and brackish water; forest health and soil stewardship; water conservation and efficiency; infrastructure and investment; working within institutional frameworks to manage drought; and communication and collaboration.

The Forum discussed the report during its deliberations and agreed that most of the topics identified in the report generally correspond with many of the Forum's recommendations, as well as Nevada's challenges and opportunities. The WGA Report is provided in Appendix E.



Lake Mead

Drought Forum Recommendations

The Forum listened to and considered numerous perspectives as part of its meeting process. Strong and sometimes conflicting views were presented on how to address the state's water resource challenges. Within this continuum, the Forum agreed there existed both opportunity and common ground—places where investments in time, coordination and funding could vastly improve Nevada's overall drought response and resilience.

The recommendations provided herein detail actions that the Forum believes can be taken now to bring about necessary and meaningful change. Governor Sandoval's leadership in addressing drought for the benefit of the state and its residents, along with further consideration and implementation of the Forum's recommendations, provide substantial and significant steps to help secure Nevada's water future.

1 WATER CONSERVATION

Water conservation is an important tool to help water users manage demands and extend the use of available resources. In many cases, conservation can help to ease the impact of water supply shortages during drought and reduce needs for additional water supplies.

In 1991, the state enacted laws requiring municipal, industrial and domestic water suppliers to adopt water conservation plans based on the climate and living conditions of their service area. For public water systems, NRS 540.121 through 540.151 was added to specify content requirements of the plans and the process and timeframes to be followed. NRS 704.662 through 704.6624 was also added to establish conservation plan requirements for those utilities regulated by the Public Utilities Commission of Nevada.

The Forum reviewed existing statutes and agreed that additional provisions could be enacted to increase water efficiency, while still recognizing regional differences in climate and other factors. The Forum recommended changes to water conservation plan requirements that include new provisions for watering restrictions, metering, conservation water rate structures and water efficiency standards for new development. The Forum agreed that technical support should be provided to help water suppliers develop meaningful and actionable plans (see also "Financial and Technical Assistance"), and compliance with submission requirements should be enforced.

The Forum also discussed the need for additional water conservation actions among agricultural water users by encouraging agricultural producers to continue to pursue water saving technology and/or best management practices. The Forum also agreed that metering all water uses in the state would be an appropriate next step. This action could significantly enhance overall water use efficiency among all water users and allow for better accounting of the state's limited water resources.

Nevada's appropriative rights system was another key conversation topic among the Forum and agricultural producers. Many producers discussed perceived risks associated with conservation, including potential loss of unused water saved as part of conservation efforts. Nevada water law is based on a "use it or lose it" doctrine (see also, "Nevada Water Law"), which requires users to demonstrate a beneficial use of water and restricts users from speculating in water rights or holding on to water rights that they do not intend to place for beneficial use in a timely manner. The Forum agreed that these provisions should be reviewed to promote conservation efforts among agricultural users and help resolve potential conflicts.

The Forum also discussed and recommended implementation of a policy directive addressing water efficiency within the power industry, and recommended strategies to improve conservation efforts within homeowner associations.

RECOMMENDATIONS

- Amend the current statute that requires all water purveyors to submit a water conservation plan to the Division of Water Resources. Amendments would add the following additional areas that purveyors must require as part of their plan, unless the requirement is deemed unnecessary by the State Engineer:
    - Meters on all connections
    - Water efficiency standards for new development
    - Tiered rate structures to promote water conservation
    - Time-of-day and day-of-week watering restrictions
- Ensure compliance with water conservation plan submittal requirements by amending the water conservation plans statute to provide enforcement capability for the State Engineer after attempts to achieve submittal compliance, including technical assistance, are unsuccessful.
- Clarify and strengthen the law to allow the State Engineer to require the installation of water meters for all water uses in the state, including domestic wells, unless such installation is deemed unnecessary by the State Engineer.

- Review potential changes and clarifications to the "use it or lose it" provisions in Nevada water law to increase opportunities and incentives for water conservation during drought and non-drought conditions.
- Encourage development and use of water saving technology and/or best management practices by agricultural and livestock producers (including, but not limited to, crop covering, drip irrigation, variable rate irrigation, center pivot irrigation, laser leveling and crop selection).
- Issue a state policy directive that requires all newly developed thermoelectric power plant projects, or all additions to existing thermoelectric facilities, to utilize dry cooling or other similar water efficient technology.
- Request local political subdivisions to explore implementation of water conservation measures where Home Owner Association Covenants, Conditions and Restrictions (CC&Rs) are to the contrary.

2 NEVADA WATER LAW

Nevada's first water law was passed in 1866 and has been amended many times since. The Office of the State Engineer was created in 1903 to protect existing water rights and to improve methods for utilizing the state's limited water resources. The State Engineer is responsible for administering and enforcing Nevada water law, which includes the appropriation of surface and groundwater in the state, and the adjudication of pre-statutory vested rights, dam safety and other duties.

Nevada water law is considered one of the most comprehensive water laws in the western United States. It is based on two basic principles: prior appropriation and beneficial use. Prior appropriation—also known as "first in time, first in right"—allows for the orderly use of the state's water resources by granting priority to senior water rights in times of shortage. This concept helps to ensure senior water users are protected, even as new uses for water are allocated.

The Forum's meetings and the Drought Summit generated significant discussion regarding Nevada water law, particularly in regard to the management of over appropriated basins; pumping impacts to senior groundwater right holders by junior pumpers; the relationship between groundwater pumping and surface water flows; adaptive management through monitoring, management and mitigation ("3M Plans"); and the nexus between Nevada's "use it or lose it" doctrine and water conservation needs (see also "Water Conservation"). Other conversations centered on place of use; management of supplemental water rights; terms of use for temporary rights; and the need for greater flexibility to manage resources during times of drought to help minimize impacts.

Forum members and participants generally agreed that current drought conditions have intensified the conversation, particularly in light of declining stream and groundwater levels, as well as dwindling storage reserves. These issues have the potential to create and/or exacerbate conflict, particularly in over-appropriated basins. The time it takes to resolve conflicts through the courts is also a concern, especially since many fundamental water management principles are not clearly defined in statutes. The Drought Forum agreed that these issues need to be addressed, with an incremental approach to guard against unintended consequences.

To help ease drought-related impacts, the Forum recommended changes to Nevada water law that clarify and strengthen the State Engineer's authority related to water management tools such as 3M Plans, Critical Management Areas and Groundwater Management Plans. Members also agreed that in times of curtailment (when water supplies are reduced or restricted), access to water for indoor use by domestic well users should be preserved.

The Forum also discussed the topic of rainwater collection and use for domestic or wildlife needs. NRS 533.030 does not specifically address the permissibility of rainwater capture and use, but does limit the diversion and use of water in the state to those entities that have a granted water right. The Forum agreed that changes to law could be implemented to allow for the use of small-scale precipitation capture devices without significant

impacts to state resources, although limitations must be defined to restrict the magnitude of these activities.

RECOMMENDATIONS

- Continue refinement of Nevada water law to strengthen the State Engineer's ability to address Critical Management Areas and provide flexibility in the development of Groundwater Management Plans for over-appropriated basins.
- Clarify Nevada water law related to the State Engineer's inherent authority to provide for adaptive water management through implementation of 3M Plans.
- Clearly define fundamental water management principles in statute.
- Seek an addition to Nevada water law that clarifies that, in times of curtailment, only outdoor use by domestic well users may be prohibited.
- Explore changing water law to allow for the use of small scale precipitation capture devices in areas where capture increases the water supply and does not conflict with existing rights.

3 MONITORING AND RESEARCH DATA

Produced by the National Drought Mitigation Center, the U.S. Drought Monitor provides summary information on the location and intensity of drought conditions occurring across the United States and Puerto Rico. The map is updated weekly by combining data and local expert input. The Drought Monitor is produced by a rotating group from the U.S. Department of Agriculture, the National Oceanic and Atmospheric Administration, and the National Drought Mitigation Center, incorporating the review from a group of 250 climatologists, extension agents and others across the nation.

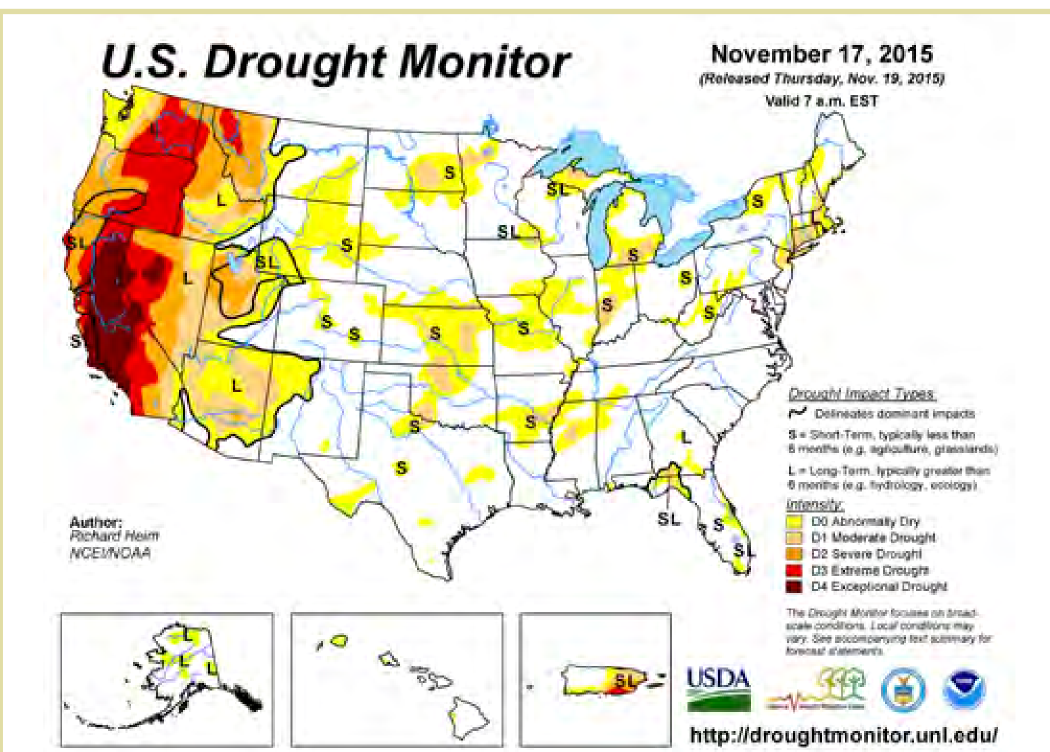
Within Nevada, the Drought Monitor is used by state and federal agencies to establish policy and management tools and to assist local planning agencies and other water users with real-time information on hydrological conditions. While the Drought Monitor is a useful tool for reporting current hydrological conditions, participants at the Forum meetings and the Summit agreed that additional information and analysis is needed to improve decision-making efforts related to livestock grazing, as well as land and environmental resource management.

The Forum agreed that narrowing information gaps through additional data collection and monitoring could significantly improve coordination between various stakeholder groups throughout the state and allow for the development of more flexible resource management strategies. As such, the Forum recommended the formation of a working group to set monitoring and research goals, and to assess monitoring recommendations. The work group's efforts will complement and enhance the applicability, value and effectiveness of the U.S. Drought Monitor through the development of new tools to increase the accuracy and accessibility of data, and improve drought forecasting through technology. The Forum agreed these coordinated efforts may help to defray expenses on mutually beneficial projects, make better use of limited staffing resources, reduce duplication of efforts and enhance interagency/stakeholder coordination and cooperation.

The Forum recognized that enhanced forecasting and monitoring tools may also be of value to other western states that are experiencing significant drought conditions. To this end, members recommended that the U.S. Drought Monitor be expanded to include multiple indicators, including state impact reporting. They also supported the addition of another Drought Monitor author in the western states and other drought-related research.

RECOMMENDATIONS

- Direct the formation of a working group of climate professionals and other relevant disciplines to set goals and assess recommendations for drought monitoring, including information gaps/site needs, prioritization of efforts, implementation strategies, and cost identification/funding strategies. This working group is encouraged to:
  - ◆ Develop a statewide monitoring network that utilizes diverse information sources to strengthen Nevada information sharing and monitoring coordination as well as centralized availability of real-time data.
  - ◆ Partner among network organizations to increase and enhance the accuracy of data, in part, by establishing standards for data collection and reporting.
  - ◆ Work with other organizations (such as NIDIS—National Integrated Drought Information System) and/or explore implementation of new technologies to improve drought monitoring, drought early warning systems and forecasts.
- Work with other western Governors to request an additional U.S. Drought Monitor author to represent western states and encourage expansion of the U.S. Drought Monitor to include multiple indicators (vegetative and hydrologic drought), including state impact reporting.
- Support development of research data related to the impacts of drought, including state tourism's offer to include questions related to drought and visitation as part of its scheduled research efforts.



As of November 17, 2015, much of Nevada is categorized to be in "moderate" to "exceptional" drought (D1 – D4).

4 FINANCIAL AND TECHNICAL ASSISTANCE

Incentive and retrofit programs have had much success in certain parts of the state, and could serve as a model for other users. However, such programs often require significant levels of funding, a limiting factor that many stakeholders face. As such, the Forum recommended that state agencies identify high-priority funding programs (including incentive programs) and associated resource needs.

The Forum also agreed that additional staffing resources will likely be needed to implement recommendations for monitoring and enforcement, as well as to provide technical assistance to water users/suppliers. Likewise, members discussed the importance of individual water users to investigate independent funding options for drought relief and conservation efficiency, including existing grants, state revolving loan funds and/or other federal emergency assistance programs.

RECOMMENDATIONS

- Direct appropriate state agencies to investigate and develop budget proposals that improve Nevada's drought response and resiliency, including possible incentive and/or rebate programs.
- Establish adequate bond funding for the state's Water Grants Program, under the purview of the Board for Financing Water Projects, for necessary capital improvements to aged water infrastructure above and beyond what a community can demonstrably afford.
- Enhance state water resources staffing capacity to support increased metering, monitoring/ inventories and enforcement, as well as technical assistance in areas such as water conservation planning.
- Direct appropriate state agencies to identify and prioritize the resources needed to implement those recommendations of the Drought Forum selected by the Governor.

5 SUPPLY AUGMENTATION AND LONG-RANGE PLANNING

In addition to exploring ways to reduce water use and improve overall efficiency, the Forum also considered opportunities to augment existing water supplies and improve drought response efforts through long-range planning.

The Forum agreed that the recharge and recovery of drought affected water supplies—including river, storage and groundwater systems—is an important priority to improve Nevada's resilience to future drought events and recommended exploring ways to enhance system recovery. While these efforts are unlikely to provide near-term drought relief due to time and financial constraints that would need to be addressed, the Forum agreed that additional steps should be taken to identify strategies that can be implemented to improve recovery of impacted systems, as well as enhance the state's long-term resiliency.

Likewise, the Forum recommended that local governments work with water purveyors to develop long-range water plans that consider both water supply and demand projections. Such planning efforts are a valuable tool in anticipating future water resource needs, as well as identify needed management strategies for use during both drought and non-drought conditions.

The Forum also agreed that the reuse of treated waste water is a valuable resource that should be explored to augment existing water supplies. As such, the Forum recommended support for the state's Water Reuse Steering Committee in exploring possible changes to reuse regulations, particularly in cases where implementation of reuse extends available water supplies. Likewise, the Forum also supported the continued monitoring of technology and other advancements that could potentially increase water supplies and/or reduce evaporative losses.

RECOMMENDATIONS

- Ask appropriate staff to explore the feasibility of additional management measures that can help to expedite the recharge and recovery of impacted river, storage and groundwater systems.

- Without affecting the inherent authority of the Nevada State Engineer, support and encourage the development of local and regional water plans that include long-term supply and demand projections in order to ensure a sustainable water supply.
- Support the work of the state's Water Reuse Steering Committee in exploring possible changes to water reuse regulations in cases where reuse extends supplies.
- Direct continued monitoring of advances, efficacy and cost efficiencies related to desalination of brackish water, cloud seeding and evaporative controls.

6 INFORMATION SHARING AND OUTREACH

The Forum discussed the availability and use of information in decision-making processes, particularly as it relates to drought response (see also "Monitoring and Research Data"). Members agreed that additional outreach tools are needed and recommended ways to better inform the public and other decision-makers of current conditions, policy intent and other drought-related issues. Implementation of these recommendations is designed to provide for more flexibility and predictability in responding to Nevada's water supply challenges, and to ensure a more consistent understanding among interested parties.

The Forum also agreed that communication with the public and other stakeholders should occur on an ongoing basis, regardless of the state's drought status. To support this effort, the Forum recommended staff resources to support current and ongoing coordination, information sharing and outreach needs.

RECOMMENDATIONS

- Work with federal partners on what climate information/data will trigger federal management actions, with the goal of enhancing predictability for asset managers and the development of a more flexible response in evolving drought conditions.
- Identify high-level messages on drought conditions and responses that can be delivered statewide to ensure consistency of messaging to all Nevada water users by state agencies, water purveyors and other stakeholders.
- Maintain a focus on water conservation messaging in Nevada even in non-drought conditions.
- Explore opportunities for judicial education on water law, such as the New Mexico Water Judges Seminar.
- Establish dedicated state staff to handle public information coordination statewide, including outreach to elected and appointed officials, as well as education programs, web site maintenance and enhancement, and assistance with information on best practices and technology transfers.

7 DROUGHT DECLARATIONS/ EMERGENCY ACTIONS

The State Drought Response Plan, updated in April 2012, was developed to define and address drought in Nevada, and to help mitigate associated impacts. The plan established a framework of actions based on three stages of drought: Drought Watch (stage 1), Drought Alert (stage 2) and Drought Emergency (stage 3). A Drought Response Committee was also formed to monitor drought conditions, collect data associated with drought, oversee intergovernmental coordination, disseminate information, report to the Governor, and work with the State Emergency Operation Center on drought response.

Subsequent to this action, the U.S. Department of Agriculture issued a final ruling that updated its disaster regulation process for drought-affected areas. The rule includes provisions for automatic disaster designations in the case of severe drought. It also removes the requirement for a State Governor to request a Secretarial disaster designation before a designation can be made. According to the rule, a drought disaster will be declared for any county that: 1) has a drought intensity value of at least D2 (Severe Drought) as reported in the U.S. Drought Monitor for eight consecutive weeks; or 2) has a drought intensity value of D3 (Extreme Drought) or higher at any time in the growing season of the affected crops.

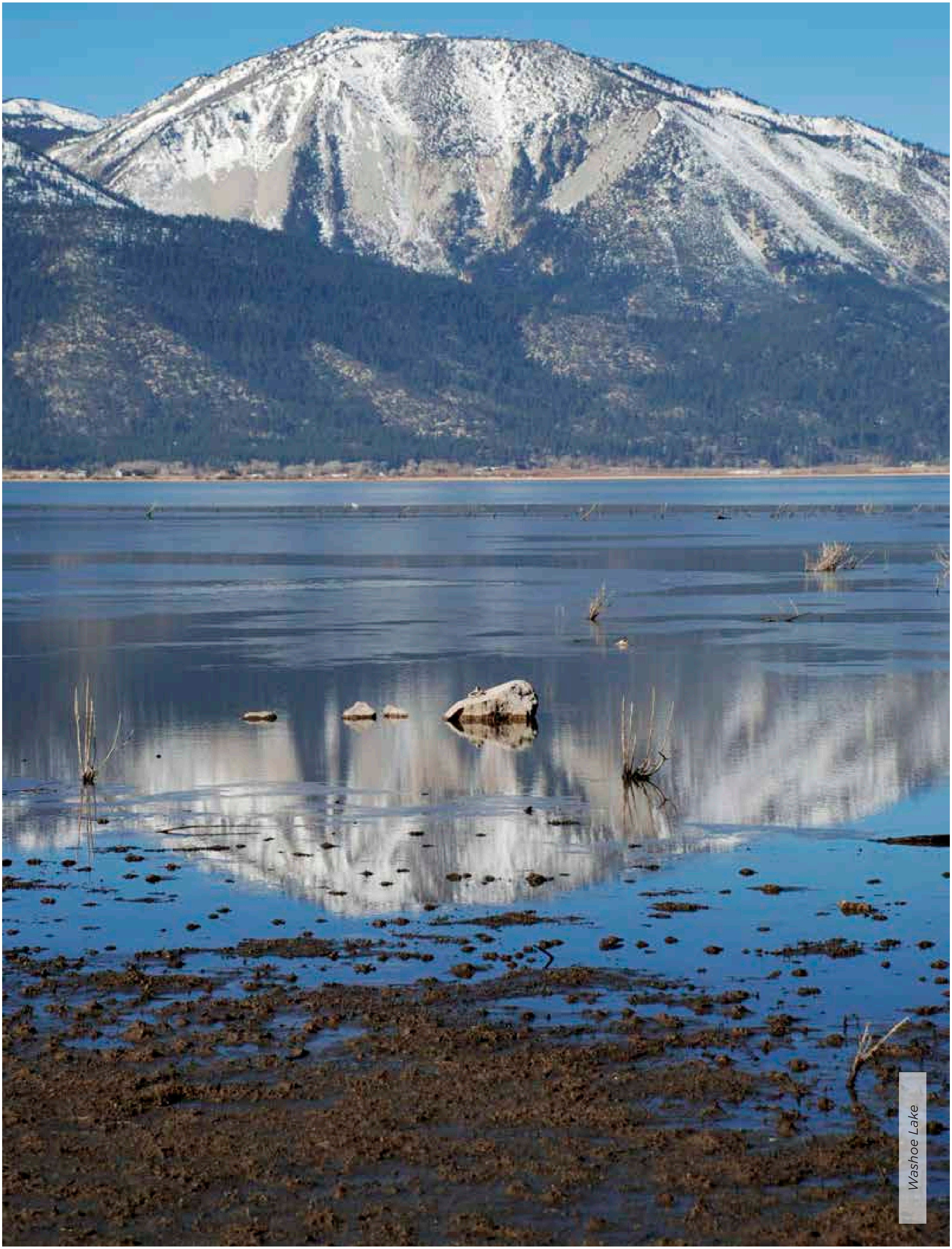
The Forum agreed that objective Nevada criteria are needed to define drought stages. Further, members agreed that the state's current Drought Response Plan should be updated to include definitions and other relevant drought response mitigation efforts resulting from the Forum's work. The Forum also recommended that the Committee review existing laws concerning water emergencies to ensure consistency.

As part of this discussion, the Forum recognized the diversity of the state's climate, water supply sources and users' overall ability to respond to drought. Members cautioned against implementing measures on a statewide basis unless conditions warranted such action and noted that emergency measures enacted should serve to preserve access to supplies. Users/suppliers that have made appropriate reductions or implemented other tools to ensure sufficient resources are available should not be penalized.

RECOMMENDATIONS

- Currently, the State Drought Response Committee consists of the State Climatologist, State Engineer and the Chief of Nevada's Division of Emergency Management. The Forum recommends expanding this committee to include representatives from TMWA, SNWA and the Nevada Department of Agriculture and directing the newly expanded State Drought Response Committee to develop broad-based, objective Nevada criteria specifically for a Governor's Drought Declaration in lieu of a declaration based solely on a U.S. Department of Agriculture determination.
- Require the Committee to further refine and define the Nevada criteria for Drought Warnings and Drought Alerts, and to clarify in the Drought Response Plan the distinctions between Drought Alerts, Drought Warnings and a Governor Drought Declaration, and a proclamation of water emergency as outlined in NRS 416.050.
- Require the Committee to update the current Drought Response Plan in light of information gathered through the Drought Forum and Governor's Drought Summit.
- Direct the Committee to explore the steps necessary for response measures such as a State Engineer's temporary suspension of forfeiture provisions or imposition of shared curtailment, as well as temporary suspension by state Environmental Protection of non-public health water quality standards.
- Direct the Committee to also review, from a water perspective, NRS Chapter 416 *Emergencies Concerning Water or Energy*, to align the chapter with the Drought Response Plan, including possible amendment of NRS 416.060 to add the term "statutes" to "rescind any regulation or order" in narrowly defined water emergencies.
- The Committee shall invite experts and make recommendations to the Governor for adding additional members as needed.

Pyramid Lake



Washoe Lake

TRUCKEE MEADOWS WATER AUTHORITY

APPENDIX 2

PRIORITIZED MAIN REPLACEMENT PROGRAM

Prioritized Main Replacement Program

August 2015

TRUCKEE MEADOWS WATER AUTHORITY

www.tmwa.com

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Executive Summary

The United States has entered the replacement era in which we need to begin rebuilding our water system infrastructure installed by earlier generations according to the American Water Works Association. Much of our drinking water infrastructure is nearing the end of its useful life and approaching the age at which it needs to be replaced. Significant investment will be required if we are to maintain the current level of water service Americans enjoy today.

The purpose of this inaugural effort was to ensure the viability, integrity and reliability of the water system for our community by developing prioritized short-term and long-term plans for water main renewal. Truckee Meadows Water Authority (TMWA) staff inventoried and analyzed existing water main infrastructure condition and service level. A scoring system was developed for prioritization primarily driven by 24 years of leak history as the best indicator of existing pipe condition. Finally, TMWA performance levels were compared to national metrics in order to guide ongoing best practices and decision making in regards to water main rehabilitation and replacement.

Results show TMWA's exceptional reliability and water main infrastructure integrity when compared nationally to public water system annual break rates, service levels and water produced but not billed. Coordination with local agencies should continue as this approach has proved to be the most cost effective and least disruptive to main replacement and rehabilitation for TMWA customers and the community. Furthermore, the current $5 million dollar annual funding level is appropriate while expenditure requirements are expected to grow to $18 million dollars annually by 2050. TMWA debt management activities will allow greater cash flow to fund water main rehabilitation and replacement expenditures into the future.

Findings and Recommendations

Short-Term Plan:

- Continue to coordinate water main rehabilitation and replacement projects with the City of Reno, City of Sparks, RTC, NDOT and Washoe County street reconstruction and utility projects. Integrating utility work prior to or concurrently with other agencies' projects has proved to be the most cost efficient and least disruptive approach to water main renewal for TMWA customers. TMWA may move forward independently with some priority projects as budgets allow.

- TMWA delivers exceptional reliability as measured by a low leak rate system-wide as well as for the top prioritized mains. TMWA's top 10 prioritized mains offer service levels of 0.3 to 1.1 leaks per 1,000 feet per year. When considering only internal costs, three breaks per 1,000 feet per year justify open-trench replacement while rehabilitation technologies can be cost-effective at two breaks per year. Therefore, no immediate action is warranted to address TMWA's prioritized mains outside of current best practices.

- Where rehabilitation or replacement are considered, priority should be focused on steel, cast iron, concrete cylinder and riveted steel water mains installed prior to 1960. These pipe materials makeup 12 percent of TMWA's water system inventory but account for 60 percent of recorded leaks. In addition, 90 percent of resulting prioritized mains were installed before 1960.

Long-Term Plan:

- Monitor leak/break rates as a measurement of pipe condition, performance, and durability. Consider rehabilitation or replacement as service levels decline or field investigations and maintenance experience validate deteriorating pipe condition and increase the risk of failure.

- Continue to collect and maintain data necessary to build a comprehensive asset management and prioritization program. Incorporate merger-acquired water mains with future updates.

- Budget and plan for increasing water main rehabilitation and replacement costs as facilities age and approach the end of their expected service life. Expenditures are expected to grow to over $18 million dollars annually by 2050. Debt management activities under consideration will allow greater cash flow to fund rehabilitation and replacement expenditures into the future.

Methodology

The purpose of this inaugural effort was to inventory and analyze existing TMWA water main infrastructure condition and service level to develop prioritized short-term and long-term plans for water main renewal. Water services were not included in this analysis. Stated goals and objectives were to:

1. Incorporate the likelihood and consequence of water main failure to reduce total system risk, associated unplanned outages and emergency repair costs.
2. Prioritize main rehabilitation and replacements based on risk and coordination with local agencies to maximize benefits and minimize costs.
3. Ensure the viability, integrity and reliability of the water system for our community.

To identify priority mains in TMWA's distribution system, the likelihood and consequence of failure for each pipe segment was estimated using data contained in our geographic information system (GIS). The likelihood of failure included such attributes as material, age, leak history, soil condition, proximity to railroads and fault lines and higher static pressure areas. The consequence of failure included diameter, hydraulic criticality, and high volume users. Each criterion was scored and mains subsequently ranked according to risk.

The results of this initial effort were driven primarily by the likelihood of failure and specifically, the leak history data as the best indicator of existing pipe condition. Datasets including critical customers, difficult access for maintenance, potential damage to surrounding high-value areas, the extent of customer outages and traffic interruptions were not available but may be incorporated in future updates. Locate the full methodology in Appendix A.

Short-Term Prioritization Plan

Street and Highway Program

Coordination with local agencies has proved to be the most cost effective and least disruptive approach to main replacement and rehabilitation for TMWA customers and the community. The Street and Highway Main Replacement Program has been funded at an average rate of $5 million dollars per year since the inception of TMWA in 2001. The average rate of main replacement under this program has been 8,000 feet per year. TMWA works cooperatively with our local agencies to keep projects on time and within budget.

Break and Leak Rates, Service Level, and Non-Revenue Water

The American Society of Civil Engineers' *2013 Report Card for America's Infrastructure* graded the nation's water infrastructure a D+ and reported that there are an estimated 240,000 water main breaks per year in the United States. Division results in an average break rate of 24 breaks per 100 miles annually since it is estimated that there are a little over one million miles of water mains installed in the U.S.

According to the American Water Works Association (AWWA), the median level of breaks and leaks has ranged from 26 to 49 per 100 miles since 2004 (*Benchmarking Performance Indicators for Water and Wastewater Utilities: 2013 Survey Data and Analyses Report)*. The 75th percentile ranged up to 89 while the 25th percentile was down to zero in one year. More typically the break rate is in the range of 15 to 20 leaks and breaks per 100 miles annually. While TMWA has not differentiated between leaks and breaks historically, the AWWA defines leaks and breaks as follows:

Leak: A leak refers to an opening in a distribution pipeline, valve, hydrant, appurtenance or service connection that is continuously losing water.

Break: A break refers to physical damage to a pipe, valve, hydrant, or other appurtenance that result in an abrupt loss of water.

TMWA's system-wide water main leak rate is very low at 3 leaks per 100 miles annually indicating very high service levels currently exist. This leak rate is based on 24 years of leak history data collected beginning in March of 1989 through February of 2013. In all, 1,067 leaks on water mains have been documented in that time (including 63 leaks due to third party damage) equating to an average total number of 45 leaks annually.

Another way to express service level is the number of leaks per year per 1,000 feet of installed water main. The TMWA system-wide rate is 0.006 leaks per 1,000 feet per year while the rates for our top 10 prioritized mains vary from 0.3 to 1.1 leaks per year. According to an AWWA Research Foundation Report, one to three breaks per 1,000 feet per year justify open trench replacement, depending on the number of services and traffic disruption involved. Rehabilitation is cost effective at 0.5 to two breaks per 1,000 feet per year according to this report. These decision threshold recommendations take into account the internal and external costs involved and customer attitudes and acceptance of the frequency and duration of service disruptions (*Customer Acceptance of Water Main Structural Reliability*, AWWA Research Foundation, 2005). Therefore, no immediate action is warranted to address TMWA's prioritized mains outside of current best practices.

View TMWA's top 10 prioritized mains in Table 1. All are steel or cast iron pipes installed prior to 1950 and have leak rates of 0.3 to 1.1 leaks per 1,000 feet per year.

Table 1: TMWA's Top 10 Prioritized Mains

Main Location	Diameter and Material	Length (ft)	Year Installed	Number of Leaks (1989-2013)	Number of Services	Leak Rate (annual leaks per 1,000 feet)
Plumas Street	12-inch steel	3,900	1948	28	32	0.3
Washington Street	6-inch steel	1,700	1925	36	60	0.9
Southridge Drive	6-inch steel	1,600	1947	19	20	0.5
Stewart Street	6-inch steel	440	1920	12	23	1.1
Moran Street	4-inch cast iron	400	1926	10	17	1.0
Haskell Alley	4-inch cast iron	400	1926	8	15	0.8
Haskell Street	6-inch steel	310	1947	8	1	1.1
Humboldt Street	6-inch steel	310	1923	7	9	0.9
Daniel Drive	6-inch steel	1,080	1947	11	25	0.4
Bartlett Street	6-inch cast iron	820	1948	9	24	0.5

TMWA's low leak rate is also reflected in TMWA's comparatively small non-revenue water use. Non-revenue water refers to water that is produced but not billed or accounted for in customers' meters. Non-revenue water can be authorized (firefighting, hydrant testing, flushing) or result from unauthorized use and leakage. The national annual average public water system non-revenue water use is 16 percent per *Water Audits and Water Loss Control for Public Water Systems,* USEPA July 2013. TMWA's non-revenue water use has been estimated at 6 percent annually.

An exhibit showing TMWA's prioritized mains displayed geographically is included in Appendix B. Exhibits showing TMWA's top 10 prioritized mains in more detail are attached in Appendix C. A table listing the top 100 prioritized mains is shown in Appendix D. Appendices F through K exhibit criterion used in the prioritization including leak history.

Prioritized Water Main Materials - Steel, Cast Iron, Concrete Cylinder, Riveted Steel

TMWA's water system consists of approximately 539 miles of polyvinyl chloride (PVC) pipe, 517 miles of asbestos cement (AC) or Transite pipe, 123 miles of ductile iron (DI) pipe, 89 miles of cast iron (CI) pipe, 72 miles of steel pipe, and a small amount of concrete cylinder pipe. The figure on the next page shows the percentage of pipe by material in TMWA's system.

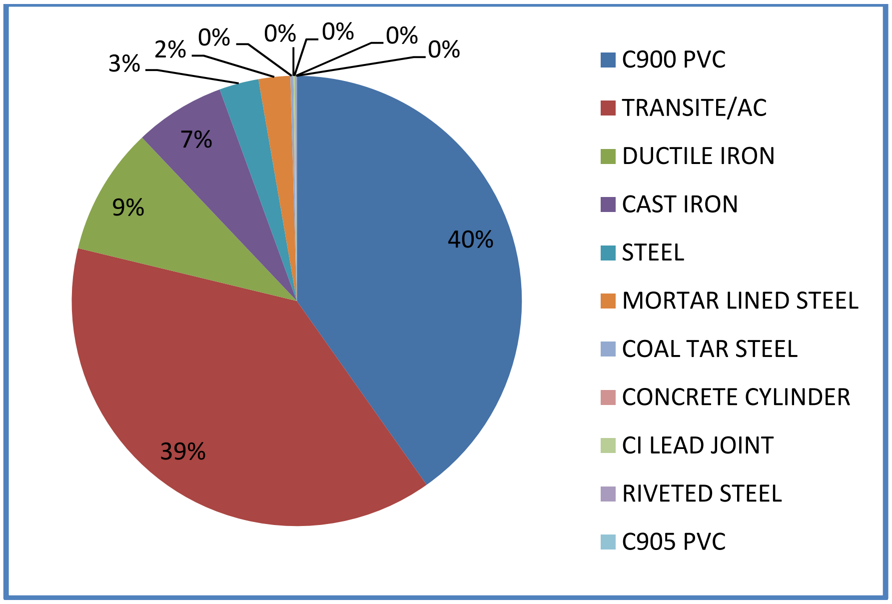

Figure 1: Percentage of Main by Material

The following two figures show the percentage of leaks by material and by type of failure. Leaks on steel mains are most commonly caused by corrosion while cracking is most common on cast iron and asbestos cement materials.

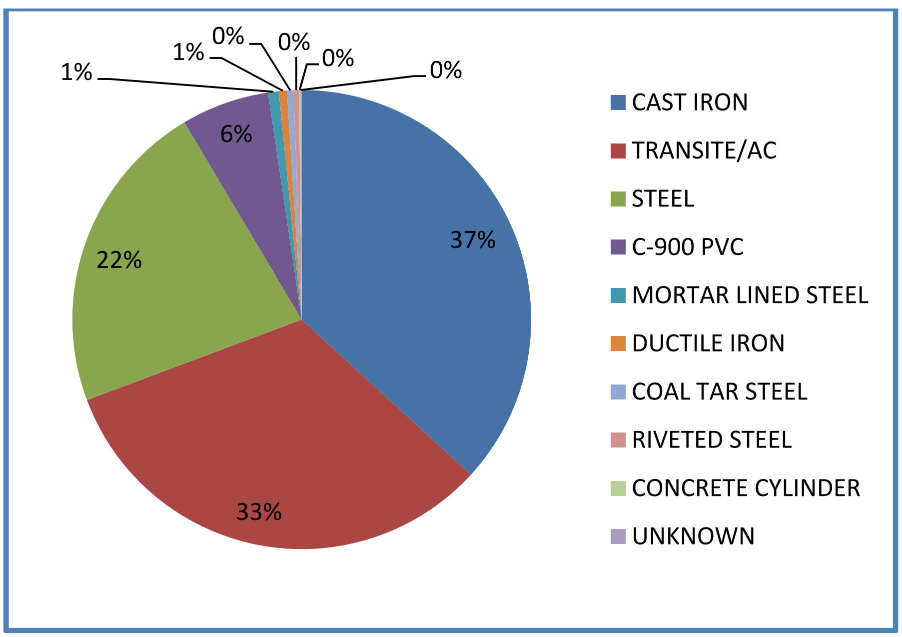

Figure 2: Percentage of Leaks by Material

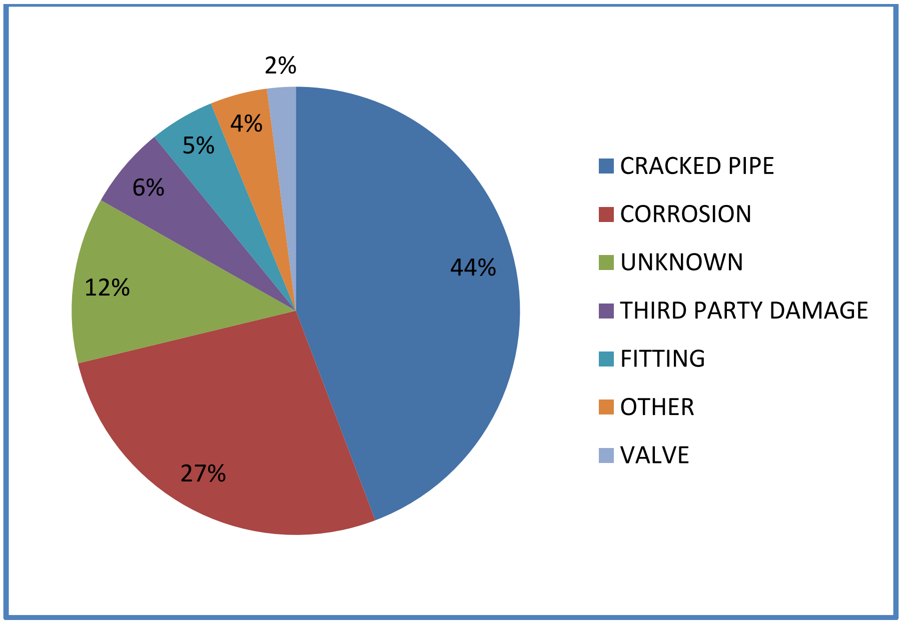

Figure 3: Percentage of Leaks by Type

The graphic below illustrates that steel, cast iron, concrete cylinder, and riveted steel pipes have the highest number of leaks per mile by material and, therefore, should be the focus of TMWA's prioritized main replacement program. As previously mentioned, these pipe materials makeup only 12 percent of TMWA's water system inventory but account for 60 percent of recorded water main leaks.

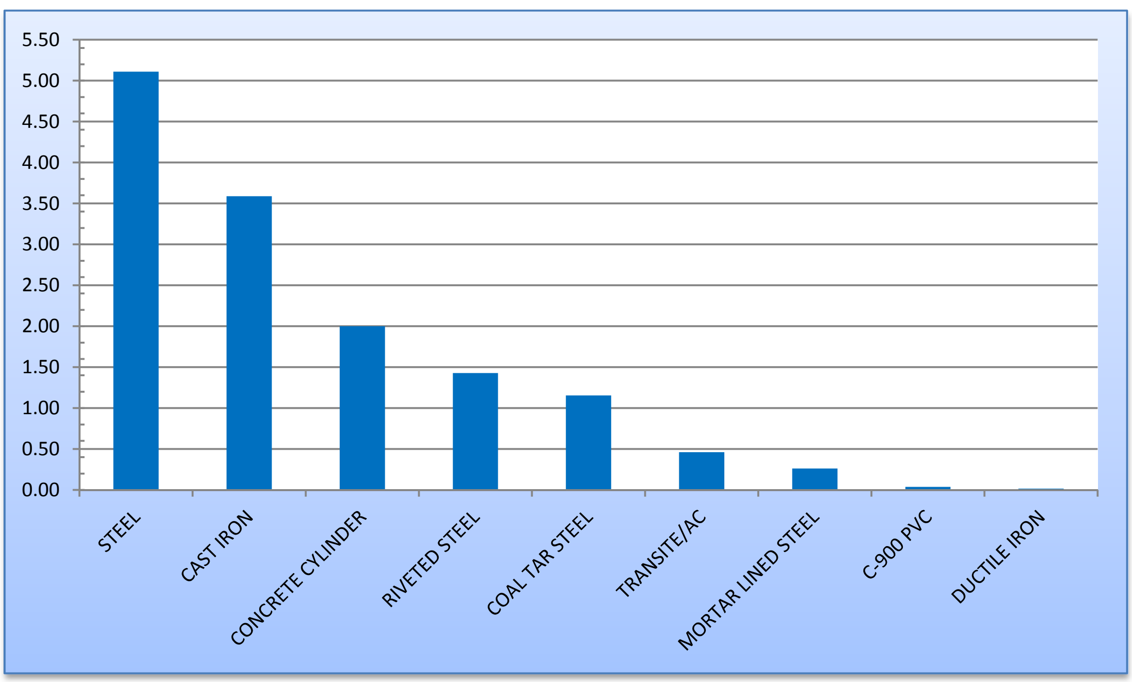

Figure 4: Number of Leaks per Mile by Material

Additionally, the age of pipe installations, as well as soil conditions and early laying practices, are linked to prioritized main results. Ninety percent of resultant prioritized mains from this analysis were installed prior to 1960. The table below shows that TMWA has 28.5 miles of these mains that were installed prior to 1960.

Table 2: Steel, Cast Iron, Concrete Cylinder Pipe Installed Prior to 1960

	Length in Feet Installed Prior to 1960					Total by Size
Main Diameter	Steel	Cast Iron	Riveted Steel	MLS	CCP	(feet)
4"	0	569	0	0	0	569
6"	3,596	52,071	0	0	0	55,667
8"	696	26,194	0	0	0	26,890
10"	1,074	702	1,130	0	0	2,906
12"	62	2,990	10,625	0	0	13,677
14"	12,687	0	0	0	1,063	13,750
16"	0	0	0	1,217	0	1,217
18"	31	0	0	0	0	31
22"	5	0	0	0	0	5
24"	34,757	0	0	1,122	0	35,879
42"	50	0	0	0	0	50
Total Feet	52,958	82,526	11,755	2,339	1,063	150,641
					Total Miles	28.5

Why Not Prioritize Asbestos Cement Mains?
While asbestos cement water mains account for 33 percent of recorded water main leaks at TMWA, the number of leaks is low at less than 0.5 per mile. The exhibit in Appendix E shows asbestos cement pipe leak history appears quite random geographically making it is difficult to predict where future leaks might occur. Asbestos cement mains should be replaced if determined necessary based on information for a specific main in conjunction with the Street and Highway Main Replacement Program.

Long-Term Prioritization Plan

Continue Service Level Monitoring
TMWA will continue to monitor leak rates as a measurement of pipe condition, performance, and durability. Rehabilitation or replacement will be evaluated as service levels decline or field investigations and maintenance efforts validate deteriorating pipe condition and increased risk of failure. Engineering staff will perform alternatives evaluations to determine whether or not priority pipes can be abandoned, rerouted, or should be rehabilitated or replaced. Replacements will continue under the existing Street and Highway Main Replacement Program budget item or will be capitalized as necessary.

Data Collection and Maintenance
Beyond TMWA's existing GIS and computerized maintenance management system Cityworks, additional data and analyses tools will be necessary for more advanced approaches to a long-term main prioritization plan. Ultimately, a life cycle planning approach including development of aging functions and determination of the effective useful service life at the pipe level could prove useful. Future updates will also include newly acquired water mains in the analyses.

Projection of Investment Requirements by Year to 2050

Much of the drinking water infrastructure nationwide is nearing the end of its useful life and approaching the age at which it needs replacement. Fortunately, TMWA's assets are generally newer than those in the eastern United States and Midwest. The figure below shows the age of installed length of main in TMWA's system by decade.

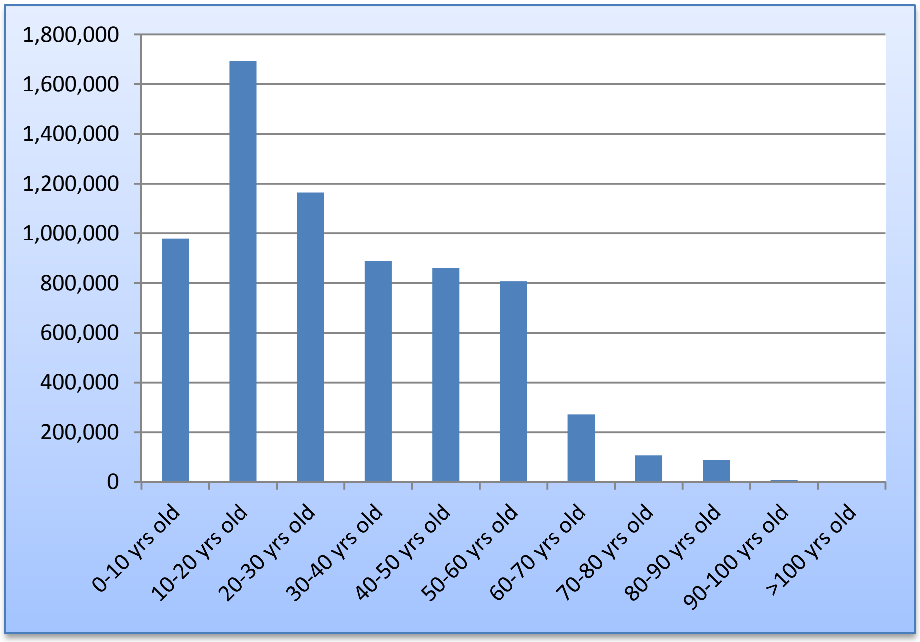

Figure 5: Age of Installed Length of Main in Feet

Nevertheless, significant investment will be required if we are to maintain the current level of water service Americans enjoy today. The AWWA has produced a report and tool for use by water utilities to project asset replacement costs through 2050 called the *Buried No Longer Pipe Replacement Modeling Tool (*Copyright 2013 AWWA*)*. This tool scales the outcomes of the larger report for specific utility criteria such as size, replacement costs, pipe age, and materials. TMWA's results estimate the growth of replacement expenditures for water mains to approximately $18 million dollars per year by 2050 (in 2012 dollars). Debt management activities under consideration will allow greater cash flow to fund rehabilitation and replacement expenditures into the future. Find the full results in Appendix L.

Further Reading

http://www.infrastructurereportcard.org/a/#p/drinking-water/overview

http://www.infrastructurereportcard.org/a/#p/state-facts/nevada

http://water.epa.gov/type/drink/pws/smallsystems/upload/epa816f13002.pdf

http://www.awwa.org/Portals/0/files/legreg/documents/BuriedNoLonger.pdf

Appendix A

Prioritized Main Replacement Analyses Methodology

Main Rehabilitation and Replacement Prioritization Methodology

Purpose:
Identify, budget and plan main rehabilitation or replacements based on risk. Coordinate with local agencies for maximum benefit and minimum cost to ensure the viability, integrity, and reliability of the water system for TMWA customers.

Task:
Develop a prioritized main replacement program using currently available information and technology incorporating the likelihood and consequence of failure to reduce total system risk, associated unplanned outages, and emergency repair costs.

Part 1 Methodology:

1. Estimate the likelihood of pipe failure:
    - a. Physical
        1. material
        2. age
        3. distribution staff field experience
    - b. Historical
        1. leak and break history
        2. maintenance records*
    - c. Spatial
        1. soil conditions
        2. proximity to railroads, fault lines
    - d. Hydraulic
        1. high static pressure areas
2. Estimate the consequence of pipe failure:
    - a. Physical
        1. diameter
    - b. Spatial
        1. potential damage to surrounding high-value areas*
        2. difficult access for maintenance or repairs*
    - c. Hydraulic
        1. pipe hydraulic criticality
    - d. Customer and Public Relations
        1. outages to critical customers*/high volume users
        2. extent of customer outages/population density/traffic interruptions*
3. Calculate risk of failure and develop a prioritized list of main replacements

Part 2 Methodology:

1. Budget and plan renewal based on risk and coordination with local agencies.
    - a. Annually correlate to planned street and highway repair or utility work
    - b. Engineering alternatives evaluation
        1. abandon, reroute, rehabilitate or replace
    - c. Perform selected field condition assessments
    - d. Prepare preliminary designs and cost estimates

Note: * Items were not included in this analysis.

Appendix B

Prioritized Mains by Risk Score

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HOMELAND SECURITY INFORMATION

(NRS 239C.210)

Appendix C

Top 10 Prioritized Mains

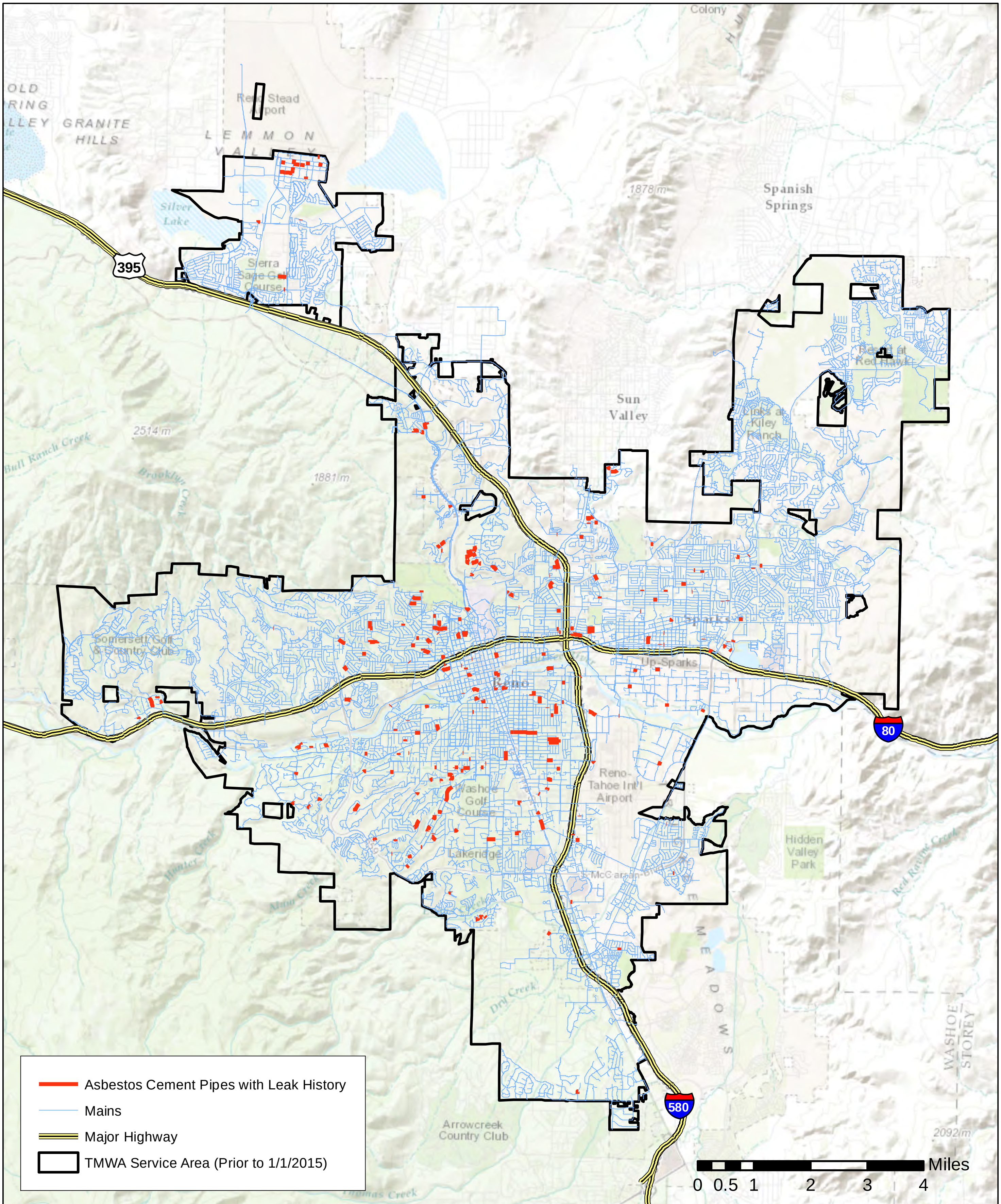
Main Location	Diameter	Material	Year Installed	Number of Leaks
PLUMAS ST	12-inch	steel	1948	28
WASHINGTON ST	6-inch	steel	1925	36
SOUTHRIDGE DR	6-inch	steel	1947	19
STEWART ST	6-inch	steel	1920	12
MORAN ST	4-inch	cast iron	1926	10
HASKELL ALLEY	4-inch	cast iron	1926	8
HASKELL ST	6-inch	steel	1947	8
HUMBOLDT ST	6-inch	steel	1923	7
DANIEL DR	6-inch	steel	1947	11
BARTLETT ST	6-inch	cast iron	1948	9
JUNIPER HILL RD	4-inch	steel	1948	6
BON REA WAY	4-inch	cast iron	1926	8
STEWART ST	6-inch	cast iron	1947	6
K ST	6-inch	cast iron	1952	6
W MOANA LN	12-inch	steel	1948	4
GENTRY WAY	8-inch	steel	1948	4
WHEELER AVE	8-inch	steel	1912	6
G ST	6-inch	steel	1947	4
LANDER ST	6-inch	cast iron	1930	4
COMSTOCK DR	6-inch	cast iron	1963	6
BASQUE LN	24-inch	steel	1960	4
MARY ST	4-inch	cast iron	1928	4
COLLEGE CT	4-inch	cast iron	1931	5
GRASSLAND PL	6-inch	cast iron	1955	5
KEYSTONE AVE	6-inch	cast iron	1950	5
MORAN ST	10-inch	steel	1917	3
WHITFIELD WAY	8-inch	cast iron	1951	3
4TH ST	4-inch	cast iron	1947	4
WASHINGTON ST	4-inch	steel	1924	3
MONROE ST	4-inch	cast iron	1928	4
STOKER AVE	6-inch	cast iron	1952	4
TOLICA ST	6-inch	steel	1947	3
WHITFIELD WAY	8-inch	steel	1949	3
WESLEY DR	6-inch	cast iron	1949	3
LODGE AVE	6-inch	cast iron	1952	10
SHANGRI-LA DR	6-inch	cast iron	1950	4
HILLSIDE DR	4-inch	cast iron	1929	5
4TH ST	6-inch	cast iron	1957	3
HASKELL ST	4-inch	cast iron	1928	3
CRANLEIGH DR	6-inch	cast iron	1951	3
E 4TH ST	8-inch	cast iron	1964	3
HUNTER LAKE DR	12-inch	steel	1954	2
HELENA AVE	8-inch	steel	1948	2

Main Location	Diameter	Material	Year Installed	Number of Leaks
HELVETIA AVE	6-inch	cast iron	1936	3
MILL ST	16-inch	MLS	1962	2
WATT ST	6-inch	steel	1947	4
ROBERTS ST	4-inch	steel	1917	2
FIELD ST	6-inch	steel	1947	2
WILLOW ST	4-inch	cast iron	1929	2
S VIRGINIA ST	4-inch	cast iron	1924	3
ROCK ALLEY	4-inch	cast iron	1930	3
N SIERRA ST	12-inch	cast iron	1949	2
EMERALD PL	6-inch	cast iron	1955	3
WILKINSON AVE	6-inch	cast iron	1950	5
N VIRGINIA ST	14-inch	steel	1959	2
WRIGHT ST	6-inch	steel	1947	2
MONROE ST	24-inch	steel	1948	2
E PRATER WAY	24-inch	coal tar steel	1978	2
CHENEY ST	4-inch	cast iron	1927	2
N CENTER ST	6-inch	steel	1919	2
COLLEGE DR	4-inch	cast iron	1927	3
ROBIN PL	4-inch	cast iron	1953	2
WESLEY DR	6-inch	cast iron	1949	2
TACOMA WAY	4-inch	cast iron	1947	2
WESTGATE RD	6-inch	steel	1947	2
W 11TH ST	6-inch	cast iron	1953	2
S MARSH AVE	6-inch	cast iron	1948	2
WRIGHT ST	6-inch	steel	1947	2
S ARLINGTON AVE	8-inch	cast iron	1932	2
TONOPAH ST	4-inch	cast iron	1928	2
SAINT LAWRENCE AVE	4-inch	cast iron	1929	2
PHILLIPS ST	6-inch	cast iron	1936	2
COLORADO RIVER BLVD	6-inch	cast iron	1946	2
MORRILL AVE	4-inch	cast iron	1929	2
WILDER ST	6-inch	cast iron	1942	2
G ST PARKING LOT	6-inch	cast iron	1952	2
HILLSIDE DR	4-inch	cast iron	1929	2
STANFORD WAY	6-inch	cast iron	1947	2
OXFORD AVE	6-inch	cast iron	1950	2
GENTRY WAY	6-inch	cast iron	1957	2
I ST	6-inch	cast iron	1950	2
MORAN ST	6-inch	cast iron	1931	2
E K ST	6-inch	cast iron	1957	2
J ST	6-inch	cast iron	1951	2
BALZAR CIR	6-inch	cast iron	1946	2
ROBIN ST	6-inch	cast iron	1951	2

Main Location	Diameter	Material	Year Installed	Number of Leaks
TRENTHAM WAY	6-inch	cast iron	1940	2
W PLUMB LN	24-inch	steel	1948	1
PALISADE DR	6-inch	cast iron	1951	2
CANYON DR	6-inch	cast iron	1955	2
BROWN ST	6-inch	cast iron	1949	2
MILL ST	6-inch	cast iron	1952	2
WILLOW ST	4-inch	cast iron	1927	2
CANYON DR	6-inch	cast iron	1950	2
FAIRFIELD AVE	6-inch	cast iron	1955	2
CLOUGH RD	4-inch	steel	1946	2
ROBIN ST	6-inch	cast iron	1950	2
SHARON WAY	24-inch	steel	1948	1
WALKER AVE	6-inch	cast iron	1953	2

Appendix E

Asbestos Cement Mains with Leak History



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TRUCKEE MEADOWS WATER AUTHORITY
Quality. Delivered.

ASBESTOS CEMENT PIPES with LEAK HISTORY
33% of Recorded Leaks 1989 to 2013

Truckee Meadows Water Authority Service Area

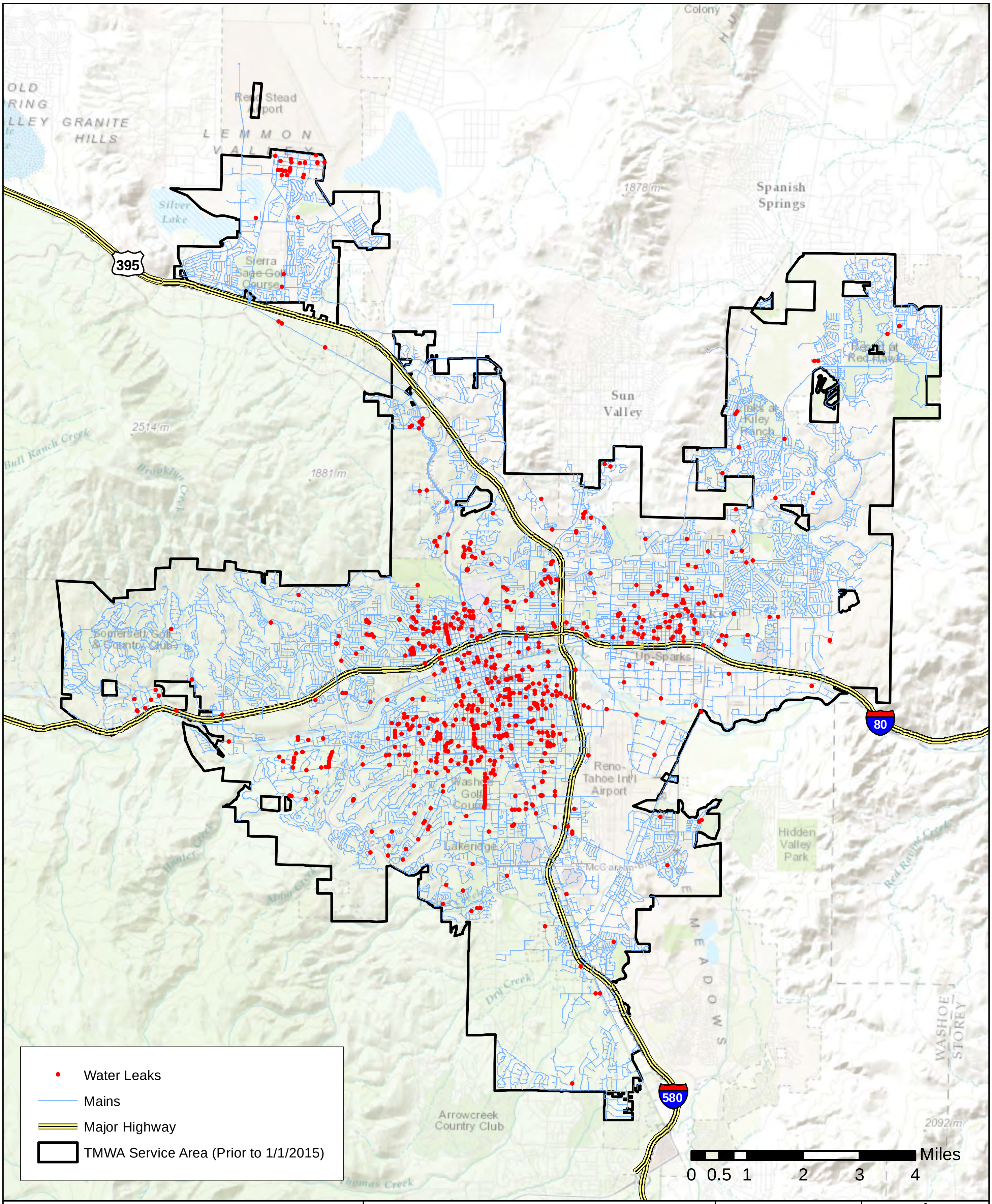
DATE	06/12/2015
MAP BY:	JK
REQUESTED BY:	LK
SCALE:	1 in = 2 miles

NORTH

NAD 83 NEVADA STATE PLANE WEST FEET

Appendix F

Water Main Leaks 1989-2013



TRUCKEE MEADOWS WATER AUTHORITY
Quality. Delivered.

WATER LEAKS ON MAINS
1989 to 2013

Truckee Meadows Water Authority Service Area

DATE	06/12/2015
MAP BY:	JK
REQUESTED BY:	LK
SCALE:	1 in = 2 miles

NORTH

NAD 83 NEVADA STATE PLANE WEST FEET

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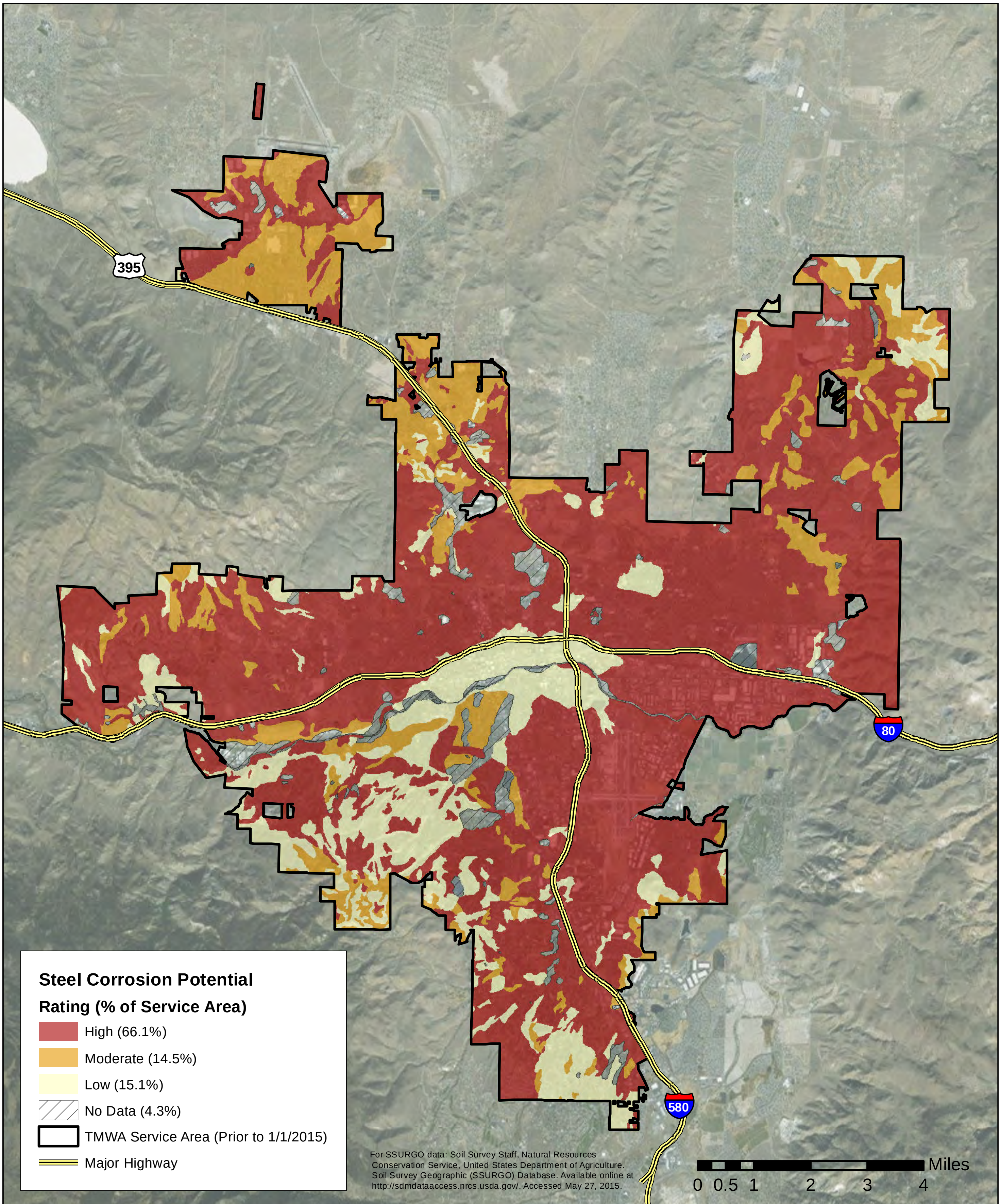
Appendix G

Soil Conditions – Steel and Concrete Corrosion Potential



TRUCKEE MEADOWS WATER AUTHORITY

Quality. Delivered.

CORROSION OF STEEL

Truckee Meadows Water Authority Service Area

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MAP BY:	JK
REQUESTED BY:	LK
SCALE:	1 in = 2 miles

NORTH

NAD 83 NEVADA STATE PLANE WEST FEET

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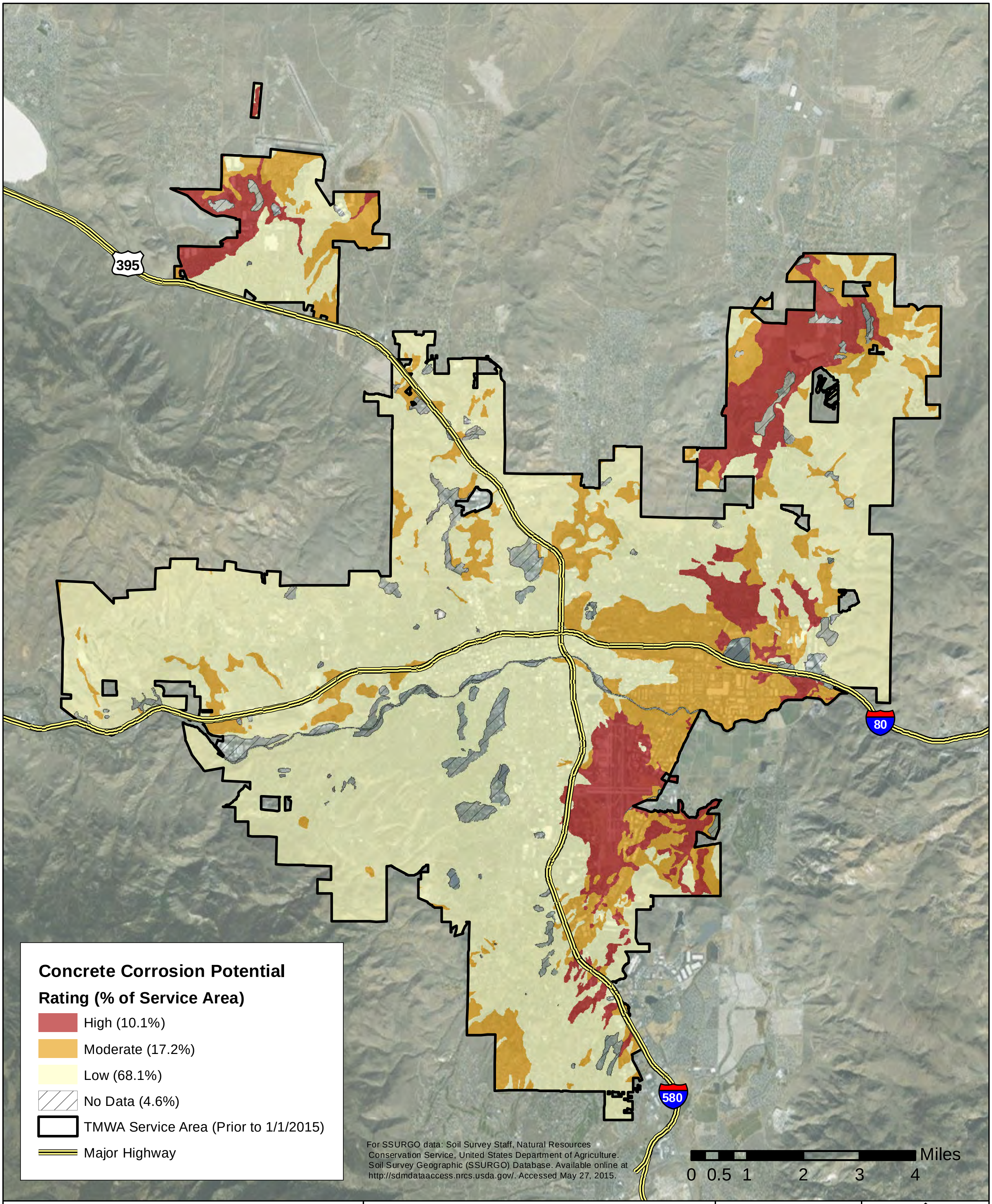

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TRUCKEE MEADOWS WATER AUTHORITY
Quality. Delivered.

CORROSION OF CONCRETE

Truckee Meadows Water Authority Service Area

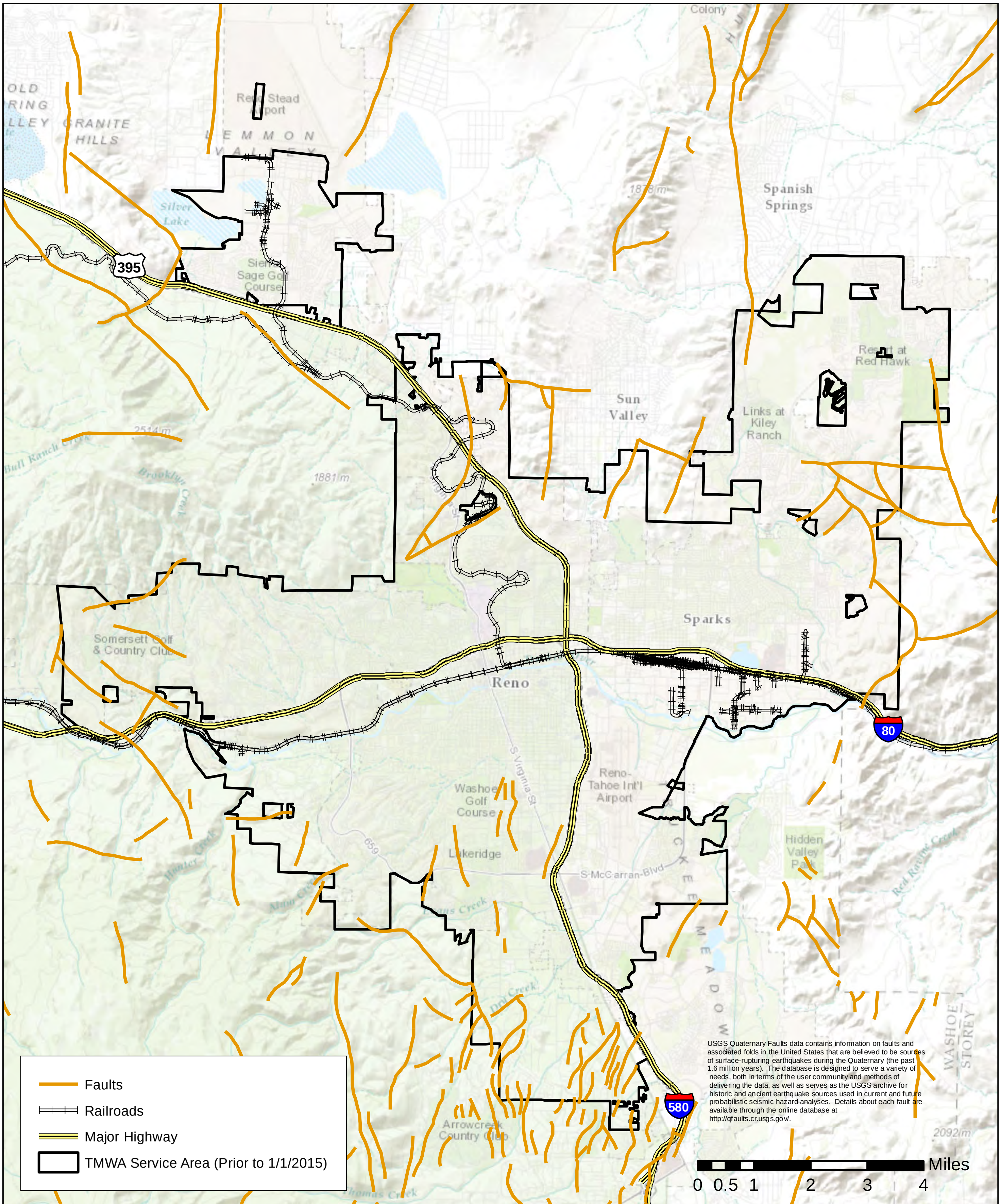
DATE	05/27/2015
MAP BY:	JK
REQUESTED BY:	LK
SCALE:	1 in = 2 miles

NORTH

NAD 83 NEVADA STATE PLANE WEST FEET

Appendix H

Railroads and Fault Lines in the Truckee Meadows



TRUCKEE MEADOWS WATER AUTHORITY
Quality. Delivered.

RAILROADS AND FAULT LINES

Truckee Meadows Water Authority Service Area

DATE	06/10/2015
MAP BY:	JK
REQUESTED BY:	LK
SCALE:	1 in = 2 miles

NORTH

NAD 83 NEVADA STATE PLANE WEST FEET

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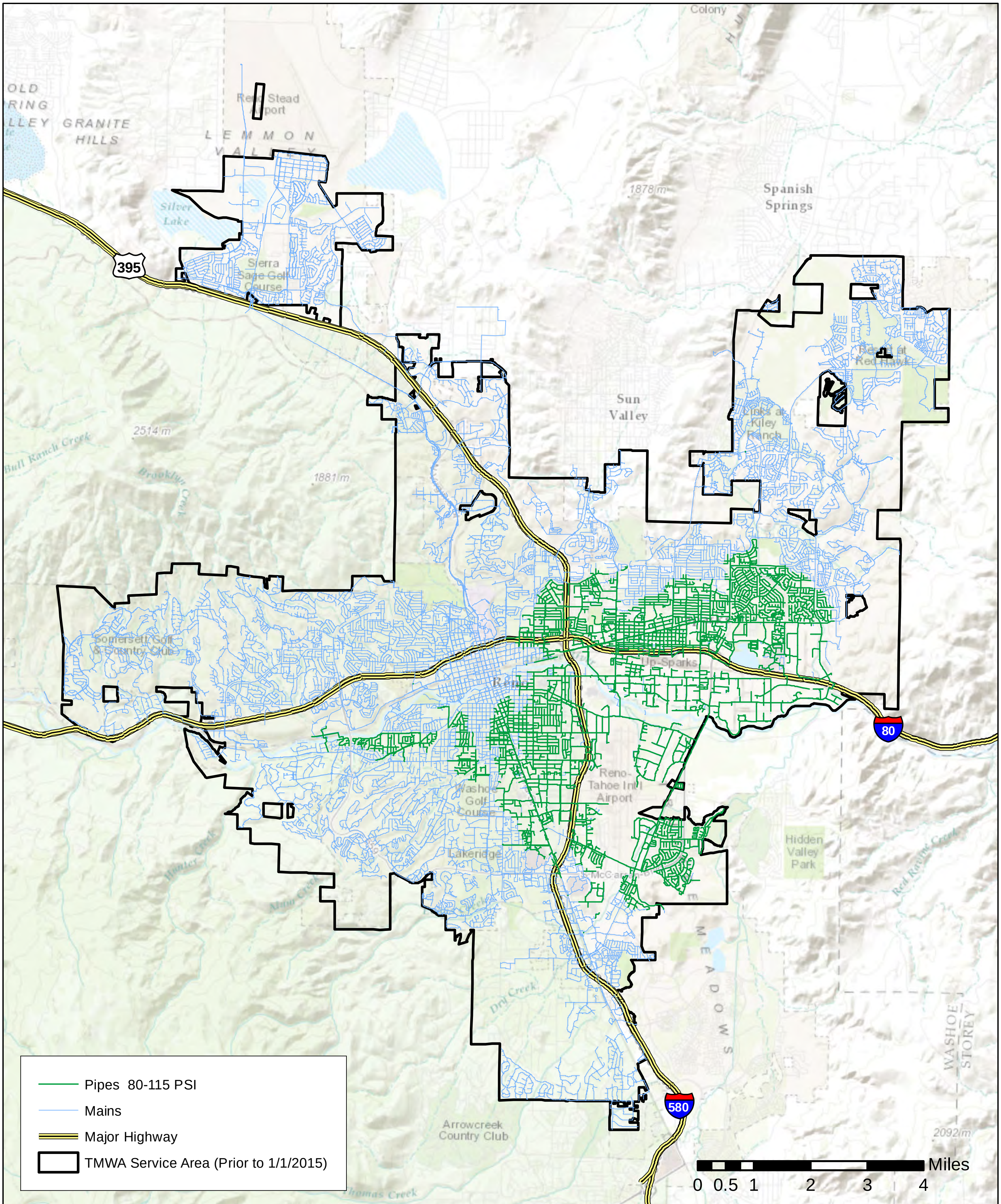
Appendix I

Static Pressure 80-115 psi



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TRUCKEE MEADOWS WATER AUTHORITY
Quality. Delivered.

STATIC PRESSURE 80-115 PSI

Truckee Meadows Water Authority Service Area

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NORTH

NAD 83 NEVADA STATE PLANE WEST FEET

Appendix J

Hydraulically Critical Mains

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HOMELAND SECURITY INFORMATION

(NRS 239C.210)

Appendix K

High Volume Users

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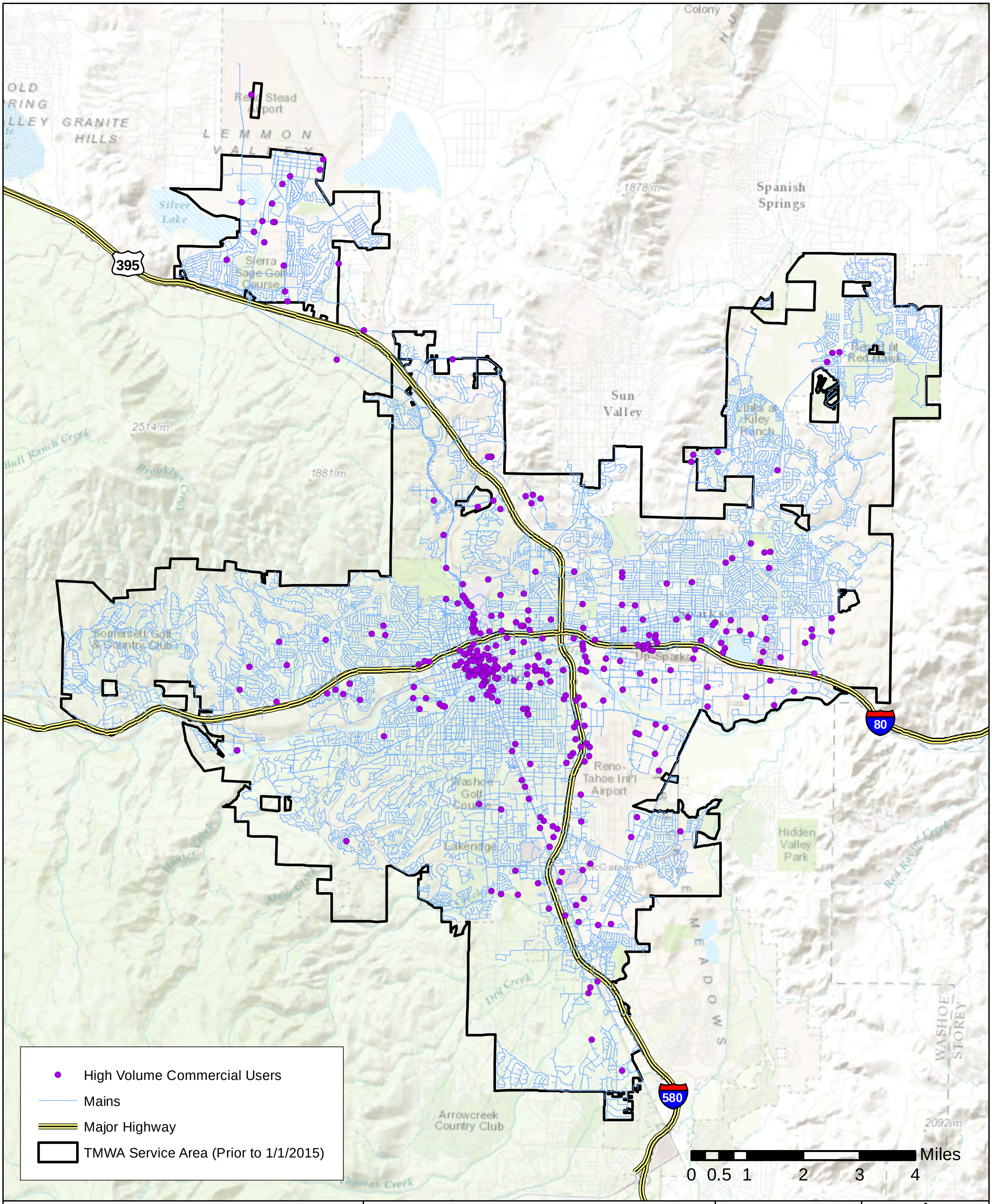
HOMELAND SECURITY INFORMATION

(NRS 239C.210)



TRUCKEE MEADOWS WATER AUTHORITY

Quality. Delivered.

HIGH VOLUME COMMERCIAL USERS

Truckee Meadows Water Authority Service Area

DATE 06/12/2015

MAP BY: JK

REQUESTED BY: LK

SCALE: 1 in = 2 miles

NORTH

NAD 83 NEVADA STATE PLANE WEST FEET

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Appendix L

AWWA Buried No Longer Pipe Replacement Modeling Tool Results

Buried No Longer™

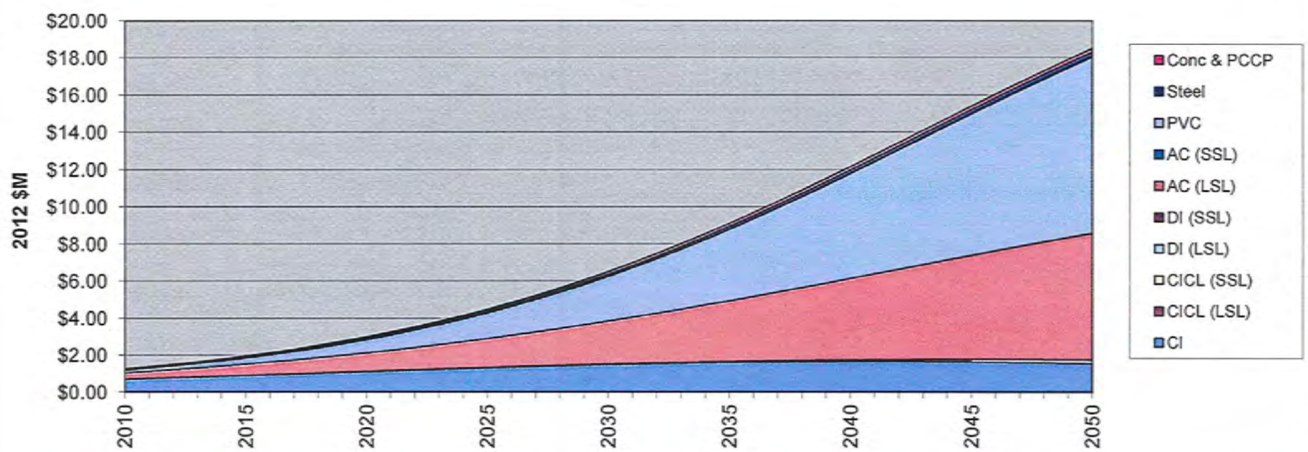
Pipe Replacement MODELING TOOL

- Terms and Conditions
- User Guide
- FAQ
- Buried No Longer Report
- BNL Modeling Tool for Excel 2003
- BNL Modeling Tool for Excel 2007 or later

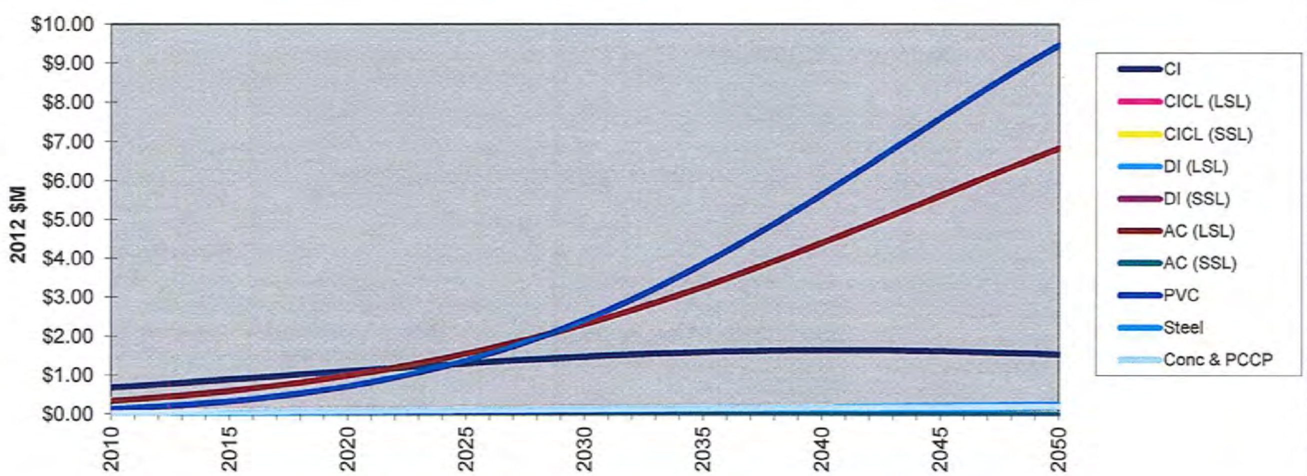
American Water Works Association

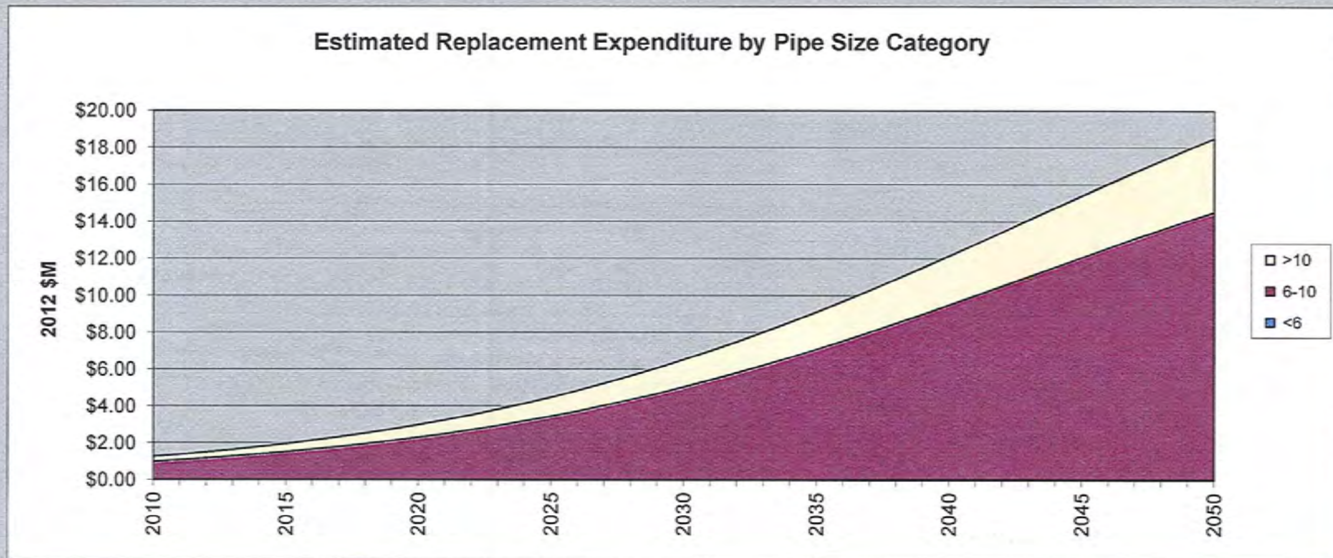
NESSIE MODEL

Estimated Replacement Expenditure by Pipe Material



Estimated Replacement Expenditure by Pipe Material: Comparative




Estimated Replacement Expenditure by Pipe Size Category
2012 $M
$20.00
$18.00
$16.00
$14.00
$12.00
$10.00
$8.00
$6.00
$4.00
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2050
>10
6-10
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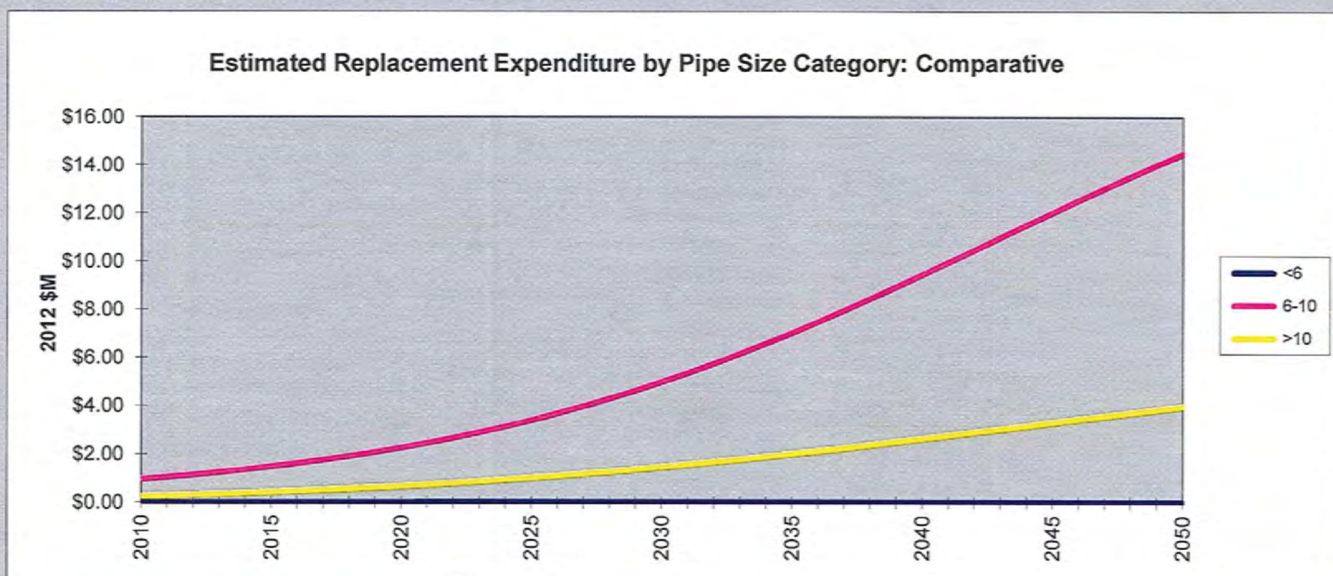
Estimated Replacement Expenditure by Pipe Size Category: Comparative
2012 $M
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$14.00
$12.00
$10.00
$8.00
$6.00
$4.00
$2.00
$0.00
2010
2015
2020
2025
2030
2035
2040
2045
2050
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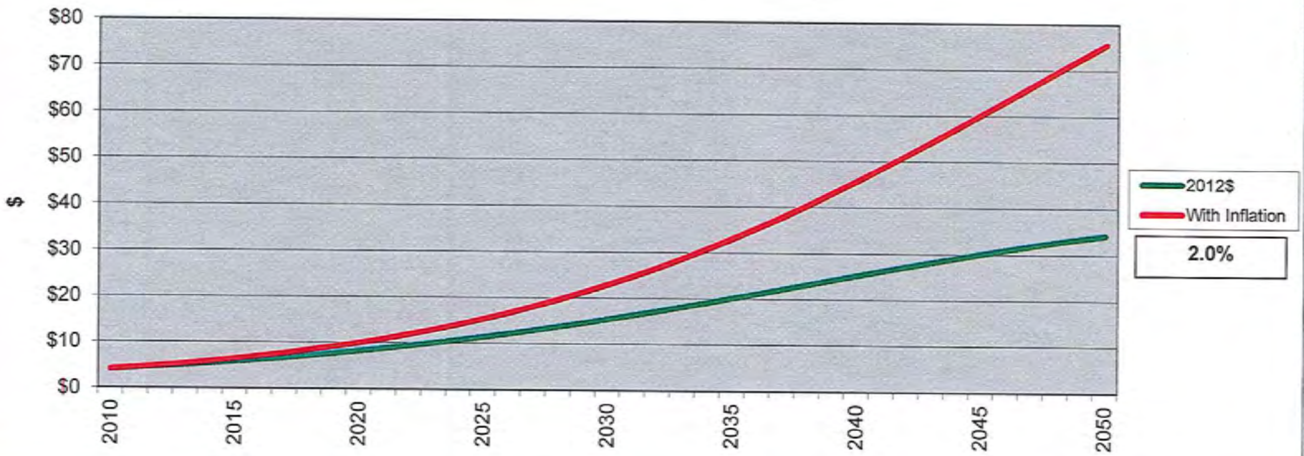
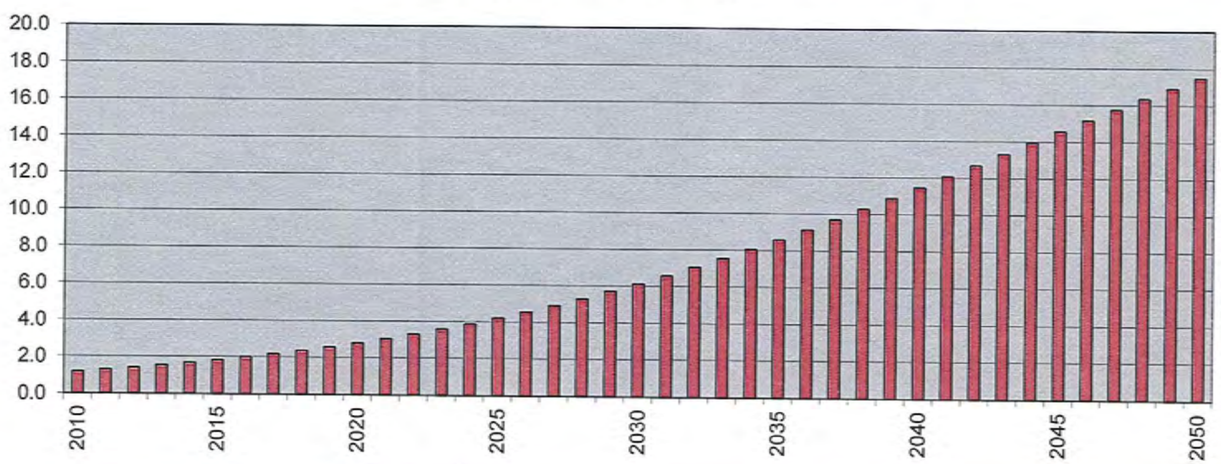
6-10
>10

Estimated Replacement Expenditure per Capita of Population Served



Estimated Replacement in Miles per Year



Pipe Replacement Base Case Input Reference Panel

Mains Network Factors

1920	Commencement Year	Ref. Model Types	Nominated System %
Ref. #	Pipe Material/Size		
1	CI <6	✓	0.0%
2	CI 6–10	✓	6.6%
3	CI >10	✓	0.0%
4	CICL (LSL) < 6	✓	0.0%
5	CICL (LSL) 6–10	✓	0.0%
6	CICL (LSL) >10	✓	0.0%
7	CICL (SSL) < 6	✓	0.0%
8	CICL (SSL) 6–10	✓	0.0%
9	CICL (SSL) >10	✓	0.0%
10	DI (LSL) < 6	✓	0.0%
11	DI (LSL) 6–10	✓	5.0%
12	DI (LSL) >10	✓	4.0%
13	DI (SSL) < 6	✓	0.0%
14	DI (SSL) 6–10	✓	0.0%
15	AC (LSL) < 6	✓	0.0%
16	AC (LSL) 6–10	✓	20.0%
17	AC (LSL) >10	✓	18.7%
18	AC (SSL) < 6	✓	0.0%
19	AC (SSL) 6–10	✓	0.0%
20	PVC < 6	✓	0.0%
21	PVC 6–10	✓	40.0%
22	Steel 6–10	×	3.0%
23	Steel >10	✓	1.7%
24	Conc & PCCP 6–10	×	0.0%
25	Conc & PCCP >10	✓	1.0%
	TOTAL		100.0%

Population Served Adjustment

300,000	Nominated 2010 Population
2.00%	Nominated Population Growth Factor (% of 2010) [Default = N/A]

Cost Adjustment Factors

2.00%	Estimated Annual Rate of Inflation (%)
$175	Local Cost/Linear Foot of 8" ($)
1,340	Local System Length (Miles)

Key Outputs for Population of 300,000

J	Reference Model

Glossary

Region/System Size	Code
Northeast Large	A
Northeast Medium & Small	B
Northeast Very Small	C
Midwest Large	D
Midwest Medium & Small	E
Midwest Very Small	F
South Large	G
South Medium & Small	H
South Very Small	I
West Large	J
West Medium & Small	K
West Very Small	L

System Size Category	Population
Large	> 50,000
Medium	10,000 – 50,000
Small	3,300 – 9,999
Very Small	< 3,300

Pipe Descriptions	
AC	Asbestos Cement
CI	Cast Iron
CICL	Cast Iron Concrete Lined
Conc.	Concrete (incl. Reinforced)
DI	Ductile Iron
PCCP	Prestressed Concrete Cylinder Pipe
PVC	Polyvinyl Chloride*
LSL	Long Service Life (Benign operating conditions and/or enhanced laying practices.)
SSL	Short Service Life (Aggressive operating conditions and/or early laying practices.)
Steel	Steel
*Note	"PVC" used as a 'catch-all' for later pipe types such as Glass Reinforced Plastic (GRP) and High Density Polyethylene (HDPE) which are not expected to impact significantly on replacement in the modeling period.

The Charts

Base Case Review Set
The Base Case outcomes illustrate the predicted levels of expenditure required to meet replacement requirements if current utility practices for main replacement are maintained.

Deferral Review Set
The Deferral outcomes illustrate what impact a deferral of a portion of the expenditure (possibly due to financial constraints) would have, with due regard to a subsequent 'catch-up' period for the water mains replacement program.

1. Estimated Replacement Expenditure by Pipe Material
This stacked chart shows the total expenditure expected each year of the modeling period (in constant 2012 $s) subdivided into the expected contribution by each pipe type.

2. Estimated Replacement Expenditure by Pipe Material: Comparative
This chart shows the same information with respect to the projected expenditure for each pipe type as shown in '1' above, but each pipe type is plotted individually.

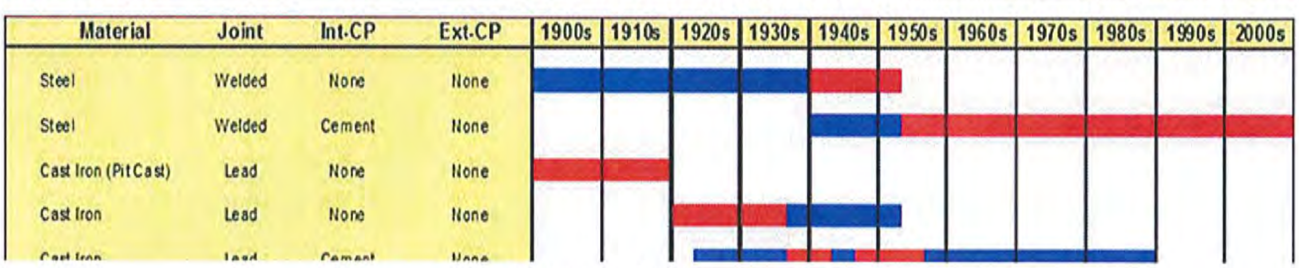
3. Estimated Replacement Expenditure by Pipe Size Category
As per '1' above but subdivided in terms of pipe size categories.

4. Estimated Replacement Expenditure by Pipe Size Category: Comparative
This chart shows the same information with respect to the projected expenditure for each pipe size category as shown in '3' above, but each pipe category is plotted individually.

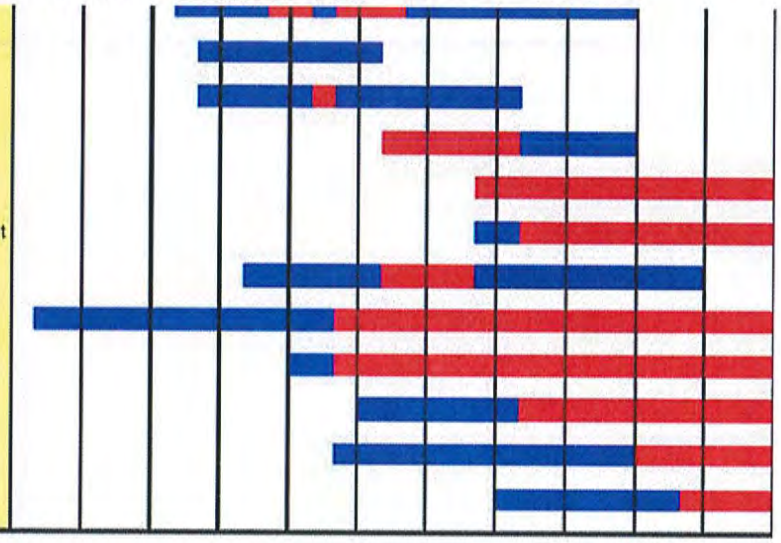
5. Estimated Replacement Expenditure per Head of Population Served
This chart shows expected per capita expenditure on replacement based on the population served; it should not be interpreted as a direct proxy for changes in household bills, as commercial and industrial sector customers are not taken into account.
The expected outcome is presented both in terms of constant 2010 dollars (as is the case for chart types 1–4 above) and what the actual cost would be in each individual year assuming an average annual inflation rate (selected by the user in the "Input" Tab).

6. Estimated Replacement in Miles per Year
Quantifies the expected asset replacement challenge in terms of miles of pipe to be replaced.

Pipe-Material Installation Eras



Cast Iron	Lead	Cement	None
Cast Iron	Leadite	None	None
Cast Iron	Leadite	Cement	None
Cast Iron	Rubber	Cement	None
Ductile Iron	Rubber	Cement	None
Ductile Iron	Rubber	Cement	PE Encasement
Asbestos Cement	Rubber	Material	Material
Reinforced Conc.	Rubber	Material	Material
Prestressed Conc.	Rubber	Material	Material
Polyvinyl Chloride	Rubber	Material	Material
HDPE	Fused	Material	Material
MO PVC	Rubber	Material	Material



Commercially Available
Predominately in Use

Derived Current Service Lives for Installed Mains

Pipe life estimates are based on pipe quality and maintenance practices between 1870 and 1970, not those of pipes purchased and installed today.

Derived Current Service Lives (Years)	CI	CICL (LSL)	CICL (SSL)	DI (LSL)	DI (SSL)	AC (LSL)	AC (SSL)	PVC	Steel	Conc & PCCP
Northeast Large	130	120	100	110	50	80	80	100	100	100
Midwest Large	125	120	85	110	50	100	85	55	80	105
South Large	110	100	100	105	55	100	80	55	70	105
West Large	115	100	75	110	60	105	75	70	95	75
Northeast Medium & Small	115	120	100	110	55	100	85	100	100	100
Midwest Medium & Small	125	120	85	110	50	70	70	55	80	105
South Medium & Small	105	100	100	105	55	100	80	55	70	105
West Medium & Small	105	100	75	110	60	105	75	70	95	75
Northeast Very Small	115	120	100	120	60	100	85	100	100	100
Midwest Very Small	135	120	85	110	60	80	75	55	80	105
South Very Small	130	110	100	105	55	100	80	55	70	105
West Very Small	130	100	75	110	60	105	65	70	95	75

LSL indicates a relatively long service life for the material resulting from some combination of benign ground conditions and evolved laying practices etc.
SSL indicates a relatively short service life for the material resulting from some combination of harsh ground conditions and early laying practices, etc.

TRUCKEE MEADOWS WATER AUTHORITY

APPENDIX 3

FREE TO CHOOSE:

PROMOTING CONSERVATION BY RELAXING OUTDOOR WATERING RESTRICTIONS

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Free to choose: Promoting conservation by relaxing outdoor watering restrictions

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ABSTRACT

Many water utilities use outdoor watering restrictions based on assigned weekly watering days to promote conservation and delay costly capacity expansions. We find that such policies can lead to unintended consequences – customers who adhere to the prescribed schedule use more water than those following a more flexible irrigation pattern. For our application to residential watering in a high-desert environment, this “rigidity penalty” is robust to an exogenous policy change that allowed an additional watering day per week. Our findings contribute to the growing literature on leakage effects of regulatory policies. In our case inefficiencies arise as policies limit the extent to which agents can temporally re-allocate actions.

1. Introduction

Water consumption across the globe has tripled in the last 50 years, and is expected to continue to rise rapidly. Water scarcity is expected to be further exacerbated by global warming via prolonged droughts and increasing system losses (Cromwell et al., 2007). The United Nations predicts that by 2030 almost half of the world’s population will be living in areas of high water stress (World Water Assessment Programme, 2009) and nearly every region in the United States has experienced drought induced water shortages over the last five to ten years (Environmental Protection Agency, 2008). The sustainable provision of water is thus one of the most critical challenges facing policy-makers in both the U.S. and world at

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large. Residential households consume close to two thirds of all publicly supplied water in the United States (Environmental Protection Agency, 2002). On average, approximately 15% of residential use is allocated to landscape and lawn irrigation. However, in the arid west and south this proportion can be as large as 30–35%. In total, an estimated seven billion gallons of publicly provided water are allocated for this purpose daily (Environmental Protection Agency, 2008, 2008). Policy makers and water utilities have thus directed considerable efforts to the management of residential outdoor irrigation. In most cases these efforts focus on outdoor watering restrictions (OWRs) that limit the timing, length, and frequency of sprinkler use.[2]

Such OWRs have been implemented in many areas within and outside the United States. As noted in Table A.9 in Appendix A, most of these regimes limit weekly watering to between one and three assigned days determined by street address. Moreover, most of these regimes (see, e.g., San Antonio or the State of Georgia) follow a paradigm whereby the number of assigned days is reduced under progressively severe drought conditions.

To date, economists have primarily focused on two aspects of OWR policies: (i) the overall impact on water demand, and (ii) the welfare effects for residential consumers. For example, Shaw and Maidment (1987) find that a one-per-five days watering restriction reduced overall demand by 3–5% during the 1984–1985 drought years in Austin, Texas. Renwick and Green (2000) examine monthly consumption for eight California water utilities during the 1985–1992 drought period and find that OWRs of a general nature generated an approximate 30% reduction in use. The second set of studies focus on welfare implications of OWRs and other drought-related water use restrictions. Typically, these studies employ non-market valuation techniques to elicit households' willingness-to-pay (WTP) to avoid such restrictions (Griffin and Mjelde, 2000; Hensher et al., 2006), or an increased risk of future restrictions (Howe and Smith, 1994; Griffin and Mjelde, 2000).

Despite the growing importance of OWRs as a Demand-Side Management (DSM) intervention, surprisingly little is known about the relative performance of different OWR implementation strategies. Given that OWRs vary substantially across communities, such omission is particularly noteworthy. This study seeks to fill this gap in the literature. We examine daily consumption data for thousands of customers in the Reno/Sparks area of Northern Nevada during the 2008 and 2010 summer months. This temporal break affords a unique opportunity to examine an exogenous policy change in OWRs that allowed households an added assigned watering day each week during the 2010 watering season.

Our analysis uncovers an unintended consequence associated with the use of assigned watering schedules – weekly water use and peaks are significantly higher during weeks that include all officially assigned watering days compared to weeks with an equal number of watering days but a more flexible pattern of use. These "rigidity penalties" are substantial, amounting to 20–25% of weekly consumption and 30–40% of weekly peaks for the typical customer. Although the 2010 policy change had a noticeable impact on daily peaks, it had no discernible effect on weekly consumption of the associated "rigidity penalties".

Viewed in its totality, our data call into question the efficacy of OWRs that limit watering to assigned days. In this regard, our analysis extends prior work exploring the unintended consequences of policy actions that either introduce heterogeneity in standards across factories or regions (Felder and Rutherford, 1993; Fowlie, 2009) or nested state and federal regulation (McGuinness and Ellermann, 2008; Goulder and Stavins, 2011; Goulder et al., 2012).[3] Whereas the cited work focuses on leakages that arise through the spatial reallocation of actions, our paper highlights that a similar phenomena can arise if policies limit the extent to which agents can *temporally* reallocate actions. In our setting, adherence to the official water schedule requires households to ignore time-varying conditions such as high wind events that reduce the efficiency of irrigation systems.

2. Empirical background and data

Water provision in the Reno/Sparks urban area is managed by the Truckee Meadows Water Authority (TMWA), a non-profit, community-owned public utility. TMWA first implemented OWRs in 1992 in reaction to a prolonged drought. They became permanent in 1996 to guard against future droughts and assure adequate flows of the Truckee River. The watering regulations allow sprinkler use during the morning and evening of assigned days determined by the last digit of a resident's address.[4] Prior to 2010, the policy allowed households two assigned watering days per week. During the 2010 watering season, the OWR was relaxed and allowed a third weekly watering day. These OWRs are only mildly enforced with infrequent water patrols and nominal fines (up to $75) for repeated violations in the same calendar year.

In 2008 TMWA initiated the collection of daily water consumption data for a large, representative sample of customers. Meter readings were obtained via nightly drive-by's using remote sensing devices. Two teams of readers covered the same

[2] Given the price inelastic nature of water demand, such regulatory interventions are more effective means to influence consumption than price-based policies (Renwick and Green, 2000; Mansur and Olmstead, 2007; Olmstead et al., 2007; Worthington and Hoffman, 2008). Furthermore, there are generally fewer equity concerns and less political resistance to OWRs than to price-based policies (Renwick and Archibald, 1998; Timmins, 2003; Brennan et al., 2007).

[3] Unintended consequences have also been documented in a number of other settings. For example, Davis and Kahn (2010) show that while trade in used vehicles between Mexico and the United States following the passage of NAFTA lowers average vehicle emissions per mile in both countries, aggregate greenhouse gas emissions rise due to lower retirement rates of used cars in Mexico. Bento et al. (2011) show how policy changes in California that allowed single-occupancy, ultra-low emission vehicles access to HOV lanes significantly increased travel times for carpoolers and had no impact on travel times for those in non-HOV lanes.

[4] There are no restrictions on watering via *hand-held* hoses.

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Table 1
Sample sizes for 2008 and 2010.

Intact weeks	2008				2010			
	HHs	%	obs	%	HHs	%	obs	%
5	3567	40.8	17,835	33.9	2084	27.2	10,420	21.5
6	2284	26.1	13,704	26.0	826	10.8	4956	10.2
7	2041	23.3	14,287	27.1	4739	61.9	33,173	68.3
8	855	9.8	6840	13.0	3	0.0	24	0.0
Total	8747	100.0	52,666	100.0	7652	100.0	48,573	100.0

Intact weeks	Overlap[a], 2008				Overlap, 2010			
	HHs	%	obs	%	HHs	%	obs	%
5	679	38.4	3395	31.6	1061	60.1	5305	52.4
6	435	24.6	2610	24.3	121	6.9	726	7.2
7	463	26.2	3241	30.1	584	33.1	4088	40.4
8	189	10.7	1512	14.1	0	0.0	0	0.0
Total	1766	100.0	10,758	100.0	1766	100.0	10,119	100.0

[a] "Overlap" comprises households sampled in both 2008 and 2010.

route for 63 consecutive days between June 22 and August 23, 2008.[5] The same exercise was repeated between June 20 and August 21, 2010 although the routes differed somewhat from the 2008 itineraries due to construction activities.[6]

Overall, we observe approximately 1.9 million daily meter readings from approximately 20,000 unique residential customers. In preparing the final data set, we eliminate premises with ownership changes or multiple ownerships during a given year's research period. We further drop households with a total of 14 or more readings of zero consumption and customers with four or more consecutive zero readings anywhere in the daily series to lower the risk of including non-permanent residences and vacation homes. These cleaning steps truncated the set of eligible residents by approximately 15% for each year.

Given our focus on weekly watering frequencies, only weeks for which we obtain a full set of readings for a given household are usable. Further, to identify a household's watering days and weekly watering patterns, a minimum number of intact weeks (MIW) was required. Yet, to maximize the number of residents present in both sample periods, we had to consider the relationship between the stringency of our MIW criterion and the size of our overlap sample. In balancing these requirements we settle for an MIW threshold of five full weeks of daily readings. After eliminating a few isolated cases with obvious water leaks or missing information on basic building characteristics we generate a final sample that includes 52,666 weekly observations from 8747 residents for 2008 and 48,573 observations from 7652 unique residents for 2010. Of these households, 1766 appear in both the 2008 and 2010 samples and comprise our "overlap" sample. Table 1 shows the distribution of intact weeks for both the full and overlap samples by year.

The top half of Table 2 depicts basic household characteristics for the two full samples. The 2010 sample comprises, on average, slightly smaller and older properties. There is also a 44% decline in average tax-assessed property value from 2008 to 2010 reflecting the severe economic downturn in Nevada over the sample period.

We combine our household data with the following basic climate indicators: average, minimum, and maximum daily temperature (in degF), average wind speed (over 24 hourly measurements, in knots), and maximum sustained wind speed (in knots, measured for ten minutes every hour). As is common in arid high-dessert climates, there were no noteworthy rainfall events during our sampling periods. Climate statistics are shown in the bottom half of Table 2. Although the summer of 2010 was slightly cooler than the summer of 2008, the wind statistics are very similar for the two sampling periods.

3. Identification of policy effects

3.1. Definition of treatments

We aim at identifying the impact of two design features of the Truckee Meadows OWRs on weekly water use and peak (maximum daily consumption in a given week)[7]: (i) the total number of permissible watering days per week and (ii) the

[5] The readings were obtained between the hours of 9pm and 3am. According to TMWA, the vast majority of households complete watering by 9pm.

[6] Drivers were instructed to proceed no slower than the posted speed limit to assure adequate spatial coverage. While this resulted in a large number of customers being included in the sample, it also generated some missing readings due to parked vehicles or other obstacles preventing a clean line-of-sight. Therefore, a completely uninterrupted series of readings is available only for a small subset of the sample.

[7] System-wide consumption peaks are important to utilities as they are closely related to the cost of water provision. Specifically, lower peak demand can be satisfied via stored water, distributed by gravity. Storage units can then be replenished at night at lower pumping costs. In contrast, high peak use

Table 2
Household and climate characteristics.

	2008				2010			
	Mean	Std.	Min.	Max.	Mean	Std.	Min.	Max.
Age	20.9	17.6	1.0	104.0	23.1	16.4	2.0	106.0
Lot size (1000 sqft)	10.1	7.0	0.0	49.7	7.6	3.3	0.0	48.8
Sqft (1000s)	2.0	0.8	0.5	15.2	1.8	0.6	0.5	7.7
Value ($10,000s)	270.5	160.2	69.4	2637.4	150.7	65.6	33.8	762.8
Fixtures	12.0	3.4	0.0	64.0	11.1	2.8	0.0	27.0
Bedrms	3.3	0.9	0.0	23.0	3.2	0.7	0.0	8.0
Bathrms.	2.4	0.7	0.0	16.0	2.2	0.6	0.0	6.0
Avg. temp (F)	77.9	3.3	69.4	84.2	75.8	4.7	61.7	85.4
Min. temp	59.9	3.5	53.1	66.0	58.9	4.8	44.6	69.1
Max. temp	95.7	3.0	89.1	102.0	92.8	5.2	78.8	102.2
Avg. wind (knots)	5.2	1.4	2.8	9.3	5.7	1.3	2.5	8.3
Max. wind	16.2	4.2	7.0	29.9	16.8	4.2	8.9	32.1
Max. gust	23.3	4.1	15.0	30.9	24.5	5.0	14.0	37.9

"pinning" of the allowable number of days to specific days of the week (say, Wednesday, Saturday), versus letting households choose their watering days in a more flexible fashion.

For the former objective, we hypothesize that granting more watering days will induce a more even distribution of weekly irrigation, and thus reduce weekly peaks for the typical household. In addition, this smoother distribution, by reducing the gap between permitted days, may curb losses due to runoff and evaporation, as households are less likely to over-soak their lawn on assigned days.

For the latter objective, we separate weekly watering patterns into three categories: (i) "Schedule" (*S*), (ii) "Schedule-plus" (*SP*), and (iii) "Off-schedule" (*OS*). The first group comprises weeks with watering patterns that correspond *exactly* to the assigned TMWA schedule. The second category describes weeks that include *all assigned days*, plus some additional ("illegal") days of outdoor use. The third group exhibits the most varied weekly watering patterns, with the common feature of *non*-watering on at least one of the assigned days. For ease of exposition we will at times combine the first two groups under the heading "Schedule-based" (SB). Thus, $S \cup SP = SB$, and $SB \cup OS =$ entire sample. This centers the analytical focus squarely on the degree to which the official schedule influences or "guides" irrigation patterns.

We hypothesize that *S* types are nudged inadvertently towards wasteful behavior for two main reasons: First, they face the "large gaps" problem mentioned above, which can lead to over-watering and corresponding losses to runoff and evaporation. Second, adherence to the official schedule requires that such households ignore time-varying natural conditions such as (common) high wind events that can further exacerbate irrigation inefficiency. Both effects are likely to increase weekly consumption and, especially, weekly peaks.

In comparison, *SP* types may be less prone to over-watering, as they distribute weekly irrigation over more-than-permitted days, but may still experience wind losses in their persistence to incorporate the assigned days. In contrast, we surmise that *OS* types pay the least attention to the official schedule, and more attention to their yard's actual water needs and/or random fluctuations in weather conditions. This makes them the most disobedient, but perhaps also the most efficient TMWA customers.

In summary, we set forth to explore whether compliance with Reno's OWR policy introduces unintended consequences that compromise conversation aims. We will henceforth refer to water losses induced by the day-of-week assignment as "*rigidity effect*".

3.2. *Identification strategy*

We have exogenous variation in the number of permitted watering days – the policy change from two to three assigned days between 2008 and 2010. Ideally, we would have also been able to exogenously randomize the flexibility with which a household can allocate these days over the course of a week, i.e. assignment to *S*, *SP*, and *OS* categories. Unfortunately, such exogenous policy variation did not occur during our research period.

Instead, we rely upon an alternate strategy for identification – other exogenous shocks that sort a given household into one type or other in an given week. Conditional on the existence of such shocks we can then exploit both cross-sectional and within household variation in weekly watering patterns to estimate the rigidity effect. This is because there are relatively few customers that follow the same weekly irrigation strategy (*S*, *SP*, or *OS*) for the entire observation period. Most households display a mixed pattern of weekly irrigation, both in terms of frequency and timing. Therefore, identification can draw on both within and between household variation.

forces daytime pumping, when electricity costs are highest. If this occurs frequently, the utility may have to undergo costly capacity expansions for water storage. Therefore, a utility generally tries to implement water use policies that reduce daily peaks at the household level.

The challenge at hand is thus to (i) identify plausible exogenous drivers that induce customers to change watering patterns, and (ii) convincingly rule out confounding effects that could drive both weekly watering patterns and outcomes of interest, i.e. weekly use and peak.

With respect to exogenous factors we provide some evidence in the empirical section that *SB* versus *OS* choices are likely driven by randomly fluctuating daily wind patterns. Specifically, a given household may want to avoid wind-induced water losses – a common problem in this rain shadow/foothill location – by transferring watering events from a windy day to the next calm day. For the Reno/Sparks case this usually means foregoing the evening application and instead watering on the next (potentially unassigned) day. *Inter*-household differences in "wind awareness" or ability to flexibly manipulate irrigation systems then drives much of the observed cross-household variation in adherence to the official schedule. Naturally, some customers may also be intrinsically more reluctant to break the official rules, and may require "stronger wind shocks" to transfer watering to an off-day. This would add additional cross-sectional variation in observed behavior.

In addition, there may be *intra*-household, time-varying differences in the daily ability to react to the threat of irrigation losses due to wind. For example, the entire household or the person in charge of the irrigation system may not be at home or unavailable on a given day to adjust the system. Similarly, on a given day the household may anticipate being unable to irrigate the next morning, and thus be reluctant to skip that day's evening application despite windy conditions. This would explain intra-household variations in the observed weekly irrigation patterns.

Regarding potentially confounding effects, our econometric specification controls for unobserved, invariant household effects, as well as weekly climate conditions. Therefore, the main concern in this respect would be confounding effects that vary both over time and across households. Most notably, one might surmise that whenever a household anticipates a week with high water need, it may switch to a more conservative watering pattern consistent with official regulations to lower the risk of fines. This would confound any causal link between the degree of adherence to the official schedule and water use. This conjecture builds on two underlying assumptions: (i) Households' weekly irrigation needs change from week to week in a heterogeneous fashion and (ii) households care about enforcement and fines. We argue that neither one is very likely.

To start, the most plausible reason that could drive a sudden need to use more water in a given week for *irrigation* purposes would be an extreme climate event, such as the anticipation of a very hot or dry week. Perhaps some households are more vulnerable to such extreme events than others, given vegetation cover, soil quality, and other landscape-related features. However, as is evident from Table 2 the local climate during our summer research period is uniformly hot and dry. There is not a single day of precipitation, and the daily temperature range is quiet narrow. The only variation comes through *daily* and rather random wind patterns, and those cannot be anticipated on a weekly basis. Thus, it is rather unlikely that any given customer experiences pronounced changes in weekly irrigation *demand* over our research period.

In addition, it is equally unlikely that the threat of a penalty would induce customers to switch from a flexible to a compliant weekly pattern, even if such heterogeneous, time-varying changes in water need existed. As stated above, the enforcement of the official watering schedule is very lenient, and fines are nominal. A household receives two warnings for blatant violations before a fine of $75 is issued. Thus, it is rather unlikely that the threat of low fine, collected with low probability, is sufficient to induce a change in behavior, irrespective of weekly water need.

Appendix B provides further evidence against this "comply if anticipated use is high" hypothesis. In summary, we feel confident to proceed with our analysis even in absence of an ideal setting with exogenous policy variation for all treatments of interest.

4. Descriptive analysis

4.1. Classification of weekly irrigation patterns

Establishing a link between consumption and weekly watering patterns requires the identification of outdoor watering events for a given household and day. Specifically, our objective is to sort the daily observations for each household into two categories: (i) days with some outdoor water use and (ii) days with indoor-only water use.

This categorization is challenging since we only observe total daily use rather than usage for different purposes. Ideally, outdoor watering days should be clearly identifiable as pronounced spikes in a customer's series of observed consumption days. However, the distinction between categories becomes blurred for households with limited need for outdoor watering or high fluctuations in indoor use. We therefore use a series of household-specific *K*-means clustering algorithms (MacQueen, 1967) to sort daily observations into a low use ("indoor only") and high use ("indoor plus some outdoor watering") category. The details of this identification strategy are given in Appendix B.

4.2. Descriptive results

Our analysis of OWR design effects requires aggregating the daily sample to a weekly format. Table 3 provides a summary of cell counts and sample percentages for the different week-type categories and watering frequencies. For ease of exposition

Table 3
Cell counts and percentages by watering frequency and week-type.

Weekly watering days	2008			2010		
	Count	% of sample	% all w/in	Count	% of sample	% all w/in
Schedule-based						
2[a]	14,497	27.5	42.8	–	–	–
3[b]	6374	12.1	9.2	12,625	26.0	35.1
4	5595	10.6	16.1	3650	7.5	3.3
>4	6053	11.5	11.6	6001	12.4	15.7
Total	32,519	61.7	25.8	22,276	45.9	24.7
Off-schedule						
0	2924	5.6	0.0	2822	5.8	0.0
1	4198	8.0	1.6	3979	8.2	0.9
2	4795	9.1	5.5	8004	16.5	9.9
3	4257	8.1	7.4	6256	12.9	8.4
4	2610	5.0	6.1	3518	7.2	7.4
>4	1363	2.6	6.5	1718	3.5	2.5
Total	20,147	38.3	4.4	26,297	54.1	6.3
All						
0	2924	5.6	0.0	2822	5.8	0.0
1	4198	8.0	1.6	3979	8.2	0.9
2	19,292	36.6	35.5	8004	16.5	9.9
3	10,631	20.2	9.0	18,881	38.9	28.9
4	8205	15.6	13.2	7168	14.8	5.4
>4	7416	14.1	10.8	7719	15.9	12.9
Total	52,666	100.0	18.5	48,573	100.0	15.8

[a] "Schedule" group for 2008.
[b] "Schedule" group for 2010.

we combine *S* and *SP* weeks into the broader *SB* category, as defined above.[8] The sparsely populated weekly frequencies of five and higher are captured as a single ">4" category. The first half of the table shows results for 2008, while the second provides summaries for 2010. The table has three blocks of rows, corresponding to *SB* weeks, *OS* weeks, and the combined sample. The "percent of sample" column relates row counts to the entire sample size for each year. For example, *SB* weeks with twice watering (i.e. the *S* group by our definition above) comprise 27.5% of the entire 2008 sample. Overall, watering patterns that are perfectly compliant with the official schedule comprise the largest sample share and account for just over a quarter of all sample weeks.

The "percent all within" column reports the percentage share for a given row count that corresponds to households that have *all* their observations in that very category. For example, approximately 42.8% of the observations in the *S* category for 2008 come from households that *always* water twice and on their assigned days. Yet, the majority of customers exhibit seasonal water patterns that include a mix of different week-types and frequencies – only 18.5% of sample weeks in 2008 and 15.5% in 2010 are associated with customers that always water with the same weekly frequency. This is important for our analysis below as it suggests that the observed differences in use and peaks between SB and OS *week*-types are *not* driven by unobserved household characteristics.

Table 4 depicts weekly use and peak by frequency and week-type. We stress three key results captured by this table. First, regardless of watering pattern, consumption increases with weekly frequency. This is consistent with prior work showing that capping weekly watering frequency reduces total use. Second, peaks remain relatively stable across frequencies in the two to four applications range. Third – and most importantly – weekly consumption and peaks are substantially higher for weeks that include all assigned days ("schedule-based") compared to weeks *of identical frequency* with more flexible watering patterns ("off-schedule"). In 2008, these differences amount to 30–40% for weekly consumption and 50–60% for weekly peak. In 2010 these differentials are slightly attenuated amounting to 25–30% for use and 24–26% for peak.[9]

[8] We stress that our classification into different watering patterns applies to a given *household-week*, not a specific *household* across the entire research period. As discussed in the next section, the majority of households switches frequently between weekly watering patterns. Therefore, there does not exist a clear and systematic classification at the household level that distinguishes along this key dimension of decreasing schedule-adherence. However, we do control for observable and unobservable household characteristics in our econometric specification.

[9] The patterns captured in Tables 3 and 4 are qualitatively similar for the overlap sample. Consumption is approximately 25–35% higher for the *SB* group than the *OS* group at all frequencies. Similarly, *SB* peaks exceed*OS* peaks by 45–55%. Summary statistics for the overlap sample are available from the authors upon request.

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Table 4
Weekly use and peak by watering frequency and week-type.

Weekly watering days	Weekly use (1000 gals.)				Weekly peak (1000 gals.)			
	2008		2010		2008		2010	
	Mean	Std.	Mean	Std.	Mean	Std.	Mean	Std.
	Schedule-based				*Schedule-based*			
2	5.84	(3.67)	–	–	2.34	(1.68)	–	–
3	6.72	(4.56)	5.39	(2.44)	2.30	(1.85)	1.65	(0.83)
4	7.24	(5.04)	5.95	(2.89)	2.19	(1.86)	1.67	(0.96)
>4	9.83	(7.73)	7.32	(4.41)	2.43	(2.26)	1.70	(1.14)
Total	6.99	(5.26)	6.00	(3.26)	2.32	(1.86)	1.66	(0.95)
	Off-schedule				*Off-schedule*			
0	2.44	(2.20)	2.03	(1.52)	0.55	(0.48)	0.46	(0.34)
1	3.38	(2.61)	2.73	(1.85)	1.30	(1.29)	1.04	(0.94)
2	4.20	(3.20)	3.82	(2.23)	1.46	(1.39)	1.37	(0.98)
3	4.80	(3.61)	4.32	(2.58)	1.42	(1.28)	1.31	(0.95)
4	5.52	(4.64)	4.75	(3.00)	1.47	(1.47)	1.31	(1.04)
>4	6.99	(5.80)	5.65	(4.53)	1.67	(1.63)	1.37	(1.24)
Total	4.26	(3.71)	3.83	(2.71)	1.30	(1.32)	1.20	(0.99)
	All				*All*			
0	2.44	(2.20)	2.03	(1.52)	0.55	(0.48)	0.46	(0.34)
1	3.38	(2.61)	2.73	(1.85)	1.30	(1.29)	1.04	(0.94)
2	5.43	(3.63)	3.82	(2.23)	2.12	(1.65)	1.37	(0.98)
3	5.95	(4.31)	5.03	(2.54)	1.95	(1.70)	1.53	(0.89)
4	6.69	(4.98)	5.36	(3.01)	1.96	(1.78)	1.49	(1.01)
>4	9.31	(7.50)	6.95	(4.49)	2.29	(2.18)	1.63	(1.17)
Total	5.95	(4.91)	4.82	(3.17)	1.93	(1.75)	1.41	(1.00)

5. Econometric framework

To examine if these descriptive results hold up when controlling for climate variations, household characteristics, and unobserved household effects we now turn to our econometric analysis. We assume that over the course of a week a given household makes daily choices on watering occurrence and total use, given watering. From the analyst's perspective these choices will be observed as joint weekly outcomes on frequency, use, and peak. We thus define such an *observed* weekly irrigation scheme (*IR*) by household i in period p as a bundle of frequency y_{1ip} (zero to seven), total use y_{2ip}, weekly peak y_{3ip}, and schedule-based pattern (*SB* vs. *OS*), i.e.

$$IR_{ip} = IR(y_{1ip}, y_{2ip}, y_{3ip}, SB_{ip}), \quad i = 1, \ldots, N, \ p = 1, \ldots, P \tag{1}$$

where SB_{ip} is an indicator equal to one if the weekly irrigation pattern corresponds to a schedule-based implementation, and equal to zero for an off-schedule pattern.

Thus, we have three outcomes of interest – y_{1ip}, y_{2ip}, and y_{3ip}. The first outcome, the number of watering days in a given week, takes the form of an integer that is naturally truncated from above at $U=7$. The remaining outcomes, weekly consumption and peak, are continuous with support over $\mathfrak{R}^+$. We wish to identify the effect of weekly watering frequency and degree-of-adherence to the OWR on use and peak. If household decisions on use and peak were completely independent from decisions related to weekly frequency, the three outcomes of interest could, in theory, be analyzed via independent estimation. For example, the use and peak equations could be estimated via simple random effects (RE) regression that includes difference-in-difference type interaction terms to capture the incremental effects of weekly frequency, irrigation pattern (*SB* vs. *OS*) and policy change (2008 vs. 2010).

However, if the frequency equation shares common unobservables with either or both of the use or peak equation, such naïve independent analysis would produce misleading results, as the right-hand-side variable "frequency" would introduce endogeneity problems. We find this to indeed be the case in comparative estimation runs.[10] Thus, a plausible econometric model for this application must accommodate the following key features: (i) limitations on the natural range of the dependent variable, (ii) household-specific effects to control for unobserved heterogeneity, and (iii) an ex-ante unrestricted covariance matrix for these unobserved effects, i.e. full correlation of all three equations. To incorporate these modeling challenges in a computationally tractable fashion we deviate from a standard linear regression framework and classical estimation, and turn instead to a hierarchical system approach, estimated via Bayesian tools.

[10] The results for these RE regressions and a discussion thereof are provided in Appendix E.

As point of departure, we combine a truncated Poisson density for the watering frequency equation with two exponential densities for weekly consumption and peak [see e.g. Munkin and Trivedi, 2003].[11] Adding the household effects yields our full specification, which we label the Hierarchical Truncated Poisson–Exponential (HTPE) model. The Hierarchical Truncated Poisson (HTP) component of the HTPE is given as

$$\begin{aligned} &f(y_{1ip}|\lambda_{1ip}, 0 \le y_{1ip} \le U) = \frac{\exp(-\lambda_{1ip})\lambda_{1ip}^{y_{1ip}}}{y_{1ip}!(\sum_{k=0}^{U} \lambda_{1ip}{}^{k}/k!)} \quad \text{with} \\ &E(y_{1ip}) = \lambda_{1ip} = \exp(\mathbf{x}_{1ip}{}'\boldsymbol{\beta}_1 + u_{1i}) \end{aligned} \tag{2}$$

where the log of the untruncated expectation, λ_{1ip}, is a linear function of vector $\mathbf{x}_{ip}$ containing household and climate variables, and individual-specific effect u_{1i}.[12]

The Hierarchical Exponential (HE) part is specified as

$$\begin{aligned} &f(y_{jip}|\lambda_{jip}) = \lambda_{jip} \times \exp(-\lambda_{jip} y_{jip}) \\ &\lambda_{jip} = \exp(-\mathbf{z}_{jip}{}'\boldsymbol{\psi}_j - \mathbf{d}_{ip}{}'\boldsymbol{\delta}_j - u_{ji}) \\ &E(y_{jip}) = \lambda_{jip}^{-1} = \exp(\mathbf{z}_{jip}{}'\boldsymbol{\psi}_j + \mathbf{d}_{ip}{}'\boldsymbol{\delta}_j + u_{ji}), \quad j = 2, 3 \end{aligned} \tag{3}$$

where the $\mathbf{z}$-vectors capture again household and climate information, the random terms are as in (2) and E denotes the expectation operator. Importantly, vector $\mathbf{d}_{ip}$ comprises a set of U indicator variables, one for each possible value of y_{1ip} that exceeds zero. The element of $\mathbf{d}_{ip}$ corresponding to the observed value of y_{1ip} is set to one, all others to zero. More concisely:

$$d_{ip,k} = \begin{cases} 1 & \text{if } y_{1ip} = k, \\ 0 & \text{otherwise} \end{cases} \quad k = 1, \ldots, U \tag{4}$$

Thus, we are allowing the intercept of the logged expectation of y_{jip}, $j = 2, 3$, to shift with the observed number of watering days compared to the implicit baseline of zero outdoor watering. This implies a proportional change of $exp(\mathbf{d}_{ip}{}'\boldsymbol{\delta}_j)$ for the expectation in absolute terms.

The model is completed by stipulating a joint density for the household effect:

$$\mathbf{u}_i = [u_{i1} \quad u_{i2} \quad u_{i3}]' \sim mvn(\mathbf{0}, \mathbf{V}_u) \tag{5}$$

where mvn denotes the multivariate normal density, and the variance matrix is ex ante unrestricted. As mentioned above, if this matrix contains non-zero covariances, a naïve model ignoring the linkage across the three equations would be plagued by endogeneity bias, since the frequency indicator $\mathbf{d}_{ip}$ appears on the right hand side of both the use and peak equation.[13]

Letting $\boldsymbol{\beta}_2 = [\boldsymbol{\psi}_2{}' \quad \boldsymbol{\delta}_2{}']'$, $\boldsymbol{\beta}_3 = [\boldsymbol{\psi}_3{}' \quad \boldsymbol{\delta}_3{}']'$, $\boldsymbol{\beta} = [\boldsymbol{\beta}_1{}' \quad \boldsymbol{\beta}_2{}' \quad \boldsymbol{\beta}_3{}']'$, and collecting all outcomes and explanatory data in vector $\mathbf{y}$ and matrix $\mathbf{X}$, respectively, the likelihood function for our model over all individuals $i = 1, \ldots, N$, unconditional on error terms, takes the following form:

$$p(\mathbf{y}|\boldsymbol{\beta}, \mathbf{V}_u, \mathbf{X}) = \prod_{i=1}^{N} \int_{\mathbf{u}_i} \left(\prod_{p=1}^{P} \left(\frac{\lambda_{1ip}^{y_{1ip}}}{y_{1ip}!(\sum_{k=0}^{U} \lambda_{1ip}{}^{k}/k!)} \lambda_{2ip}\lambda_{3ip} \exp(-(\lambda_{2ip} y_{2ip} + \lambda_{3ip} y_{3ip})) \right) \right) f(\mathbf{u}_i|\mathbf{V}_u) d\mathbf{u}_i \tag{6}$$

Given the N multi-dimensional integrals over $\mathbf{u}_i$ this model would be challenging to estimate using conventional Maximum Likelihood procedures. We therefore employ a Bayesian estimation framework.

We begin by specifying the prior distribution for the primary model parameters, $\boldsymbol{\beta}$ and $\mathbf{V}_u$. We choose a standard multivariate normal prior for $\boldsymbol{\beta}$, and inverse Wishart (IW) priors for $\mathbf{V}_u$, i.e. $\boldsymbol{\beta} \sim mvn(\boldsymbol{\mu}_0, \mathbf{V}_0)$, $\mathbf{V}_u \sim IW(\psi_0, \boldsymbol{\Psi}_0)$. The IW parameters are the degrees of freedom and scale matrix, respectively. The IW density is parameterized such that $E(\mathbf{V}_u) = (\psi_0 - k_r - 1)^{-1}\boldsymbol{\Psi}_0$. We facilitate the implementation of our posterior simulator (Gibbs Sampler) by augmenting the model with draws of the error components $\{\mathbf{u}_i\}_{i=1}^{N}$.[14] The augmented posterior distribution is proportional to the priors times the augmented likelihood, i.e.

$$p(\boldsymbol{\beta}, \mathbf{V}_u, \{\mathbf{u}_i\}_{i=1}^{N}, |\mathbf{y}, \mathbf{X}) \propto p(\boldsymbol{\beta}) \times p(\mathbf{V}_u) \times p(\{\mathbf{u}_i\}_{i=1}^{N}||\mathbf{V}_u) \times p(\mathbf{y}|\boldsymbol{\beta}, \{\mathrm{u}_i\}_{i=1}^{N}, \mathbf{X}) \tag{7}$$

[11] The exponential component has similar distributional characteristics as the familiar log-normal regression model, but exhibits more desirable mixing properties in our Bayesian estimation framework.

[12] It should be noted that the restrictive mean–variance equality that is a prominent feature of the standard Poisson density no longer holds under truncation (e.g. Rider, 1953). A second reason for the mean–variance equality to break down is the inclusion of the random household effect. See, for example Hausman et al. (1984).

[13] We also included an observation-specific error in an earlier specification. The parameter estimates generated by that model were virtually identical to those produced by the single-error specification, and both variances and covariances associated with the observational error emerged of negligible magnitude compared to the variance component for the individual-level effect.

[14] The data augmentation step circumvents the need to directly evaluate the integrals in (6). A general discussion of the merits of this technique of data augmentation is given in Tanner and Wong (1987). Applications with data augmentation involving hierarchical count data models include Chib et al. (1998) and Munkin and Trivedi (2003).

Table 5
Estimation results for frequency equation and error terms.

	Mean	Std.	Prob(>0)
Constant	−4.415	(0.519)	0.000
mintemp	−0.050	(0.050)	0.161
maxtemp	0.151	(0.048)	0.999
avgwind	−0.988	(0.281)	0.000
maxwind	0.407	(0.134)	1.000
gdd	0.022	(0.012)	0.958
lnland	0.087	(0.007)	1.000
lnvalue	0.237	(0.010)	1.000
year2010	4.129	(0.731)	1.000
mintemp × 2010	−0.198	(0.064)	0.001
maxtemp × 2010	−0.395	(0.086)	0.000
avgwind × 2010	0.760	(0.295)	0.997
maxwind × 2010	−0.281	(0.139)	0.019
gdd × 2010	0.061	(0.019)	0.999
Std.'s and corr.'s for $\mathbf{u}_i$			
σ_1	0.434	0.004	1.000
ρ_{12}	0.056	0.014	1.000
σ_2	0.477	0.005	1.000
ρ_{13}	−0.005	0.014	0.364
ρ_{23}	0.985	0.001	1.000
σ_3	0.527	0.005	1.000

Mean = posterior mean; std. = posterior standard deviation; prob(>0) = share of posterior density to the right of zero.

where the last term describes the likelihood function conditioned on all error terms.

The Gibbs Sampler draws consecutively and repeatedly from the conditional posterior distributions $p(\boldsymbol{\beta}|\{\mathbf{u}_i\}_{i=1}^N, \mathbf{y}, \mathbf{X})$, $p(\mathbf{V}_u|\{\mathbf{u}_i\}_{i=1}^N)$, and $p(\{\mathbf{u}_i\}_{i=1}^N|\boldsymbol{\beta}, \mathbf{V}_u, \mathbf{y}, \mathbf{X})$. Draws of $\boldsymbol{\beta}$ and $\{\mathbf{u}_i\}_{i=1}^N$ require Metropolis–Hastings (MH) subroutines in the Gibbs Sampler. Posterior inference is based on the marginals of the joint posterior distribution.[15]

6. Estimation results

6.1. Posterior results

The regressors in the parameterized expectation of the frequency equation include a combination of home characteristics and climatic variables to control for temperature and wind speed, in addition to an indicator for the 2010 irrigation season and the interaction of this indicator with the various climate variables. The parameterized mean functions for use and peak include additional home characteristics that control for indoor water use and exclude some of the climate variables for identification purpose. These equations also feature indicators for weekly watering frequency, the interaction of these terms with indicators for the 2010 watering season and schedule based weekly watering patterns, and the two-fold interaction of the schedule based and 2010 indicators with both our frequency variables and different wind measures.[16]

We estimate all models using the following vague but proper parameter settings for our priors: $\boldsymbol{\mu}_0 = 0$, $\mathbf{V}_0 = 100 \times I_k$, $\psi_0 = 5$, and $\boldsymbol{\Psi}_0 = I_3$. We discard the first 20,000 draws generated by the Gibbs Sampler as "burn-ins", and retain the following 10,000 draws for posterior inference. We assess convergence of the posterior simulator using Geweke's (1992) convergence diagnostics (CD). These scores clearly indicate convergence for all parameters. To gauge the degree of serial correlation in our Markov chains we also compute autocorrelation coefficients at different lags for all model parameters. These AC values drop below 0.25 by the 10th lag for most parameters, and by the 20th lag for all model elements. This indicates that our posterior simulator has reasonably efficient mixing properties.

The posterior results for the frequency equation are shown in Table 5. The table also captures the results for the elements of the error variance matrix $\boldsymbol{\Sigma}$, expressed as standard deviations and correlations. For each parameter we report posterior means, posterior standard deviations, and the probability mass of a given marginal posterior that lies above the zero-threshold. The effects of our various climatic controls are as expected. For example, the frequency of weekly watering events is higher on weeks with higher maximum daily temperatures and lower on weeks with higher average daily wind speeds. Interesting, however, the effect of such controls are attenuated for the 2010 season. Taken jointly, our data thus suggest that climate conditions have a more pronounced effect on the variability of watering frequency when the official OWR ceiling is lower.

Turning to the elements of $\boldsymbol{\Sigma}$ in the lower half of Table 5, we note that with exception of ρ_{13} all terms are estimated with high precision (i.e. exhibit low posterior standard deviation relative to the mean). The standard deviations (labeled σ_j, $j = 1$,

[15] The detailed steps of the posterior simulator and the Matlab code to implement this model are available from the authors upon request.
[16] Details on household and climate regressors are provided in Appendix D.

Table 6
Estimation results for use and peak equations.

	Weekly use			Weekly peak		
	Mean	Std.	Prob(>0)	Mean	Std.	Prob(>0)
Constant	−10.766	(0.773)	0.000	−12.706	(0.766)	0.000
freq1	0.392	(0.025)	1.000	0.883	(0.026)	1.000
freq2	0.584	(0.025)	1.000	0.980	(0.026)	1.000
freq3	0.720	(0.026)	1.000	0.989	(0.027)	1.000
freq4	0.821	(0.029)	1.000	0.992	(0.031)	1.000
freq567	0.967	(0.036)	1.000	1.048	(0.036)	1.000
SB × freq2	0.208	(0.066)	1.000	0.379	(0.068)	1.000
SB × freq3	0.197	(0.066)	0.999	0.334	(0.068)	1.000
SB × freq4	0.179	(0.068)	0.995	0.307	(0.071)	1.000
SB × freq567	0.200	(0.071)	0.999	0.233	(0.072)	0.999
year2010	0.185	(0.740)	0.593	−0.178	(0.730)	0.403
freq1 × 2010	−0.010	(0.036)	0.393	−0.009	(0.036)	0.385
freq2 × 2010	0.034	(0.035)	0.837	0.073	(0.035)	0.978
freq3 × 2010	0.045	(0.036)	0.895	0.071	(0.036)	0.977
freq4 × 2010	0.053	(0.041)	0.901	0.092	(0.041)	0.990
freq567 × 2010	0.038	(0.049)	0.786	0.064	(0.048)	0.909
SB × freq3 × 2010	−0.052	(0.144)	0.361	−0.257	(0.147)	0.039
SB × freq4 × 2010	−0.049	(0.146)	0.357	−0.244	(0.150)	0.049
SB × freq567 × 2010	−0.041	(0.147)	0.395	−0.200	(0.151)	0.088

Results for household and climate variables are omitted for brevity, but are given in Appendix D. Mean = posterior mean; Std. = posterior standard deviation; Prob(>0) = share of posterior density to the right of zero.

. . ., 3) are of non-negligible magnitude, which confirms the presence of unobserved household effects in all three equations. Household unobservables are highly correlated for equations two and three, and we find a mild, positive correlation between the frequency and the use equations.[17]

Posterior results for the weekly use and peak equations are summarized in Table 6. Regarding weekly use, the table captures three main results. First, consumption increases clearly with weekly frequency. Furthermore, this result remains essentially unchanged in 2010. Second, weeks associated with schedule-based (*SB*) watering exhibit increased use compared to the implicit off-schedule (*OS*) baseline at *any* frequency. These rigidity penalties amount to 20–23%, and are highest for weeks that follow the official schedule exactly.[18] Third, controlling for frequency and watering pattern, the residual policy effect is of negligible magnitude.

The results for weekly peak are given in the last three columns of the table. In contrast to use, peaks do not change much over frequency in either year. However, as for use, peaks are substantially larger for *SB*-type weeks compared to *OS*-type patterns in 2008, and this difference is greater at lower frequency levels. This gap diminishes in 2010, as peaks for *SB*-type implementations decrease by 18–23% compared to the 2008 season, and peaks for *OS*-types increase slightly (by 6–9%). The reduction in the “rigidity penalty” for peaks in 2010 compared to 2008 likely reflects the additional flexibility afforded to compliant customers by the revised OWRs. Schedule-adherent households now have more options to reduce daily watering on windy days and are less likely to face the dilemma of incurring wind losses or violating official rules by making up for a skipped application on non-assigned days.

However, we also acknowledge that to some extent this reduction in rigidity gap, especially via increased peaks for *OS*-types, might be an artifact of our classification scheme: Some 2010 customers may have been sluggish to adjust to the new schedule. As a result, the “rigid” weeks produced by these residents, classified as *SB* in 2008, are counted as *OS*-types in 2010.[19] As such, our estimates can be interpreted an upper bound on the effect of the policy change on the rigidity penalty for peak use.

The remaining findings for the peak model mirror those from the weekly use equation: namely, there are no noteworthy residual policy effects. Overall, we conclude that the results produced by our complete econometric specification support the descriptive findings from the preceding section.

[17] As illustrated in the Appendix E, this linkage via unobservables between equations one and two is sufficient to produce inconsistent parameter estimates for both use and peak models if the system is estimated via independent random effects regressions.

[18] We use the conversion formula of $\exp(\beta) - 1$ suggested by Halvorsen and Palmquist (1980) to interpret marginal effects associated with binary variables, given the log-normal form of the parameterized mean function.

[19] Recall that every *SB* designated week must include outdoor use on *all* assigned days. Hence, any 2008 schedule-adherent household who fails to adjust to the new OWRs by watering on the third allowable day and switching to the new assigned week-days during 2010 would produce *OS*-type weeks for that year – even if there was no change in the actual watering pattern relative to the 2008 season.

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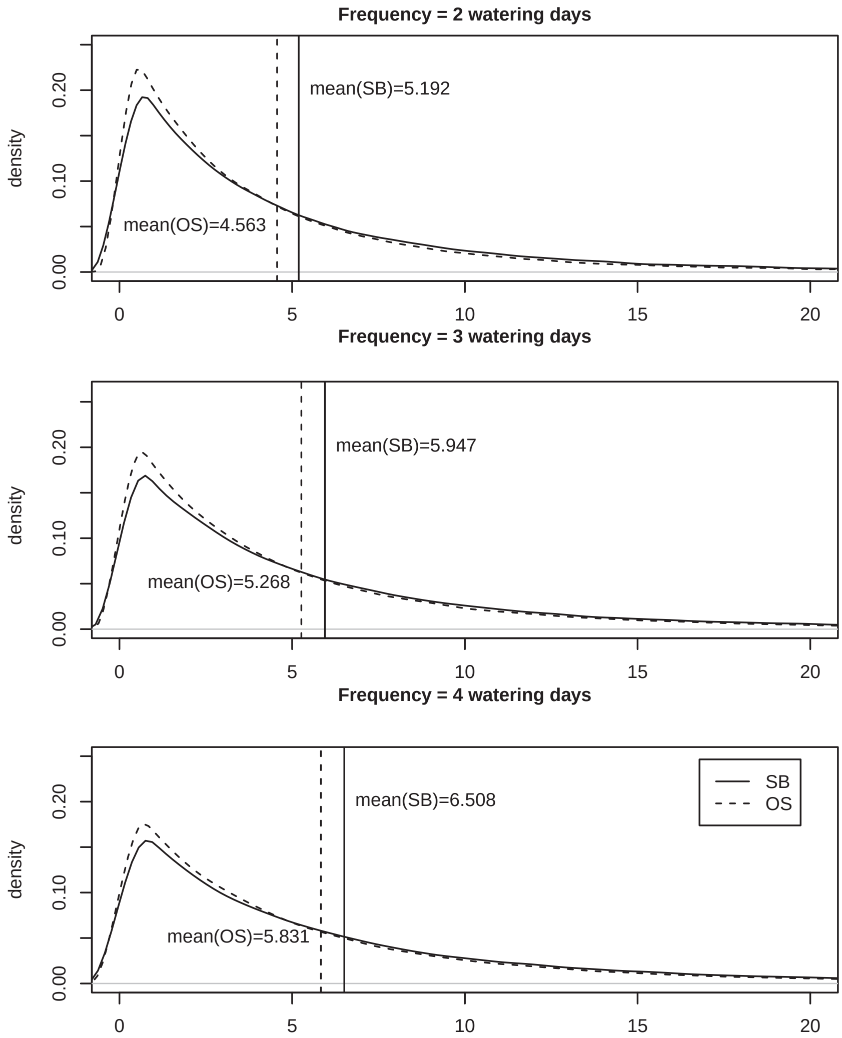

Fig. 1. Predictive distributions of weekly use for a typical household (1000 gallons).

6.2. Predictive analysis

For a more direct comparison of weekly consumption and peak across weeks with different watering patterns we generate posterior predictive densities (PPDs) for each irrigation type (*SB* vs. *OS*). Formally, these PPDs are given as

$$p(y_j|\mathbf{x}_{\mathrm{tf}}) = \int_{\boldsymbol{\theta}} \Big(\int_{u_{ij}} ((y_j|\mathbf{x}_{\mathrm{tf}}, \boldsymbol{\beta}, u_{ji}) f(u_{ji}|\mathbf{V}_u)) du_{ij}) \Big) p(\boldsymbol{\theta}|\mathbf{y}, \mathbf{X}) d\boldsymbol{\theta}, \quad j = 2, 3, \tag{8}$$

where $\mathbf{x}_{\mathrm{tf}}$ denotes a specific combination of watering pattern $t \in \{SB, OS\}$ and frequency $f \in \{2, 3, 4\}$, and vector $\boldsymbol{\theta}$ comprises the entire set of model parameters. In practice, we simulate these PPDs by (i) drawing 10 random coefficients from $f(u_{ji}|\mathbf{V}_u)$), (ii) computing λ_{ij} for each u_{ij} as given in (2), and (iii) drawing y_j from the exponential density with expectation λ_{ij}. We repeat steps (ii) and (iii) for all 10 draws of u_{ij}, and steps (i) through (iv) for all 10,000 draws of $\boldsymbol{\theta}$ from the original Gibbs Sampler.

Except for the combination $t = SB$, $f = 2$, which is only meaningful for 2008, we derive separate PPDs for $y_j|\mathbf{x}_{\mathrm{tf}}$ for 2008 and 2010 by setting the 2010 indicator and interaction terms accordingly in the covariate matrix for the use and peak equations. We combine these year-specific PPDs for final analysis as there is discernible difference in watering behavior across these years once we control for climatic and household specific variables. The latter are set to their grand sample means for this predictive analysis.

The resulting PPDs are depicted in Fig. 1 for use and Fig. 2 for peak. Each subplot shows PPDs for *SB* and *OS* types for a given frequency. Posterior predictive expectations are superimposed as vertical lines and labeled with their respective numerical value (in 1000 gallons). As is evident from Fig. 1, the *SB* pattern produces higher expected use than the *OS* pattern

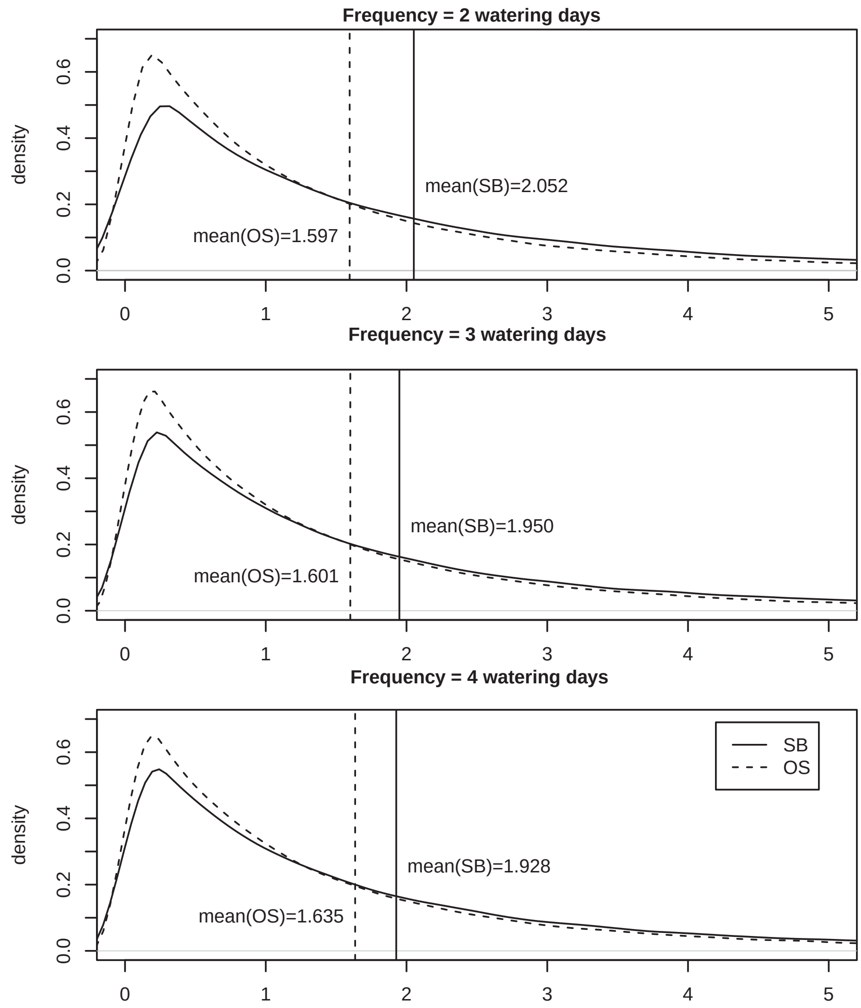

Fig. 2. Predictive distributions of weekly peak for a typical household (1000 gallons).

at all frequencies, with a slightly decreasing relative gap from 14% at $f=2-12\%$ at $f=4$. As shown in Fig. 2 these differences in posterior predictive expectation are even more pronounced for peak. At two watering days, the *SB* pattern generates a peak that is approximately 28% higher than the *OS* peak. At three watering days, this difference reduces to 22%, and at a frequency of four it amounts to close to 18%. Overall, these predictive results support our descriptive and analytical findings – a watering pattern that closely follows the officially assigned days produces noticeably higher weekly consumption and substantially higher peaks than a more flexible distribution of *the same number of watering days* across a given week.

7. The wind effect

As mentioned at the onset, we believe that the assignment of household-weeks into different watering patterns is largely driven by exogenous shocks in the form of high wind events. Specifically, some customers switch to more flexible irrigation patterns to avoid wind-induced water losses. Conversely, households that follow the assigned schedule are more likely to water under adverse natural conditions such as high wind events. This increases both use and peak, as it takes more water per week and per daily application to provide adequate irrigation for a given landscape.

To explore this conjecture in greater detail, we compute the percentage of watering days that fall on either a windy or very windy day.[20] The results are captured in Table 7. In 2008 the average watering day had a 51% chance of occurring on a windy day and an 18% chance of coinciding with a very windy day. Importantly, these percentages are higher for the *SB* group compared to the *OS* segment at essentially all frequencies. In 2008, this difference is especially pronounced for the

[20] “Windy days” are those with a maximum sustained wind speed that exceeds the sample mean (16.51 knots). “Very windy” days are defined as those with a maximum sustained wind speed at the 75th percentile (19 knots) or higher.

Table 7
Wind events by watering frequency and week type.

Weekly watering days	2008		2010		All	
	% windy	% very windy	%windy	% very windy	%windy	% very windy
Schedule-based						
2	57.02	21.40	–	–	57.02	21.40
3	52.32	19.50	48.82	18.09	50.00	18.57
4	52.21	19.37	48.58	17.66	50.78	18.69
>4	46.75	15.29	47.09	17.34	46.92	16.32
Total	51.71	18.58	48.08	17.72	50.06	18.19
Off-schedule						
2	50.68	19.08	47.73	18.38	48.83	18.65
3	48.65	16.60	46.94	17.67	47.63	17.24
4	49.51	17.18	46.99	17.25	48.07	17.22
>4	47.40	15.14	46.58	16.42	46.94	15.85
Total	49.14	17.09	47.11	17.57	47.94	17.37
All						
2	55.44	20.82	47.73	18.38	53.18	20.11
3	50.85	18.34	48.20	17.95	49.15	18.09
4	51.35	18.67	47.80	17.46	49.70	18.11
>4	46.86	15.27	46.99	17.16	46.93	16.23
Total	51.00	18.17	47.70	17.66	49.35	17.91

Table 8
Random effects probit estimation of daily watering decision (translated into marginal effects).

2008				2010			
	Coeff.	s.e.	*z*		Coeff.	s.e.	*z*
	Weekly frequ. = 2 (n = 135,044)						
Windy	0.074	0.004	17.870				
Windy × SB	0.049	0.004	12.070				
Avg. temp.	0.011	0.000	25.190				
	Weekly frequ. = 3 (n = 74,417)				*Weekly frequ. = 3 (n = 132,167)*		
Windy	0.033	0.005	6.290	Windy	0.003	0.004	0.670
Windy × SB	0.053	0.005	9.900	Windy × SB	0.013	0.004	3.030
Avg. temp.	0.005	0.001	8.380	avg. temp.	0.001	0.000	2.730
	Weekly frequ. = 4 (n = 57,435)				*Weekly frequ. = 4 (n = 50,176)*		
Windy	0.055	0.006	8.510	Windy	0.000	0.006	0.070
Windy × SB	0.053	0.006	8.430	Windy× SB	0.016	0.006	2.470
Avg. temp.	0.009	0.001	12.310	avg. temp.	0.001	0.000	1.450

S category – the share of windy days exceeds the correponding value for *OS*/twice a week by over 6%. In general, *SB* type weeks were 3–6% more likely to occur on a windy day and 2–3% more likely to fall on a very windy day than *OS* type weeks of comparable frequency. In 2010, which had slightly fewer windy days overall compared to 2008, the difference in the relative frequency of wind events across week-types reduces to 1–2% for windy days and falls below the 1% mark for very windy days. However, as for 2008, the *S* category experiences the highest risk of wind exposure.

To provide more rigorous support for this “wind hypothesis” we estimate a Probit models of *daily* watering decision on average daily temperature (F), an indicator for “windy day” (with max. sustained speed exceeding the sample mean of 16 knots), an interaction term for “windy” and “SB”, and a random household effect. We estimate separate models for the two sample years, and weekly frequencies of 2, 3, and 4 watering days.

The results are captured in Table 8. For ease of interpretation, the estimated coefficients are presented as marginal effects, conditional on a random effect of zero. As can be seen from the table, in 2008 the probability of a observed watering day to coincide with above-average wind conditions is approximately 5% higher for an “SB” type HW compared to an “OS” type. This difference shrinks to 1–3% in 2010, but is still significant. Thus, the Probit estimates pair up well with our descriptive insights in supporting the conjecture that wind events may well be the main driver of the observed variability in weekly watering patterns, and associated differences in use and peaks across irrigation types.[21]

[21] Irrigation losses due to wind can easily amount to 40–50% in arid climates, even under moderate wind speeds of 10 mph (8–9 knots) or less (Bauder, 2000; Duble, 2013). Naturally, these losses are further exacerbated if even the water that hits the ground completely misses its target, which is a common occurrence for the relatively small yards in our research area.

8. Conclusion

This study is the first to examine how the *design* of outdoor watering restrictions impacts residential water use at the houehold level. Using a unique, customer specific data set of daily consumption over multiple irrigation seasons that include an inter-season policy change, we arrive at several important and novel findings. Most centrally, both the cap on weekly frequency *and* the address-based assignment of specific watering days matter for conservation outcomes. While the former is confirmed to be necessary for curbing consumption, the latter undermines conservation goals.

We find that higher frequencies unambiguously translate into higher weekly use. However, we uncover an unintended consequence of OWRs with days-of-week assignments: weekly use and peak are higher the more closely a given households follows the assigned schedule. These "rigidity penalties" are substantial and amount to approximately 20–25% of weekly consumption and 30–40% of weekly peaks.

The policy change from two to three assigned days per week produced two main effects. First, it induced the intended switch in watering patterns for a considerable segment of customer-weeks. Second, we observe a pronounced reduction in peaks at the system-wide level – an effect driven predominantly by lower peaks for schedule-based weeks. In contrast, overall weekly use changes little in reaction to the new policy.

For policy-makers, our results suggest that adjusting existing OWRs to allow for flexible watering patterns could produce substantial water savings at relatively low implementation costs. Moreover, as inefficiency penalties are highest at low frequencies, our findings also cast doubt on the effectiveness of policies that reduce the number of assigned days under progressively severe drought conditions. In such situations, a frequency reduction combined with a "free-to-choose" policy is likely to promote greater conservation. Naturally, violations of allowed weekly frequencies would be more difficult to detect under such a policy, since permissible applications would no longer be pegged to a given day-of-week for a given address. However, the fact that many current customers adhere – at least loosely – to the official regulations despite weak enforcement by the utility suggests that social norms and "neighborly supervision" may be stronger drivers of compliance than officially posted fines. These norms would still be in force under more flexible policies, as nearby neighbors can easily keep track of other households' weekly watering frequency.

Our analysis extends prior work exploring the unintended consequences of nested policies, and those that introduce heterogeneous standards across firms and/or regions. Whereas the extant literature focuses on leakages generated by the spatial reallocation of effort, our paper highlights another channel through which leakages may arise – by hampering the temporal reallocation of effort. In our setting, adherence to the official watering schedule requires households to ignore time-varying weather patterns that reduce the efficacy of outdoor watering.

It is easy to envision other domains where similar patterns could arise. For example, many utilities have explored time-of-day pricing as a means to manage residential energy consumption and associated greenhouse gas emissions. To the extent that such pricing schemes cause a shift in demand from peak to non-peak hours, the overall impact on carbon could fall short of expectations as the marginal fuel source during peak hours is often less carbon intensive than base load generators (the marginal fuel source during non-peak periods). The identification of such temporal leakages and the design of policies that are robust to such unintended consequences should provide ample opportunities for future research.

Appendix A. Outdoor watering restrictions in the United States

See Table A.9.

Appendix B. Evidence against confounding effects

If there were any other time-varying factors that drive water need in a heterogeneous fashion we should see pronounced variation over time in the fraction of different watering types. Table B.10 shows, for each week of our research period, the number of households included in the sample, and the percentage of watering types. The last two columns of the table capture the two types we use in our empirical model, *SB* and *OS*. For additional insight, we also show the percentage, of the total sample, of perfectly compliant types, or *S* types (which are nested within *SB*). We further split these *S* types into the percentage of household-weeks (HWs) that come from households that *always* follow the schedule (labeled as "always" in the table), and the remaining share of HWs contributed by "occasional" perfect compliers (labeled as "occ") in the table.

As can be seen from the table, there are no pronounced shifts in the proportion of type assignments over time. This puts in question the proposition that a substantial share of *OS* types become *SB* types due to a systematic weekly shock that affects water need. Table 2 in the main text and Table B.10 combined also show that the hottest weeks in 2008 (week 3) and 2010 (week 4) do *not* produce the highest proportion of *S* or *SB* types in the overall watering pattern.

It is also obvious from Table B.10 that perfectly compliant HWs, or *S* types constitute the minority of *SB* types in any given week. Most HWs that are *SB* have a watering pattern that adds one or more days to the official schedule. In other words, they are already cheating to some extent. Throughout our analysis we compare *SB* types and *OS* types *conditional on the same weekly frequency*. This means that an *OS* type cheats just slightly more than an *SB* type of the same frequency. Therefore, the probability of detection and fines should not be all that different between the two types.

Furthermore, if the "behave to avoid fines when water needs are high" conjecture were to hold, we would expect to see higher use for *S* types compared to one-off *SB* types. For example, in 2008, an *S* type would water exactly twice. We can then

Table A.9
Examples of cities with outdoor watering restrictions (as of June 1, 2010).

City	Population (1000s)	Utility	Restriction period	Time-of-day restrictions	Days per week restrictions for sprinklers	Assigned watering days for sprinklers	Other restrictions	Special rules for manual watering
CALIFORNIA								
Los Angeles	4095	L.A. Dept. of Water and Power	Ongoing, since June 2009, year-round	No watering 9am–4pm	2 days/week	Mo, Thu only, all addresses	15 min. max. runtime per cycle	None
San Diego	1376	The City of San Diego	Ongoing since June 1, 2009, restrictions change across seasons	No watering 10am–6pm	3 days/week	Assigned by address	10 min. max. run-time per cycle	No restrictions on run-time
Fresno	505	City of Fresno	Ongoing, restrictions change across seasons	No watering 6am–7pm	3 days/week	Assigned by address	Restrictions on landscaping (no bluegrass)	None
Long Beach	495	Long Beach Water	Ongoing	No watering 9am–4pm	3 days/week	Mo, Thu, Sat only, all addresses	10 min. max. run-time per cycle	None
NEVADA								
Las Vegas	478	Las Vegas Valley Water District	Ongoing, since 2002, restrictions change across seasons	No watering 11am–7pm (summer only)	3 days/week (spring, fall only)	Assigned by address	None	Allowed any time, any day
Reno/Sparks	419	Truckee Meadows Water Authority	Ongoing, since 1996, summer only	No watering noon to 6pm	3 days/week[a]	Assigned by address	None	Allowed any time, any day
COLORADO								
Denver	555	Denver Water	May 1–Oct. 1	No watering 10am–6pm	None	N/A	No watering during strong winds or rain; limitations on run-time per cycle	None
TEXAS								
Dallas	1189	Dallas Water Utilities	April 1–Oct. 31	No watering 10am–6pm	None	N/A	No watering during rain	Allowed any time, any day
San Antonio	1145	San Antonio Water System	Year-round (severity of restrictions based on aquifer level)	No watering 10am–8pm	1 day/week ("Stages 1, 2")	Assigned by address	None	Allowed any time, any day
Austin	657	Austin Water	Ongoing, since Nov.21, 2009	No watering 10am–7pm	2 days/week	Assigned by address	None	Allowed any time, any day
GEORGIA								
Entire State placed under non-drought schedule as of June 1, 2010	9829	Environmental Protection Division	Ongoing, since June 1, 2010 (restrictions become more severe during declared drought)	None	3 days/week	Assigned by address	None	None
FLORIDA								
Jacksonville	835	St. John's River Water Management District	Ongoing, restrictions change across seasons	No watering 10am–4pm	2 days/week (summer schedule)	Assigned by address	60 min. max. run-time per cycle	None
Miami	391	Miami-Dade Water and Sewer Department	Ongoing, year-round	No watering 10am–4pm	2 days/week (summer schedule)	Assigned by address	None	Allowed daily for 10 min.
Tampa	331	City of Tampa Water Department	Ongoing, year-round	No watering 10am–6pm	1 day/week	Assigned by address	Only one cycle allowed per day	Same as sprinkler rules for lawns, else unrestricted

[a] 2 days 1996–2009, 3 days as of 2010.

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Table B.10
Percentages of watering types over time.

		S				
Week	Sample	Always	occ.	Total	SB	OS
2008						
1	8468	12%	15%	28%	60%	40%
2	8270	13%	16%	29%	61%	39%
3	8572	12%	16%	28%	64%	36%
4	2488	9%	15%	24%	58%	42%
5	3163	9%	15%	25%	60%	40%
6	5825	10%	16%	26%	59%	41%
7	7774	12%	17%	29%	62%	38%
8	7235	12%	14%	26%	66%	34%
9	871	14%	16%	30%	63%	37%
2010						
1	5765	9%	14%	24%	38%	62%
2	7338	9%	15%	24%	43%	57%
3	1853	9%	15%	24%	47%	53%
4	7317	9%	17%	26%	48%	52%
5	7420	9%	18%	27%	48%	52%
6	6074	9%	19%	28%	50%	50%
7	5512	9%	18%	27%	44%	56%
8	7294	9%	18%	27%	47%	53%

SB = schedule-based (all assigned days are used); OS = off-schedule (not all assigned days are used); S = schedule-exact, perfect compliance; S/always = from households that always show perfect compliance; S/occ. = from households that occasionally show perfect compliance.

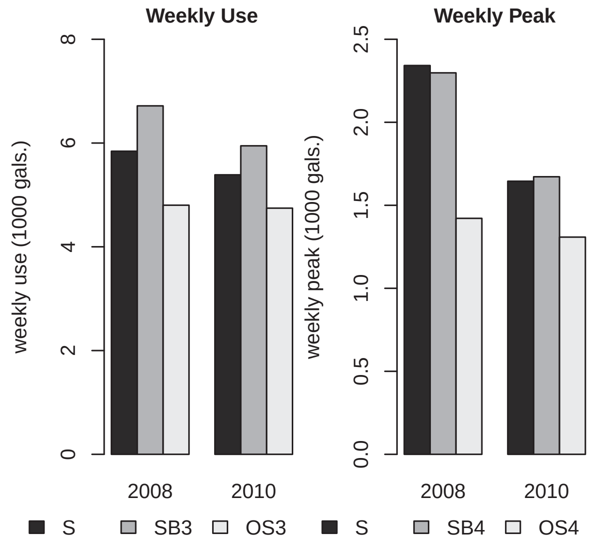

Fig. 3. Weekly use and peak for *S* and "one-off" types.

compare the resulting weekly use to that of an $SB-3$ type that uses one additional day. In the same vein, we can compare an *S* type for 2010 (3 allowable watering days) to an $SB-4$ type. In both cases we would expect use to increase under the *S* regime under the conjecture.

However, as is evident from Fig. 3, the one-off *SB* types use *more* water than perfect compliers and have comparable peaks to *S* types in both years. This picture is more consistent with the notion that when a households needs more water, it simply adds an additional day. This directly contradicts the "revert to *S* when need is high" hypothesis.

Appendix C. Identification of outdoor watering days

Our identification of outdoor watering days thus proceeds in the following steps:

1. We start with a simple *K*-means clustering algorithm (MacQueen, 1967) at the household level to classify each day as a "high use" or "low use" occurrence. Our objective is to confidently interpret high use days as days with outdoor irrigation, and low-use days as days with strictly non-irrigation consumption. We use six different clustering algorithms. The first

three are based on actual daily use, the second set of three on logged use.[22] Within each set, the first algorithm uses the Euclidean distance between observation points and the current pair of cluster centroids as a sorting criterion, the second uses Euclidean distance squared, and the third absolute distance (Vinod, 1969; Massart et al., 1983). In each case we use the mean consumption on assigned and unassigned days, respectively, as starting values for the cluster centroids.

We find that within each triplet all three algorithms agree on sorting for every single observation in both the 2008 and 2010 data sets. This indicates robustness to the choice of similarity measure, which is reassuring. As expected, the versions based on logged use, which are less sensitive to outliers and thus lower the threshold for observations to fall into the higher category, identify about 10–15% more observations as watering days than the versions based on actual use in gallons in each data set.

However, *all six versions* are in complete agreement for all daily observations associated with 1644 (18.8%) of households in 2008, and 890 households (11.7%) in 2010. These are likely customers that exclusively water via automated sprinkler systems, producing very pronounced differences in usage between irrigation and non-irrigation days. Within these subgroups, the sorting into watering and non-watering days perfectly aligns with *assigned* watering days for 604 (6.9%) of customers in 2008, and 422 (5.5%) of customers in 2010. For these households we can be especially confident that the observations flagged as non-watering days truly and exclusively capture indoor, or non-irrigation, use. In the following, we label these households as “Full Agreement, Full Compliance” (FAFC) cases.

An inspection of sample statistics on basic building and lot characteristics assures us that these FAFC cases are not systematically different in measurable ways from the remainder of the data set.[23] Thus, we deem them suitable as a representative sub-sample that provides reliable and important information on non-irrigation use.

2. Our next goal is to utilize information on winter use and the fact that the Reno/Sparks climate precludes any water use for outdoor irrigation during the cold season to validate the cluster analysis results. Specifically, using available data on monthly consumption during the January-March period preceding our summer data collections, we compute *average daily winter use* and the ratio of daily summer use to average daily winter use for each household in both data sets. Focusing again on the FAFC observations, we then inspect the sample distribution of this ratio for unassigned days. For 2008, the mean and standard deviation for this ratio amount to 2.3 and 2.4, respectively. For 2010, the mean equals 1.85, and the standard deviation is 1.7. According to TMWA, indoor use is higher in summer for the typical household due to factors such as a larger average daily household size as school and college-age children spend more time at home, a higher level of outdoor and athletic activities, increasing water use for drinking, cleaning, laundry, and showers, increased use for the watering of indoor plants, and water use for cooling units. The lower average for 2007 is likely due to the slightly cooler summer that year, as described in the main text.
3. We interpret the above results as indicative of the typical household in the Reno/Sparks area consuming approximately twice as much water per day for non-irrigation purposes in summer than in winter. Based on the standard deviations for the FAFC segment given above, we would further expect daily non-irrigation use *for any household* not to exceed a ratio to winter use in excess of $3 \times 2.4 = 7.2$ in 2008 and of $3 \times 1.7 = 5.1$ in 2010.
4. For our final classification step we generally adopt the cluster analysis results based on absolute use, but we recode all observations flagged as “non-watering” days that exceed the three-standard deviation thresholds given above as “watering days”. This results in 19,479 changes (8.2% of observations originally flagged as non-watering) for the 2008 data, and 17,818 changes (8.6% of observations originally flagged as non-watering) for the 2010 set. These recoded observations are likely associated with households that employ some *daily* baseline watering system, as mentioned above. Due to the latency of the baseline irrigation the cluster analysis fails to identify these non-sprinkler days as irrigation days. Adding information on winter use to our analysis allows us to correct this shortcoming.

Appendix D. Details on econometric specification and results

The household and climate regressors in the frequency equation are: log of lot size in square feet (“lnland”), log of tax-assessed land value (“lnvalue”), the weekly average of, respectively, daily minimum and maximum temperature (“mintemp”, “maxtemp”), the weekly average of daily average wind in knots (“avgwind”), the weekly average of maximum daily sustained wind (“maxwind”), and total weekly growing degree days (“gdd”). For a given calendar day, the latter is computed as (maximum daily temperature + minimum daily temperature)/2 − 50. All climate indicators are measured in units of 10 for a more balanced scaling of the regressor matrix.

Equations two (weekly use) and three (weekly peak) include the additional home features log of square footage (“lnsf”), number of bedrooms, number of water fixtures, and age plus age squared. The dropped climate variables (for identification purpose) are “mintemp”, “maxtemp”, and “gdd”.

The full results for equations two and three are given in Table D.11.

[22] We add an increment of one gallon to each zero-usage observation before taking logs

[23] These comparison tables are available from the authors upon request

Table D.11
Estimation results for use and peak equations, Bayesian model.

	weekly use Mean	Std.	Prob(>0)	weekly peak Mean	Std.	Prob(>0)
Constant	−10.766	(0.773)	0.000	−12.706	(0.766)	0.000
freq1	0.392	(0.025)	1.000	0.883	(0.026)	1.000
freq2	0.584	(0.025)	1.000	0.980	(0.026)	1.000
freq3	0.720	(0.026)	1.000	0.989	(0.027)	1.000
freq4	0.821	(0.029)	1.000	0.992	(0.031)	1.000
freq567	0.967	(0.036)	1.000	1.048	(0.036)	1.000
SB × freq2	0.208	(0.066)	1.000	0.379	(0.068)	1.000
SB × freq3	0.197	(0.066)	0.999	0.334	(0.068)	1.000
SB × freq4	0.179	(0.068)	0.995	0.307	(0.071)	1.000
SB × freq567	0.200	(0.071)	0.999	0.233	(0.072)	0.999
lnland	0.389	(0.010)	1.000	0.439	(0.011)	1.000
lnsf	0.170	(0.033)	1.000	0.154	(0.036)	1.000
lnvalue	0.294	(0.028)	1.000	0.344	(0.030)	1.000
fixtures	−0.002	(0.003)	0.324	−0.005	(0.004)	0.079
bedrooms	0.042	(0.009)	1.000	0.032	(0.009)	1.000
age	0.218	(0.011)	1.000	0.280	(0.012)	1.000
age2	−0.020	(0.001)	0.000	−0.025	(0.002)	0.000
avgtemp	0.051	(0.081)	0.735	−0.007	(0.079)	0.470
avgwind	−0.070	(0.453)	0.442	−0.064	(0.462)	0.453
maxwind	0.050	(0.184)	0.615	0.008	(0.188)	0.506
avgwind × SB	−0.222	(0.563)	0.349	0.002	(0.575)	0.500
maxwind × SB	0.032	(0.199)	0.567	−0.058	(0.204)	0.386
year2010	0.185	(0.740)	0.593	−0.178	(0.730)	0.403
freq1 × 2010	−0.010	(0.036)	0.393	−0.009	(0.036)	0.385
freq2 × 2010	0.034	(0.035)	0.837	0.073	(0.035)	0.978
freq3 × 2010	0.045	(0.036)	0.895	0.071	(0.036)	0.977
freq4 × 2010	0.053	(0.041)	0.901	0.092	(0.041)	0.990
freq567 × 2010	0.038	(0.049)	0.786	0.064	(0.048)	0.909
SB × freq3 × 2010	−0.052	(0.144)	0.361	−0.257	(0.147)	0.039
SB × freq4 × 2010	−0.049	(0.146)	0.357	−0.244	(0.150)	0.049
SB × freq567 × 2010	−0.041	(0.147)	0.395	−0.200	(0.151)	0.088
avgtemp × 2010	−0.025	(0.082)	0.391	0.016	(0.080)	0.583
avgwind × 2010	0.333	(0.486)	0.76	0.515	(0.500)	0.848
maxwind × 2010	−0.109	(0.187)	0.258	−0.143	(0.192)	0.240
avgwind × SB × 2010	−0.020	(0.063)	0.372	−0.033	(0.065)	0.304
maxwind × SB × 2010	0.010	(0.021)	0.688	0.021	(0.021)	0.837

mean = posterior mean; std. = posterior standard deviation; prob(>0) = share of posterior density to the right of zero.

Appendix E. Independent random effects regressions

If the random household effects were not correlated across the three equations, the parameters in the use and peak models could in theory be consistently estimated via simple, independent random effects regressions. For the coefficients in the mean function consistency in such a naïve independent framework would hold even if equations two and three were correlated, as long as their respective correlations with equation one is truly zero. This is because the dependent variable of equation one, weekly watering frequency, enters the other two equations on the right hand side (in form of binary indicators), and would thus cause endogeneity problems if there existed a link between equation one and the other two models via the unobservable household effects.

From Table 5 in the main text we see that ρ_{13} is negligible with large posterior uncertainty, but ρ_{12}, while small, is positive and estimated with relatively high precision. To examine to what extent ignoring this correlation would affect parameter estimates, we run two independent random effects (RE) regressions for weekly use and peak with the exact same regressors as in our Bayesian Hierarchical Exponential (HE) models. The dependent variables are in log-form.

If endogeneity is not an issue, the two frameworks, Bayesian HE, and classical RE, should produce asymptotically identical results for the following reasons: (i) both are based on the same log-linear parameterized mean function, which assures the same interpretation for marginal effects, (ii) the normal density, which forms the basis for the RE regressions, and the exponential density which underlies the HE model, are both in the family of linear exponential distributions. Therefore, a mis-specification of the (combined) variance of error terms in the likelihood function should not affect consistency of coefficient estimates in the parameterized mean function [see e.g. Cameron and Trivedi, 2005, ch. 5], and (iii) while the RE regression has an additional normally distributed idiosyncratic error, both preliminary runs of an expanded Bayesian model and the RE results indicate that the variance of that error term is small compared to the variance of the household effect.[24] Finally, with over 100,000 observations, we would expect good asymptotic properties from both frameworks.

[24] The RE output indicates that 82–86% of total error variability is assigned to the household effect.

Table E.12
Estimation results for the independent RE regressions.

	Weekly use Mean	Std.	Weekly peak Mean	Std.
Constant	−8.039	(0.255)***	−10.186	(0.301)***
freq1	0.457	(0.006)***	0.870	(0.008)***
freq2	0.669	(0.006)***	0.980	(0.008)***
freq3	0.818	(0.007)***	1.026	(0.008)***
freq4	0.935	(0.008)***	1.056	(0.009)***
freq567	1.076	(0.009)***	1.118	(0.011)***
SB × freq2	0.101	(0.015)***	0.186	(0.019)***
SB × freq3	0.099	(0.015)***	0.151	(0.019)***
SB × freq4	0.089	(0.016)***	0.116	(0.019)***
SB × freq567	0.136	(0.016)***	0.093	(0.020)***
lnland	0.426	(0.009)***	0.482	(0.009)***
lnsf	0.258	(0.027)***	0.266	(0.030)***
lnvalue	0.134	(0.019)***	0.176	(0.022)***
fixtures	0.005	(0.003)***	0.001	(0.003)
bedrooms	0.021	(0.007)***	0.012	(0.008)
age	0.019	(0.001)***	0.025	(0.001)***
age2	0.000	(0.000)***	0.000	(0.000)***
avgtemp	0.011	(0.002)***	0.007	(0.002)***
avgwind	−0.026	(0.011)***	−0.020	(0.013)
maxwind	0.015	(0.004)***	0.010	(0.005)*
avgwind × SB	−0.014	(0.013)	−0.003	(0.016)
maxwind × SB	0.002	(0.004)	−0.003	(0.006)
year2010	0.530	(0.174)***	0.288	(0.215)
freq1 × 2010	−0.004	(0.009)	0.007	(0.011)
freq2 × 2010	0.013	(0.009)	0.040	(0.011)***
freq3 × 2010	0.015	(0.009)	0.045	(0.011)***
freq4 × 2010	0.026	(0.010)**	0.063	(0.013)***
freq567 × 2010	0.006	(0.012)	0.031	(0.015)**
SB × freq3 × 2010	−0.002	(0.033)	−0.164	(0.041)***
SB × freq4 × 2010	−0.005	(0.034)	−0.147	(0.042)***
SB × freq567 × 2010	−0.009	(0.034)	−0.128	(0.042)***
avgtemp × 2010	−0.007	(0.002)***	−0.004	(0.002)*
avgwind × 2010	0.043	(0.012)***	0.051	(0.014)***
maxwind × 2010	−0.019	(0.005)***	−0.021	(0.006)***
avgwind × SB × 2010	−0.021	(0.015)	−0.027	(0.018)
maxwind × SB × 2010	0.009	(0.005)**	0.016	(0.006)***

* significant at the 10% level.
** significant at the 5% level.
*** significant at the 1% level.

Table E.12 depicts the full results for the RE regressions. Comparing these results to the posterior means in Table 1, we see that the RE models systematically under-estimate the incremental increase in use and peak at any frequency for SB-type weeks (variables “SB × freq2” through “SB × freq567”). Expressed in percentage terms, this bias is of considerable magnitude, ranging from 7 to 11% for use and 15 to 21% for peak.

Furthermore, the RE models estimates pure policy effects for use peak (“year2010”) that are 30–40% larger, respectively, than the small effects produced by the correlated Bayesian system.

Finally, the RE model under-estimates the reduction in peak for SB-types compared to 2008 (“SB × freq3 × 2010” through “SB × freq567 × 2010”) by approximately 5%. We thus conclude that the additional complexitities in estimation from switching to a fully correlated triple-equation system are justified for our application.

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APPENDIX 4

LANDSCAPE CODES:

FINDINGS AND RECOMMENDATIONS

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STAFF REPORT

TO: **Chairman and Board Members**
FROM: **Laine Christman**
DATE: **January 12, 2016**
SUBJECT: **Report on review of Reno, Sparks and Washoe County landscape and water conservation ordinances and discussion, action and direction to staff on recommendations to local governments for landscape and water conservation ordinance amendments**

Discussion: In August 2004, Truckee Meadows Water Authority's ("TMWA") staff examined the landscape ordinances of local governments and provided recommendations regarding changes to those ordinances to increase water conservation. In July of 2005, a staff report was produced on the findings and recommendations of that analysis. See the Appendix for details of this report.

As directed by TMWA's Board, in April of 2015 municipal landscaping ordinances were reexamined by staff to determine what changes had been made concerning landscaping in new and existing developments. Overall, municipal landscaping ordinances remained unchanged since 2005.

Through September, a series of meetings were held with TMWA staff, municipal planners, staff from the Washoe County District Health Department, and representatives from the building industry to address the following issues raised by TMWA staff:

1. Increasing customer inquiries regarding discrepancies between TMWA's conservation goals and municipal ordinances for drought-tolerant landscaping.

2. Deviations in water conservation and landscape ordinances between municipalities.

As a result of those discussions, staff has identified new recommendations for the TMWA's Board's consideration regarding possible recommendations for revisions to the existing municipal ordinances. This report presents those findings and recommendations for potential government action (see pages 3 and 4).

Special thanks goes to the following staff members and consultants who provided valuable input during the course of these meetings:

Claudia Hanson, City of Reno
Armando Ornelas, City of Sparks
Roger Rundle, City of Sparks
William Whitney, Washoe County
Roger Pelham, Washoe County
Bob Webb, Washoe County Community Services Department
Jeff Jeppson, Washoe County Health District
Jim Smitherman, Northern Nevada Water Planning Commission
Angela Fuss, CFA
Jess Traver, BANN
Ryan Hansen, Hansen Landscape Architects

Municipal Ordinances - Findings and Recommendations

Row	Category	CITY OF RENO Description	CITY OF RENO Code	WASHOE COUNTY Description	WASHOE COUNTY Code	CITY OF SPARKS Description	CITY OF SPARKS Code	Recommendations*
	I. Landscaping Ordinances - Findings							
1	***A. Turf Standards***							
2	Width Requirements	5ft minimum	Section 18.12.1210	5ft minimum	Section 110.412.60	8ft minimum	Section 20.32.090	To reduce potential for overspray and runoff onto streets/storm drains, the **minimum width of narrow turf strips within all municipalities should be expanded to 8ft plus a 2ft setback** from impervious surfaces which drain to the street. Any landscaping strips that cannot meet this requirement should contain drip irrigation only.
3	Total Area Requirements	50% maximum in multi-fam, industrial, model homes.	Section 18.12.1210	50% minimum in multi-family	Section 110.412.60	80% maximum of landscaped area	Section 20.32.090	Industrial - 0% max allowable turf Commerical - 25% max allowable turf Multi-family - 50% max allowable turf Single Family - 50% max allowable turf
4	Slope Ratio Requirements	3:1	Section 18.12.1210	4:1	Section 110.412.60	4:1	Section 20.32.090	None
5	***B. Water Conservation Standards***							
6	Water Efficient Plants Requirements	Promoted	Section 18.12.1201	Encouraged	Section 110.412.20 Section 110.412.35	Requires use of resource-efficient guidelines and principles. Resource-efficient materials are any living material that is drought-tolerant or low-water use.	Section 20.32.010	Modify ordinances **to require a percentage of water efficient planting** within new developments. Collaborate with Cooperative Extension/Nevada Landscape Association to identify a list of acceptable drought-tolerant vegetation.
7	Hydro-zoning (grouping vegetation by water requirements)	Not specified	N/A	Required	Section 110.412.65	Encouraged	Section 20.32.010	Require use of hydro-zoning practices whenever applicable.
8	***C. Non-living material Standards***							
9	Area	25% maximum	Section 18.12.1209	50% maximum	Section 110.412.60	10% maximum	Section 20.32.090	None
10	***D. Tree Standards***							
11	Minimum spacing between trees	One tree and six shrubs per 300sqft	Section 18.12.1209	One tree every 50 feet	Section 110.412.35 Section 110.412.40 Section 110.412.45	One tree every 300ft (residential) and one tree evrey 500 ft (other zones)	Section 20.32.090	None
12	Width of planting area	10ft minimum	Section 18.12.1205	8ft minimum	Section 110.412.60	10ft minimum	Section 20.32.090	None

* Recommendations only apply to new developments. No recommendations for existing developments are advocated that this time

Municipal Ordinances - Findings and Recommendations

		CITY OF RENO		WASHOE COUNTY		CITY OF SPARKS		
Row	**Category**	**Description**	**Code**	**Description**	**Code**	**Description**	**Code**	**Recommendations***
13	***E. Total Landscape Standards***							
14	Residential	20%	Section 18.12.1205	20%	Section 110.412.35	20%	Section 20.32.080TBL	None
15	Commerical	15-20%	Section 18.12.1205	20%	Section 110.412.40	10-25%	Section 20.32.080TBL	None
16	Industrial/Agriculture	Industrial - minimum of the front area	Section 18.12.1205	10%	Section 110.412.45	6%	Section 20.32.080TBL	None
17	***F. Soil Standards***							
18	Soil analysis	Not specified	N/A	Encouraged	Section 110.412.15	Not specified	N/A	Require a soil analysis during development planning phase to determine potential for runoff and necessary mulch/irrigation
19	Soil depth	Loosened 8 inch minimum with 2 inch organic soil on top	Section 18.12.1210	Not specified		Loosened 8 inch minimum with 2 inch organic soil on top	Section 20.32.090	None
20	Mulch	4 inch minimum in all landscape areas with there is no ground cover	Section 18.12.1209	3 inch minimum in all landscape areas with there is no ground cover	Section 110.412.60	4 inch minimum in all landscape areas with there is no ground cover	Section 20.32.090	None
21	**II. Irrigation Ordinances - Findings**							
22	***A. Watering schedules***							
23	Prohibited days for watering lawn	(1) Premises with even addresses - Tuesday, Thursday, and Saturday (2) Premises with odd addresses - Wednesday, Friday, Sunday	Section 12.14.085	(1) Premises with even addresses - Tuesday, Thursday, and Saturday (2) Premises with odd addresses - Wednesday, Friday, Sunday	Chapter 40.225	1. Residences with **even** addresses—Wednesday and Saturday or on Monday in lieu of one of these two days; 2. Residences with **odd** addresses—Thursday and Sunday or on Monday in lieu of one of these two days; and 3. Commercial customers—Tuesday and Friday.	Section 13.50.075	Revise Sparks' ordinance to reflect TMWA's regulations.
24	Water Schedule violation fines	1rst violation -$0; 2nd violation $25; 3rd violation $75	Section 12.14.210	1rst violation -$0; 2nd violation $25; 3rd violation $75	Chapter 40.266	1rst offense: $25; 2nd offense: $50; 3rd offense: $100	Section 13.50.110	Penalty structures should reflect TMWA's water waster penalty structure. More information on TMWA's rules that pertain to water waste (Rule 2) can be found at http://tmwa.com/customer_services/waterrules/.
25	***B. Irrigation System Design***							
26	Moisture sensors/rain shutoff equipment	Not specified	N/A	encouraged	Section 110.412.65	Not specified	N/A	None
27	Use of efficient irrigation system	Required	Section 18.12.1210	Not specified	N/A	Not specified	N/A	Require use of efficient irrigation system whenever possible

* Recommendations only apply to new developments. No recommendations for existing developments are advocated that this time

TRUCKEE MEADOWS WATER AUTHORITY

APPENDIX 5

ENHANCED DEMAND-SIDE MANAGEMENT PROGRAMS AND ACTIONS

Enhanced Demand-Side Management Programs and Actions

Extended drought periods can result in severe consequences to socio-ecologic systems. As experiences in 2014 and 2015, within the TMWA service area (and most of the western U.S.), prolonged, dry hydrologic periods can occur. In order to enact policy that mitigates potential vulnerabilities to local water resources, TMWA must consider management tactics to mitigate drought periods that extend beyond those experienced over the past century (see Chapter 2 for a discussion of effects of local climate change). Should prolonged, dry hydrologic conditions persist, there are a myriad of possible programs not included in TMWA's current Conservation Plan that could be deployed to further reduce demand for water.

TMWA's Conservation Plan is oriented around efficient use by its customers **every year**. In periods of extended drought, TMWA's demand-side management programs ("DMPs") can be enhanced and oriented toward targeted reductions in monthly water use. Depending on projected use of drought reserves, TMWA first defines the target reduction needed to ensure drought reserves are adequate to serve its customers over that year and multiple succeeding years. For example, starting in May of 2015 TMWA asked its customer to reduce their water use by *at least* 10 percent compared to their monthly usage in 2013. Once a target is established, then a suite of actions that will facilitate this reduction are selected and implemented within a specified timeline. These programs and measures can have significant administration costs and lengthy timelines in order to be implemented, and/or require additional action(s) by local governments. Moreover, some actions can have adverse, long-term economic impacts to TMWA and the community at large; therefore TMWA weighs all the costs and potential benefits each action might have when creating the suite of actions it will deploy.

Conjunctive implementation of the appropriate types of actions is the key to successfully meeting the targeted water use reduction goal. Any decision on a new suite of conservation actions must also considers how interdependent individual actions can have with one another. For example, should additional watering restrictions or moratoriums be put into place, monitoring and enforcement must be enhanced to ensure compliance is met. Similarly, if rebates are considered, such as those designed to reduced turf or increase the use of water efficient technology, changes in local laws might be necessary to guarantee future development reflect the desired outcome(s) (i.e., restricting the amount of turf new properties can have or requiring the use water efficient irrigation technology).

Table 1 provides a list of various enhanced demand-side management actions ("*e*DMPs"), which, in addition to TMWA standard programs described in Chapter 5, could be deployed depending on projected use of drought reserves. The table lists qualitative estimates of the associated costs and benefit potentials based on prior studies for each *e*DMP.

Table 1: Potential Enhanced Demand-side Management Programs and Associated Costs and Benefits

Type	Action Taken	Program Costs[1]	Level of Effort to Implement[2]	Level of Customer Participation	Level of Water Savings Per Customer	Benefit Potential[3]
Customer Education	Information on Water Usage	Moderate	Moderate	High	Moderate	at least a 6% reduction in demand
Pricing Mechanism	Rate Schedule Adjustment (marginal increase)	Low	Moderate	High	Low	2% reduction for a 10% increase in the block rate
Pricing Mechanism	Rate Schedule Adjustment (moderate increase)	Low	Moderate	High	Moderate	2% reduction for a 10% increase in the block rate
Pricing Mechanism	Rate Schedule Adjustment (significant increase)	Low	Moderate	High	High	2% reduction for a 10% increase in the block rate
Pricing Mechanism	Seasonal Drought Rate (marginal increase)	Low	Moderate	High	Low	2% reduction for a 10% increase in the block rate
Pricing Mechanism	Seasonal Drought Rates (moderate increase)	Low	Moderate	High	Moderate	2% reduction for a 10% increase in the block rate
Pricing Mechanism	Seasonal Drought Rate (significant increase)	Low	Moderate	High	High	2% reduction for a 10% increase in the block rate
Pricing Mechanism	Violation Fines (marginal increase)	Moderate	High	Low	Low	2% reduction for a 10% increase in the block rate
Pricing Mechanism	Violation Fines (moderate increase)	Moderate	High	Low	Moderate	2% reduction for a 10% increase in the block rate
Pricing Mechanism	Violation Fines (significant increase)	Moderate	High	Low	High	2% reduction for a 10% increase in the block rate
Enhanced Metering	Daily meter reading of all customers	High	High	High	Low	Reduction potential not quantified
Enhanced Metering	Metering of all domestic wells	High	High	Low	Low	Reduction potential not quantified
Rebate	Rebate: Turf Conversion	High	High	Low	Moderate	~30% reduction in use per service
Rebate	Rebate: Efficient Irrigation Technology	Moderate	Moderate	Moderate	Moderate	20-50% improvement in irrigation efficiency
Rebate	Rebate: Low-flow Appliances	Moderate	Moderate	Moderate	Low to Moderate	High variability in savings depending on appliance
Watering Restrictions	Restrictions on Business	Moderate	Moderate	Moderate	Low	Reduction potential not quantified
Watering Restrictions	Weekly watering: 1	Moderate	High	High	Moderate	Reduction potential not quantified
Watering Restrictions	Weekly watering: NONE	Moderate	High	High	High	~75% reduction in water use per service with irrigation
Watering Restrictions	Moratorium on Car Washing	Low	High	High	Low	Reduction potential not quantified
Watering Restrictions	Mandatory Water Budgets	Moderate	High	High	Moderate to High	Reduction dependent upon budget amount
Landscape Requirements	Ordinances: Xeriscape Requirement (some xeriscape)	Moderate	Low	Moderate	High	~30% reduction in use per service
Landscape Requirements	Ordinances: Turf Requirements (no new turf)	Moderate	Low	Moderate	High	~30+% reduction in use per service
Landscape Requirements	Ordinances: Efficient Irrigation Technology	Moderate	Low	Low	Moderate to High	20-50% improvement in irrigation efficiency
Landscape Requirements	Ordinances: Certified Car Wash Program	Moderate	Low	Low	Low	Reduction potential not quantified
Landscape Requirements	Ordinances: Water Capture Requirements	Moderate	Low	Low	Low	Reduction potential not quantified
Landscape Requirements	Ordinances: Homeowner Association Restrictions (new developments)	Moderate	Low	Low	High	~30% reduction in use per service
Landscape Requirements	Ordinances: Homeowner Association Restrictions (all developments)	Moderate	Low	Moderate	High	~30% reduction in use per service

1. Cost includes but is not limited to increases in number of personnel, vehicles, IT support, messaging/advertising, local entity enforcement, or administrative support.

2. Level of effort to implement includes but is not limited to how/type/frequency of messaging/advertising delivered, numbers of personnel required to deploy, public hearings, community resistance.

3. Benefit potential is based on results from previous studies.

Customer Education

Information on Water Usage. Information can be a very powerful tool to help consumers make more informed decisions. Different types of information can be used to promote additional customer savings in various ways including: cost-saving information, targeted analytics, and social norms persuasion. As of the writing of this WRP, TMWA is engaged in a sample study to determine the effect of several informational products on customer water conservation, in order to determine if such programs are effective means of conservation during droughts.

- Cost-saving Information. Educating customers about water waste has been a major part of TMWA's past conservation efforts. In the future, customers can be provided with even more specific information on the cost-saving nature of different water saving practices.
- Targeted Analytics. Providing customers with tailored information regarding their water use can be a power mechanism for changing water usage behavior. Highly customized informational products gives customers' knowledge beyond their monthly usage by providing daily usage, comparing current usage to past usage, and indicating whether customers have met any established conservation goals. This knowledge gives customers a great ability to identify where they can alter their behavior to use water more efficiently.
- Social Norms Persuasion. Customers can also be supplied with information about how their usage compares with similar properties in their neighborhood. Research has suggested that such "social pressure" leads many above-average water users to conserve more water in order to better fit in with their neighborhood.

Pricing Mechanisms

Rate Schedule Adjustment. Water rates provide a pricing signal to customers so that they use water efficiently. For example, in the TMWA service area, on average, customers who converted from a monthly-flat-rate schedule to a metered rate reduced their water consumption by 39 percent. Moreover, a reduction in usage was seen in both indoor water use, as well as, outdoor use, indicating many aspects of the customer's water usage behavior were altered toward more efficient use. Since increasing water rate prices is a market-based approach to water reduction, it implies reductions are voluntary. A customer decides how much he/she wants to conserve based on their bottom line. A study conducted by the Economics Department at the University of Nevada on single-family metered water user in Washoe County indicates that a 10 percent increase in metered rates is associated with a two percent decrease in water use, on average (Lott et al. 2013). Currently TMWA only adjusts rates in order to meet the cost of service, which requires an in-depth cost of service study. However, TMWA could evaluate rate adjustments as a method to conservation without creating negative impacts to its revenues.

Seasonal Drought Surcharge. A drought surcharge could be a potential method to encourage enhanced water conservation. Like rate adjustments, a drought surcharge is a market-based approach meaning any water conservation as a result is voluntary. A drought surcharge is an adjustment that is temporary as it only applies during periods when TMWA must use storage reserves to meet demands (typically during the irrigation season). Once the system's reserves are reestablished, the drought surcharge is lifted and prices would return to the normal rate schedules. Due to this flexibility, it can be seen as a more attractive option than a permanent rate increase to reduce water demand. A drought surcharge is also flexible in that it can have a variety of different structures, i.e., it can be a flat surcharge, a variable surcharge based on the percentage of use, or can be integrated directly into the tiered rate schedule (i.e., applied only to certain blocks of water use). A well-thought out drought surcharge structure has to consider ease of implementation, customer classes affected, equity within and between customer classes, and the long-term consequences to demands and revenues.

<u>Water Violation Penalty Adjustment.</u> Preliminary analysis on TMWA's Water Watcher program indicates, on average, residential customers who were issued a penalty for water waste violations *did not* decrease water consumption after the fine was issued. In some cases residential violators increased use after a penalty was issued. Results indicate residential violators are typically wealthier and live on larger lots compared to TMWA's typical residential customer. The current penalty schedule's fee structure likely does not prohibit water violations because of the average socio-economic status of the offenders (i.e., the penalty amount may be perceived as nominal). Increasing the amount a violator would pay would provide more of a monetary incentive to abide by TMWA's water usage regulations. Penalty adjustments could be made depending on the severity of the violation and the severity of drought periods. The inclination for TMWA to issue a penalty (as opposed to taking other, non-punitive measures) could also be directly correlated to any additional water use restrictions, such as watering day restrictions, moratoriums on car washing, etc. To determine an optimal water violation penalty structure that would achieve the desired results, more analysis about how the penalty structure alters the customers' propensity to save water is warranted.

Rebates

<u>Turf Conversion</u>. Turf-dominated properties use approximately four times more water than xeriscaped properties. Replacing turf with a more water-conscious landscape is a method for long-lasting water conservation. A turf conversion rebate program incentivizes residents to replace their turf by offsetting the cost of re-landscaping by providing a rebate based on the per-square-foot amount of lawn removed. Some studies on turf conversion programs indicate a residential customer can reduce his/her water consumption by approximately 30 percent. The main reason such a program can be effective is because it usually implies a more efficient irrigation system is used (i.e., a sprinkler-dominated irrigation system often is converted to drip-dominated system). Turf conversion programs are typically implemented by the water purveyor or water-controlling municipality using funded from new development fees, customer rate revenues, or local/state grants. In order to have a significant effect of reducing water consumption, tens of millions of square feet of turf must be converted at costs in the tens of millions as well. In addition to the total cost of the rebates, administrative costs are associated with the program's implementation and oversight including the application process, rebate administration, and compliance checks.

<u>Efficient Irrigation Technology</u>. Overuse of water in irrigation is due, in part, to inefficiencies in the water delivery system. Since irrigation controls are predominately automated, once water

timers are set, they are often forgotten about. However, over the irrigation season precipitation and/or wind events can occur during watering times. Unless the customer is able to manually adjust timers accordingly, the result is the application of water when irrigation is not necessary or highly inefficient. Many of the existing irrigation controllers utilize technology that predate the era of "smart" devices. High efficiency irrigation technology such as "smart" controllers can make real-time adjustments to irrigation schedules based on weather information, saving 20-50 percent of the water relative to standard controllers. Such technology is ideal for commercial applications because it eliminates the need for travel to multiple controller sites. The downside to "smart" controllers is the cost. For commercial applications when considering the saving in the monthly water bill and labor costs associated with manually changing watering schedules, savings could be achieved in as little as one irrigation season. A cheaper alternative to the "smart" controller is a rain sensor. Like the "smart" controller, a rain sensor will prohibit watering during precipitation events. For residential applications, this technology could be preferable since it is a fraction of the cost of "smart" controllers. A program that provides rebates for purchases of "smart" irrigation controllers or rain sensors could help replace older technology and increase irrigation efficiency on existing residential and commercial properties. Unlike, turf conversion rebate programs, these rebate programs would require substantially less funding and administrative oversight overall. Such automatic changes in watering times can conflict with assigned watering day schedules, so variances for watering during off-schedule times should be considered along with the accompanying administrative cost to manage those with variances.

Low-Flow Appliances. As with irrigation technology, many existing homes that predate enhanced standards in plumbing codes have appliances (e.g., toilets, dishwashers, washing machines, etc.) that are considered inefficient by current standards. For example, dishwashers made before 1994 use ten gallons more water than modern dishwashers. New, water-efficient toilets can provide overflow prevention and leak detection, and use approximately 20 percent less water than the standard 1.6 gallons per flush toilets. Similarly, water-efficient washing machines use up to 50 percent less water than older machines. A program that provides rebates for purchases of water-efficient appliances could incentive some customers to replace existing inefficient appliances. This would lower indoor water consumption overall, as well as, reduce peak day demands. However, the overall effectiveness of the program relative to the total cost to TMWA must be considered. Indoor use only account for a small percentage of monthly water use during periods of drought when reserves are be used. If the goal is to target reduced use during periods of drought, this option might not be as effective as other options. If the goal is a campaign to reduce water usage long-term, then such an option might be practical.

Enhanced Metering

Daily Metering of All Customers. Currently the majority of meters on TMWA's service connections provide readings on water usage aggregated at the monthly level (approximately 23 - 37 days). However, new water meter technology allows for the collection of daily meter readings. Water measurement at this level of granularity would provide TMWA with information that would be helpful in identifying more water violations (i.e., irrigating on incorrect days or incorrect times), the ability to provide better information on customer water use (e.g. targeted analytics), as well as, the ability to notify customers of potential leaks in real-time. This level of monitoring would ensure water efficient behavior is consistent across the TMWA service area. Given that the majority of TMWA service connections do not have this type of meter installed, a retrofit program to switch out the existing meters would be in the millions of dollars range over a multi-year timeline.

Metering of Domestic Wells. While TMWA provides meters for all its service connections, properties that obtain water from domestic wells do not have meters to track groundwater pumping. While these individuals are not TMWA customers, they share the same groundwater resources and therefore should conserve water like the rest of the community. In order to monitor private groundwater extraction, meters could be installed on all domestic wells. Such an action would require statutory change in the NRS and a method of funding the program.

Water Restrictions

Restrictions on Businesses. Should drought periods persist and a state of emergency be declared in Washoe County, TMWA could ask all businesses within the food industry serve all items on paper plates and provide disposable utensils in order to remove the need to wash dishes. As well, TMWA could ask that all cleaning services utilize cleaning products that don't require water. Within the hotel industry, TMWA could be asking that establishments restrict their laundry services to only what is absolutely necessary. TMWA could also place restrictions on water used in fountains and water features. While these actions would reduce commercial demand, in order to comply such restrictions could place additional financial stress on businesses. For compliance to be uniform, additional monitoring and enforcement mechanisms would need to be in place.

Moratorium on Washing Cars. In the event that a drought emergency is declared, TMWA could place restrictions on using potable water to wash cars, restricting the activity to only commercial car wash businesses that have a certified water reclamation system. Customers caught violating this requirement would be fined accordingly; such as action would require additional monitoring and enforcement to ensure compliance.

Mandatory Water Budgets. Currently, all conservation by TMWA customers is strictly voluntary. However, should extended drought periods persist; all customers could be given individualized water budget (i.e., a set amount that may be used within a month). Should a customer exceed the budgeted usage specified, a penalty surcharge could be incurred. Individualized water budget amounts could be estimated based on historic averages for each service connection and scaled down to achieve a targeted reduction goal. Implementation of individualized water budgets would be a long process. Increased communication and educational programs would be necessary to inform customers of the change. There is a potential for an impact TMWA's revenue stream which could result in a dramatic increase in the cost customers pay for water.

Once-Per-Week Watering. In the event that a drought emergency is declared, TMWA could change the three-day-a-week water schedule to a once-per-week watering scheduling. Customers caught violating this requirement would be fined accordingly. This action could drastically reduce water usage but could result in adverse consequences including a spike in peak day usage, severe overwatering, and damage to property owners' landscaping.

Moratorium on All Outdoor Watering. In the event that a drought emergency is declared, TMWA could place a temporary moratorium on *all* outdoor watering. Customers caught violating this requirement would be fined accordingly. Since irrigation uses the majority of the water used by a service during the warmer months, this actions would ensure adequate drinking water is available during that time. However, the impacts to TMWA's revenue stream could result in a dramatic spike in the cost customers pay for water. Furthermore, this action could result in irreparable damage to property owners' landscaping causing widespread economic losses.

Landscape Requirements

The next water conservation programs discussed below *are not* actions TMWA could take directly to promote conservation. However, in the past TMWA has worked with local municipalities to promote water-conscious local ordinance. The following paragraphs discuss potential water saving actions local municipalities can take with respect to future development. The savings such actions would have vary depending on the number of properties which would be impacted by the changes.

New Development Landscape Requirements. Turfed landscape is often over-watered and prone it inefficient irrigation (over-spray, evaporation loss, etc.), with as little as 40 percent of the water that is applied to turfed areas actually being used by the grass. Within TMWA's service area, local municipal ordinances dictate minimum amounts of turfed area properties must have (based on jurisdiction and zoning district). As the region grows and new developments are established, these ordinances could be amended to set limits on the maximum amount of turf a new property could have. Ordinances could also prohibit the laying of sod or planting of new grass seed during drought periods. If drought periods persist indefinitely, a moratorium on any new turfed areas could be implemented as a last resort. Such amendments to local ordinances could be paired with a rebate program for existing property owners, in order to gain maximum effectiveness.

Xeriscape requirements. Studies have indicated xeriscape is a water-conserving alternative to turf. Drought-tolerant vegetation (often native plants) can survive on less water (approximately 30 percent less than turf) and often become dormant (i.e., do not grow) during the hottest part of the summer. Currently, while local ordinances encourage the use of drought-tolerant landscape practices, none require xeriscaping on properties. Landscape ordinances could be amended to require the use of drought-tolerant plants for new buildings and minimum areas of xeriscape could be specified to ensure the majority of new landscaping is water-conscious.

Efficient Irrigation Technology requirements. As discussed previous in the Rebates section, new technology on efficient irrigation systems is readily available. Landscaping ordinances could be amended to require the use of "smart" controllers in all new commercial buildings and rain sensors in all residential developments. Such amendments could be paired with a rebate program for existing commercial and residential owners in order to gain maximum effectiveness.

Water-Capture Device Requirements. During precipitation events most of the water that falls on impervious surfaces is channeled to storm drains and eventually to the Truckee River. While significant rainstorms are not common in Washoe County, some climate change predictions indicate rain will become more frequent in the future. Water capturing devices such as rain barrels and onsite storage tanks can capture rain water to be used in irrigation at a later date. While retrofitting existing building with such devices would be relatively cost-prohibitive, amending building codes to require the installation of water-capture devices on new buildings and residences could reduce the amount of water required on a given property. Similarly, much of the water used inside a building is not consumed and could be reused onsite. This "gray water" that results from washing, cleaning, and similar activities could be recycled and used on irrigation. This action not only would conservation the amount of potable water supplied to services, but would also lower the amount of water (and associated costs) the Truckee Meadow Water Reclamation Facility would have to process. The benefits of such a requirement depend heavily on the amount of rainfall expected over time. Should rain events become more commonplace, such a requirement could help lower demand for potable water.

Certified Car Wash Program. Practices within the car wash industry vary. Standards on high pressure nozzles, water capture and disposal systems, and leak detection can change from business to business. In order to ensure the highest standard for water conservation is achieved uniformly, municipalities could partner with the local car wash industry to develop a water-saving car wash standardization program that identifies Best Management Practices. A provision that requires all businesses within the car wash industry adhere to these practices would ensure compliance is met.

Homeowner Associations Restrictions. Currently, rules and regulations within private agreements for residential planned unit developments ("PUD") supersede city and county landscaping ordinances. Private agreements under Homeowner Associations can either help or hinder efforts by restricting how occupants can manage their properties. Approval of future developments could require all private agreements associated with PUDs are consistent with municipal ordinances regarding water conservation and landscaping requirements. Allowing property owners under current private agreements the option to convert existing turf on their landscape to a water conserving alternative would facilitate an even greater reduction in water usage. Per NRS 116.330 property owners have the right to install or maintain drought tolerant landscaping on their properties so long as it is compatible with the community design and is approved by the governing body. Local government entities could work with Homeowners Association to ensure such transitions could be made by residents on existing properties whom are interested in doing so.

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